Bedfordshire Natural Capital Assessment

Part 3: Maps and results for Central Bedfordshire

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Report prepared for and funded by:
Central Bedfordshire Council, in association with Bedford Borough Council, Luton Borough Council and the Bedfordshire Local Nature Partnership

Version: Final

June 2020

Executive Summary

This report describes a project to produce a detailed natural capital (habitat) basemap for Central Bedfordshire, to model and map the physical and economic benefits (ecosystem services) that flow from the natural capital, and to identify opportunities to enhance accessible natural greenspace, biodiversity and a range of ecosystem services. It is part of a larger project to complete a natural capital assessment for the whole of Bedfordshire and separate reports have also been produced for Bedford Borough and Luton Borough. The main Bedfordshire report should be consulted for details on methodology and further background. The overall project was commissioned by Bedford Borough Council, Central Bedfordshire Council, and Luton Borough Council, through the Bedfordshire Local Nature Partnership.

The first part of the project was to produce a detailed map of the current habitats present across Central Bedfordshire. This used Ordnance Survey MasterMap polygons as the underlying mapping unit and then utilised a series of different data sets to classify each polygon to a detailed habitat type. The final basemap covered an area of 71,567 ha or 716 km^2 and contained 525,914 polygons, each of which was classified to an appropriate habitat type. It shows that Central Bedfordshire is dominated by arable land, which makes up 55% of the area (39,441 ha). Woodland and scrub habitats take up 10.5% (7,565 ha) of the area. Semi-natural and marshy grasslands make up 2.8%, while water makes up just 1.2% of the area. Built-up areas and infrastructure make up 6.9% of the land area, with gardens comprising 4.8%. To gain a more complete picture of the natural capital baseline across the area, a range of additional maps were created to give an indication of environmental quality across a broad set of criteria, covering air, water, agricultural quality, site protection and public access.

In total, 10 ecosystem services were modelled and mapped: carbon storage and sequestration, air purification, noise regulation, local climate (urban heat) regulation, water flow regulation, water quality regulation, food production, timber production, and accessible nature. Maps showing the demand for air purification, noise regulation, local climate regulation and accessible nature were also produced. Demand was focussed on the urban centres in Central Bedfordshire. The capacity to provide these services was highest in the northern part of Central Bedfordshire in areas away from urban centres where patches of woodland and other semi-natural habitats mainly occurred, especially on the Greensand Ridge. Across the area, there is a mismatch between demand and supply.

Overall, the natural capital assets of Bedfordshire deliver £100 million annually, with a present value of £2.1 billion over 50 years. The most valuable ecosystem service is air quality regulation, generating £42.8 million in benefits annually, with a present value of £1.6 billion over 50 years. Also particularly valuable are recreation and physical health benefits, delivering annual benefits of £40.3 and £15.5 million respectively, with a present values (over 50 years) of £1.03 billion and £573 million. Agricultural production produces an annual gross margin of £26.8 million, but once costs and subsidies are taken into account, this reduces to £1.6 million annually, with a present value of £40.8 million over 50 years. However, these benefits are cancelled out by the associated emissions, which cost £4.6 million annually and have a present value of £266 million.

Habitat opportunity mapping is a Geographic Information System (GIS) based approach used to identify potential areas for the expansion of key habitats to meet different objectives, whilst taking constraints into account. Opportunity maps were created for three different broad habitat types – semi-natural grassland, broadleaved and mixed woodland, and wet grassland and wetland – and for six different ecosystem services.

Semi-natural grasslands are evenly spread across Central Bedfordshire. However, although a number of these patches are ecologically connected into a network, many patches remain disconnected, but there is good opportunity to enhance connectivity through habitat creation. Larger areas of broadleaved and mixed woodland habitat networks are concentrated in northern Central Bedfordshire in the Greensand Ridge and ancient woodlands are particularly focused in this area. Habitat creation could further increase connectivity. Wet grassland and wetland habitat networks are much less significant in Central Bedfordshire, with only a few small and widely dispersed habitat patches across the county, most of which are ecologically isolated from each other, and opportunities are mostly focussed on expanding existing habitat patches.

Opportunities for water flow regulation are present over much of Bedfordshire, with the majority of opportunities relating to areas of arable fields on sloping land. In contrast, the vast majority of opportunities to improve water quality are located adjacent to watercourses. The best opportunities to ameliorate air pollution were located in and around urban areas and along the main road network and a similar pattern was revealed when considering opportunities to reduce noise pollution. Opportunities to regulate local climate (reduce urban heat) tended to fall on the outer fringes of urban areas, due to the large number of constraints in urban centres. Opportunities for increasing access to the natural environment were concentrated in a ring around the edges of urban areas, when based on creating new habitats, but were often slightly further from towns, but in more natural habitats, such as woodland, when considering opening up access to existing sites.

Opportunity maps were combined to highlight areas where new habitat can be created that provides opportunities to enhance more than one of the services mapped previously. Maps were created showing the total number of opportunities that could be delivered by creating new broadleaved woodland, semi-natural grassland, or wet grassland, first treating all opportunities equally, and then by restricting combined opportunities to areas that present a biodiversity opportunity. Additional maps could be created combining opportunities with different weightings if desired.

The maps and GIS layers produced for this project have a wide range of potential applications. Possible projects for enhancing the outputs and taking this work forward are described in the main Bedfordshire report and include dissemination of results, mapping habitat quality (condition), and refining the most promising areas to take forward.

The opportunity maps can be used to assist with the development of nature recovery networks, green infrastructure strategies and planning, locating the best places for biodiversity offsetting and net gain initiatives, for agri-environment scheme targeting, woodland creation for carbon offsetting, and as an important step towards producing a local natural capital plan or natural capital investment plan for the area.

Contents

1. Introduction

Central Bedfordshire Council have identified the need for an assessment of its natural capital, the benefits that this provides and the opportunities to enhance it, particularly in light of its economic and social development ambitions. Natural capital refers to the stock of assets provided by the natural environment with capacity to produce goods and services that are of value to people (NCC 2014)[1], often classified into provisioning, regulating and cultural ecosystem services (EEA, 2016[2], Hein et al., 2016[3]). Natural capital comprises land and minerals, fresh, tidal and marine waters, air, species and ecological systems, together with supporting natural processes and functions[3]. In many respects, it supports all forms of other 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 woodlands, are not included in the decisions of 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[4]). 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[5]. Furthermore, the central role of natural capital in delivering quality of place is being increasingly recognised.

Central Bedfordshire lies at the heart of the OxCam Arc, a strategic growth area with developing plans for additional housing, new road and rail links and other infrastructure. This presents both a challenge and an opportunity with regard to the natural environment. A challenge if the environment and environmental regulations are seen as a hindrance to development, but a great opportunity if development can be planned to deliver benefits to both people and the natural world, potentially unlocking large sums of money to deliver ambitious nature recovery and public access programmes. But to achieve those ambitions it is important that people are aware of the current stock of natural capital, the benefits that it provides (and the demand for those benefits), and the best opportunities to enhance those natural capital assets.

Natural capital is also becoming increasingly embedded across multiple policy domains, including the likely inclusion of a mandatory requirement for biodiversity net gain for all new developments subject to the provisions of Town and Country Planning Act, as set out in the Environment Bill. There is further ambition, as expressed in the Government's 25 Year Plan for the Environment, to move towards environmental and natural capital net gain in the future, backed by changes to the National Planning Policy Framework and the new Planning White Paper. The Environment Bill also sets out the requirement for nature recovery networks and strategies, while the Agriculture Bill paves the way for a new Environmental Land Management Scheme (ELMs), with a central tenet of farmers and land managers being paid public money for public goods, based on natural capital principles. Further policy alignment is

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[1] NCC 2014. Towards a Framework for Defining and Measuring Changes in Natural Capital. Working Paper 1, Natural Capital Committee.

[2] EEA 2016. Common International Classification of Ecosystem Services (CICES) , European Environment Agency, Copenhagen. https://cices.eu/

[3] Hein, L., Bagstad. K., Edens, B., Obst, C., de Jong, R., Lesschen, J.P. (2016). Defining Ecosystem Assets for Natural Capital Accounting. PLoS ONE,11(11): e0164460. doi:10.1371/journal. pone.0164460

[4] TEEB. 2010. The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations. Earthscan, London and Washington

[5] TEEB. 2012. The Economics of Ecosystems and Biodiversity in Business and Enterprise. Earthscan. London; New York.

achieved through the requirements for action on climate change and commitments to go carbon neutral, including the planting of large areas of new woodland.

Central Bedfordshire Council, therefore, commissioned this project to produce a natural capital assessment for the area. It is part of a larger project to complete a natural capital assessment for the whole of Bedfordshire, and separate reports have also been produced for Bedford Borough and Luton Borough. The project had the following five aims:

1. Create a detailed natural capital (habitat) basemap based on the best available existing data.
2. Model and map the benefits (the ecosystem services) that flow from the natural capital present across the county and the demand for those benefits, where possible.
3. Calculate the monetary value of those benefits wherever possible.
4. Identify the current provision of accessible natural greenspace within the Bedfordshire region and how this compares against national standards.
5. Create habitat opportunity maps for biodiversity enhancement and for a range of ecosystem services, showing where new habitats could be best created, whilst taking constraints into account.

1.1 The natural capital and ecosystem services framework

The natural environment underpins people's wellbeing and economic prosperity, providing multiple benefits to society, yet is consistently undervalued in decision-making. 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). 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 (Fig. 1).

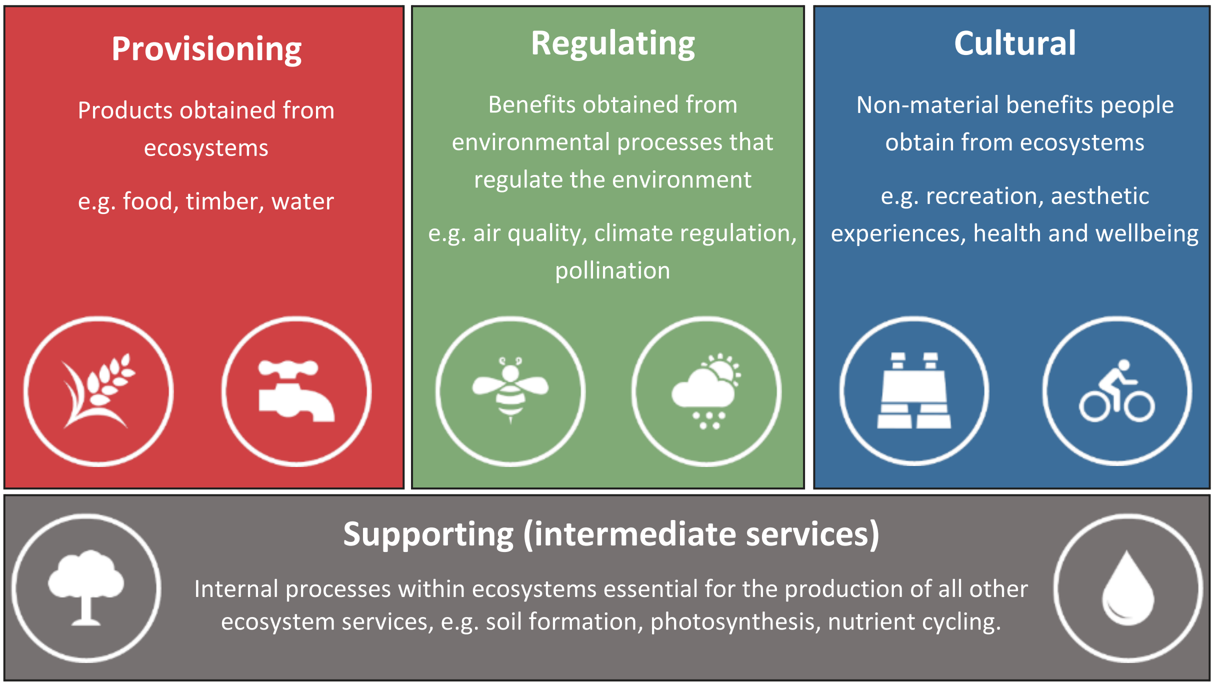

Figure 1 Key types of ecosystem services (based on MA 2005 and EEA 2016).

Much work is progressing on how to deliver the natural capital and ecosystem services approach on the ground and how to use it to inform and influence management and decision-making. One of the most important steps is to recognise and quantify ecosystem service delivery (the physical flow of services derived from natural capital). Additional insight can be gained by taking a spatial perspective on the variation in ecosystem service supply and demand across a study area using a Geographic Information System (GIS). Maps are able to highlight hotspots and coldspots of ecosystem service delivery, highlight important spatial patterns that provide much additional detail, and are inherently more user friendly than non-spatial approaches. When information on supply and demand for ecosystem services is known, it is also then possible to determine objectively the best areas to create habitat to increase the supply of each particular ecosystem services in a process known as habitat opportunity mapping. By overlaying opportunity areas for each objective, it is possible to identify areas where changing habitats could deliver multiple benefits.

1.2 Report structure and scope

All methods used herein are described within the Bedfordshire main report. A key first step in any natural capital project is to understand the natural capital assets present across the study area. To this aim, Section 2 outlines the habitats present across Central Bedfordshire. It also highlights the most important habitats for biodiversity, and maps the sites that have received international, national or local designation for their nature conservation interest. We also include a range of additional maps to give a more complete picture of the state of natural capital across Bedfordshire, covering air, water, and agricultural quality, and public access.

Section 3 then uses this natural capital basemap to model and map the ecosystem services delivered by that natural capital. We assess ten different ecosystem services and whenever possible we also map the demand for these services across the area. Section 4 estimates the annual monetary flows from seven ecosystem services and Section 5 assesses accessible natural greenspace in relation to national standards.

Section 6 then considers opportunities for enhancing biodiversity and ecosystem services across Central Bedfordshire. We consider three different broad habitats – broadleaved and mixed woodland, semi-natural grassland, and wet grassland and wetland – and six different ecosystem services. The individual opportunity maps are then overlain in Section 7, to identify opportunity areas where multiple benefits could be delivered, creating maps that focus on biodiversity, and which focus on all benefits equally. Conclusions and further steps are briefly presented in Section 8.

Please note that the habitat basemap is based on existing data, and although it has been checked by local experts, it has not been extensively ground-truthed, so will be prone to some error. It does, however, provide the most comprehensive and detailed coverage that is possible at this time. Note also that the opportunity mapping identifies areas based on landscape-scale ecological principles and ecosystem services models and does not take into account local site-based factors that may impact on suitability. Any areas suggested for habitat creation will require ground-truthing before implementation. The maps should be seen as a tool to highlight key locations and to guide decision making, rather than an end in themselves.

One of the key outputs from this project are the numerous GIS maps and layers. These have been supplied to Central Bedfordshire Council and key project partners. The main Bedfordshire report provides maps and comparative data across the three local authority areas, and separate reports are available for Bedford Borough and Luton Borough, focussing on the results from those areas.

2. The baseline – natural capital assets

2.1 Broad habitats

The approach used to map habitats is described in the main Bedfordshire report, along with comparative data for the three local authority areas. The final basemap covered an area of 71,567 ha or 716 km^2 and contained 525,914 polygons, each of which was classified to an appropriate habitat type.

Figure 2 (overleaf) shows the distribution of broad habitat types across Central Bedfordshire and the area and percentage cover is shown in a little more detail in Table 1. Central Bedfordshire is dominated by cultivated (arable) land, making up 55% of the area (39,441 ha). The combined cover of all woodland, scrub and tree habitat types make up 10.5% of the area (7,565 ha). Semi-natural and marshy grasslands make up 2.8%, while water makes up just 1.2%. Built-up areas, and infrastructure (roads, railways, pavements and paths) make up 6.9% of the land area, with gardens comprising 4.8%.

Table 1 Area and percentage cover of broad habitat types across Central Bedfordshire

Broad habitat	Area (Ha)	% cover
Cultivated / disturbed land (arable)	39,441	54.62
Uncertain agriculture	1,027	1.42
Improved grassland	10,643	14.74
Semi-natural grassland	1,866	2.58
Marshy grassland	131	0.18
Heathland	11	0.02
Fen, marsh and swamp	27	0.04
Broadleaved woodland	4,499	6.23
Coniferous woodland	1,124	1.56
Mixed woodland	304	0.42
Scrub	221	0.31
Trees / Parkland	1,416	1.96
Hedgerows	907	1.26
Water	870	1.21
Rock, exposure and waste	477	0.66
Built-up areas and infrastructure	5,004	6.93
Garden	3,477	4.82
Mixed / other / uncertain	420	0.58
Unclassified (land currently under development)	338	0.47
TOTAL	**72,205**	**100**

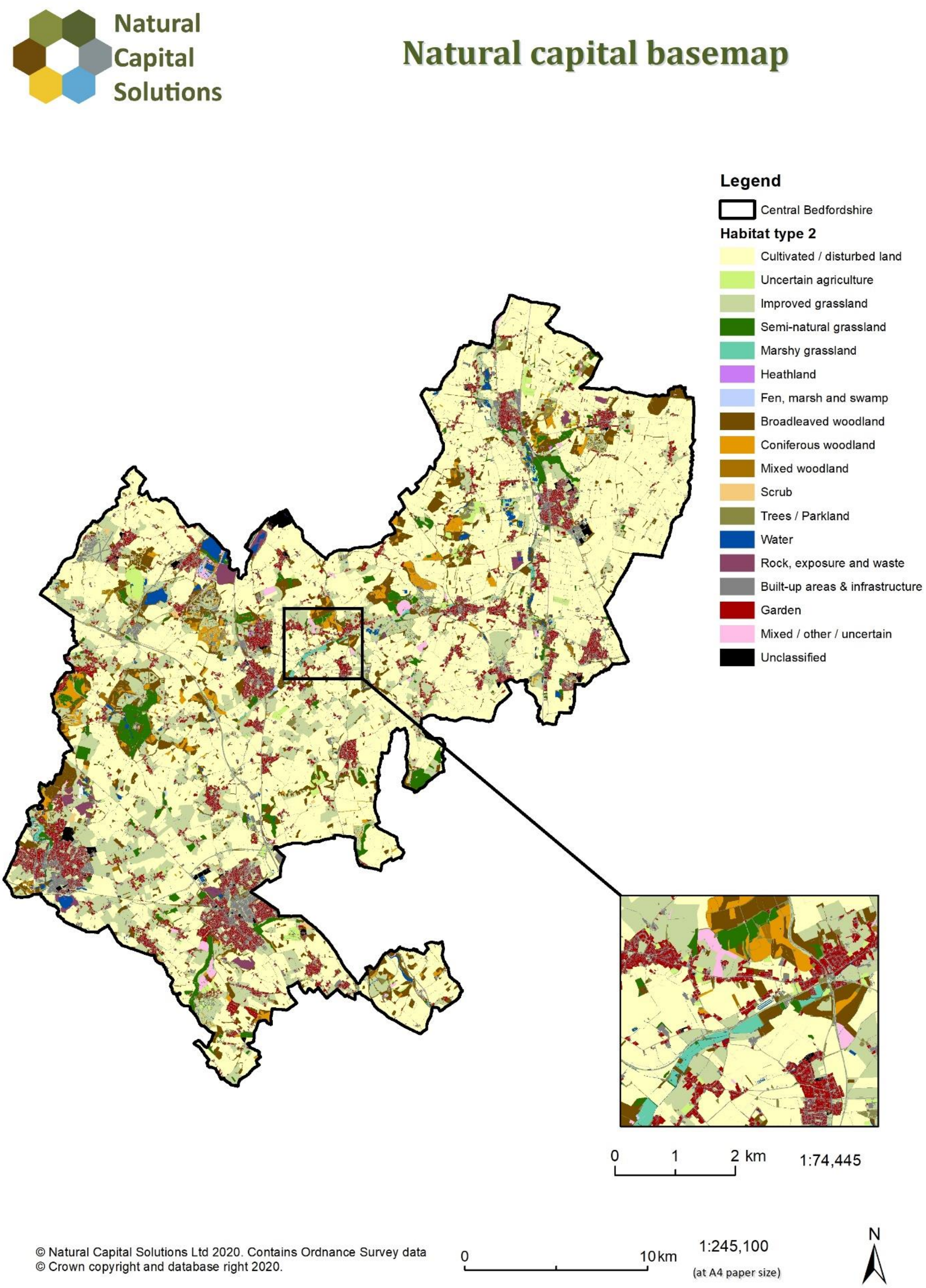

Figure 2 Broad habitats across Central Bedfordshire. Note that Unclassified sites are those that are currently under development.

2.2 High quality habitats

The highest quality semi-natural habitats can be identified from the basemap and are shown in Figure 3, although note that this is based on habitat type and not on condition, which was not assessed here. In total 5,557 ha, which represents 7.8% of Central Bedfordshire, contain these high-quality habitats. The greatest amounts are 4,497 ha of broadleaved woodland, 304 ha of mixed woodland and 256 ha of neutral grassland. However, this includes all broadleaved and mixed woodland, some of which will not have been high quality. There are also 213 ha of calcareous grassland, 98 ha of acid grassland, and 131 ha of floodplain grazing marsh and marshy grassland. Note that it was not possible to distinguish high quality parkland from any areas containing scattered trees, or higher quality rivers, streams and standing water, hence these habitat types have not been included on this map. Mixed habitats were also not included as although some of these areas are likely to be high quality habitat, not all such areas will be.

2.3 Nature conservation designations

The location of designated sites is shown on Figure 4. In total 346 ha are designated as LNRs within Bedfordshire (0.28% of the total land area). The total amount of land designated as NNRs within Bedfordshire is 173 ha (0.14% of the total area) with an additional 1,374 ha (1.11%) designated as SSSI and 6,365 ha (5.15%) designated as AONB. There was significant overlap across each of the designations, with the total amount of land receiving some level of protection amounts to 7,490 ha, or 6.06% of the total area of Bedfordshire.

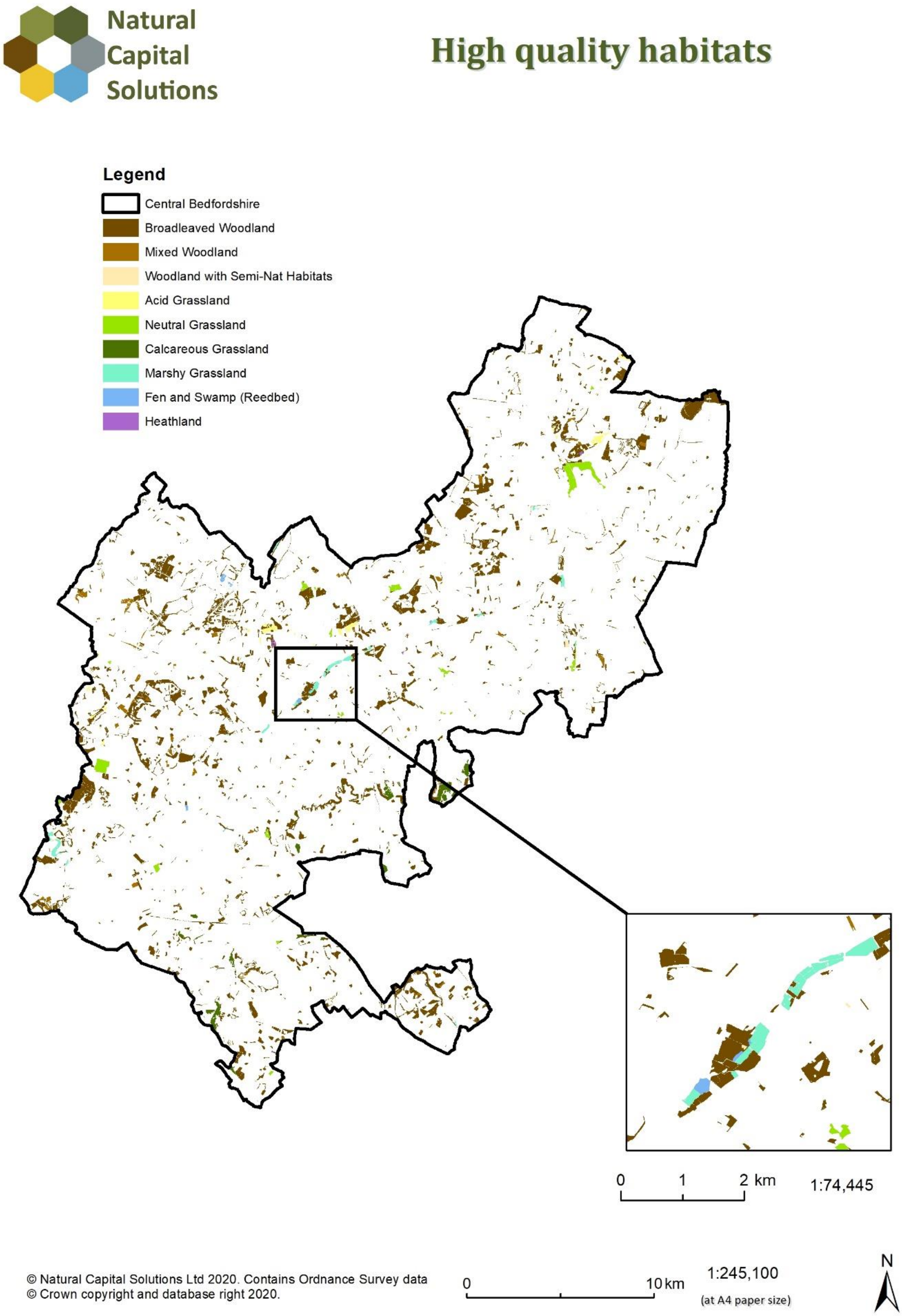

Figure 3 High quality habitat types, identified from the basemap.

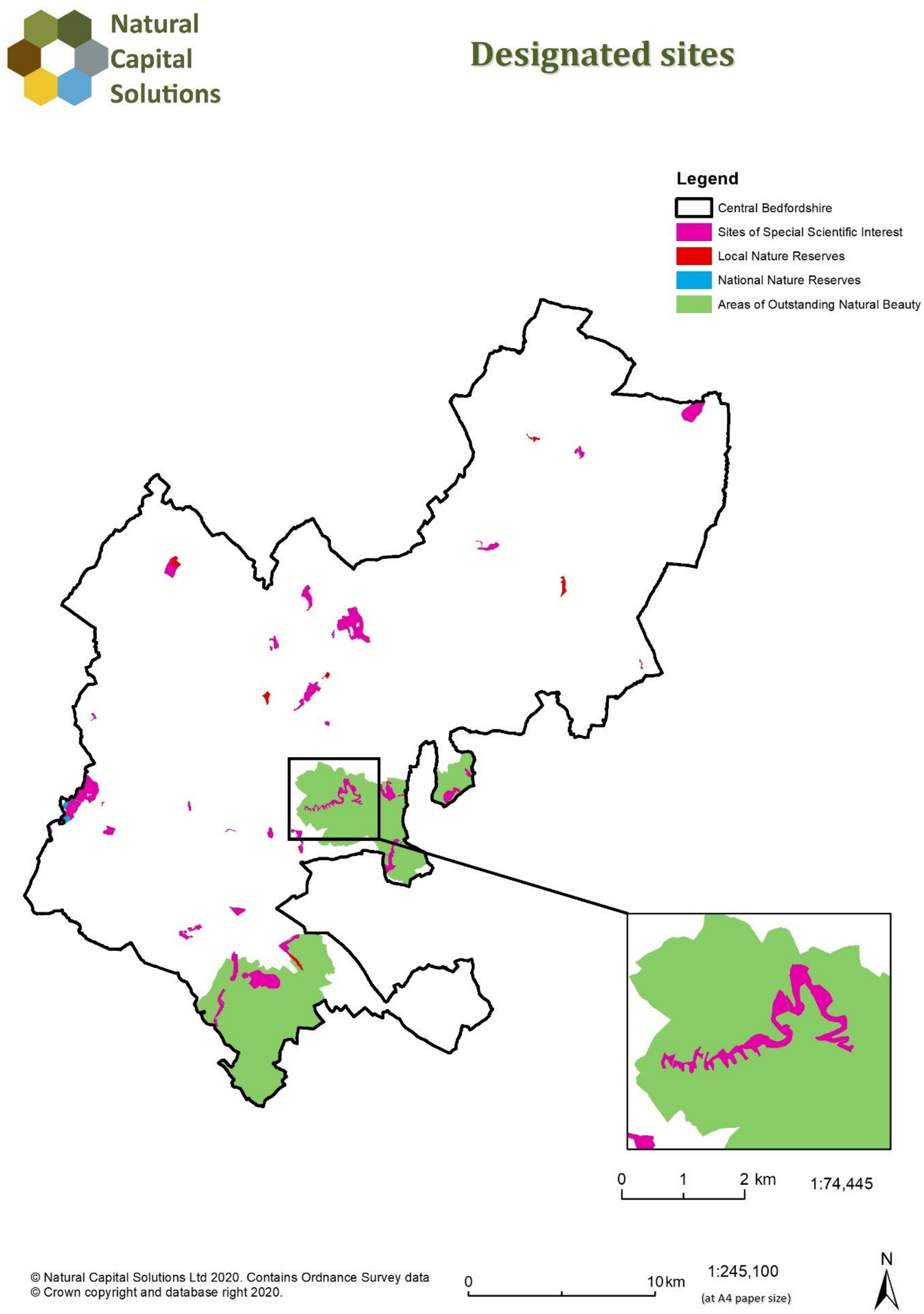

Figure 4 International, national and locally designated sites for nature conservation. Note that all SACs are also designated as SSSIs.

2.4 Environmental quality and natural capital assets

Mapping the type, extent and location of habitats is a key component of a natural capital asset register. However, to build a more complete picture, we have also created maps that provide indicators of environmental quality across air, land and water, canopy cover and information on public access:

- **Modelled background air pollution data** was obtained from Defra, and was used to create a map showing $PM_{2.5}$ (particulate matter at 2.5 µm, Figure 5a) and another showing NO_x (nitrogen oxides, Figure 5b). Both maps are fairly similar, with the M1 showing up as the most significant pollution hotspot, along with the A1, A421, Ampthill and Flitwick to a lesser extent.
- **Overall water body class of WFD River Waterbody Catchments** combines ecological status with chemical status to form an overall assessment of the quality of the waterbody. There are five classes (high, good, moderate, poor, or bad). This is mapped in Figure 5c and shows that river water body condition varies widely from good to bad, with no clear pattern to this variation.
- **Agricultural Land Classification** assesses the potential for land to support different agricultural uses, based on a combination of climate, site and soil characteristics. The map for the study area is shown in Figure 5d and shows that the majority of the western side of the area is classified as Grade 3 agricultural land, but the eastern half of the county is much more variable, containing areas from Grade 1 (the best) to 4.
- **Canopy cover** was mapped for each Ward across the study area based on data from the UK Ward Canopy Cover Map, coordinated by Forest Research. The map (Figure 6a) highlights that canopy cover is highest in Wards along the Greensand Ridge, with at least 15% cover across this area and reaching 23.8% in Aspley and Woburn Ward. Canopy cover is considerably lower outside of this area, generally from 5-15%.
- **Public Rights of Way** were mapped based on a layer supplied by CBC and is shown in Figure 6b. This is a key information source for determining access to the countryside and accessible nature and shows generally high PRoW density, but with some parts of the LA area to the centre-east with considerably lower density.

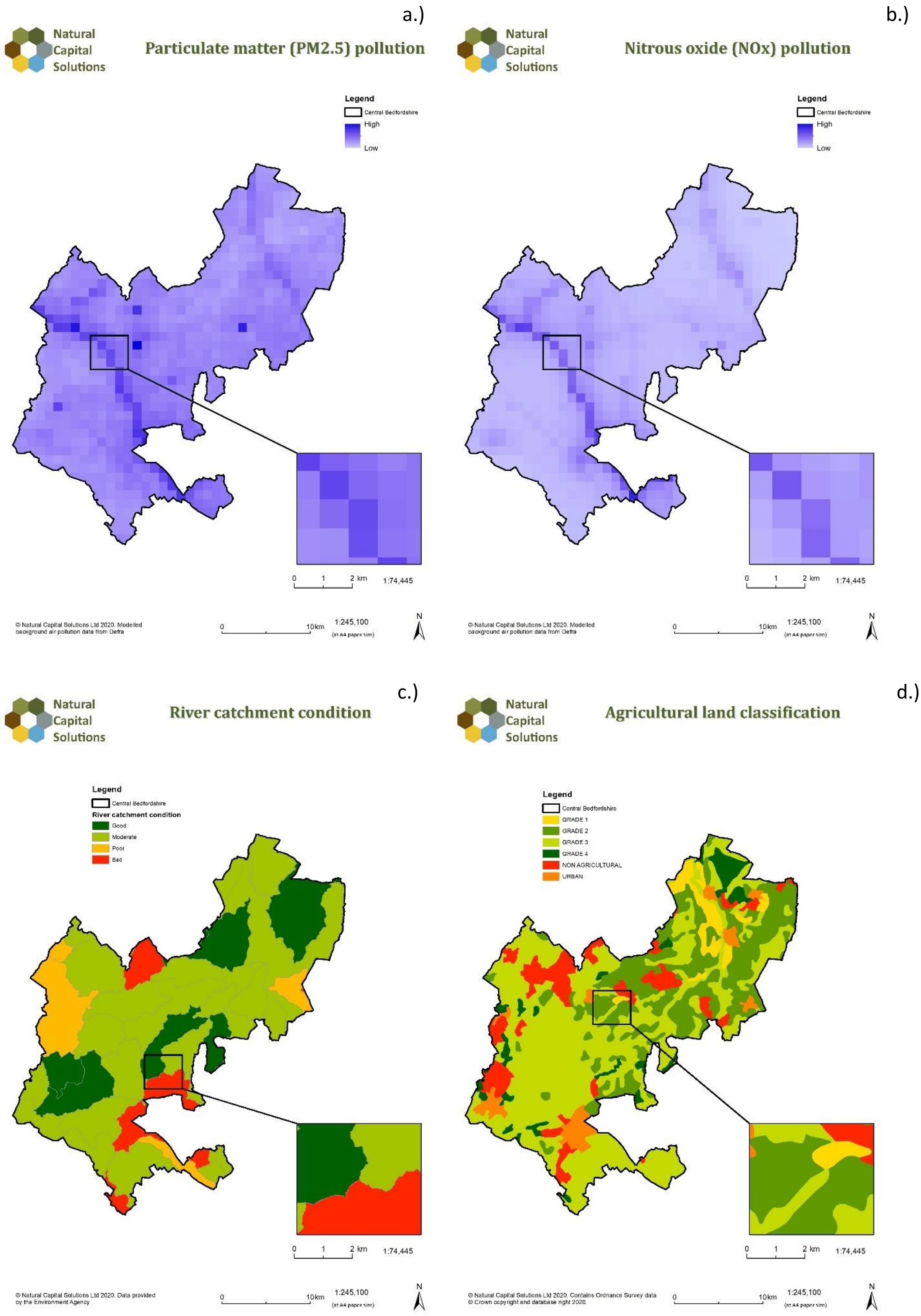

Figure 5 Environmental quality and natural capital asset maps showing a.) air quality with respect to $PM_{2.5}$, b.) air quality NO_x, c.) overall water body class, and d.) agricultural land classification.

