Morris Resource Economics Ltd

Cheshire and Warrington Natural Capital Audit and Investment Plan

5. Case studies report

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1. Introduction

The Cheshire and Warrington Local Enterprise Partnership (C&W LEP) have identified the need for an assessment of the interrelationship between natural capital and its economic and social development ambitions for the area. Natural Capital is defined as:

> *"..elements of nature that directly or indirectly produce value or benefits to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions"* (Natural Capital Committee 2014[1]).

It is the stock of natural assets (e.g. soils, water, biodiversity) that produces a wide range of ecosystem services that provide benefits to people. These benefits include food production, regulation of flooding and climate, pollination of crops, and cultural benefits such as aesthetic value and recreational opportunities.

Natural capital supports all other forms of capital on which human systems depend, whether man-made, human or social. However, many of the outputs produced by natural capital, such as the regulation of flooding and atmospheric gases by forest lands, are not included in the decisions of private individuals or organisations. This is because they often involve non-priced public goods that are not traded in the market place and are not subject to formal property rights and entitlements (TEEB, 2010[2]). Elements of natural capital are therefore liable to be overused, degraded, depleted and eventually lost, with consequences for long term welfare and the sustainability of economic systems. There is now much greater awareness of the role of natural capital in the design and achievement of economic and social development strategies, with strong links to business and enterprise[3]. The C&W LEP's interest in natural capital assessment is also set within its commitment to develop quality of place as a platform for sustained growth.

The C&W LEP have commissioned this project to produce a Natural Capital Audit, and support the development of a Natural Capital Investment Plan for the area. This is driven by the need not only to manage risks to the natural environment associated with economic development that could undermine successful achievement, but also to explore the opportunities to tap into new funding sources and mechanisms for innovative investments that can achieve substantial gains for people and the natural world. In this respect, there is a need to develop a strategic network of natural capital oriented projects to support and extend C&W LEP's strategy through to 2040, engaging key stakeholder interests in the process. The investment plan covers the three local authority areas of Cheshire West and Chester, Cheshire East, and Warrington.

An extensive evidence base has been built-up to support the development of the **Natural Capital Investment Plan** (NCIP). This is presented in the form of five technical reports:

1. **Natural capital audit and policy analysis** – a baseline assessment of the natural capital assets currently present across Cheshire and Warrington, the benefits that flow from those assets and their monetary value, together with an analysis of policies at the local and national scale that effect natural capital, and an identification of priority themes and sectors.

[1] Natural Capital Committee 2014. Towards a Framework for Defining and Measuring Changes in Natural Capital. Working Paper 1, Natural Capital Committee.
[2] TEEB. 2010. The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Earthscan, London and Washington
[3] TEEB. 2012. The Economics of Ecosystems and Biodiversity in Business and Enterprise. Earthscan. London; New York.

2. **Intervention and investment opportunities report** – habitat opportunity mapping to identify the best locations to deliver specific or multiple objectives, along with mapping of strategic themes based on local policies, to prioritise locations for investment.
3. **Workshop report** – write-up of stakeholder workshop to present the approach used to map natural capital opportunities, and to discuss key priorities across C&W.
4. **Future financing report** – review of emerging financing options, including a typology of different funding opportunities, the ecosystem services and habitats covered by each, and an approach to identifying the most appropriate funding mechanism for different projects.
5. **Case studies report** – presentation of five case studies to demonstrate how the opportunity maps can be used to identify habitat creation potential based on different objectives, to highlight the benefits of such projects, and to show how funding requirements and potential funding sources can be identified.

This report is the fifth of these technical reports; the **Case studies report**. The aims of this report are to:

a) Demonstrate how the opportunity maps can be used to develop natural capital investment proposals for a range of different objectives.
b) Model and map changes in benefits projected to occur due to the proposed investments in each case study.
c) Calculate the monetary value of the investments and perform an economic appraisal, including cost benefit analysis.
d) Identify funding requirements and potential funding sources.

1.1 Report structure and scope

Section 2 outlines the objectives behind each case study and presents a summary of the main methodological approach used in the assessment that follows. Sections 3 to 7 then present each of the case studies in turn. Each case study begins by describing and mapping the natural capital assets present under the baseline and the opportunities identified across the site, before summarising the proposed interventions and the changes to habitats. The resulting change in ecosystem services is then modelled and mapped, and the monetary benefits calculated, alongside costs of the proposed works. These costs and benefits are brought together in an economic appraisal that calculates net present value of the investment and the cost benefit ratio, and potential funding sources are identified.

Section 8 performs an analysis across all five case studies, focussing on costs and benefits, project feasibility and opportunities for funding.

The case studies are illustrative, and have not be ground-truthed. The aim is to show the application of the approach across different policy objectives and the type and magnitude of benefits, costs and potential economic performance that could typically be achieved. A more detailed assessment would be required to confirm details and to support decision making for investment.

2. Approach

2.1 Selection of case study sites

The cases studies were chosen to illustrate the approach for a number of different objectives. The case studies selected were:

1. **Sustainable agricultural production** – using the opportunity maps to highlight key interventions at the farm scale. The case study site was selected in conjunction with the Cheshire Farms Estate Land Agent. Location = the Ridley Estate, part of the Cheshire Farms Estate.
2. **Carbon sequestration and biodiversity enhancement** – examining the use of peatland restoration to achieve these aims. Location = the Goyt Valley SSSI and around.
3. **Water quality and flow improvements (and biodiversity enhancement)** – predominantly through woodland planting in lowland areas. Location = the lower Dean.
4. **Priorities and opportunities focus 1** – identifying locations where multiple external policy priorities (strategic themes) overlap with the potential to deliver multiple benefits (opportunities) at the same time. Location = two areas to either side of Northwich.
5. **Priorities and opportunities focus 2** – identifying locations where multiple external policy priorities (strategic themes) overlap with the potential to deliver multiple benefits (opportunities) at the same time. Location = northern edge of Warrington.

The locations of the five case study sites are shown in Figure 1.

2.2 Summary of methods

Identifying opportunities and developing the investment proposals

As part of the wider NCIP process, a series of opportunity maps were developed, showing areas where new habitat can be created that will be able to deliver particular benefits, whilst taking constraints (such as existing land uses or historic sites) into account. Opportunities have been mapped to:

- **enhance biodiversity** for five different broad habitat types (broadleaved and mixed woodland, semi-natural grassland, mire, heathland, and wet grassland and wetland),
- **reduce surface water runoff** (and hence flood risk),
- **reduce soil erosion and improve water quality**,
- **ameliorate poor air quality**,
- **reduce noise pollution**,
- **regulate local climate** (reduce urban heat), and
- **increase public access to natural greenspace**.

The full methodological details behind the opportunity mapping and maps for the whole of Cheshire and Warrington are presented in Technical Report 2. These were used to guide the optimal locations for habitat changes and the most appropriate habitats to create at each location within the case study sites. They were also used to guide where public access should be enhanced. The basemap was then altered to show the new habitats planned at each case study site and public accessibility.

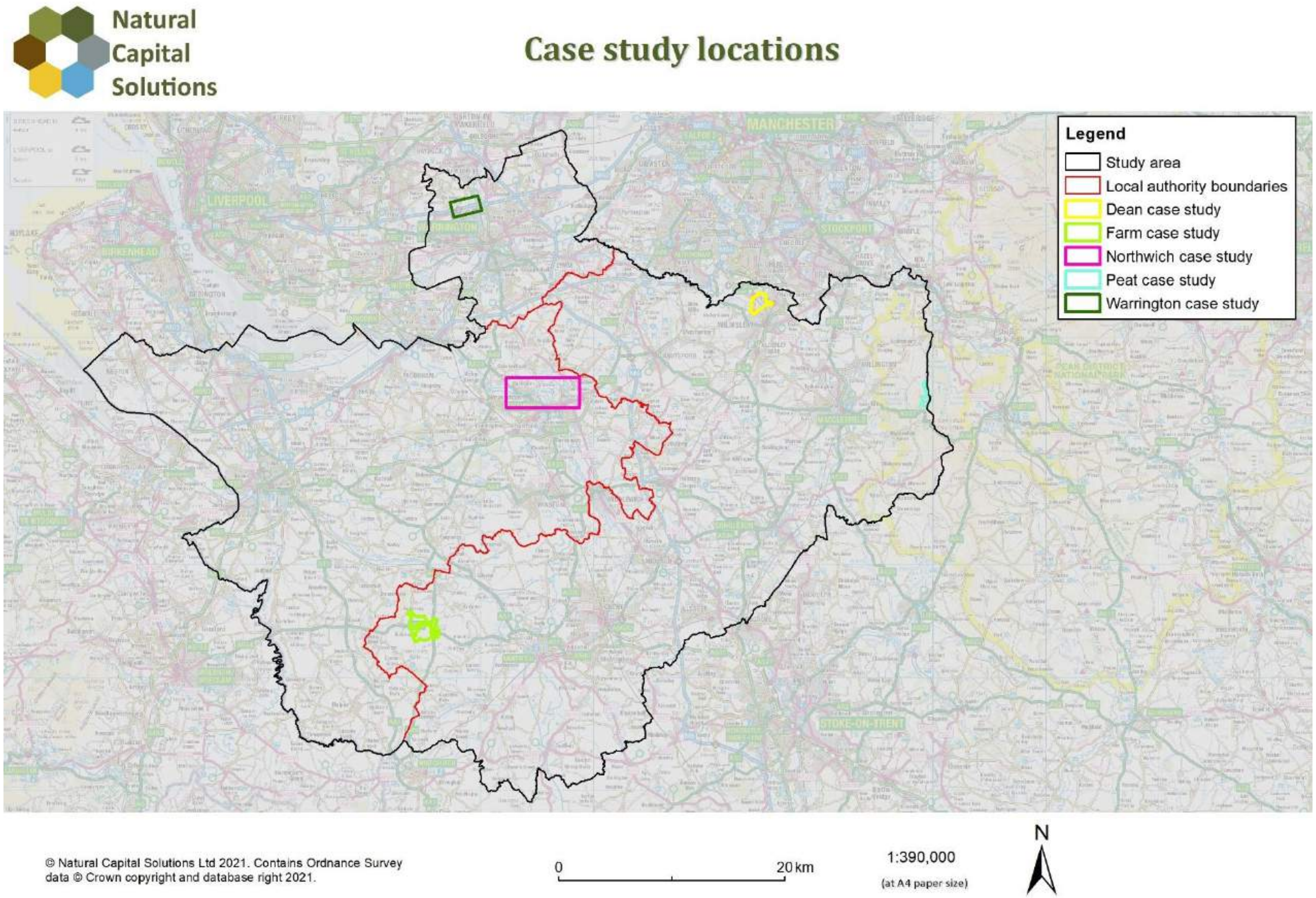

Figure 1 Location of the five case study sites in Cheshire and Warrington.

Changes in land cover and habitat type

For each case study area, estimates of land cover and habitat type were derived for the baseline situation and the with-project intervention situation. The difference between the two showed the type and magnitude of change. The main changes in land cover relate to agriculture, woodland/forestry, semi-natural areas, and other recreational greenspace.

Assessing changes in benefits

Once the new natural capital (habitat) map had been created for the proposed interventions at each case study site, it was then possible to quantify and map the benefits that the natural capital provides and the change across the two maps. A variety of methods were used. In all cases the models were applied at a 5m by 5m 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, hydrology of soil types data). Note, however, that most of the models are indicative (showing that certain areas have higher capacity than other areas) and are not process-based mathematical models (e.g. hydrological models). A brief description of each ecosystem service and the outcomes are provided in Box 1 (below), with full methodological details provided in Technical Report 1 of the Natural Capital Investment Plan.

Box 1: Ecosystem services assessed at each case study site.

- **Carbon storage capacity** estimates the amount of carbon stored in each habitat type. It applies average values (tC/ha) for each habitat type taken from Natural England (2019)[4] which are then normalised on a 0-100 scale. As such it does not take into account habitat condition or management, which can cause variation in amounts of carbon stored.
- **Air purification capacity** (air quality regulation) estimates the relative ability of vegetation to trap airborne pollutants or ameliorate air pollution. Woodland habitats are by far the most effective habitat type at providing this service, but all woody habitats including hedgerows and scattered trees have some effect.
- **Noise regulation capacity** is the capacity of the land to diffuse and absorb noise pollution. Complex vegetation cover, such as woodland, trees and scrub, is considered to be most effective, and the effectiveness of vegetation increases with width.
- **Local climate regulation capacity** estimates the capacity of an ecosystem to cool the local environment and cause a reduction in urban heat maxima. Natural vegetation, especially trees / woodland and water bodies, are able to have a moderating effect on local climate, making nearby areas cooler in summer and warmer in winter.
- **Pollination capacity** measures the capacity of the land to provide pollination services by estimating the probability that wild insect pollinators will visit each particular pixel of land.
- **Water flow regulation capacity** is the capacity of the land to slow water runoff and thereby potentially reduce flood risk downstream, based on land use, slope and soil type.
- **Accessible nature capacity** maps the availability of natural areas and scores them by their perceived level of naturalness.

[4] Sunderland T, Waters RD, Marsh DVK, Hudson C, Lusardi J. (2019) Accounting for National Nature Reserves: A natural capital account of the National Nature Reserves managed by Natural England. Natural England Research Report, Number 078.

In all cases the capacity to deliver each ecosystem service was mapped relative to the values present across Cheshire and are normalised on a 0-100 scale. In the resulting maps, areas delivering high provision of each service (good areas) are shown in yellow, and areas with low provision are shown in purple. In addition, we have calculated the mean score for each service under the baseline and the investment scenario and the percentage change compared to the baseline.

Monetary valuation and economic appraisal

We estimated the annual monetary flow of the following ecosystem services: air quality regulation, carbon sequestration, greenhouse gas emissions from agriculture, recreation, physical health, agricultural production, timber production, and agri-environment and future ELMs-type options. Table 1 outlines the indicators used to quantify both the physical and monetary flows of these services.

Table 1 Ecosystem services and indicators for physical and monetary measurement.

Ecosystem service	Physical flow	Valuation
Air quality regulation	Tonnes of $PM_{2.5}$ absorbed	Costs avoided £/tonne of $PM_{2.5}$ /year
Carbon sequestration	Quantity of CO_2 sequestered	£/tonne of CO_2
Greenhouse gas emissions from agriculture	GHG/ha	£/ha/year
Recreation	Number of visits	Welfare value/visit/year
Physical health	Active visits	£/QUALY/year
Agricultural production	ha	£/ha/year
Timber/woodfuel production	m^3/ha	£/m^3/year
Agri-environment options	ha under each option	£/ha/year

Annual monetary flows of ecosystem services have been calculated based on the latest valuation techniques available in the scientific literature and approaches adopted by the Office for National Statistics (ONS 2017[5]), and recent Defra guidance to standardise approaches to the valuation of ecosystem services[6]. The methods used to calculate these are described in more detail in the Technical Appendix at the end of the report (Annex B).

Broadscale assessments of extra benefits and costs for each case study were estimated over a 50-year project life, assuming a fixed baseline counterfactual. Constant 2021 prices were used throughout, inflation adjusted using ONS GDP deflators. Assumptions were made about the phasing of project implementation with capital costs incurred over the first 3 years of project life, with benefits phased from year 3 onwards. Capital costs include a cost for design and supervision during implementation.

[5] ONS (2017) Principles of Natural Capital Accounting. Office for National Statistics
[6] Defra (2020). Enabling a Natural Capital Approach (ENCA).

Annual costs include management, operations and capital replacement costs in total equivalent to between 8% and 10% of initial capital costs per year. A reality check on average benefits and costs per ha of development suggested the assumptions were reasonable for the purpose here.

The assessment adopts an economic perspective, excluding taxes and subsidies. Land costs are excluded. Unpaid farm labour is charged at appropriate rates. Farm income support is excluded, agri-environment payments are regarded as a crude and incomplete indicator of the value of biodiversity outcomes. Net Present Value and Benefit Cost Ratio are estimated at the Treasury Discount Rates, as well as Internal Rates of Return. Sensitivity analysis showed feasibility estimates are reasonably stable over a range of critical values.

Note that the estimates of benefits under-identify the potential benefits to biodiversity and the water environment, partly because these are difficult to monetise and partly because this high-level assessment does not support context specific estimates. Biodiversity payments are grossly under-valued by using agri-environment payments as an indication of societal 'willingness to pay'. Water quality, water resource, and flood risk management benefits are potentially important benefits, but their valuation requires more detailed assessment than is possible here.

Identifying funding requirements and potential funding sources

The funding requirements for each case study are based on an assessment of:

- Costs: capital and revenue;
- Benefits: linked to ecosystem services where these could be quantified and monetised;
- Benefit-cost ratio: benefits divided by costs to give an indication of the extent to which the case study is economically 'worthwhile'; and
- Internal rate of return (IRR): the annual rate of growth an investment is expected to generate.

The above information along with the types of ecosystem services that are targeted as key benefits to be delivered by the case studies, as well as the other ecosystem services that could also be delivered indirectly for investment in natural capital, are used as the basis for selecting which funding mechanisms may be most appropriate. The selection process is based on analysis of a variety of potential funding mechanisms and the extent to which they are tailored to specific ecosystem services and have been used to deliver natural capital investments. This information has been used to develop a spreadsheet 'funding mechanism selector'. The target (core) ecosystem services to be delivered along with the indirect (secondary) services that may also be desired within the case study areas are then used in this spreadsheet to identify which funding mechanisms are most appropriate. Further details are provided for each case study in turn, followed by consideration of the potential for funding at the larger scale incorporating all five case studies in Section 8.

3. Case study 1: Sustainable agricultural production

Case study 1 focuses on examining how the opportunity maps can be used to highlight interventions at the farm scale and potentially modified through ELMs or other funding mechanisms. The approach is trialled on the **Ridley Estate**, which forms part of the Cheshire Farms Estate. The location was selected in conjunction with the Cheshire Farms Estate Land Agent.

3.1 Baseline natural capital assets

Figure 2 (overleaf) shows the distribution of broad habitat types across the estate under the current situation and the area and percentage cover is shown in Table 2. The asset register demonstrates that the farm is dominated by improved grassland (308 ha, 77% of the total farm area). The farm also has 71 ha of cultivated land (17.6%), with just 0.6 ha of semi-natural or wet grassland, which makes up 0.1% of the total farm area. Broadleaved woodland occupies 4.6 ha, boundary features (hedgerows) a further 6.1 ha, while water makes up 4.2 ha of the estate.

3.2 Identifying opportunities

Opportunities exist for planting broadleaved woodland and semi-natural grassland, that will be ecologically connected to existing habitat, and these are shown in Figure 3. Opportunities for semi-natural grassland are focussed on two areas within the estate. Woodland opportunities are more spread out in multiple locations. There is only one existing large block of woodland, to the centre west, which is an obvious focus for expansion, but there is also a large woodland block outside the estate to the west, and it would be possible to reconnect a number of the small pockets of existing woodland. Although no areas were identified for expanding wet grassland, due to the absence of existing areas of wet grassland or wetland at the site, a number of fields close to the River Weaver were known to be prone to flooding and were identified as suitable locations for creating these habitats.

Opportunities to enhance ecosystem services were also identified and key services are shown in Figure 4. Opportunities to reduce surface runoff tend to be concentrated on the eastern half of the estate, whereas opportunities to improve water quality by reducing soil erosion are focused on the arable fields and adjacent to watercourses. Opportunities to ameliorate air pollution were focussed around areas with greatest demand, and are therefore located almost entirely on fields to either side of the A49 and A534, which cut through the centre of the estate. Opportunities for reducing noise pollution (not shown) followed a similar pattern to the air pollution opportunity map, with areas identified adjacent to the main roads. There were no opportunities to moderate local climate (reduce urban heat), due to the rural location of the estate. Similarly, no opportunities were identified to provide accessible natural greenspace based on local demand, due to the low population of the area, although enhanced access could benefit visitors from further afield.

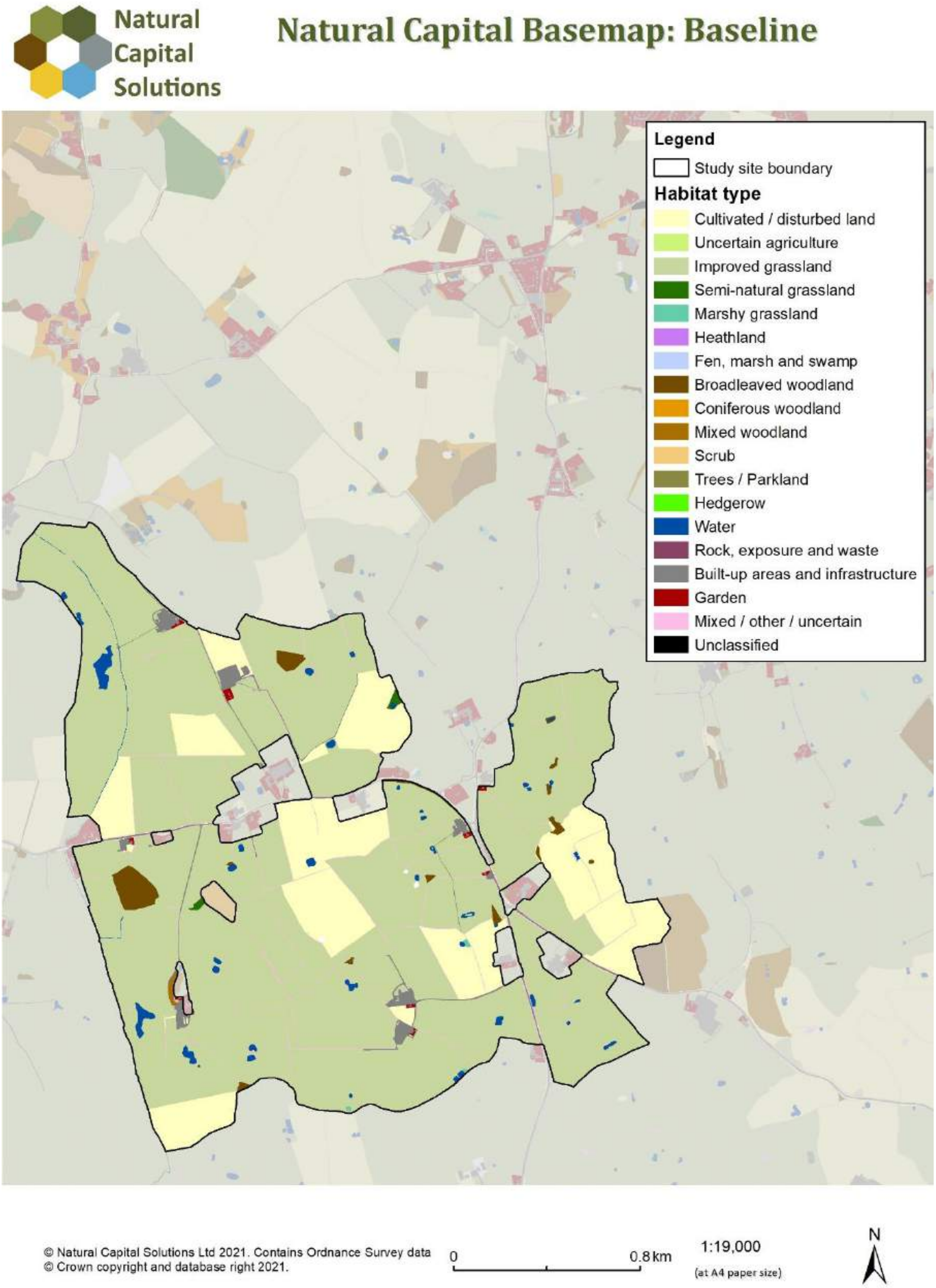

Figure 2 Broad habitats across the Ridley Estate under the baseline (present day) situation.

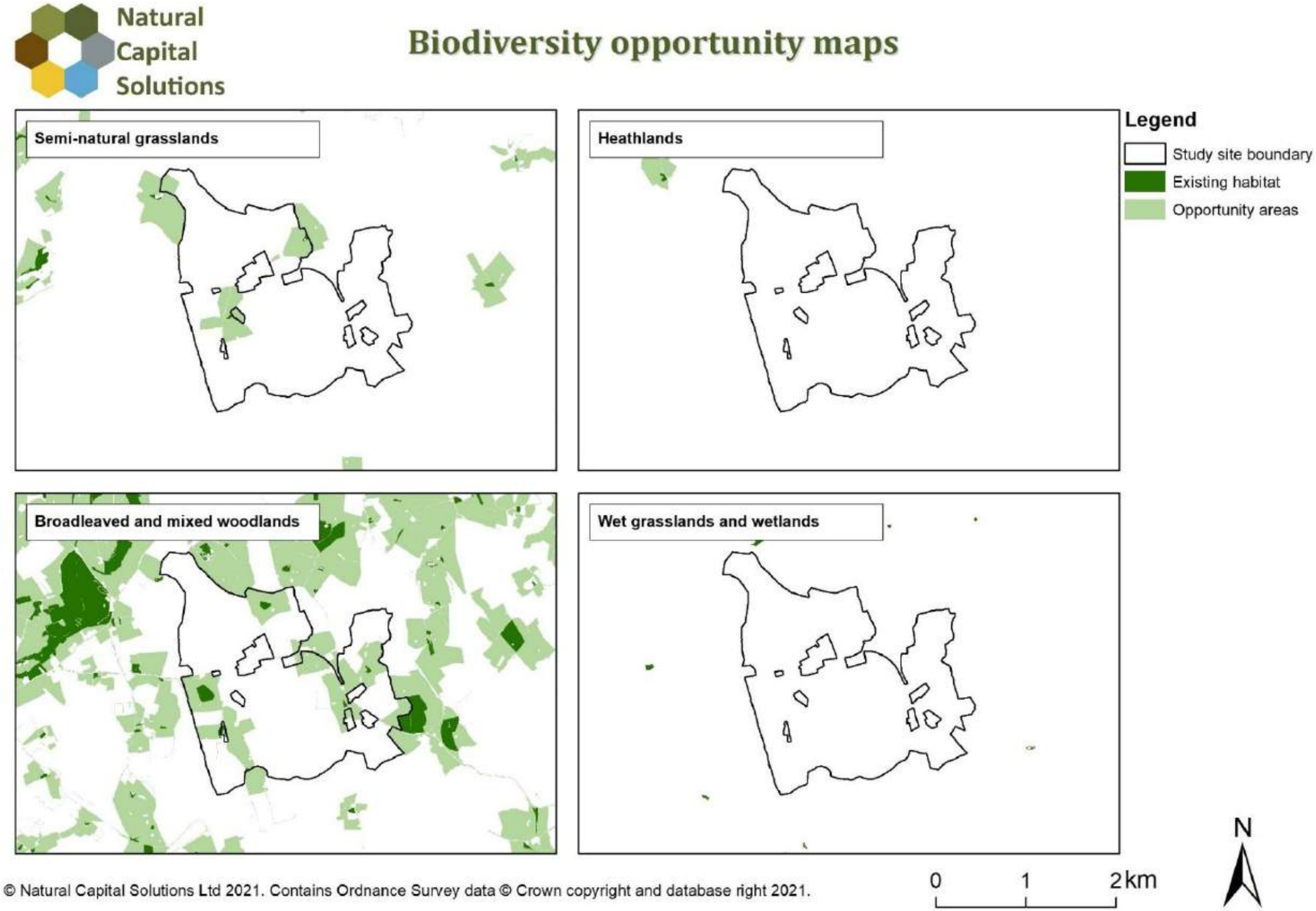

Figure 3 Ridley Estate biodiversity opportunity maps for semi-natural grassland habitats, broadleaved and mixed woodland habitats, heathlands, and wet grassland and wetland habitats. These maps identify whole fields that present opportunities.

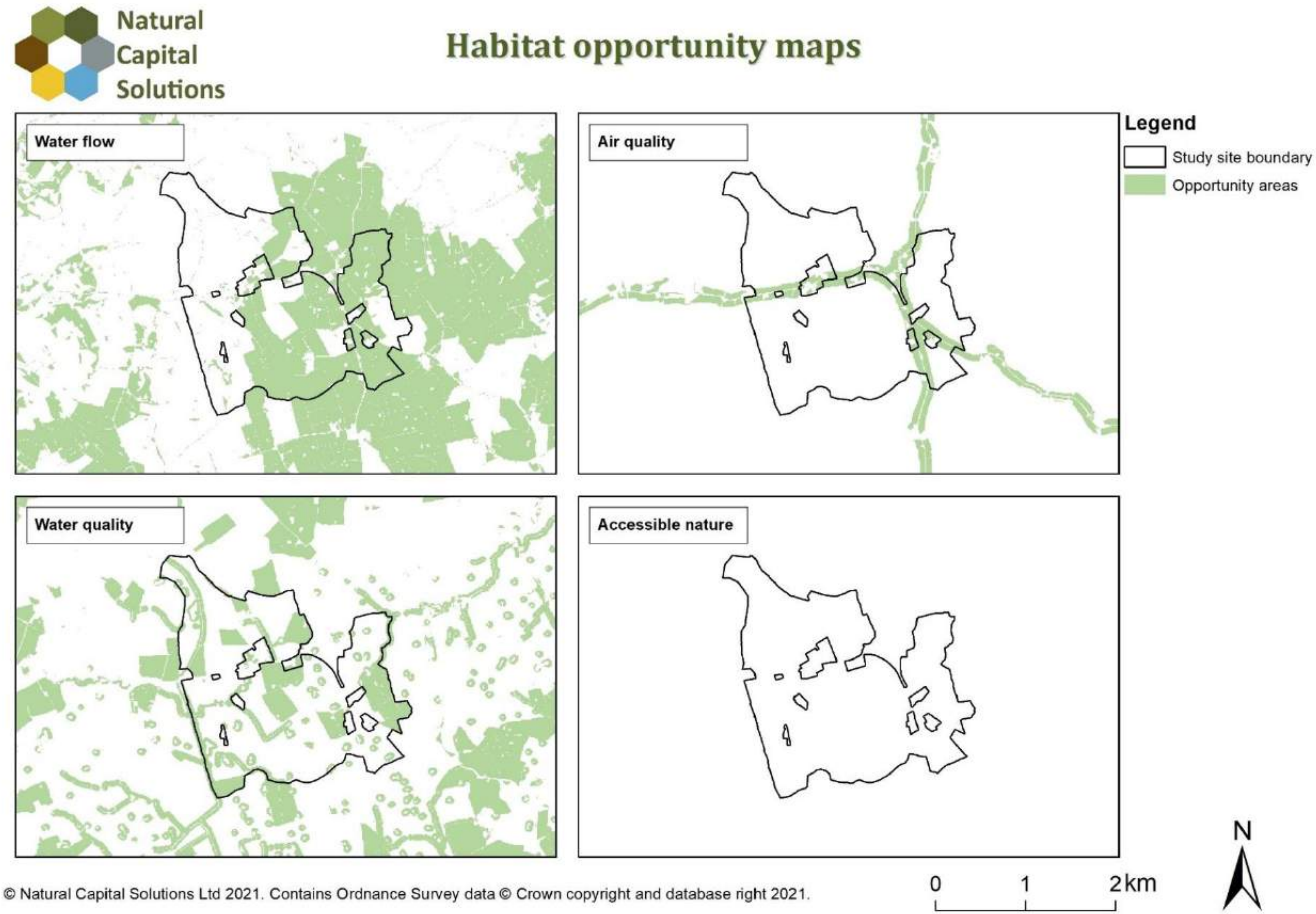

Figure 4 Ridley Estate habitat opportunity maps for water flow, water quality, air quality and accessible nature.

3.3 Interventions planned and changes to habitats

The opportunity maps (Figures 3 and 4) were used to guide which habitats to create and their optimal locations. Habitats based on the planned interventions are shown in Figure 5 and the area and percentage cover of habitats under the baseline and the planned interventions are shown in Table 2. This focused on a change from improved grassland (-35 ha) and cultivated/disturbed land (-15 ha) to broadleaved woodland (+26 ha), semi-natural grassland (+11 ha), marshy grassland (+7 ha), and mixed woodland (+5 ha).

New woodland has been located adjacent to the existing patch of woodland in the centre west of the estate, on the extreme east, adjacent to a large woodland patch outside of the estate, and to either side of the A49/A534 to the east, where opportunities for air quality enhancement, noise reduction and water flow (runoff) reduction coincide. It is suggested that new semi-natural grassland is created in biodiversity opportunity areas adjacent to existing small patches of this habitat, and as field margins around some of the arable fields, to trap soil erosion and enhance water quality. Marshy grassland can be created in fields adjacent to headwaters of the River Weaver in the north-west of the estate, which are prone to flooding and would also enhance water quality. Some of the fields to be converted to woodland on the west of the site are also prone to flooding and could be used to create wet woodland.

Table 2 Area and percentage cover of broad habitat types across the Ridley Estate under the baseline and the intervention scenario.

