# Mapping natural capital, ecosystem services and opportunities for habitat creation in Buckinghamshire


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# Executive Summary

This report describes a project to produce a detailed natural capital (habitat) basemap for the whole of Buckinghamshire, to model and map the benefits (ecosystem services) that flow from the natural capital, and to identify opportunities to enhance biodiversity and a range of ecosystem services. It was commissioned by Buckinghamshire County Council (now Buckinghamshire Unitary Authority).

The first part of the project was to produce a detailed map of the current habitats present across Buckinghamshire. 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 156,500 ha or 1,565 km$^2$ and contained 985,000 polygons, each of which was classified to an appropriate habitat type. It shows that Buckinghamshire is dominated by arable and improved grassland, together making up 63% of the area (98,000 ha), but with woodland and scrub habitats taking up 13% (20,400 ha), an area considerably greater than the other counties in the OxCam Arc. Semi-natural and marshy grasslands make up 5.6%, while water makes up just 0.8% of the area. Built-up areas and infrastructure make up 6.2% of the land area, with gardens comprising 6.0%. The basemap showed that the habitats of Buckinghamshire are distinctly different in the south compared to the north, with the majority of the woodland in the southern half of the county, with the north more dominated by agricultural land.

In total, 10 ecosystem services were modelled and mapped: carbon storage, carbon sequestration, air purification, noise regulation, local climate (urban heat) regulation, water flow regulation, water quality regulation, food production, timber production, and accessible nature. The key importance of woodland for the provision of a range of services was highlighted, particularly in the south of the county. Larger blocks of accessible woodland, are especially important, such as Burnham Beeches, Penn Wood, Wendover Woods, the Ashridge Estate and Bernwood Forest.

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 Buckinghamshire, especially in Aylesbury and High Wycombe, and urban areas adjacent to the road network were also seen to be hotspots for demand. The capacity to provide these services is often quite high around urban areas in southern Buckinghamshire, where woodland and other semi-natural habitats occur on the fringes of towns, and these areas should be protected and expanded, even if not important for biodiversity. In the northern half of the county there is much more of a mismatch between demand and supply.

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.

For semi-natural grasslands, the area to the north-west of Aylesbury provides the greatest density of habitat, although many patches remain disconnected, and this area presents the greatest opportunities for habitat creation to connect habitat patches. Broadleaved and mixed woodland habitat networks are concentrated in the southern half of Buckinghamshire, where much of the area forms a near continuous patch of ecologically connected habitat. Habitat creation could further increase connectivity. Wet grassland and wetland habitat networks are much less significant in

Buckinghamshire, with only a few small habitat patches along the River Thame and a few other locations in the north of 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 Buckinghamshire, with the exception of a flat central belt, 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 in the north half of the county, 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 combing opportunities with different weightings if desired.

The maps and GIS layers produced for this project have a wide range of potential applications. We outline two possible projects for enhancing the outputs and taking this work forward:

1. Mapping habitat quality (condition) would enable habitat restoration to be considered alongside the habitat creation opportunities identified here. It would also then be possible to create a baseline biodiversity assessment using the Biodiversity Metric 2.0 tool, for assessing biodiversity net gain.
2. It is recommended that the maps are refined further in relation to existing plans and priorities, and that a workshop is held with local stakeholders to ground-truth locations, provide rules to target certain habitats or certain ecosystem services in different locations, and to prioritise locations 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, for woodland creation for carbon offsetting, and as an important step towards producing a local natural capital plan for the area.

# Contents

# 1. Introduction

Buckinghamshire County Council (now Buckinghamshire Unitary Authority) has 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 forest lands, 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.

Buckinghamshire lies at the heart of the OxCam Arc, a strategic growth area intended to supply a million more houses than currently allocated, along with 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 hinderance 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 habitats assets.

Natural capital is also becoming increasingly embedded across multiple policy domains, including the mandatory requirement for biodiversity net gain for all new developments, as set out in the Environment Bill, with an ambition 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

[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.

goods, based on natural capital principles. Further policy alignment is achieved through the requirements for action on climate change and commitments to go carbon neutral, including the planting of large areas of new woodland.

Buckinghamshire CC therefore commissioned this project to produce a natural capital assessment for the area, with the following three 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. Create habitat opportunity maps for biodiversity enhancement and for a range of ecosystem services, showing where new habitats could be created that are most appropriate from an ecological point of view, or provide the best opportunities for enhancing a range of benefits, whilst taking constraints into account.

This project has proceeded in parallel with work to complete an identical assessment for Milton Keynes, funded by the Buckinghamshire & Milton Keynes Natural Environment Partnership.

## 1.1 The natural capital and ecosystem services framework

The natural environment underpins our 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).

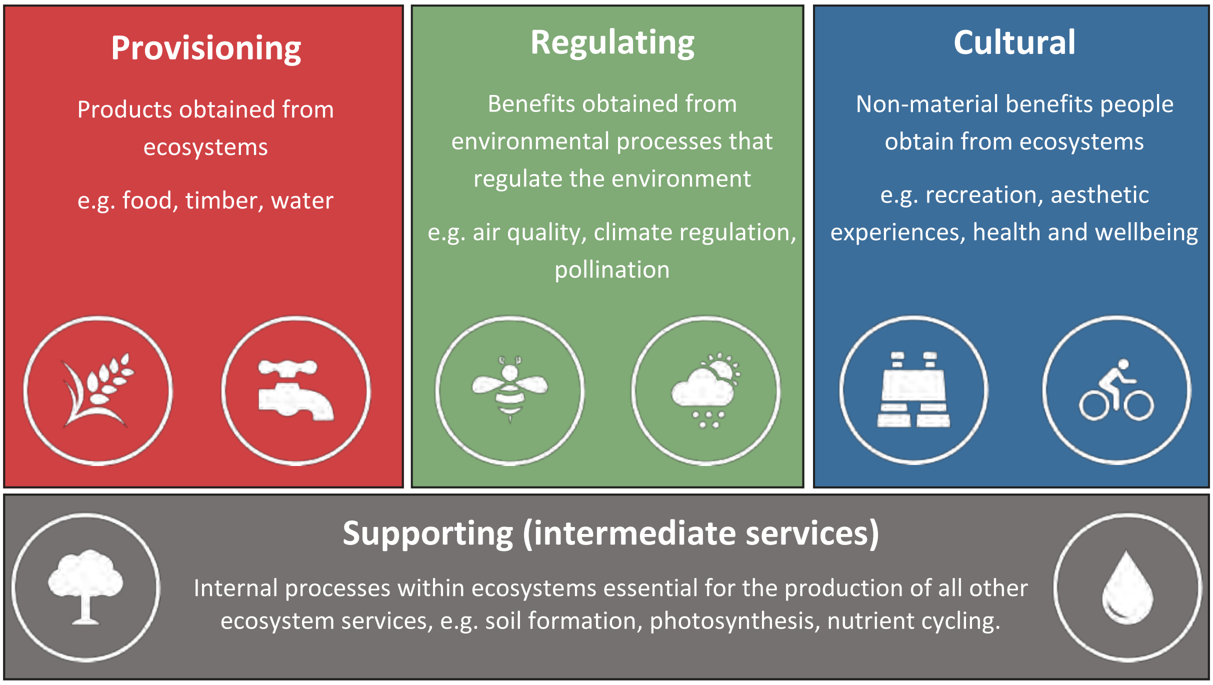



**Figure 1:** Key types of ecosystem services (based on MA 2005)

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

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 begins by describing how the baseline natural capital assets were mapped, before presenting the resulting habitat map and outlining the habitats present across Buckinghamshire. 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.

Section 3 then uses this natural capital basemap to model and map the ecosystem services delivered by that natural capital. We assess 10 different ecosystem services and whenever possible we also map the demand for these services across the area. Section 4 then considers opportunities for enhancing biodiversity and ecosystem services across Buckinghamshire. 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 5, 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 6.

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 Buckinghamshire Council and a list of available layers is provided in Annex 2.

# 2. The baseline – natural capital assets

## 2.1 Approach to mapping habitats

The first and perhaps most important part of the whole project was to produce a detailed map of the current habitats present across Buckinghamshire. This is the key component of any assessment of natural capital assets, and is required before an assessment of ecosystem services (Section 3) or habitat opportunity mapping (Section 4) can be undertaken. To do this we 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 and to associate a range of additional data with each polygon. The data that was used to classify habitats is shown in Box 1.

**Box 1: Data used to classify habitats in the basemap:**

- OS MasterMap Topography layer
- OS VectorMap District
- OS MasterMap Greenspace data
- Combined habitat map – supplied by Buckinghamshire and Milton Keynes Environmental Records Centre (BMERC)
- Additional habitat layers (e.g. traditional orchards, Road Verge Nature Reserves) supplied by BMERC
- Natural England Priority Habitats Inventory
- Centre for Ecology and Hydrology (CEH) Landcover Map 2015
- CEH Woody Linear Features data set (hedgerows map)
- Ancient Woodland Inventory data
- Built-up Area Boundaries data
- Local Wildlife Sites – supplied by BMERC
- Digital terrain model (based on OS Terrain 5 data)

Further information on how polygons were assigned to habitats is provided in Box 2 (overleaf). Polygons were classified into Phase 1 habitat types and were also classified into broader habitat groups. The final basemap covered the whole of Buckinghamshire (and Milton Keynes, which is reported separately), and covers an area of 156,500 ha or 1,565 km$^2$. It contained 985,000 polygons, each of which was classified to an appropriate habitat type.