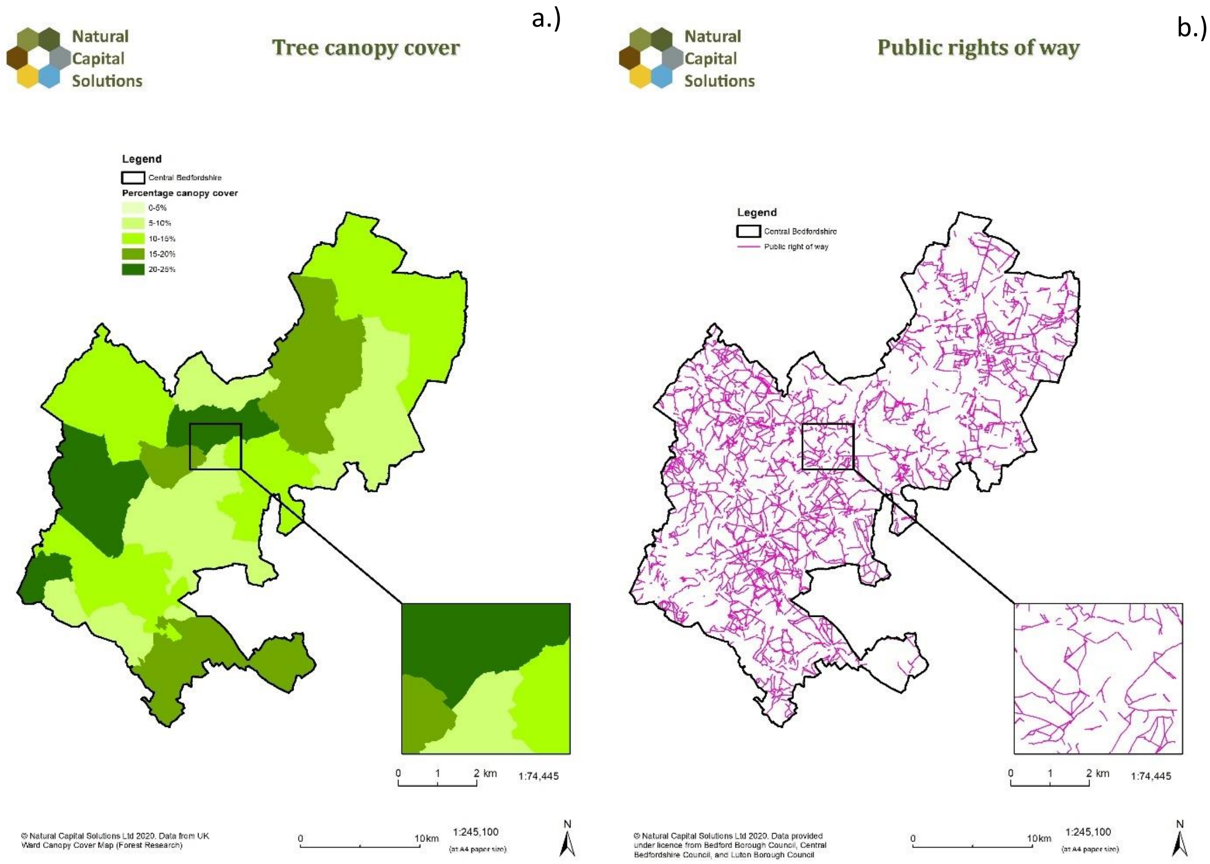

Figure 6: Environmental quality and natural capital asset maps showing a.) canopy cover for each Ward, and b.) Public Rights of Way.

3. Modelling and mapping ecosystem services (physical flows)

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

- Carbon storage
- Carbon sequestration
- Air purification
- Noise regulation
- Local climate regulation
- Water flow regulation
- Water quality regulation
- Agricultural production
- Timber production
- Accessible nature

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

For every ecosystem service listed, the capacity of the natural environment to deliver that service – or the current supply – was mapped. For air purification, noise regulation, local climate regulation, and accessible nature, it was also possible to map the local demand (the beneficiaries) for these services. The importance and value of ecosystem services can often be dependent upon its location in relation to the demand for that service, hence capturing this information provides useful additional insight. Mapping demand was not, however, possible, for the other services where there was no obvious method to apply, or local demand is not relevant, such as food or timber production (demand for food and timber production is national and does not vary by location in a meaningful way).

3.1 Carbon storage capacity

Figure 7 (overleaf) shows baseline carbon storage capacity across the study area. The score is out of a maximum possible of 100 (given to broadleaved woodland).

Carbon storage capacity in the region is clustered in areas of habitats such as broadleaved woodland and other woodland types, which are particularly efficient at carbon storage. However, most green spaces in the region support some level of carbon storage, with much lower levels in urban areas dominated by buildings and sealed surfaces. Woodland in the Greensand Ridge appears as a strip of red patches across the northern half of the map.

3.2 Carbon sequestration

The baseline carbon sequestration map displayed in Figure 8 shows high areas of carbon sequestration (in red). These are areas of mostly broadleaved woodland. Coniferous woodland plantations show up as orange, and are also reasonably good at sequestering carbon. Coniferous woodland often sequesters carbon at a faster rate than broadleaved woodland, but it is usually managed for timber, which involves regular thinning, hence reducing the accumulation of carbon.

3.3 Air purification capacity (air quality regulation)

Woodland is by far the best habitat at intercepting and absorbing air pollution, with the very highest scores from coniferous forests. The lowest scores (dark blue) are from man-made sealed surfaces and water features which effectively have zero capacity to ameliorate air pollution.

Of particular note are the woodland areas, apparent as dark red patches of high air purification capacity in Figure 9. These occur most frequently along the Greensand Ridge. Urban areas display much lower levels of air purification capacity in general (the dark blue patches).

3.4 Air purification demand

Air purification demand is highest in urban centres as these have both higher air pollution levels and higher populations that would benefit from better air quality. The main road network is also clearly visible as a major pollution source, and where these main roads pass through built up areas, there is increased demand for air purification, for example along the A5 as it passes through Dunstable. On Figure 10, the areas of highest demand are clustered around the small towns in the region, such as Dunstable, Leighton Buzzard, Flitwick, Biggleswade and Sandy. Outside of these clusters, demand is relatively low across the study region.

3.5 Noise regulation capacity

This model is similar to the air purification capacity model and similarly to that, woodland is by far the most effective habitat at absorbing noise. However, the effects are modest, with reductions of 2-4 dB typically recorded across dense tree belts. Figure 11 shows a broadly similar spatial pattern to Figure 9, air purification capacity. Noise regulation capacity is relatively low in urban areas, and highest in woodland areas, concentrated in the central and northern parts of the county. Outside of this area, noise regulation capacity is variable and occurs mainly in clusters around green spaces across the region.

3.6 Noise regulation demand

Figure 12 shows noise regulation demand across Central Bedfordshire. Demand is greatest in urban areas close to major roads, as these contain large populations, with potentially poor health scores, that would benefit from noise abatement from the main roads. The greatest demand occurs in Dunstable, Leighton Buzzard, Flitwick, Biggleswade, Brogborough and Sandy. The M1 generates a wide swathe of demand, bisecting the western half of the area.

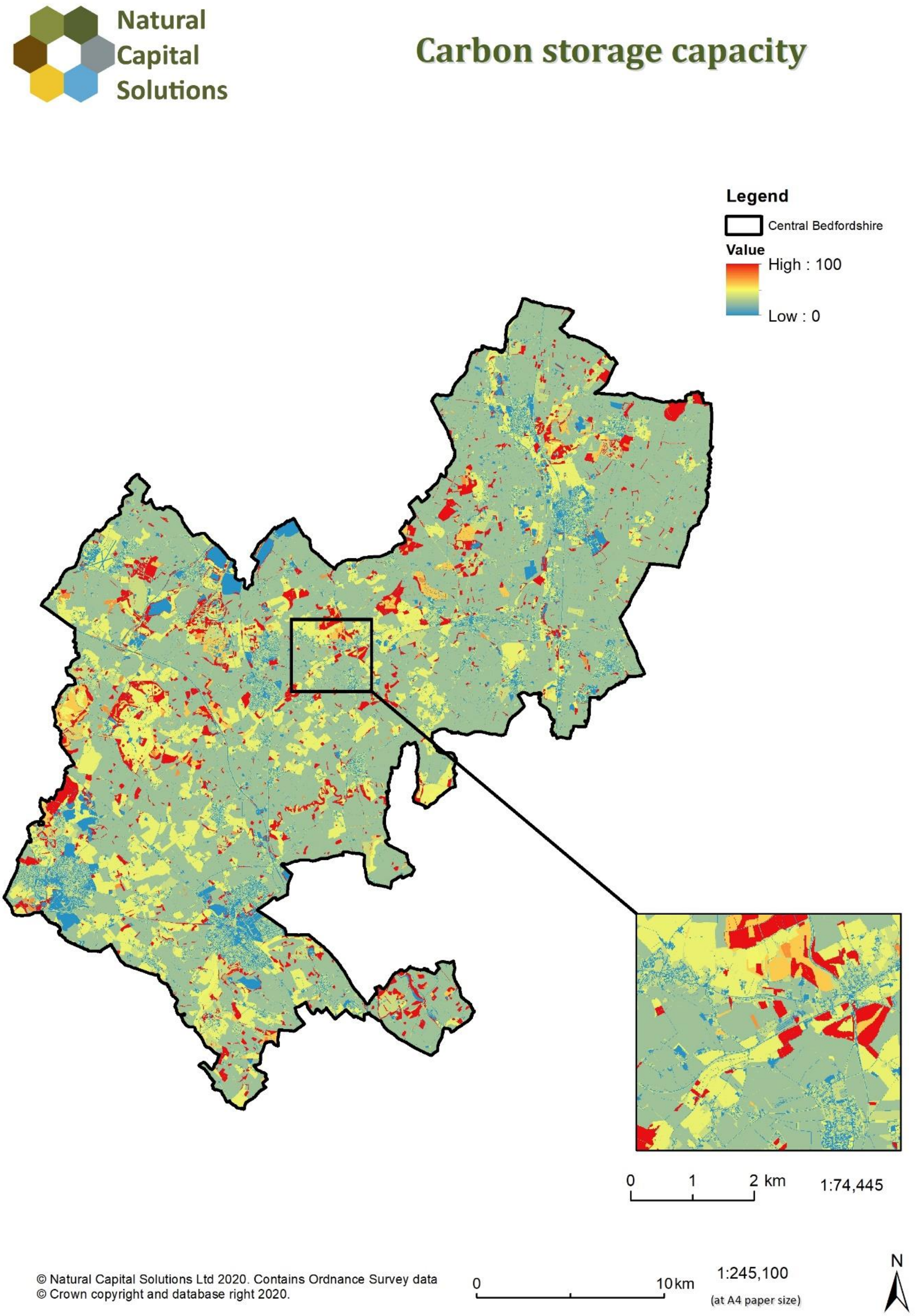

Figure 7 Carbon storage capacity across Central Bedfordshire. Inset map shows level of detail in the map for a representative location.

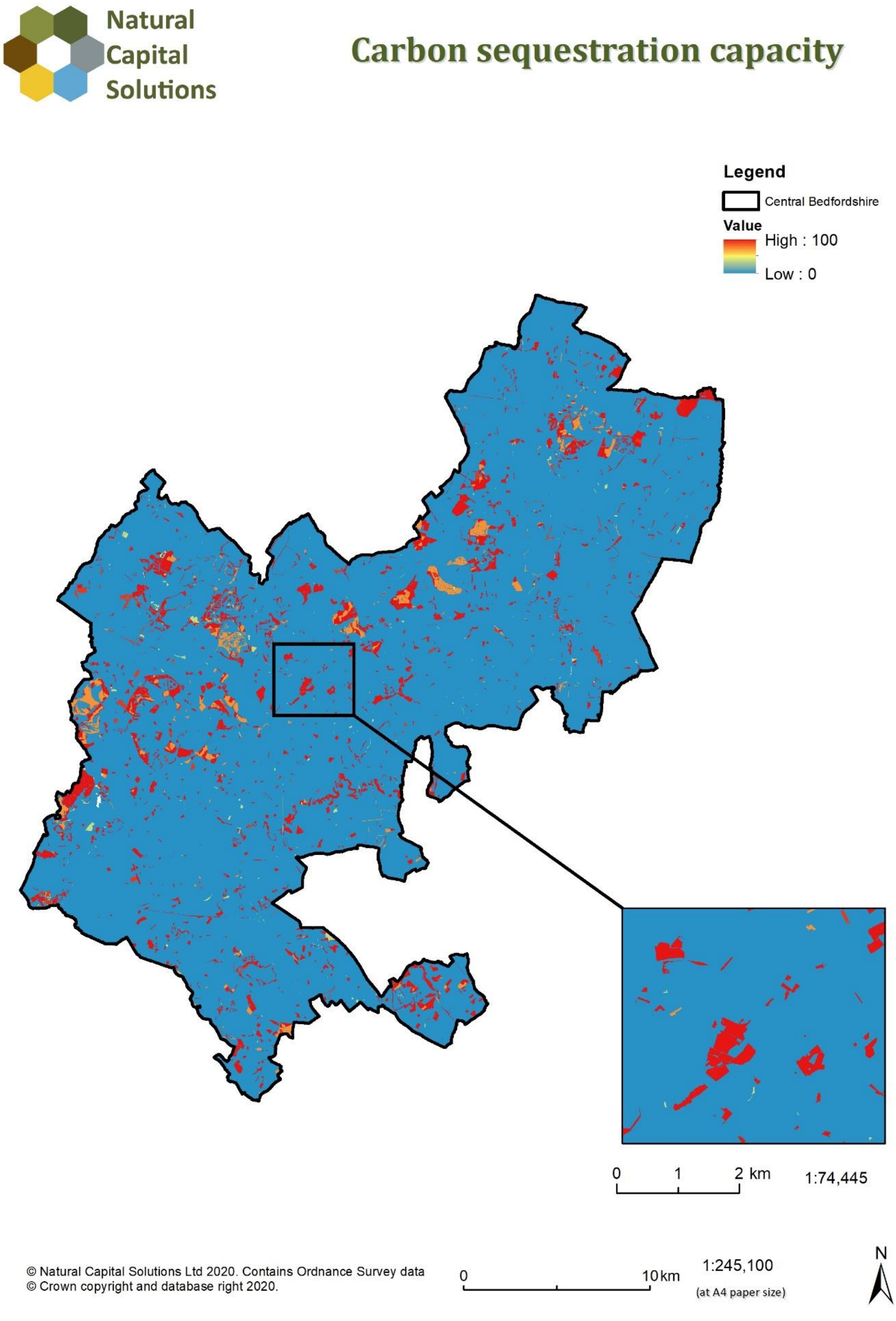

Figure 8 Carbon sequestration capacity across Central Bedfordshire.

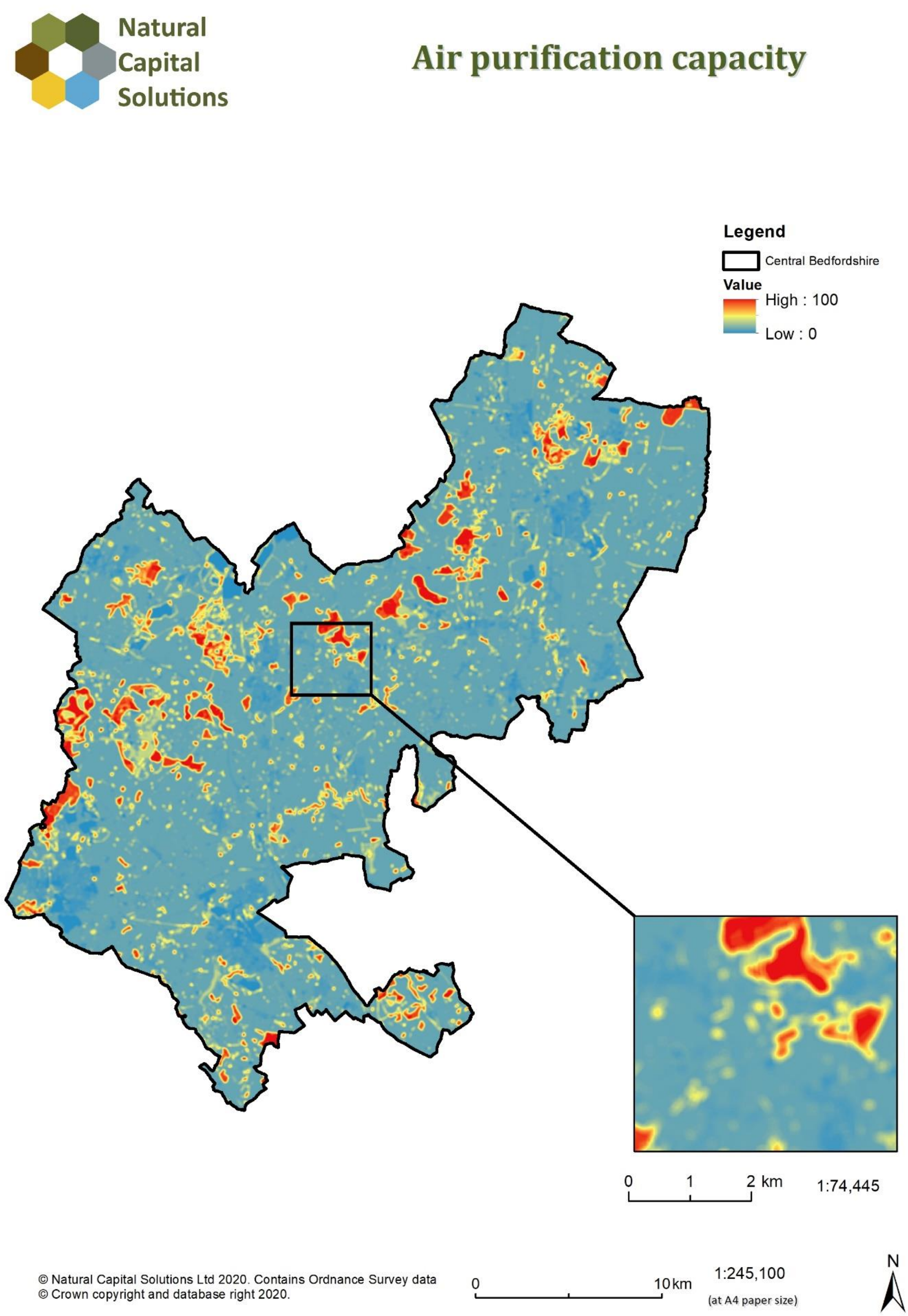

Figure 9 Air purification capacity across Central Bedfordshire.

Figure 10 Air purification demand across Central Bedfordshire

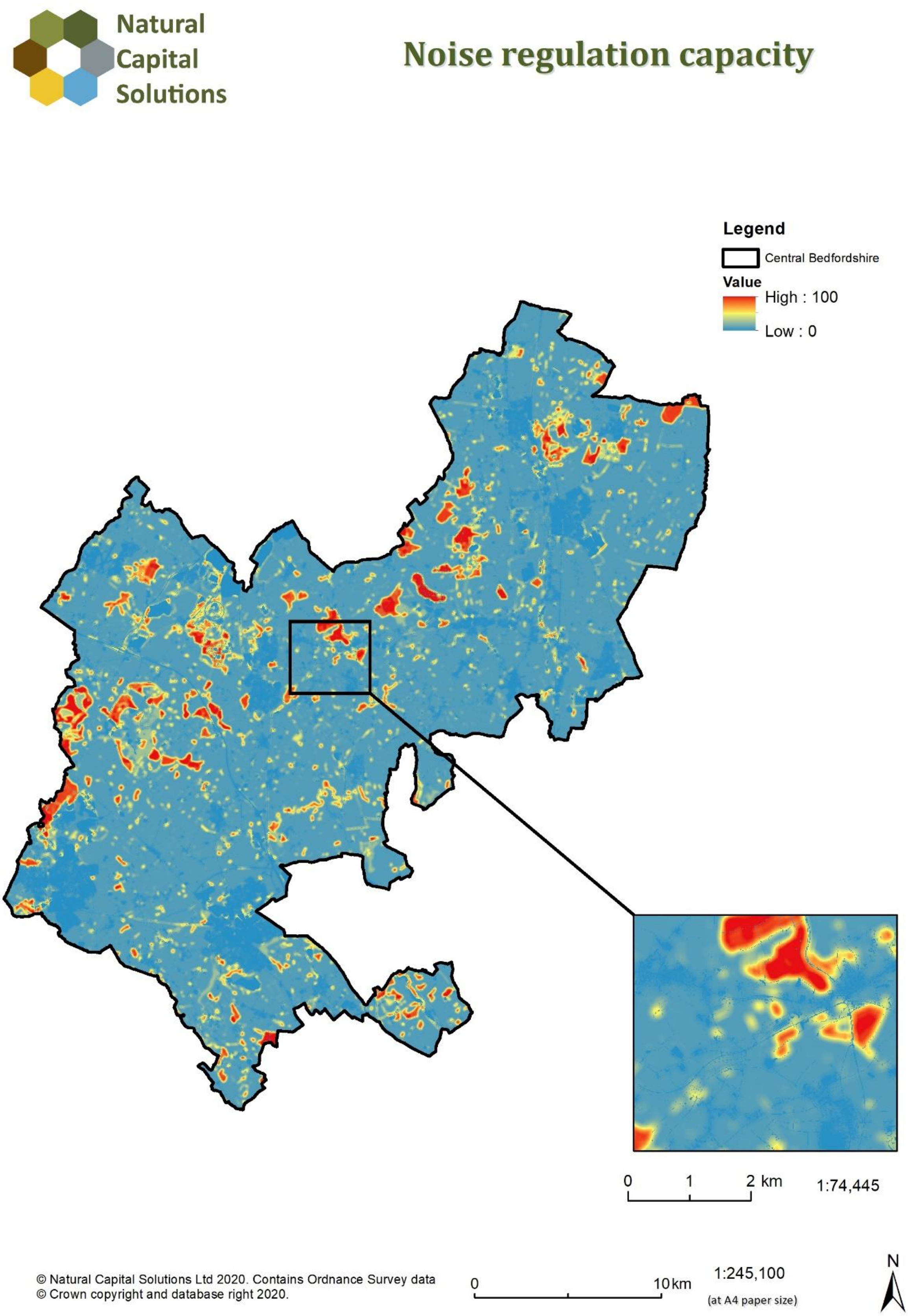

Figure 11 Noise regulation capacity across Central Bedfordshire.

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Noise regulation demand

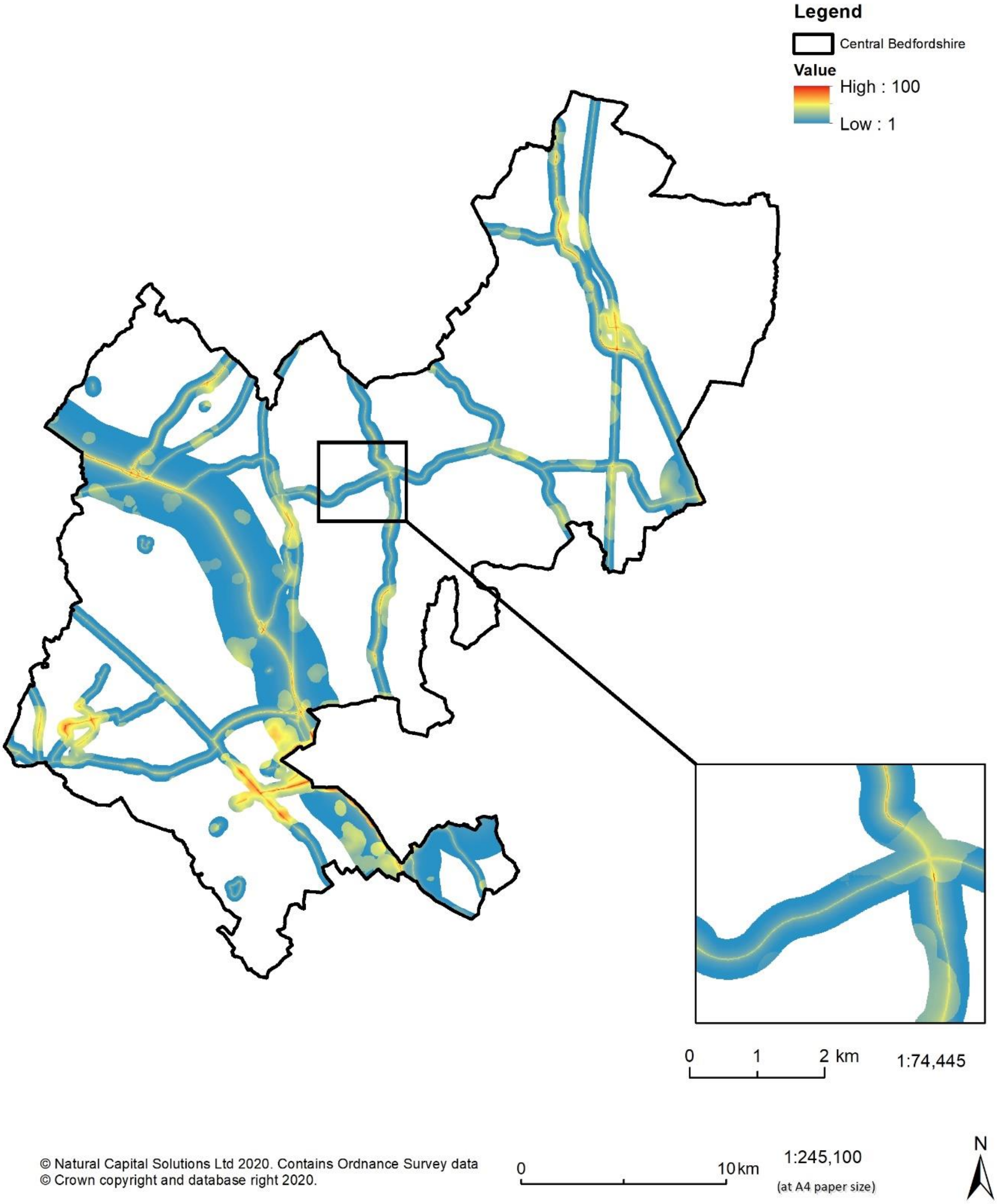

Figure 12 Noise regulation demand across Central Bedfordshire. Areas with zero demand have been excluded to improve map legibility.

3.7 Local climate regulation capacity

Figure 13 shows local climate regulation capacity across Central Bedfordshire. In the absence of large bodies of water, larger areas of woodland provide the highest local climate regulation capacity in the region. For this reason, Figure 13 shows a similar capacity pattern to Figures 9 and 11. In much of the remaining region, away from woodland and water bodies, capacity is significantly lower.

3.8 Local climate regulation demand

Figure 14 shows local climate regulation demand across the Central Bedfordshire. By removing areas of zero demand, it is immediately clear that demand is heavily clustered around minor towns such as Dunstable, Leighton Buzzard, Flitwick, Biggleswade and Sandy. Demand for local climate regulation is effectively zero outside of these centres, and so interventions looking to reduce the disparity between capacity and demand in this service would benefit heavily from investing in capacity in urban areas to meet this concentrated demand.

3.9 Water flow capacity

The worst locations for slowing water runoff (blue on the map, Figure 15) are areas of impermeable surface and slopes. Though not particularly visible at a regional scale, impermeable sealed surfaces are prominent in urban areas, where water flow regulation capacity is quite poor.

In comparison, the best areas for water flow regulation capacity are woodland patches with gentle slopes (red on the map, Figure 15). This is because woodland and gentle slopes both help to slow the surface water flow.

Note that it would be possible to incorporate information on soil type and permeability into the model, which is another important aspect of runoff, so would improve the model further.

3.10 Water quality capacity (soil erosion reduction)

Figure 16 shows water quality capacity across Central Bedfordshire. Capacity is generally lower within arable fields, especially those on slopes and close to watercourses. Conversely, capacity is generally higher in areas away from watercourses with woodland land covers. Note that this model focuses on soil erosion and hence rural diffuse pollution, and not on urban diffuse pollution, which is why the built-up areas score highly.

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Local climate capacity

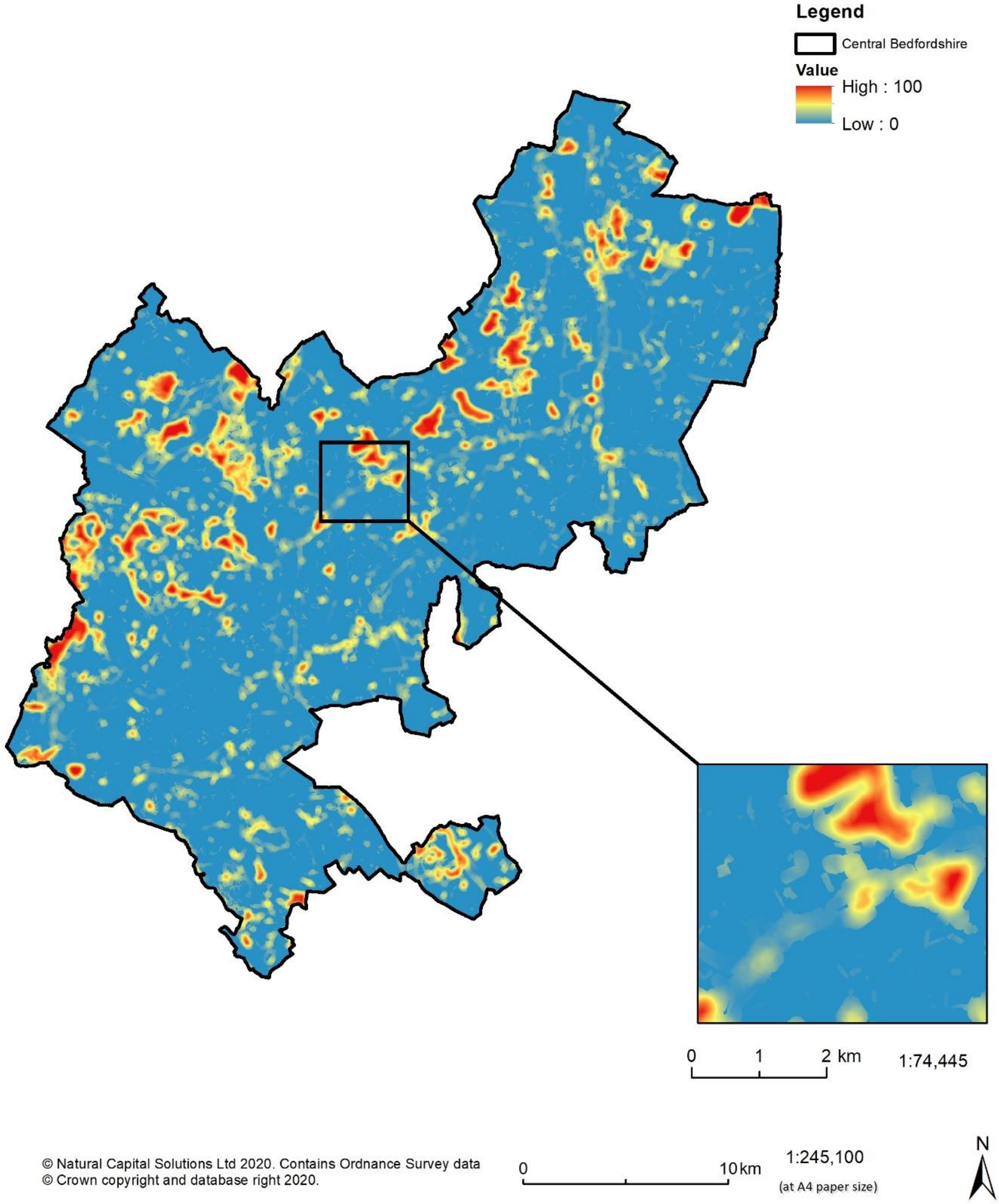

Figure 13 Local climate regulation capacity across Central Bedfordshire.

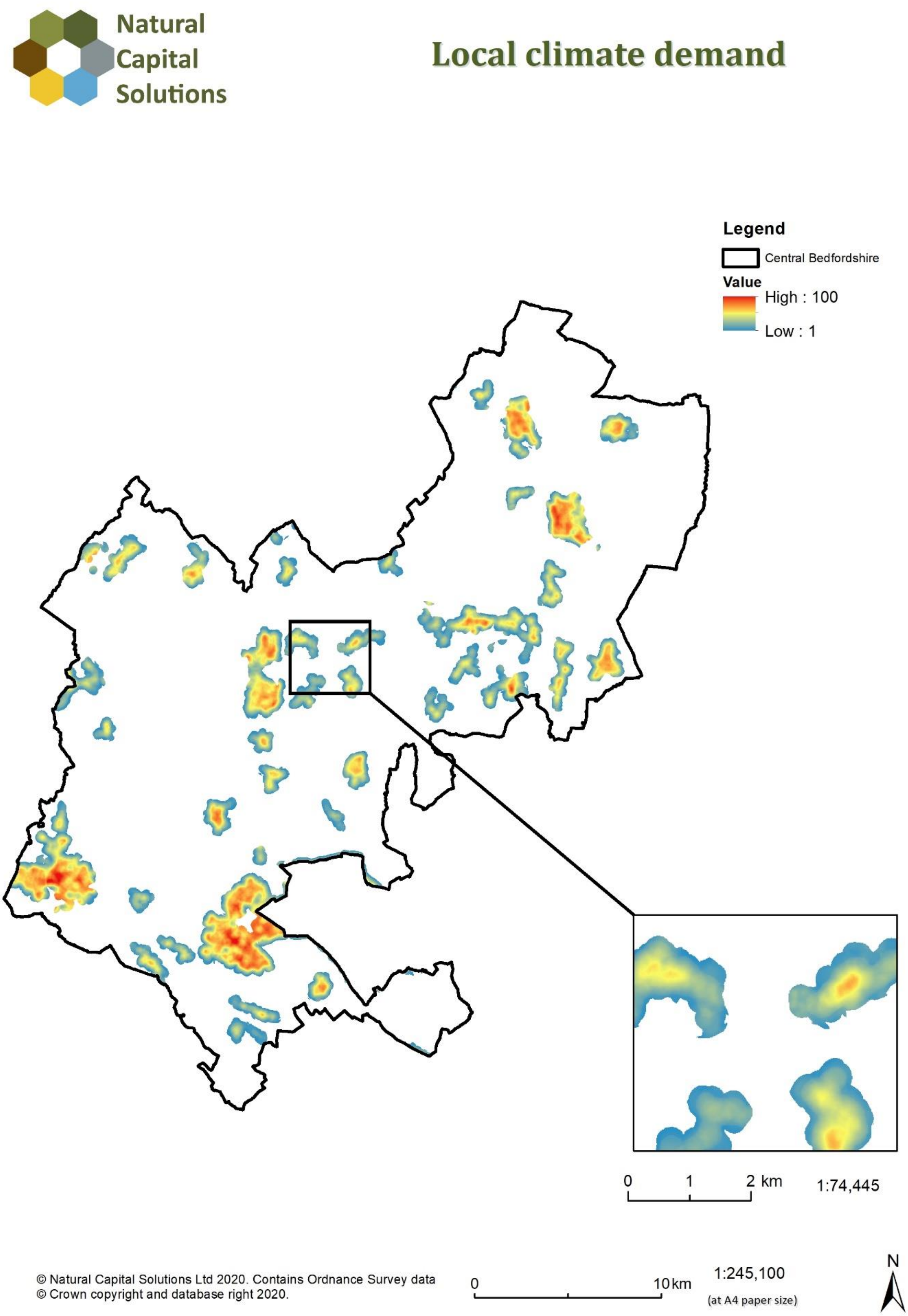

Figure 14 Local climate regulation demand across Central Bedfordshire. Areas with zero demand have been excluded to improve map legibility.