Broad habitat	Area (Ha)		% Cover		Change (Ha)
	Baseline	Intervention	Baseline	Intervention	
Cultivated / disturbed land	70.8	56.1	17.6	14.0	-14.7
Improved grassland	308.0	273.4	76.7	68.1	-34.6
Semi-natural grassland	0.4	11.4	0.1	2.8	11.0
Marshy grassland	0.2	7.5	0.0	1.9	7.3
Swamp	0.1	0.1	0.0	0.0	0.0
Broadleaved woodland	4.6	30.9	1.1	7.7	26.3
Mixed woodland	0.3	5.1	0.1	1.3	4.9
Scrub	0.0	0.0	0.0	0.0	0.0
Boundaries	6.1	5.9	1.5	1.5	-0.2
Water	4.2	4.2	1.0	1.0	0.0
Built up areas	4.0	4.0	1.0	1.0	0.0
Garden	0.6	0.6	0.1	0.1	0.0
Infrastructure	2.5	2.5	0.6	0.6	0.0
TOTAL	401.7	401.7	100	100	-

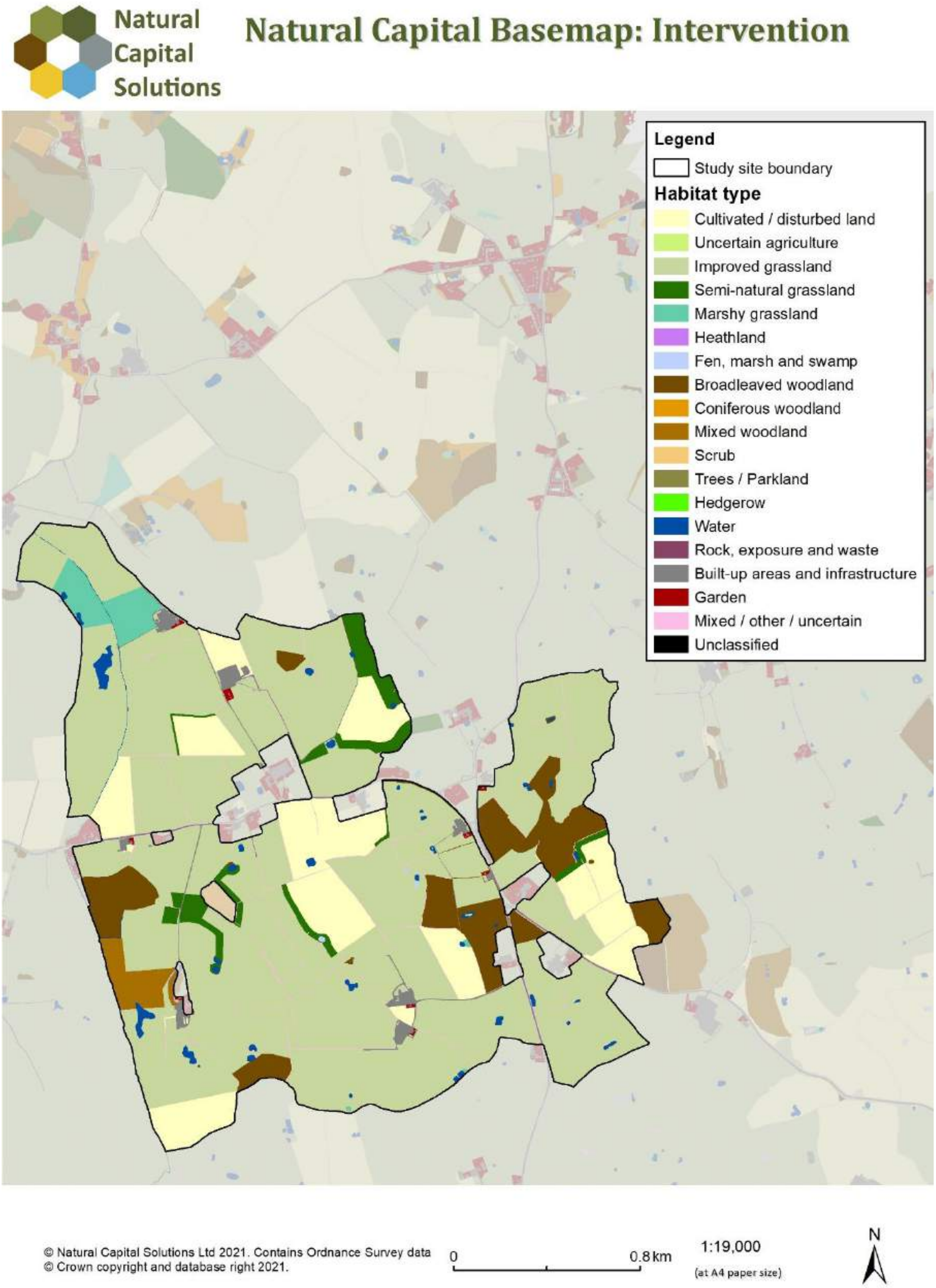

Figure 5 Habitats across the Ridley Estate under the proposed interventions.

3.4 Change in ecosystem service provision

The ecosystem services delivered by the estate were quantified and mapped for the baseline and intervention scenario and the change in benefits calculated. The mean score for each ecosystem service and the percentage change is shown in Table 3.

- **Carbon storage capacity** – there is a 10.8% increase in carbon storage projected to occur under the interventions. As can be seen from the yellow areas in Figure 6, the increase is driven by the woodland planting.
- **Air purification capacity (air quality regulation)** – under the proposed interventions, there is a 44% increase in delivery of this service. Again, the new woodland blocks, are primarily responsible for the increases, as is evident from Figure 7. The blocks of woodland to the east of the estate, on either side of the A49 and A534, are located in opportunity areas for air quality regulation, meaning that that they have been optimally located to deliver benefits in areas with greater demand, close to the main road.
- **Noise regulation capacity** – the areas of woodland across the farm, show on the map as yellow (Figure 8), indicating high capacity in these locations. There is an 37.5% increase in capacity under the interventions compared to the baseline. Several of the new woodland plantings, on either side of the main roads are located in opportunity areas for this service.
- **Local climate regulation capacity** – the larger areas of woodland appear on the map (Figure 9) as areas delivering this service and the new woodland blocks have a dramatic effect on the delivery of this service. There is a very large increase in this service under the proposed interventions, although this is from a low base. Note, however, that although the estate is now able to provide moderate levels of this service, there is no demand for this service in this location, due to its rural setting.
- **Pollination capacity** – pollination capacity is generally high across the landscape with most locations within easy reach of wild pollinators. It is very high under the baseline (Figure 10), but increases further under the intervention scenario (0.6% increase). The increase is due to the planting of semi-natural grassland and field margins. Note that this service could be increased further by additional planting of field margins around the arable fields.
- **Water flow regulation capacity** – water flow capacity is generally quite high across the farm (Figure 11), under both scenarios. Table 3 shows that values improve by 6.7% under the interventions. As slope and soil type does not change under different land management, these changes are related to changes in “roughness” of the habitats, or the friction that each different land use creates for water movement. High levels of roughness slow water flow (enhance this service) and woodland is effective at increasing roughness.
- **Accessible nature capacity** – there are no plans for increasing public access under the proposed interventions, hence the scores are similar under the baseline and investment scenario, with the small increase due to creating slightly more natural habitats (Figure 12). Accessible nature capacity could be enhanced by opening up access to some of the newly created habitats.

Table 3 Mean ecosystem service capacity scores and percentage change for each of the ecosystem services quantified across the Ridley Estate under the baseline and intervention scenario.

Ecosystem Service	Ecosystem service score		% change
	Baseline	Intervention	
Carbon storage capacity	19.6	21.7	10.8
Air purification capacity	10.9	15.8	44.4
Noise regulation capacity	12.1	16.6	37.5
Local climate regulation capacity	1.1	7.3	538
Pollination regulation capacity	94.8	95.4	0.6
Water flow regulation capacity	50.7	54.2	6.7
Accessible nature capacity	10.1	10.3	2.7
MEDIAN % CHANGE			10.8

Overall change

Overall, all seven of the ecosystem services mapped increased under the proposed natural capital interventions. The median change was a 10.8% increase in ecosystem service capacity compared to the baseline (Table 3).

Physical flows of ecosystem services

In addition to the ecosystem services that have been mapped, the physical flows of seven ecosystem services have been calculated (Table 4). These show that carbon sequestration increases significantly (by 263 tonnes of CO_2), an additional 0.8 t $PM_{2.5}$ is absorbed and 281 m^3 of timber/woodfuel could be harvested each year under the proposed interventions. On the other hand, the amount of land under agricultural production falls, although this does also lead to a fall of 42 tCO_2e in greenhouse gas emissions from agriculture.

Table 4 Annual physical flows of ecosystem services under the baseline and intervention scenario for the Ridley Estate.

Ecosystem Service	Units	Annual physical flow	
		Baseline	Intervention
Carbon sequestration	tCO_2e	67.5	330.9
Air quality regulation	$tPM_{2.5}$	1.3	2.1
Timber/woodfuel production	m^3	43.6	324.8
Recreation	Visits	0	0
Physical health	QALY	0	0
Agricultural production	Hectares	379	337
GHG emissions from agriculture	tCO_2e	1580	1410

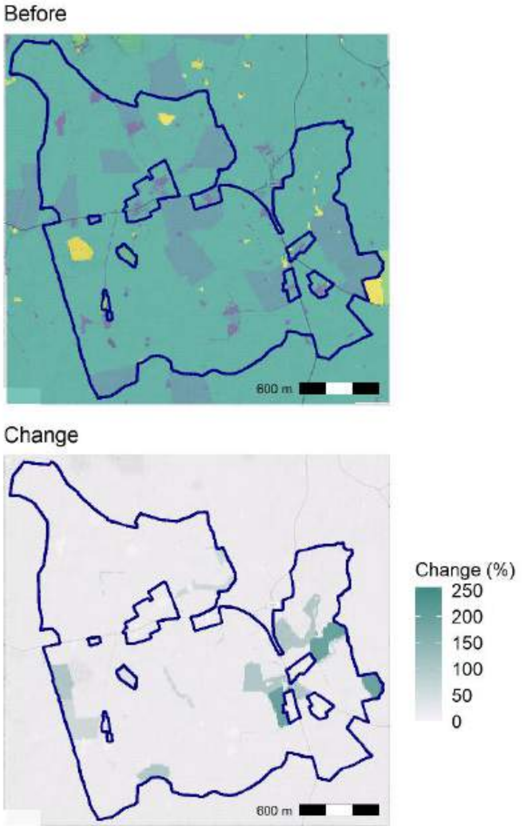

Figure 6: Carbon storage capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

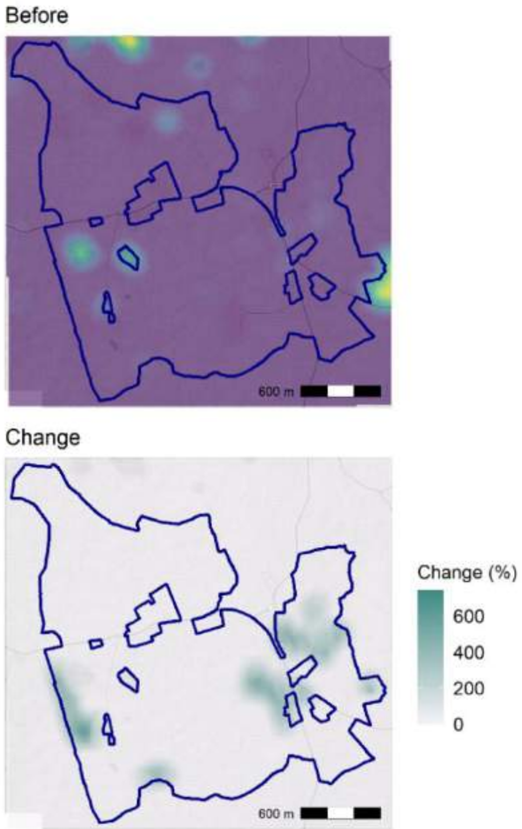

Figure 7: Air purification capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

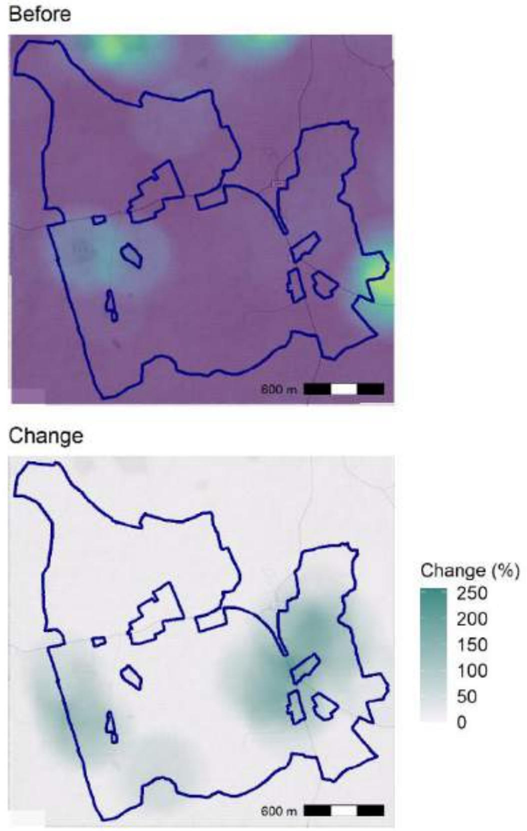

Figure 8: Noise regulation capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

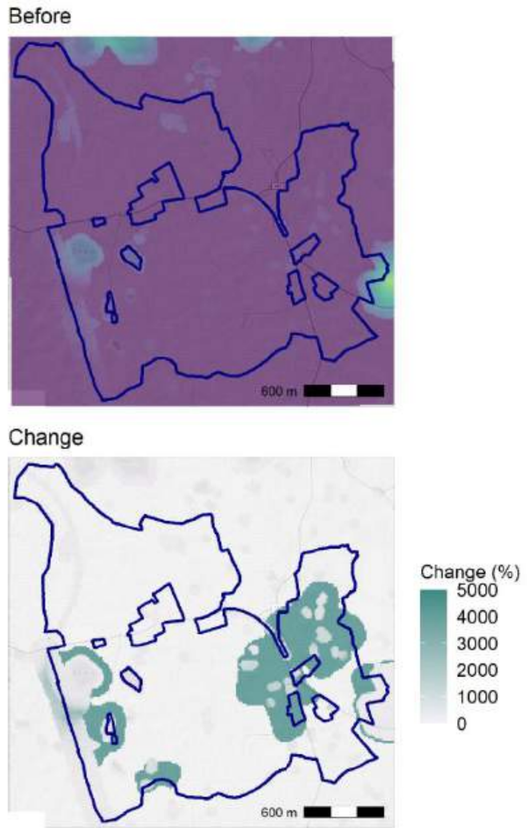

Figure 9: Local climate regulation capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

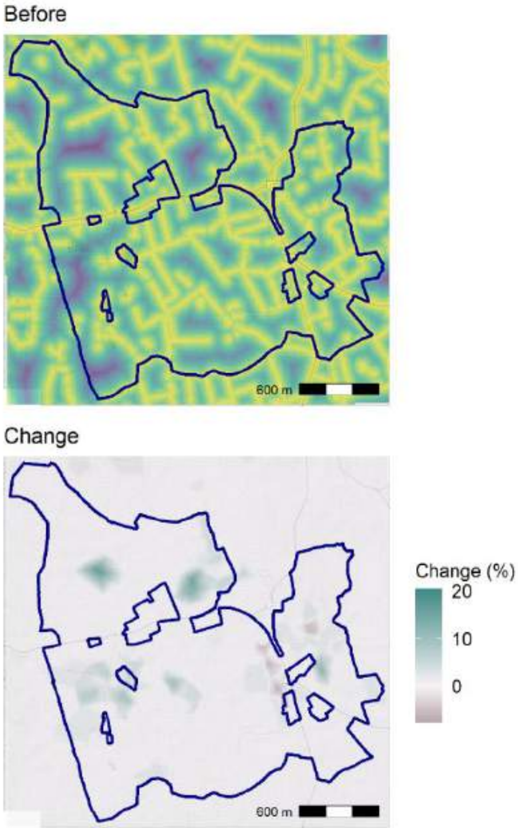

Figure 10: Pollination capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

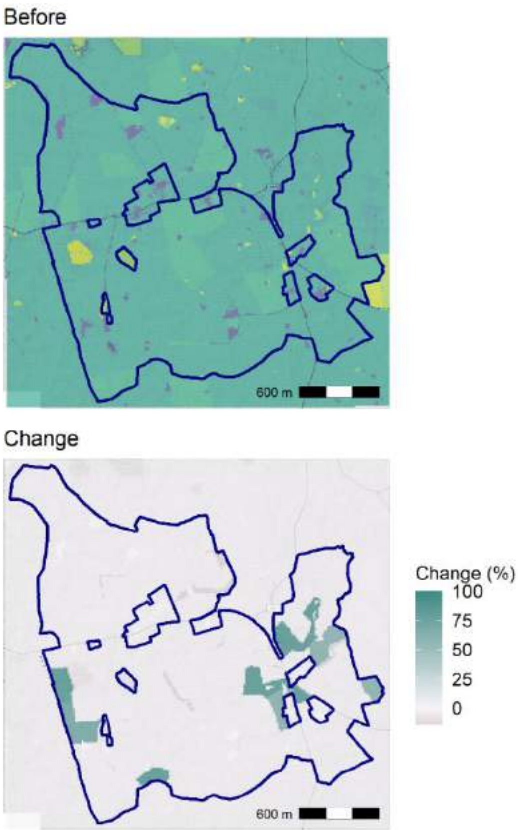

Figure 11: Water flow regulation capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

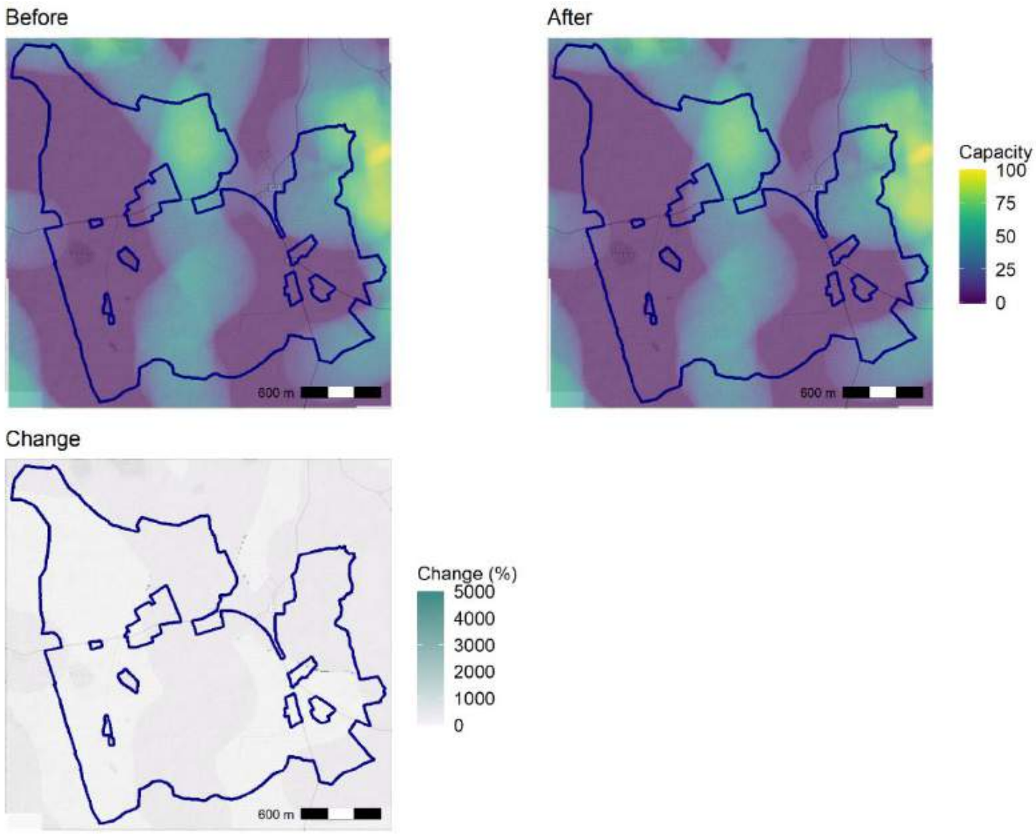

Figure 12: Accessible nature capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

3.5 Economic appraisal and potential funding

The monetary flow of benefits was estimated for all ecosystem services for which this was possible. Full costs and benefits, presented on a per hectare basis, are shown in Table A1 (Annex A). Note that a number of the benefits mapped in Section 3.4 could not be valued, such as water flow regulation. Also, the proposed scheme is likely to result in biodiversity benefits, but these were not valued. It would be possible to assess these using the Biodiversity Metric, but this would require site specific information on habitat condition. Woodland and agri-environment payments have been used as an expedient and incomplete estimate of biodiversity value.

The case involves a switch from improved to conservation grassland and a reduction in dairy production, reducing net margins from agricultural provisioning services. The core services targeted by this investment are carbon sequestration and air quality regulation, with secondary services including water quality regulation and biodiversity. The funding mechanism selector identifies the following as the most appropriate funding mechanisms to deliver this suite of core and secondary services:

- ELMs;
- Woodland Equity Fund;
- Woodland Code; and
- Forestry Commission Woodland Creation.

The amount of funding required reflects provisions for initial capital costs plus allowance for working capital over a 5-year period. The investment requires up-front costs in terms of woodland planting and restoration of semi-natural and marshy grassland, as well as revenue (on-going costs) related to maintenance and management of the woodland and grassland. Should there be less up-front funds available, then it may take longer to plant woodlands or restore the grassland, so the benefits would also likely be reduced (since they would not occur until later).

The total funding need for the case study is estimated at £472,000 for the first five years of the project, or £1,174 per hectare. This is made up of capital cost funding (including management costs), estimated at £319,000 (£794 per hectare), and working capital of £153,000 (£380 per hectare). These are short-term up front-costs (up to 5 years) needed to enable the natural capital investment. A full breakdown of funding requirements is given in Table A2 (Annex A).

With **projected benefits of the case study of £1.8 million** over 50 years and a **Net Present Value** (benefits minus costs) of **£1.05 million**, this gives a **benefit-cost ratio of 2.4** and an **internal rate of return (IRR) of 15%**. The benefits vary by type of ecosystem service provided, totalling £222 per ha, and broken down as follows (top four benefit contributions shown; it is also important to note that there are additional ecosystem service benefits that cannot currently be captured in monetary terms):

- Air quality regulation: £150 per ha
- Carbon sequestration: £53 per ha
- Reduction in agricultural greenhouse gas emissions: £32 per ha
- Timber/woodfuel production: £13 per ha

The potential value of carbon credits (based on voluntary carbon market price, 2021) is £8,770 per year (see Table A3 in Annex A). Note that this is based on the average price received in the Woodland Carbon Guarantee third auction (October 2020), and prices are thought to have increased significantly since then. Using the BEIS traded central price estimate for 2025 would give a value of £26,345 per year. Neither of these prices are the same as the carbon price used in the economic appraisal, which was based on the BEIS central non-traded carbon price and reflects the societal value of carbon, and is significantly higher.

The scale of funding required means that ELMs is likely to be appropriate for the case study in isolation, and a woodland equity fund is unlikely to be suitable for such a small area. The Forestry Commission England Woodland Creation Offer, which covers tree planting on farms may be suitable, once launched, at this small-scale. The high level of up-front (capital funding needed) means that funds specifically tailored to woodland creation are more likely to be appropriate, rather than mechanisms that attract funding based on ecosystem service delivery.

4. Case study 2: Carbon sequestration and biodiversity enhancement

Case study 2 is focused around the potential for peatland restoration to deliver carbon sequestration and biodiversity benefits in and around the **Goyt Valley SSSI**. The mapping work suggests that an area of around 80 ha could be converted from semi-natural grassland and restored to rewetted blanket bog.

4.1 Baseline natural capital assets

Figure 13 (overleaf) shows the distribution of broad habitat types across the site under the current situation and the area and percentage cover is shown in Table 5. The site is a degraded blanket bog on deep peat and is currently assessed to be in unfavourable condition by Natural England. Semi-natural grassland is the dominant habitat (80 ha, 90%), with blanket bog making up 8.5 ha (9.6%). The site is open access under the CRoW Act.

4.2 Identifying opportunities

Although biodiversity opportunity maps are available for the site (Figure 14), in this particular case study they are less relevant, as the site is a degraded blanket bog on deep peat and restoring the blanket bog is the key biodiversity objective for the site. The presence of semi-natural grassland is an indicator that the site is currently too dry, likely caused by a network of drains.

Opportunities to enhance ecosystem services were also identified and some of these are shown in Figure 15. The site is situated in an opportunity area to reduce runoff (water flow). This is compatible with restoration of the site for biodiversity as the same works will be required to achieve both goals. As the site is not close to any major urban areas, it does not provide opportunities for air quality, noise regulation or accessible nature.

Degraded peatland is a major emitter of carbon, hence restoring it will provide significant opportunities to reduce emissions.

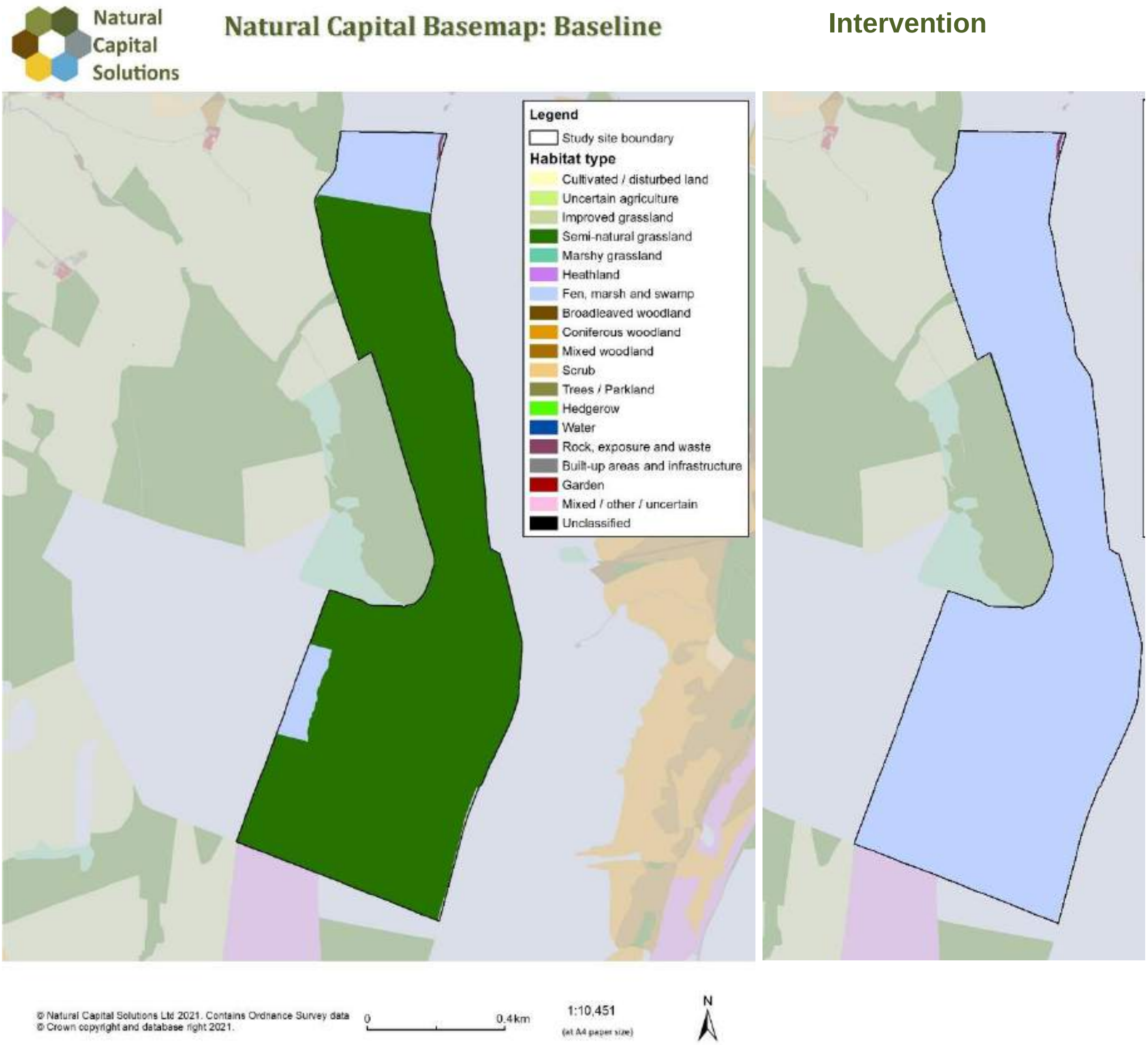

Figure 13 Broad habitats across the Goyt Valley SSSI under the baseline (present day) and intervention situations.

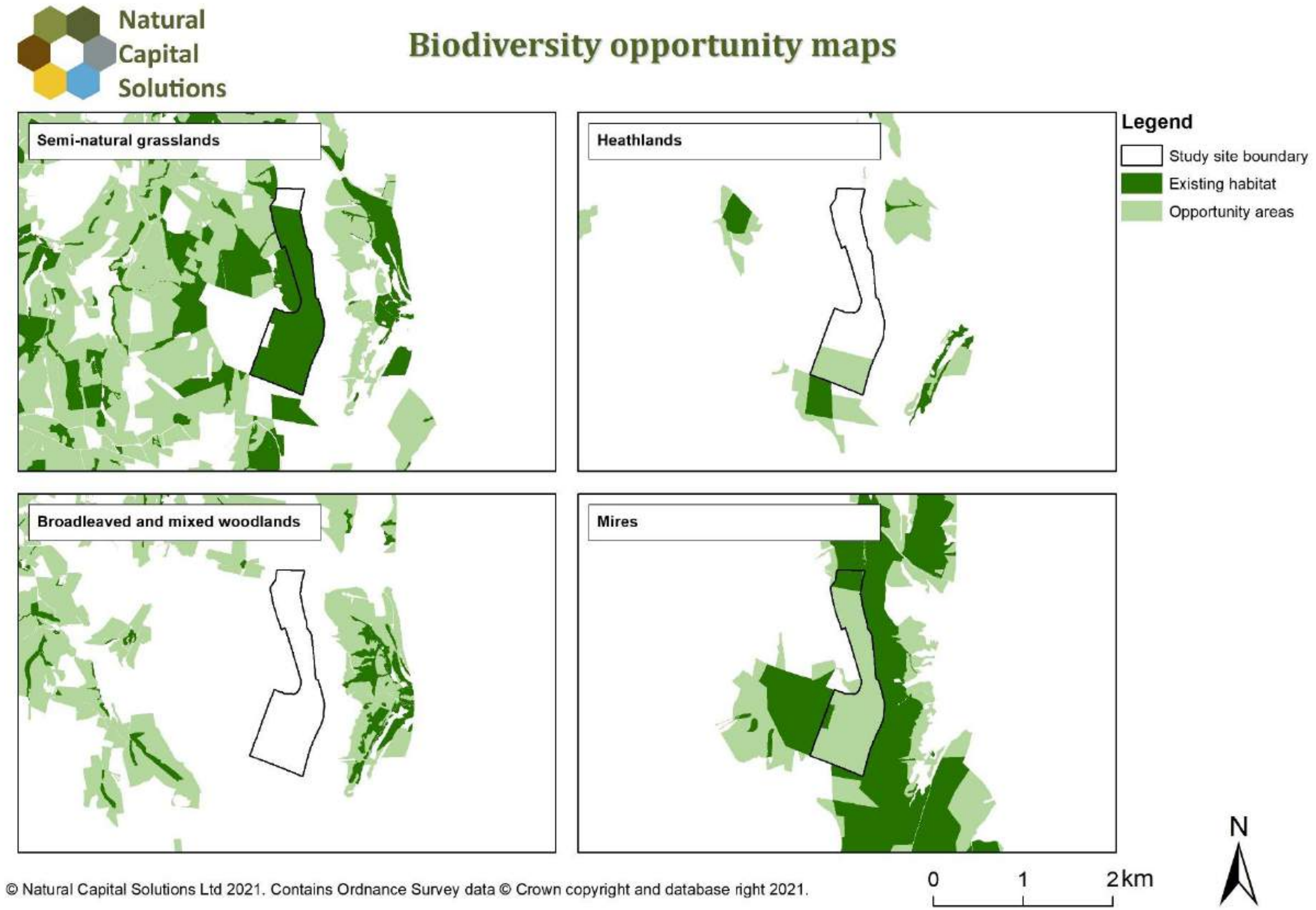

Figure 14 Goyt Valley SSSI biodiversity opportunity maps for semi-natural grassland habitats, broadleaved and mixed woodland habitats, heathlands, and wet grassland and wetland habitats. These maps identify whole fields that present opportunities.