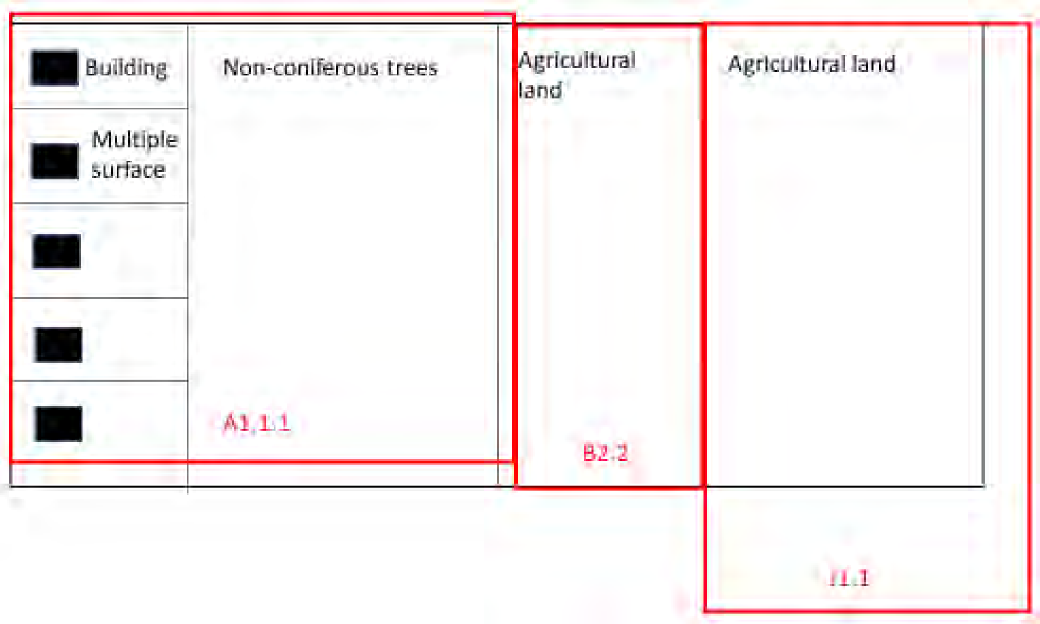
Note that the basemap provides the best approximation of habitat types that can be achieved based on available data. It was checked by experts at the Buckinghamshire and Milton Keynes Environmental Records Centre but has not been ground-truthed further and will inevitably contain errors. A particular challenge was classifying polygons where more than one habitat was present. Mixed habitats containing woodland and scrub, or grassland with woodland were classified in detail, but not all combinations of habitats could be accommodated. Other areas, where there was a mismatch between data sources, or land use is changing rapidly remained a challenge.

**Box 2: Assigning habitats**

Our approach to assigning habitats is illustrated pictorially below. OS MasterMap is the most detailed and accurate mapping available across Great Britain and identifies all roads, buildings, fields and other features as individual polygons (shown pictorially as the black layer below). However, information on the habitat of these features is limited. We used a series of rules and other layers to classify each polygon. For example, we used rules to assign features as houses, gardens, industrial / commercial buildings and so on.

The habitat information provided by BMERC was then overlain (red layer in Fig.1) and the degree of overlap calculated using zonal statistics. This does not always match precisely so, for example, if a habitat polygon marked as semi-natural broadleaved woodland (A1.1) overlaid houses, gardens and a polygon identified as non-coniferous trees in MasterMap (red polygon on left, below), we could now assign the non-coniferous tree polygon more accurately as semi-natural broadleaved woodland, but the houses and gardens would be left unchanged.

A number of additional rules and layers were used to gradually build up as complete a picture as possible. For example, areas identified as improved grassland, but within urban areas, were classified as amenity grassland. All polygons were assigned to a Phase 1 habitat type, although areas currently undergoing development were marked as unclassified. Upon initial completion, the basemap was checked against Google and Bing maps and manual alterations were made in a number of places where miss-classifications had occurred or where habitats could be assigned with greater certainly.



## 2.2 Broad habitats

Figure 2 (overleaf) shows the distribution of broad habitat types across Buckinghamshire and the area and percentage cover is shown in a little more detail in Table 1. Buckinghamshire is dominated by cultivated land and improved grassland, making up 63% of the area (98,000 ha), although this is less than surrounding counties. The combined cover of all woodland, scrub and tree habitat types make up 13.0% of the area (20,400 ha), considerably higher than surrounding counties. Semi-natural and marshy grasslands make up 5.6%, while water makes up just 0.8%. Built-up areas, and infrastructure (roads, railways, pavements and paths) make up 6.2% of the land area, with gardens comprising 6.0%.

**Table 1:** Area and percentage cover of broad habitat types across Buckinghamshire

| Broad habitat | Area (Ha) | % cover |
|---|---|---|
| Cultivated / disturbed land | 47,828 | 30.56 |
| Uncertain agriculture | 886 | 0.57 |
| Improved grassland | 50,519 | 32.28 |
| Amenity grassland | 5,165 | 3.30 |
| Semi-natural grassland | 8,454 | 5.40 |
| Marshy grassland | 267 | 0.17 |
| Heathland | 164 | 0.10 |
| Fen, marsh and swamp | 81 | 0.05 |
| Scrub | 348 | 0.22 |
| Trees / Parkland | 1,613 | 1.03 |
| Broadleaved woodland | 14,365 | 9.18 |
| Coniferous woodland | 1,788 | 1.14 |
| Mixed woodland | 2,265 | 1.45 |
| Hedgerows | 928 | 0.59 |
| Water | 1,222 | 0.78 |
| Built-up areas | 5,416 | 3.46 |
| Infrastructure | 4,235 | 2.71 |
| Garden | 9,429 | 6.03 |
| Rock, exposure and waste | 425 | 0.27 |
| Unclassified | 176 | 0.11 |
| Mixed / other / uncertain | 916 | 0.59 |
| **TOTAL** | **156,489** | **100.00** |

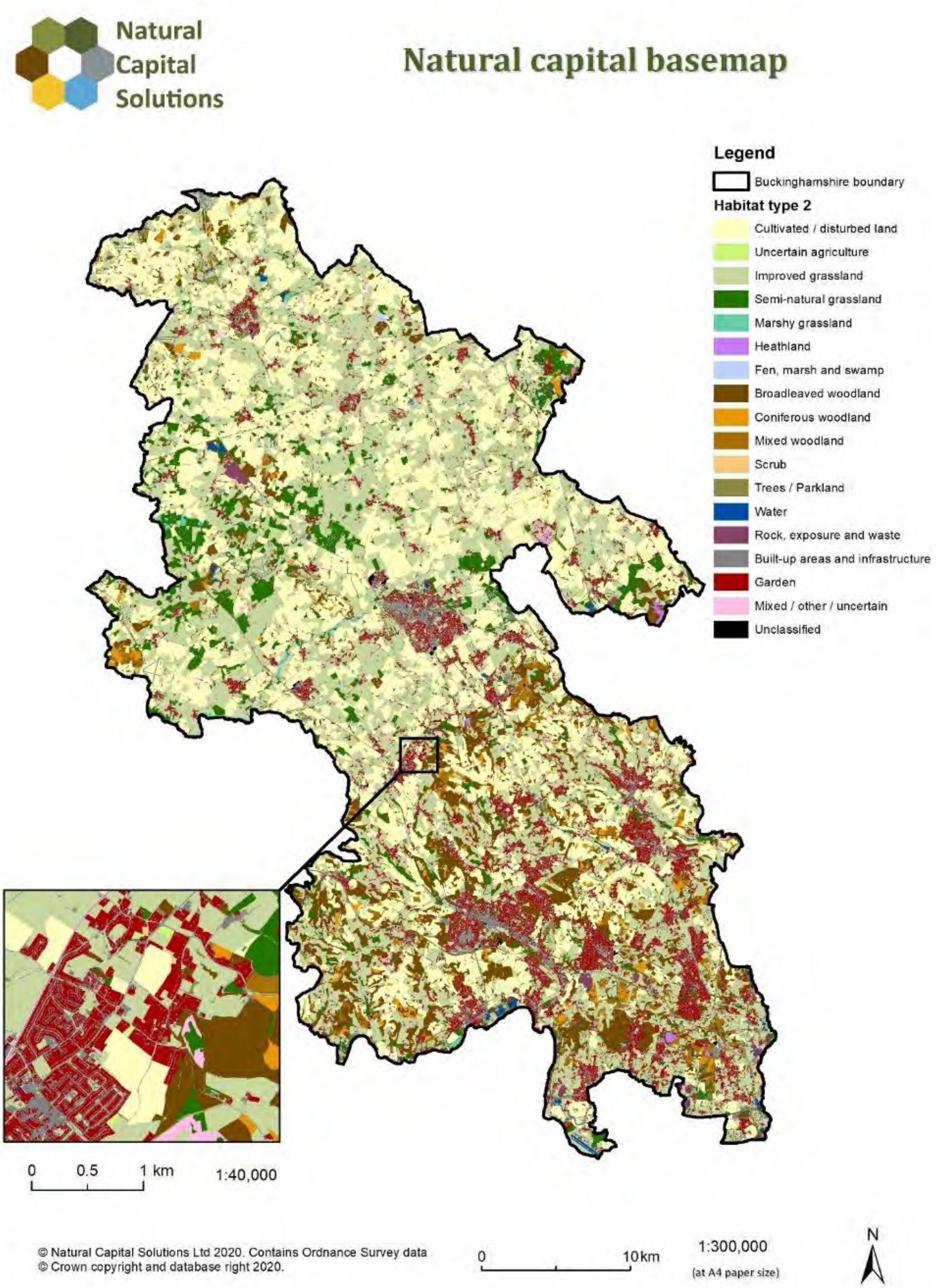



**Figure 2:** Broad habitats across Buckinghamshire.

## 2.3 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 20,274 ha, which represents 13.0% of Buckinghamshire, contain these high-quality habitats. The greatest amounts are 14,365 ha of broadleaved woodland, 2,265 ha of mixed woodland and 2,297 ha of neutral grassland. However, this include all broadleaved and mixed woodland, some of which will not have been high quality. There are also 658 ha of calcareous grassland, 109 ha of acid grassland, and 267 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.