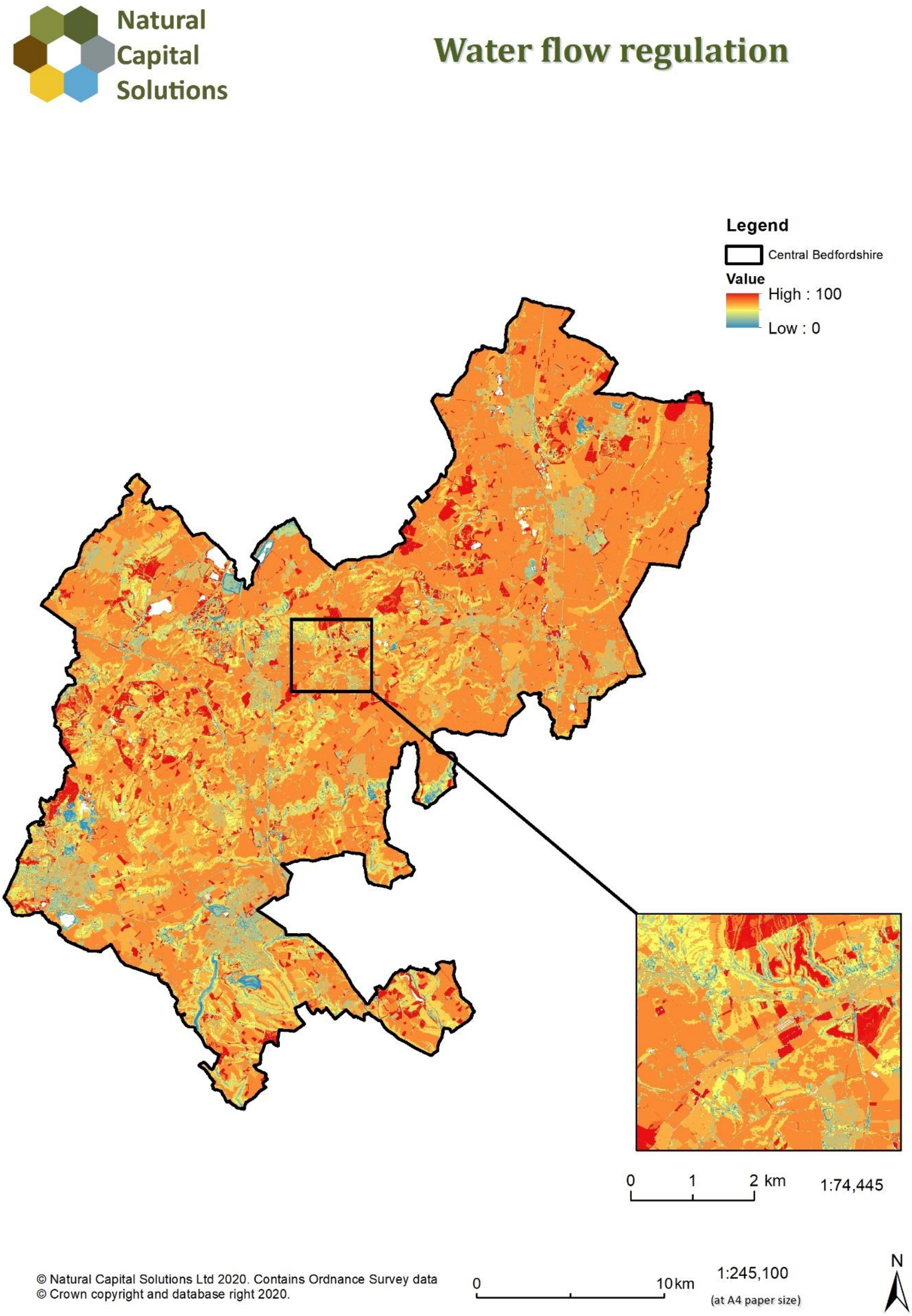

Figure 15 Water flow regulation capacity across Central Bedfordshire.

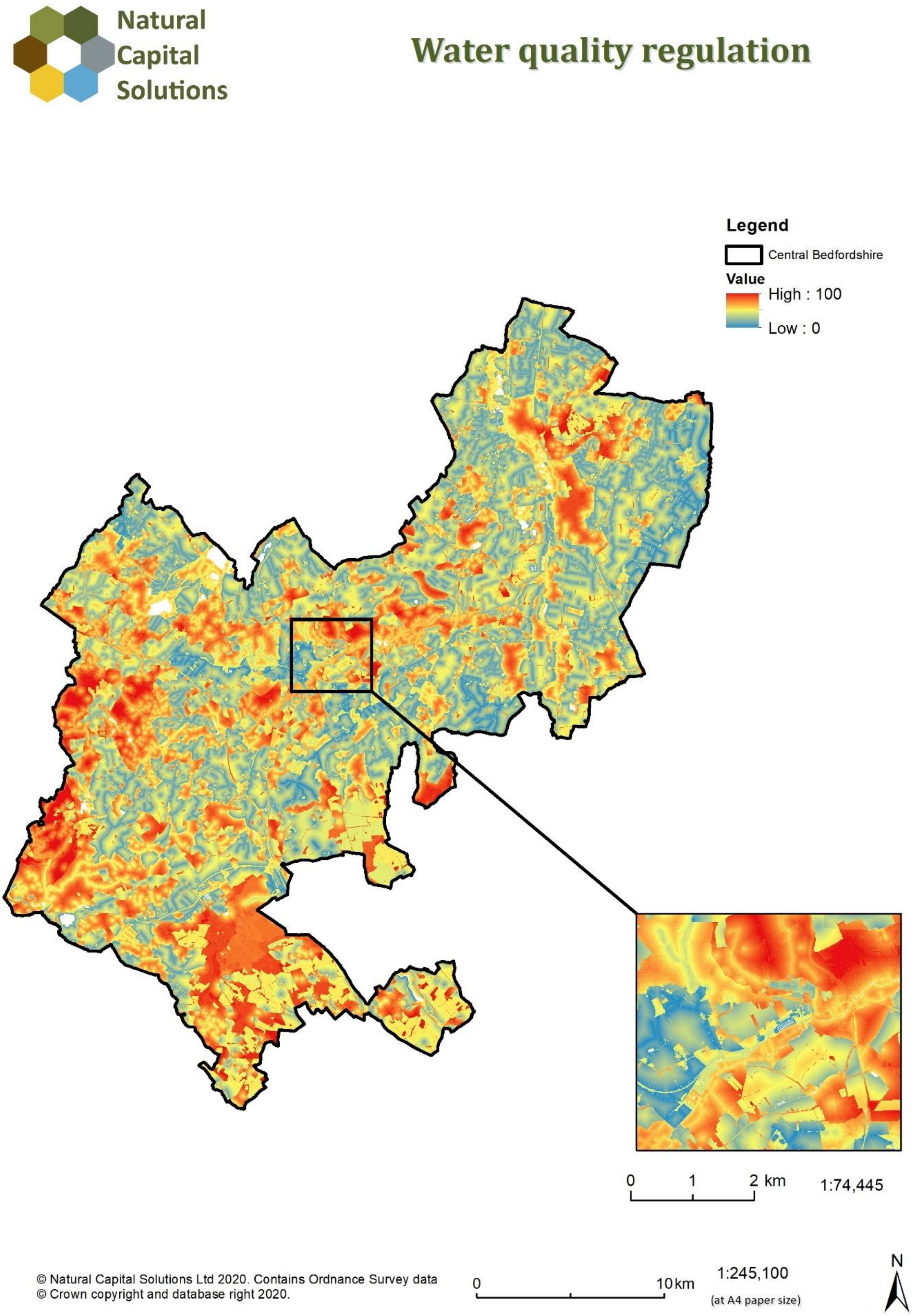

Figure 16 Water quality regulation capacity across Central Bedfordshire.

3.11 Food production capacity

While the majority of Central Bedfordshire has a medium to low food production capacity (yellow/light blue in Figure 17), there are significant areas of high food production capacity (red to orange in Figure 17). The low to medium food production areas have an Agricultural Land Classification of Grade 3 and Grade 4. The high food production areas are areas of Grade 2 and 1 land, which is predominantly down to arable and horticulture and likely to be highly productive. Urban areas have a very low production capacity reflecting the limited production resulting from gardens (clearly this can be high in some cases, but it is beyond the scope of this project to consider this).

3.12 Timber / woodfuel capacity

Larger patches of high timber and woodfuel production capacity are predominantly scattered throughout the north of Central Bedfordshire (Figure 18), along the Greensand Ridge. Coniferous woodland gives the highest capacity and is shown in red whereas broadleaved woodland produces medium levels of timber / woodfuel and is shown in yellow / green. Broadleaved woodland is the dominant woodland cover type in Central Bedfordshire, although small pockets of coniferous woodland are scattered throughout the area.

3.13 Accessible nature capacity

Figure 19 shows accessible nature capacity for publicly accessible land only. Accessible nature capacity is highest in Aspley Heath, Potton Wood, Maulden Wood and Stewartby Lake / Millennium Country Park. Access is lowest in more rural areas across the unitary authority, where public footpaths provide the only access in predominantly agricultural areas.

3.14 Accessible nature demand

Demand for accessible nature (see Figure 20) is focussed around where people live, hence there is significant demand from the numerous small towns across the county, such as Dunstable, Leighton Buzzard, Flitwick, Biggleswade and Sandy.

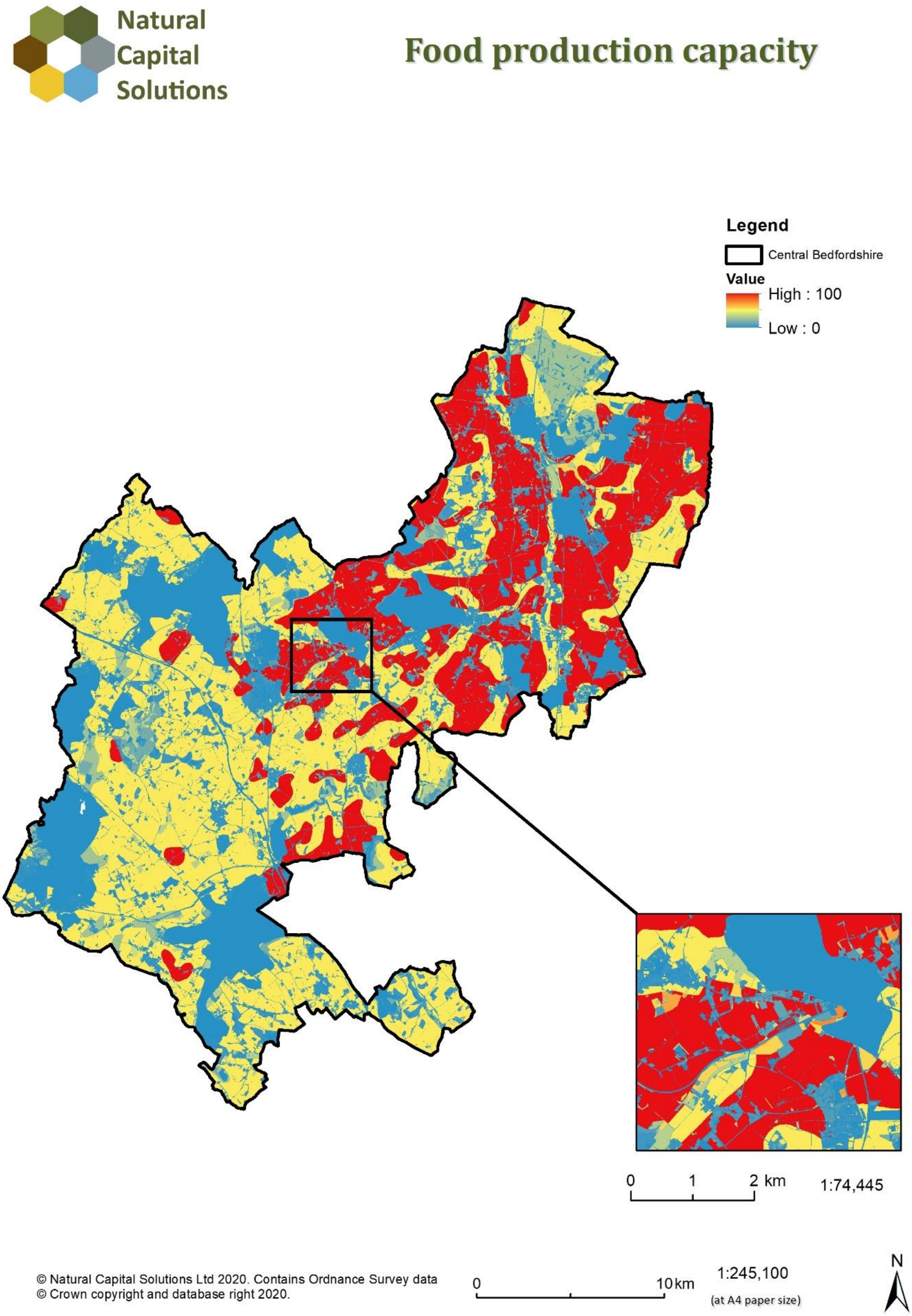

Figure 17 Food production capacity across Central Bedfordshire.

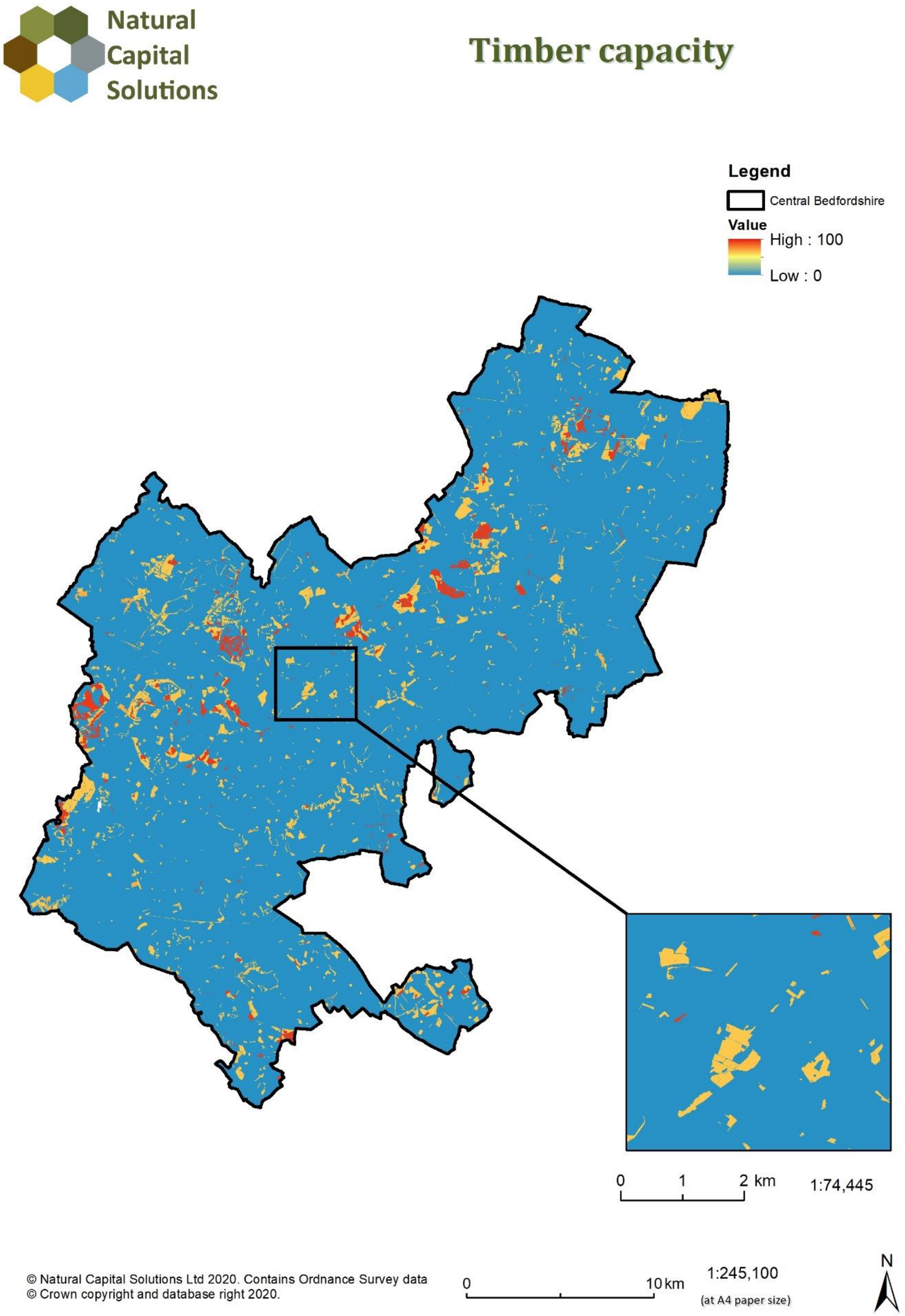

Figure 18 Timber / woodfuel capacity across Central Bedfordshire.

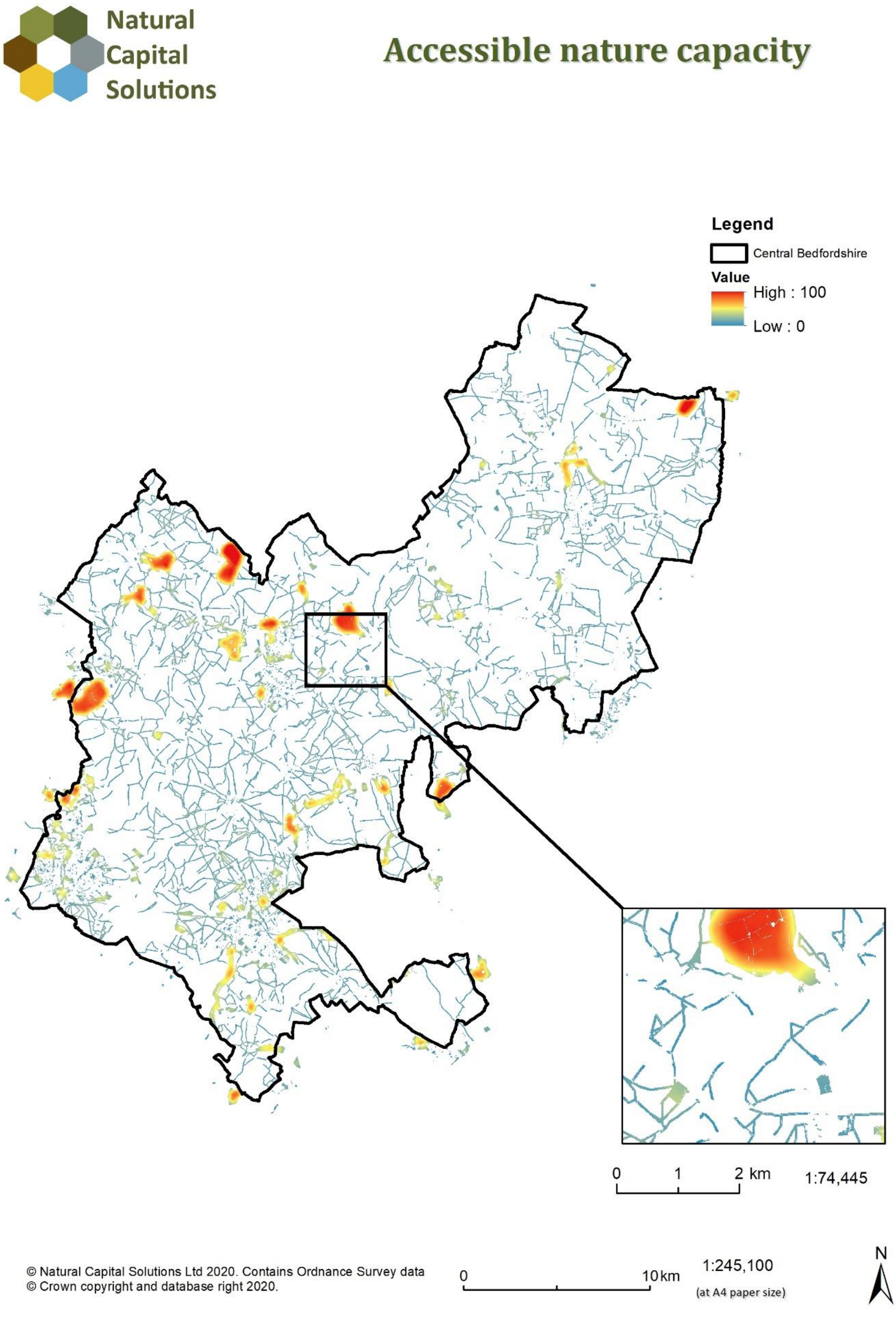

Figure 19 Accessible nature capacity across Central Bedfordshire. Areas with zero capacity have been excluded to improve map legibility.

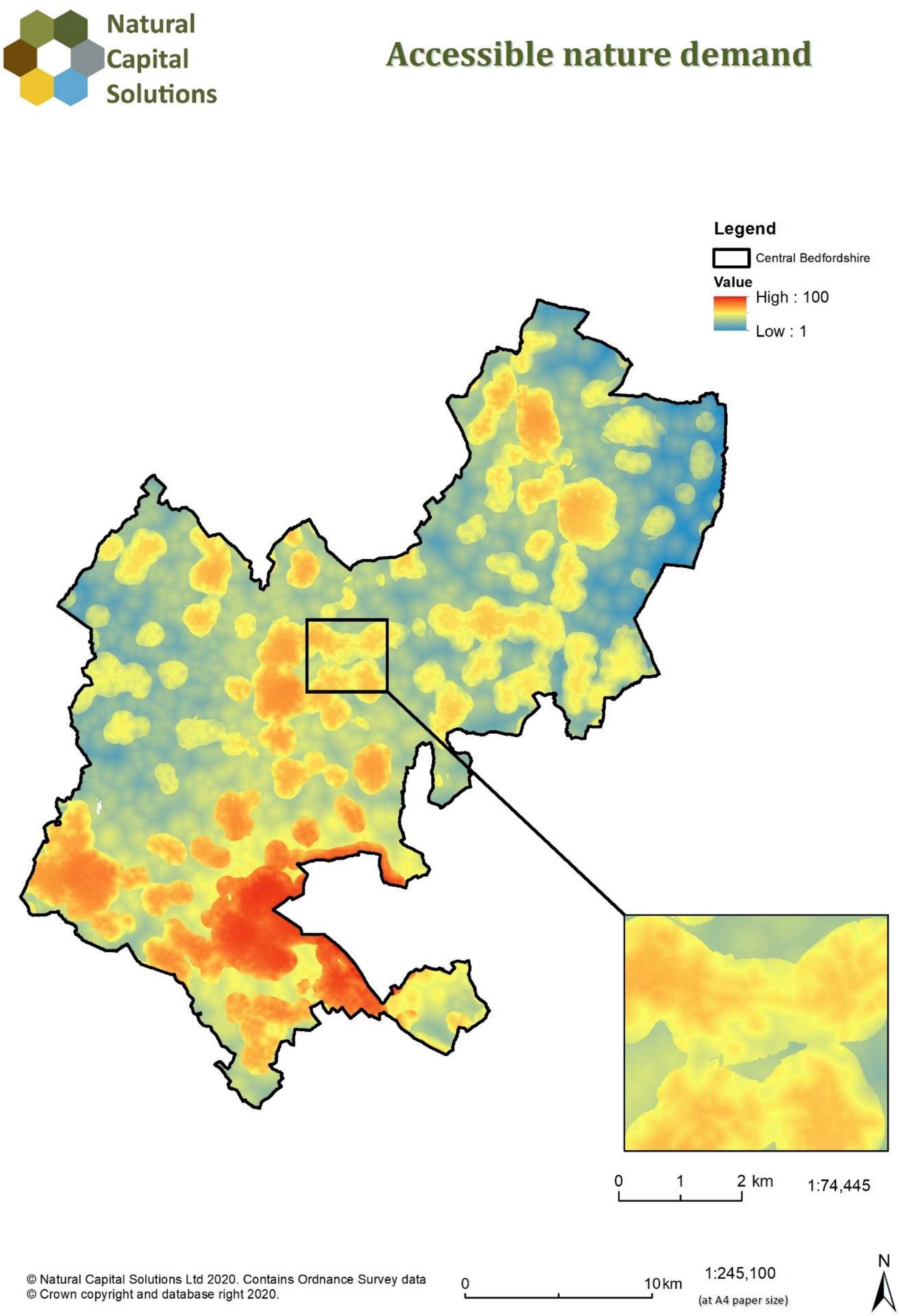

Figure 20 Accessible nature demand across Central Bedfordshire

4. Baseline ecosystem service valuation (monetary flows)

We estimated the annual monetary flow of the following ecosystem services: air quality regulation, carbon sequestration, GHG emissions from agriculture, recreation, physical health, agricultural production and timber production. Table 2 outlines the indicators used to quantify both the physical and monetary flows of these services.

Table 2 Ecosystem services and indicators for physical and monetary measurement.

Ecosystem service	Physical flow	Valuation
Air quality regulation	Tonnes of $PM_{2.5}$ and SO_2 absorbed	Costs avoided £/tonne of $PM_{2.5}$ and SO_2 /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

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[6]), and recent Defra guidance to standardise approaches to the valuation of ecosystem services[7]. The physical and monetary flows of the ecosystem services are presented below for Bedfordshire as a whole. The methods used to calculate these are described in more detail in the Technical Appendix at the end of the main Bedfordshire report (Annex 2).

Vegetation can be effective at contributing to **air quality regulation**, with surface area being the most important determinant of capacity. Trees are much more effective than grass at this, and capacity increases significantly as trees grow and their surface area increases. The woodland and grass vegetation across Central Bedfordshire is estimated to absorb 586 tonnes of $PM_{2.5}$ (particulate matter 2.5 micrometres of less in diameter) annually, at an annual value of £42.8 million with a present value (over 50 years) of £1.6 billion (Table 3).

Carbon sequestration is the uptake of carbon by plants as they grow, with woodlands being much the most effective habitat at this in Central Bedfordshire. In total, the average annual carbon sequestration in Central Bedfordshire is of 53,200 tonnes of carbon per year (tCO_2e) at an annual value of £3.7 million

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

and a present value (over 50 years) of £215 million. Overall, **agricultural GHG emissions** outweigh carbon sequestration within Central Bedfordshire as agriculture emits 65,700 tCO_2e per year, at a **cost** of £4.55 million annually, and a present value of £266 million (Table 3).

Table 3 Annual physical flows, annual monetary flows (2020, £M) and present value over 50 years (£M) of ecosystem services for Central Bedfordshire.

Ecosystem service	Annual physical flow	Annual monetary flow (£M)	Present Value over 50 years (£M)
Air quality regulation	586	42.8	1,580
$tPM_{2.5}$			
Carbon sequestration	53,200	3.68	215
tCO_2e			
GHG emissions from agriculture	-65,700	-4.55	-266
tCO_2e			
Recreation	13,800,000	40.3	1,030
Visits			
Physical health	1,030	15.5	573
QALY			
Agricultural production	48,100	1.60	40.8
Hectares			
Timber/woodfuel production	60,400	1.13	28.9
m^3			
Total vlaues:	**NA**	**100**	**3,200**

NB. Figures shown to 3 significant figures. Any discrepancies due to rounding.

The Central Bedfordshire region has high recreational value. Using the ORVal tool (see Technical Appendix in the main report) we were able to estimate the number of **recreational visits** made to publicly accessible greenspaces in Central Bedfordshire (Tables 3). Note that this does not include benefits from Centre Parcs, which is private. Across Central Bedfordshire there are an estimated 13.8 million recreational visits per year. The same tool estimates the welfare value derived from these visits, and these are valued at £40.3 million annually, with a present value (over 50 years) of £1 billion. A subset of these visitors will also receive **physical health benefits** through making regular active visits that meet national physical activity guidelines (20 minutes of moderate intensity exercise every day). It is estimated that there are 30,300 active visitors every year to publicly accessible greenspaces in Central Bedfordshire, which is equivalent to 1,030 Quality Adjusted Life Years (QALY). This delivers an annual value of £15.5 million, and a present value of £573.1 million (Table 3).

The total area of land in **agricultural production** in Bedfordshire is 48,100 ha (Table 3). This is predominantly arable (39,400 ha), with 8,700 ha improved and rough grasslands for grazing livestock (mainly cattle). This produces an annual gross margin of £26.8 million. However, when all costs and subsidies (including the Basic Payment Scheme) are excluded, the annual value of agricultural production in Central Bedfordshire is only £1.6 million, with a present value (over 50 years) of £40.8 million.

We have also looked at the woodland asset from a **timber and woodfuel** production perspective. This does not mean that the woodland is necessarily being harvested for these purposes, rather it is another way of exploring the value of woodland in the region. If the woodlands in Central Bedfordshire were to be manged for timber and woodfuel production, they would be able to produce approximately 60,400 m^3 per year under their current management and averaged over a full woodland production cycle (Table 3). This has an annual value of £1.1 million, and a present value of £28.9 million (Table 3).

In total, the value of the benefits delivered by the natural capital assets that we quantified across Central Bedfordshire is £100 million annually, with a present value of £3.2 billion over 50 years.

4.1 Sensitivity analysis

A sensitivity analysis examined the low, central and high estimates of all the benefits we valued (Table 4). This demonstrates the overall sensitivity of the natural capital values. The overall natural capital value ranges from a present value (over 50 years) of £1.4 billion under the lowest benefits estimates up to £8.6 billion under the highest benefits estimates. This large difference highlights the challenges of placing a monetary value on some services. A key point, however, is that even under the low benefit estimate, the natural capital assets of the region will deliver a substantial benefit worth at least £47.3 million annually, which is £1.4 billion in present value terms.

Table 4 Sensitivity analysis showing low, central and high estimates of the benefits provided by the natural capital assets of Central Bedfordshire.

Ecosystem service	Annual values (2020) (£M)			Present value (over 50 years) (£M)		
	Low	Central	High	Low	Central	High
Air quality regulation	9.26	42.8	131	342	1,580	4,850
Carbon sequestration	1.84	3.68	5.52	102	215	327
GHG emissions from agriculture	-2.28	-4.55	-6.83	-127	-266	-405
Recreation	30.2	40.3	50.3	771	1,030	1,280
Physical health	7.75	15.5	62.0	287	573	2,290
Agricultural production	-330	1.60	8.46	-8.42	40.8	216
Timber/woodfuel production	850	1.13	1.42	21.7	28.9	36.2
Total value:	**47.3**	**100**	**252**	**1,390**	**3,200**	**8,600**

NB. Figures shown to 3 significant figures. Any discrepancies due to rounding.

This analysis shows the high levels of uncertainty inherent in valuing ecosystem service benefits. Valuation of ecosystem services should be seen as appropriate at indicating the approximate magnitude of benefits, but not their exact values. It has allowed the comparison of values for a broad suite of services to be compared across Central Bedfordshire. It also demonstrates the range of benefits that the natural environment can provide. However, these results need to be interpreted with care, and in the knowledge that whilst the highest quality and most readily available data and methods were used, there are limitations and assumptions that need to be borne in mind.

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

Table 5 Summary of uncertainties in the calculation of physical flows and monetary values of each natural capital benefit, and an overall assessment of confidence, using a red, amber, green (RAG) rating.

Natural capital benefits	Assessment of uncertainties	RAG rating
Air quality regulation	Biophysical estimates based on averages for broadleaved and coniferous trees and grassland. Valuation follows ONS guidance.	
Carbon sequestration	Well studied, standardised carbon lookup tables available. Valuation uses UK Government non-traded carbon price.	
Agricultural emissions	Receiving increasing attention as part of climate change accounting. Valuation uses UK Government non-traded carbon price.	
Recreation	Welfare values from a welfare function model from the ORVal tool. This is a good model and based on a travel cost method, but it is nonetheless a model.	
Physical health	The most uncertain of the services measured. High uncertainty over who would make frequent and active visits to the green spaces and the monetary value of these benefits. There is also a potential here for double counting with the amenity service.	
Agricultural production	Based on extensive data collected by Defra annually and market prices.	
Timber production	Well studied over many years as part of forestry management. Valuation uses market prices.	

For the services that have been included here, a range of assumptions have been made, and these are outlined when describing the methodology (see Technical Appendix in the main Bedfordshire report). In addition, a summary of the main uncertainties is provided for each service in Table 5 (above), along with a RAG rating highlighting the overall confidence in each estimate. For most ecosystem services these assumptions are minimal, as established production functions exist linking natural capital to ecosystem service production, and levels of production to monetary value. For some services, despite fast developing research in relevant areas, broad assumptions have to be made because these links are not clear. This is particularly the case for physical health, and this estimate should, therefore, be used with care.

5. Accessible natural greenspace

5.1. Introduction

We assessed access to natural greenspace within Central Bedfordshire using Natural England's Accessible Natural Greenspace Standards (ANGSt). These standards stipulate that everyone should have an accessible natural greenspace:

- Of at least 2 ha in size, no more than 300 m from home.
- At least one accessible 20 ha site within 2 km of home.
- One accessible 100 ha site within 5 km of home.
- One accessible 500 ha site within 10 km of home.

Please see the main Bedfordshire report for more information on accessible natural greenspace and how they were determined.