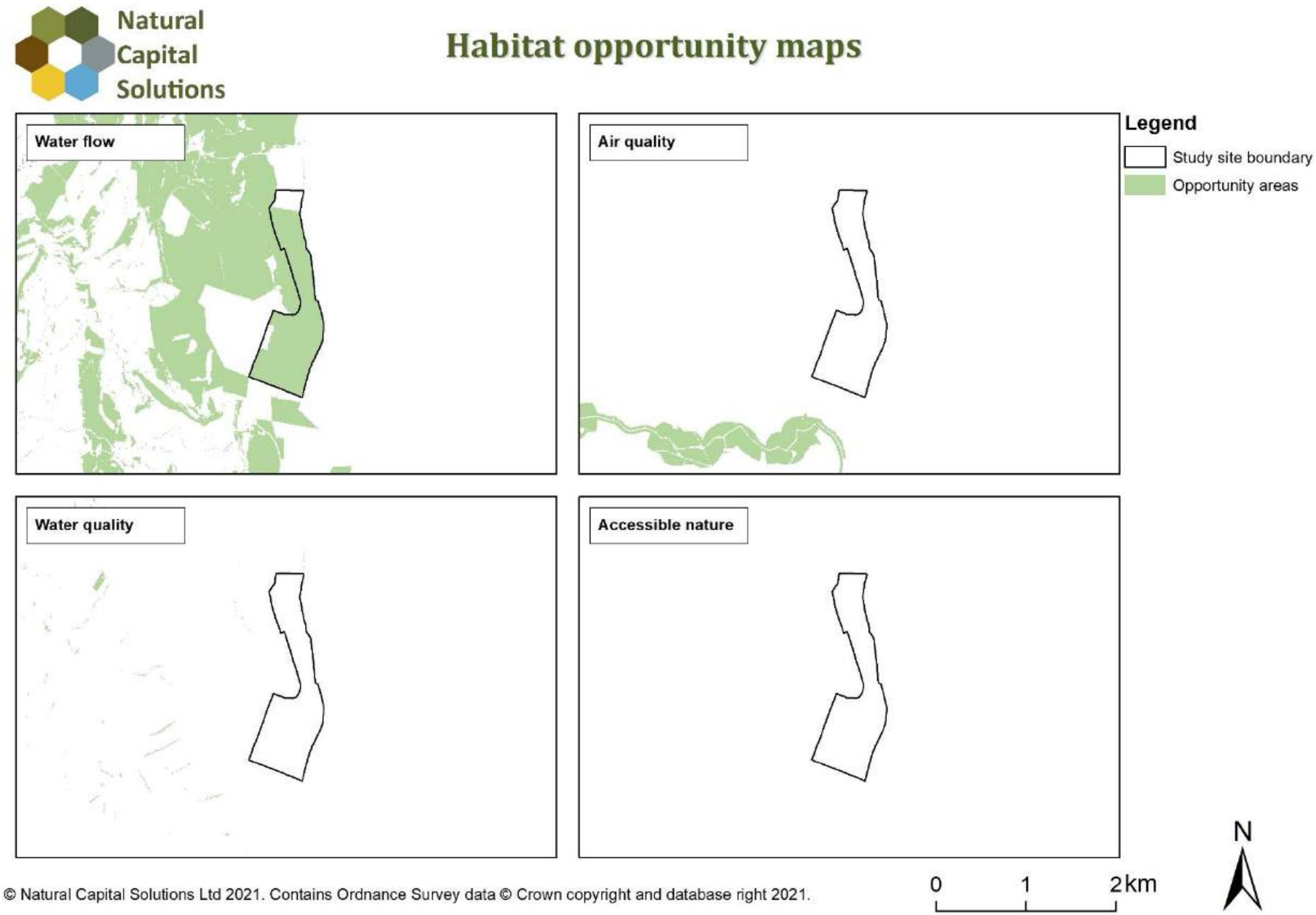

Figure 15 Goyt Valley SSSI habitat opportunity maps for water flow, water quality, air quality and accessible nature.

4.3 Interventions planned and changes to habitats

In terms of planning habitats and interventions, this is a much simpler case study than the other four. The entire area is suitable for restoration of blanket bog, with the post-restoration habitats shown in Figure 13 and Table 5. This can be achieved through blocking drains, reducing grazing (including erecting fencing), and planting sphagnum on bare peat areas. The restoration work will result in the site changing from a drained, modified bog (with semi-natural grassland) to a rewetted (semi-natural) bog.

Table 5 Area and percentage cover of broad habitat types across the Goyt Valley SSSI under the baseline and the intervention scenario.

Broad habitat	Area (Ha)		% Cover		Change (Ha)
	Baseline	Intervention	Baseline	Intervention	
Improved grassland	0.1	0.1	0.1	0.1	0.0
Semi-natural grassland	80.2	0.2	90.2	0.2	-80.1
Mire	8.5	88.6	9.6	99.6	80.1
Natural rock	0.1	0.1	0.1	0.1	0.0
TOTAL	88.9	88.9	100	100	-

4.4 Change in ecosystem service provision

The ecosystem services delivered by the site were quantified and mapped for the baseline and intervention scenario and the change in benefits calculated. The mean score for each ecosystem service and the percentage change is shown in Table 6. Note that carbon storage capacity was not included for this site, but carbon sequestration is calculated overleaf.

- **Noise regulation capacity** – is relatively low at the site and is unchanged following the interventions (Figure 16 top). However, there is no demand for this service at the site.
- **Local climate regulation capacity** – there is zero capacity to deliver this service either before or after the planned interventions (Figure 16 middle), but like noise regulation there is no demand in this location as it is nowhere near any urban areas.
- **Pollination capacity** – is extremely high before restoration, as semi-natural grassland is considered to be optimal habitat for pollinators. Capacity will decline by 18% following restoration as rewetted bog is less optimal for pollinators, although still remains high (Figure 16 bottom).
- **Water flow regulation capacity** – restoring the site will be extremely good for reducing runoff and this is picked up in this model, which shows that water flow regulation increases by 57% following restoration (Figure 17 top).
- **Accessible nature capacity** – as the site is fully open access, it achieves a good score for this service under the baseline. Even though access does not change, the restored site will achieve a higher score for naturalness following restoration, which means that the accessible nature capacity score increases by 15.9% and the site delivers a very capacity for this service (Figure 17 bottom).

Table 6 Mean ecosystem service capacity scores and percentage change for each of the ecosystem services quantified across the Goyt Valley SSSI under the baseline and intervention scenario.

Ecosystem Service	Ecosystem service score		% change
	Baseline	Intervention	
Noise regulation capacity	10.4	10.4	0.0
Local climate regulation capacity	0.0	0.0	0.0
Pollination regulation capacity	99.3	81.1	-18.3
Water flow regulation capacity	34.0	53.4	56.7
Accessible nature capacity	75.6	87.6	15.9
MEDIAN % CHANGE			0.0

Overall change

Overall, two of the five ecosystem services mapped increased under the proposed natural capital interventions, two were unchanged, and one declined. The median change was a therefore 0% (Table 6). However, the key objectives of the interventions were based around water flow regulation, carbon sequestration (see below) and biodiversity, all of which increase substantially following restoration.

Physical flows of ecosystem services

In addition to the ecosystem services that have been mapped, the physical flows of five ecosystem services have been calculated (Table 7). Degraded bog emits large amounts of carbon and the study area is currently emitting 393 tonnes of CO_2 each year. Restoring the blanket bog will reduce these emissions almost to zero, with a net reduction of emissions of 393 tCO_2e annually. In addition, recreation and physical health benefits are predicted to increase by 15% and air quality regulation by 10.6%.

Table 7 Annual physical flows of ecosystem services under the baseline and intervention scenario for the Goyt Valley SSSI.

Ecosystem Service	Units	Annual physical flow	
		Baseline	Intervention
Carbon sequestration	tCO_2e	-393.3	-0.6
Air quality regulation	$tPM_{2.5}$	0.22	0.24
Timber/woodfuel production	m^3	0	0
Recreation	Visits	48,400	55,700
Physical health	QALY	3.63	4.17

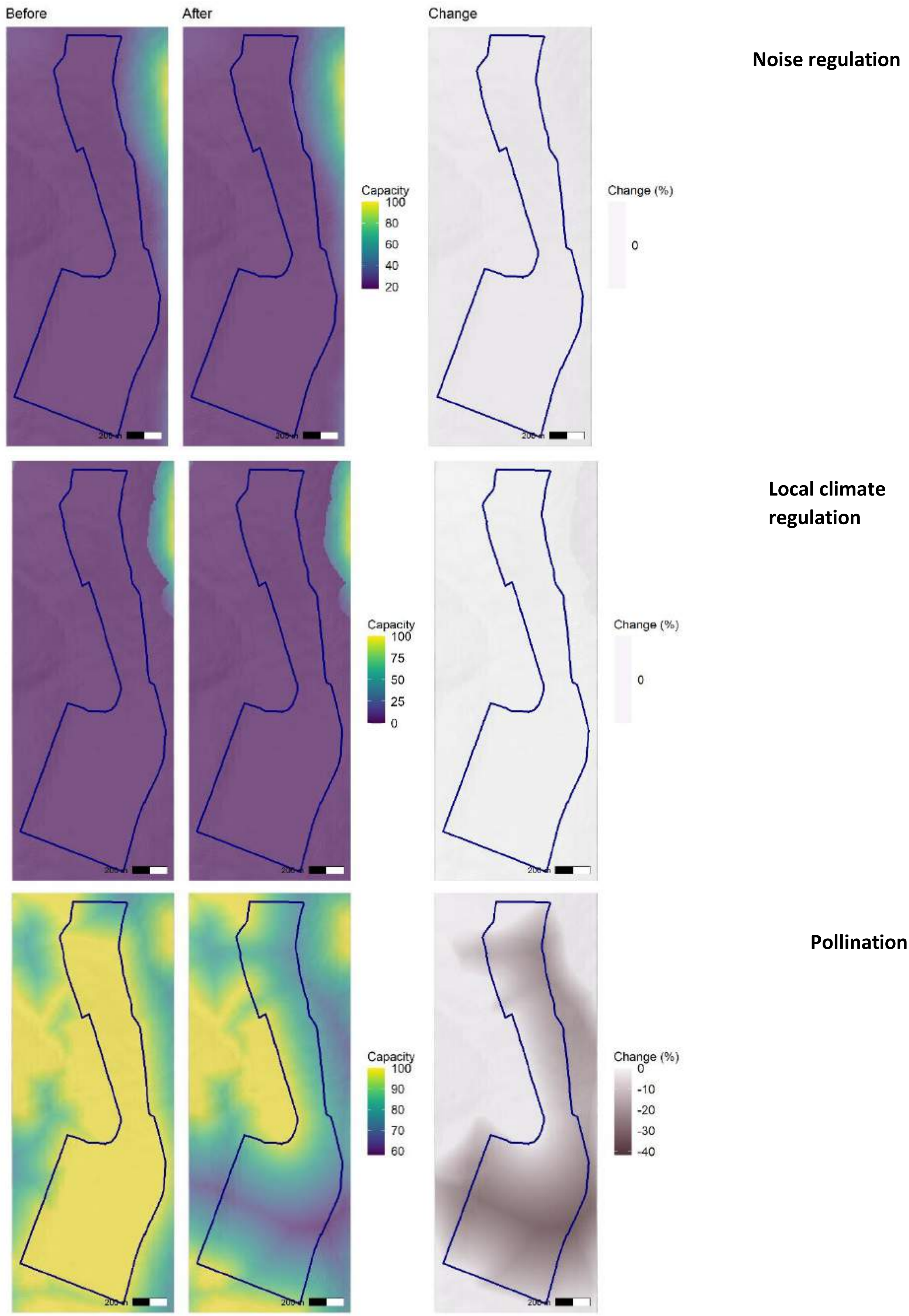

Figure 16 Noise regulation (top), local climate regulation (middle), and pollination (bottom) for the current situation, under the proposed interventions, and highlighting the change between the two.

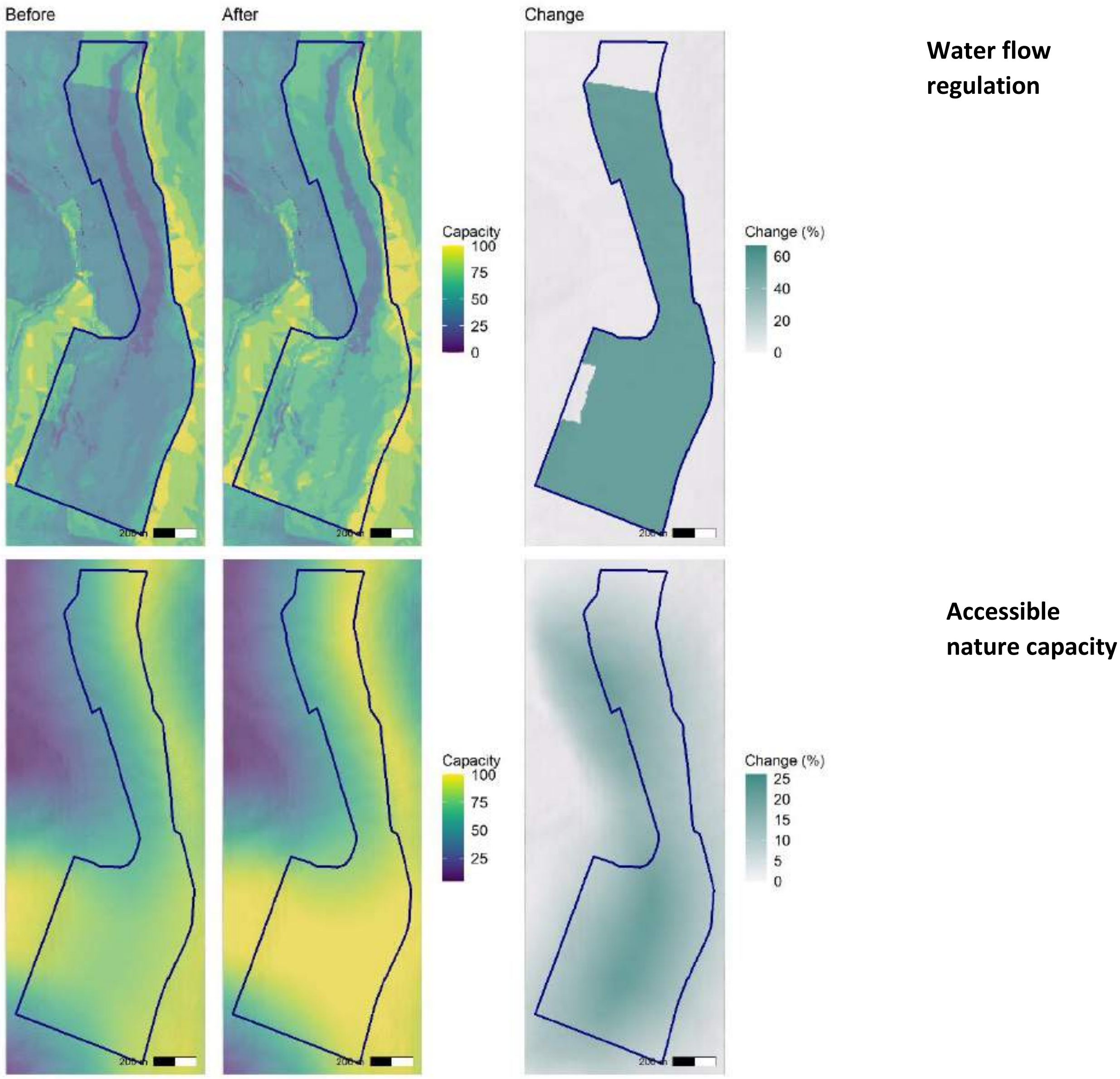

Figure 17 Water flow regulation (top) and accessible nature capacity (bottom) for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

4.5 Economic appraisal and potential funding

The monetary flow of benefits was estimated for all ecosystem services for which this was possible. Full costs and benefits, presented on a per hectare basis, are shown in Table A1 (Annex A).

The core services targeted by this investment are carbon sequestration and biodiversity, with secondary services including water flow regulation and accessible nature experience (enhanced recreation due to increased biodiversity). The funding mechanism selector identifies the following as the most appropriate funding mechanisms to deliver this suite of core and secondary services:

- Investment Readiness Fund
- Nature for Climate Fund (specifically in relation to the England Peat Action Plan)

The amount of funding required reflects provisions for initial capital costs plus allowance for working capital over a 5-year period. The investment requires up-front costs in terms of fencing to promote sustainable livestock grazing, block installation to grips and gullies to improve the water table and planting of large area of sphagnum moss. Revenue costs (on-going costs) relate to maintenance and management of the peatland. Should there be less up-front funds available, then it may take longer to undertake some of the up-front restoration activities, so the benefits would also likely be reduced (since they would not occur until later).

The total funding need for the case study is estimated at £187,000 for the first five years of the project, or £2,101 per ha. This is made up of capital cost funding (including management costs), estimated at £129,000 (£1,451 per hectare), and working capital of £58,000 (£650 per hectare). These are short-term up front-costs (up to 5 years) needed to enable the natural capital investment.

With **projected benefits of the case study of £1.4 million** over 50 years and a **Net Present Value of £1.1 million**, this gives a **benefit-cost ratio of 4.4** and an **internal rate of return (IRR) of 24%**. The benefits vary by type of ecosystem service provided, totalling £799 per ha, and broken down as follows (top four benefit contributions shown; it is also important to note that there are additional ecosystem service benefits that cannot currently be captured in monetary terms):

- Carbon sequestration: £340 per ha
- Recreation: £301 per ha
- Physical health: £92 per ha
- Sustainable agriculture (agri-environment): £31 per ha

The potential value of carbon credits (based on voluntary carbon market price, 2021) is £6,819 per year (see Table A3 in Annex A).

The Nature for Climate Peatland Grant Scheme is a competitive grant scheme that will run until 2025. Its focus is on landscape-scale applications meaning that a small case study location may not be sufficient to attract funding. Instead, the focus is on restoration of entire hydrological units of peatland. In all cases, match funding is required of a minimum of 15% (or more normally 25%) of the total project costs[7]. Inclusion of peatland restoration in larger bids, e.g. through Investment Readiness may be more appropriate, capturing this small scale project within a much broader change to help lever funding.

[7] HM Government (2021): Nature for Climate Peatland Grant Scheme, 30 April 2021, available at: https://www.gov.uk/guidance/nature-for-climate-peatland-grant-scheme on 1 June 2021.

5. Case study 3: Water quality and flow improvements

Case study 3 is focused on areas that can deliver water flow reductions and water quality enhancements, alongside biodiversity improvement and other benefits. The case study location was identified by studying maps across the whole Bollin catchment, to identify areas that could best deliver these benefits. The chosen location was the lower **Dean**, just upstream of its confluence with the River Bollin. The total area of the site is 182 ha.

5.1 Baseline natural capital assets

Figure 18 (overleaf) shows the distribution of broad habitat types across the study area under the current situation and the area and percentage cover is shown in Table 8. The asset register demonstrates that improved (including amenity) grassland is the dominant habitat across the study area, taking up 99.7 ha, or 52.4% of the total area. Woodland, tree and scrub habitats make up 32.9 ha (17.3%) of the area and cultivated land occurs on 12.9 ha (6.8%). Built-up areas, garden and infrastructure (roads, railway, paths and pavements) make up a combined 33.7 ha or 17.7% of the land area. The River Dean flows through the site, although it only takes up 3.2 ha (1.7%) of the area. There are no semi-natural grasslands, heathlands or mire habitats present in the study area.

5.2 Identifying opportunities

Given the lack of semi-natural grasslands, heathlands and mire habitats within or close to the study area, there are no opportunities to create these habitats that will be ecologically connected to existing habitats (Figure 19). These habitats could still be created, but would be less significant from an ecological point of view as they would be isolated from existing habitats. On the other hand, multiple opportunities exist for planting broadleaved and mixed woodland, that will be ecologically connected to existing habitat, and these are shown in Figure 19. Opportunities are present over much of the study area, especially close to the river, where much of the existing woodland occurs.

Multiple opportunities to enhance ecosystem services were also identified and key services are shown in Figure 20. Opportunities to reduce surface runoff are located throughout the area, particularly on the areas of existing improved grassland. There are fewer opportunities to improve water quality by reducing soil erosion, but these do still occur, concentrated on the arable (cultivated land) areas. As the site is located adjacent to an urban area, hence with high demand, much of the area provides an opportunity to ameliorate air pollution and for reducing noise pollution (not shown). There were also some opportunities to moderate local climate (reduce urban heat), immediately adjacent to the urban areas (not shown). Likewise, given its location, much of the site presents an opportunity to provide accessible natural greenspace close to where people live.

A number of the individual opportunities described above overlap. As a focus of the case study was on water flow and water quality, a map was produced showing multiple opportunities, but was constrained to highlight only those locations that presented opportunities to reduce water flow and /or enhance water quality. The resulting map (Figure 21) shows that by altering habitats in these locations, multiple benefits (multifunctionality) can be delivered at the same time. In most of the areas highlighted, between 5 and 7 opportunities (orange to red coloured areas on the map) can be delivered simultaneously. This occurs especially on areas of improved grassland close to the built-up areas and close to the river.

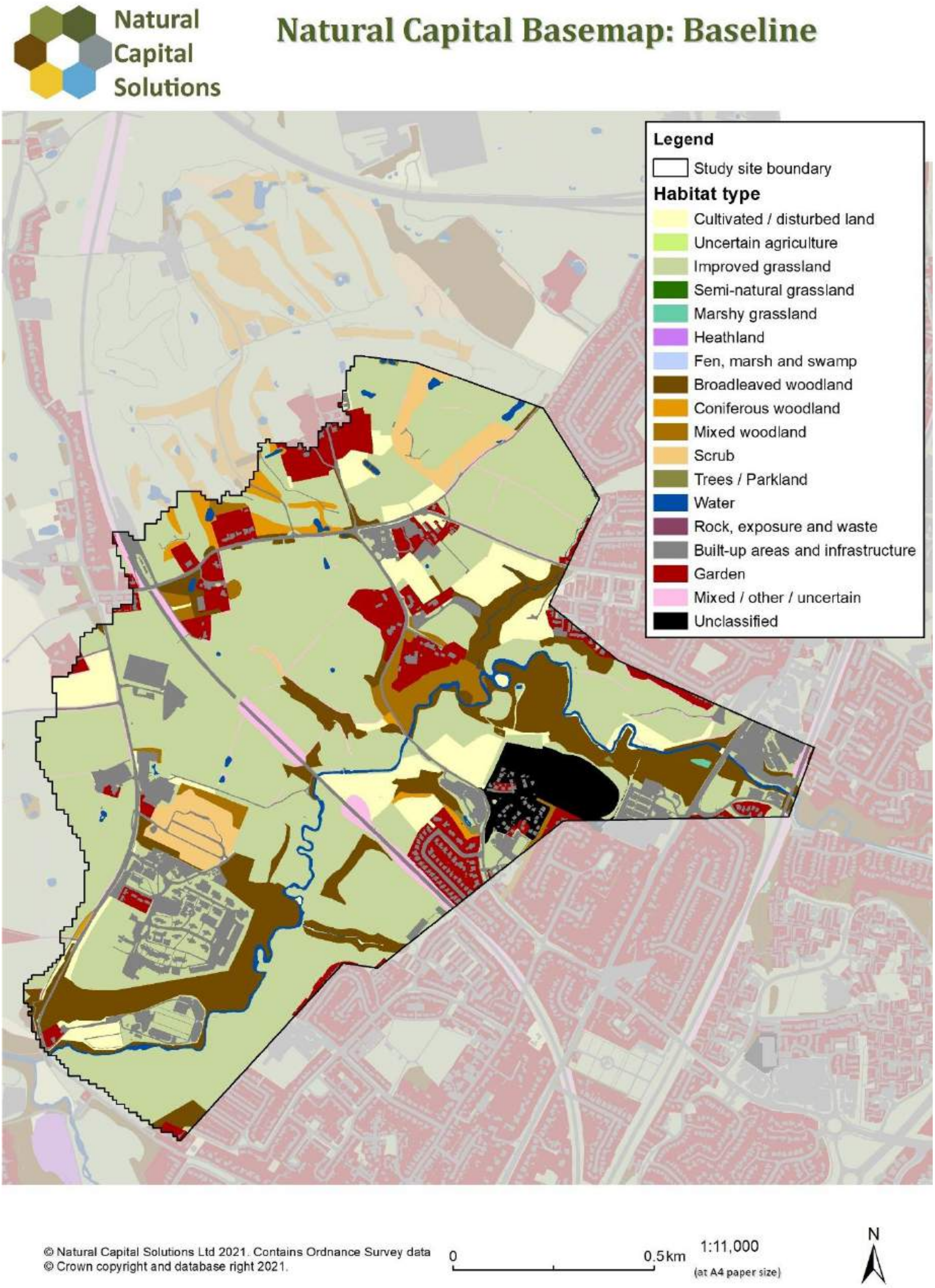

Figure 18 Broad habitats across the lower Dean under the baseline (present day) situation.

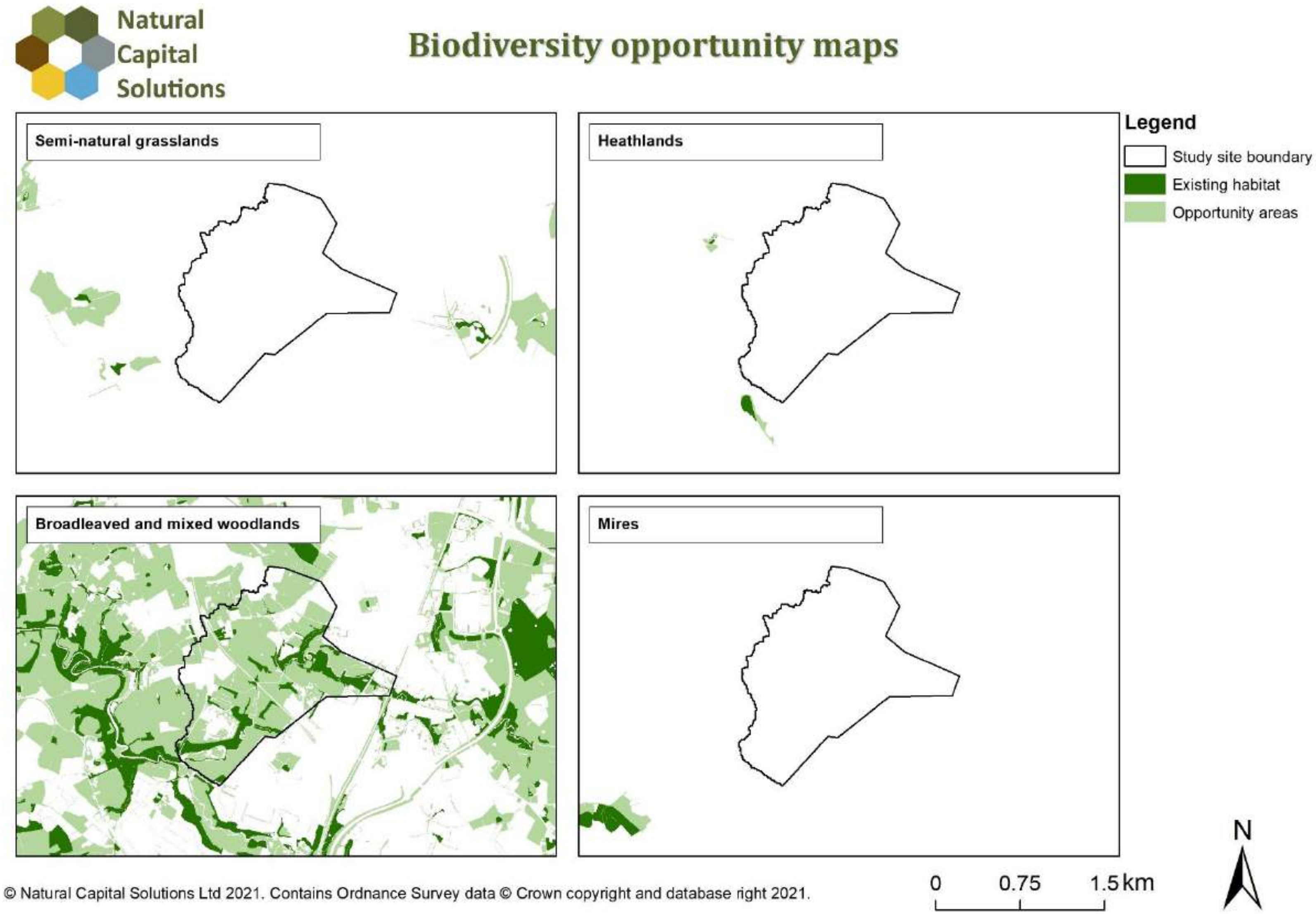

Figure 19 Lower Dean biodiversity opportunity maps for semi-natural grassland habitats, broadleaved and mixed woodland habitats, heathlands, and wet grassland and wetland habitats. These maps identify whole fields that present opportunities.

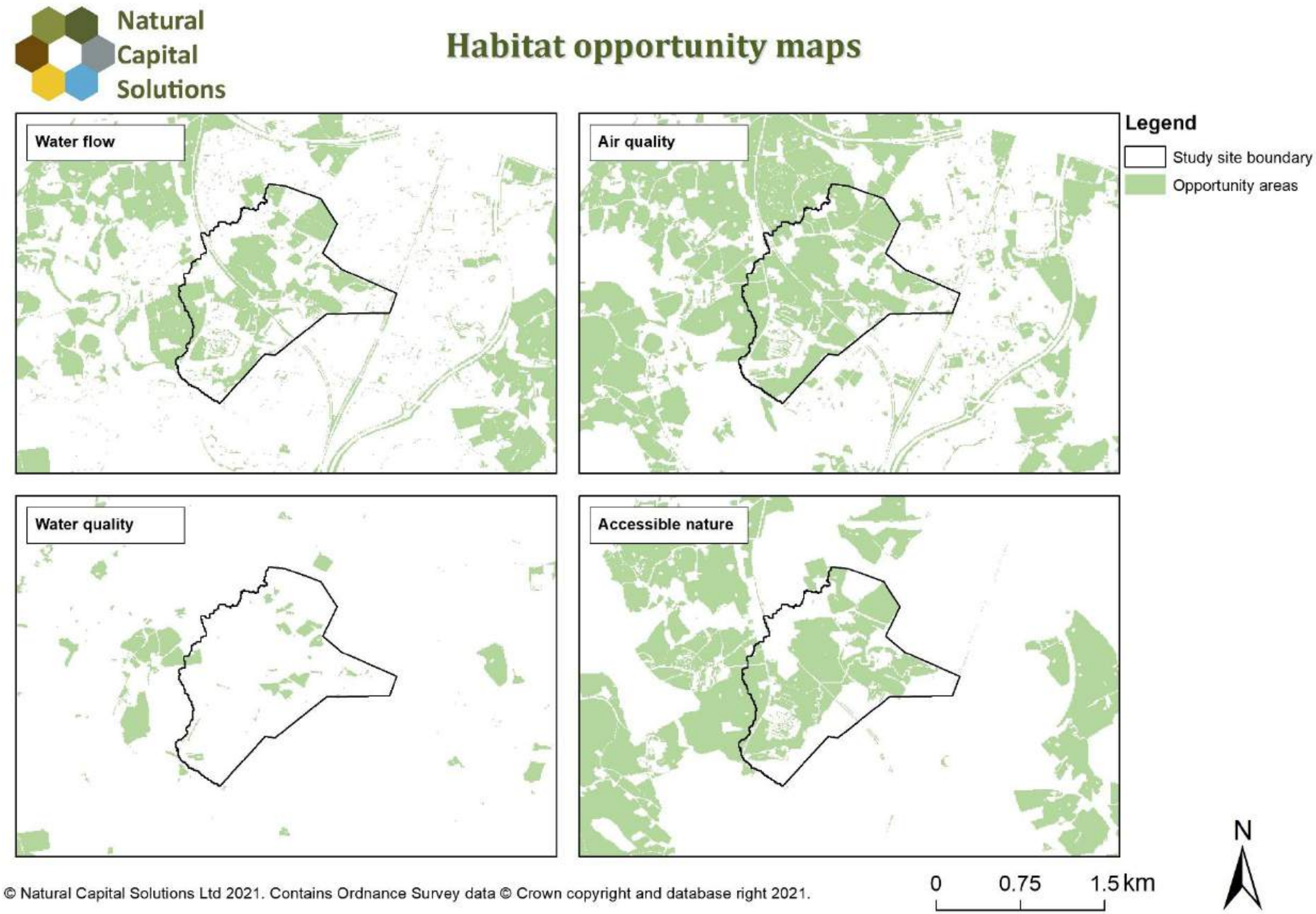

Figure 20 Lower Dean habitat opportunity maps for water flow, water quality, air quality and accessible nature.