## 2.4 Nature conservation designations

The location of designated sites is shown on Figure 4. Key sites include the Chilterns Beechwoods, Burnham Beeches and Aston Rowant, which are considered to be of international importance for their woodland assemblages and have been designated as Special Areas of Conservation (SACs) and SSSIs. In total 932 ha are designated as SACs within Buckinghamshire (0.60% of the total land area). The total amount of land designated as SSSIs within Buckinghamshire is 2,516 ha, or 1.61% of the total area, with an additional 5,983 ha (3.82%) designated as Local Wildlife Sites and 200 ha (0.13%) designated as a Local Nature Reserves. All the SACs are also designated as SSSIs, and there is a little overlap in the other designations, hence the total amount of land receiving some level of protection amounts to 8,577 ha, or 5.48% of the total area of Buckinghamshire. Note that a number of additional non-statutory schemes are used to show sites of local biological interest, such as Biological Notification Sites, and Road Verge Nature Reserves (not shown on Figure 4).

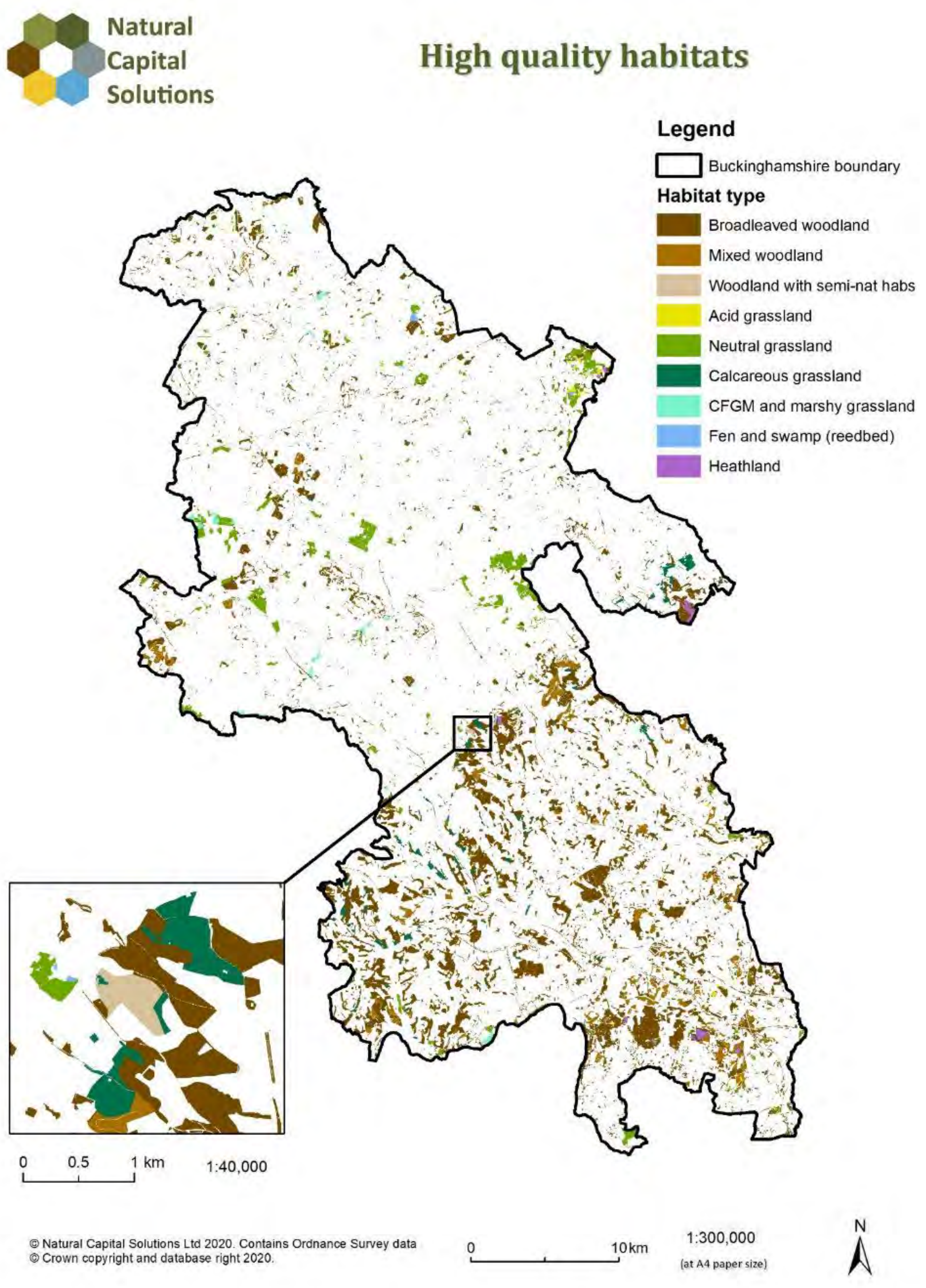



**Figure 3:** High quality habitat types, identified from the basemap.

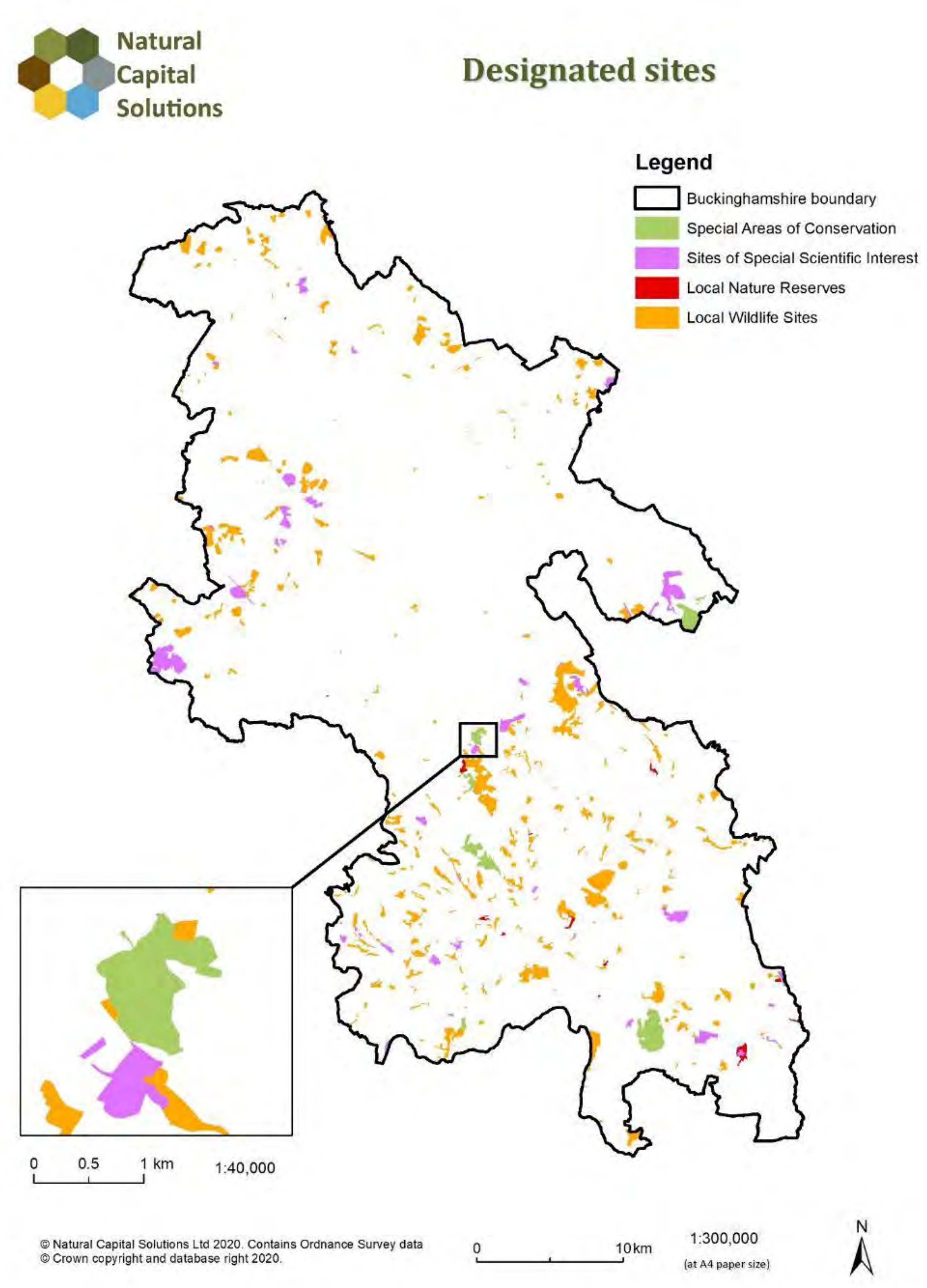



**Figure 4:** International, national and locally designated sites for nature conservation. Note that all SACs are also designated as SSSIs.

# 3. Modelling and mapping ecosystem services (physical flows)

Once a detailed habitat basemap had been created for Buckinghamshire, 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 all of 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.

## 3.1 Carbon storage capacity

### What is it and why is it important?

Carbon storage capacity indicates the amount of carbon stored naturally in soil and vegetation. Carbon storage and sequestration is seen as increasingly important as we move towards a low-carbon future. The importance of managing land as a carbon store has been recognised by the UK government, and land use has a major role to play in national carbon accounting. Changing land use from one type to another can lead to major changes in carbon storage, as can restoration of degraded habitats. Note that carbon storage measures the stock of carbon in the natural environment, whereas carbon sequestration (Section 3.2) measures its annual flow.