5.2. Accessible natural greenspace in Central Bedfordshire

Figure 21 displays the accessible natural greenspace within Central Bedfordshire, as well in the wider Bedfordshire area. The amount of accessible natural greenspace within Central Bedfordshire equates to an area of 3,255 ha. The largest accessible natural greenspace site was 235 ha. Figure 22 displays the buffers used during the ANGSt analysis. Only 30.97% of Central Bedfordshire residents live within 300m of accessible natural greenspace ≥ 2 hectares in size (see Table 6). However, 79.77% of Central Bedfordshire residents live within 2 km of accessible natural greenspace ≥ 20 hectares in size and 88.92% of Central Bedfordshire residents live within 5 km of accessible natural greenspace ≥ 100 hectares in size. Unfortunately, there are no accessible greenspace sites ≥ 500 hectares in size within 10 km of Central Bedfordshire residents. There are also a small percentage (7.05%) of Central Bedfordshire residents who fall outside all of the ANGSt criteria. Finally, areas that failed the ANGSt criteria tended to be less deprived than areas that passed, indicating that most of these areas were rural locations where deprivation is generally lower.

Table 6 The number and percentage of residents within Central Bedfordshire passing or failing each of Accessible Natural Greenspace Standards (ANGSt). Also shown are the mean IMD scores for those areas within Central Bedfordshire that pass or fail of Accessible Natural Greenspace Standards (ANGSt). Higher IMD scores are indicative of higher levels of deprivation.

ANGSt	No Residents		% Residents		Mean IMD score	
	Pass	Fail	Pass	Fail	Pass	Fail
Within 300m of ≥ 2 ha site	90,548	201,825	31.0	69.0	10.7	10.3
Within 2km of ≥ 20 ha site	233,233	59,140	79.8	20.2	11.0	8.1
Within 5km of ≥ 100 ha site	259,990	32,384	88.9	11.1	10.8	7.2
Meets at least one access to greenspace standard	271,754	20,619	93.0	7.05	10.6	7.6

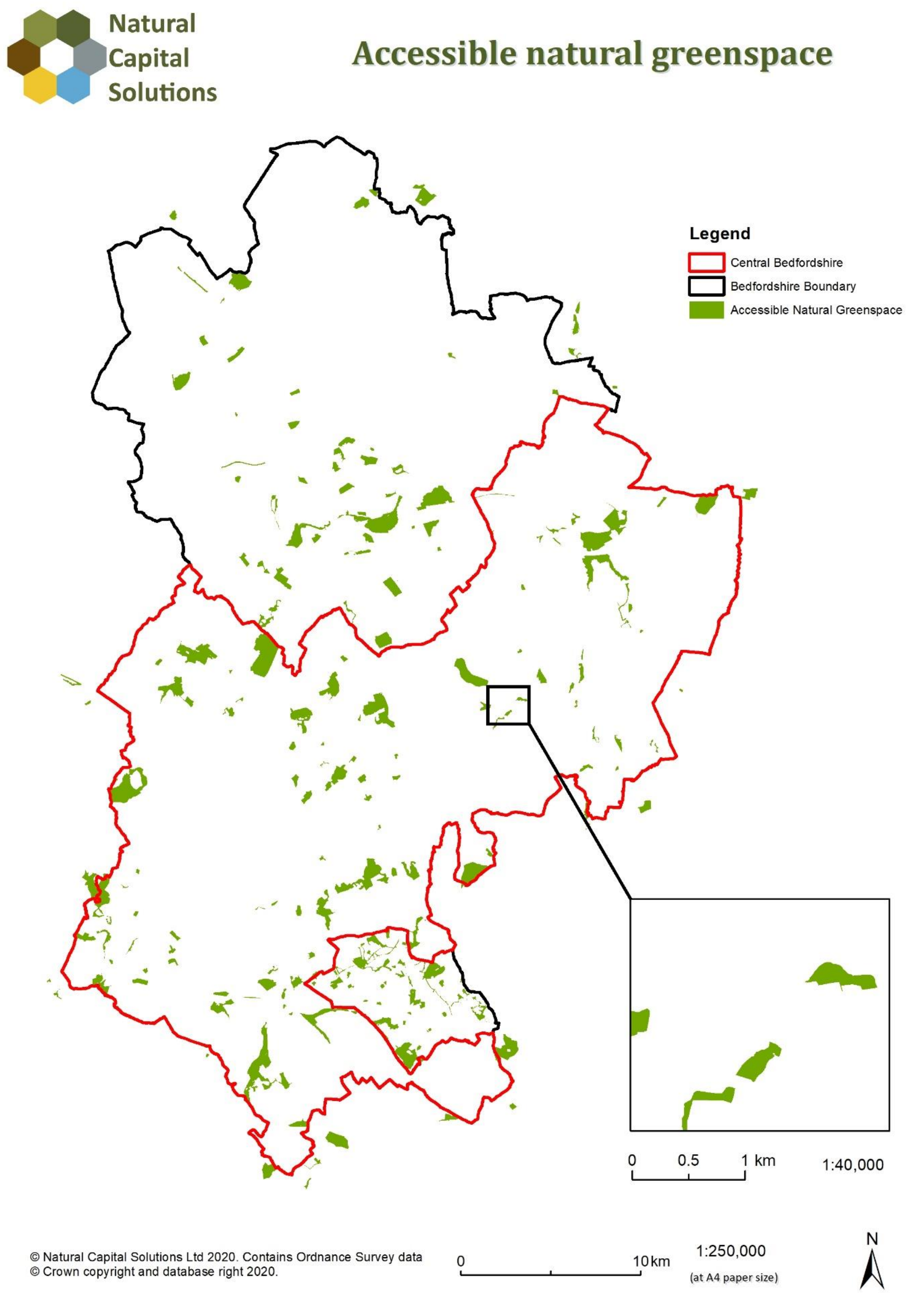

Figure 21 Accessible natural greenspace within and just outside Central Bedfordshire and across the wider Bedfordshire area

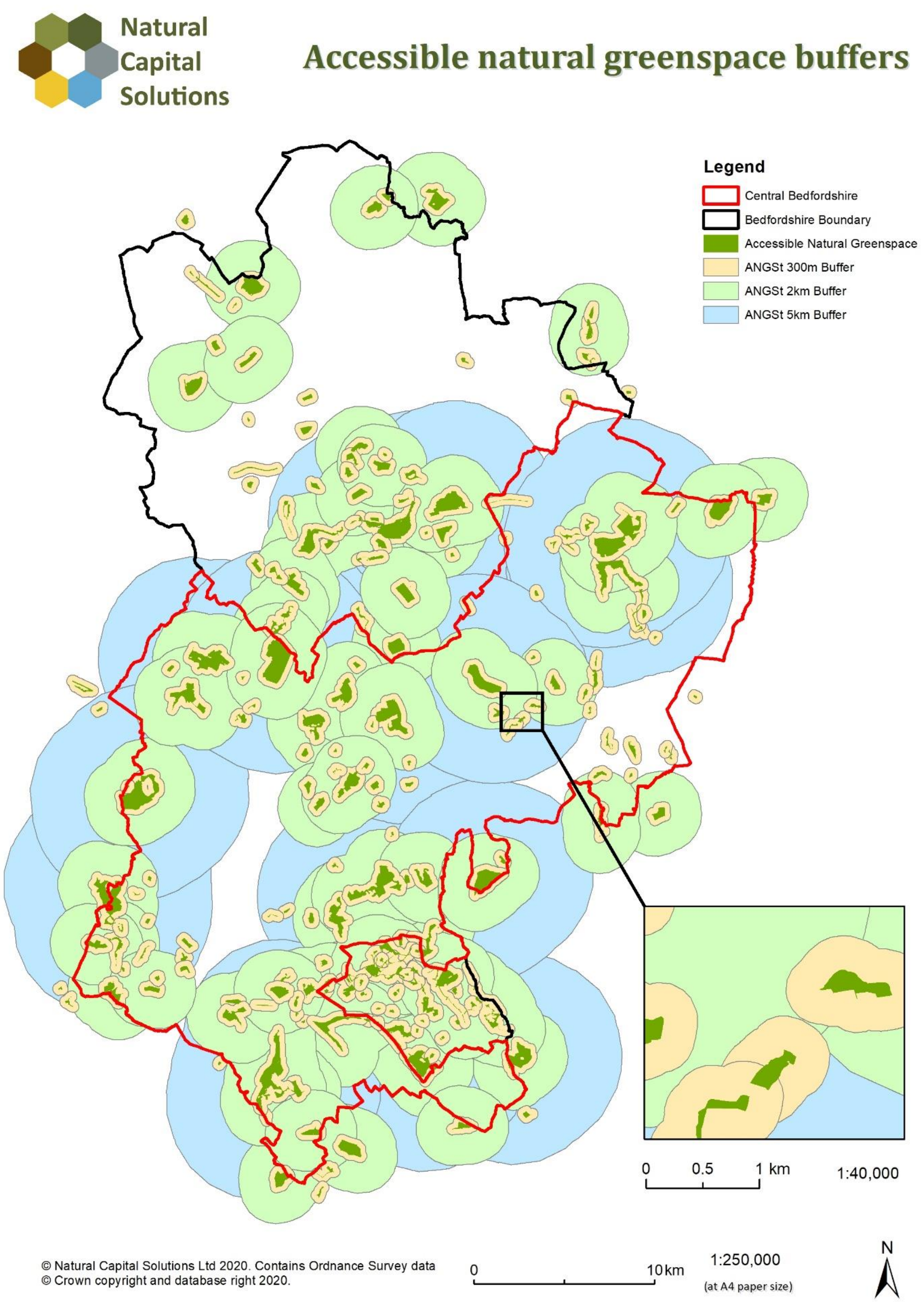

Figure 22 The buffers used during ANGSt analysis

6. Habitat opportunity mapping

6.1 Introduction

Habitat opportunity mapping is a Geographic Information System (GIS) based approach used to identify potential areas for the expansion of key habitats. It aims to identify possible locations 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. Opportunity mapping constraints are displayed in Figure 23 below. In this project, opportunities for new habitats across a range of different benefits have been mapped. This has included mapping opportunities for the following:

1) To enhance biodiversity
2) To reduce surface runoff
3) To reduce soil erosion and improve water quality
4) To ameliorate air pollution
5) To reduce noise pollution
6) To regulate local climate (reduce urban heat)
7) To increase access to natural greenspace

6.2 Opportunity mapping for biodiversity enhancement

The importance of landscape-scale conservation and ecological networks has become increasingly recognised over recent years. Many wildlife sites have become isolated in a landscape of unsuitable habitats and efforts are now being directed towards linking existing habitat patches and increasing connectivity. Species are more likely to survive in larger habitat networks, are able to move and colonise new sites, and are more resilient to climate change and other detrimental impacts.

Habitat opportunity mapping to enhance biodiversity follows this ethos by using ecological networks to identify potential areas for new habitats. Identified areas will be ecologically connected to existing habitats, thereby expanding the size of the existing network, increasing connectivity and resilience, and potentially increasing the ecological quality of the new site. It was performed for three key habitat groupings, incorporating the main semi-natural habitats found in Bedfordshire. The broad habitats and their constituent types are shown in the table below:

Broad habitat	Specific habitats included
Semi-natural grassland	Acid, neutral, calcareous, rough and semi-improved grasslands
Wet grassland & wetlands	Marshy grassland, floodplain grazing marsh, lowland fen and swamp (reedbed)
Woodland	Broadleaved and mixed woodland types (excludes coniferous woodland, parkland or individual trees)

Biodiversity opportunity mapping followed a four-step process, as explained below, and was based on the approach developed by Catchpole (2006)[8] and Watts et al. (2010)[9]. Full methodological details are provided in the main Bedfordshire report. Note that opportunity areas for the three broad habitats often overlap, and no attempt has been made to ascertain the most suitable habitat at a particular location.

6.2.1 Results

The results are illustrated here for semi-natural grassland habitats, with the broadleaved and mixed woodland, and wet grassland and wetland maps following in Annex 1. The permeability of the landscape for typical semi-natural grassland species is shown on Figure 24. Darker areas are more permeable, meaning that typical species are expected to travel further across these habitats and hence will be less of a barrier to movement. For all three broad habitat types, arable fields are the most significant barrier to movement. Buildings and infrastructure are also significant barriers, but gardens and greenspaces help to make urban areas less impermeable.

The habitat network map for semi-natural grassland is shown on Figure 25. Habitats that are ecologically connected are linked within a network shown in grey. White space between habitat patches indicate that the patches are not ecologically connected and dispersal between the patches is less likely to occur. Semi-natural grasslands are evenly but sparsely dispersed across Central Bedfordshire (Figure 25). However, although a number of these patches are ecologically connected into a network, many patches remain disconnected, although there is good opportunity to enhance connectivity through habitat creation (see below). A few large patches exist in the south-west and east. Broadleaved and mixed woodland habitat networks (Figure A2) are concentrated in the north and across the centre of Central Bedfordshire, in the Greensand Ridge, where a number of patches are ecologically connected. Woodland in the rest of the area is much more ecologically isolated. Wet grassland and wetland habitat networks (Figure A6), are much less significant in the area, with only a few small and ecologically isolated habitat patches.

Constraints to creating new habitats were removed and are shown in Figure 23. Note that additional factors could be used as constraints, for example best and most versatile agricultural land (or the more stringent Grade 1 land). This was not applied as a constraint here as it would still be possible to create riparian buffer strips and similar small habitat enhancements in such areas, even if whole field are not converted. Hence it was felt that agricultural land classification would work better as a factor to screen against when deciding on areas to take forward, rather than as a fixed constraint.

Once constraints shown in Figure 23 were removed, the resulting maps show biodiversity opportunity areas. Figures 26 and 27 illustrates these for semi-natural grassland habitats, with the other habitats in Annex 1. Figure 26 shows the opportunity zones as buffers around existing sites, while Figure 27 highlights whole fields where habitats could be created, as these are a more meaningful management unit for conservation action. There are multiple areas in the northern part of Central Bedfordshire around the previously identified habitat network, where semi-natural grassland could be created to considerably enlarge and connect existing networks, along with smaller opportunities scattered throughout the remaining area. Broadleaved and mixed woodland opportunities (Figure A4) exist throughout the study area, although with particular density in the north, where field-scale habitat creation could increase the

[8] Catchpole, R.D.J. (2006). Planning for Biodiversity – opportunity mapping and habitat networks in practice: a technical guide. *English Nature Research Reports*, No 687
[9] Watts, K., Eycott, A.E., Handley, P., Ray, D., Humphrey, J.W. & Quine, C.P (2010). Targeting and evaluating biodiversity conservation action within fragmented landscapes: an approach based on generic focal species and least-cost networks. *Landscape Ecology,* 25: 1305–1318.

connections between woodland patches, or connect more isolated fragments to create a more resilient network. For wet grassland and wetlands (Figure A8), opportunities are much more limited and are mostly focussed on expanding existing habitat patches.

Please note that in many places the biodiversity opportunity maps overlap, hence a piece of land may have been identified as being potentially suitable for habitat creation for two, or even all three, different habitat types. This occurs where existing areas of the three habitat types are in close proximity to each other. This issue can be addressed by setting priorities for habitats to take forward in different locations.

6.2.2 Opportunities to expand ancient woodland sites

Annex 2 describes an additional analysis completed to identify opportunities focused around ancient woodland sites. Ancient woodland is woodland that has been in existence since at least 1600 and represents the most important and biodiverse woodland sites in the UK. Opportunities to expand and reconnect these sites represents the highest priority areas for woodland creation, from a biodiversity perspective. Please see Annex 2 for full details and map.

Natural Capital Solutions

Opportunity mapping constraints

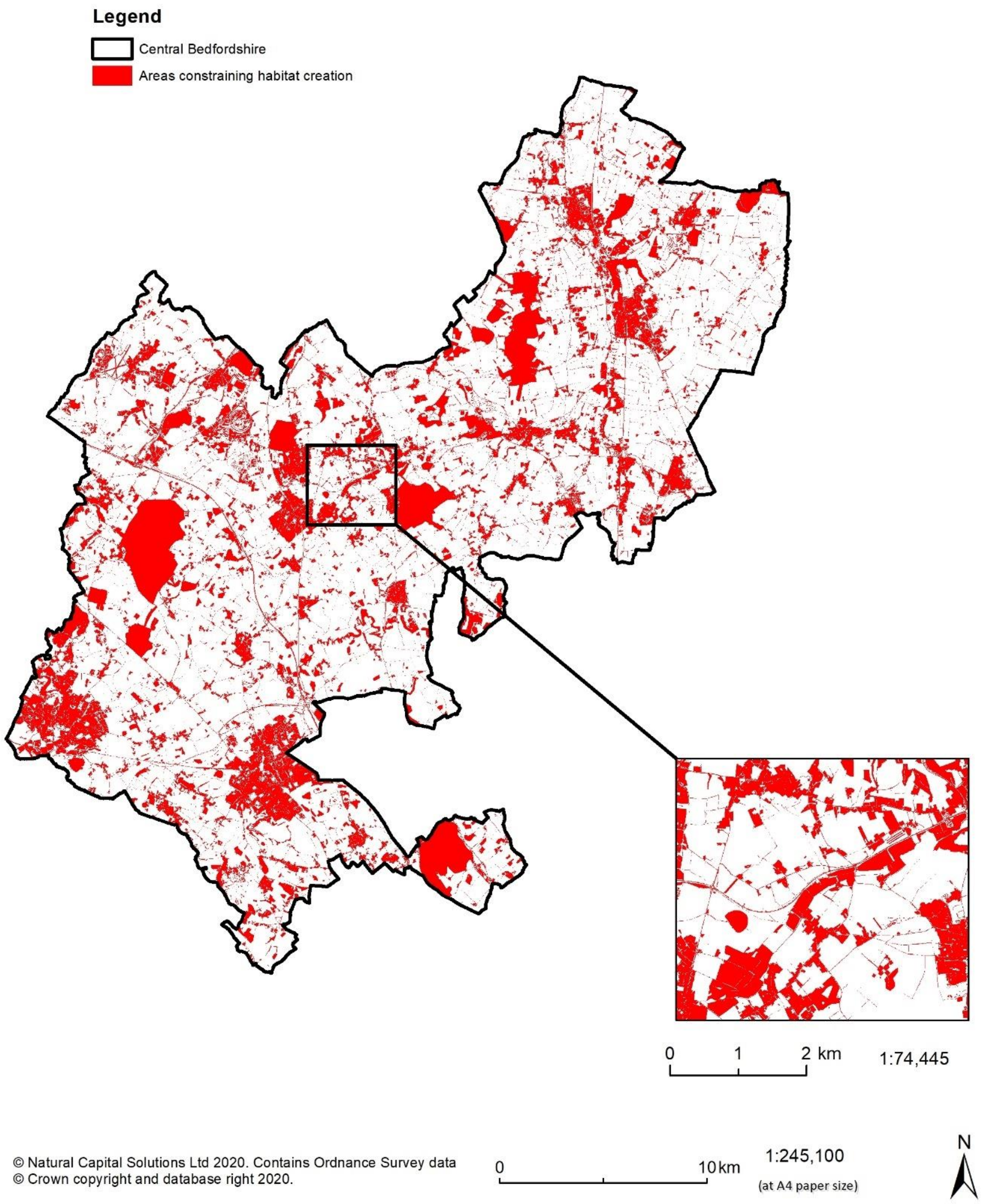

Figure 23 Key constraints taken into account during habitat opportunity mapping across Central Bedfordshire. These included land use constraints (infrastructure, buildings, gardens and water), high quality habitats, historic sites, and gas pipelines and overhead lines (for woodland only).

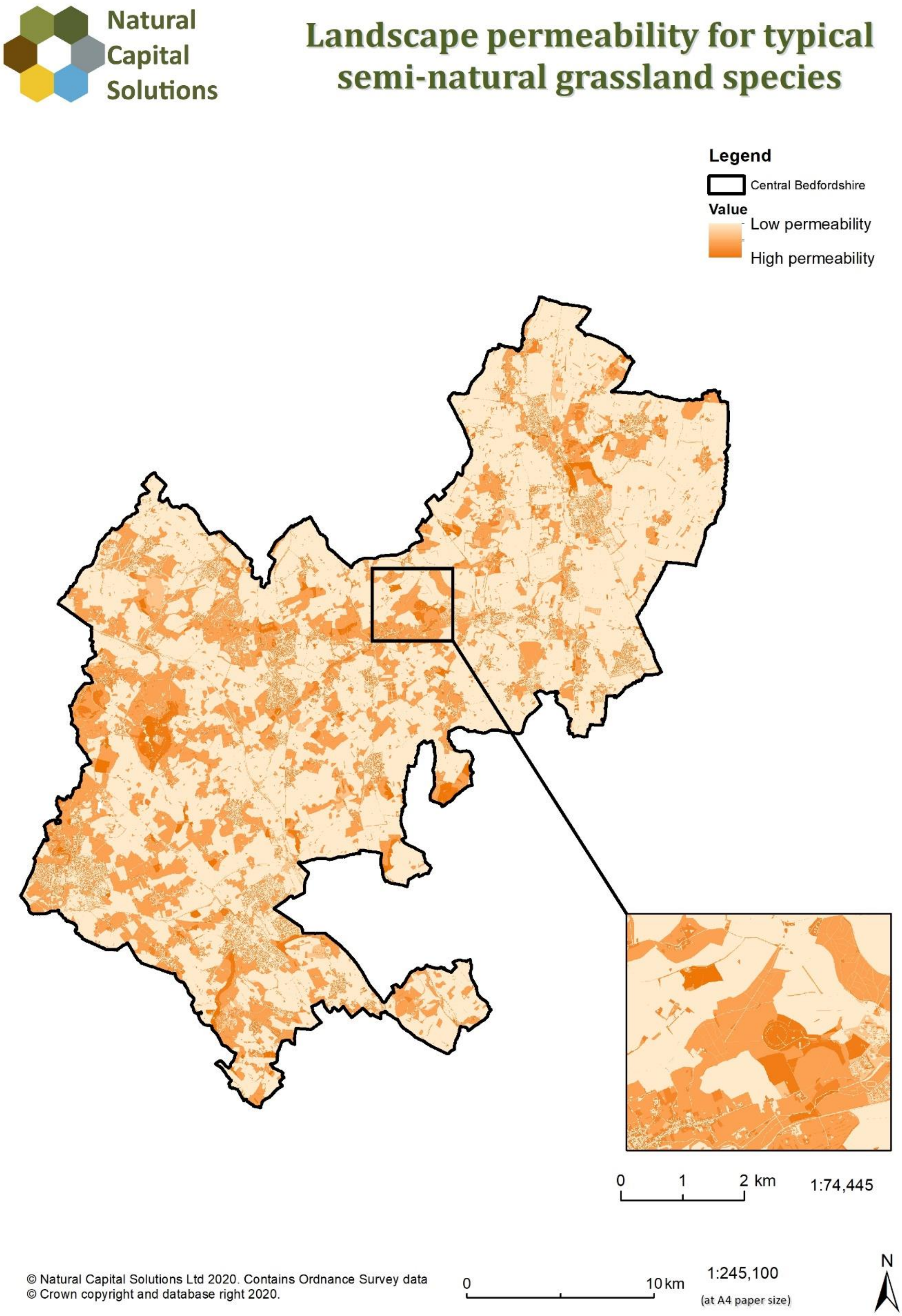

Figure 24 Landscape permeability for typical semi-natural grassland species across Central Bedfordshire.

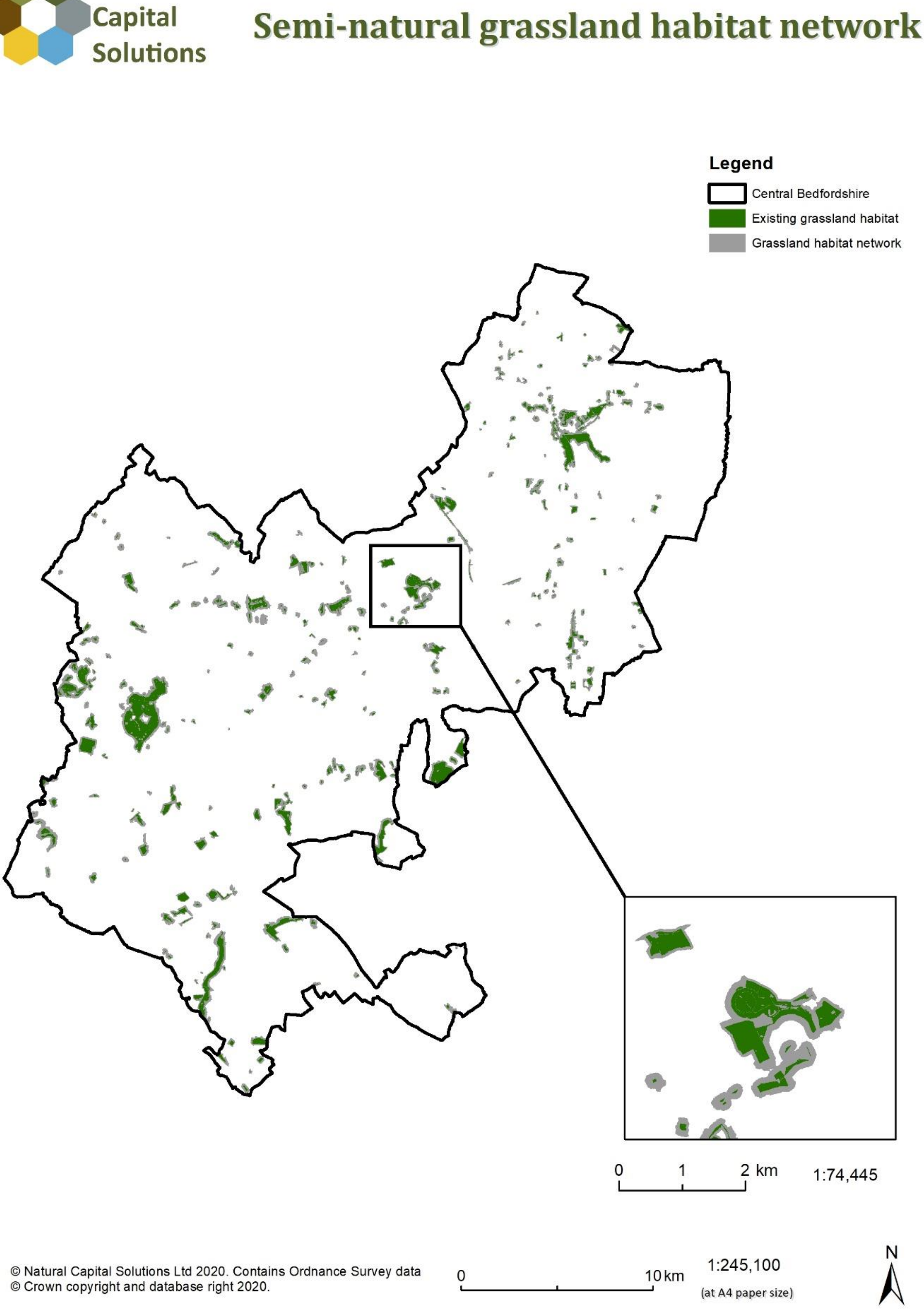

Figure 25 Habitat network for semi-natural grasslands across Central Bedfordshire.

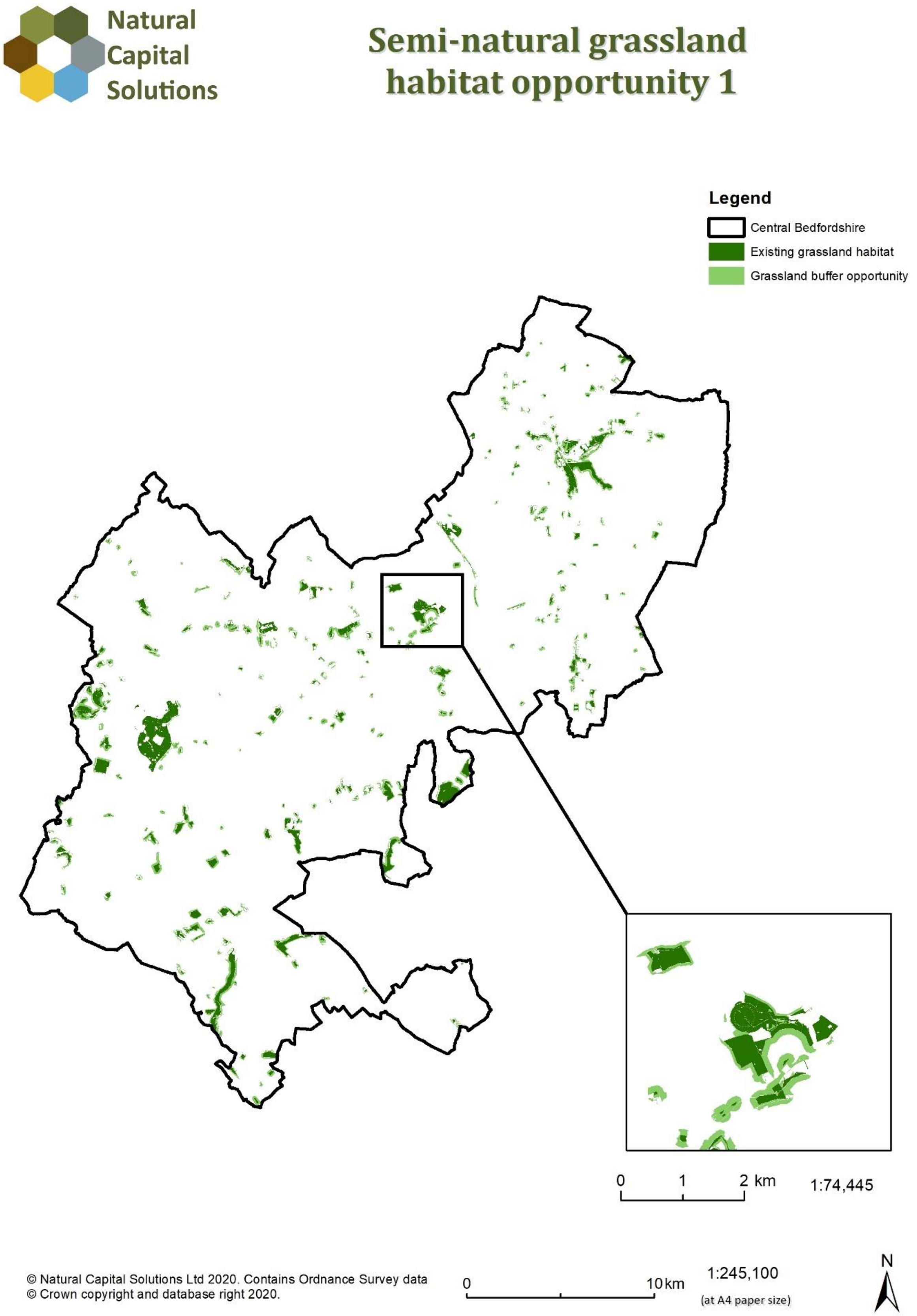

Figure 26 Buffer biodiversity opportunity areas for semi-natural grassland across Central Bedfordshire.

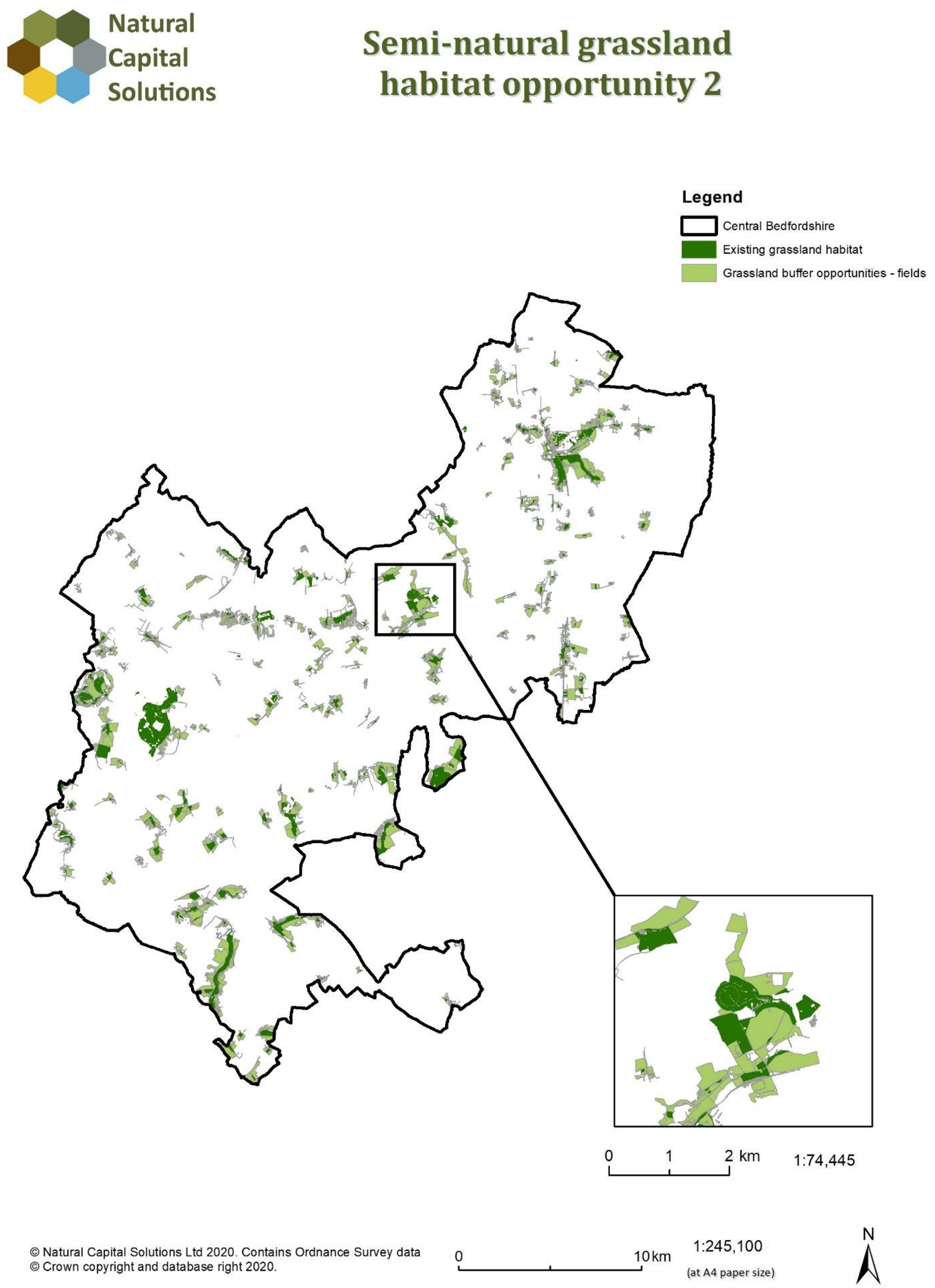

Figure 27 Field scale biodiversity opportunity areas for semi-natural grassland across Central Bedfordshire.