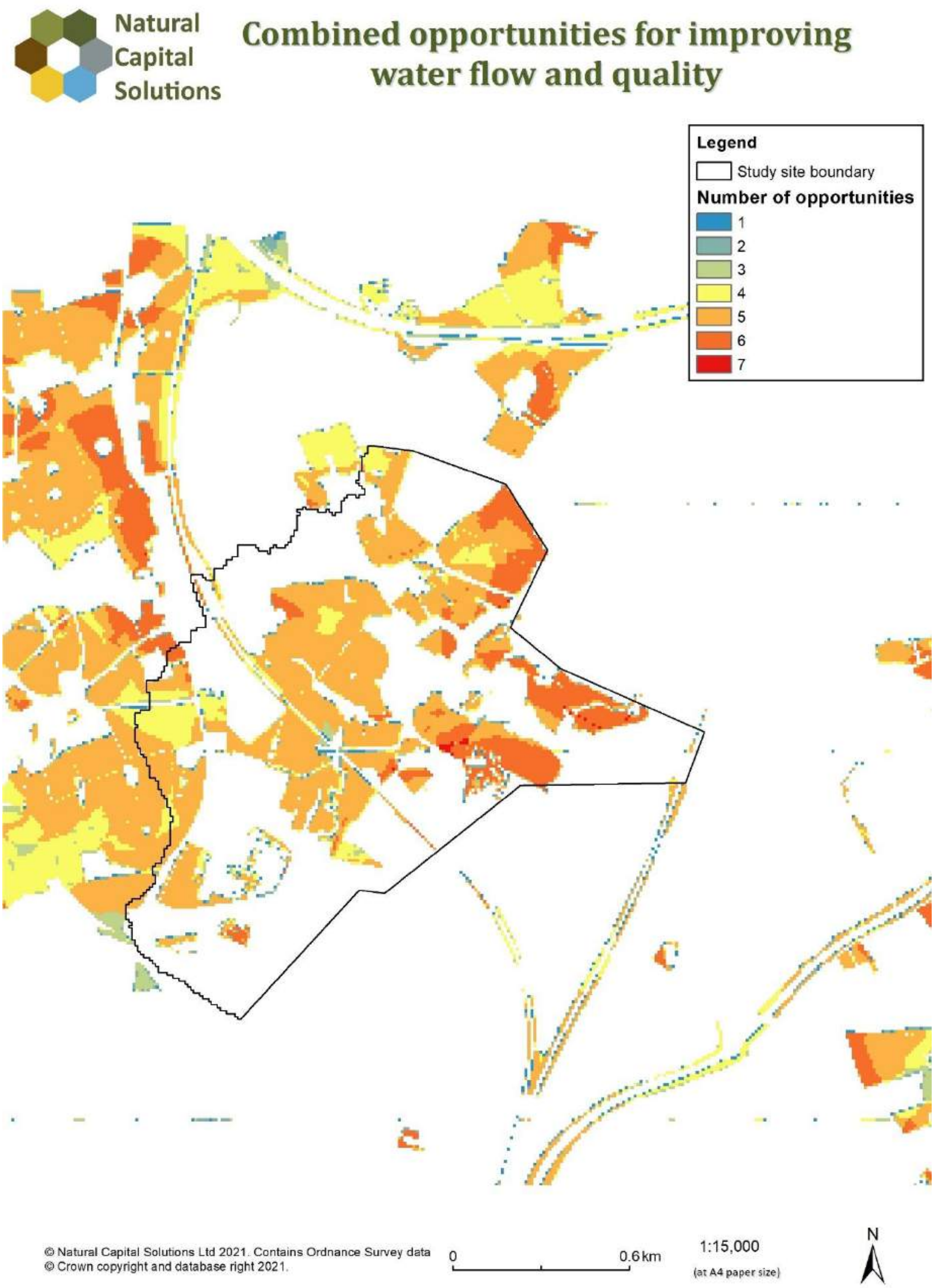

Figure 21 Combined opportunities for the Dean study area, limited to areas that provide opportunities for either reducing water flow or enhancing water quality.

5.3 Interventions planned and changes to habitats

The opportunity maps (Figures 19 and 20) were used to guide which habitats to create and their optimal locations. Habitats based on the planned interventions are shown in Figure 22 and the area and percentage cover of habitats under the baseline and the planned interventions are shown in Table 8. This focused on the planting of woodland (broadleaved +24 ha, trees/parkland +9.2 ha). This change occurs mainly on improved grassland (which reduces by 26.7 ha) and cultivated/disturbed land (-3.6 ha).

New woodland has been predominantly located adjacent to the River Dean where it expands and connects up existing woodland patches, as well as extending to the north. These areas were selected as they present opportunities to deliver water flow, water quality and biodiversity benefits in the same location. Given the sites location adjacent to an urban area (Wilmslow / Handforth), the new habitats to the north east of the railway line have been made publicly accessible (areas that fall within the accessible nature opportunity areas). New areas of parkland have also been suggested, alongside the accessible woodland, and works to enable access are included in the costs (Section 5.5).

Table 8 Area and percentage cover of broad habitat types across the Dean study area under the baseline and the intervention scenario.

Broad habitat	Area (Ha)		% Cover		Change (Ha)
	Baseline	Intervention	Baseline	Intervention	
Cultivated / disturbed land	12.9	7.5	6.8	3.9	-3.6
Improved and amenity grassland	99.7	73.0	52.4	38.4	-26.7
Marshy grassland	0.1	0.5	0.0	0.3	0.5
Unknown grassland	1.9	1.9	1.0	1.0	0.0
Swamp	0.1	0.1	0.0	0.0	0.0
Broadleaved woodland	22.2	45.0	11.7	23.6	22.8
Coniferous woodland	2.1	2.1	1.1	1.1	0.0
Mixed woodland	3.6	3.6	1.9	1.9	0.0
Scrub	5.0	5.0	2.6	2.6	0.0
Trees / Parkland	0.1	9.4	0.1	4.9	9.2
Boundaries	1.2	0.8	0.6	0.4	-0.4
Water	3.2	3.2	1.7	1.7	0.0
Built up areas	14.1	14.1	7.4	7.4	0.0
Garden	11.5	11.5	6.0	6.0	0.0
Infrastructure	8.1	4.3	8.1	4.3	0.00
Unclassified	4.7	4.7	2.5	2.5	0.0
TOTAL	190.2	190.2	100	100	-

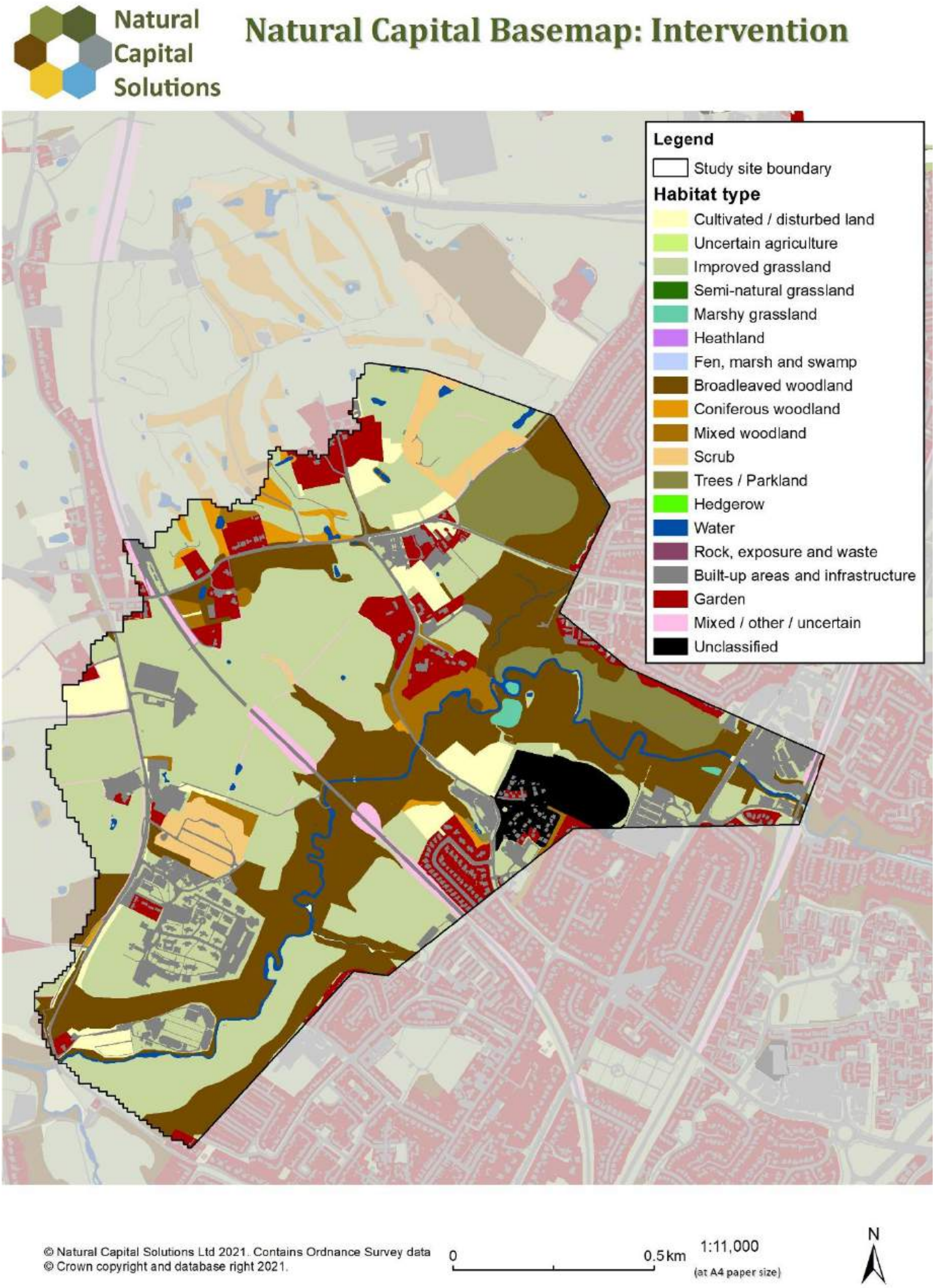

Figure 22 Habitats across the lower Dean study area under the proposed interventions.

5.4 Change in ecosystem service provision

The ecosystem services delivered by the site were quantified and mapped for the baseline and intervention scenario and the change in benefits calculated. The mean score for each ecosystem service and the percentage change is shown in Table 9.

- **Carbon storage capacity** – there is a 16.3% increase in carbon storage projected to occur under the interventions. As can be seen from the green-yellow areas in Figure 23, the increase is driven by the woodland planting.
- **Air purification capacity (air quality regulation)** – under the proposed interventions, there is a 48% increase in delivery of this service. Again, the new woodland blocks, are primarily responsible for the increases, as is evident from Figure 24.
- **Noise regulation capacity** – the areas of woodland across the site show on the map as yellow (Figure 25), indicating high capacity in these locations. There is an 42.7% increase in capacity under the interventions compared to the baseline..
- **Local climate regulation capacity** – the larger areas of woodland appear on the map (Figure 26) as areas delivering this service and the new woodland blocks have a dramatic effect on the delivery of this service. There is a very large increase in this service under the proposed interventions (increase of 98%).
- **Pollination capacity** – is generally high across the landscape with most locations within easy reach of wild pollinators. It is very high under the baseline (Figure 27), but declines slightly under the intervention scenario (1.1% decrease), although remaining high. This is due to the extensive new areas of woodland, which is not an optimal habitat for pollinators.
- **Water flow regulation capacity** – is generally quite high across the study area (Figure 28), under both scenarios. Table 9 shows that values improve by 12.4% under the interventions. As slope and soil type does not change under different land management, these changes are related to changes in "roughness" of the habitats, or the friction that each different land use creates for water movement. High levels of roughness slow water flow (enhance this service) and woodland is effective at increasing roughness.

Table 9 Mean ecosystem service capacity scores and percentage change for each of the ecosystem services quantified across the Dean study area under the baseline and intervention scenario.

Ecosystem Service	Ecosystem service score		% change
	Baseline	Intervention	
Carbon storage capacity	19.5	22.7	16.3
Air purification capacity	24.9	36.9	48.1
Noise regulation capacity	29.3	41.8	42.7
Local climate regulation capacity	16.1	32.0	98.3
Pollination regulation capacity	92.9	91.9	-1.1
Water flow regulation capacity	47.2	53.0	12.4
Accessible nature capacity	32.7	46.1	40.9
MEDIAN % CHANGE			40.9

- **Accessible nature capacity** – increases significantly under the proposed interventions (by 40.9%), due both to increasing the amount of land with public access and to increasing the naturalness of the land that is accessible (Figure 29).

Overall change

Overall, six of the seven ecosystem services mapped increased under the proposed natural capital interventions. The median change was a 40.9% increase in ecosystem service capacity compared to the baseline (Table 9).

Physical flows of ecosystem services

In addition to the ecosystem services that have been mapped, the physical flows of seven ecosystem services have been calculated (Table 10). These show that carbon sequestration increases significantly (by 214 tonnes of CO_2), an additional 0.54 t $PM_{2.5}$ are absorbed and 203 m^3 of timber/woodfuel could be harvested each year under the proposed interventions. There is projected to be a large increase in visits to the site once public access is opened up at the site, providing significant health benefits for the nearby population. On the other hand, the amount of land under agricultural production falls, although this does also lead to a fall of 134 tCO_2e in greenhouse gas emissions from agriculture.

Table 10 Annual physical flows of ecosystem services under the baseline and intervention scenario for the Dean study area.

Ecosystem Service	Units	Annual physical flow	
		Baseline	Intervention
Carbon sequestration	tCO_2e	265	479
Air quality regulation	$tPM_{2.5}$	1.32	1.86
Timber/woodfuel production	m^3	256	459
Recreation	Visits	0	174,000
Physical health	QALY	0	13.0
Agricultural production	Hectares	79.0	50.4
GHG emissions from agriculture	tCO_2e	471	337

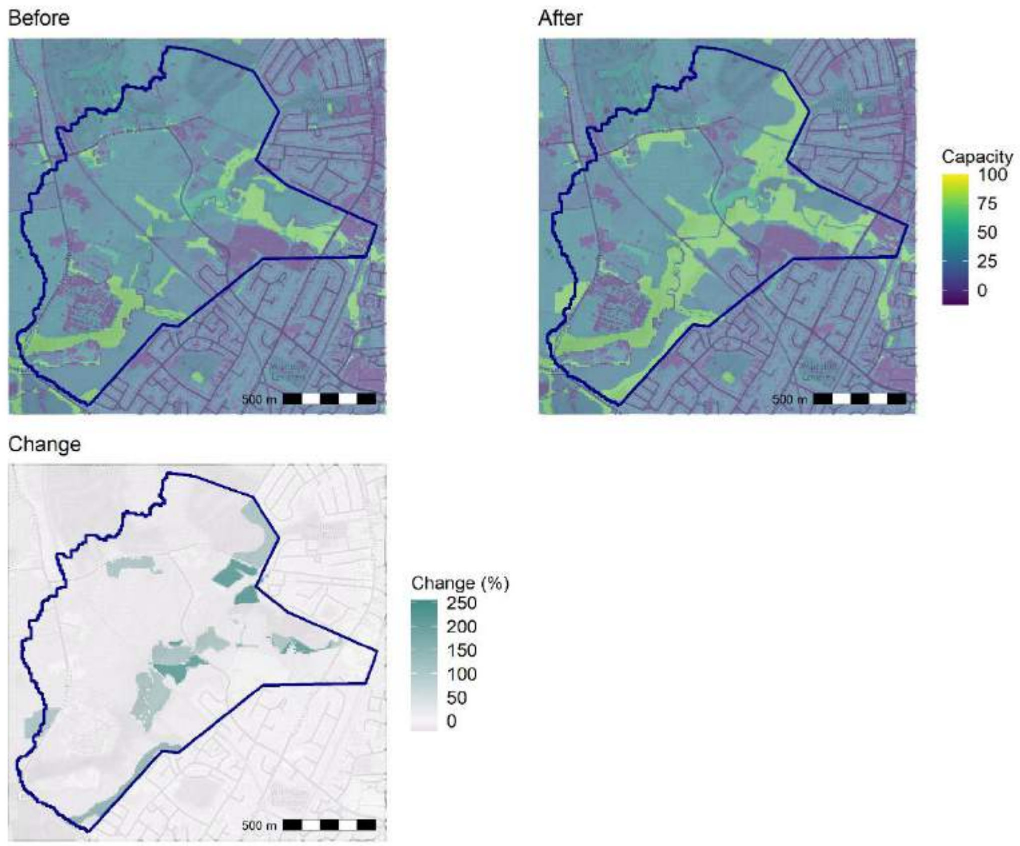

Figure 23 Carbon storage capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

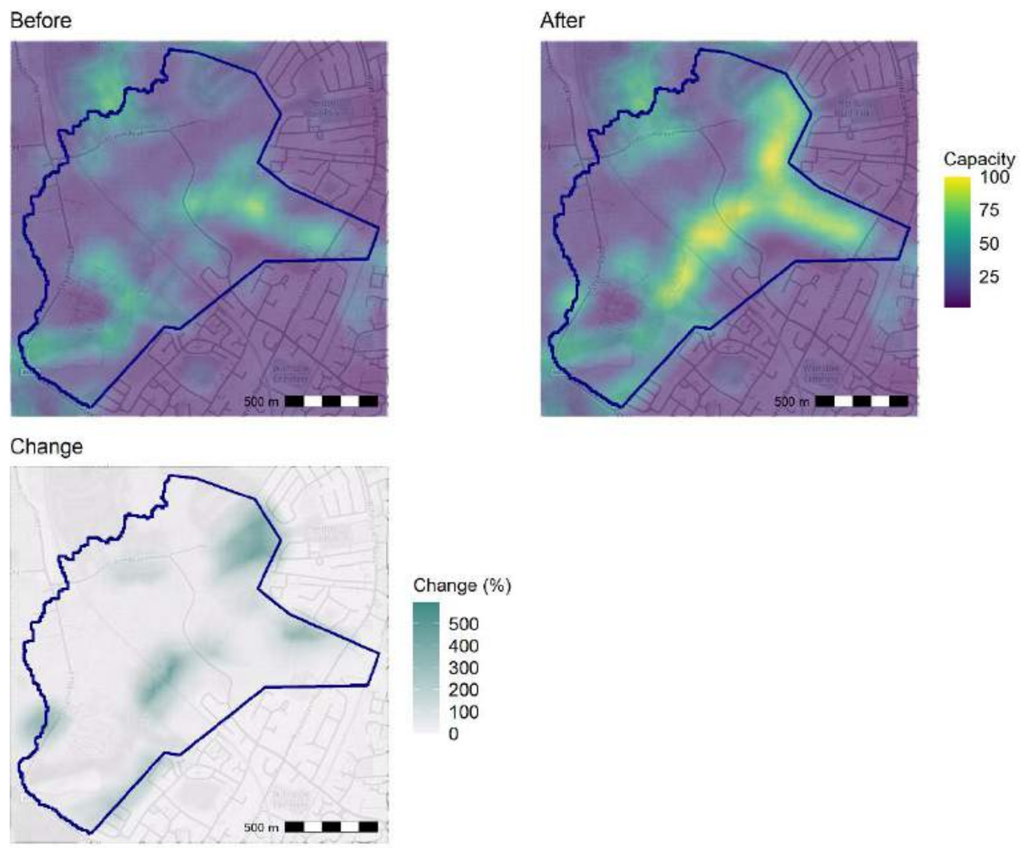

Figure 24 Air purification capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

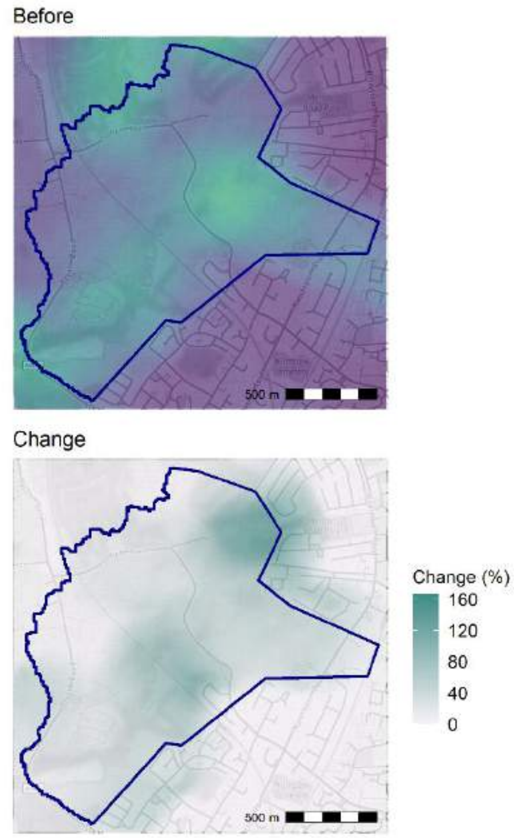

Figure 25 Noise regulation capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

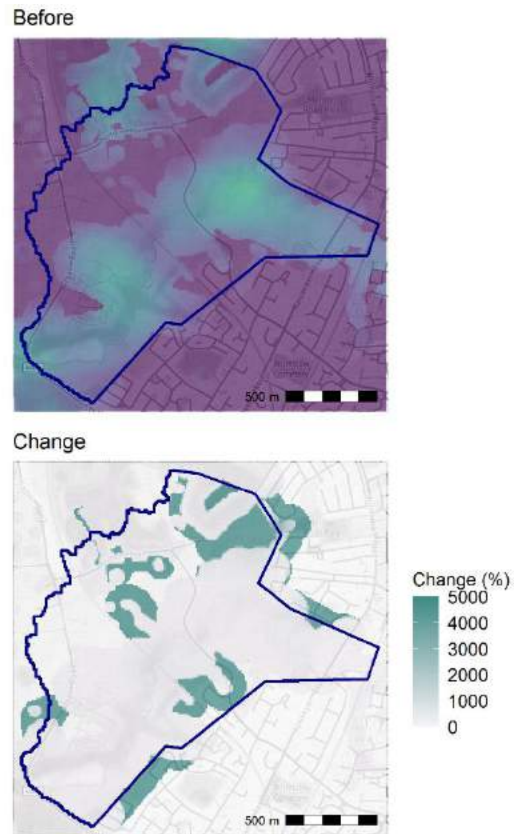

Figure 26 Local climate regulation capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

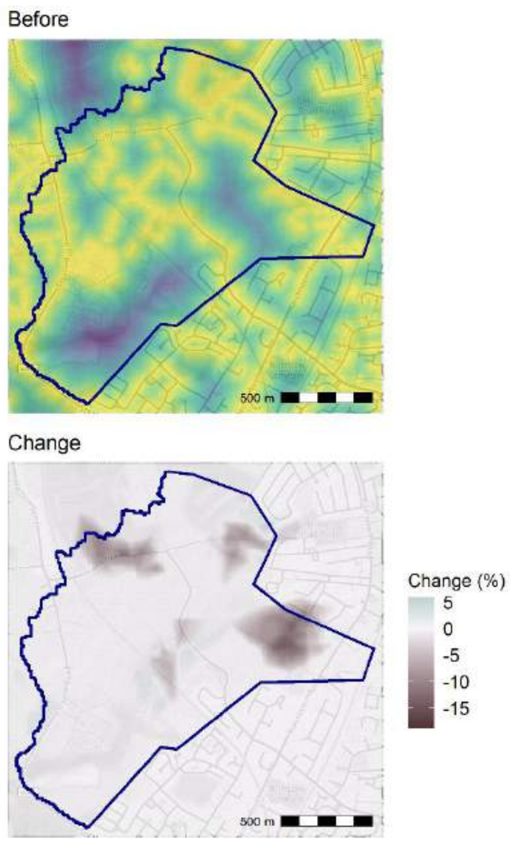

Figure 27 Pollination capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

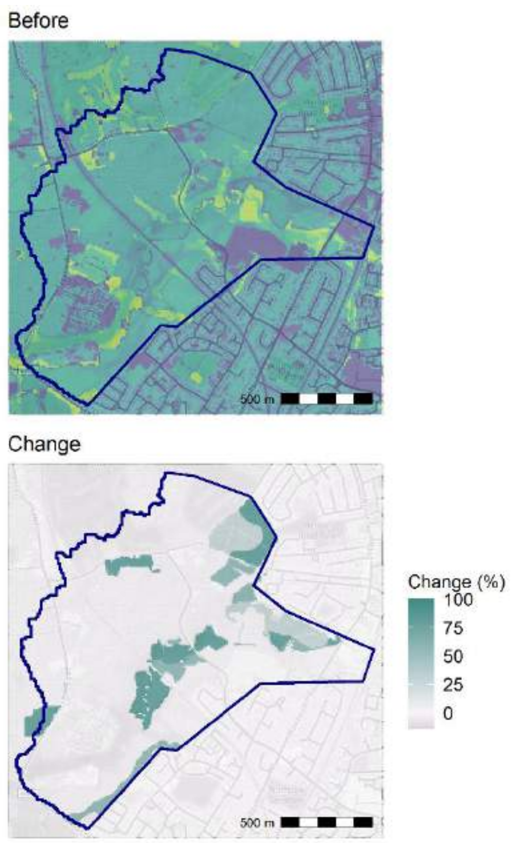

Figure 28 Water flow regulation capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

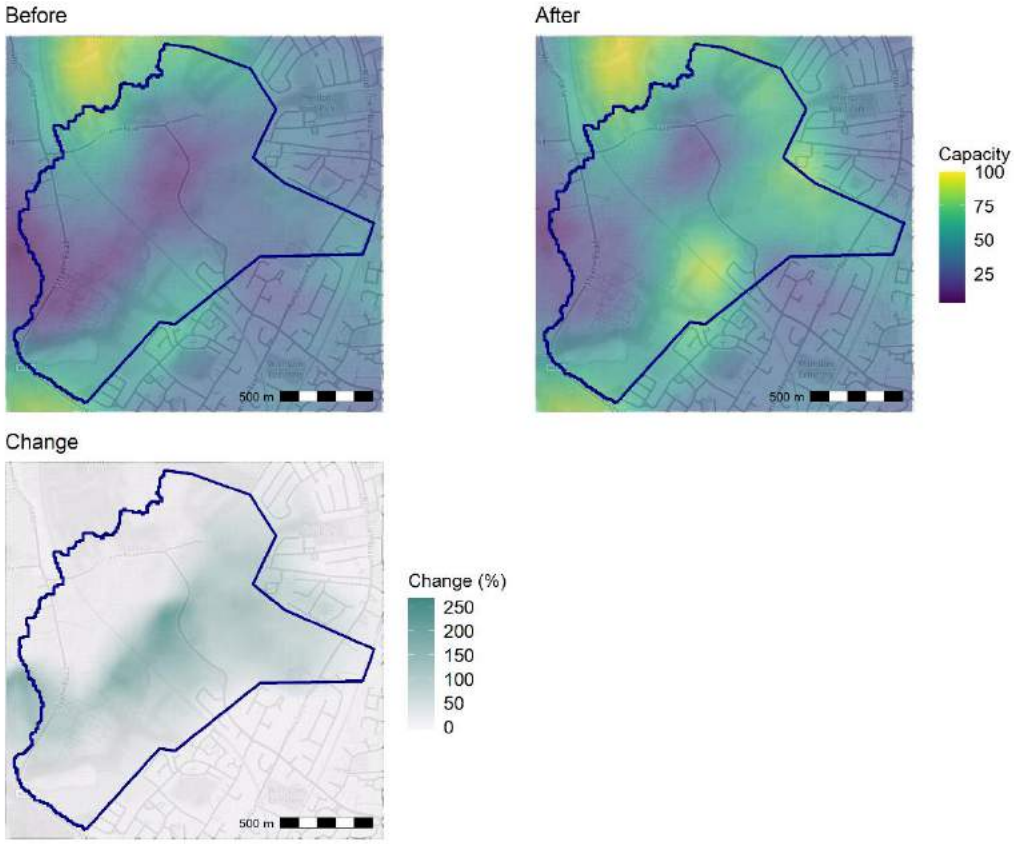

Figure 29 Accessible nature capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

5.5 Economic appraisal and potential funding

Full costs and benefits, presented on a per hectare basis, are shown in Table A1 (Annex A). The changes planned at the case study site are intended to deliver LEP economic and social outcomes in terms of improvement to:

- Water flow regulation;
- Water quality regulation; and
- Biodiversity.

A key benefit is the creation of public access over 31ha, enabling delivery of recreation and health benefits. Benefits from water flow regulation and biodiversity are recognised but cannot be monetised. Other benefits will also occur indirectly as a result of the habitat changes, including noise reduction, air quality regulation and carbon sequestration.

The reductions in improved grassland and cultivated land mean that there is a reduction in agricultural output, but the impact of this is minimal in terms of economic value.

The core services targeted in this case study for investment are water flow regulation, water quality regulation, and biodiversity, with secondary services of carbon sequestration, air quality regulation and noise regulation. The funding mechanism selector identifies the following as the most appropriate funding mechanisms to deliver these core and secondary services:

- Investment Readiness Fund;
- ELMs;

- Sustainable drainage systems (SuDS); and
- Forestry Commission Woodland Creation.

The amount of funding required reflects provisions for initial capital costs plus allowance for working capital over a 5-year period. These up-front costs are needed for woodland planting and parkland creation, as well as revenue (on-going costs) related to maintenance and management of the woodland and parkland. Should there be less up-front funds available, then it may take longer to plant woodlands or enable public access, so the benefits would likely be reduced (since they would not occur until later).

The total funding need for the case study is estimated at £740,000 for the first five years of the project, or £3,893 per hectare. This is made up of capital cost funding (including management costs), estimated at £533,000 (£2,802 per hectare), and working capital of £207,000 (£1,091 per hectare). These are short-term up front-costs (up to 5 years) needed to enable the natural capital investment. A full breakdown of funding requirements is given in Table A2 (Annex A).

With **projected benefits of the case study of £6.1 million**, over 50 years and a **Net Present Value** (benefits minus costs) of **£4.8 million**, this gives a benefit-cost ratio of 4.8 and an **internal rate of return (IRR) of 23%**. The benefits vary by type of ecosystem service provided, totalling £1,721 per ha, and broken down as follows (top four benefit contributions shown; it is also important to note that there are additional ecosystem service benefits that cannot currently be captured in monetary terms):

- Recreation: £789 per ha
- Air quality regulation: £448 per ha
- Physical health: £301 per ha
- Carbon sequestration: £87 per ha

The potential value of carbon credits (based on voluntary carbon market price, 2021) is £10,615 per year (see Table A3 in Annex A). Note that this is based on the average price received in the Woodland Carbon Guarantee third auction (October 2020), and prices are thought to have increased significantly since then. Using the BEIS traded central price estimate for 2025 would give a value of £31,886 per year. Neither of these prices are the same as the carbon price used in the economic appraisal, which was based on the BEIS central non-traded carbon price and reflects the societal value of carbon, and is significantly higher.

The scale of funding required means that ELMs and SuDS could be appropriate for the case study. The Forestry Commission England Woodland Creation Offer, which covers tree planting on farms may be suitable, once launched, at this small-scale. Mersey Forest, along with a number of partners have submitted an application through the Environment Agency’s Investment Readiness Fund that focuses on the River Bollin catchment (including the River Dean) and would be highly suitable for funding this case study. This includes objectives to double woodland cover (at least 250 ha within the first 10 years), create or mange 900 ha of semi-natural or marshy grassland and 75 ha of mire within 25 years. These objectives fit with the proposals for all five case studies, although only Case Study 3 sits within the area covered by the IRF application.

6. Case study 4: Priorities and opportunities focus - Northwich

Mapping produced as part of the wider NCIP project identified locations where multiple opportunities could be delivered at the same location, and mapping of key policy themes identified the locations of greatest policy priority. The methodology behind these maps is described in Technical Report 2 (Intervention and investment opportunities report), along with maps for the whole of Cheshire and Warrington. Case studies 4 and 5 focus on areas where opportunities and policy priorities overlap, highlighting areas where multifunctional benefits could be delivered in areas of greatest need. With this focus, Case study 4 covers two locations adjacent to urban areas to the east and west of **Northwich**.

6.1 Baseline natural capital assets

Figure 30 (overleaf) shows the distribution of broad habitat types across the case study area under the current situation and the area and percentage cover is shown in Table 11. The map and asset register demonstrate that the area is made up of a broad range of habitats. Improved grassland (which includes amenity grassland) is the most frequent habitat, taking up 538 ha (31.1%), and cultivated land (arable) occupies 253 ha (14.6%) of the area. But a significant component of urban Northwich sits within the study area, consisting of 218 ha of built-up areas, 129 ha of gardens and 104 ha of infrastructure (a combined 25.9%). Woodland is also a significant habitat, with 219 ha of broadleaved woodland (12.7%), and all woodland, scrub and tree categories occupy 279 ha (16.1%) of the area. Semi-improved and marshy grassland make up a combined 82 ha, or 4.7% of the area. Water is a significant feature, taking up 84 ha (4.8%), with the River Weaver and its tributary the Witton Brook flowing through the centre of the study area, and a number of pools and flashes present, including Neumann's Flashes and Haydn's Pool. Much of the centre of the site is publicly accessible greenspace, including Carey Park, Marbury Country Park and Anderton Nature Park.

6.2 Identifying opportunities

Biodiversity opportunities exist for a range of habitats, that will be ecologically connected to existing habitat, and these are shown in Figure 31. Opportunities for semi-natural grassland are focussed on expanding the areas of existing habitat, especially to the east of the existing greenspace, with some further opportunities in the large river meander south of Barnton to the west. There are a wide range of opportunities for woodland expansion, spread throughout the study area. A few opportunities exist to expand patches of wet grassland close to the river, especially adjacent to Wincham Brook in the east, and between the River Weaver and the Weaver Navigation to the west of Northwich.

Opportunities to enhance ecosystem services were also identified and some of these are shown in Figure 32. Opportunities to reduce surface runoff tend to be found on the areas that are currently under arable or improved grassland towards the eastern and western sides of the study area. Opportunities to improve water quality by reducing soil erosion are focused almost exclusively on the arable fields, such as to the far west, adjacent to the River Weaver, to the north of Barnton and north of Wincham. There are multiple opportunities to ameliorate air pollution, focussed in and around the built-up areas, and opportunities for reducing noise pollution (not shown) followed a very similar pattern. Opportunities to moderate local climate (reduce urban heat) were also present in the area (not shown), located immediately adjacent to the urban areas. Finally, there are numerous opportunities to provide accessible natural greenspace based on local demand, particularly in the whole area surrounding Barnton to the west and around Wincham to the east (Figure 32).