### How is it measured?

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

**In all the ecosystem services maps that follow, the highest amounts of service provision and demand (hotspots) are shown in red, with a gradient of colour to blue, which shows the lowest amounts (coldspots).**

### Results for Buckinghamshire

Figure 5 (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. These are particularly prevalent in the southern half of the county. However, most green spaces of the region support some level of carbon storage, with much lower levels in urban areas dominated by buildings and sealed surfaces.

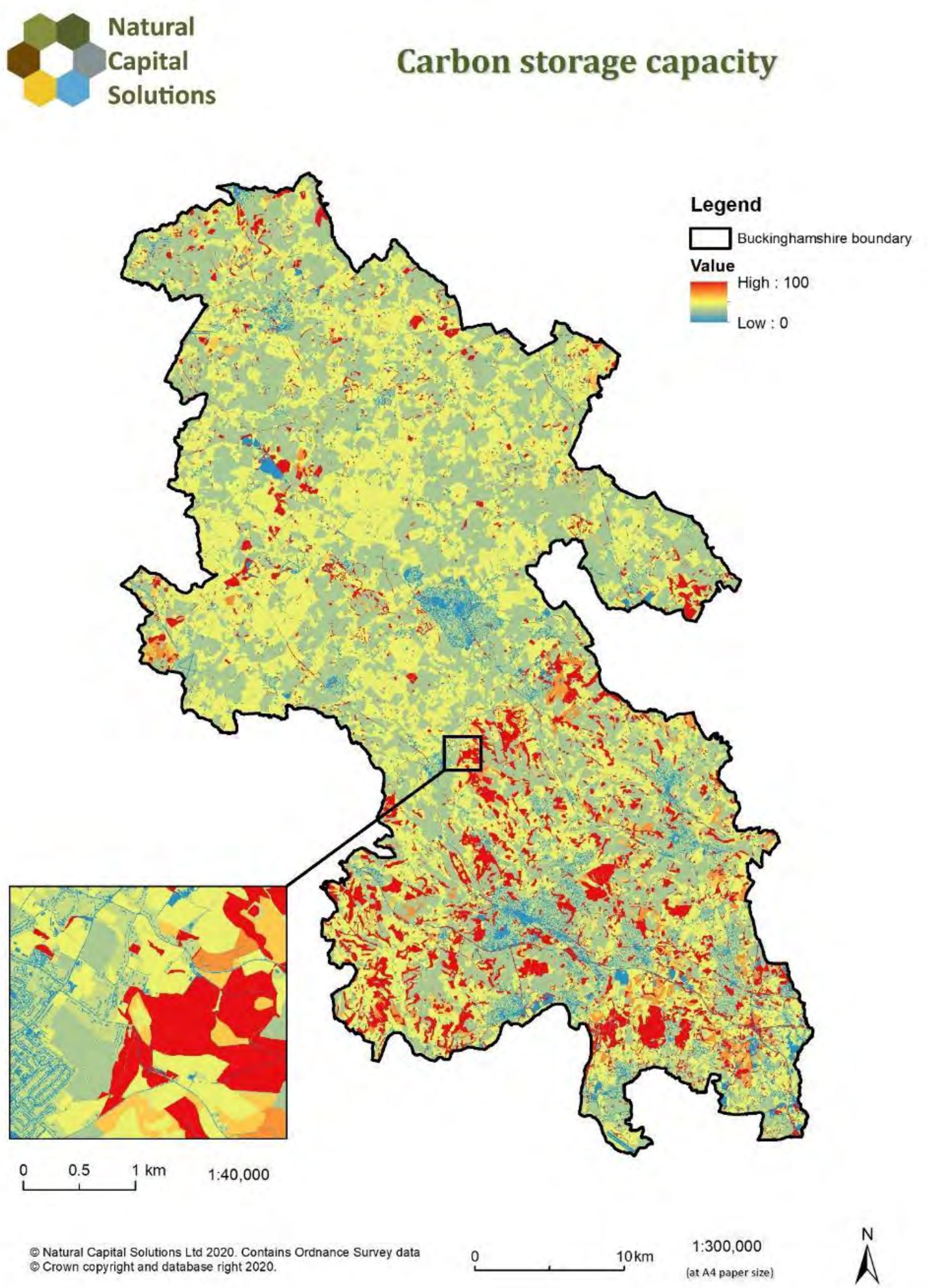



**Figure 5.** Carbon storage capacity across Buckinghamshire. Inset map shows level of detail in the map for a representative location.

## 3.2 Carbon sequestration

### What is it and why is it important?

Carbon is sequestered (captured) by growing plants. Plants that are harvested annually (e.g. arable crops, improved grassland) will be approximately carbon neutral over the course of a year as the sequestered carbon is immediately harvested. There is very little information about sequestration in other habitats (apart from woodland), but these are likely to be very low. Therefore, estimates are solely based on woodland carbon sequestration.

### How is it measured?

Carbon sequestration rates for woodland and other habitats with trees were calculated following the UK Woodland Carbon Code methodology and look-up tables (Woodland Carbon Code 2018[6]). Coniferous woodland sequestration rates were averaged over a 60-year period and deciduous woodland sequestration rates were averaged over a 100-year period, as this is the length of a typical forestry cycle for these woodland types. Information on species composition was taken from the Forestry Commission's National Inventory of Woodland and Trees County Report for Buckinghamshire (2002[7]). Yield classes for each tree species in Buckinghamshire were derived from Forest Research's Ecological Site Classification tool (http://www.forestdss.org.uk/geoforestdss/). Average spacing between trees was assumed, and it was assumed that deciduous woodland was not thinned, but coniferous areas were. The annual sequestration rate for each species was then multiplied by the proportion of each species to give the total annual sequestration estimate for each woodland type.

The calculations included areas of parkland and scrub. The former sites were assessed to, on average, have 20% tree cover with a broadleaved mix of sycamore, ash and birch. Areas of scrub were calculated at half the sequestration rates of deciduous woodland of the same species mix.

Maps of the sequestration rate were scaled from 0 to 100 for consistency with the other maps.

### Results for Buckinghamshire

The baseline carbon sequestration map (Figure 6) shows high areas of carbon sequestration (in red) predominantly in the south of the county. 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.

[6] Woodland Carbon Code (2018) Carbon calculation guidance v2. March 2018. Forestry Commission.
[7] Forestry Commission (2002) National Inventory of Woodland and Trees County Report for Buckinghamshire. Forestry Commission.

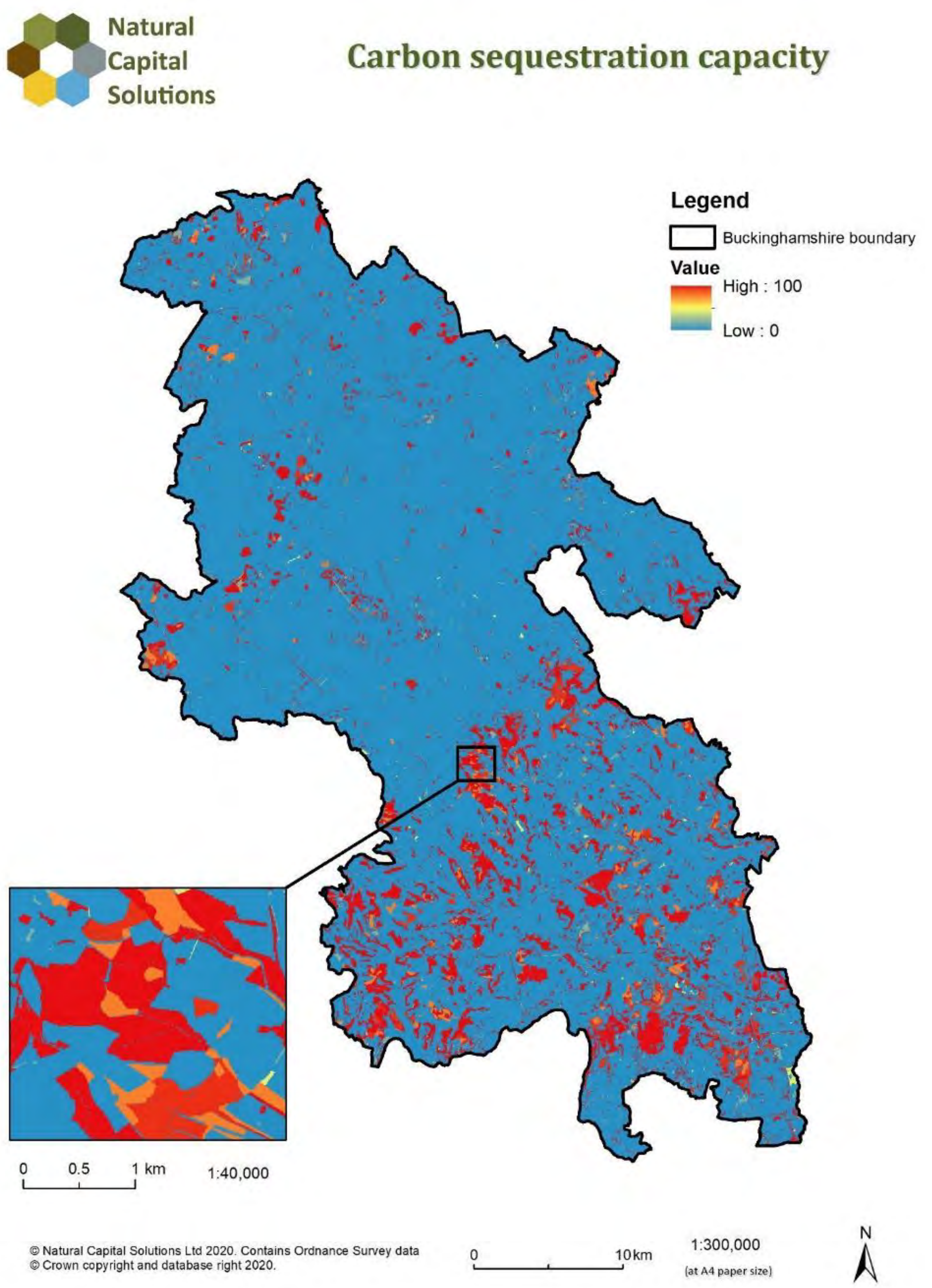



**Figure 6** Carbon sequestration capacity across Buckinghamshire.

## 3.3 Air purification capacity (air quality regulation)

### What is it and why is it important?

According to the World Health Organisation, air pollution is the greatest environmental health risk in Western Europe and globally. In the UK alone, it is estimated to have an effect equivalent to 29,000 deaths each year and is expected to reduce the life expectancy of everyone in the UK by 6 months on average, at a cost of around £16 billion per year (Defra 2016[8]). Air pollution also contributes to climate change, reduces crop yields, and damages biodiversity.