6.3 Opportunity mapping to reduce surface runoff

There is growing interest in working with natural process to reduce downstream flood risk. These projects aim to “slow the flow”, reduce surface water runoff and retain water away from the main river channels for as long as possible. The most likely approach to achieve this aim will involve planting woodland, although measures could also include woody debris dams and attenuation ponds in upstream areas. Opportunity mapping to reduce surface runoff was undertaken based on the water flow model described in Section 3.9 and highlights areas across the whole catchment where changing land-use would have the greatest impact on reducing runoff. Full methods for all opportunity mapping are provided in the accompanying Bedfordshire report.

6.3.1 Results

Once land use constraints were removed, many areas that are currently poor for surface water runoff remained and these where identified as opportunity areas on Figure 28. Opportunities are present over much of Central Bedfordshire, with the majority of opportunities relating to areas of arable fields on sloping land. The opportunity areas have been displayed in relation to fields and plots of land in Figure 29.

Note that some of the worst areas for water flow regulation highlighted in Figure 15 relate to buildings and infrastructure, which were not assessed as part of this project, although could be suitable for the installation of green roofs and other types of retrofitted Sustainable Drainage Systems (SuDS).

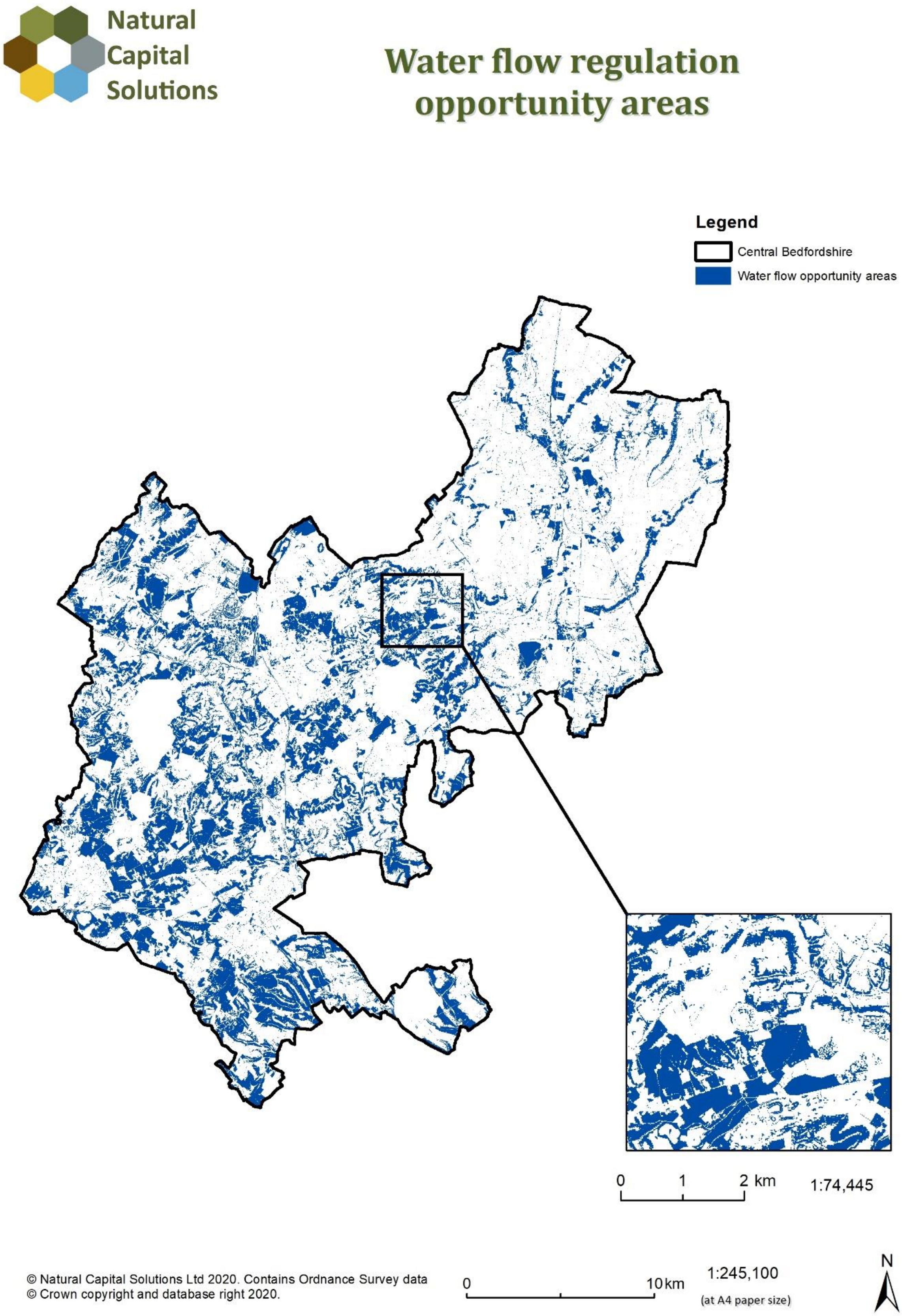

Figure 28 Water flow regulation opportunity areas across Central Bedfordshire.

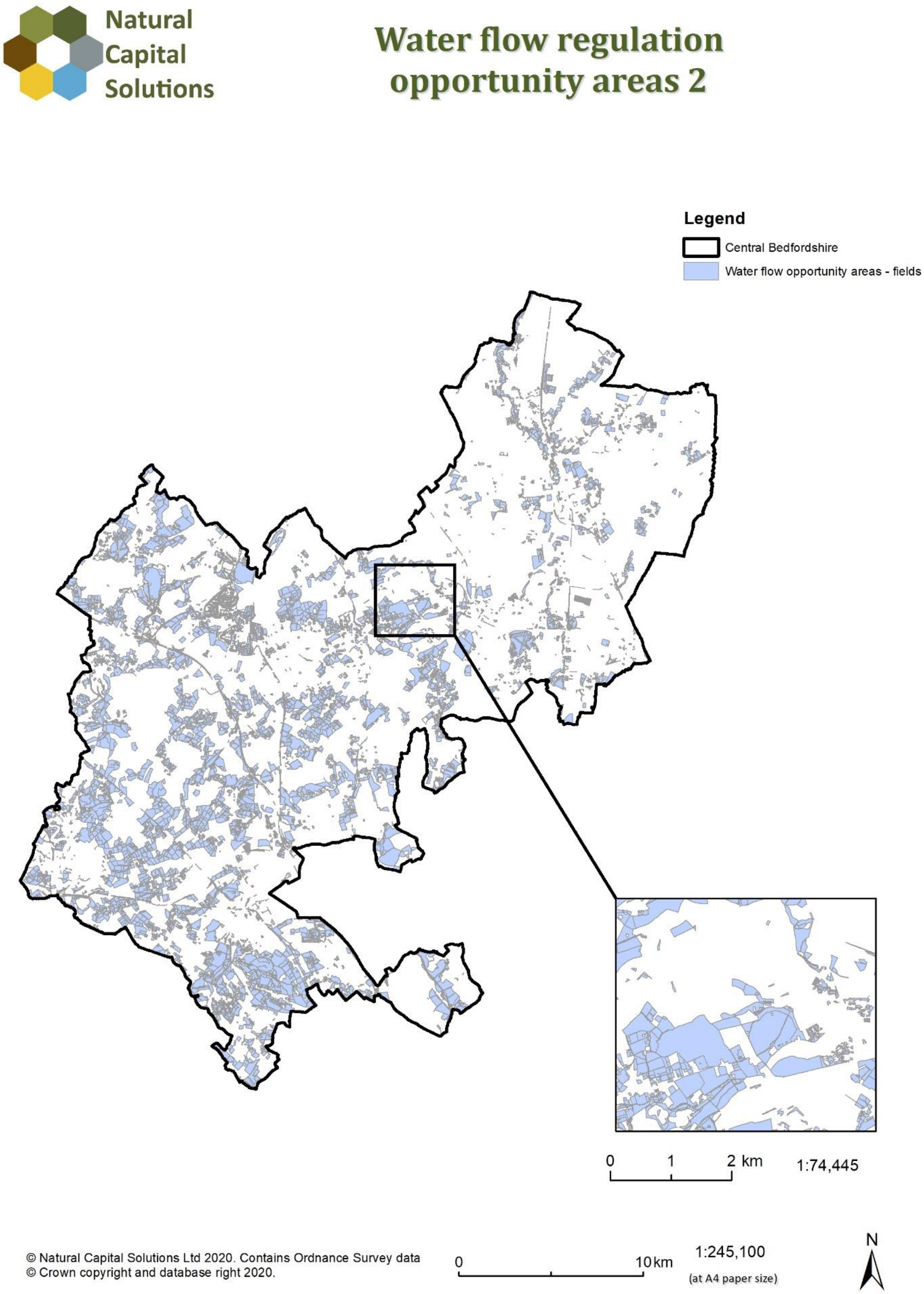

Figure 29 Field scale water flow regulation opportunity areas across Central Bedfordshire

6.4 Opportunity mapping to reduce soil erosion and improve water quality

Agricultural and urban diffuse pollution have a major impact on water quality in lowland areas in the UK. There is growing interest in catchment sensitive farming and working with natural processes to tackle this issue. These aim to reduce the amount of sediment and pollutants entering the watercourses in the first place by, for example, adjusting farming practices and planting riparian buffer strips. Opportunity mapping focussed on identifying areas at highest risk of sedimentation and soil erosion, based on catchment land use characteristics, distance to watercourse, slope length and land use erosion risk. It highlights areas across the whole catchment where changing land use would have the greatest impact on reducing soil erosion and hence improving water quality. Note that the focus is on sedimentation risk from agricultural diffuse pollution, and built-up areas (urban diffuse pollution) are not as well accounted for in the existing model.

6.4.1 Results

Arable farmland scores particularly badly when mapping water quality regulation (Section 3.10) at both a coarse and a fine scale of assessment and these areas are, therefore, highlighted as the areas with greatest opportunity to reduce sediment loads and enhance water quality on the opportunity map (Figure 30). In addition, distance to watercourses is another key factor. The western half of Central Bedfordshire has fewer watercourses and also less arable than the east, hence the majority of opportunities to improve water quality are located in the eastern half of the county.

Sediment loads, and therefore opportunity areas, can be variable across short distances as it is partly dependent upon slope and distance to water course, which change rapidly over short spaces, and is why many of the identified areas are linear stretches adjacent to watercourses. These areas would be ideal places to install riparian buffer strips, ideally of woodland, but any habitat offering year-round cover would help. Local constraints on tree planting, such as those imposed by IDBs, will also need to be considered.

A map of whole fields where opportunities for reducing soil erosion and enhancing water quality would be most effective has been created (Figure 31). As noted, however, the areas that would be most effective for tackling water quality are often zones adjacent to watercourses, and changing land use in riparian buffer strips may be the most effective solution, rather than converting whole fields.

Comparing the opportunity maps for water flow (Figure 28) with water quality (Figure 30), reveals that there is not much overlap between the two. The most effective locations for reducing surface water runoff tend to occur on slopes, many of which are in the west of the study area, whereas the most effective areas to enhance water quality are immediately adjacent to water courses on arable fields, which are more frequent in the eastern half of the study area. It is likely that habitat features created for one will still enhance the other, it is simply that the top 25% of target areas do not overlap in many locations. Woodland would be the most effective habitat to deliver these opportunities, although semi-natural grasslands, wet grasslands and wetlands would also deliver benefits.

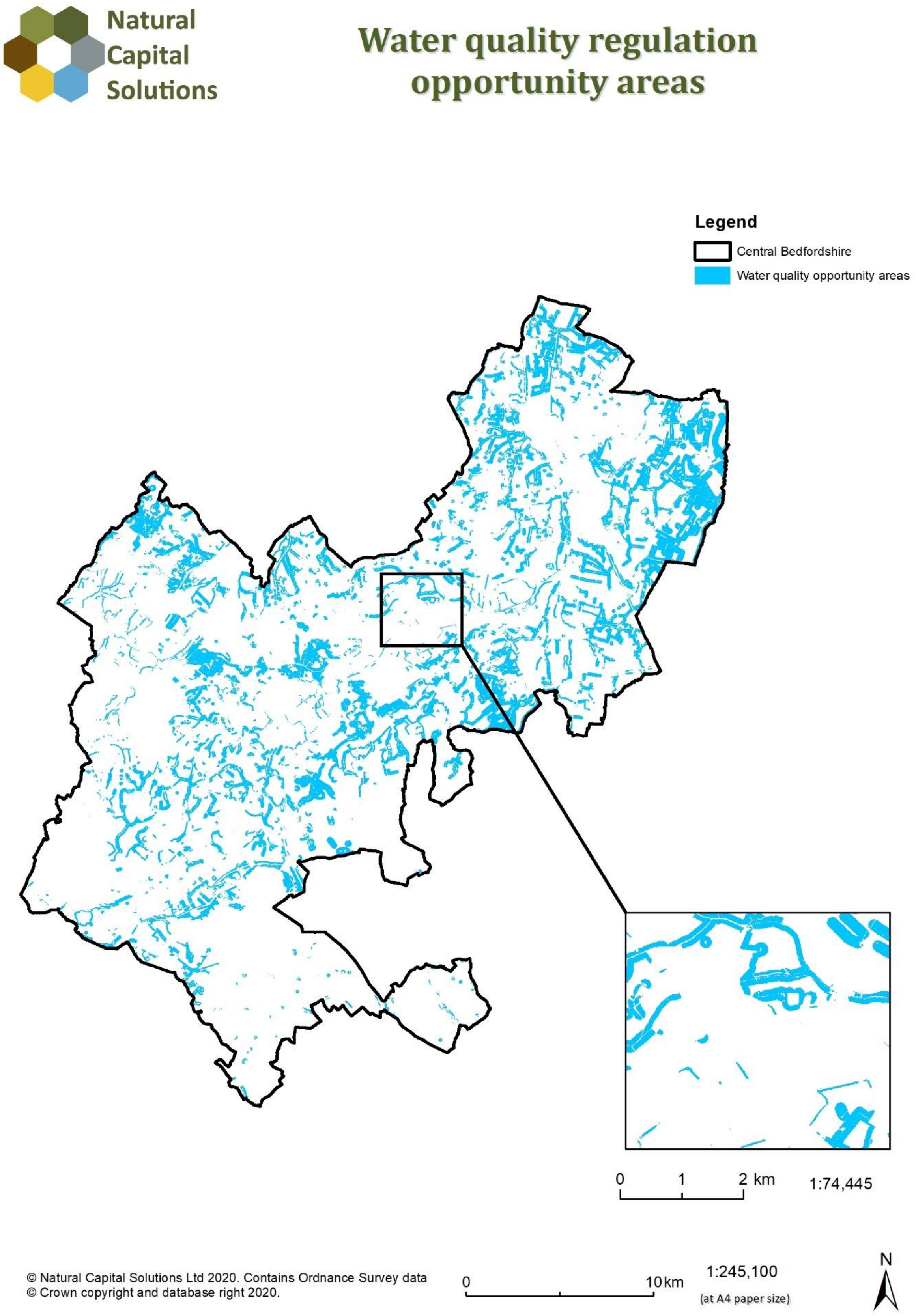

Figure 30 Water quality regulation opportunity areas across Central Bedfordshire.

Water quality regulation opportunity areas 2

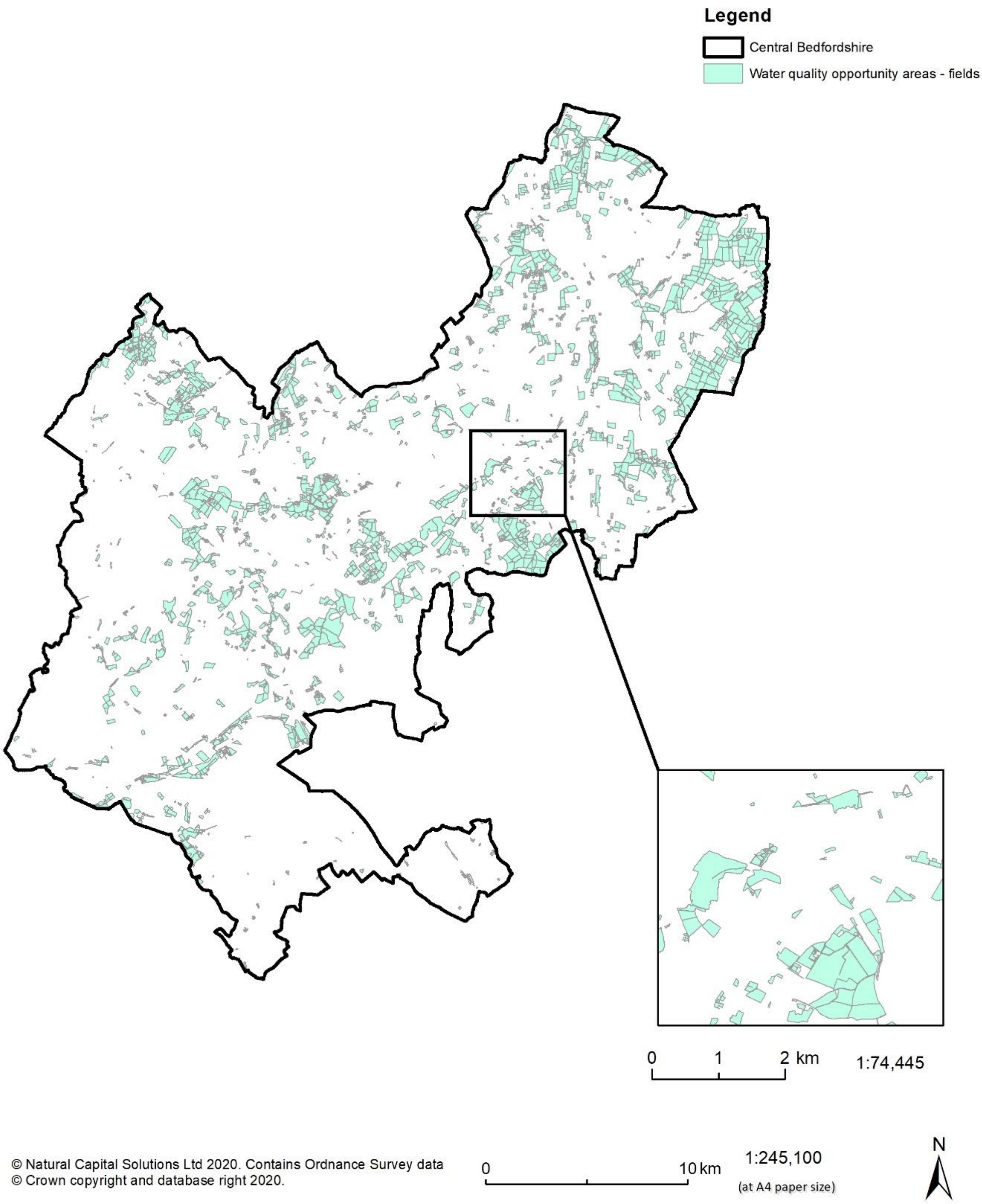

Figure 31 Field scale water quality regulation opportunity areas across Central Bedfordshire.

6.5 Opportunity mapping to ameliorate air pollution

To map opportunities to use the natural environment to ameliorate air pollution, a slightly different approach was used compared to water flow and water quality. Air pollution is often highly localised, and vegetation is most effective at mitigating pollutants when planted close to pollution sources. Opportunities to ameliorate air pollution were therefore focussed around areas with greatest demand. As described in Section 3.4, demand is assumed to be highest in areas where there are likely to be high air pollution levels and where there are lots of people who could benefit from the air quality regulation service. The opportunity maps therefore highlight areas that currently have no trees, but where it would be most beneficial to plant them.

6.5.1 Results

As described previously, demand for air quality regulation (Figure 10) is highest in the main urban centres as these have both higher air pollution levels and higher populations that would benefit from better air quality, and also along the main road networks. Inevitably, when the focus on air quality regulation is in the major towns, large areas are constrained, where it would not be possible to plant trees or other green infrastructure. However, unconstrained areas do remain, and these were highlighted on the opportunity map (Figure 32). Opportunity areas along the main roads were also highlighted. Whole plots were also identified (Figure 33), although on this occasion this was similar to the previous map. These locations potentially provide the opportunity to plant trees that could trap air pollution in areas where there is the greatest need for this service. Note that this does not include pavements, where further opportunities may be present, if pavements are sufficiently wide.

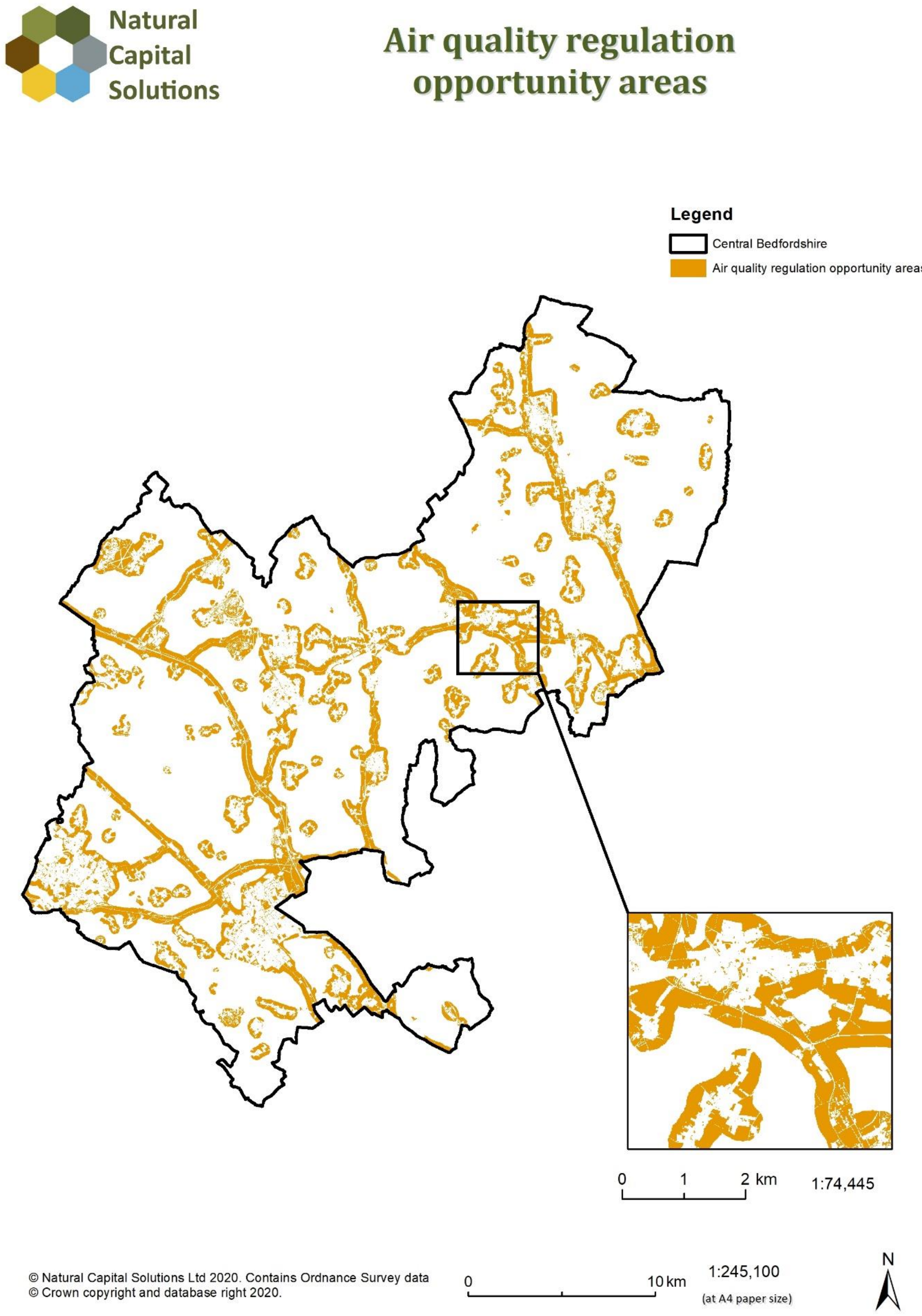

Figure 32 Air quality regulation opportunity areas across Central Bedfordshire.

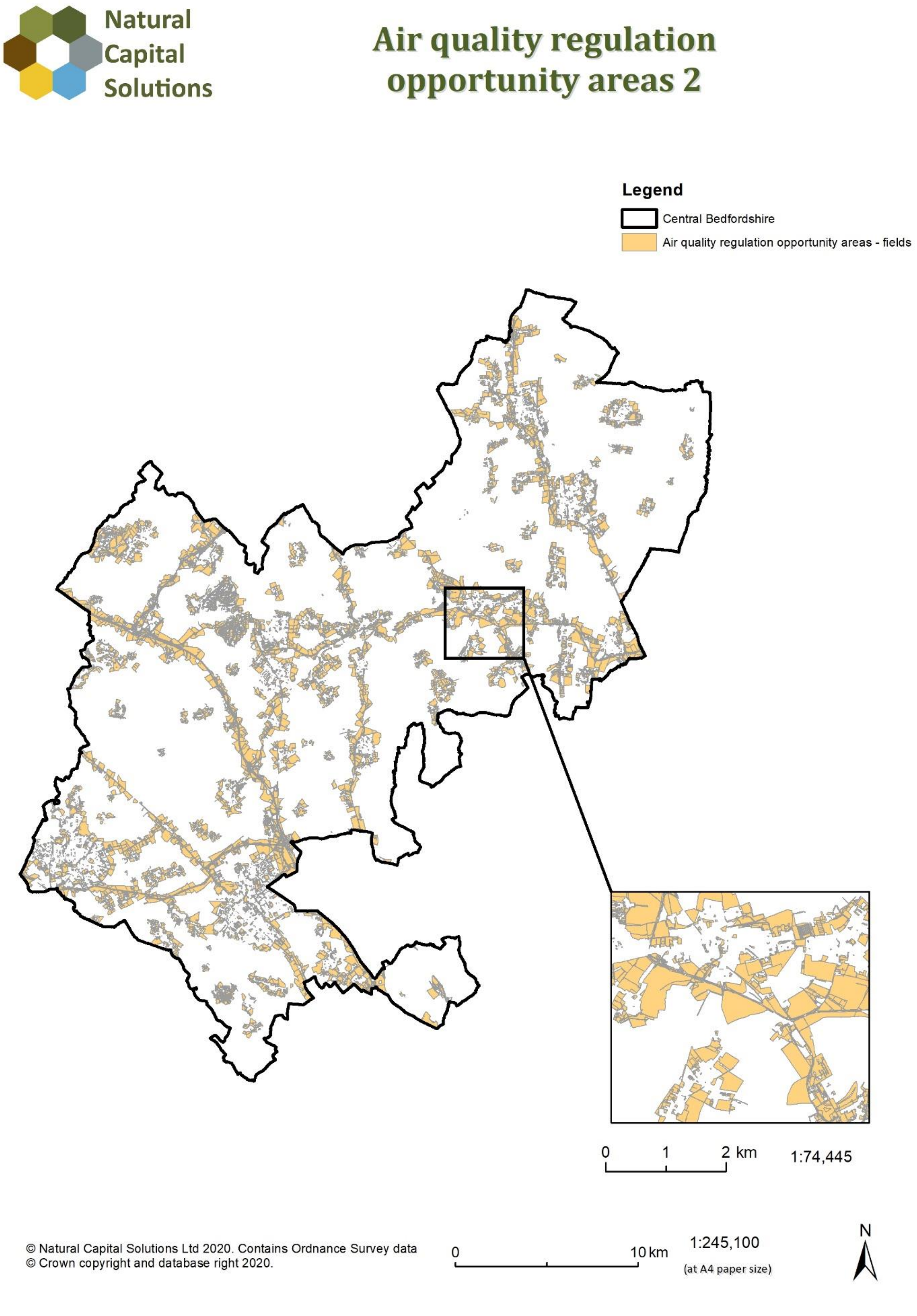

Figure 33 Field (plot) scale air quality regulation opportunity areas across Central Bedfordshire.

6.6 Opportunity mapping to reduce noise pollution

Opportunities to reduce noise pollution were mapped in a very similar way to the air quality regulation opportunity mapping just described. This was focussed around areas with greatest demand for noise regulation, as described in Section 3.6. Dense plantings of trees and scrub are the habitat type that could potentially reduce noise pollution; the opportunity maps therefore highlight areas that currently have no trees, but where it would be most beneficial to plant them.

6.6.1 Results

Similarly to air quality regulation, demand for noise regulation (Figure 12) is highest in the main urban centres and adjacent to the road and rail network, especially the motorway, as these have both higher noise pollution levels and higher populations that would benefit from noise screening. Given the large number of constraints in urban centres, the majority of the opportunity areas identified fall on the outer fringes of urban areas and adjacent to the road network, although a number of urban centre location have also been identified (Figure 34). Whole plots were also identified and shown in Figure 35. These locations potentially provide the opportunity to plant trees and scrub belts that could help to block and screen noise pollution.

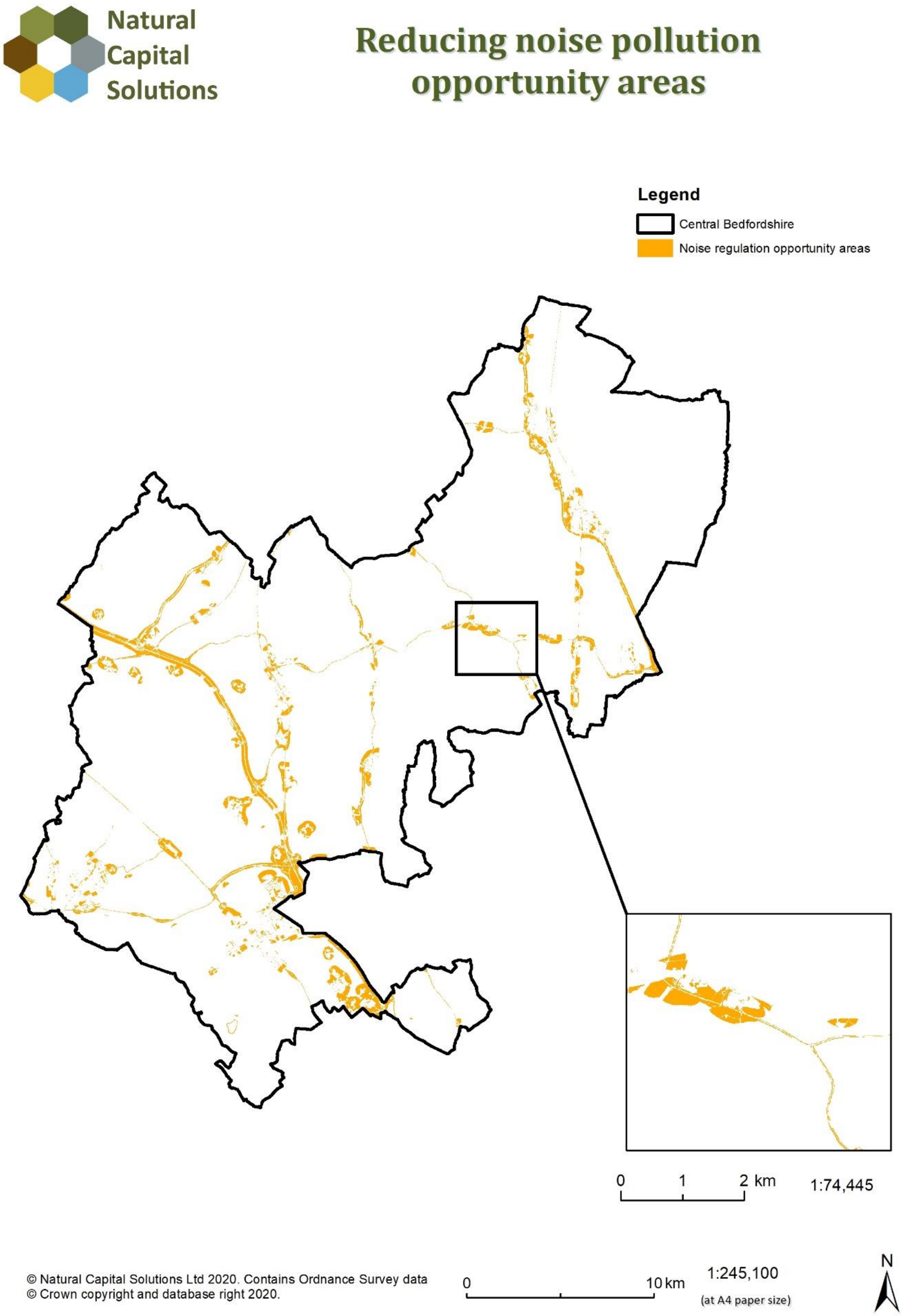

Figure 34 Noise regulation opportunity areas across Central Bedfordshire.