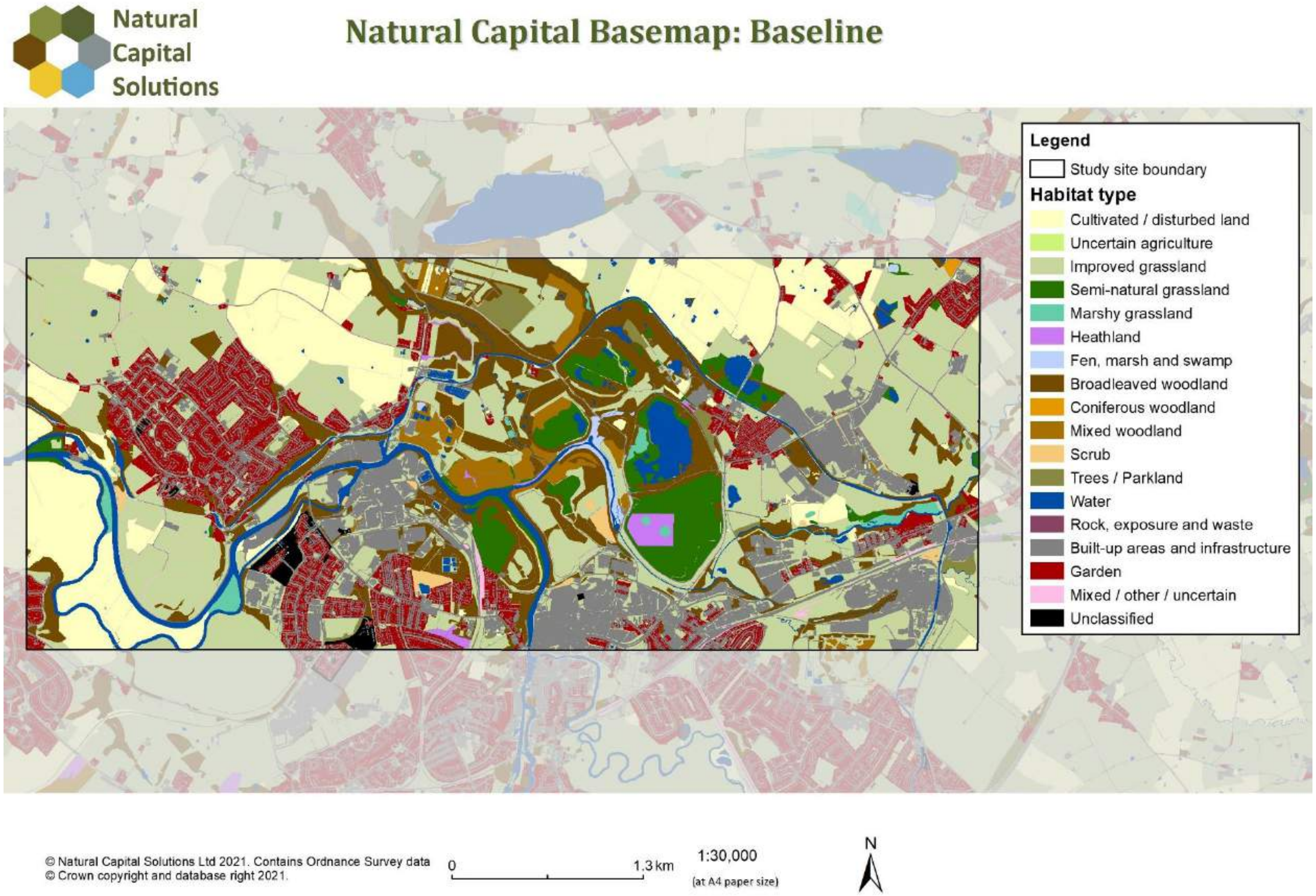

Figure 30 Broad habitats across the Northwich case study area under the baseline (present day) situation.

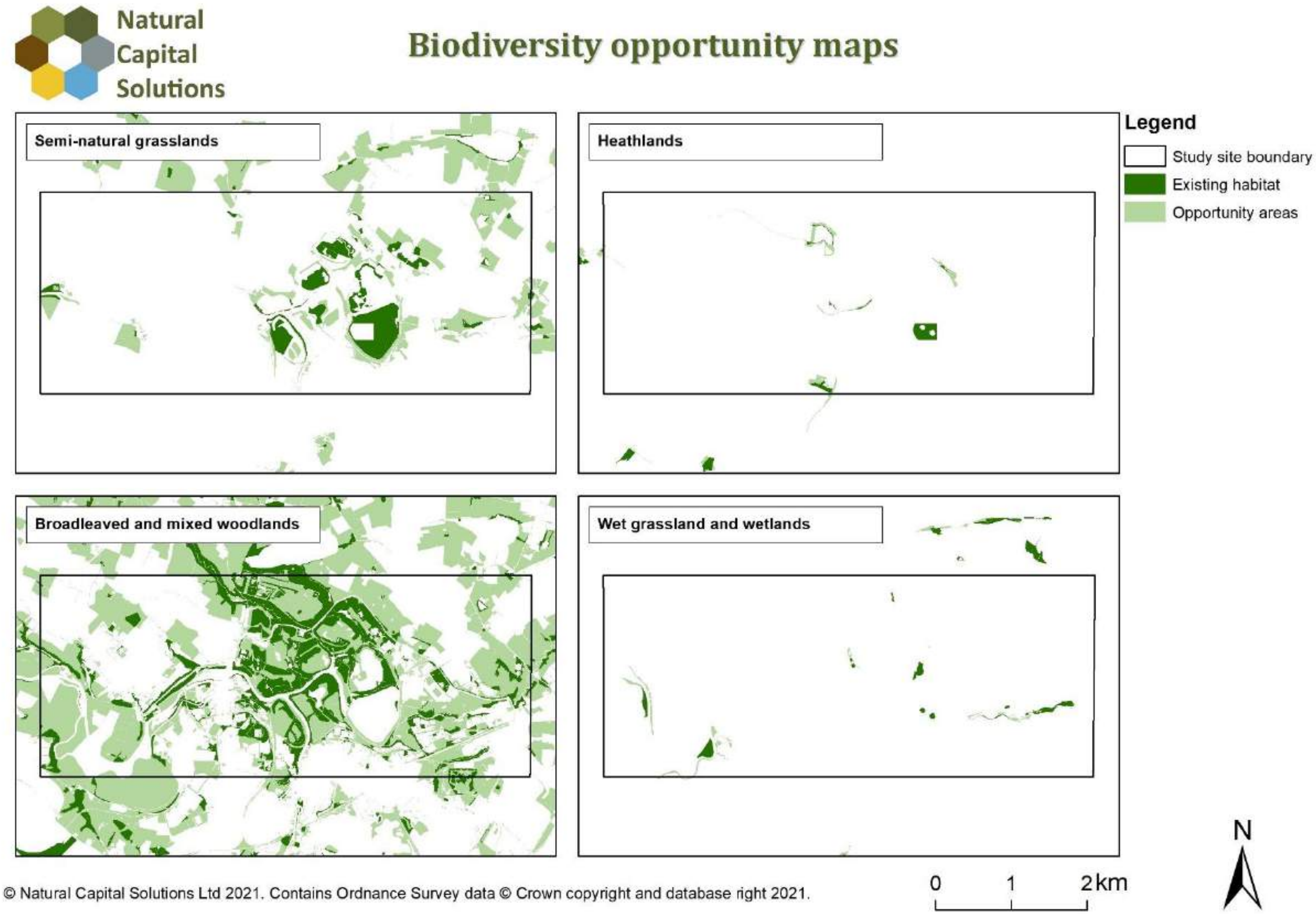

Figure 31 Northwich case study biodiversity opportunity maps for semi-natural grassland habitats, broadleaved and mixed woodland habitats, heathlands, and wet grassland and wetland habitats. These maps identify whole fields that present opportunities.

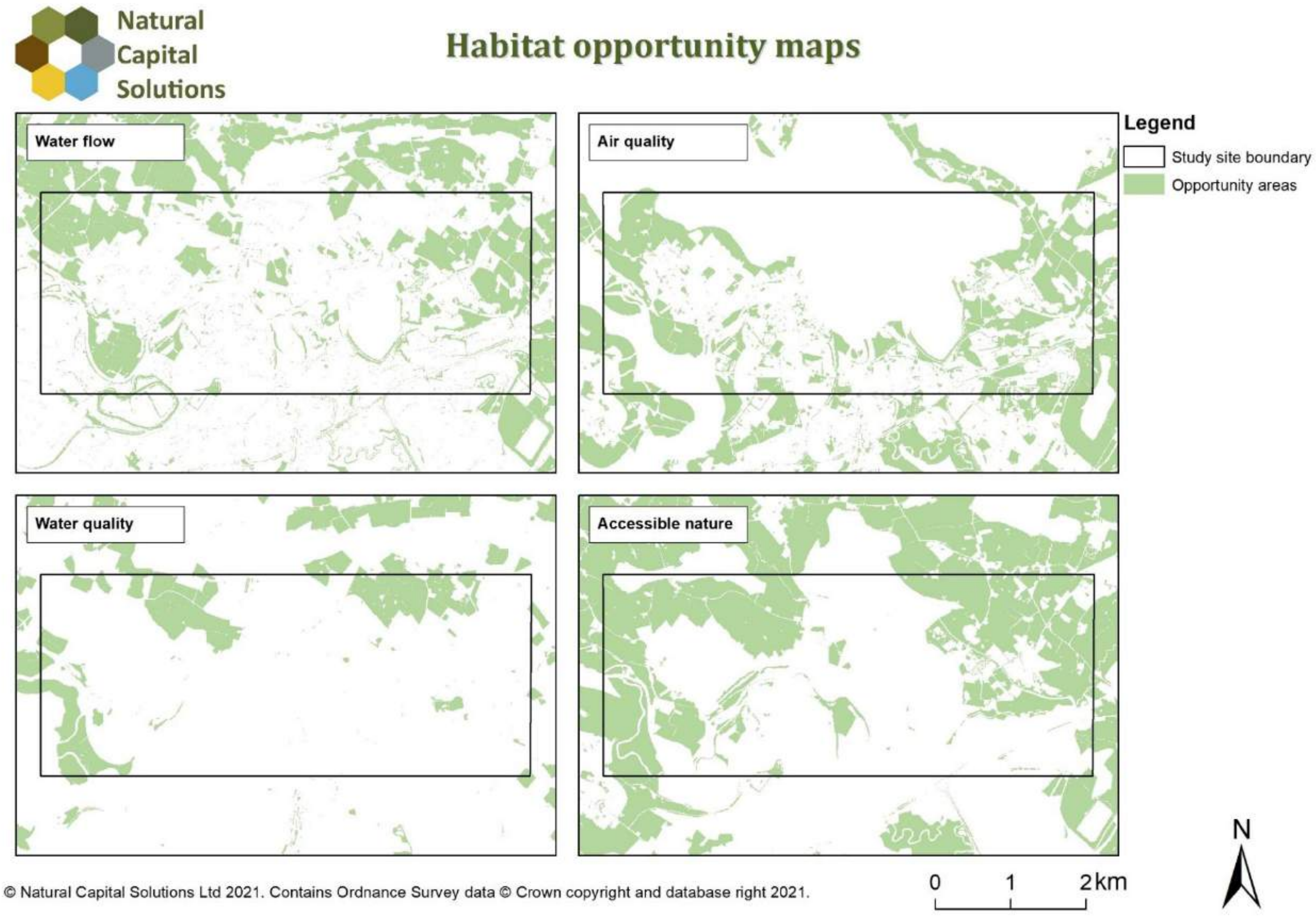

Figure 32 Northwich case study habitat opportunity maps for water flow, water quality, air quality and accessible nature.

A number of the individual opportunities described above overlap. The resulting map is shown in Figure 33 (top) and highlights areas where multiple benefits (multifunctionality) can be delivered in the same location. The area surrounding Barnton to the west of the study area and to the north of the Wincham Brook in the east, are locations where between four and seven opportunities could be delivered at the same time. The bottom panel of Figure 33 shows the location of policy themes, highlighting where multiple policy priorities overlap. For clarity the map only shows areas where three policy themes overlap (high priority) or four or more themes overlap (highest priority). Areas to the west of Barnton and around the Wincham Brook are again highlighted. Thus, creating new habitats in these locations would enable multiple benefits to be delivered in areas of overlapping policy priority.

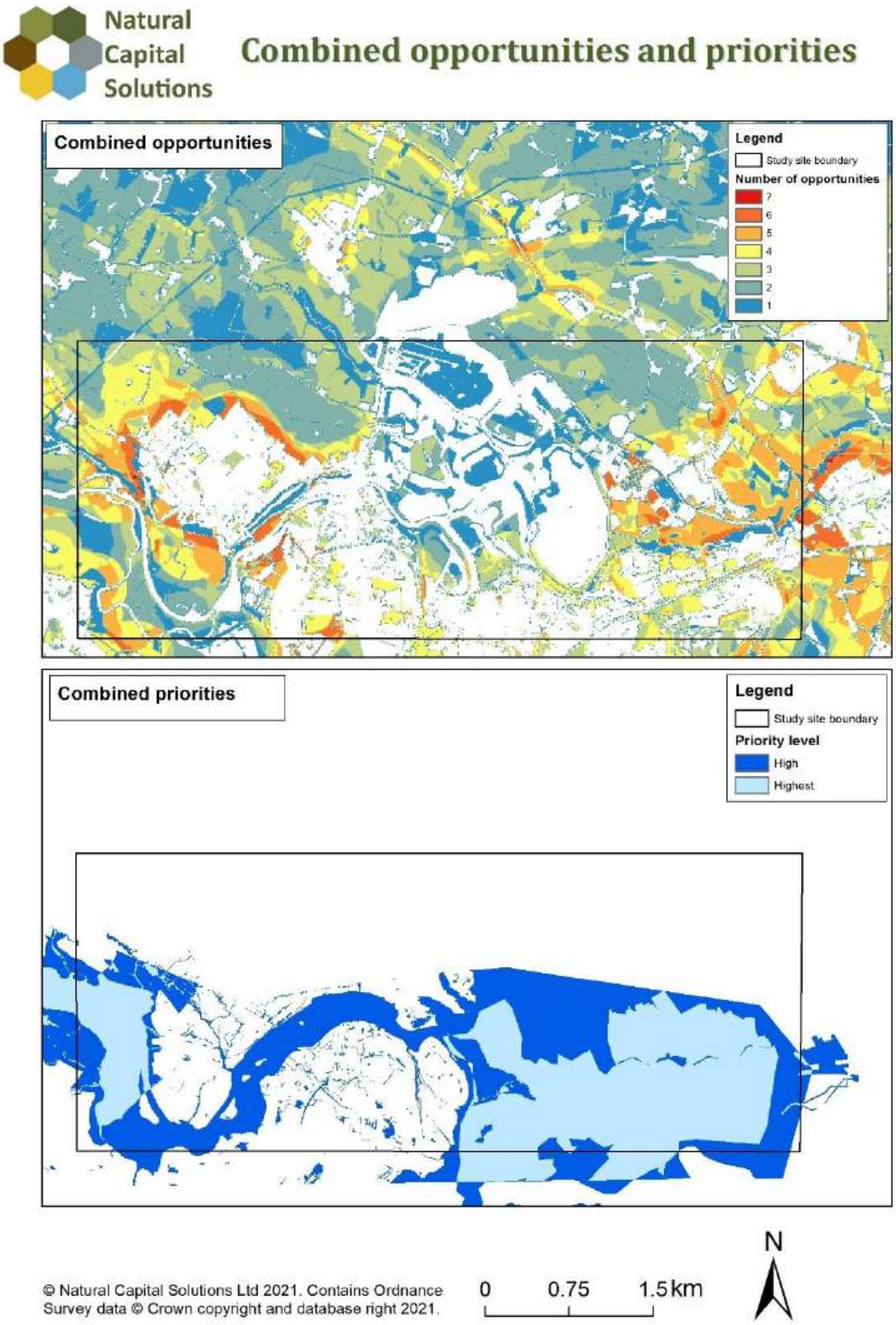

Figure 33 Combined opportunities (top) and combined priorities (bottom) for the Northwich case study.

6.3 Interventions planned and changes to habitats

The opportunity maps (Figures 31 and 32) were used to guide which habitats to create and their optimal locations. Habitats based on the planned interventions are shown in Figure 34 and the area and percentage cover of habitats under the baseline and the planned interventions are shown in Table 11. This results in an increase in broadleaved woodland (+35 ha), semi-natural grassland (+28 ha), trees/parkland (+5.8 ha) and a small area of marshy grassland (+1.6 ha) and a reduction in improved grassland (-62 ha) and cultivated/disturbed land (-8.3 ha).

Most of the new habitat is focussed to the north and south of Barnton (to the west of the study area) and around Wincham and the Wincham Brook to the east. Multiple opportunities coincide in the large meander in the River Weaver to the south of Barnton and this would be a good location for creating semi-improved grassland and woodland, while an area of accessible woodland could be planted to the north to provide multiple benefits. New wet grassland can be created between the River Weaver and the Weaver Navigation. The fields to the north of the Wincham Brook provide a good location to create a mix of woodland, semi-natural grassland and parkland habits, with public access, that can connect into and expand the existing accessible greenspaces.

Table 11 Area and percentage cover of broad habitat types across the Northwich case study area under the baseline and the intervention scenario.

Broad habitat	Area (Ha)		% Cover		Change (Ha)
	Baseline	Intervention	Baseline	Intervention	
Cultivated / disturbed land	252.7	244.4	14.6	14.1	-8.3
Improved and amenity grassland	537.7	476.0	31.1	27.5	-61.7
Semi-natural grassland	73.5	101.9	4.2	5.9	28.4
Marshy grassland	8.8	10.3	0.5	0.6	1.6
Heathland	8.5	8.5	0.5	0.5	0.0
Swamp	5.1	5.1	0.3	0.3	0.0
Broadleaved woodland	218.8	253.8	12.7	14.7	35.1
Coniferous woodland	0.9	0.9	0.1	0.1	0.0
Mixed woodland	35.6	35.6	2.1	2.1	0.0
Scrub	19.7	19.7	1.1	1.1	0.0
Trees / Parkland	3.9	9.7	0.2	0.6	5.8
Boundaries	13.4	12.4	0.8	0.7	-0.9
Water	84.1	84.1	4.9	4.9	0.0
Built up areas	217.5	217.5	12.6	12.6	0.0
Garden	128.8	128.8	7.4	7.4	0.0
Infrastructure	103.8	103.8	6.0	6.0	0.0
Unclassified	10.6	10.6	0.6	0.6	0.0
Other	5.6	5.6	0.3	0.3	0.0
TOTAL	**1728.8**	**1728.8**	**100**	**100**	**-**

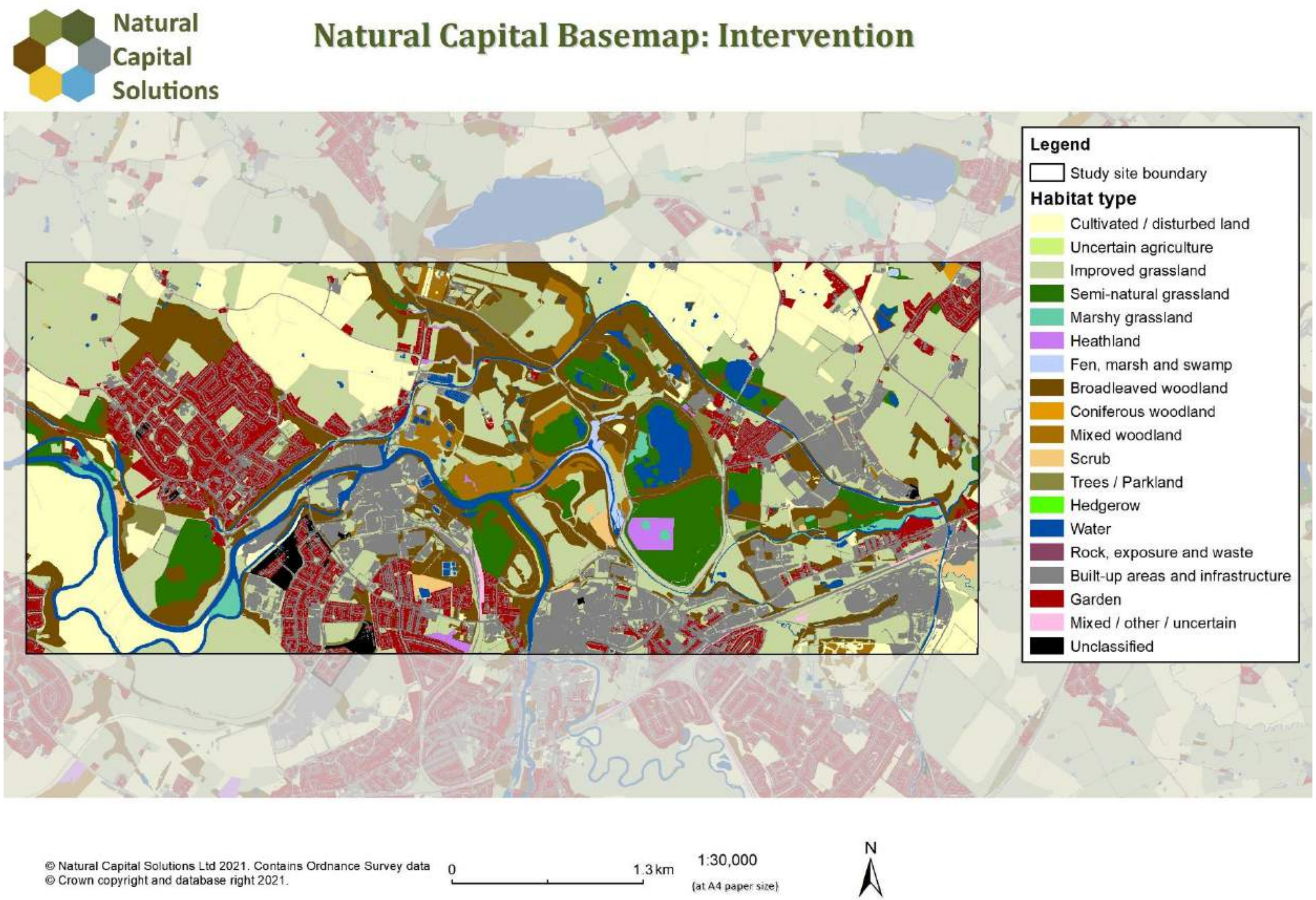

Figure 34 Habitats across the Northwich case study area under the proposed interventions.

6.4 Change in ecosystem service provision

The ecosystem services delivered by the case study site were quantified and mapped for the baseline and intervention scenario and the change in benefits calculated. The mean score for each ecosystem service and the percentage change is shown in Table 12. Note that the total site area is much bigger than the previous case studies and much of the central part of the site (especially the urban parts) is unchanged, hence some of the percentage changes below appear smaller than in the other case studies.

- **Carbon storage capacity** – there is a 3.2% increase in carbon storage projected to occur under the interventions. As can be seen from the green-yellow areas in Figure 35, the increase is driven by the woodland planting at the two sides of the study area.
- **Air purification capacity (air quality regulation)** – under the proposed interventions, there is an 8.3% increase in delivery of this service. Again, the new woodland blocks, especially the new area of broadleaved woodland to the north of Barnton, are primarily responsible for the increases, as is evident from Figure 36.
- **Noise regulation capacity** – the areas of woodland across the site show clearly on the map (Figure 37), with the large area of new woodland planting to the north of Barnton being the most obvious change between the baseline and the intervention. There is an 8.2% increase in capacity under the interventions compared to the baseline..
- **Local climate regulation capacity** – shows a similar pattern to air purification and noise regulation capacity, with the larger areas of woodland most apparent on the map (Figure 38). The new areas of woodland increase the delivery of this service by 12.8%.
- **Pollination capacity** – is generally high across the landscape with most locations within easy reach of wild pollinators. It is very high under the baseline (Figure 39), but increases very slightly under the intervention scenario (0.1% increase). The new semi-natural grasslands increase the delivery of this service but are offset by the new woodlands, which is not an optimal habitat for pollinators.
- **Water flow regulation capacity** – is moderate across the study area (Figure 40), under both scenarios. Table 12 shows that values improve by 2.1% under the interventions. This is mostly due to the new woodland plantings, which increase roughness across the landscape. It is lowest (purple) in areas of sealed surfaces (buildings and infrastructure).

Table 12 Mean ecosystem service capacity scores and percentage change for each of the ecosystem services quantified across the Northwich case study area under the baseline and intervention scenario.

Ecosystem Service	Ecosystem service score		% change
	Baseline	Intervention	
Carbon storage capacity	17.6	18.2	3.2
Air purification capacity	18.7	20.2	8.3
Noise regulation capacity	24.4	26.4	8.2
Local climate regulation capacity	19.4	21.9	12.8
Pollination regulation capacity	94.7	94.8	0.1
Water flow regulation capacity	44.6	45.6	2.1
Accessible nature capacity	31.3	33.9	8.5
MEDIAN % CHANGE			8.2

- **Accessible nature capacity** – increases by 8.5% under the proposed interventions, due both to increasing the amount of land with public access and to increasing the naturalness of the land that is accessible (Figure 41).

Overall change

Overall, all seven of the ecosystem services mapped increased under the proposed natural capital interventions. The median change was an 8.2% increase in ecosystem service capacity compared to the baseline (Table 12).

Physical flows of ecosystem services

In addition to the ecosystem services that have been mapped, the physical flows of seven ecosystem services have been calculated (Table 13). These show that carbon sequestration increases significantly (by 306 tonnes of CO_2), an additional 0.8 t $PM_{2.5}$ is absorbed and 313 m^3 of timber/woodfuel could be harvested each year under the proposed interventions. Importantly, 146,000 more visits would be expected into the natural environment, generating an extra 10.7 QALYs of physical health benefits. On the other hand, the amount of land under agricultural production falls by 63 ha, although this does also lead to a fall of 286 tCO_2e in greenhouse gas emissions from agriculture.

Table 13 Annual physical flows of ecosystem services under the baseline and intervention scenario for the Northwich case study area.

Ecosystem Service	Units	Annual physical flow	
		Baseline	Intervention
Carbon sequestration	tCO_2e	2316	2622
Air quality regulation	$tPM_{2.5}$	10.5	11.3
Timber/woodfuel production	m^3	2302	2615
Recreation	Visits	685,000	831,000
Physical health	QALY	51.3	62.2
Agricultural production	Hectares	580	517
GHG emissions from agriculture	tCO_2e	3327	3041

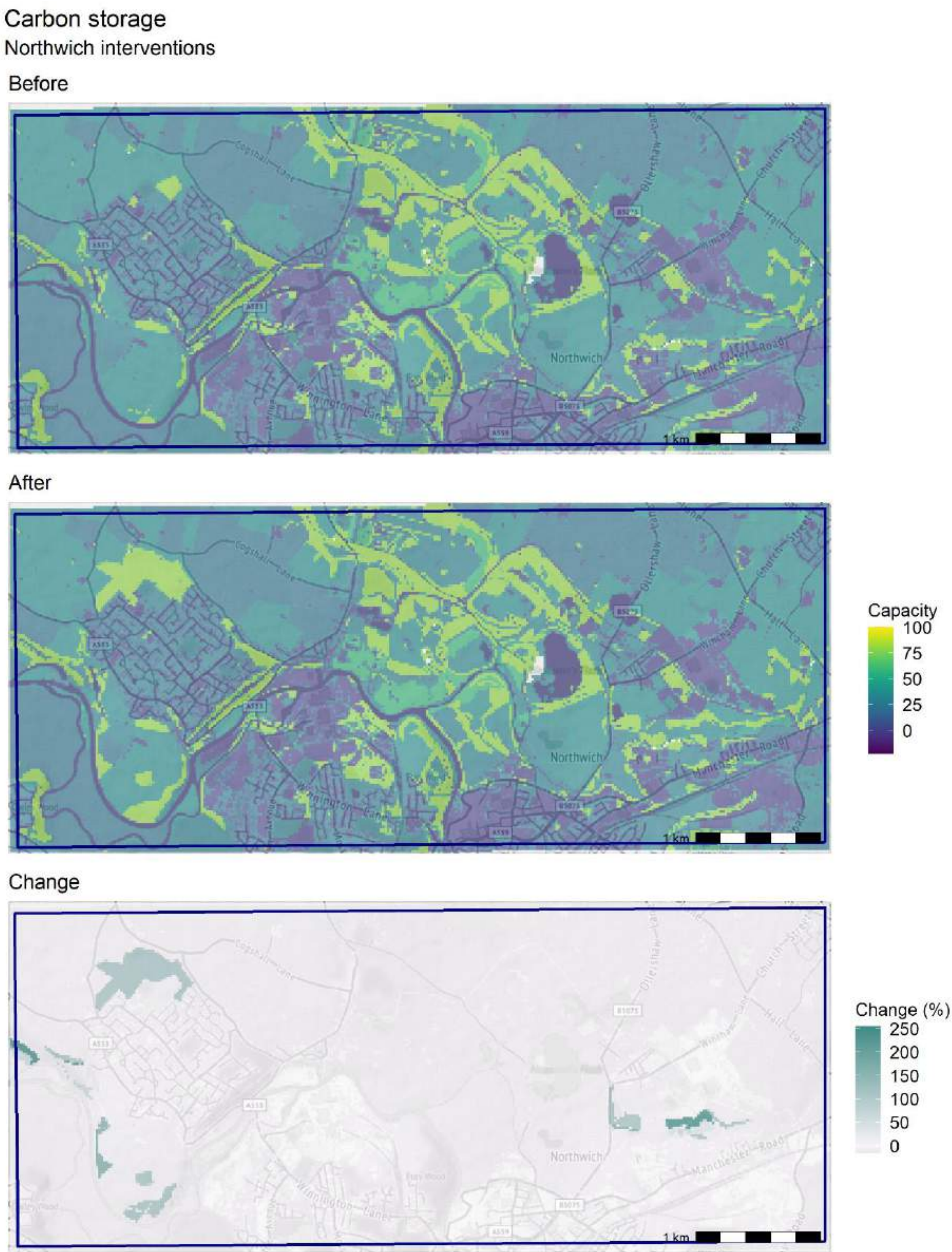

Figure 35 Carbon storage capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

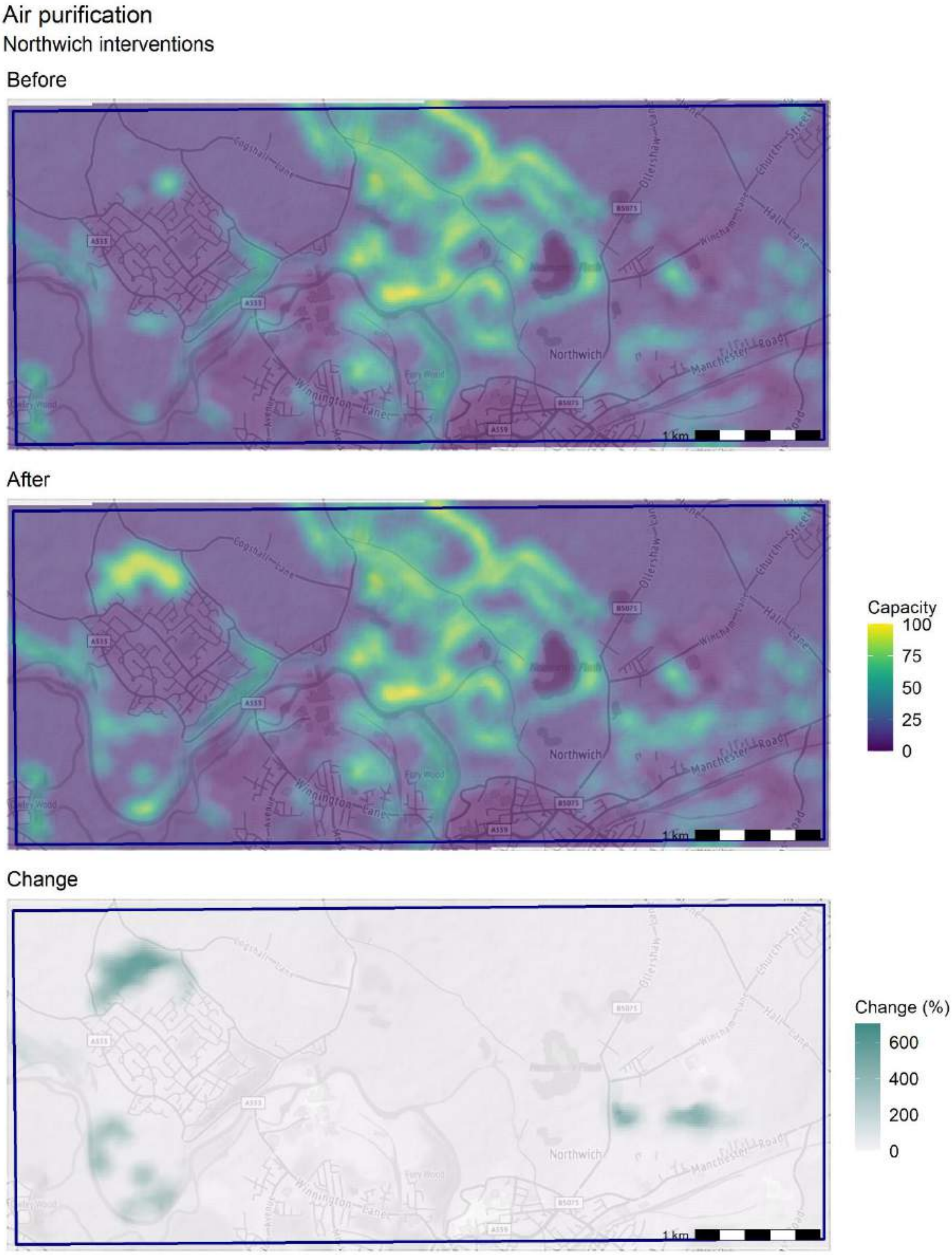

Figure 36 Air purification capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