Air purification capacity estimates the relative ability of vegetation to trap airborne pollutants or ameliorate air pollution. Vegetation can be effective at mitigating the effects of air pollution, primarily by intercepting airborne particulates (especially $PM_{10}$ and $PM_{2.5}$) but also by absorbing ozone, $SO_2$ and $NO_X$. Trees provide more effective mitigation than grass or low-lying vegetation, although this varies depending on the species of plant. Coniferous trees are generally more effective than broadleaved trees due to the higher surface area of needles and because the needles are not shed during the winter.

### How is it measured?

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

The final capacity score was calculated for each 10m by 10m cell across the study area, and was scaled on a 0 to 100 scale, relative to values present within the mapped area. High values (red) indicate areas that have the highest capacity to trap airborne pollutants and ameliorate air pollution.

### Results for Buckinghamshire

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 densely forested areas, apparent as dark red patches of high air purification capacity in Figure 7. These include much of southern Buckinghamshire, with more isolated patches in Aylesbury Vale. Urban areas display much lower levels of air purification capacity in general.

[8] Defra (2016) Air pollution in the UK 2015. Crown Copyright.

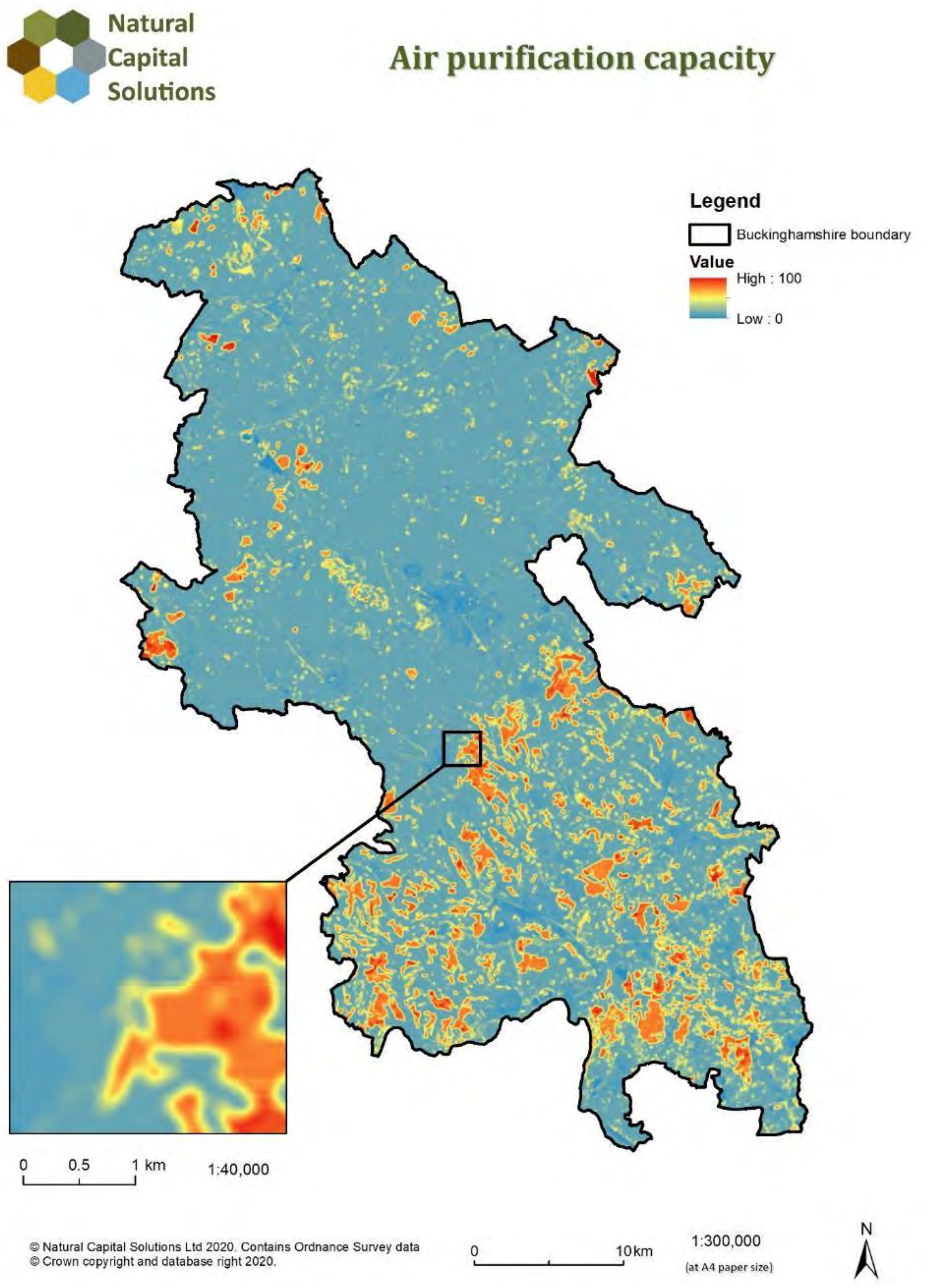



**Figure 7** Air purification capacity across Buckinghamshire.

## 3.4 Air purification demand

### What is it and why is it important?

Air purification demand estimates societal and environmental need for ecosystems that can absorb and ameliorate air pollution. Demand is assumed to be highest in areas where there are likely to be high air pollution levels and where there are lots of people who could benefit from the air purification service.

### How is it measured?

Air purification demand was mapped using a model from EcoServ GIS. The model combines two indicators of air pollution sources (log distance to roads, and % cover of sealed surfaces) and two indicators of societal need for air purification (population density, and Index of Multiple Deprivation health score).

The scores for each indicator were normalised and combined with equal weighting. The final score was then projected on a 0 to 100 scale, relative to values present within the study area. High values (red) denote areas with the greatest demand for air purification as a service.

### Results for Buckinghamshire

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. On Figure 8, the areas of highest demand are clustered around major towns in the region, particularly in Aylesbury and High Wycombe, but also in Buckingham and the towns in the Chilterns and South Bucks. Outside of these clusters, demand is relatively low across the study region.

### Balancing supply and demand for air purification services

By considering both the air purification capacity and demand maps (Figures 7 and 8), it is clear that there is a significant spatial disparity in air purification capacity and demand, with the former being higher in rural areas and the latter higher in urban areas. Planting (or maintaining) trees and woodland close to main roads and other pollution sources in built-up areas would be highly beneficial, with considerable benefits to society. Air pollution can be very localised, hence it is important to consider the specific location of trees to gain the maximum benefit of this service.

Trees are very effective at mitigating the effects of air pollution. However, there are major differences in the ability of different species to intercept pollution. The location of trees relative to pollution sources also determines how effective they are at removing pollutants, with trees close to sources being the most effective. Urban woodland is particularly effective as it has high capacity to absorb pollution and is also situated in locations likely to have high demand for the service.