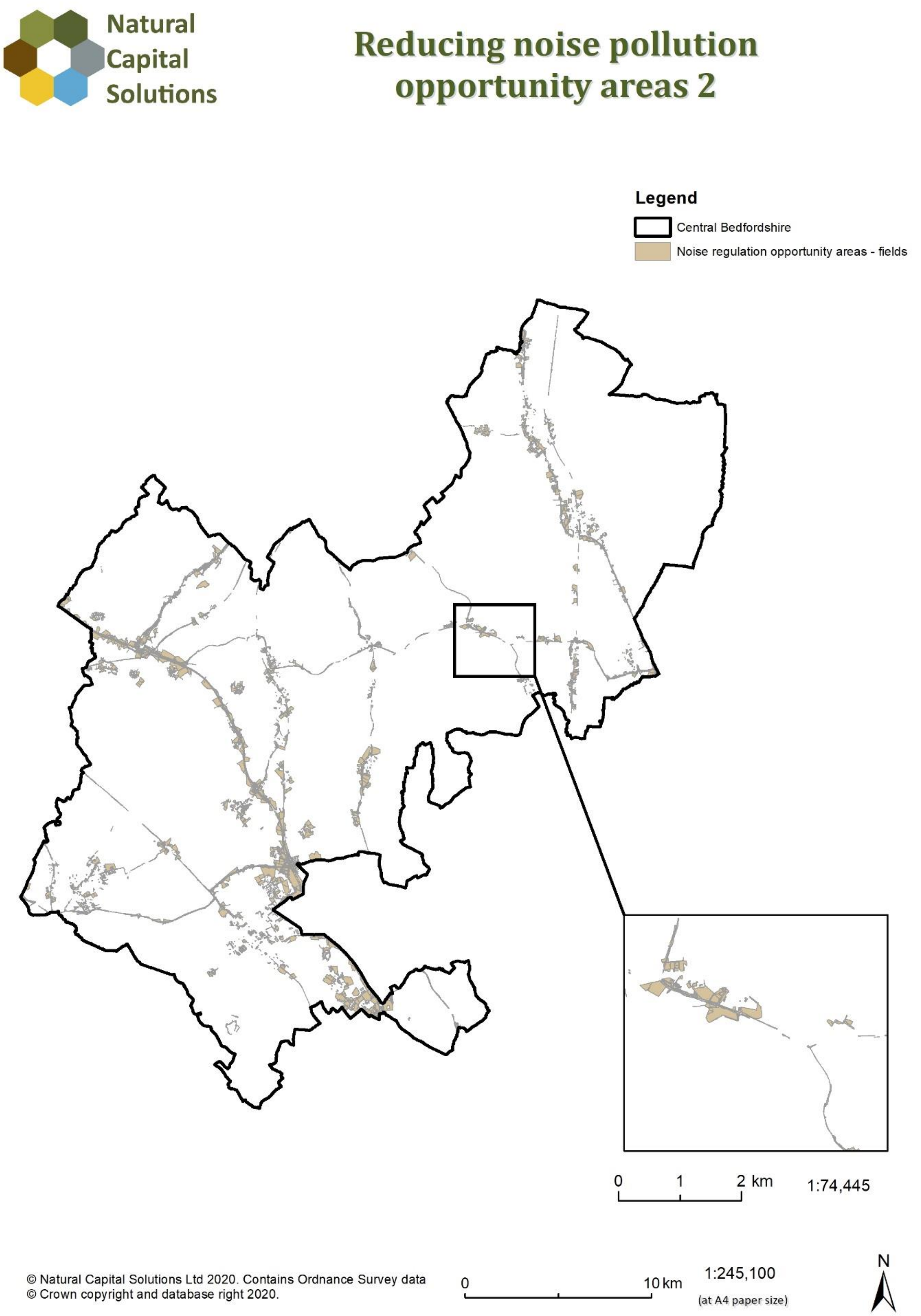

Figure 35 Field (plot) scale noise regulation opportunity areas across Central Bedfordshire.

6.7 Opportunity mapping to regulate local climate (reduce urban heat)

Opportunities to regulate local climate were mapped using the same approach as for air quality regulation and noise regulation. This therefore, focuses on areas of highest demand, where there is currently low capacity. Using the natural environment to regulate local climate can best be achieved by either plating trees / woodland, or creating waterbodies such as ponds and lakes. The larger the area of habitat created, the greater the effect that it will have on urban temperatures, although even individual trees will have a small positive impact.

6.7.1 Results

Demand for local climate regulation (Figure 14) is highest in the main urban centres and the size of the urban heat island effect increase with size of urban area and amount of sealed surface. As with air pollution regulation and noise regulation, the majority of the opportunity areas identified fall on the outer fringes of urban areas, due to the large number of constraints in urban centres, although some of the urban centre locations have also been identified (Figure 36). As for the other services, whole plots were also identified and shown in Figure 37. These locations potentially provide the opportunity to plant trees and woodland or to create water features that could help to reduce the urban heat island effect.

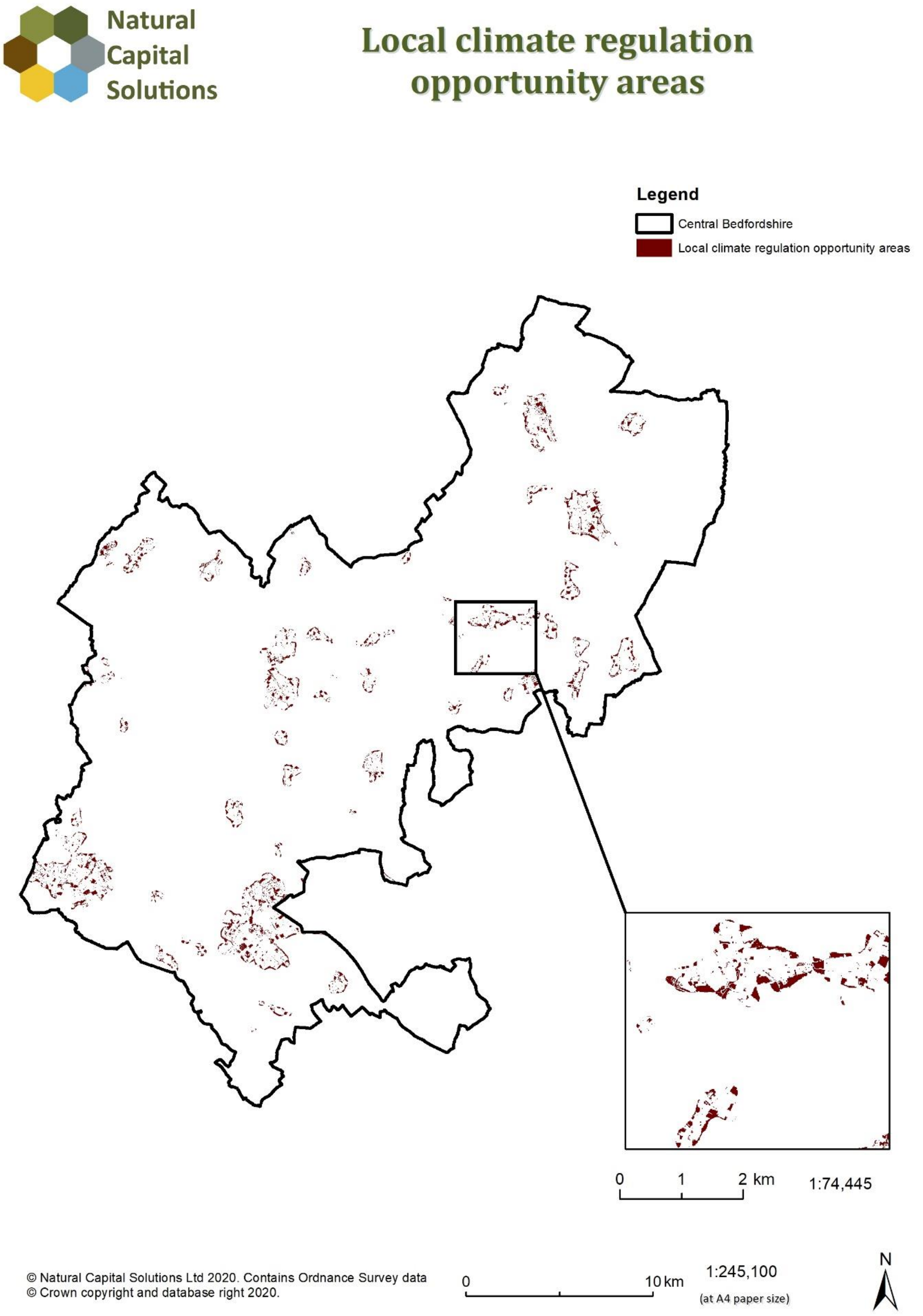

Figure 36 Local climate regulation opportunity areas across Central Bedfordshire.

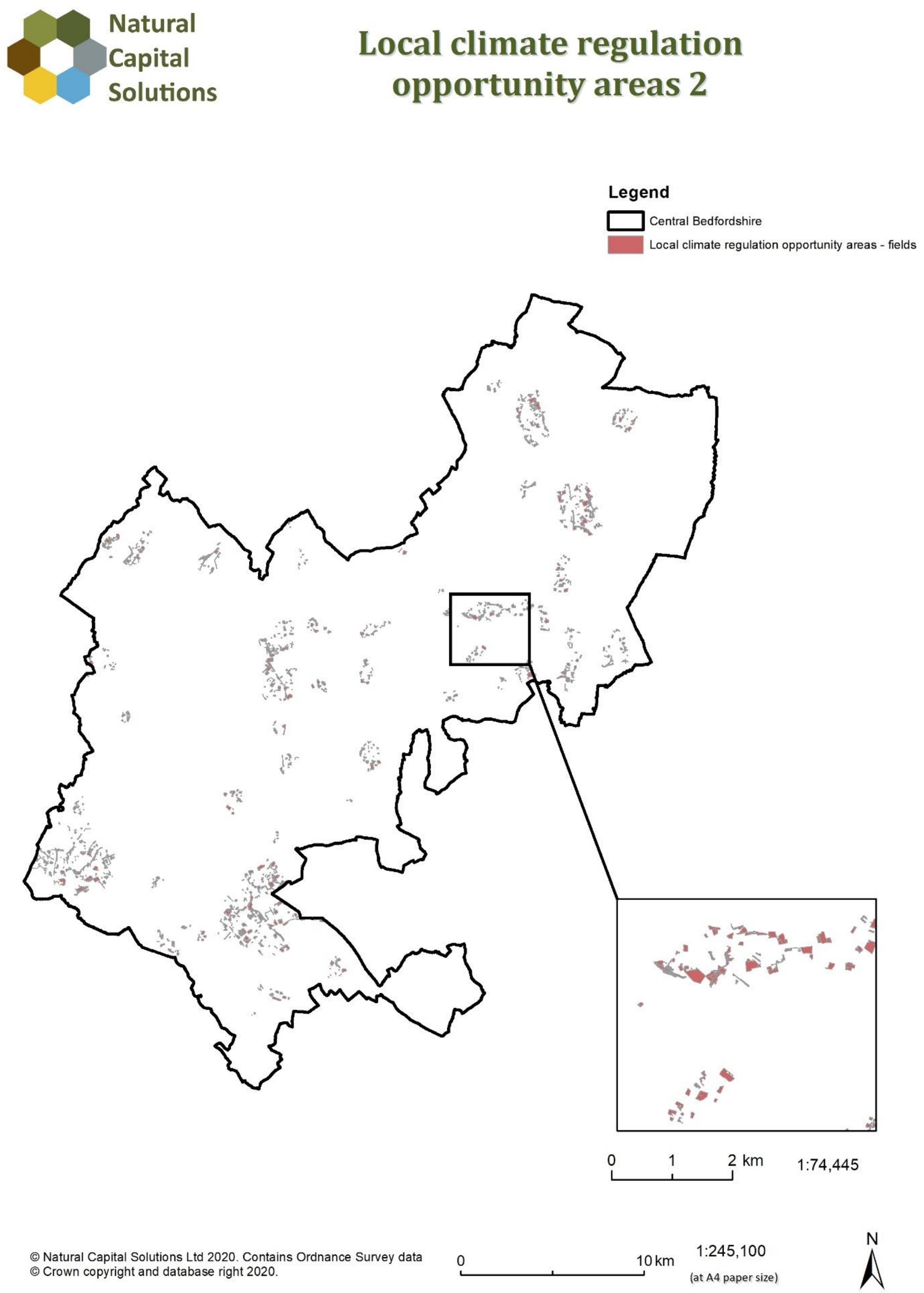

Figure 37 Field (plot) scale local climate regulation opportunity areas across Central Bedfordshire.

6.8 Opportunity mapping to enhance recreation in the natural environment

There are many benefits of enhancing public access to natural greenspaces and the key features that maximise benefits are proximity to where people live and the naturalness of the habitats. Here, opportunities to provide accessible natural greenspace were mapped, first based on creating new habitats at new sites, based purely on demand, and then by also considering opening up access to existing sites, by taking into account the naturalness of existing habitats.

6.8.1 Results

Demand for accessible natural greenspace was described in Section 3.14 and is strongly focussed around the urban areas in the study area. Therefore, it is perhaps unsurprising that the majority of the opportunity areas identified (Figures 38 & 39) are centred around the urban areas across the study area. As opportunities for new greenspaces are usually highly constrained within urban areas, opportunity areas tend to form a ring around the edges of these areas These are also often locations that have been targeted for sustainable urban extensions and other development, so it is important that planners and developers take into account the strong demand for greenspace at these sites from both the new developments and from the existing population.

Although demand is greatest around the larger towns, these locations often do not contain the most natural habitats, and the perceived naturalness of habitats throughout the study area is shown on Figure 40. Woodland, semi-natural grassland, and water features are considered to be the most natural habitats in the area and can be clearly identified in red on the map, especially the larger blocks of these habitats. When demand is balanced against the naturalness of the existing habitats, a different pattern of opportunity areas emerges (Figures 41 & 42). The association with the larger towns is now much weaker, although still present, as areas of poor habitat adjacent to towns are not selected. Areas of higher quality habitat are now more likely to be selected, especially when those are relatively close to towns. In general, when considering only demand for access to greenspace, opportunities are selected that are immediately adjacent to urban areas, but these are often on arable fields and improved grassland. Hence new habitats would need to be created to enhance the quality of the greenspace offering. When the perceived naturalness of existing habitats is also considered, areas are often slightly further from towns so with slightly poorer access, but more natural habitats, such as woodland are often selected.

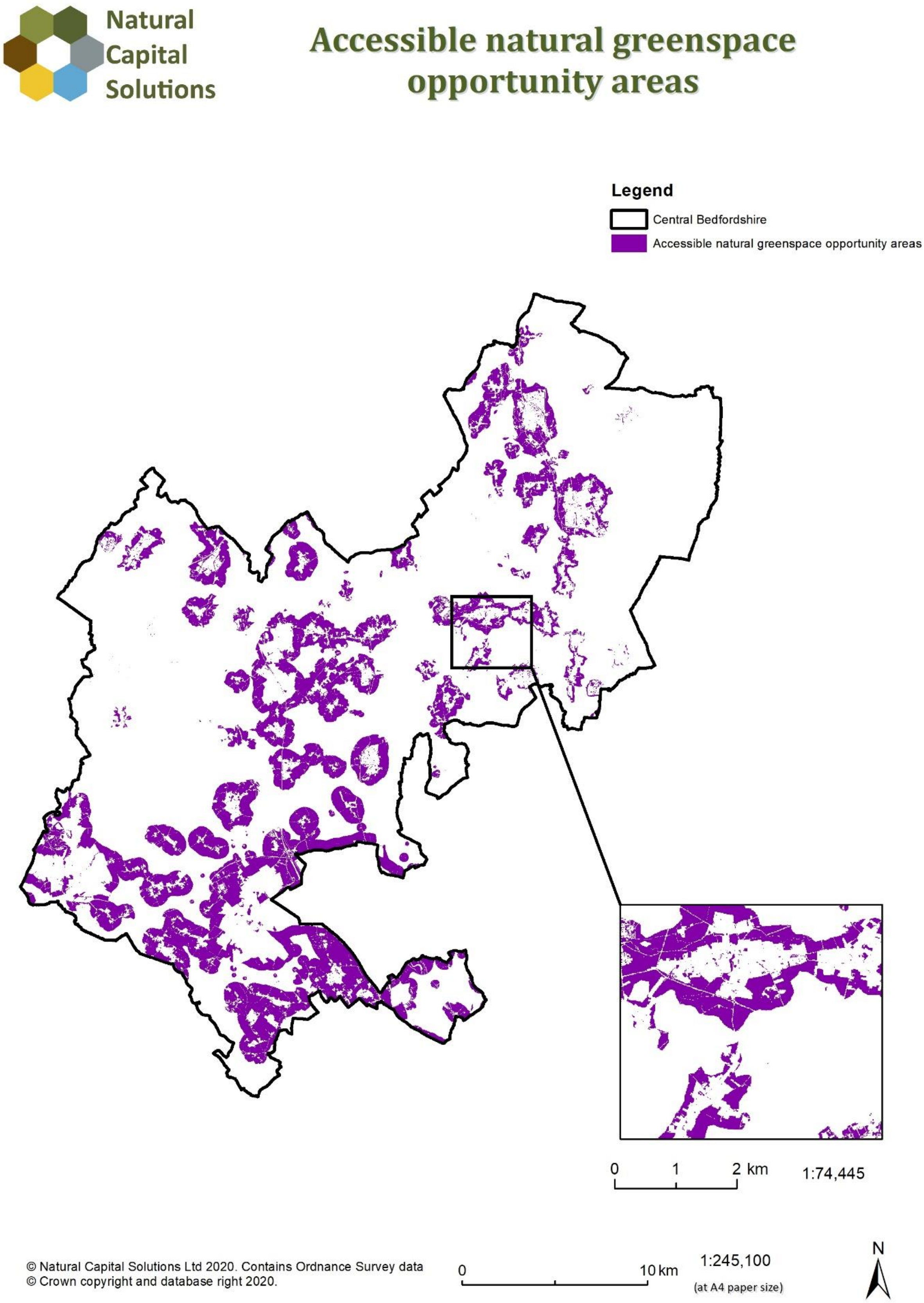

Figure 38 Accessible natural greenspace opportunity areas across Central Bedfordshire.

Natural Capital Solutions

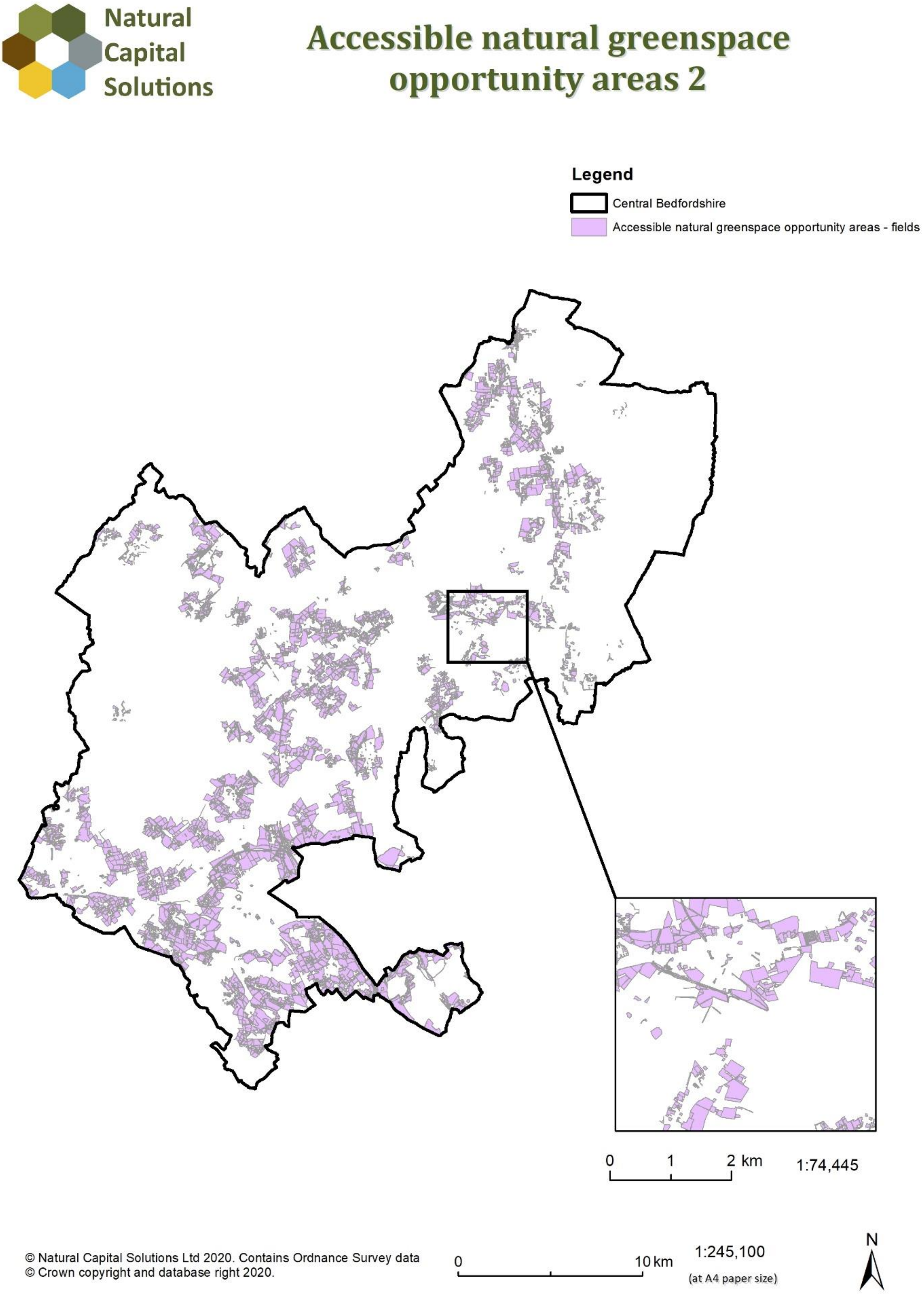

Figure 39 Field (plot) scale accessible natural greenspace opportunity areas across Central Bedfordshire.

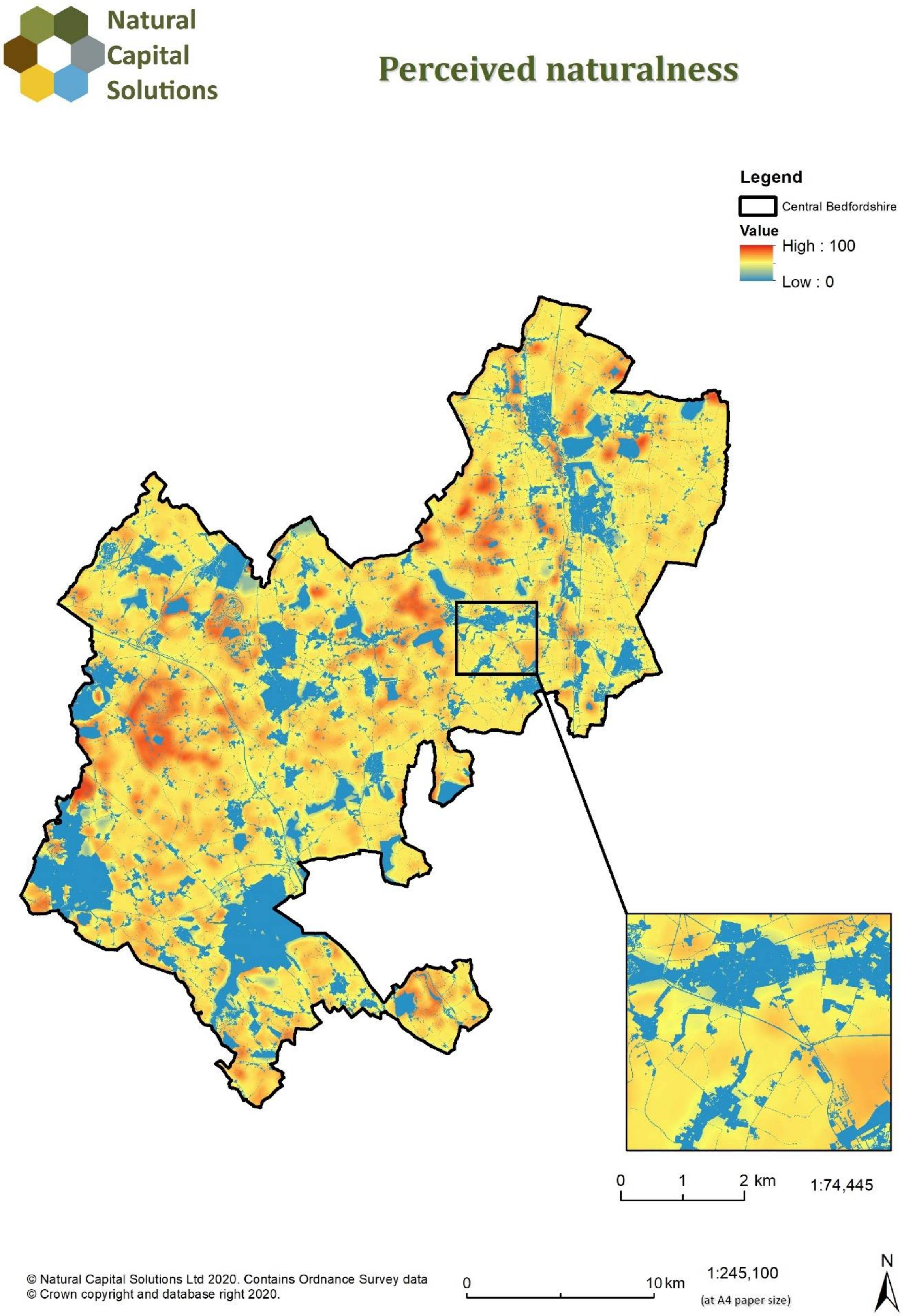

Figure 40 Perceived naturalness of habitats across Central Bedfordshire.

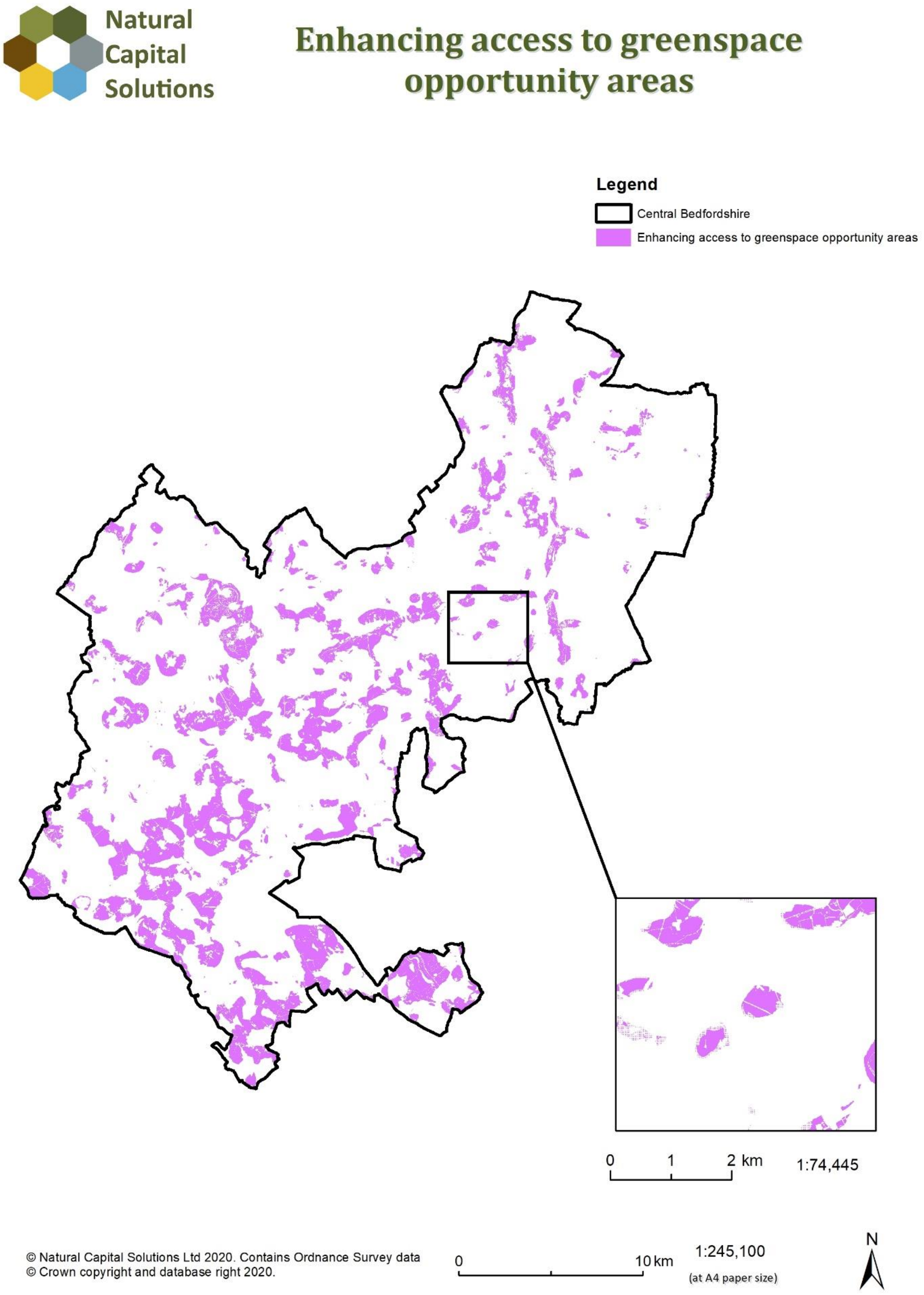

Figure 41 Opportunities for enhancing access to existing natural greenspaces across Central Bedfordshire.

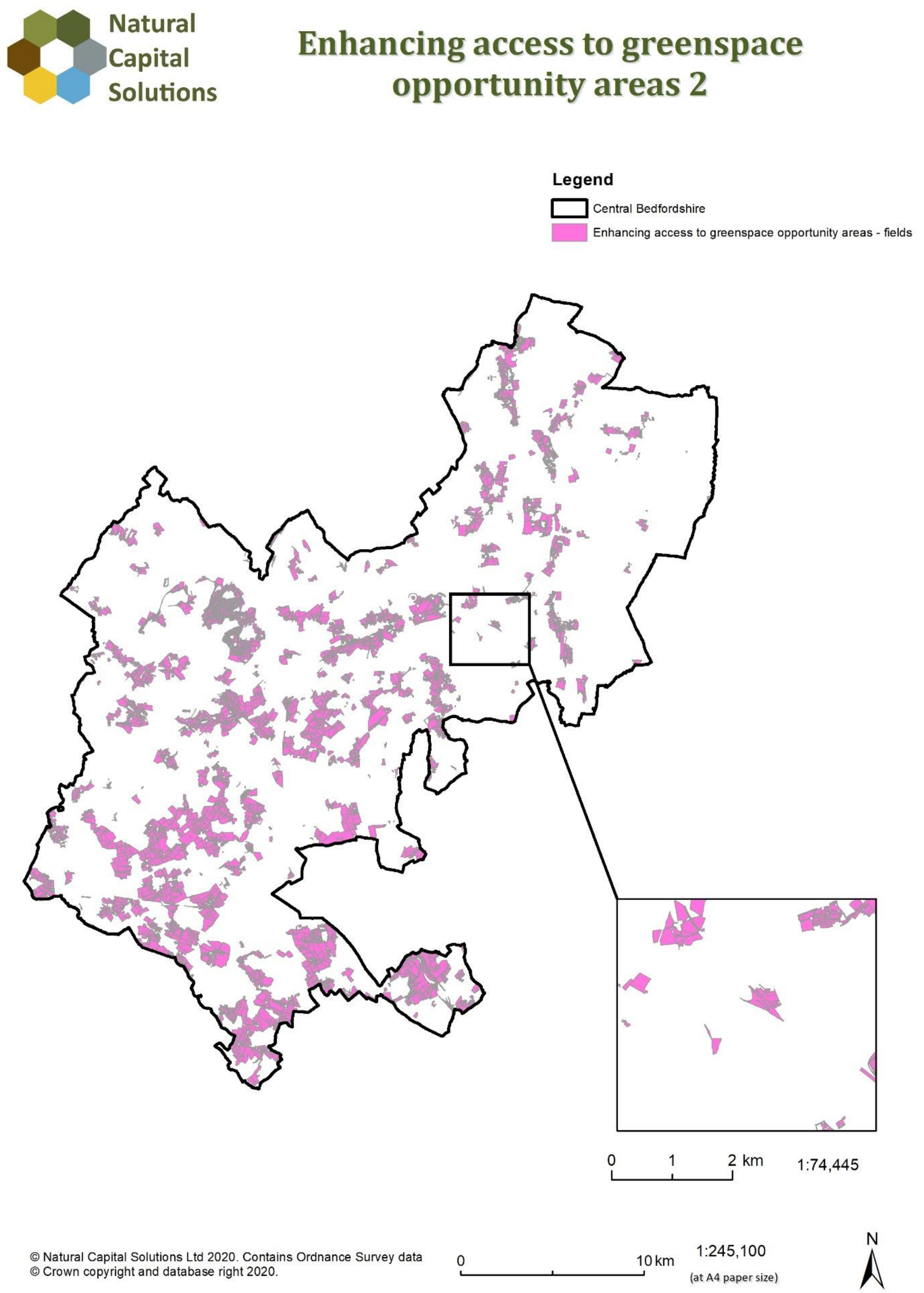

Figure 42 Field (plot) scale Opportunities for enhancing access to existing natural greenspaces across Central Bedfordshire.

7. Combined opportunities for new habitats

In addition to mapping the individual opportunities presented in Sections 6, it is also possible to examine multiple opportunities, which are areas where new habitat can be created that provides opportunities to enhance more than one of the services mapped previously. This is assessed by overlaying each individual opportunity map already created to determine the degree of overlap, examining each of the main habitat types in turn. This is focussing on the top 25% of opportunity areas for each ecosystem service, so is only considering the higher levels of service provision. In reality, creating any new habitat for one ecosystem service is likely to provide benefits for other services, even if this does not fall within the top 25%. We have combined maps in two ways for each habitat:

1. Treating biodiversity opportunities and all ecosystem service opportunities equally, hence all opportunities are included in the final maps.
2. Restricting combined opportunities to areas that present a biodiversity opportunity. Hence opportunities are only included for areas that are ecologically connected to existing habitats. This follows the ethos of environmental net gain being focused on biodiversity net gain first, and then natural capital net gain as an additional feature.

It would also be possible to create maps with different weightings for different services. For example, if stakeholders considered water flow and access to nature as being the most important local priorities, then these opportunities could be given greater weighting. This has not been attempted here, but it would be possible to combine the maps in any way wanted. Note that as the assessment below is concerned with creating new habitats, the opportunity map for accessible natural greenspace based solely on demand (Figure 38), was used rather than the one that examined existing habitats alongside demand (Figure 41).

7.1 Combined opportunities for new broadleaved and mixed woodland

Opportunities to deliver enhancement to water flow, water quality, air quality, noise, and local climate regulation (Sections 6.3-6.7), can all be best achieved through planting trees and woodland, and woodland is also one of the best habitats for creating high quality accessible natural greenspace (Section 6.8). Therefore, the opportunity maps for all of these services were overlain with the opportunity map for biodiversity enhancement through the creation of broadleaved and mixed woodland. Note that creating woodland habitats will also deliver benefits in the form of **carbon sequestration**. These have not been mapped separately as location is not especially important for carbon sequestration (although there will be some difference in the growth rate of trees in different places). Hence all of the locations identified in the maps below would also deliver this service.

The results are shown on Figure 43, which maps the existing areas of broadleaved and mixed woodland and an overlay of all the seven different opportunity areas, and on Figure 44 when constrained to areas that present biodiversity opportunities. The maps highlight the number of different opportunity areas that overlap (out of a maximum of seven) for each 10m by 10m pixel across the study area. The results show that while there are large areas that only offer one opportunity, there are many areas that offer multiple opportunities. Locations at the edges of the main towns are most often highlighted as being able to deliver multiple services on Figure 43. If the aim of woodland creation was to maximise the delivery of as many ecosystem services as possible, then it is these locations that would deliver the greatest benefits to society.