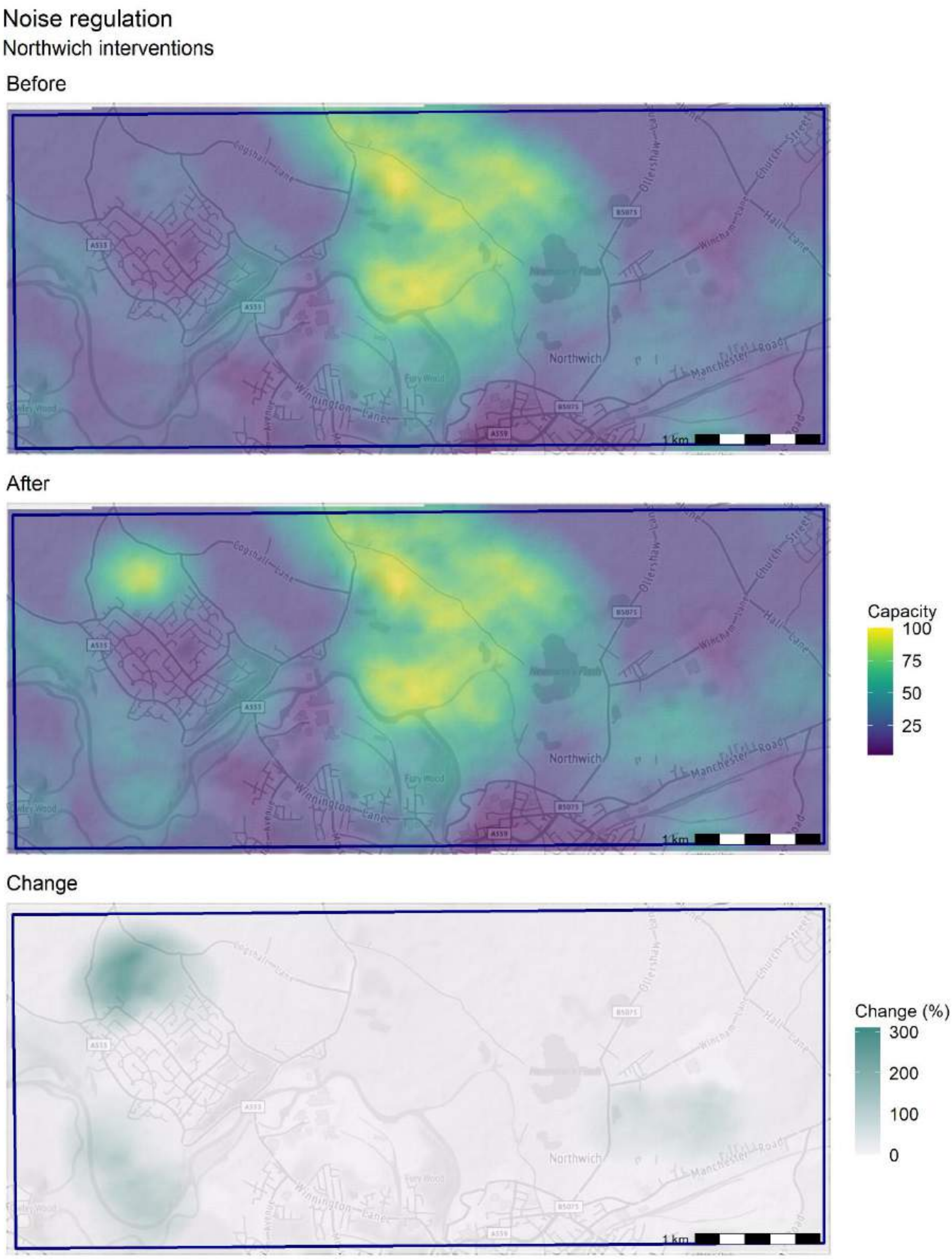

Figure 37 Noise regulation capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

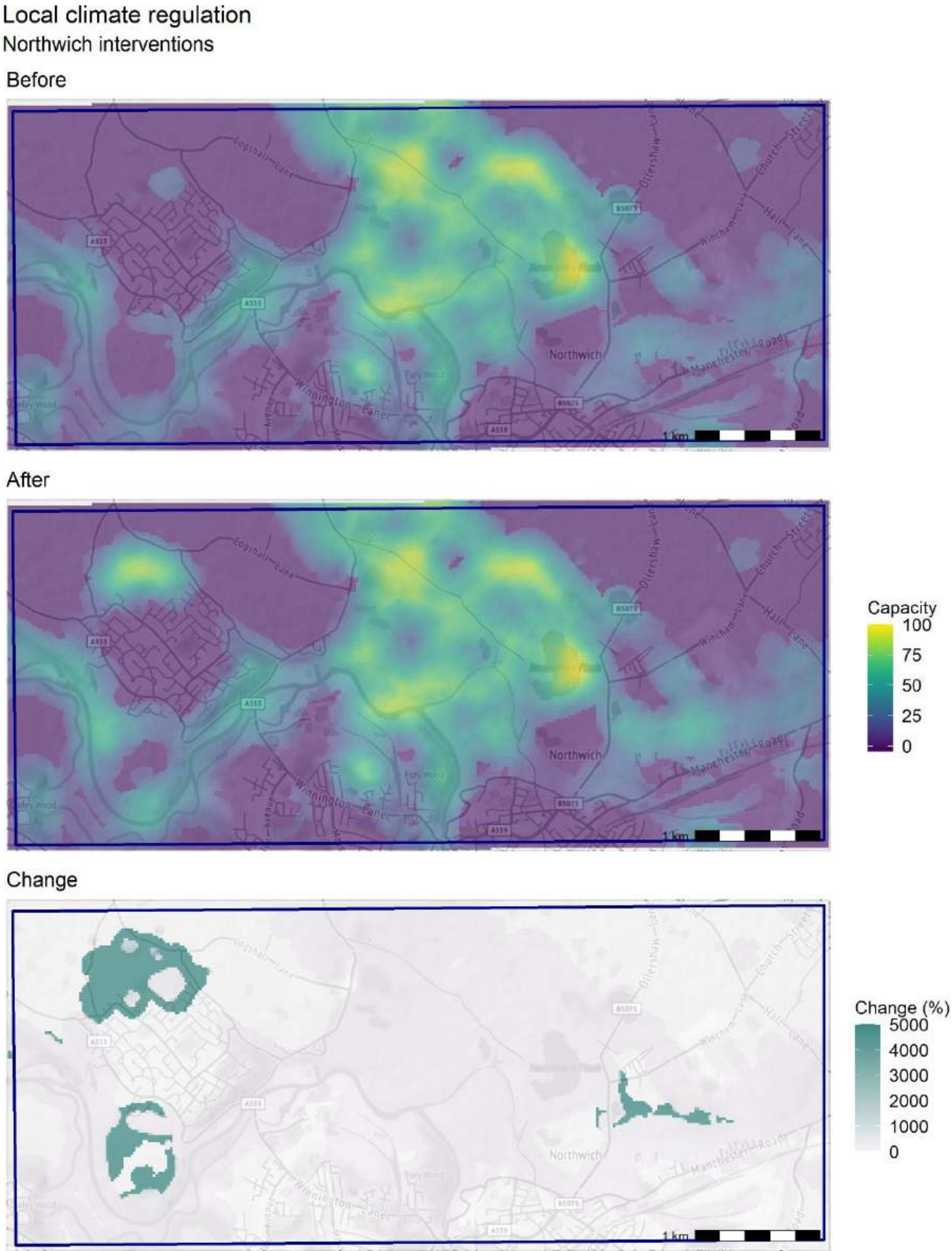

Figure 38 Local climate regulation capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

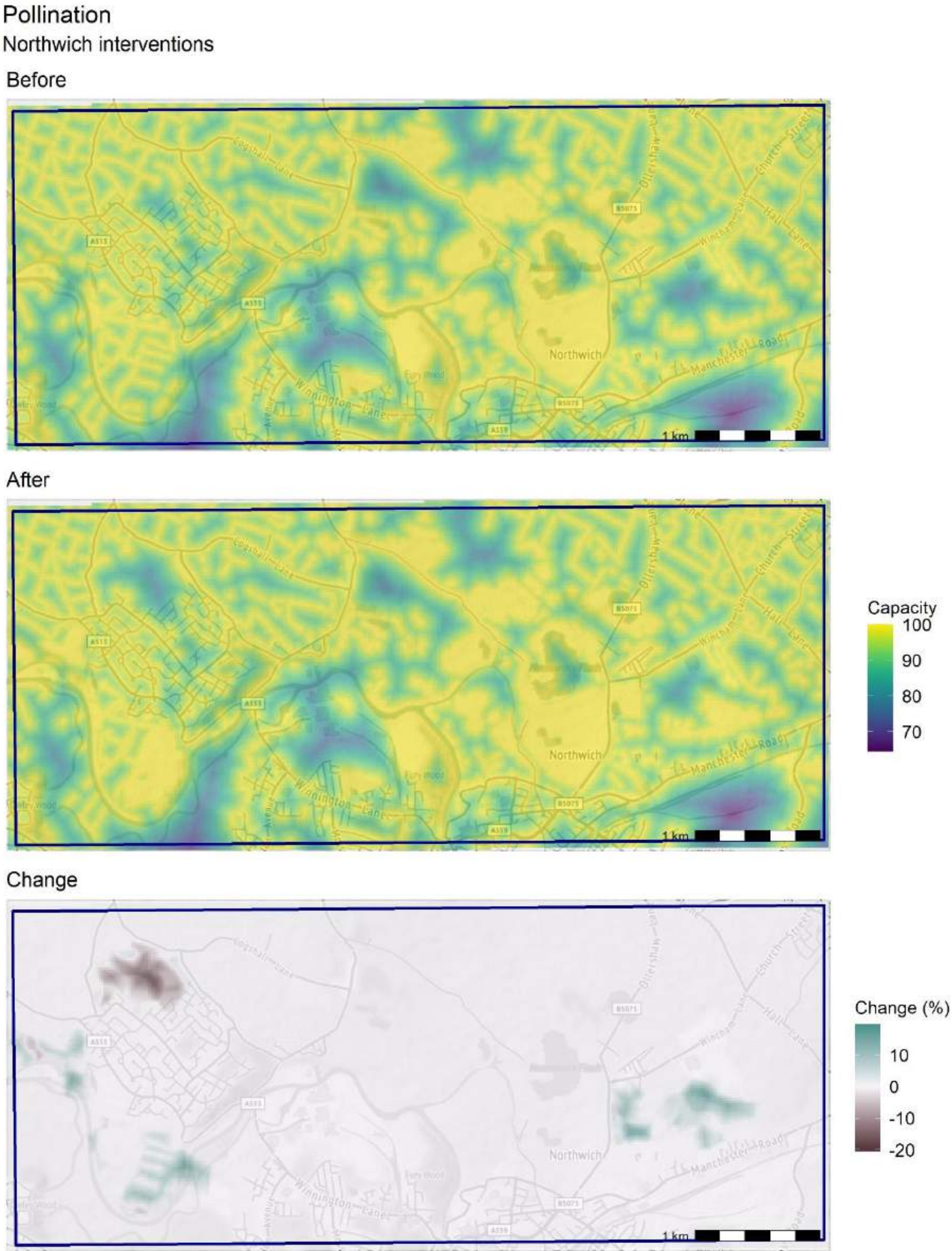

Figure 39 Pollination capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

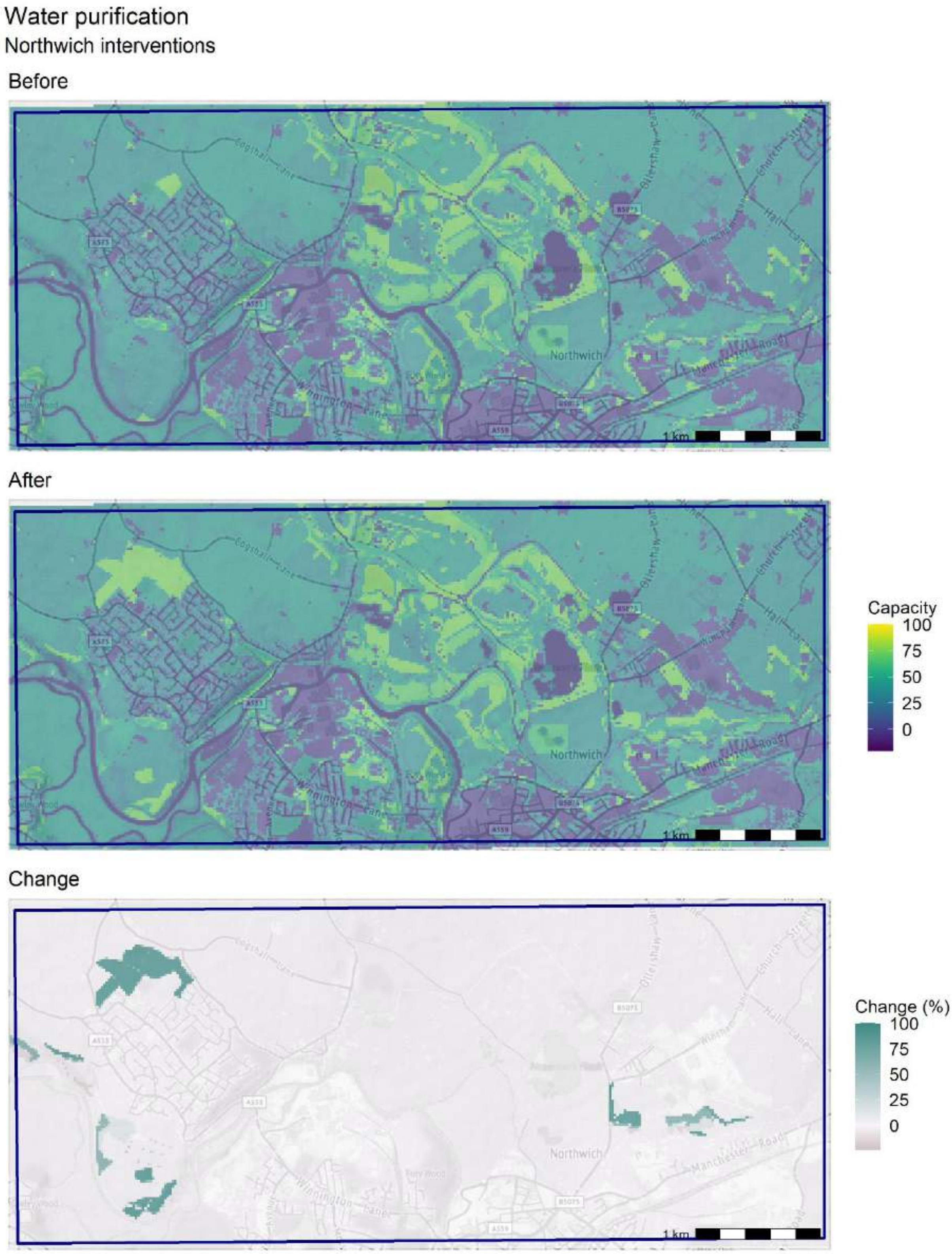

Figure 40 Water flow regulation capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

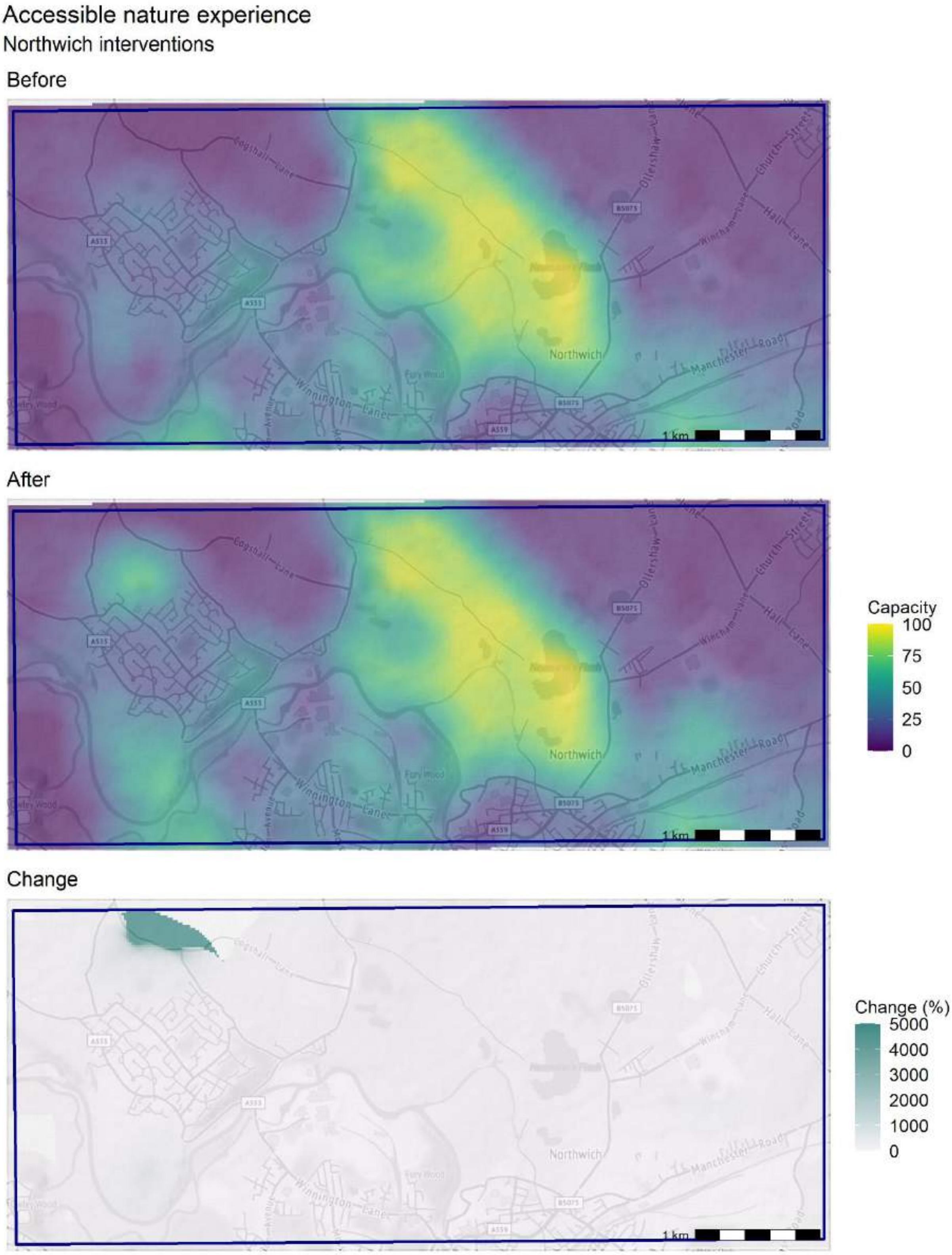

Figure 41 Accessible nature capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

6.5 Economic appraisal and potential funding

The monetary flow of benefits was estimated for all ecosystem services for which this was possible. Full costs and benefits, presented on a per hectare basis, are shown in Table A1 (Annex A). As before, this does not include a number of benefits that could not be valued, such as water benefits and biodiversity.

The ambition is to deliver multifunctional benefits in the areas of greatest need, and full public access to the new habitats. The focus is on delivering benefits to those living and working in Northwich, as well as delivering wider economic and social outcomes, such as carbon sequestration and water flow regulation, through:

- Recreation and access to nature;
- Physical health;
- Local climate regulation;
- Air quality regulation; and
- Noise regulation.

The reductions in areas of improved grassland and cultivated land mean that there is a reduction in agricultural output, with this reduced to around zero in the case study area (once subsidies are stripped out).

The core services targeted by this investment are access to nature (recreation), physical experiences (linked to health) and local climate regulation, with secondary services including air quality regulation, carbon sequestration and biodiversity. The funding mechanism selector identifies the following as the most appropriate funding mechanisms to deliver this suite of core and secondary services:

- Investment Readiness Fund;
- Place-based portfolio;
- Woodland equity fund;
- Forestry Commission woodland creation.

The amount of funding required reflects provisions for initial capital costs plus allowance for working capital over a 5-year period. The investment requires up-front costs in terms of woodland planting, parkland creation and creation of semi-natural and marshy grassland, as well as revenue (on-going costs) related to maintenance and management of the woodland, parkland and grassland. Should there be less up-front funds available, then it may take longer to plant woodlands, create the parkland or create the grasslands, so the benefits would also likely be reduced (since they would not occur until later).

The total funding need for the case study is estimated at £1.8 million for the first five years of the project, equivalent to £1,050 per hectare. This is made up of capital cost funding (including management costs), estimated at £1.25 million (£725 per hectare, and working capital of £563,000 (£325 per hectare). These are short-term up front-costs (up to 5 years) needed to enable the natural capital investment.

With **projected benefits of the case study of £16.0 million** over 50 years and a **Net Present Value of £13.0 million**, this gives a **benefit-cost ratio of 5.3** and an **internal rate of return (IRR) of 25%**. The benefits vary by type of ecosystem service provided, totalling £557 per ha, and broken down as follows (top four benefit contributions shown; it is also important to note that there are additional ecosystem service benefits that cannot currently be captured in monetary terms):

- Recreation: £343 per ha
- Physical health: £95 per ha
- Air quality regulation: £75 per ha

- Carbon sequestration: £14 per ha

The potential value of carbon credits (based on voluntary carbon market price, 2021) is £50,341 per year (see Table A3 in Annex A).

As with the other case studies, the small scale may mean it is not appropriate for a woodland equity fund but the Forestry Commission woodland creation offering or combining the case study sites within a place-based portfolio approach that enables a larger-scale bid for funding to be developed, or a blended finance approach that combines funds from different sources.

7. Case study 5: Priorities and opportunities focus – Warrington

Case study 5 is similar to case study 4 in that it is focused on delivering multiple benefits and multiple policy drivers in and around an urban area. The location is **Warrington** with the site divided into two by the M62. The area to the south is to be fully publicly accessible, with the area to the north focused on buffering the effects of the M62. There will be a wide range of benefits, especially for recreation, but other benefits include air quality regulation, physical health, local climate regulation, noise regulation and carbon sequestration.

7.1 Baseline natural capital assets

Figure 42 (overleaf) shows the distribution of broad habitat types across the study area under the current situation and the area and percentage cover is shown in Table 14. The map and asset register show that the site is dominated by cultivated land to the north of the motorway and by urban and improved (amenity) grassland habitats to the south. In total, cultivated land makes up 106 ha (30.7%) of the site, while built-up areas and infrastructure make up a combined 97.9 ha (28.3%) and improved (including amenity) grassland makes up 92.3 ha (26.7%). Broadleaved woodland is a significant habitat in the study area (27.7 ha, 8.0%), but there are very few other semi-natural habitats present. The Sankey Brook flows through the site from north to south, with water taking up 2.9 ha, or 0.8% of the area.

7.2 Identifying opportunities

Biodiversity opportunities are almost entirely limited to woodland, with very little opportunity to expand other semi-natural habitats given their low occurrence in the area. However, there are opportunities spread over much of the site for planting broadleaved woodland that will be ecologically connected to existing habitat, and these are shown in Figure 43. Given the highly constrained nature of the urban areas, these opportunities are focused to the north of the M62 and in a triangle of land adjacent to the Sankey Brook to the south of the motorway.

Opportunities to enhance ecosystem services were also identified and key maps are shown in Figure 44. Opportunities to reduce surface runoff are limited, but there are extensive opportunities to improve water quality by reducing soil erosion on the arable fields, predominantly to the north of the motorway. Given the location of the site on the edge of a major urban conurbation and next to a motorway, there are good opportunities to ameliorate air pollution, reduce noise pollution (not shown) and moderate local climate (reduce urban heat, not shown). Similarly, there is high demand for accessible natural greenspace and hence almost all of the area that is not constrained (i.e. not built up or gardens) falls into an opportunity areas for this service.

A number of the individual opportunities described above overlap. The resulting map is shown in Figure 45 (top) and highlights areas where multiple benefits (multifunctionality) can be delivered in the same location. Adjacent to the M62 to the north, close to the Sankey Brook and in the triangle of land south of the M62 are locations where between four and seven opportunities could be delivered at the same time. The bottom panel of Figure 45 shows the location of policy themes, highlighting where multiple policy priorities overlap. For clarity the map only shows areas where three policy themes overlap (high priority) or four or more themes overlap (highest priority). The areas identified above also fall within these policy priority areas meaning that creating new habitats in these locations would enable multiple benefits to be delivered in areas of overlapping policy priority.

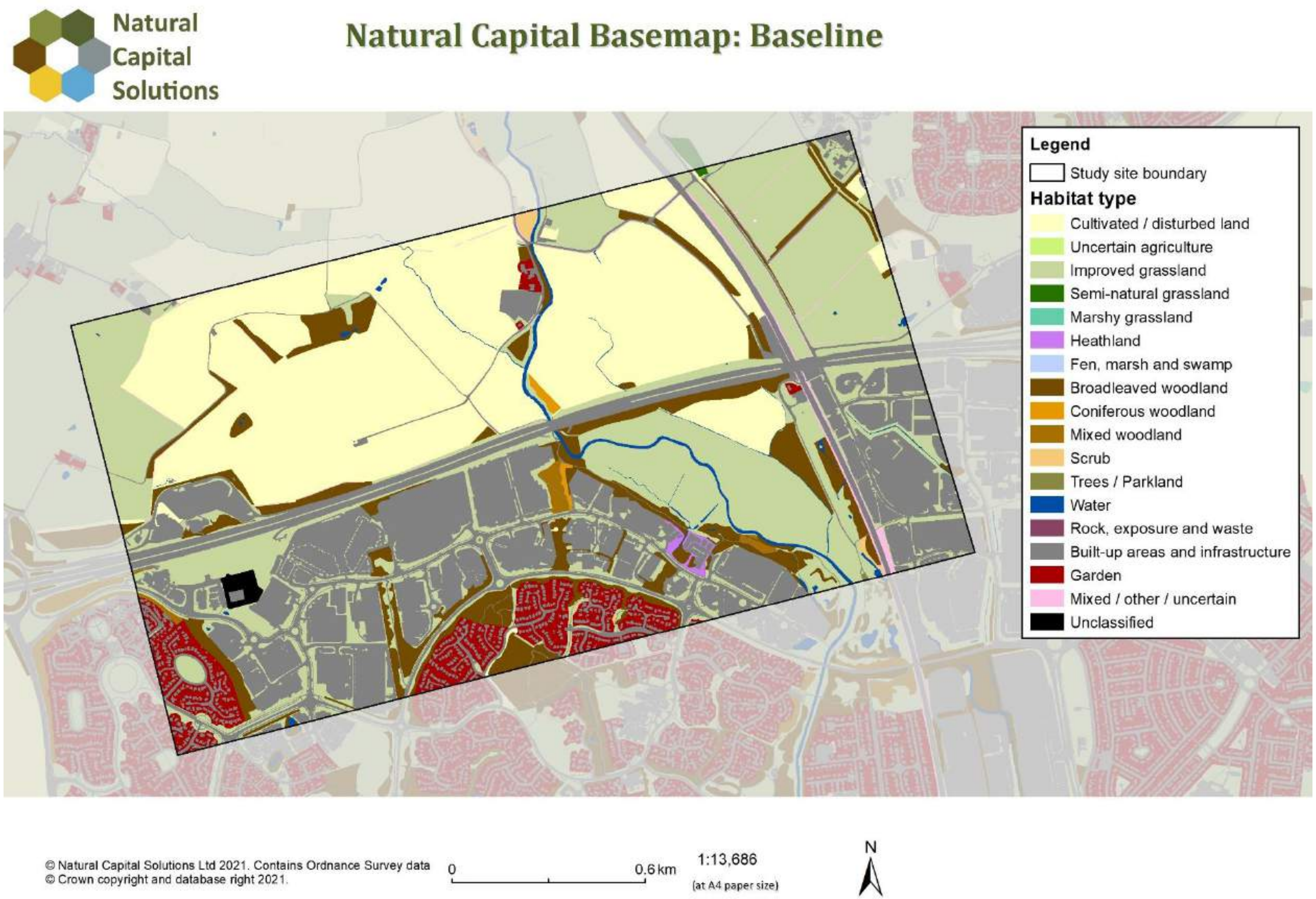

Figure 42 Broad habitats across the Warrington case study area under the baseline (present day) situation.

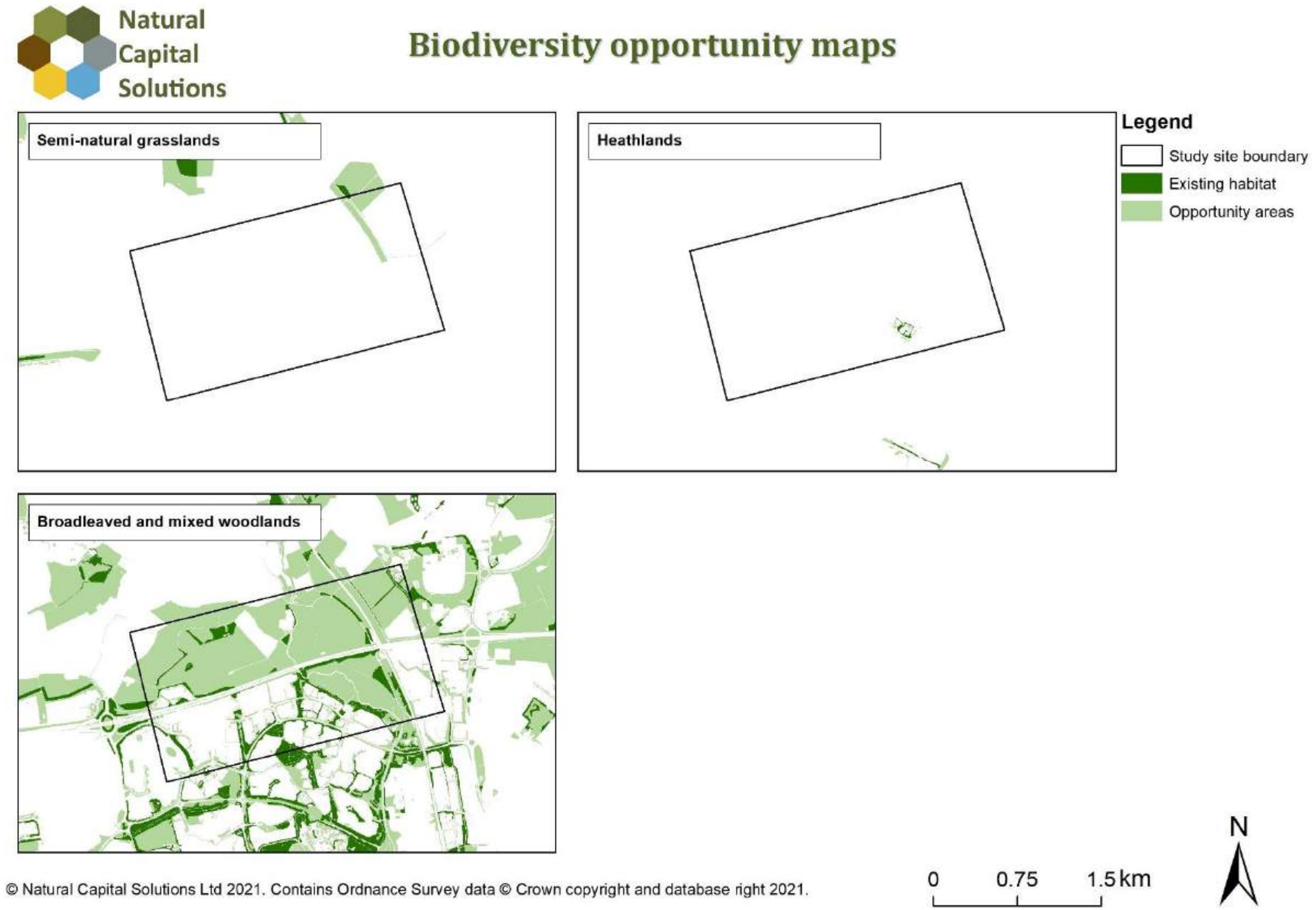

Figure 43 Warrington case study biodiversity opportunity maps for semi-natural grassland habitats, broadleaved and mixed woodland habitats, heathlands, and wet grassland and wetland habitats. These maps identify whole fields that present opportunities.