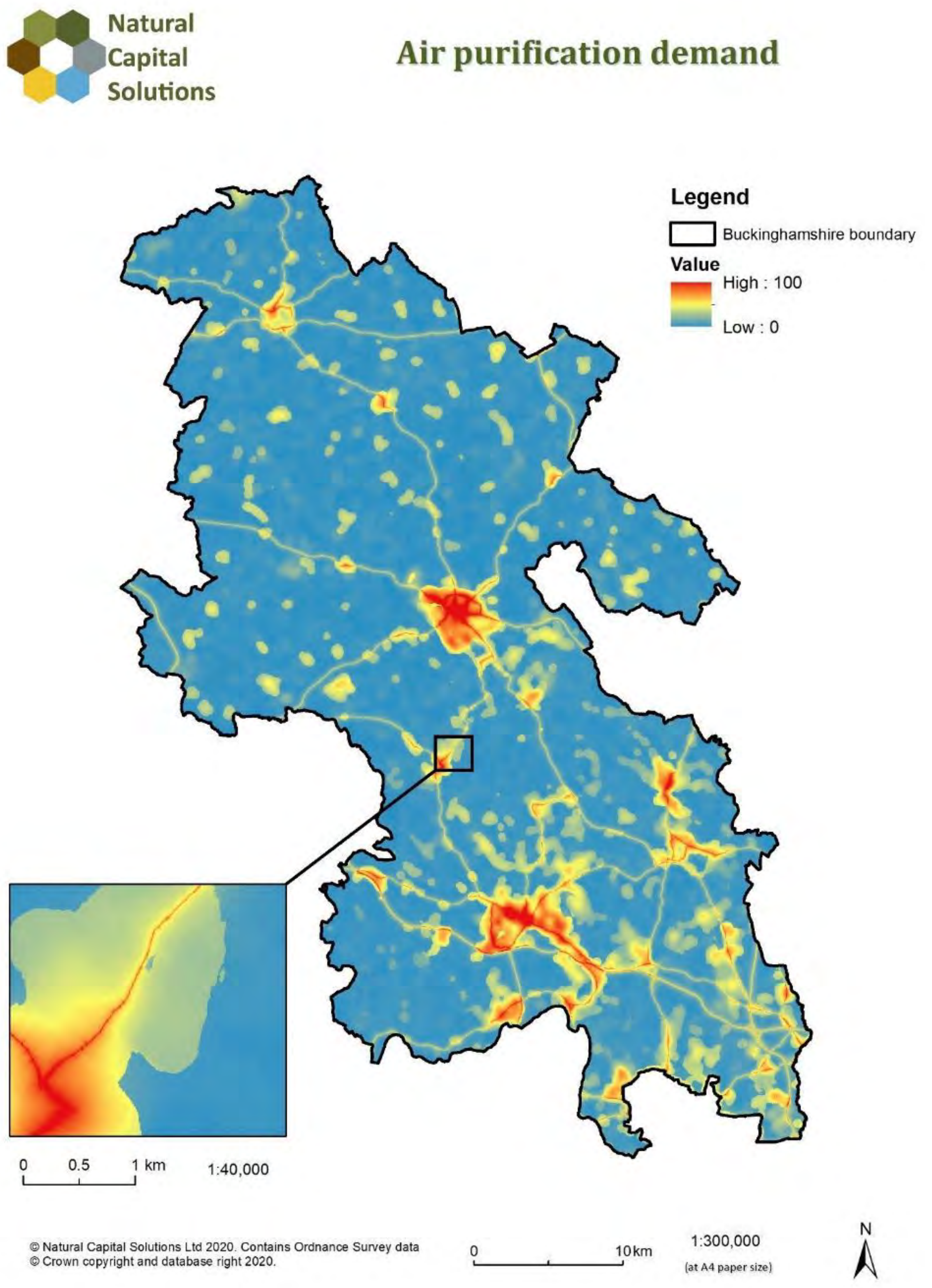



**Figure 8** Air purification demand across Buckinghamshire

## 3.5 Noise regulation capacity

### What is it and why is it important?

Noise regulation capacity is the capacity of the land to diffuse and absorb noise pollution. Noise can impact on health, wellbeing, productivity and the natural environment and the World Health Organisation (WHO) have identified environmental noise as the second largest environmental health risk in Western Europe (after air pollution). It is estimated that the annual social cost of urban road noise in England is £7 to £10 billion (Defra 2013[9]). Major roads, railways, airports and industrial areas can be sources of considerable noise, but use of vegetation can screen and reduce the effects on surrounding neighbourhoods. Complex vegetation cover, such as woodland, trees and scrub, is considered to be most effective, although any vegetation cover is more effective than artificial sealed surfaces, and the effectiveness of vegetation increases with width.

### How is it measured?

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

### Results for Buckinghamshire

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 9 shows a broadly similar spatial pattern to Figure 7, air purification capacity. Noise regulation capacity is relatively low in urban areas, and highest in forested areas, concentrated in the south of the county. Outside of this area, noise regulation capacity is variable and occurs mainly in clusters around green spaces across the region.

[9] Defra (2013) Noise pollution: economic analysis. Crown Copyright.

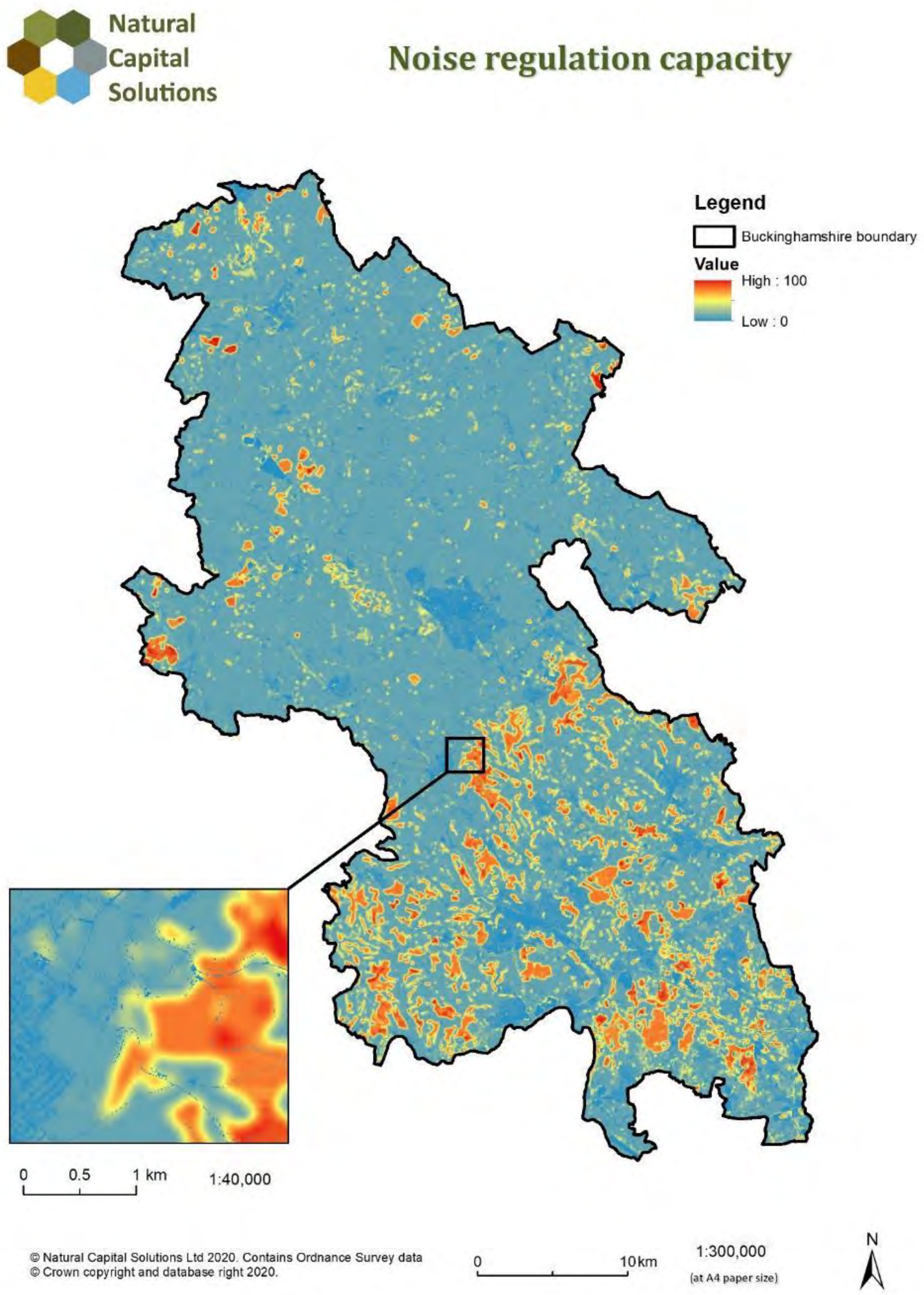



**Figure 9** Noise regulation capacity across Buckinghamshire.

## 3.6 Noise regulation demand

### What is it and why is it important?

Noise regulation demand estimates societal and environmental need for ecosystems that can absorb and reflect anthropogenic noise.

**How is it measured?**

Noise regulation demand was mapped using a modified version on an EcoServ GIS model. The model combines one indicator that maps noise sources (inverse log distance to different road classes and railways, custom built for the study area based on Defra noise modelling) and two indicators of societal demand for noise abatement (population density, and Index of Multiple Deprivation health scores).

Scores are on a 1 to 100 scale, relative to values present within the study area. High values (red) indicate areas that have the highest demand for noise regulation as a service.

### Results for Buckinghamshire

Figure 10 shows noise regulation demand across the Buckinghamshire region. 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 Aylesbury and High Wycombe and there is also significant demand in Chesham. Note the major impact of the M40 motorway along the south of the county and the M25 in the south-east corner, with noise pollution spreading much further than for the A roads and railways.

### Balancing supply and demand for noise regulation services

The pattern of supply and demand for this service is rather similar to that of air purification, with a spatial disparity between capacity and demand - capacity is concentrated in more rural areas and demand is clustered around urban areas, as well as roads and railways. Again, planting trees close to main roads and other noise sources would be the most effective mitigation.

Studies in many countries have shown that densely planted tree belts can reduce noise levels, but the effects are modest, with reductions of 2-4 dB typically recorded. Note however, that there is some evidence to suggest that the presence of vegetation blocking views of a noise source such as a road can enhance the perception of noise reduction. Densely planted and complex vegetation cover such as trees mixed with scrub is considered to be most effective, although any vegetation cover is more effective than artificial sealed surfaces.