When considering habitat creation for biodiversity as the primary driver (Figure 44), the number of locations is reduced, but there remain many, particularly in the northern half of the county, where existing woodland is common. Areas close to towns and the road network remain the best locations for delivering multiple benefits.

7.2 Combined opportunities for new semi-natural grassland

Creating semi-natural grassland will not be as effective at reducing water flow or enhancing water quality as planting woodland, but it is likely to be significantly better than arable and is likely to enhance the provision of these services. It will not, however, be very effective at ameliorating air pollution, reducing noise pollution, or regulating local climate (although better than sealed surfaces for each of these services). Hence combined opportunities were examined for four out of the seven services: water flow, water quality, accessible natural greenspace, and biodiversity enhancement, while air quality, noise, and local climate regulation were not included.

Combined opportunities for new semi-natural grasslands are not quite as extensive as for woodland, but are still spread across the whole county (Figure 45). Similarly to woodland, there are many areas that support multiple opportunities, with the majority of these being close to the towns. When opportunity areas are restricted to areas that deliver biodiversity benefits for this habitat (Figure 46), opportunity areas are reduced, although still extensive.

7.3 Combined opportunities for new wet grassland and wetlands

Opportunities for new wet grassland and wetlands were mapped in the same way as for semi-natural grassland, except that all opportunities were restricted to areas within the indicative floodplain. Thus four out of the seven services were included, with air quality, noise, and local climate excluded. Wetland habitats can be effective at reducing water flow and enhancing water quality.

The location of opportunities for this habitat type is far more restricted than for the previous two (Figure 47), due to the requirement for being located on floodplains. The river networks across Central Bedfordshire offer some opportunities, with the majority occurring on the floodplain of the River Ivel and its tributaries. When considering opportunities close to existing habitats (Figure 48), there are very few opportunity areas.

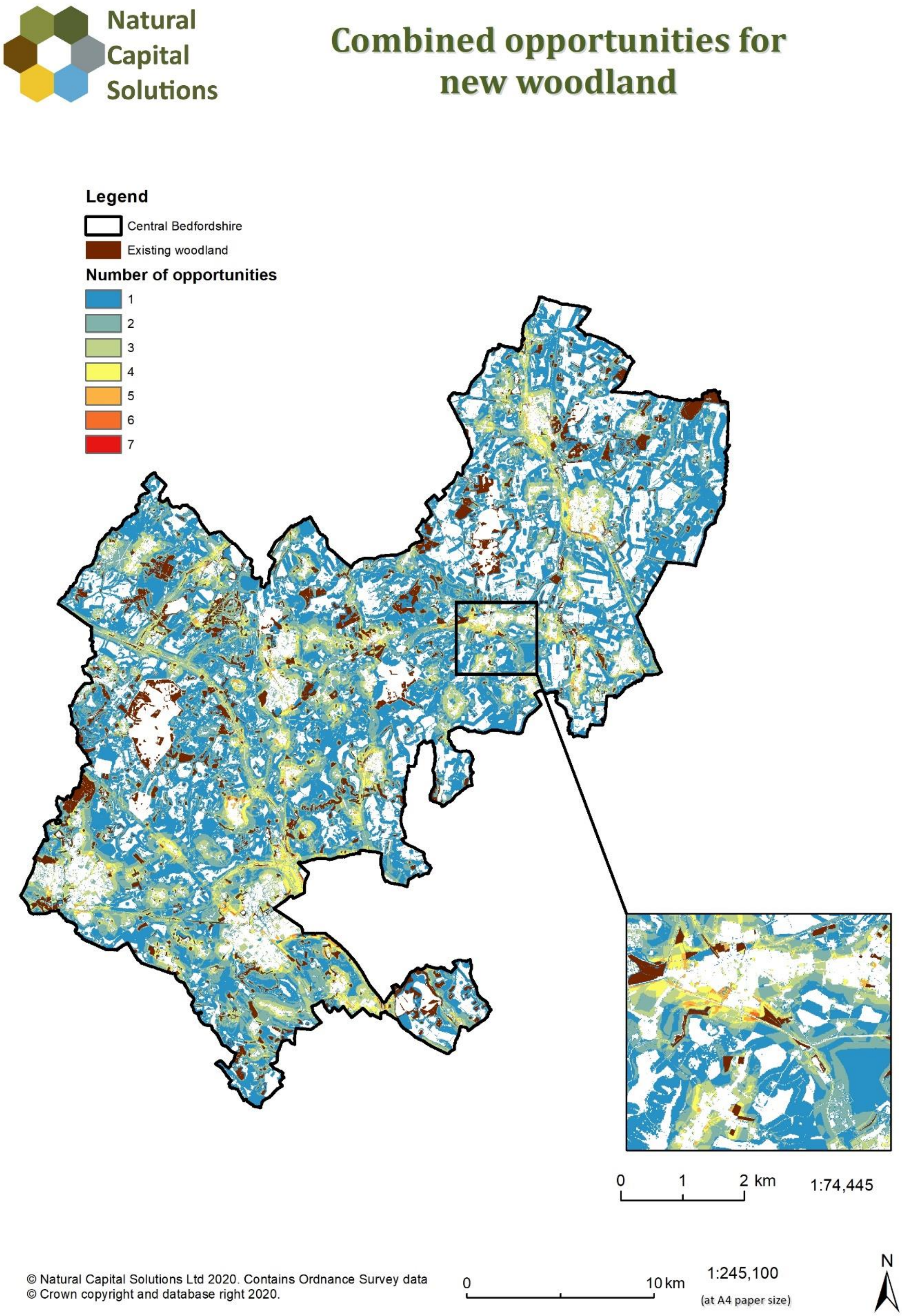

Figure 43 Existing broadleaved and mixed woodland, and combined opportunities for new woodland, across Central Bedfordshire.

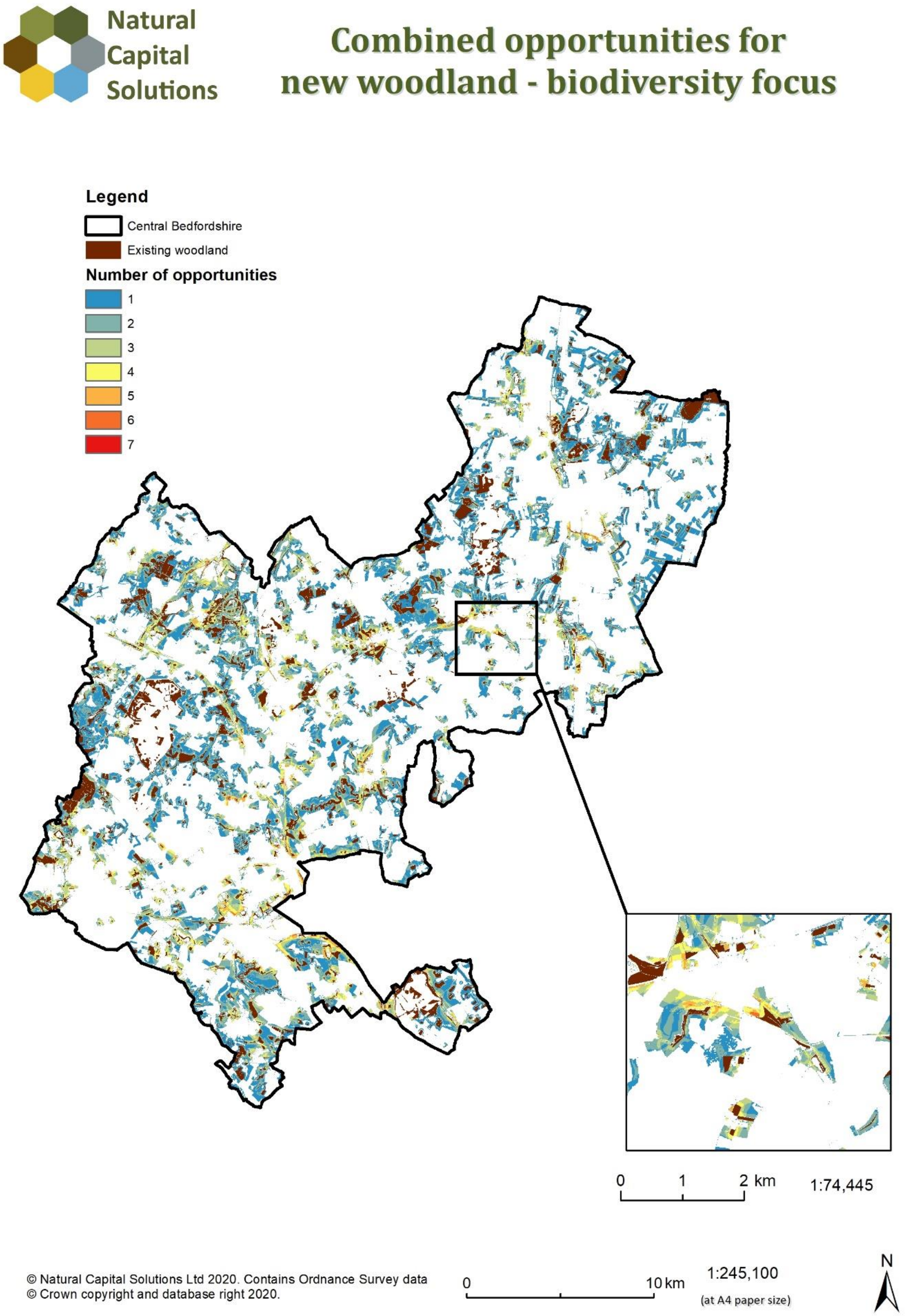

Figure 44 Combined opportunities for new woodland across Central Bedfordshire, restricted to areas that are ecologically connected to existing woodlands.

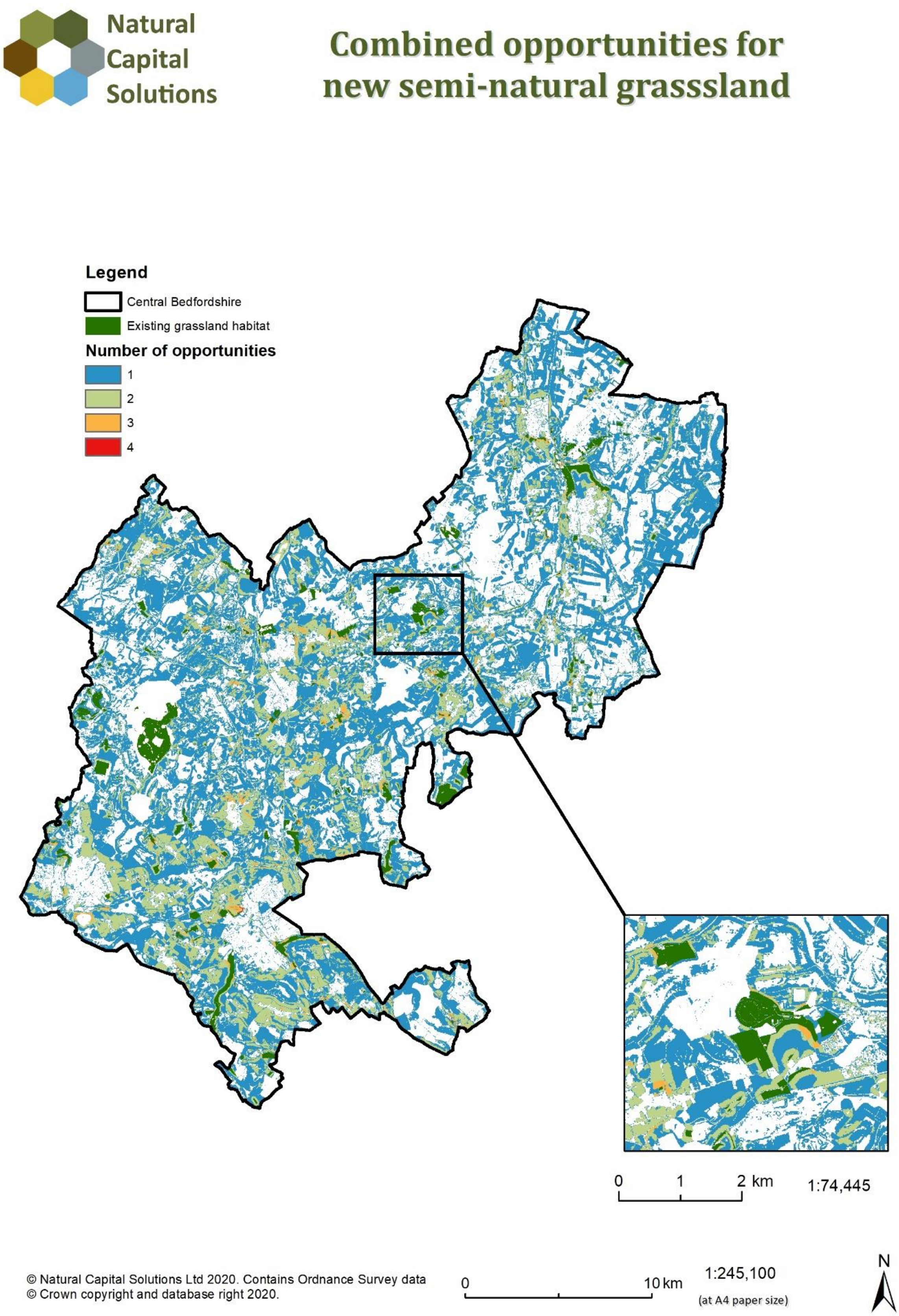

Figure 45 Existing semi-natural grasslands, and combined opportunities for new grasslands, across Central Bedfordshire.

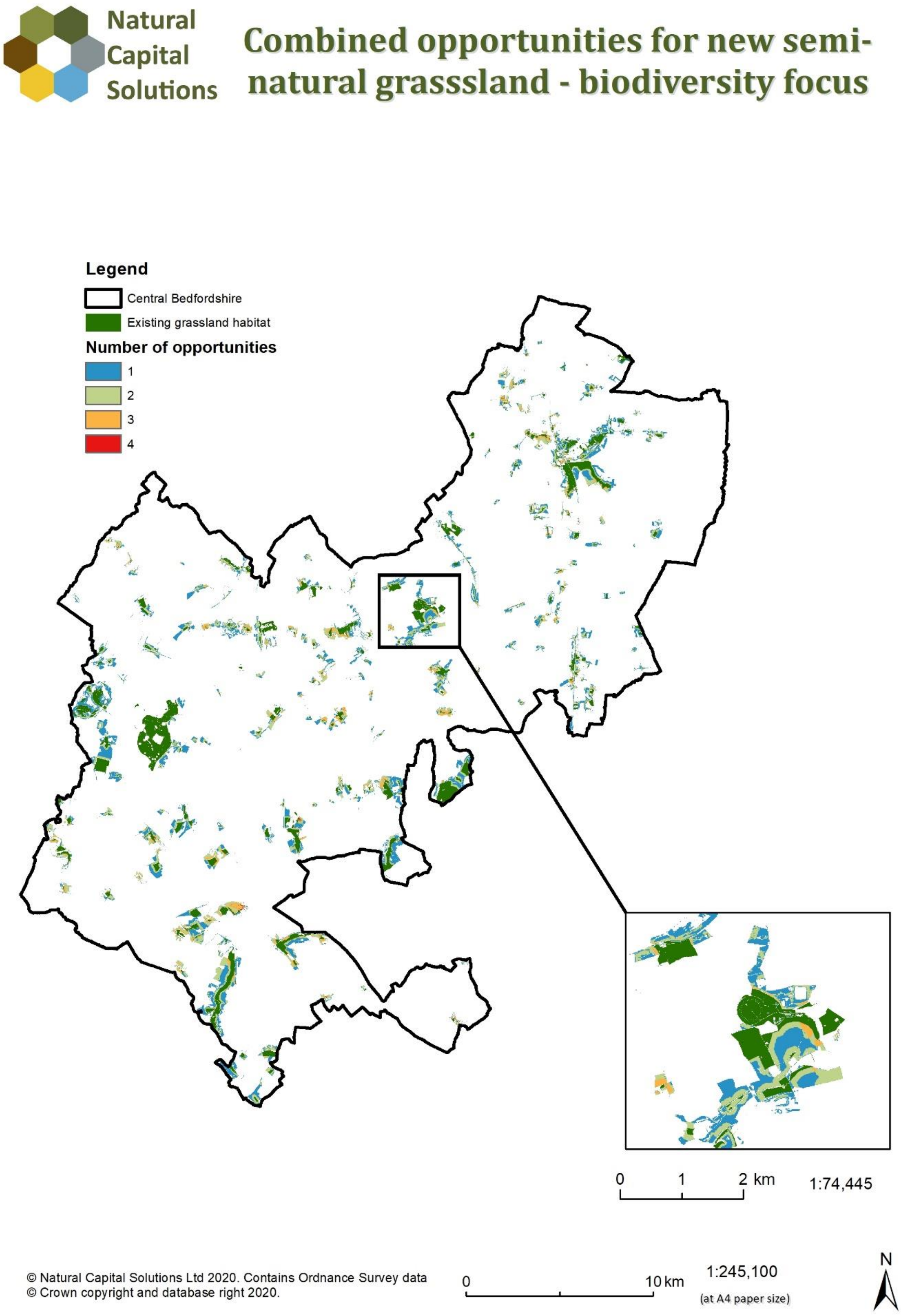

Figure 46 Combined opportunities for new semi-natural grasslands across Central Bedfordshire, restricted to areas that are ecologically connected to existing grasslands.

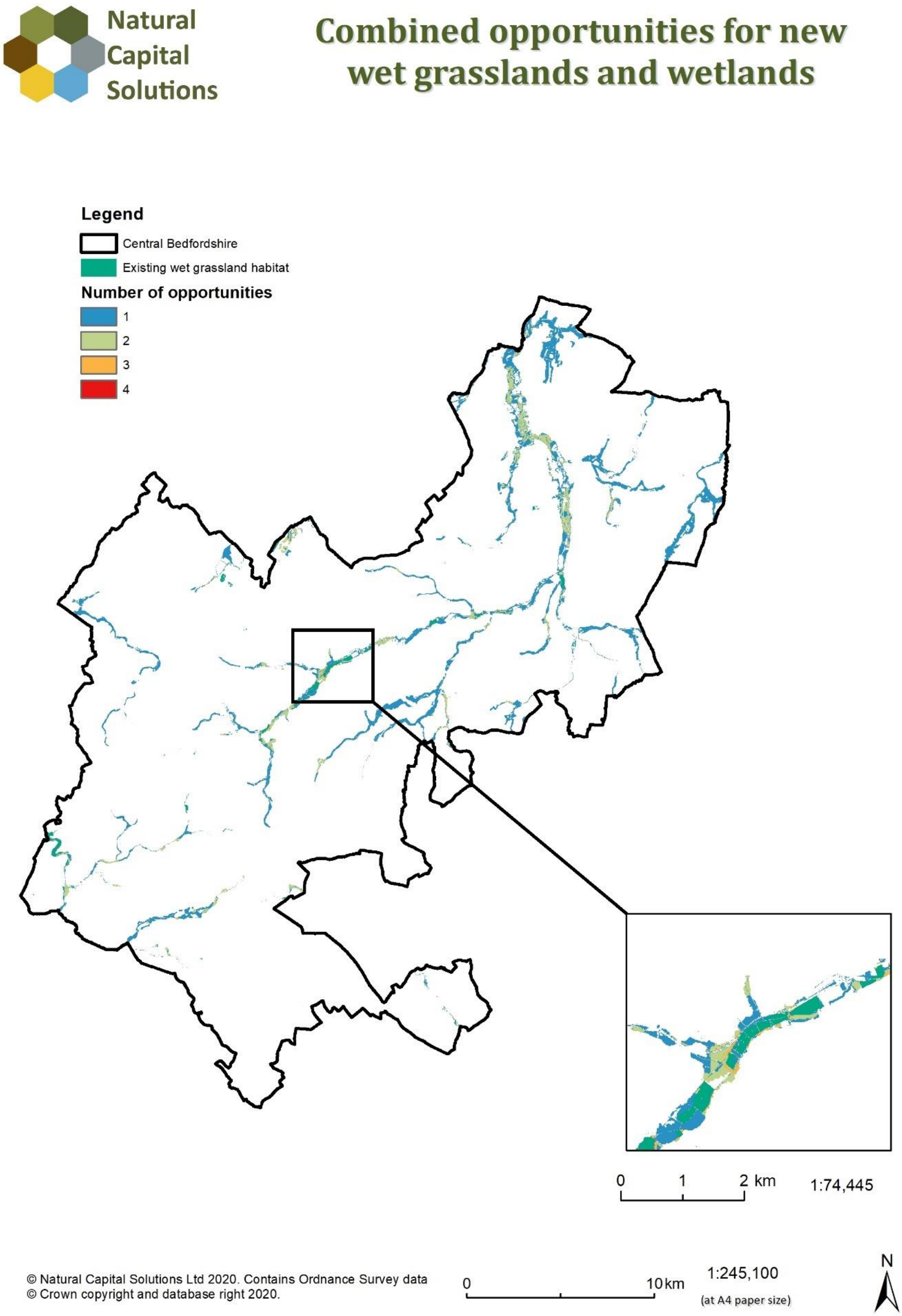

Figure 47 Existing wet grasslands and wetlands, and combined opportunities for new wetlands, across Central Bedfordshire.

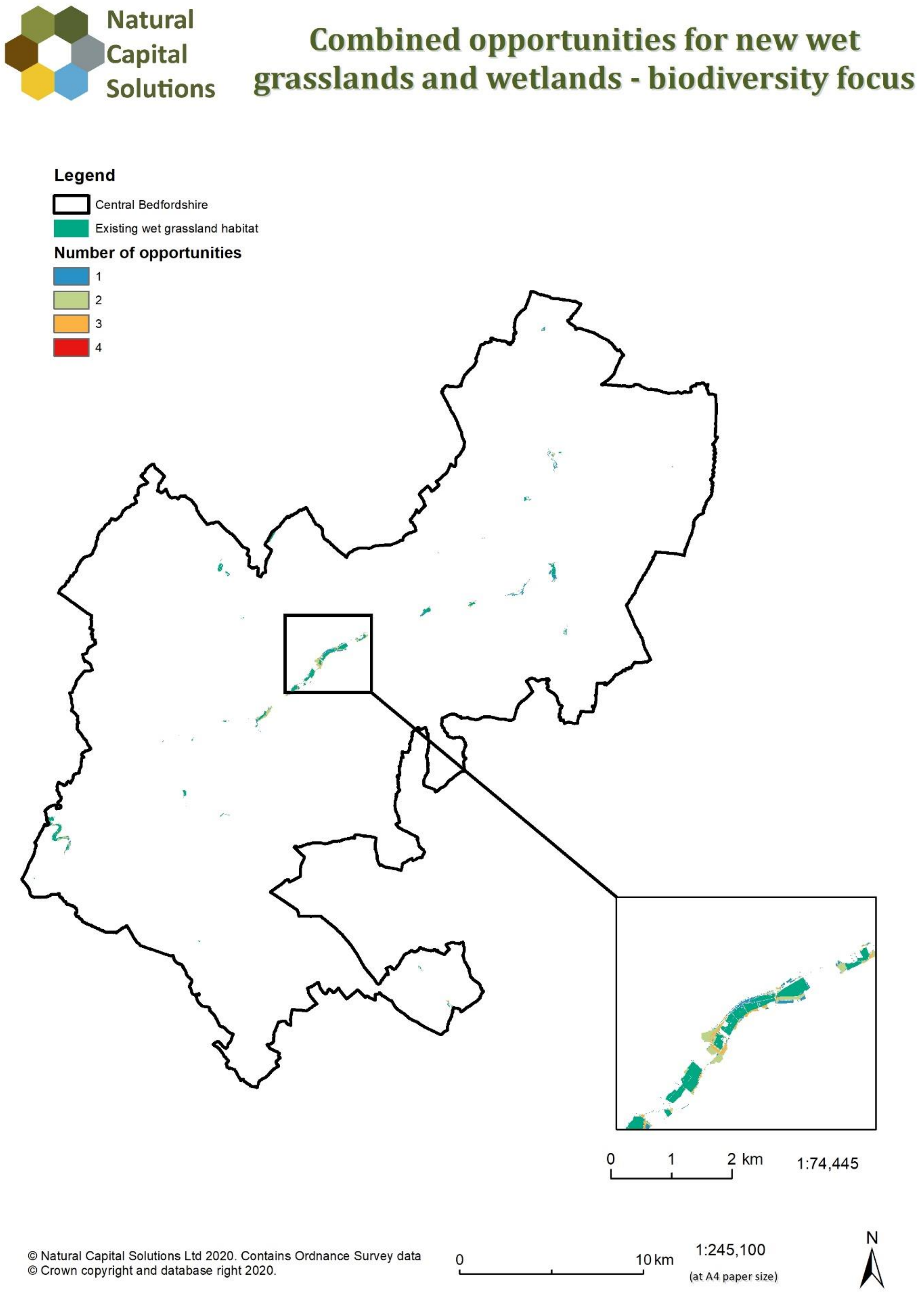

Figure 48 Combined opportunities for new wet grasslands and wetlands across Central Bedfordshire, restricted to areas that are ecologically connected to existing wetlands.

8. Conclusions

This project has produced a detailed habitat basemap using the best available data to assign Phase 1 habitat types to each plot of land and building across Central Bedfordshire (and for the whole of Bedfordshire). It provides the most comprehensive and detailed coverage that is possible at this time and should have a wide range of applications. Central Bedfordshire is dominated by arable land and improved grassland, but there are also significant areas of woodland in the Northern half of the area, predominantly along the Greensand Ridge. Tree and woodland categories take up 10.5% of Central Bedfordshire. Semi-natural and marshy grassland take up 2.8% of the area. Built up areas, infrastructure and gardens make up a combined 11.8% of the area.

The ecosystem service maps demonstrate the spatial pattern of provision of ten different ecosystem services, and the demand for four. The maps demonstrate that the woodland asset is important for high levels of provision of carbon storage, carbon sequestration, air quality, noise, local climate, and water flow regulation and timber/woodfuel production benefits. The mapping also shows that many of these woodlands provide hotspots of access to nature. Ecosystem delivery is greatest in the northern half of the area, where the majority of the larger woodlands are located, but is still high in pockets in other locations. Food production is greater in the east.

The demand maps of air quality, noise, local climate regulation and accessible nature show clearly the importance of ecosystem service delivery to the urban centres in Central Bedfordshire. Urban areas adjacent to the road network are also hotspots for demand. The capacity to provide these services is often quite high around urban areas in Central Bedfordshire, where woodland and other semi-natural habitats occur, and these areas should be protected and expanded, even if not important for biodiversity.

The monetary value of the benefits provided by natural capital are large: £100 million per annum across Central Bedfordshire, representing an asset value (present value) of £3.20 billion over 50 years. Benefits in terms of air quality regulation, recreation and physical health are particularly large. When carbon sequestration is balanced against agricultural emissions, Bedfordshire as a whole is a net emitter of carbon dioxide of 12,500 tonnes per year, at a cost of £0.87 million annually.

An assessment of Accessible Natural Greenspace Standards (ANGSt) has shown that Central Bedfordshire has a reasonably good provision of greenspaces. Overall, 80% of residents across the Borough live within 2km of a 20 ha site and 89% live within 5km of a 100 ha site. However, only 31% of people live within 300m of a small greenspace (at least 2ha in size) and there are no large greenspaces over 500 ha in size in the area. Creating new accessible greenspaces should therefore focus on creating small neighbourhood greenspaces and on expanding existing sites to create large flagship site(s).

Habitat opportunity maps have been created showing where new habitats could be created for biodiversity enhancement for three broad habitat types, as well as for six different ecosystem services. Note, however, that the maps have not been ground-truthed or checked against other data, and so individual locations will need to be assessed further before being taken forward. The maps should be considered as a resource to highlight potential locations for habitat creation or restoration projects, rather than as an end in themselves. The maps are best examined on a Geographic Information System, and GIS layers have been provided.

The opportunity maps for biodiversity highlight areas that are best located in terms of their connectivity with existing habitat patches and are, therefore, most appropriate from an ecological point of view. Enhancing connectivity and expanding habitat networks is a key priority for biodiversity conservation and climate change adaptation at present, and these maps can be used as the basis for creating nature recovery networks across the county. They also highlight areas where biodiversity offsetting should be focussed, under the new requirement to achieve biodiversity net gain for all new developments. Furthermore, the opportunity maps for ecosystem services highlight the best areas to create habitats to enhance the delivery of each ecosystem service in turn, based on where demand is high and capacity is currently low. These can be used to identify project locations to meet each particular need or can be combined to show areas where new habitat can deliver multiple objectives. If combined with the biodiversity opportunity maps, they can be used in offsetting project to deliver additional benefits. Access to greenspace for people can be highly beneficial for physical and mental health and well-being and the monetary value of these benefits can be extremely high. Habitats for biodiversity and green infrastructure (GI) in general can also make important contributions to all the other ecosystem services mapped in this report. Semi-natural habitats are multi-functional, meaning that an investment focussing on one benefit (e.g. natural flood risk management), can deliver multiple additional benefits, hence offering excellent value for money.

8.1 Next steps

The maps and GIS layers produced for this project provide an extensive evidence base with a wide range of potential applications. The layers can also be combined in a wide variety of different ways, depending on the issue being addressed, the key priorities, and the location. Hence it would be possible to present the results in a number of different ways and there would be merit in producing different outputs for different audiences. There are a number of possible projects that could be developed to take this work forward. These include dissemination of results, mapping habitat quality, refining the most promising areas to take forward, and completion of a Natural Capital Investment Plan. These ideas are described in more detail in the main Bedfordshire report.

Annex 1: Additional biodiversity opportunity maps

Natural Capital Solutions

Landscape permeability: Broadleaved and mixed woodland species

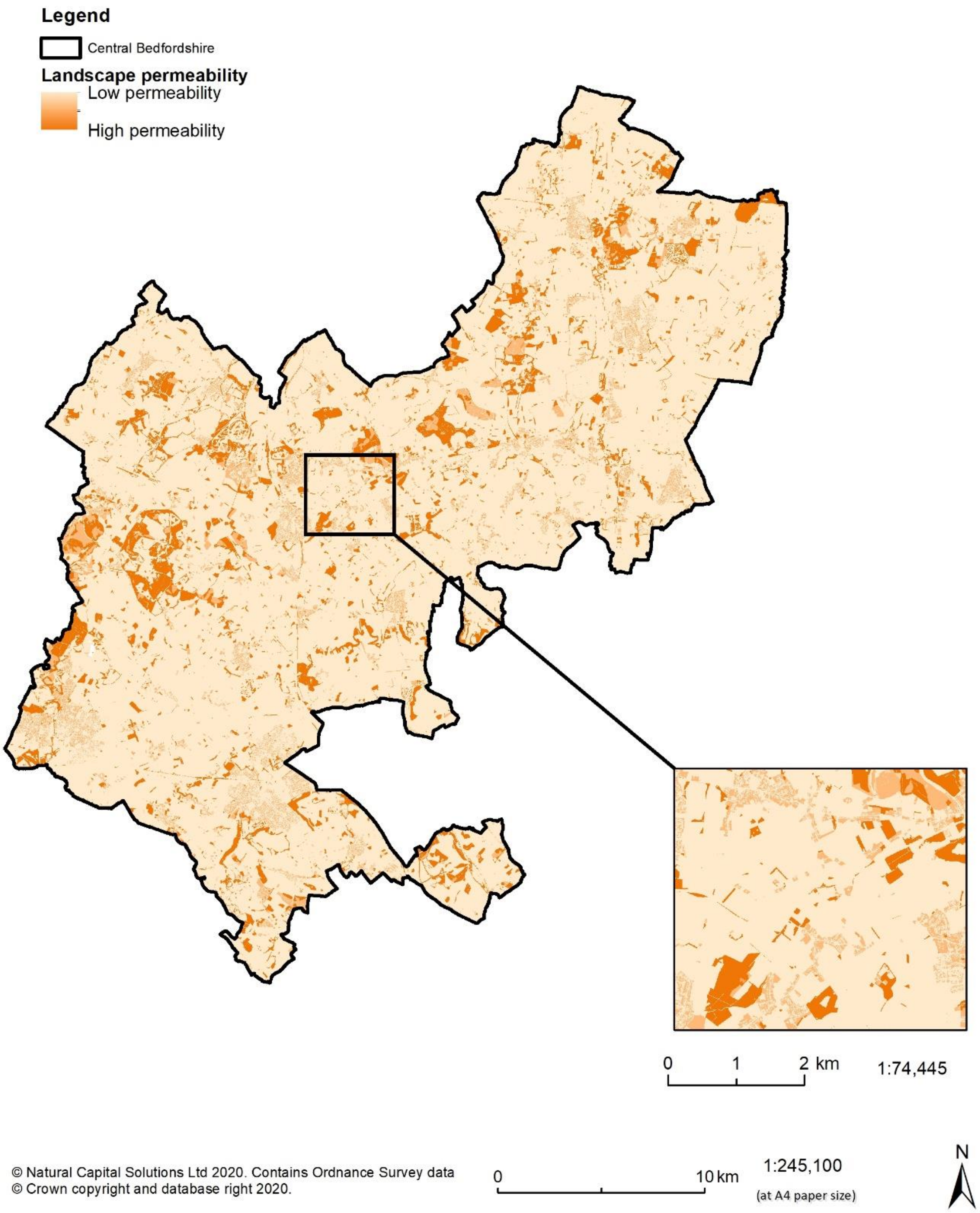

Figure A1 Landscape permeability for typical broadleaved and mixed woodland species across Central Bedfordshire.