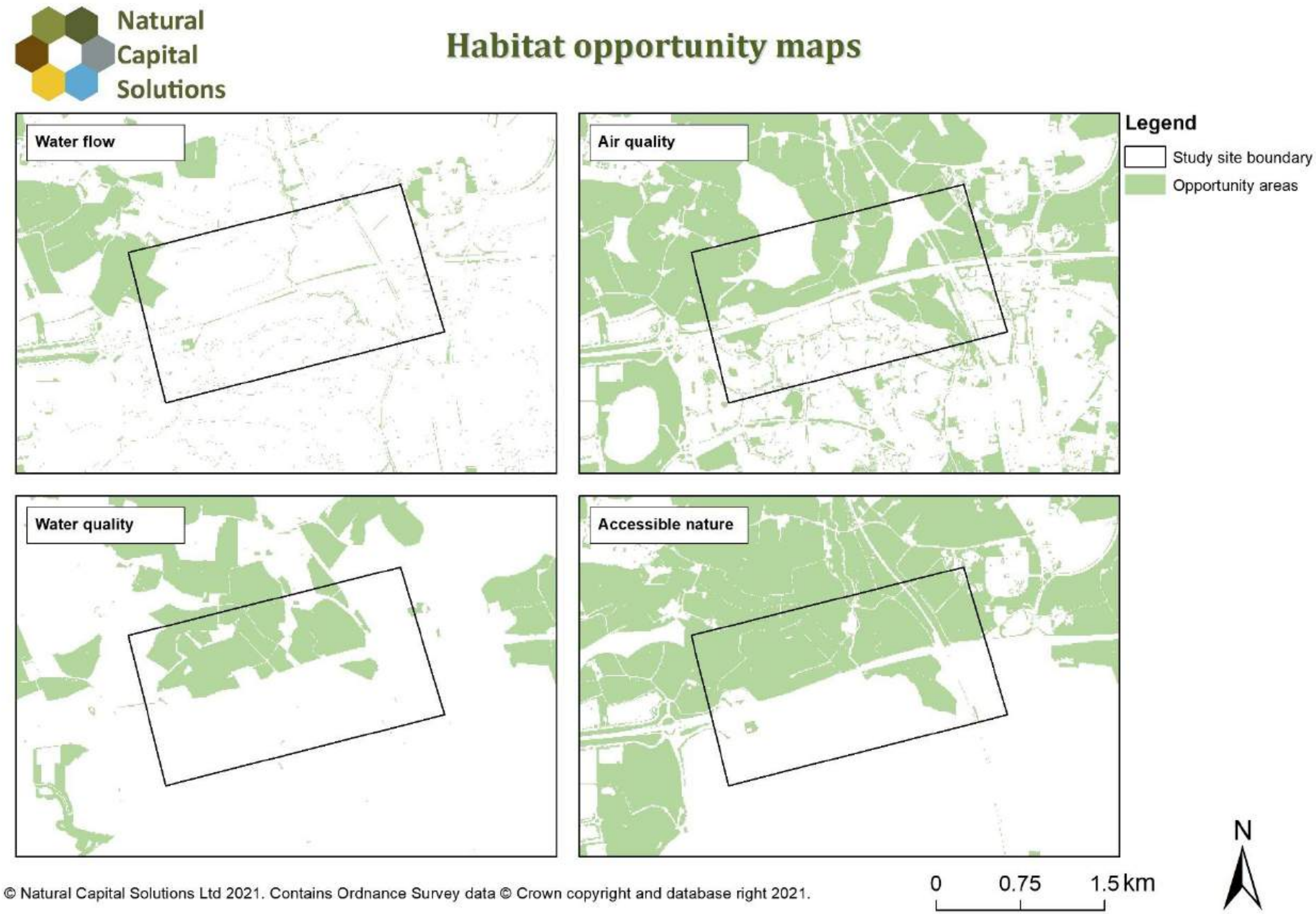

Figure 44 Warrington case study habitat opportunity maps for water flow, water quality, air quality and accessible nature.

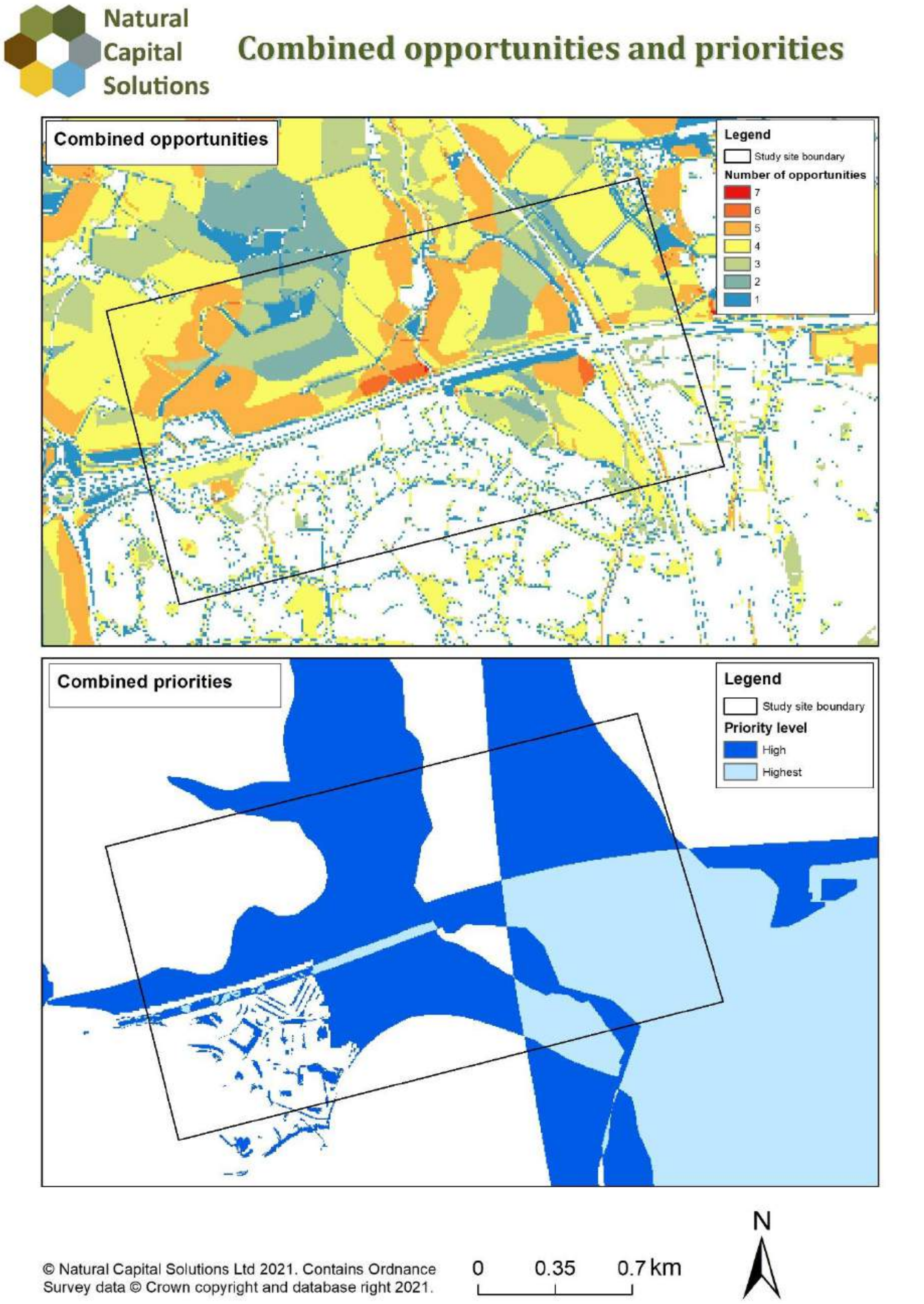

Figure 45 Combined opportunities (top) and combined priorities (bottom) for the Warrington case study.

7.3 Interventions planned and changes to habitats

The opportunity maps (Figures 43 and 44) were used to guide which habitats to create and their optimal locations. Habitats based on the planned interventions are shown in Figure 46 and the area and percentage cover of habitats under the baseline and the planned interventions are shown in Table 14. The change in natural habitat relates to a reduction in cultivated/disturbed land (-27.6 ha) and improved grassland (-13.8 ha) and creation of broadleaved woodland (+33 ha), trees/parkland (+4.9 ha) and semi-natural grassland (+2.7 ha). There will also be a small increase in area of freshwater (+0.4 ha).

New habitats have been created in two zones. The triangle of land to the south of the motorway, adjacent to the Sankey Brook, is to be converted to a publicly accessible woodland and park, predominantly broadleaved woodland, but with patches of parkland, grassland and water features. This is a key area, where accessible woodland would provide multiple benefits in an area of high priority for investment. The second zone is a thick strip of land to the north of the M62, which would be planted with broadleaved woodland. This would act as a buffer to the motorway, ameliorating air pollution, noise pollution, moderating local climate and enhancing water quality. Semi-natural grassland would also be created adjacent to the railway line. Given the lack of easy access and closeness to the Motorway, it has been assumed that the habitats to the north of the M62 would not be publicly accessible for the purposes of this assessment, although with additional access and safety features, the two zones of habitat creation could be linked into a larger public park.

Table 14 Area and percentage cover of broad habitat types across the Warrington case study under the baseline and the intervention scenario.

Broad habitat	Area (Ha)		% Cover		Change (Ha)
	Baseline	Intervention	Baseline	Intervention	
Cultivated / disturbed land	106.2	78.6	30.7	22.7	-27.6
Improved and amenity grassland	92.3	78.5	26.7	22.7	-13.8
Semi-natural grassland	0.1	2.8	0.0	0.8	2.7
Unknown grassland	1.1	1.1	0.3	0.3	0.0
Heathland	0.5	0.5	0.2	0.2	0.0
Broadleaved woodland	27.7	61.1	8.0	17.7	33.4
Coniferous woodland	0.6	0.6	0.2	0.2	0.0
Mixed woodland	1.3	1.3	0.4	0.4	0.0
Scrub	0.7	0.7	0.2	0.2	0.0
Trees / Parkland	0.0	4.9	0.0	1.4	4.9
Boundaries	1.4	1.3	0.4	0.4	-0.1
Water	2.9	3.4	0.8	1.0	0.4
Built up areas	61.6	61.6	17.8	17.8	0.0
Garden	11.9	11.9	3.4	3.4	0.0
Infrastructure	36.3	10.5	36.3	10.5	0.0
Unclassified	1.0	1.0	0.3	0.3	0.0
TOTAL	345.5	345.5	100	100	-

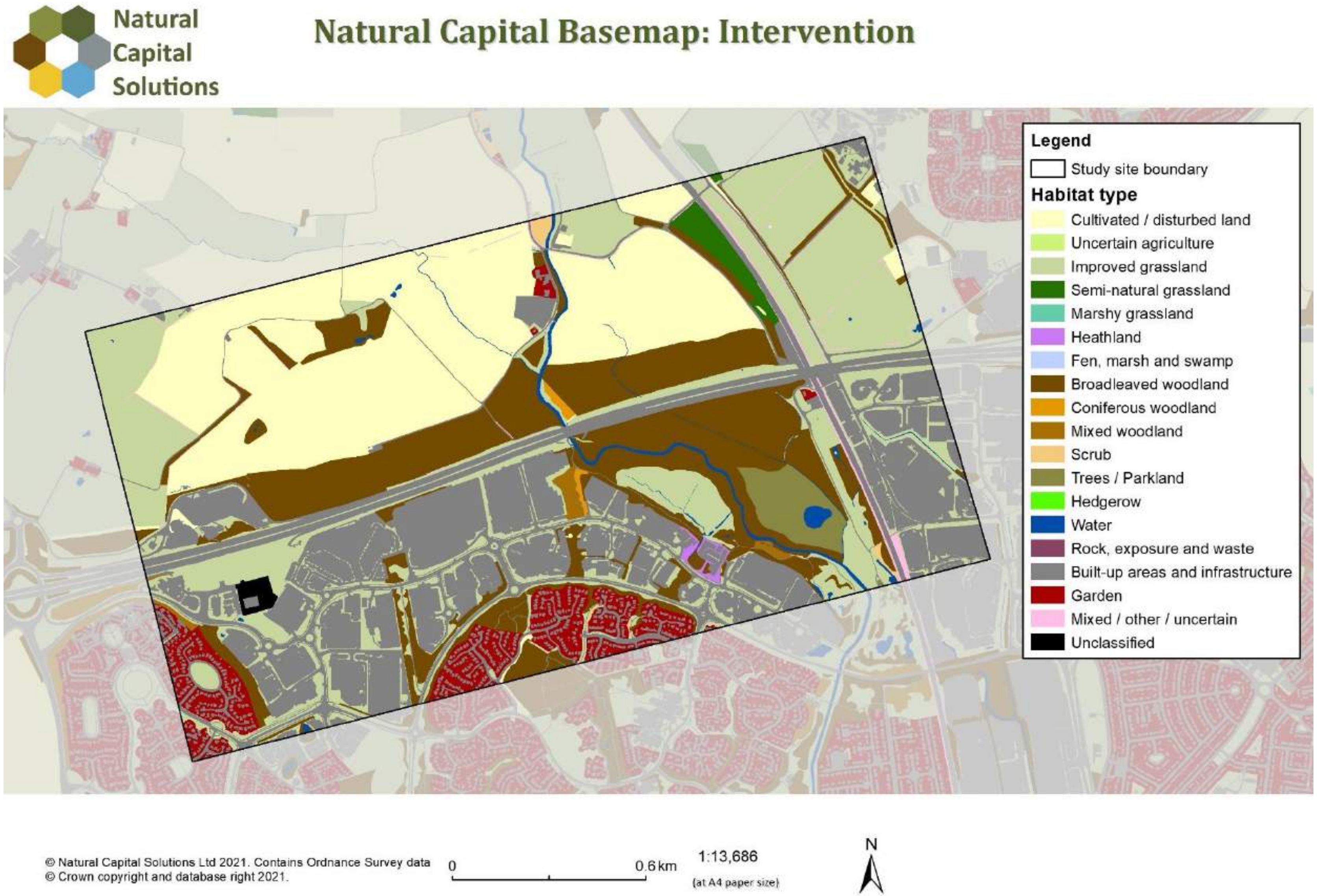

Figure 46 Habitats across the Warrington case study area under the proposed interventions.

7.4 Change in ecosystem service provision

The ecosystem services delivered by the case study site were quantified and mapped for the baseline and intervention scenario and the change in benefits calculated. The mean score for each ecosystem service and the percentage change is shown in Table 15.

- **Carbon storage capacity** – given the extensive woodland planting in this case study, there is a 22.0% increase in carbon storage projected to occur under the interventions. This is clearly apparent as the green-yellow areas in Figure 47.
- **Air purification capacity (air quality regulation)** – under the proposed interventions, there is a very large 55.3% increase in delivery of this service. The new woodland plantings are primarily responsible for the increases, as is evident from Figure 48.
- **Noise regulation capacity** – again, the large areas of new woodland planting are easily apparent on the map (Figure 49), leading to a significant increase in capacity of 54.2% under the interventions compared to the baseline.
- **Local climate regulation capacity** – shows a similar pattern to air purification and noise regulation capacity, with the areas of new woodland apparent on the map (Figure 50), especially the large block to the south of the motorway. The delivery of this service more than doubles (increase of 139%).
- **Pollination capacity** – is generally high across the landscape with most locations within easy reach of wild pollinators. It is very high under the baseline (Figure 51) and is almost identical under the intervention scenario (0.1% increase). The new patch of semi-natural grassland caused the largest increase in the delivery of this service but is offset by the new woodlands, which is not an optimal habitat for pollinators (although woodland edge is).
- **Water flow regulation capacity** – is moderate across the study area (Figure 52), under both scenarios. Table 15 shows that values improve by 10.0% under the interventions. This is almost entirely due to the new woodland plantings, which increase roughness across the landscape. It is lowest (purple) in areas of sealed surfaces (buildings and infrastructure).

Table 15 Mean ecosystem service capacity scores and percentage change for each of the ecosystem services quantified across the Warrington case study under the baseline and intervention scenario.

Ecosystem Service	Ecosystem service score		% change
	Baseline	Intervention	
Carbon storage capacity	14.0	17.0	22.0
Air purification capacity	13.2	20.6	55.3
Noise regulation capacity	23.4	36.1	54.2
Local climate regulation capacity	8.3	19.8	138.9
Pollination regulation capacity	93.7	93.8	0.1
Water flow regulation capacity	42.0	46.1	10.0
Accessible nature capacity	19.5	33.0	69.3
MEDIAN % CHANGE			54.2

- **Accessible nature capacity** – increases very significantly, by 69.3%, under the proposed interventions, due primarily to increasing the amount of land with public access to the south of the motorway, but also due to increasing the naturalness of the land that is accessible (Figure 53).

Overall change

Overall, all seven of the ecosystem services mapped increased under the proposed natural capital interventions. The median change was a 54.2% increase in ecosystem service capacity compared to the baseline (Table 15), which is the greatest of the five case studies.

Physical flows of ecosystem services

In addition to the ecosystem services that have been mapped, the physical flows of seven ecosystem services have been calculated (Table 16). These show that carbon sequestration and timber/woodfuel more than doubles, with an increase of 294 tonnes of CO_2 and 281 m^3 of timber each year on average. Air quality regulation also increases significantly, with an additional 0.78 t $PM_{2.5}$ absorbed under the proposed interventions. In addition, 83,000 more visits would be expected into the natural environment, generating an extra 6.2 QALYs of physical health benefits. On the other hand, the amount of land under agricultural production falls by 39 ha, although this does also lead to a fall of 173 tCO_2e in greenhouse gas emissions from agriculture.

Table 16 Annual physical flows of ecosystem services under the baseline and intervention scenario for the Warrington case study.

Ecosystem Service	Units	Annual physical flow	
		Baseline	Intervention
Carbon sequestration	tCO_2e	259	553
Air quality regulation	$tPM_{2.5}$	1.44	2.22
Timber/woodfuel production	m^3	266	563
Recreation	Visits	268,000	351,000
Physical health	QALY	20.1	26.3
Agricultural production	Hectares	157	118
GHG emissions from agriculture	tCO_2e	830	657

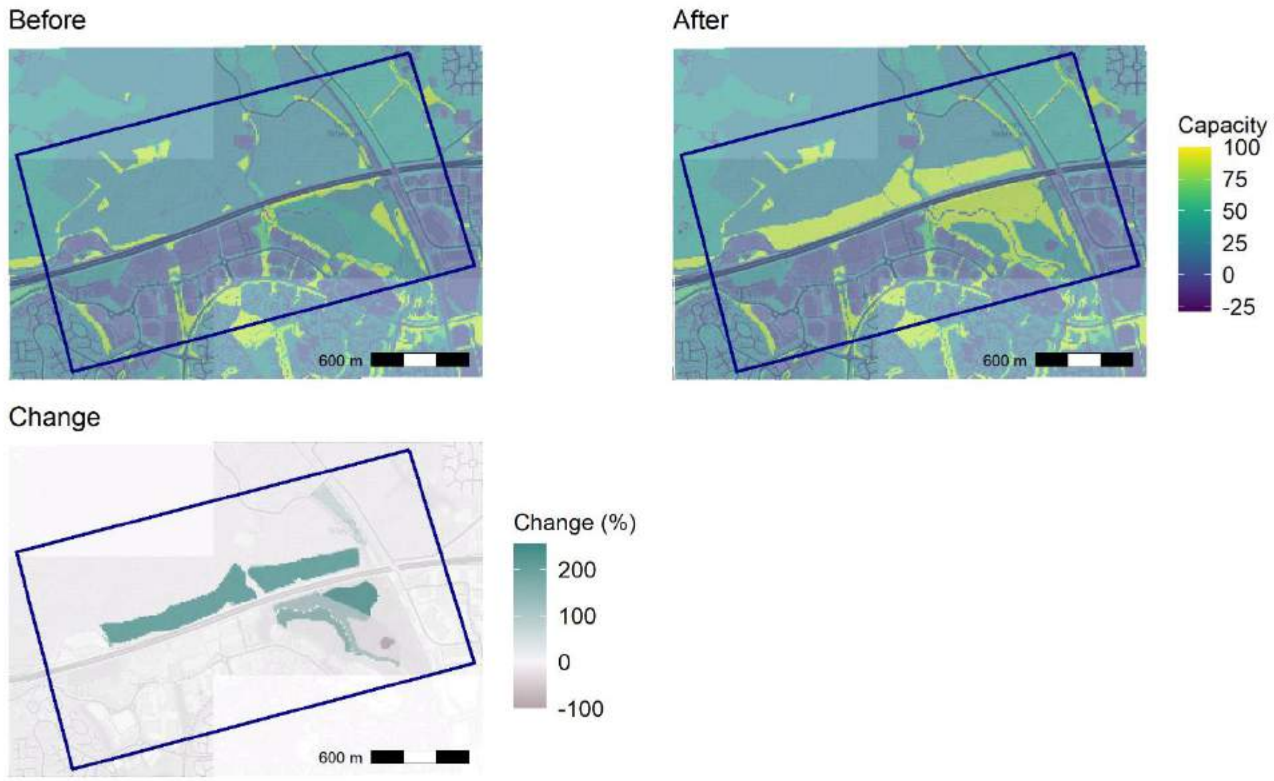

Figure 47 Carbon storage capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

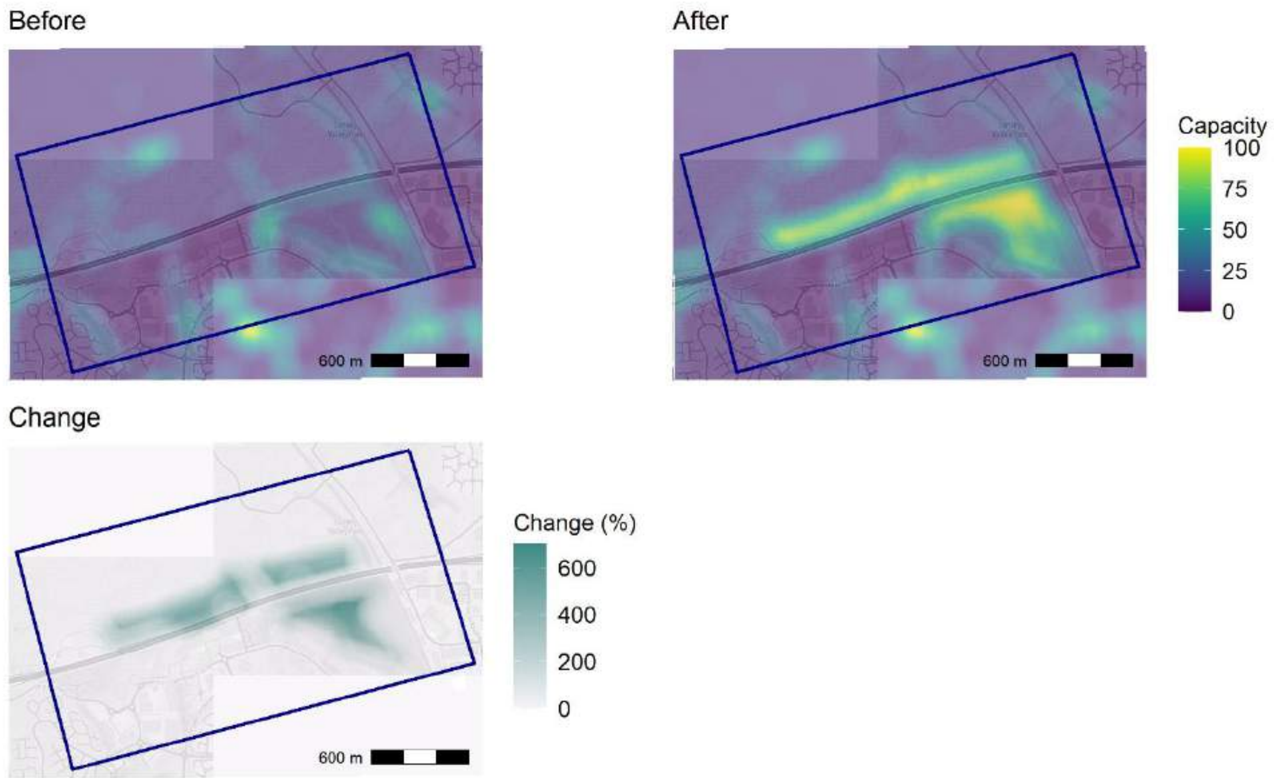

Figure 48 Air purification capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

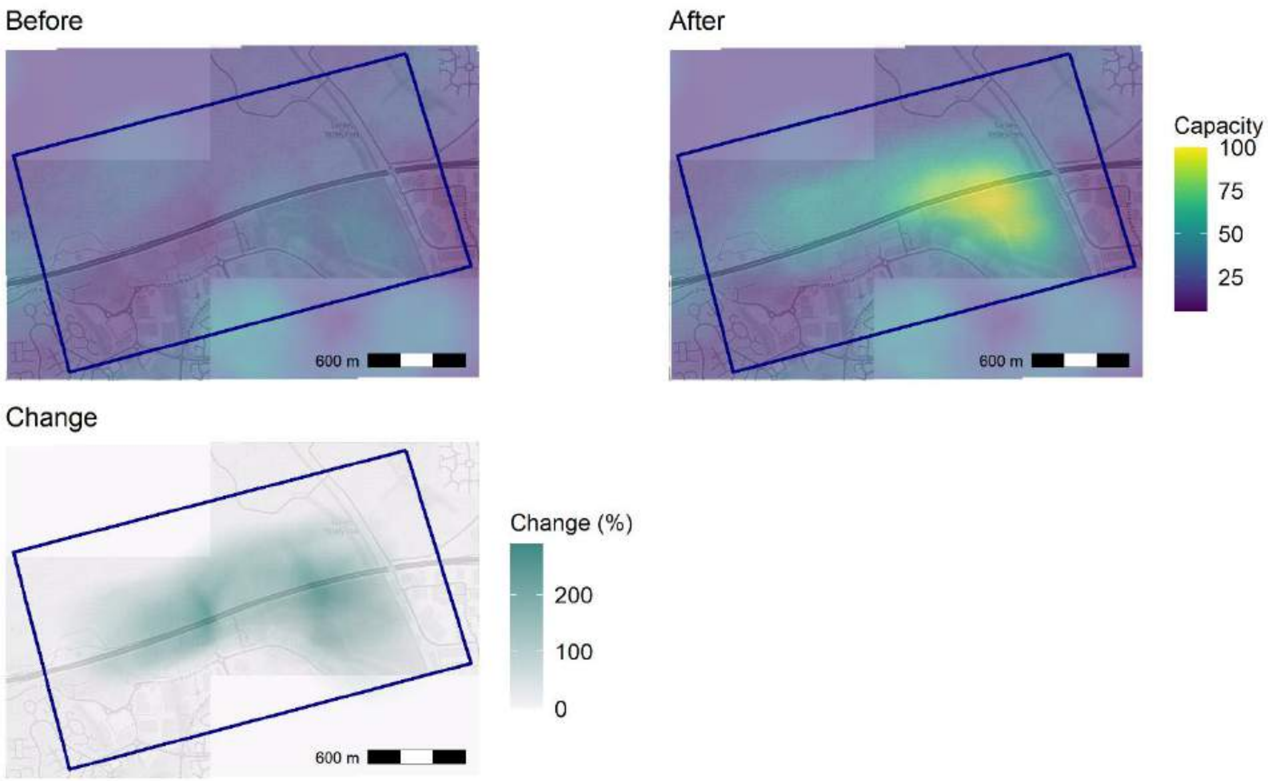

Figure 49 Noise regulation capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

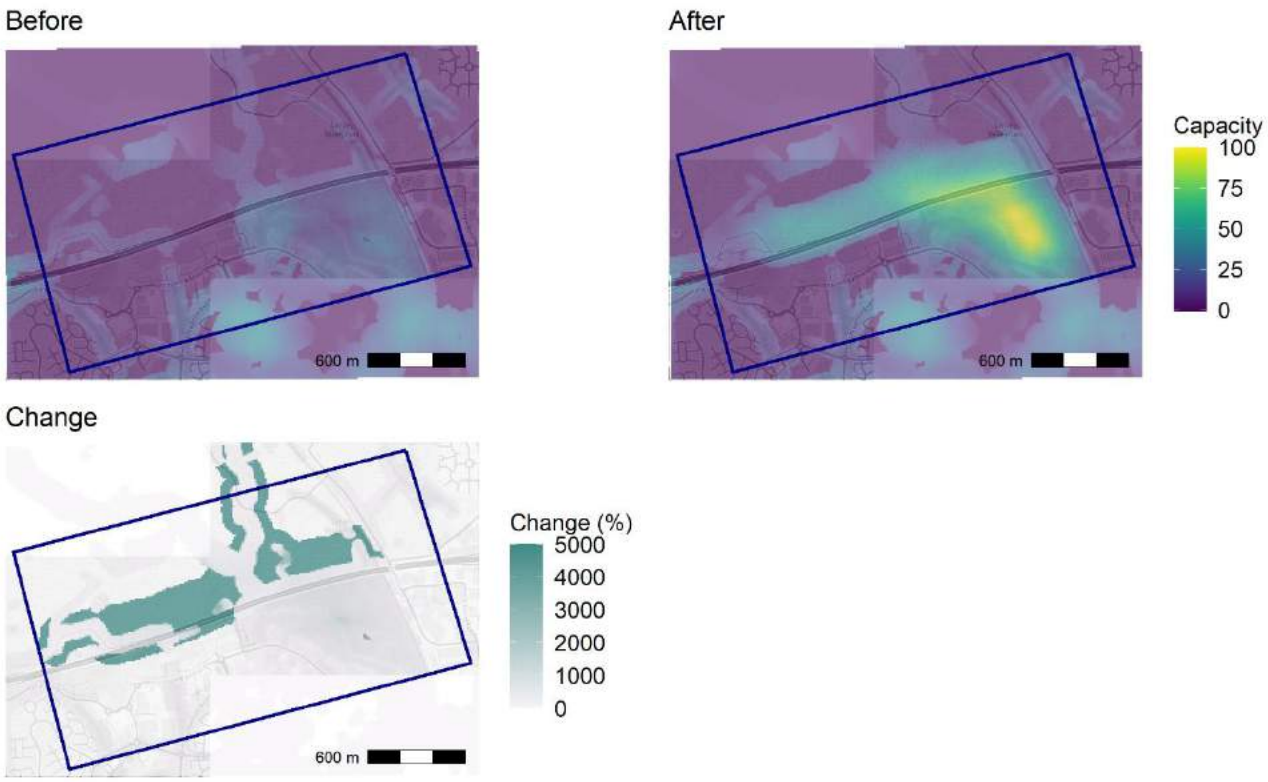

Figure 50 Local climate regulation capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

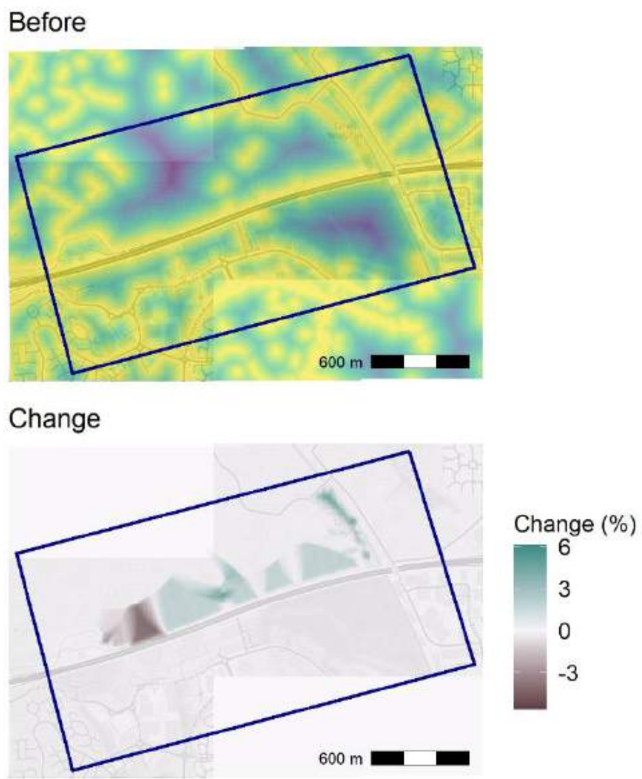

Figure 51 Pollination capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

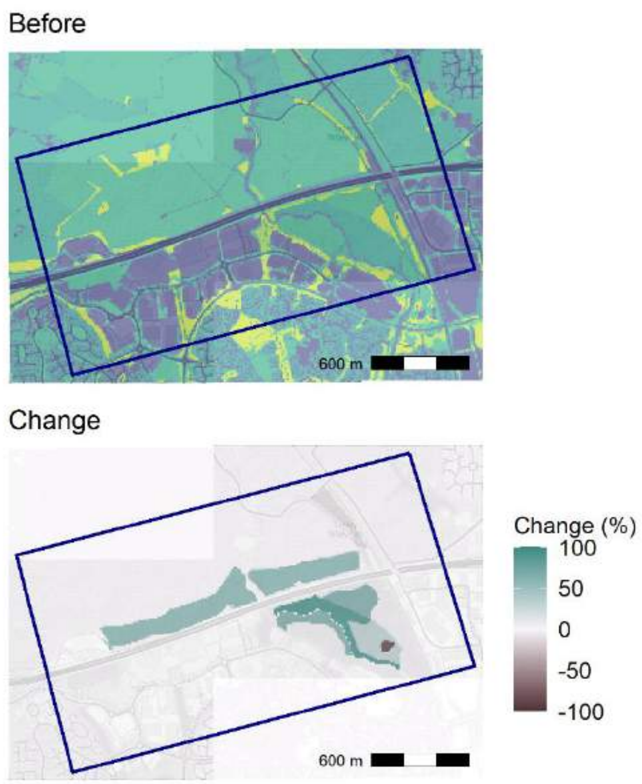

Figure 52 Water flow regulation capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

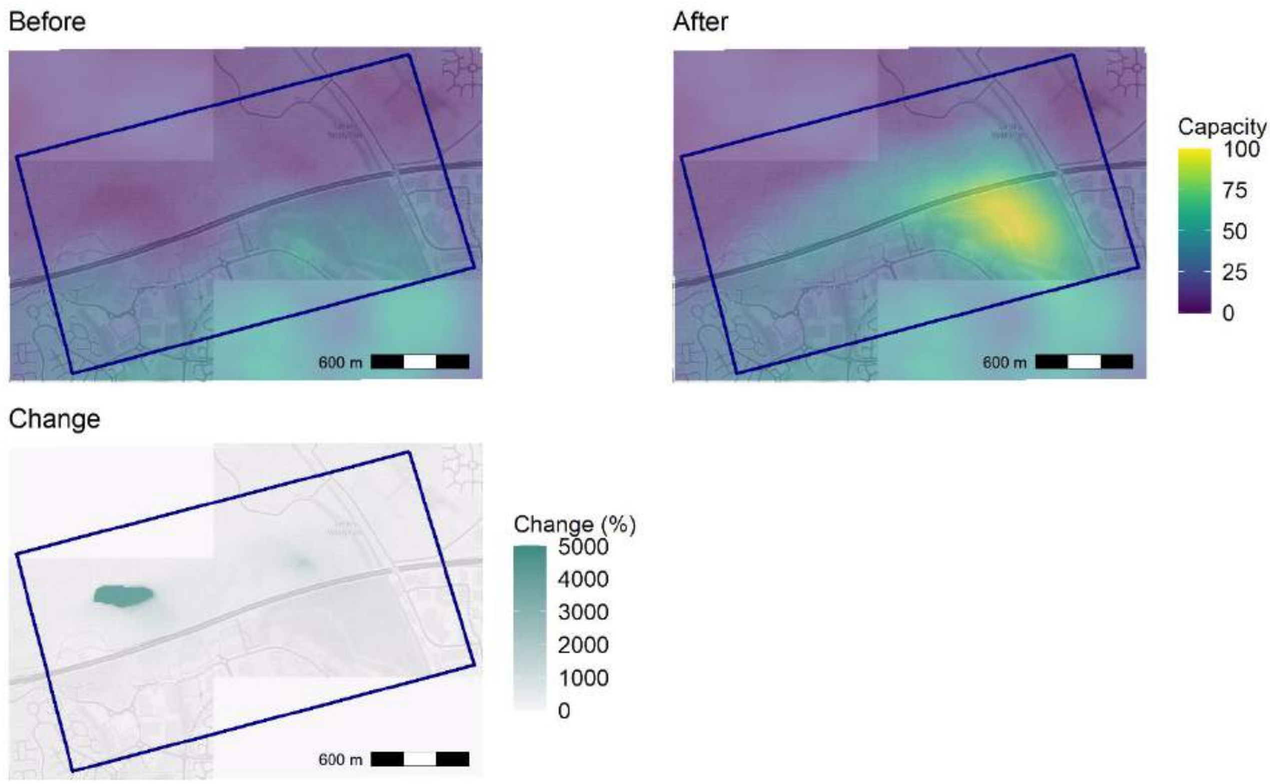

Figure 53: Accessible nature capacity for the current situation (before), under the proposed interventions (after), and highlighting the change between the two.