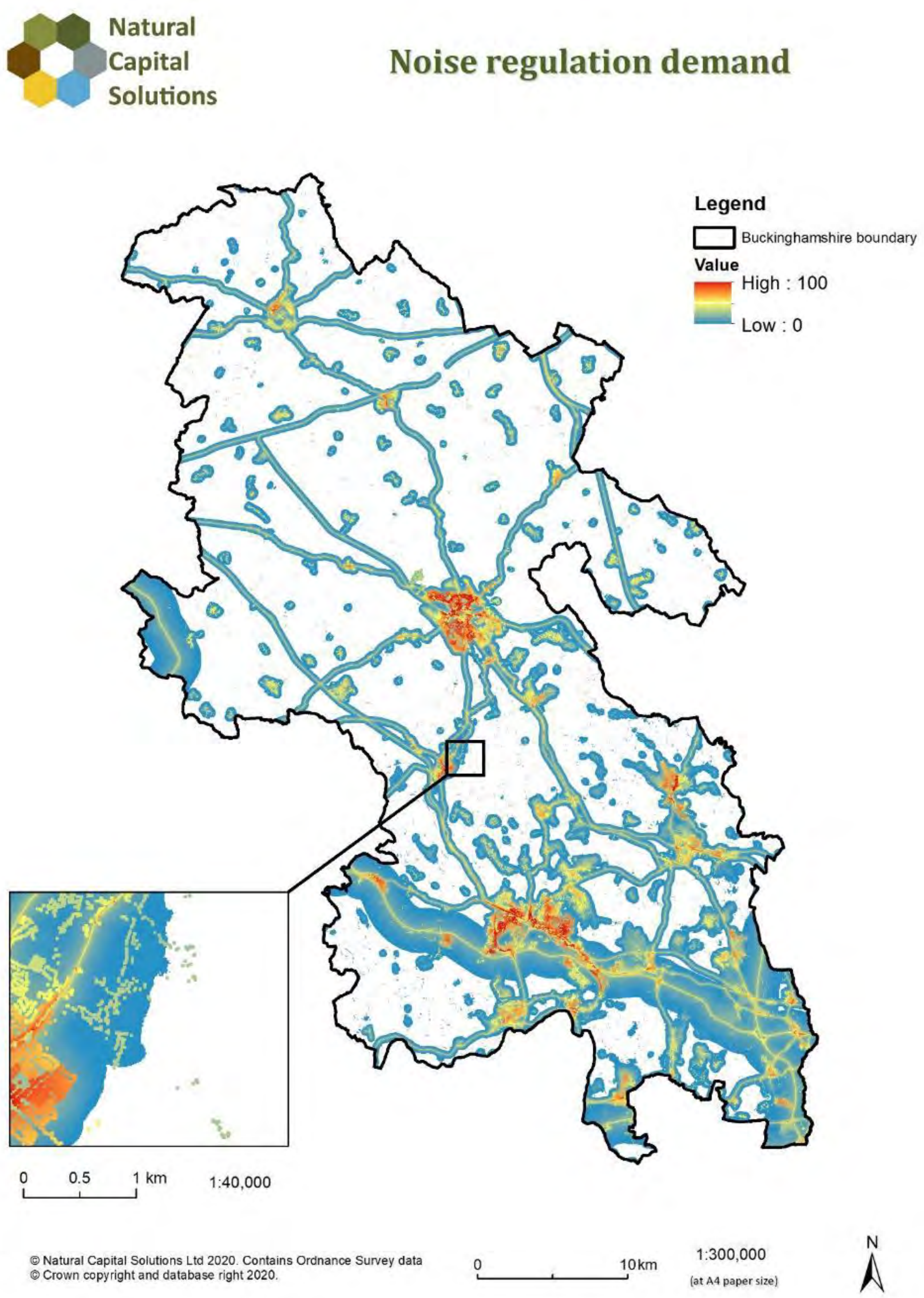



**Figure 10** Noise regulation demand across Buckinghamshire. Areas with zero demand have been excluded to improve map legibility.

## 3.7 Local climate regulation capacity

### What is it and why is it important?

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

### How is it measured?

Local climate regulation capacity was mapped using an EcoServ GIS model. The model calculates the proportion of the landscape that is covered by woodland / scrub and water features within a 200m radius around each 10m by 10m cell across the study area. However, temperature regulating effects of woodland and water will also occur in nearby adjacent areas, with the distance of the effect dependent on the patch size of the natural area. To incorporate this effect, a buffer was applied around each woodland / water patch, with wider buffers modelled around larger natural sites. Note that this model only includes woodland / scrub and water features which provide the most significant effects. All green space is beneficial compared to artificial sealed surfaces, so a future iteration of the model could include all natural surfaces.

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

### Results for Buckinghamshire

Figure 11 shows local climate regulation capacity across Buckinghamshire. In the absence of large bodies of water, larger areas of woodland, such as Burnham Beeches, Wendover Woods, Ashridge, Common Wood and Penn Wood provide the highest local climate regulation capacity in the region. For this reason, Figure 10 shows a similar capacity pattern to Figures 7 and 9, with service provision greatest in the south. These benefits can extend into adjacent urban areas. In much of the remaining region, away from woodland and water bodies, capacity is significantly lower.

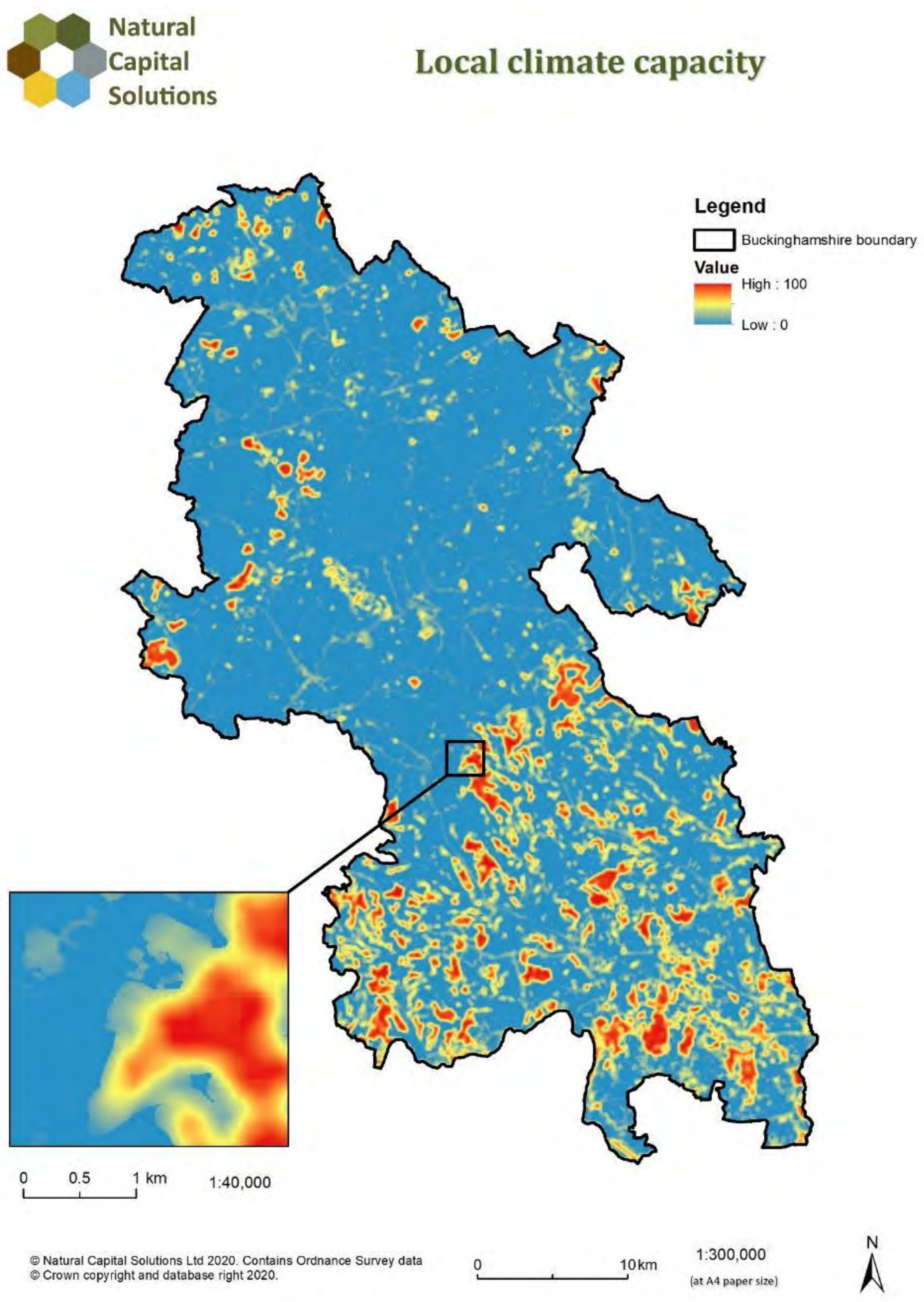



**Figure 11** Local climate regulation capacity across Buckinghamshire.

## 3.8 Local climate regulation demand

### What is it and why is it important?

Local climate regulation demand estimates societal and environmental need for ecosystems that can regulate local temperatures and reduce the effects of the urban heat island.

### How is it measured?

Local climate regulation demand was mapped using a bespoke EcoservR model, originally adapted from EcoServ GIS. The model combines one indicator showing the location of areas suffering from the urban heat island effect (the proportion of sealed surfaces), with two indicators showing societal need for local climate abatement (population density, and proportion of the population in the highest risk age categories – defined as under 10 and over 65).

Scores are on a 0 to 100 scale, relative to values present within the study area. High values (red) indicate areas that have the highest demand for local climate regulation as a service.

### Results for Buckinghamshire

Figure 12 shows local climate regulation demand across the Buckinghamshire region. By removing areas of zero demand, it is immediately clear that demand is heavily clustered around urban centres, with Aylesbury and High Wycombe providing particularly large areas of high demand, but also a number of other towns, particularly in the south. 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.

### Balancing supply and demand for local climate regulation services

Demand for this service is focussed around the larger, more densely populated communities. The large areas of woodland adjacent to towns in the south of the county, and especially those that extend into urban areas, are particularly beneficial with respect to local climate regulating services as they are able to bring moderating conditions into the heart of these urban areas. Installing water features and planting trees would be the most effective way to extend these benefits to other areas, particularly when these are installed close to or within built-up areas.

Although regulating local climate and moderating the impacts of the urban heat island effect may be considered to be a relatively low priority at present, its importance is likely to increase over time due to climate change and an increasing (and ageing) population.