Natural Capital Solutions

Broadleaved and mixed woodland habitat network

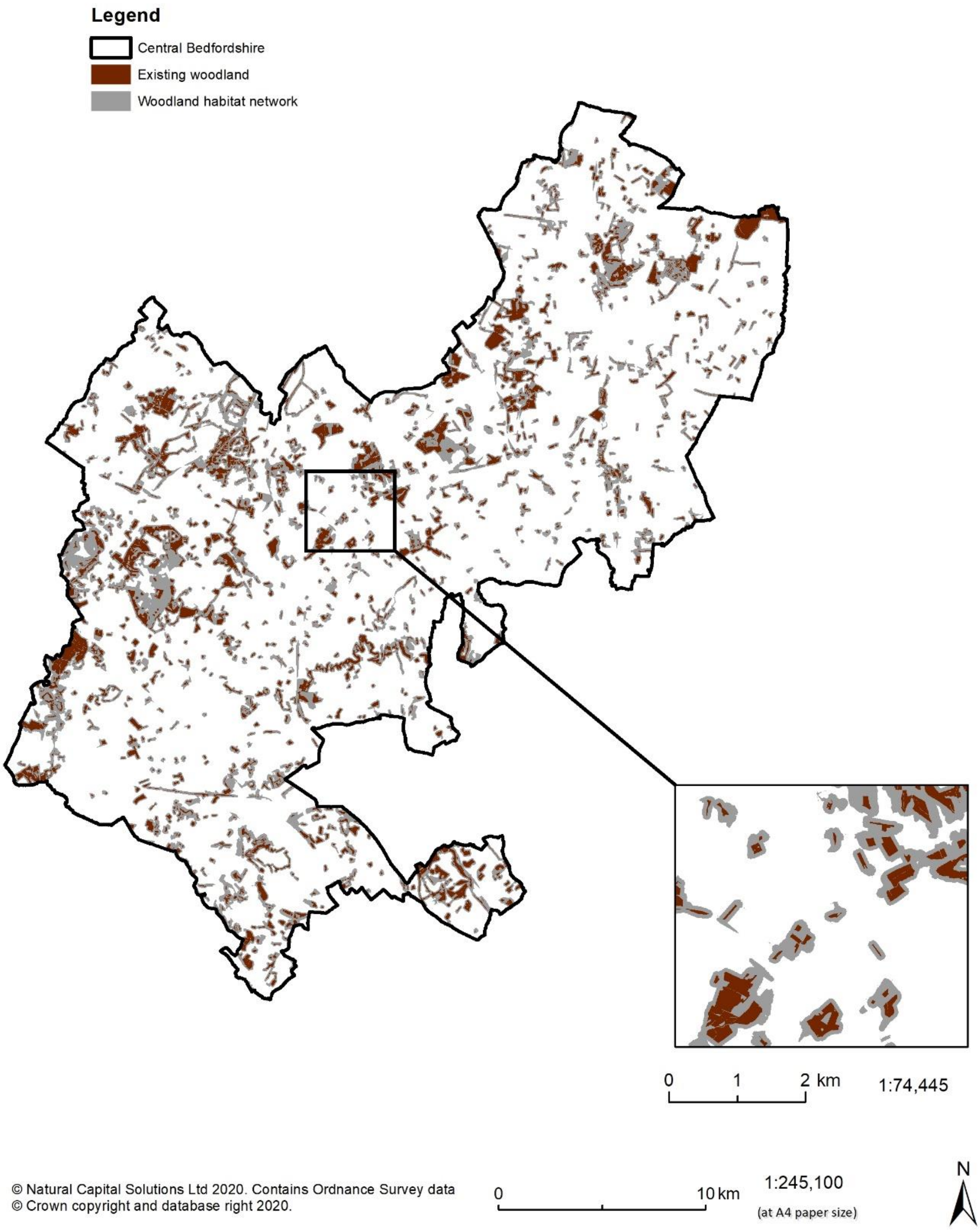

Figure A2 Habitat network for broadleaved and mixed woodlands across Central Bedfordshire.

Natural Capital Solutions

Broadleaved and mixed woodland habitat opportunity 1

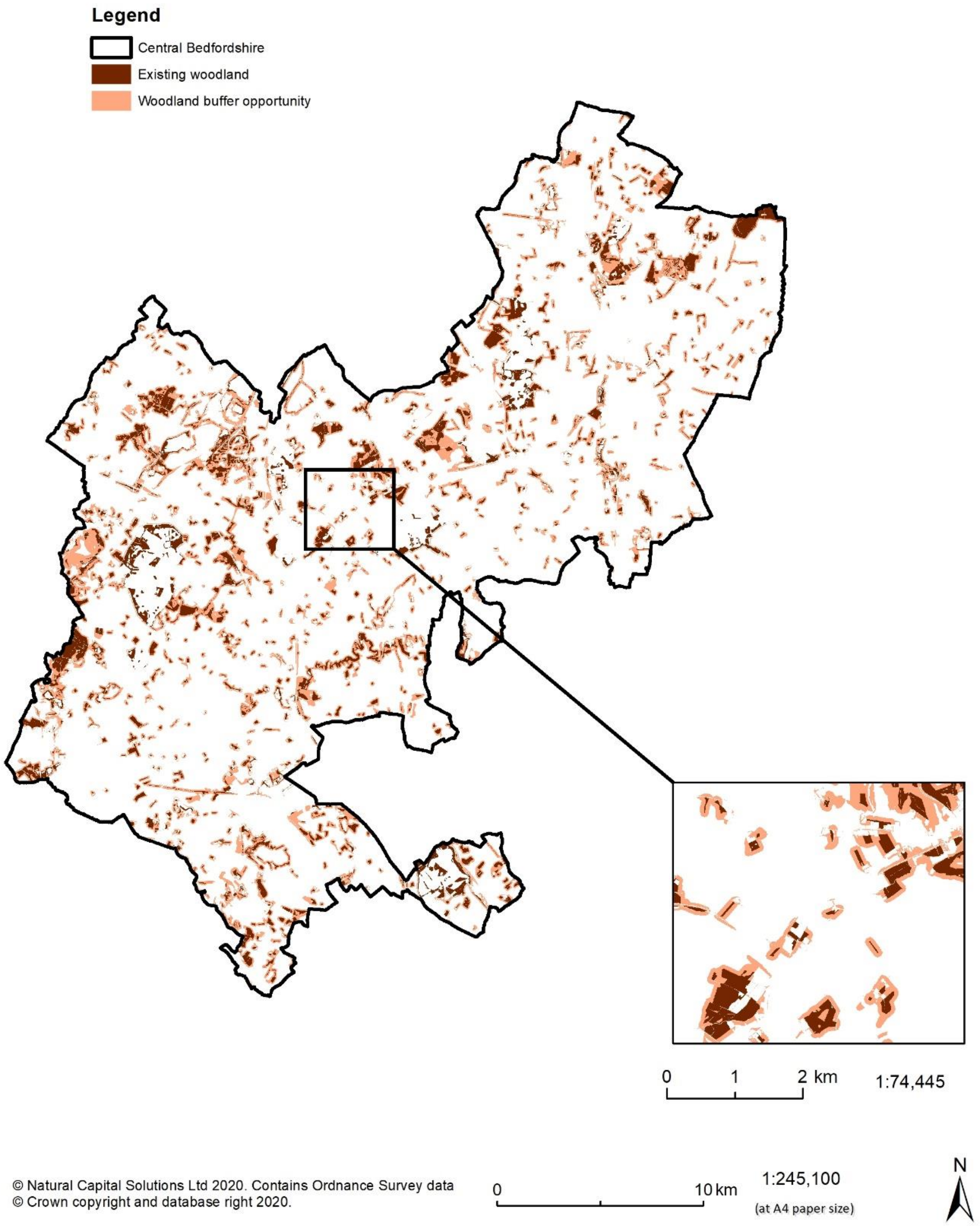

Figure A3 Buffer biodiversity opportunity areas for broadleaved and mixed woodlands across Central Bedfordshire.

Natural Capital Solutions

Broadleaved and mixed woodland habitat opportunity 2

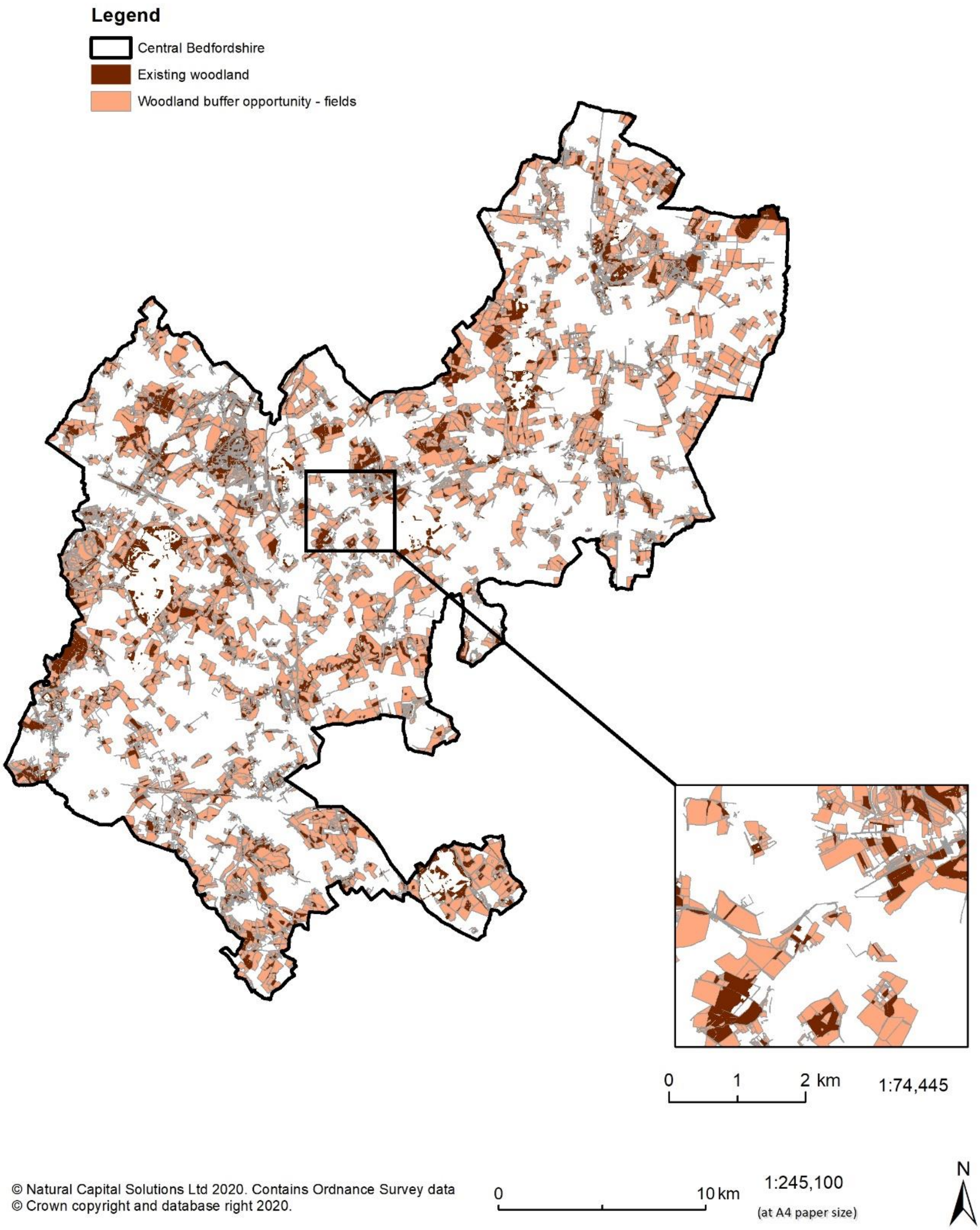

Figure A4 Field scale biodiversity opportunity areas for broadleaved and mixed woodlands across Central Bedfordshire.

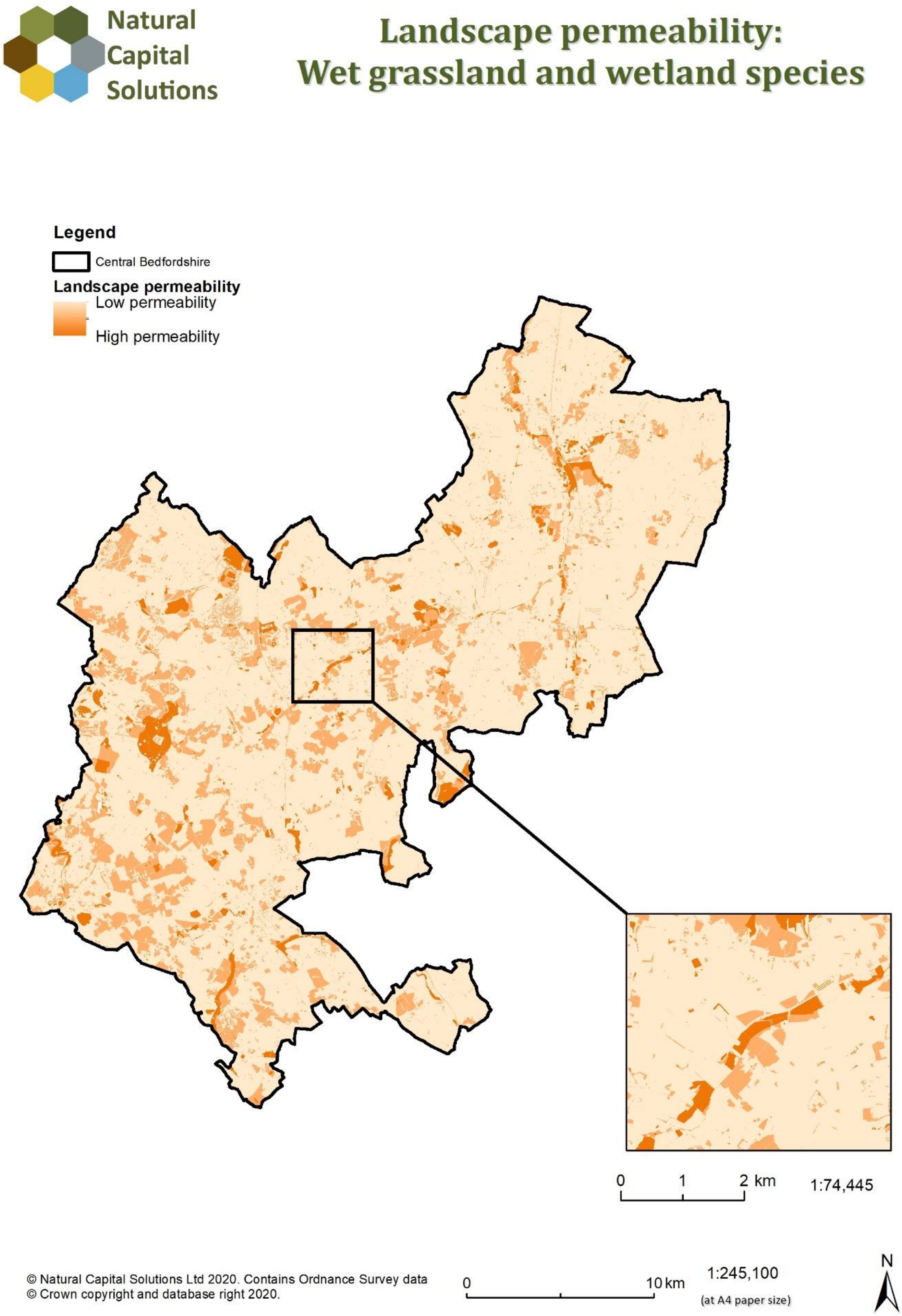

Figure A5 Landscape permeability for typical wet grassland and wetland species across Central Bedfordshire.

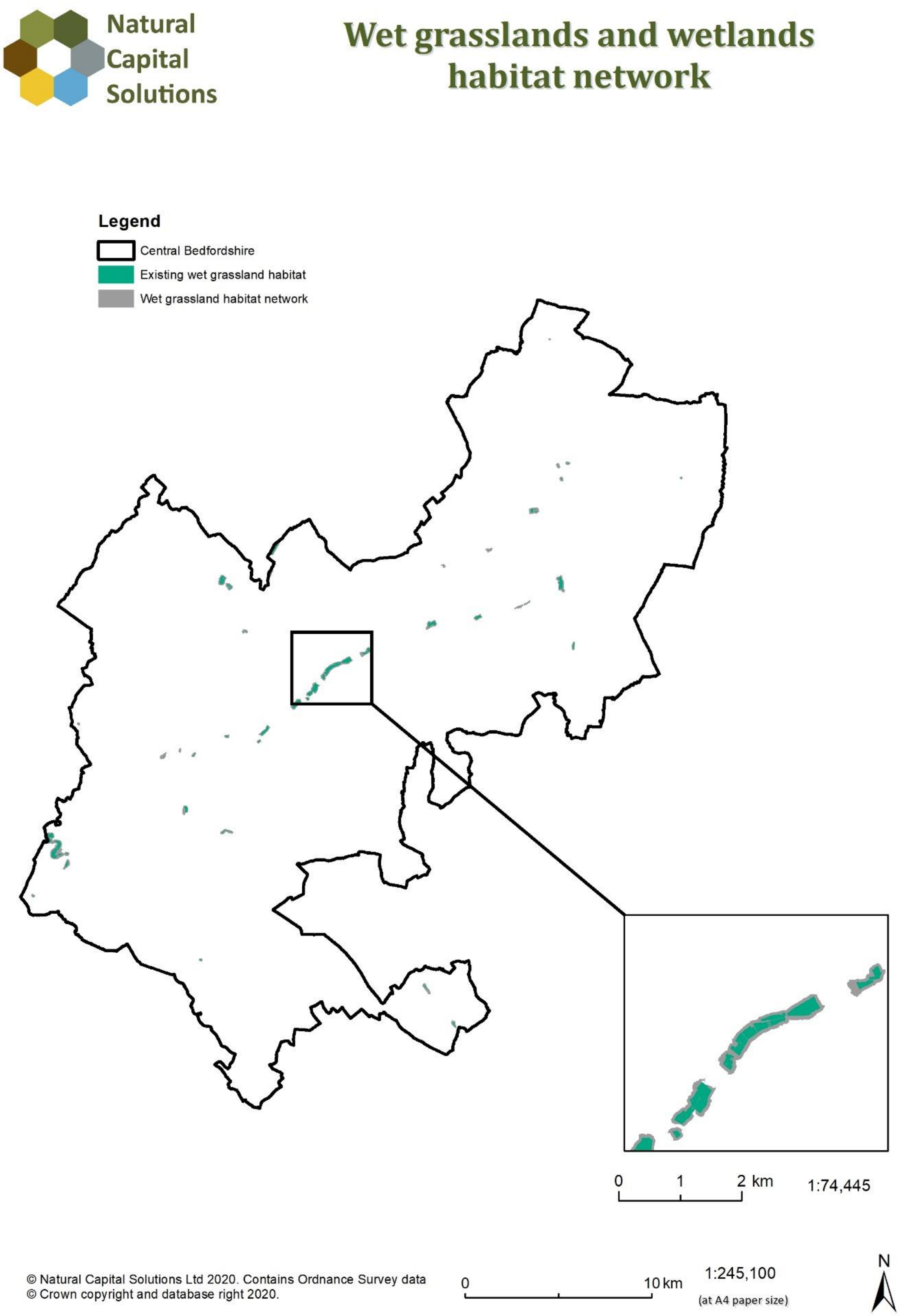

Figure A6 Habitat network for wet grassland and wetlands across Central Bedfordshire.

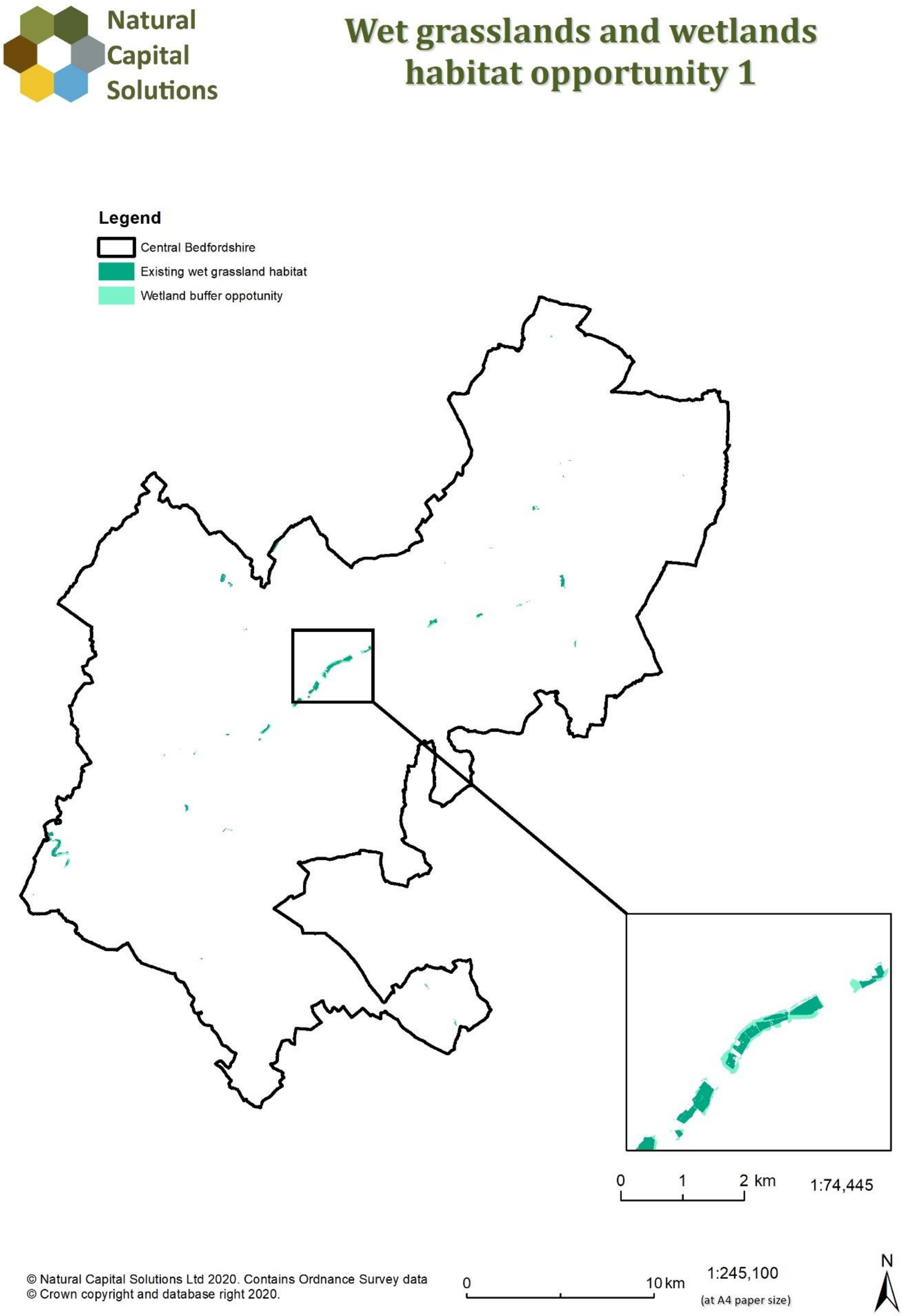

Figure A7 Buffer and stepping-stone biodiversity opportunity areas for wet grassland and wetlands across Central Bedfordshire.

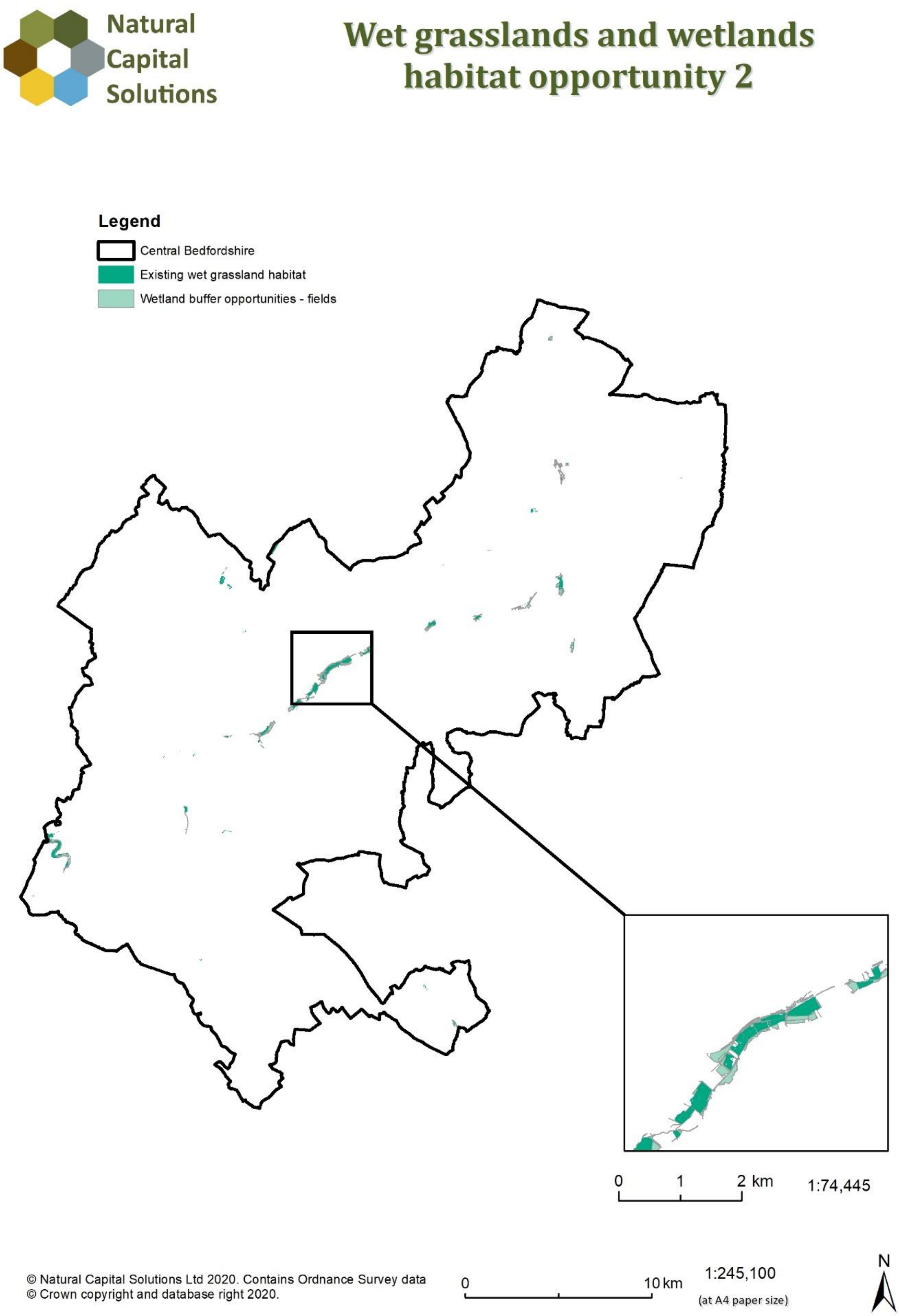

Figure A8 Field scale biodiversity opportunity areas for wet grassland and wetlands across Central Bedfordshire.

Annex 2: Opportunities to expand ancient woodland sites

Introduction

Ancient woodland is woodland that has been in existence since at least 1600 and represents the most important and biodiverse woodland sites in the UK. There are two types of ancient woodland identified: ancient semi-natural woodland (ASNW) and plantations on ancient woodland sites (PAWS), which are locations where the original tree cover has largely been felled and replaced by plantation forestry, but understory flora and abiotic conditions often remain similar to that of ancient semi-natural woodland and are sites that can be readily returned to a more natural state. In this Annex, we present opportunities for woodland expansion around ancient woodland sites, which can be compared to wider opportunities around all broadleaved and mixed woodland areas, as described in Section 6.2.

Approach

To identify ancient woodlands, we used the Ancient Woodland Inventory, published by Natural England, which highlights all ancient semi-natural woodland (ASNW) and plantations on ancient woodland sites (PAWS). Opportunity mapping was then completed in the same way as described in Section 6.2 (full details in the main Bedfordshire report), but restricting source woodlands to ancient woodland sites only. In addition to identifying buffer opportunities (locations immediately adjacent to exiting sites), we also identified stepping stone opportunities. These are potential sites that fall outside of the ecological network, but are immediately adjacent to it and could potentially be used to create stepping-stone habitats that could link up more distant habitat patches.

Results

Central Bedfordshire contains 1,795 ha of ancient woodlands, consisting of 941 ha of ancient semi-natural woodlands and 853 ha of plantations on ancient woodland sites (Table A1). Together these occupy 2.5% of the land area. The majority of the ancient woodland lies within the Greensand Ridge, a distinctive area of sand and sandstone that forms a ridge between the clay vales of lowland Bedfordshire, to the south of Bedford, with some patches in the Chilterns at the southern edge of Central Bedfordshire. Woodland cover as a whole was shown in Table 1 and occupies 5,927 ha or 8.2% of the area. Ancient woodlands therefore make up approximately 30% of the woodland resource across the area, although only about half of these are ancient semi-natural woodlands. Note that although all the ancient semi-natural woodlands will be broadleaved woodlands, several of the PAWS sites are coniferous woodland, therefore, the ancient woodlands are not a subset of the broadleaved woodland category. The ancient woodlands are mapped in Figure A9.

Table A1 Area and percentage cover of ancient woodland across Central Bedfordshire.

Broad habitat	Area (Ha)	% cover
Ancient semi-natural woodlands (ASNW)	941	1.3
Plantations on ancient woodland sites (PAWS)	853	1.2
Total ancient woodlands	**1,795**	**2.5**

Opportunities to expand ancient woodlands are shown in Figure A9. Opportunities exist across the Greensand Ridge and in the Chilterns to the south, and will be particularly effective at joining together sites that are currently relatively close together but are disconnected. In some locations creating these opportunities will create quite large networks of sites. Note that Figure A9 shows the field scale opportunities – whole fields that present opportunities and fall within an opportunity zone, with buffer opportunities identified adjacent to existing sites, and stepping-stone opportunities identified slightly further away.

Figure A4 shows field scale buffer opportunity areas for the wider broadleaved and mixed woodland resource, not limiting the analysis to ancient woodland, and shows that extensive opportunities are present across the area. Woodland is currently spread right across Central Bedfordshire, but is rather scattered into lots of fairly small patches. Woodland creation based on the opportunity maps could increase the connections between these woodland patches, to create a much larger, more resilient network.

Conclusion

Central Bedfordshire contains a number of ancient woodland sites, predominantly across the Greensand Ridge and in the Chilterns, within a larger network of woodland. The ancient woodland patches are largely ecologically isolated from each other. Opportunity mapping has identified locations where new woodland could be created to enlarge existing ancient woodland sites and to start to connect sites, thereby increasing the ecological resilience of the network. Opportunities have also been mapped for the wider broadleaved and mixed woodland network (described in section 6.2), which offers opportunities to expand woodland cover and increase connections across the area.

In terms of priorities for woodland conservation across Central Bedfordshire, we would recommend the following (in priority order):

1. Explore options for restoration of PAWS sites wherever possible. These are locations that occupy ancient woodland sites and often still contain ancient woodland flora, mycorrhizal (fungal) communities and abiotic conditions that could help to establish ecologically rich sites following careful management.
2. The opportunity areas identified around existing ancient woodland sites (Figure A9), represent the priority locations for new woodland creation as these can be used to expand, buffer and join together existing sites. This will increase the resilience of the existing network and enable it to better withstand pressures caused by climate change and other factors. They can also be used to provide recreational opportunities in woodland, thereby reducing impacts on any sensitive ancient woodland sites.
3. Opportunity mapping around the wider network of broadleaved and mixed woodland (Figure A4) has identified a series of locations of secondary importance for habitat creation. Many of these locations could still be important for expanding woodland cover, enhancing connectivity, and delivering a range of ecosystem services, so would be worthy of further investigation, but are less important from an ecological perspective compared to the above.

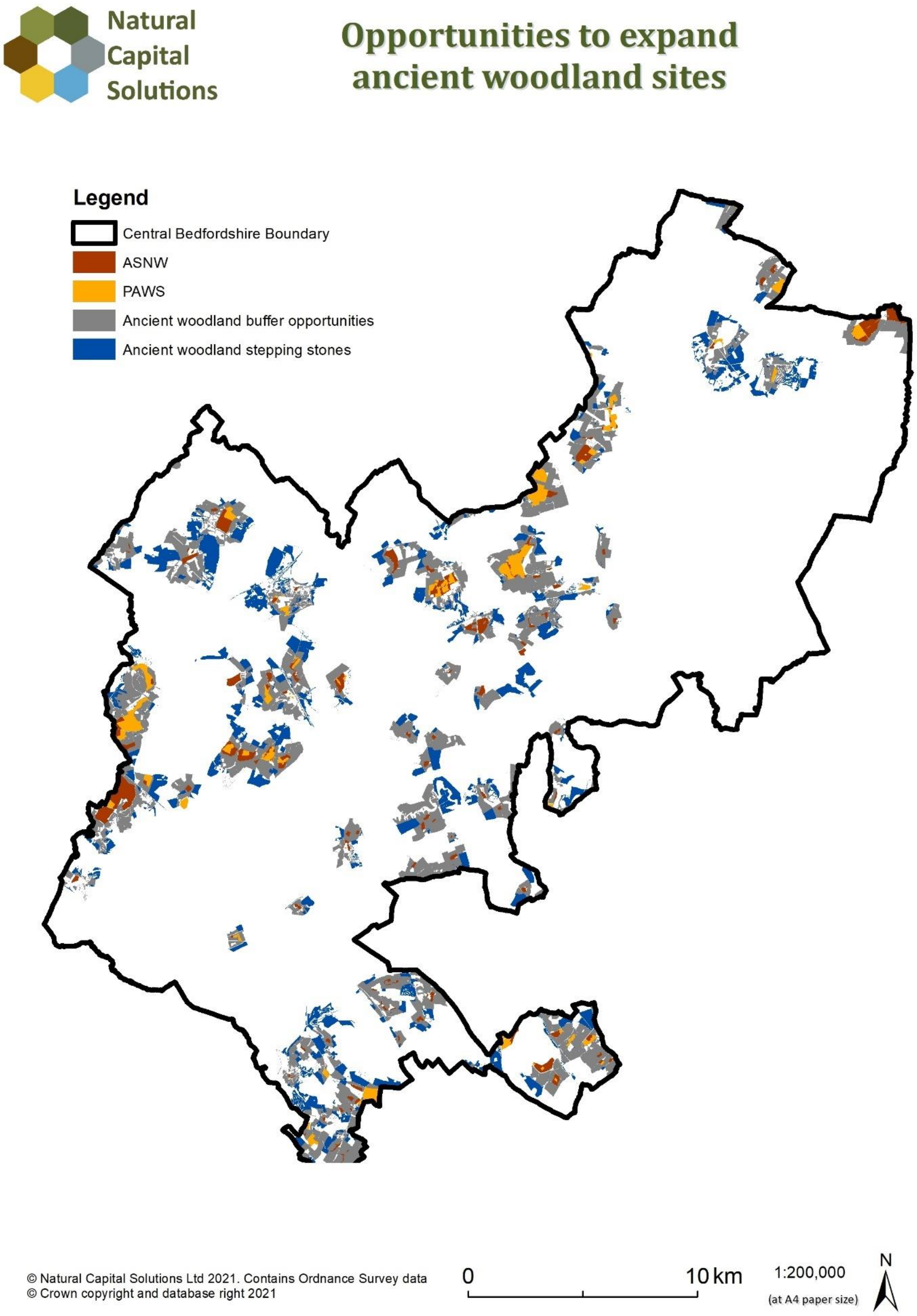

Figure A9 The location of ancient woodlands across Central Bedfordshire and field-scale opportunities to expand these habitats. ASNW are ancient semi-natural woodlands and PAWS are plantations on ancient woodland sites.