7.5 Economic appraisal and potential funding

The monetary flow of benefits was estimated for all ecosystem services for which this was possible. Full costs and benefits, presented on a per hectare basis, are shown in Table A1 (Annex A).

The core services targeted by this investment are recreation, physical health, carbon sequestration, air quality regulation and noise regulation, with secondary services including water flow regulation and biodiversity. The funding mechanism selector identifies the following as the most appropriate funding mechanisms to deliver this suite of core and secondary services:

- Investment Readiness Fund;
- Woodland equity fund;
- Forestry Commission woodland creation; and
- Habitat bank.

The amount of funding required reflects provisions for initial capital costs plus allowance for working capital over a 5-year period. The investment requires up-front costs to plant new woodland, create small areas of parkland and semi-natural grassland on what was arable land. Revenue costs (on-going costs) relate to maintenance and management of the woodland, parkland and grassland. Should there be less up-front funds available, then it may take longer to undertake some of the up-front restoration activities, so the benefits would also likely be reduced (since they would not occur until later).

The total funding need for the case study is estimated at £0.96 million for the first five years of the project, equivalent to £2,786 per hectare. This is made up of capital cost funding (including management costs), estimated at £725,000 (£2,099 per hectare), and working capital of £238,000 (£688 per hectare). These are short-term up front-costs (up to 5 years) needed to enable the natural capital investment.

With **projected benefits of the case study of £9.9 million** over 50 years and a **Net Present Value of £8.2 million**, this gives a **benefit-cost ratio of 5.7** and an **internal rate of return (IRR) of 27%**. The benefits vary by type of ecosystem service provided, totalling £1,539 per ha, and broken down as follows (top four benefit contributions shown; it is also important to note that there are additional ecosystem service benefits that cannot currently be captured in monetary terms):

- Recreation: £659 per ha
- Air quality regulation: £484 per ha
- Physical health: £269 per ha
- Carbon sequestration: £65 per ha

The potential value of carbon credits (based on voluntary carbon market price, 2021) is £12,561 per year.

The scale of funding required means that a woodland equity fund is unlikely to be suitable for such a small area. The Forestry Commission England Woodland Creation Offer, which covers tree planting on farms may be suitable, once launched, at this small-scale. Habitat Banking is linked to funds such as for peatland restoration or the nature for climate fund, as well as biodiversity and environmental net gain. The size of the area (41 ha) may not be sufficient to generate a habitat bank on its own, but offsets associated with biodiversity net gain could be a potential source of funds.

8. Analysis across all five case studies

Table 17 summarises each of the five case studies. Each case study has explored different objectives and demonstrated how the opportunity maps can be used to highlight the most appropriate location to create new habitats and the most suitable habitat to create in each of those locations. The opportunity maps can be used both at a site scale (as above), and to guide the selection of sites that will deliver the greatest benefits in priority locations. This broader scale use of the maps is explored further in the Intervention and Investment Opportunities Report (Technical Report 2).

The impacts of the natural capital interventions proposed for each case study site were assessed using both quantitative ecosystem services models and through a cost-benefit analysis. The models showed that in almost all cases, ecosystem service delivery was greater following the interventions than under the baseline situation. In most cases multiple benefits can be delivered, providing benefits in addition to the targeted primary objective; such interventions are therefore multi-functional. This also has implications for funding, with the possibility of stacking benefits and opening up additional funding sources (see Funding Opportunities section below).

The assessments presented here do not attempt to value the biodiversity benefits, hence biodiversity benefits provide additional benefits achieved by the planned interventions across all the case study sites. Biodiversity benefits are partially represented by agri-environment payments, but these do not reflect the true value. In particular, agri-environment payment rates are generally based on costs of interventions, or income forgone, rather than on payment by outcomes or on any attempt to value biodiversity enhancement.

Benefits and Costs

The case study projects vary in terms of the type and relative importance of benefits and associated costs (Table A1). Carbon sequestration and/or carbon storage and air quality regulation are important benefits linked particularly to woodland expansion and restoration, and peatland management. Enhanced public access and use delivers important benefits in terms of recreation and physical health. The impacts on the value of agricultural production are small, except for dairy land, reflecting the relatively modest net margins for arable and negative margins for non-dairy grassland (excluding subsidies). It is noted that potential important benefits pertaining to biodiversity and the water environment are not valued here. Indicative extra benefits at full development (not discounted) range between about £220/ha and £1,720/ha, highest where air quality benefits are combined with recreation and associated physical health benefits.

The main capital costs are associated with investments in priority habitat expansion and restoration, notably for woodlands and peatland. Investment in infrastructure for improved public access is important where existing provision is limited. Land based initiatives and capital investments to provide full potential for water related benefits are probably under-identified here. Capital costs range between about £800/ha and £2,800/ha, highest where woodland investments occur alongside infrastructure for public access.

Project Feasibility

For the assumptions made, the five illustrative cases appears feasible at the Treasury test discount rates. Benefit:Cost ratios range between 2.4 and 5.7, and annual equivalent yields (internal rates of return) are between 15% and 27%. It is noted that unquantified biodiversity and water related benefits would increase the estimated economic worth of the projects.

Table 17 Summary of estimated economic performance of illustrative case studies.

£ 2021 values

Case	Dominant land use	Area ha	Main land use changes	PV Benefit at test DR	PV Costs at test DR	NPV at test DR	Benefit: Cost	Internal Rate of Return	Funding requirement	Benefit Types
		(i) total , (ii) non developed (iii) land use change		£000	£000	£000	ratio	%	(i) Capital, (ii) Capital plus Ops costs to year 5 : £'000	(i) primary (ii) secondary
Farm : Ridley Cheshire Farm Estates	Enclosed farmland: mainly dairy	(i) 401, (ii) 374, (iii) 50	arable and improved grass switched to semi natural grassland and woodland	1,824	773	1,051	2.4	15	(i) 319, (ii) 471	(i) carbon and air quality (ii) water quallity, biodiversity
Peat	Upland peatland	(i) 89, (ii) 89, (iii) 81	degraded to restored peatland, blanket bog	1,374	309	1,065	4.4	24	(i) 129, (ii) 187	(i) carbon and air quality (ii) recreation
Dean	Arable and improved grass	(i) 190, (ii) 130, (iii) 32	arable and improved grass to woodland and wood pasture	6,102	1,275	4,827	4.8	23	(i) 533, (ii) 740	(i) water quality and flow regulation (monetary value underidentified) (ii) recreation, biodiversity
Northwich	Arable improved grassland and woodlands: (urban context)	(i) 1728, (ii) 1394, (iii) 70	restoration and expansion of woodland	15,960	3,009	12,951	5.3	25	(i) 1,253, (ii) 1,812	(i) recreation and public health, multiple benefits adjacent to urban area (ii) biodiversity
Warrington	Arable and grassland, with woodland, (urban context	(i)345, (ii) 233, (iii) 41	arable and improved grass to woodland and parkland , and woodland restoration	9,942	1,733	8,209	5.7	27	(i) 725, (ii) 963	(i) air quality and recreation, multiple benefits on urban fringe (ii) biodiversity, water quality and flow regulation

* non developed refers non built land areas

The predicted feasibility of the projects appear stable over a wide range of benefit and cost assumptions. The Cheshire Farms Project would remain economically feasible at the test discount rate provided benefit estimates are at least 45% of the best single estimate shown in Table A1, and total costs are no greater than 2.5 times the best estimate. The other projects, returning higher Benefit:Cost ratios, would remain feasible at benefit and cost estimates at about 25% and 4 times of the best single estimates respectively.

The individual projects are relatively modest in scale, ranging from about 100 ha to 1,700 ha. Initial capital costs range between £0.13 million and £1.25 million, indicating the scale of possible funding requirements (Table A2). The estimates are illustrative: a detailed assessment involving site specific enquiry would be needed to provide confident estimates for investment decision making. The estimates are however indicative of potential net benefits and investment opportunities at the larger scale.

Funding opportunities across all five case studies

The case studies identify a range of different mechanisms that could be applied to deliver the investments needed. However, often these identify that the small scale of the proposed case studies would make use of a specific funding mechanism more restricted. Therefore, consideration has been given as to the potential use of blended finance, where an organisation (such as a Special Purpose Vehicle) could bring together different sources of funds in order to deliver a wider range, and potentially more beneficial overall, scale of natural capital change.

Table 18 summarises the core and secondary services that are driving investment in each of the five case studies. The table also shows the proposed area (in ha) of the suggested change in habitats.

Table 18 Summary of changes across the five case study sites and the core and secondary benefits achieved.

<table>
<tr><th rowspan="2">Ecosystem service</th><th colspan="5">Case study</th></tr>
<tr><th>1
Sustainable agriculture</th><th>2
Peat restoration</th><th>3
Water quality and flow</th><th>4
Northwich</th><th>5
Warrington</th></tr>
<tr><td>Total area of case study (which may benefit from improvements to existing natural capital as well as change in habitats)</td><td>401 ha</td><td>89 ha</td><td>190 ha</td><td>1,728 ha</td><td>345 ha</td></tr>
<tr><td>Area of land use change to new habitats</td><td>50 ha</td><td>81 ha</td><td>32 ha</td><td>70 ha</td><td>41 ha</td></tr>
<tr><td>Air quality regulation</td><td bgcolor="#4f6228">Core</td><td></td><td bgcolor="#c4d79b">Secondary</td><td bgcolor="#c4d79b">Secondary</td><td bgcolor="#4f6228">Core</td></tr>
<tr><td>Noise regulation</td><td></td><td></td><td bgcolor="#c4d79b">Secondary</td><td></td><td bgcolor="#4f6228">Core</td></tr>
<tr><td>Carbon sequestration</td><td bgcolor="#4f6228">Core</td><td bgcolor="#4f6228">Core</td><td bgcolor="#c4d79b">Secondary</td><td bgcolor="#c4d79b">Secondary</td><td bgcolor="#4f6228">Core</td></tr>
<tr><td>GHG emissions from agriculture</td><td bgcolor="#4f6228">Core</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Recreation</td><td></td><td bgcolor="#c4d79b">Secondary</td><td></td><td bgcolor="#4f6228">Core</td><td bgcolor="#4f6228">Core</td></tr>
<tr><td>Physical health</td><td></td><td></td><td></td><td bgcolor="#4f6228">Core</td><td bgcolor="#4f6228">Core</td></tr>
<tr><td>Local climate regulation</td><td></td><td></td><td></td><td bgcolor="#4f6228">Core</td><td></td></tr>
<tr><td>Agricultural production</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Timber/woodfuel production</td><td bgcolor="#4f6228">Core</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Water quality regulation</td><td bgcolor="#c4d79b">Secondary</td><td></td><td bgcolor="#4f6228">Core</td><td></td><td></td></tr>
<tr><td>Water flow regulation</td><td bgcolor="#c4d79b">Secondary</td><td bgcolor="#c4d79b">Secondary</td><td bgcolor="#4f6228">Core</td><td></td><td bgcolor="#c4d79b">Secondary</td></tr>
<tr><td>Biodiversity</td><td bgcolor="#c4d79b">Secondary</td><td bgcolor="#4f6228">Core</td><td bgcolor="#4f6228">Core</td><td bgcolor="#c4d79b">Secondary</td><td bgcolor="#c4d79b">Secondary</td></tr>
<tr><td colspan="6">Key: [dark green] Core ecosystem services [light green] Secondary ecosystem services</td></tr>
</table>

The table shows that carbon sequestration and biodiversity benefits are common across all five case studies. Air quality regulation and water flow regulation are also core or secondary services for four of the five case studies, while recreation is a core service in two case studies. Therefore, a higher-level mechanism that could help fund these services across multiple sites in Cheshire and Warrington may provide the strategic level approach to funding that will help deliver multiple benefits. This suite of ecosystem services compares well to the services identified as priorities from the policy analysis (carbon avoided and sequestration, air quality regulation, water flow regulation as primary services with water quality regulation, biodiversity and access to nature as secondary services). The case studies also illustrate important differences between local priorities according to context. Hence, the need for an approach to funding that can facilitate delivery of a wide suite of services and benefits responsive to local needs and opportunities.

Expansion and restoration of woodland provides carbon sequestration alongside a range of other benefits, including biodiversity, water flow and air quality regulation, and recreational and amenity benefits.

There are numerous funds and applications that could be used, as part of a blended finance scheme, to generate income associated with woodland creation. Many current funds, such as the Local Authority Treescapes Fund or the Woodland Carbon Fund are close to (or beyond) application dates. However, funds for woodland creation are likely to persist, not least to enable the Government to meet its ambitions for woodland creation through the Defra England Tree Action Plan 2021-2024, through the Nature for Climate Fund, and the recently announced Forestry Commission England Woodland Creation Offer.

Peatland restoration is particularly important to arrest carbon loss in degraded peat soils and, like woodlands, can provide a range of benefits for water resources, biodiversity and people enjoying the countryside. A more detailed assessment of peatlands in Cheshire East is provided in Cheshire Wildlife Trust (2021)[8]. The England Peat Action Plan also includes the announcement of the Nature for Climate Peatland Grant Scheme (also through the Nature for Climate Fund) and the aim for immediate restoration of at least 35,000 ha of peatland by 2025[9].

New funding mechanisms to enhance environmental land management are proposed under the new Sustainable Farming Incentive, and the new Local Nature Recovery and Landscape Recovery Systems (Defra 2021). These new measures aim to meet the long-term goals of the 25 Year Environment Plan, providing the opportunity for strategic approaches to woodland creation, peatland restoration and farmed areas across the Cheshire & Warrington LEP area. The potential to deliver landscape scale improvements by working strategically at the LEP level should increase the likelihood that applications for funding are successful.

Indeed, the recently launched project through the Investment Readiness Fund (IRF) (initially focused on the Bollin catchment) via Mersey Forest will provide a mechanism to attract private investment to secure natural capital benefits across the Bollin catchment. The approach being developed through this IRF project to develop long-term contracts with natural capital buyers, and fixed-term, fixed-rate bonds with natural capital investors could be extended to the full Cheshire & Warrington area. This approach could help enable sufficient funds to be secured but allow the flexibility to also deliver local priorities.

[8] Cheshire Wildlife Trust (2021) Peatlands of Cheshire East: An Assessment of Greenhouse Gas Emissions and Biodiversity.
[9] Defra (2021): England Peat Action Plan, May 2021, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/987859/england-peat-action-plan.pdf on 1 June 2021.

Annex A: Further results of the economic appraisal

Table A1 Summary of estimated benefits at full development and capital costs (£/ha) for illustrative case study projects

Project Areas ha	402		89		190		1729		346	
	Cheshire Farms		Peat		Dean		Northwich		Warrington	
Benefits	£/ha	%	£/ha	%	£/ha	%	£/ha	%	£/ha	%
Carbon sequestration	53	24%	340	43%	87	5%	14	2%	65	4%
Air quality regulation (PM2.5)	150	68%	19	2%	448	26%	75	14%	484	31%
Timber	13	6%			18	1%	3	1%	14	1%
Recreation			301	38%	789	46%	343	62%	659	43%
Physical Health			92	11%	301	17%	95	17%	269	17%
Agric Production	-43	-19%	17	2%	2	0%	0	0%	-11	-1%
Agri environment	5	2%	31	4%	10	1%	1	0%	-3	0%
Woodland environment	11	5%			18	1%	14	2%	26	2%
Agricultural green house gas e	32	14%			49	3%	11	2%	35	2%
Total	222	100%	799	100%	1721	100%	557	100%	1539	100%

Estimated Capital Costs	£/ha	%	£/ha	%	£/ha	%	£/ha	%	£/ha	%
Land Based										
Woodlands	531	67%	0	0%	779	28%	426	59%	960	46%
Grassland and other	19	2%	721	50%	99	4%	17	2%	4	0%
Field management(hedges)	32	4%	141	10%	105	4%	50	7%	77	4%
Water related	45	6%	108	7%	121	4%	19	3%	80	4%
subtotal	626	79%	969	67%	1104	39%	512	71%	1120	53%
Infrastructure										
Cultural : recreation and access	6	1%	172	12%	1029	37%	56	8%	404	19%
Other	2	0%	20	1%	109	4%	12	2%	154	7%
subtotal	9	1%	192	13%	1138	41%	68	9%	559	27%
Total works	635	80%	1161	80%	2242	80%	580	80%	1679	80%
Management Costs	159	20%	290	20%	560	20%	145	20%	420	20%
Total capital	794	100%	1451	100%	2802	100%	725	100%	2099	100%
	£'000		£'000		£'000		£'000		£'000	
Total capital costs £	319		129		533		1253		725	

Funding Needs

Table A2 shows for each case study project the composition of the total initial capital investment and incremental working capital requirements over the first five years of project life. As referred to above, total funding requirements vary between £0.19 million and £1.82 million, disaggregated here by cost component.

Table A2 Funding requirements for initial capital and working capital by case study project

Case Study Projects		**Ridley Farms**	**Peats**	**Dean**	**Northwich**	**Warrington**
Area	ha	402	89	190	1729	346
Capital costs						
Woodlands	£	213,364	64,058	148,135	736,661	331,680
Other land based	£	38,248	22,100	61,865	148,518	55,364
subtotal	£	251,612	86,158	210,000	885,179	387,044
Cultural	£	3,500	17,069	216,398	117,500	192,993
Total	£	255,112	103,227	426,398	1,002,679	580,037
Management Des & Sup'n	£	63,778	25,807	106,600	250,670	145,009
Total Capital	£	318,890	129,034	532,998	1,253,349	725,046
Working capital (first 5 years)						
Land management (ELMs type)	£	48,748	25,464	42,127	236,261	56,146
Management and Operations	£	103,875	32,284	165,336	326,372	181,407
Total Working Capital	£	152,624	57,748	207,463	562,633	237,552
Total Capital + Working Capital	£	471,514	186,782	740,460	1,815,981	962,599
Total capital	£/ha	794	1451	2802	725	2099
Total Working Cap	£/ha	380	650	1091	325	688
Total Cap+Working	£/ha	1174	2101	3893	1050	2786

Working capital includes Land management costs associated with payments to land managers for ELMs type options based on Countryside Stewardship legacy (cost based) rates.

Potential for carbon Credits

The potential value for carbon credits is very sensitive to assumptions about traded prices (Table A3). For example, estimated credit based payments (before transaction costs) could range between £21/ha/year and £66/ha/year for the Cheshire Farms (Ridley Estate) case assuming the current 2021 Woodland Carbon Guarantee Third Auction traded carbon price (£17/tCO2e) and the forward 2025 UK Government BEIS estimate for traded carbon (£52/tCO2e in 2021 prices) respectively[10]. The Peatland restoration project generates the highest estimated carbon credits per ha at £75/ha/year and £230/ha/year respectively, albeit over a relatively small area of 89 ha.

Table A3 Potential value of carbon credits by project and carbon price

Case Study Projects		**Ridley Farms**	**Peats**	**Dean**	**Northwich**	**Warrington**
Area	ha	402	89	190	1729	346
Average annual tCO2e						
woodland (new) sequest'n	t CO2 e/yr	331	394	479	2,622	553
agric (reduced emissions)	t CO2 e/yr	176	0	134	286	173
Total	t CO2 e/yr	507	394	613	2,908	726
Potential value of carbon credits						
Woodland Carbon Guar 2021	£/year	8,770	6,819	10,615	50,341	12,561
BEIS traded central 2025	£/year	26,345	20,484	31,886	151,225	37,734
Woodland Carbon Guar 2021	£/ha/year	22	77	56	29	36
BEIS traded central 2025	£/ha/year	66	230	168	87	109

Notes

Carbon prices £2021 values : £/tCO2e

Woodland Carbon Guarantee Third Auction	£17
BEIS traded central price 2025	£52

[10] It is noted that the economic appraisal uses UK BEIS non traded carbon prices for the period 2021 - 2050 expressed in 2021 values

Annex B: Valuation methods

Carbon sequestration

Carbon sequestration rates for woodland and other habitats with trees were calculated following the UK Woodland Carbon Code methodology and look-up tables (Woodland Carbon Code 2018[11]). Coniferous woodland sequestration rates were averaged over a 60-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 these woodland types. Information on species composition was taken from the Forestry Commission's National Inventory of Woodland and Trees County Report for Cheshire (2002[12]). Yield classes for each tree species in Cheshire were derived from Forest Research's Ecological Site Classification tool (http://www.forestdss.org.uk/geoforestdss/). Average spacing between trees was assumed, and it was also assumed that deciduous woodland was not thinned, but coniferous areas were. The annual sequestration rate for each species was then multiplied by the proportion of each species to give the total annual sequestration estimate for each woodland type. For new woodland planting under the investment scenarios, we assumed a species mix typical for Cheshire and obtained the yield class for each species at each case study site from Forest Research's Ecological Site Classification tool.

Monetary flows were calculated using the Government's non-traded central carbon price for 2021 (DBEIS 2019[13]). 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 a 50-year period, after discounting using the discount rate suggested in HM Treasury (2019[14]).

Air quality

The ability of woodland and grassland at the case study sites to absorb particulate matter ≤2.5μm in diameter ($PM_{2.5}$) was measured. For new habitats created under the investment scenarios, we assumed that the habitats were fully established. This will overestimate their ability to absorb pollutants in the early years following planting, but it was beyond the scope of this assessment to consider incremental changes over time. Quantifying the physical flow of the air quality regulation service was based on the absorption calculation in Powe & Willis (2004[15]) and the method in ONS (2016[16]). The deposition rates for $PM_{2.5}$ in coniferous woodland, deciduous woodland, and grassland were taken from Powe & Willis (2004). Average background pollution concentrations for $PM_{2.5}$ 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 2020 (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

[11] Woodland Carbon Code (2018) Carbon calculation guidance v2. March 2018. Forestry Commission.
[12] Forestry Commission (2002) National Inventory of Woodland and Trees County Report for Cheshire. Forestry Commission
[13] DBEIS (2019) Carbon priced and sensitivities 2010-2100 for appraisal in HM Treasury (2018) The Green Book. Central Government guidance on appraisal and evaluation, version 3. London.
[14] HM Treasury (2019) The Green Book. Crown Copyright.
[15] Powe, N., A., & Willis, K.G. (2004) Mortality and morbidity benefits of air pollution (SO2 and PM10) absorption attributable to woodland in Britain. *Journal of Environmental Management,* 70, 119-128.
[16] ONS (2016) Annex 1: Background and methods for experimental pollution removal estimates. UK National Accounts.

most common broadleaf tree species (ash, beech, horse chestnut, oak, silver birch) in the UK using the Woodland Trust data averages tool.

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[17]). 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 woodland and grassland habitats was equal to the average damage cost of that pollutant. The $PM_{2.5}$ damage cost estimates depend on the location (urban size or rural) and source of pollution and so was determined separately for each cases study site. When calculating the present value over 50 years, the absorption rate was assumed to be constant. The Defra damage cost of $PM_{2.5}$ is in 2017 prices, and so was adjusted to reflect inflation up to 2021. 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).

GHG emissions from agriculture

Agricultural activities release CO_2 and other greenhouse gasses such as methane and NO_2 into the atmosphere, with emissions highly variable depending on the type of farming practices employed. These emissions can therefore negate the benefits obtained through carbon sequestration of habitats within a site.

The greenhouse gas emissions of the site were calculated by multiplying the area of each crop type and the numbers of livestock by emissions figures for each crop type and livestock type in Bateman et al. (2013[18]). These emission figures are based on three types of agricultural emissions:

1. Emissions from typical farming practices (e.g. tillage, sowing, spraying, harvesting, and the production, storage and transportation of fertilizers and pesticides).
2. Emissions of N_2O from fertilizers.
3. Emissions of N_2O and methane from livestock, caused by enteric fermentation and the production of manure.

As we did not have site specific livestock numbers, these were based on average stocking densities for Cheshire. The total physical flow of greenhouse gas emissions was calculated by adding crop type and livestock emissions (in tCO2e). These were monetised using the DBEIS (2019) non-traded central carbon price, as described for carbon sequestration above, and discounted at the standard rate.

Recreational benefits

The annual physical and monetary flows of recreation was estimated using the University of Exeter's Outdoor Recreation Valuation Tool (ORVal) version 2.0 (https://www.leep.exeter.ac.uk/orval/). This tool uses a statistical model called 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, and the availability and quality of any alternative greenspaces. The model, through a welfare function, also describes the welfare an individual derives from making different recreational choices, and the welfare values are, therefore, provided by the tool. The welfare gained

[17] Defra (2019) Air quality damage costs guidance. Crown Copyright.
[18] Bateman, I. J. et al. (2013) Bringing ecosystem services into economic decision-making: Land use in the United Kingdom. Science 341 45-50.

from a particular greenspace will depend on a number of factors (e.g. socio-economic status, month of the year) and the benefits experience at a site is traded-off against the costs of travelling to the site.

To obtain a valuation under the investment scenario for each case study, the "create sites" function was used within the ORVal tool. A site boundary was drawn based on the area of land that would become publicly accessible, with habitats assigned within the tool based on the habitats in the investment maps. This function was also used in some case studies for the baseline, where sites (or parts of sites) were already publicly accessible. For further details of the ORVal model see the advanced technical report for details: https://www.leep.exeter.ac.uk/orval/pdf-reports/ORValII_Modelling_Report.pdf.

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. Physical health is more commonly valued, although methods are still being refined. The physical flow of health benefits delivered by the case studies were valued using an approach developed by White et al. (2016[19]), who analysed the implications of recreational physical activity in the natural environment on health in England. The method relies on estimates of visitors to natural environments who meet recommended activity guidelines (based on both duration and intensity of physical activities).

The first step in the calculations was to estimate the number of visitors to the publicly accessible green areas at the case study sites. These were taken from the University of Exeter's Outdoor Recreation Valuation Tool (ORVal) version 2.0. As for the recreational benefits, to estimate visitors under the investment scenarios, new sites were created within the ORVal tool. Using this estimate we converted the visits (which includes repeat visits by the same individuals) to the number of visitors (individuals), using a visit rate calculated from the latest 5 years of national MENE survey data from Natural England. These can be 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. This physical health benefit can, therefore, be estimated 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 remains under review. It has been estimated to be worth £20,000 (White et al. 2016), and £60,000 (HM Treasury 2019). However, the recent Defra ENCA project suggests a more conservative value of £15,000 should be used, and this is what is used here.

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.

Timber 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 (see carbon sequestration section). For new woodland planting under the investment scenarios, we assumed a species mix typical for Cheshire and obtained the yield class for each species

[19] White, M.P. et al. (2016) Recreational physical activity in natural environments and implications for health: A population based cross-sectional study in England. Preventative Medicine 91 383-388.

at each case study site from Forest Research's Ecological Site Classification tool (http://www.forestdss.org.uk/geoforestdss/).

The annual monetary flows for the woodland areas were calculated by multiplying the yield by the standing price of timber or woodfuel. This gave an average yield over 100 years for broadleaved woodland (60 years for coniferous woodland) and does not calculate how this changes annually as the woodland develops. The average price for softwood in 2021 was taken from the Forestry Commissions Coniferous Standing Sales Price Index (Forestry Commission 2021[20]). The price for broadleaved timber in 2015 ranged from £15 to high quality timber reaching £250 per m^3 standing (ABC 2015[21]). We assume the lowest value here for woodfuel, and convert this to 2021 prices using Government deflators. To convert to a present value the annual value was multiplied by the standard government discount rate (3.5%) for each respective year up to 50 years.

Agriculture

Estimates of Gross Output, Gross Margins and Net Margins (£/ha) for the main crop and livestock enterprises in the study area were based on data from the Annual Farm Business Survey (RBR, various) for the North West region 2013/14 to 2018/19[22], supplemented by data from Redman (2020)[23]. Prices were adjusted to 2021 values. Estimates were also derived from agri-environment receipts (£/ha) for current land uses. Estimates of Net Margin for grassland (£/ha) were based on stocking rates (Livestock units/ha) and net margins per head of livestock according to type (£/Livestock unit). Changes in land use were thus reflected in changes in Net Margin.

The key indicator used was Net Margin £/LU that included charges for selected so-called fixed costs at the farm scale. Land costs and income support were excluded. Costs for unpaid farm family labour were included. However, allowance was made for proportionate changes in farm fixed costs such as labour and machinery when farms switch land use or move to less intensive systems. Thus the estimates indicate economic value added.

It is noted that under the current policy regime, the 'average' Net Margin for (non-dairy) beef and sheep systems are negative in the absence of income subsidies. Hence, reducing stock numbers and stocking intensities is associated with reduced economic 'losses', that is economic gain. Moving to less intensive grassland can simultaneously generate environmental benefits.

Agri-environment and future ELMs-type options

Estimates of agri-environment revenues net of management costs received by land managers under current arrangements were obtained from RBR sources[24]. Estimates of future agri-environment payments under the proposed Environmental Land Management (ELMs) options, including woodland and agro-forestry options, were based on the legacy payments rates of the Countryside Stewardship Scheme. Actual payment rates will be determined following the ongoing Defra ELMs Test and Trials programme.

The capital and annual management costs for land management interventions, including expansion and restoration of woodlands, peatland and semi natural habitats, and the conversion of arable and

[20] Forestry Commission (2020) Timber price indices. Data to March 2020.
[21] ABC (2015) The agricultural budgeting and costing book. 81st edition, Argo Business Consultants.
[22] RBR, (various publication years). Farm Business Survey Results, Rural Business Research. Available at: https://www.ruralbusinessresearch.co.uk/
[23] Redman, G (2020). The John Nix Pocketbook for Farm Management 2021, 51st edition. Melton Mowbray: Agro Business Consultants.
[24] Rural Business Research, as above

improved grassland to high nature land use, were based on estimates from Redman (2020), Natural England/RSPB/Wildlife Trust Sources, and reviews of peatland and related nature restoration projects.