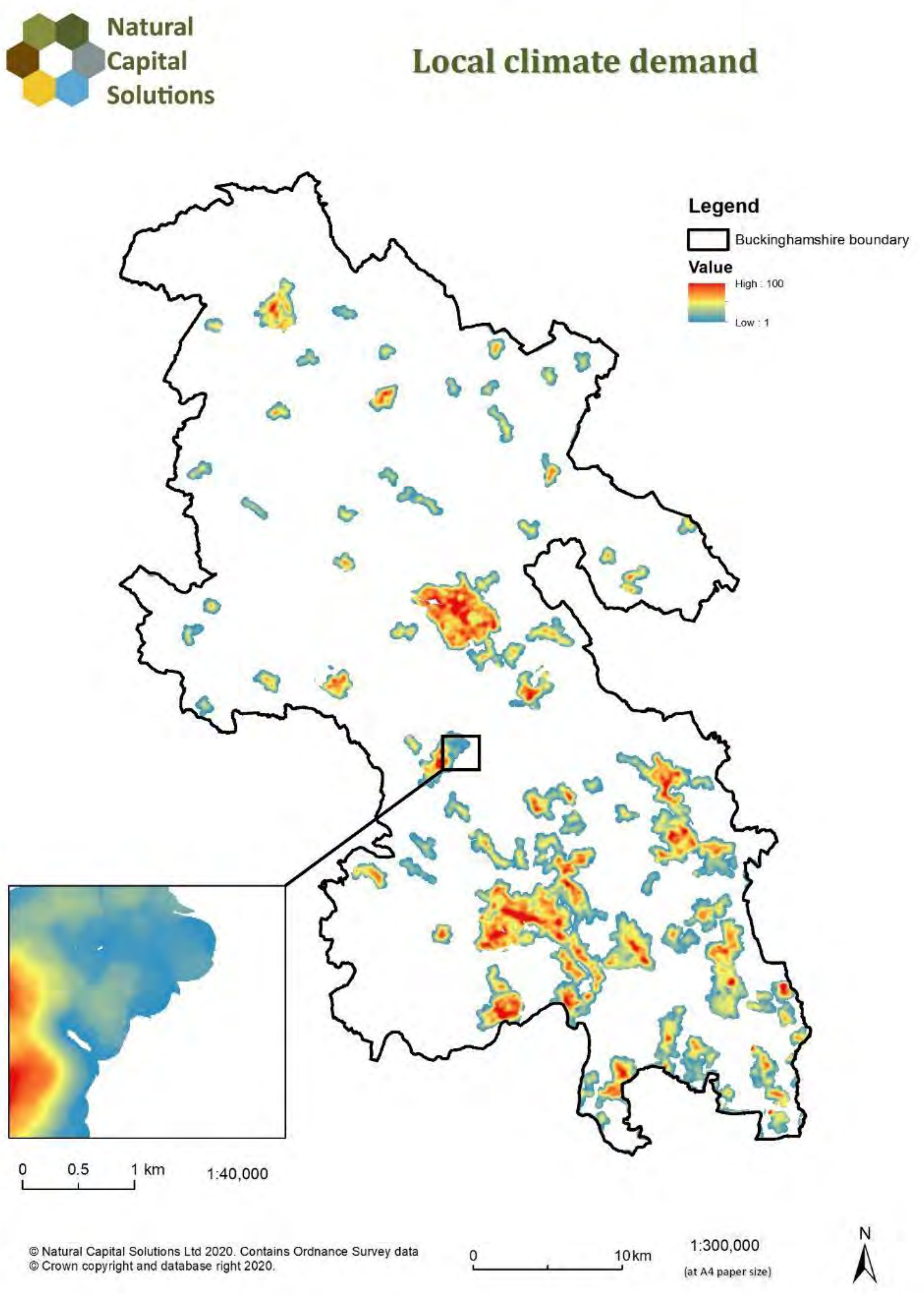



**Figure 12** Local climate regulation demand across Buckinghamshire. Areas with zero demand have been excluded to improve map legibility.

## 3.9 Water flow capacity

### What is it and why is it important?

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

### How is it measured?

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

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

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

Each indicator was normalised from 0-1, then added together and projected on a 0 to 100 scale, as for the other ecosystem services. Note that this is an indicative map, showing areas that have generally high or low capacity and is not a hydrological model. High values (dark orange and red) indicate areas that have the highest capacity to slow water runoff.

### Results for Buckinghamshire

The best locations for slowing water runoff are areas of woodland on flat land. The worst areas (blue on the map, Figure 13) 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, and the slopes that are prevalent in the Chilterns are also poor for this service.

In comparison, areas such as Penn Wood, Naphill Common, Dropmore, Farnham Common, and a number of other woodland patches throughout the county, are characterised by gentle slopes and woodland, which slows surface water flow, have excellent water flow regulation capacity.

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.

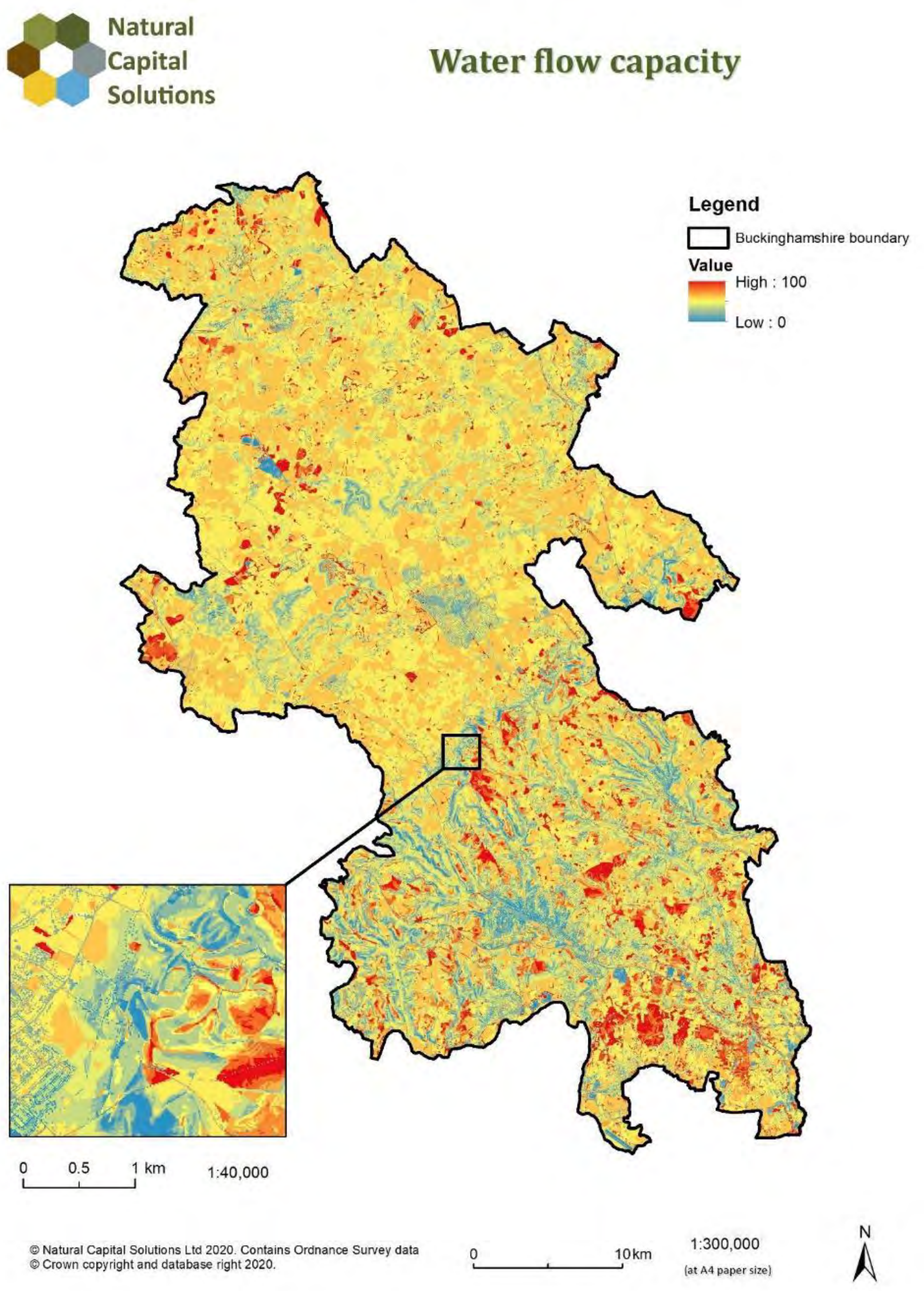



**Figure 13** Water flow regulation capacity across Buckinghamshire.

## 3.10 Water quality capacity

### What is it and why is it important?

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

### How is it measured?

A modified version of an EcoServ GIS model was developed, which combines a coarse and fine-scale assessment of pollutant risk.

At a coarse scale, catchment land use characteristics were used to determine the overall level of risk. The percentage cover of sealed surfaces and arable farmland in each sub-catchment (EA Waterbody catchment) was calculated and the values were re-classified into a number of risk classes. There is a strong link between the percentage cover of these land uses and pollution levels, with water quality particularly sensitive to the percentage of sealed surfaces in the catchment.

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

- **Distance to watercourse** – using a least cost distance analysis, taking topography into account.
- **Slope length** – using a flow accumulation grid and equations from the scientific literature. Longer slopes lead to greater amounts of runoff.
- **Land use erosion risk** – certain land uses have a higher susceptibility to erosion and standard risk factors were applied from the literature. Bare soil is particularly prone to erosion.

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

### Results for Buckinghamshire

Once again, the results are different in the north compared to the south of the county (Figure 14). In the north, scores are generally lower, with arable fields, and especially those parts on slopes and close to watercourses scoring least well. Scores in the south are generally higher, especially those areas away from watercourses with woodland land covers.

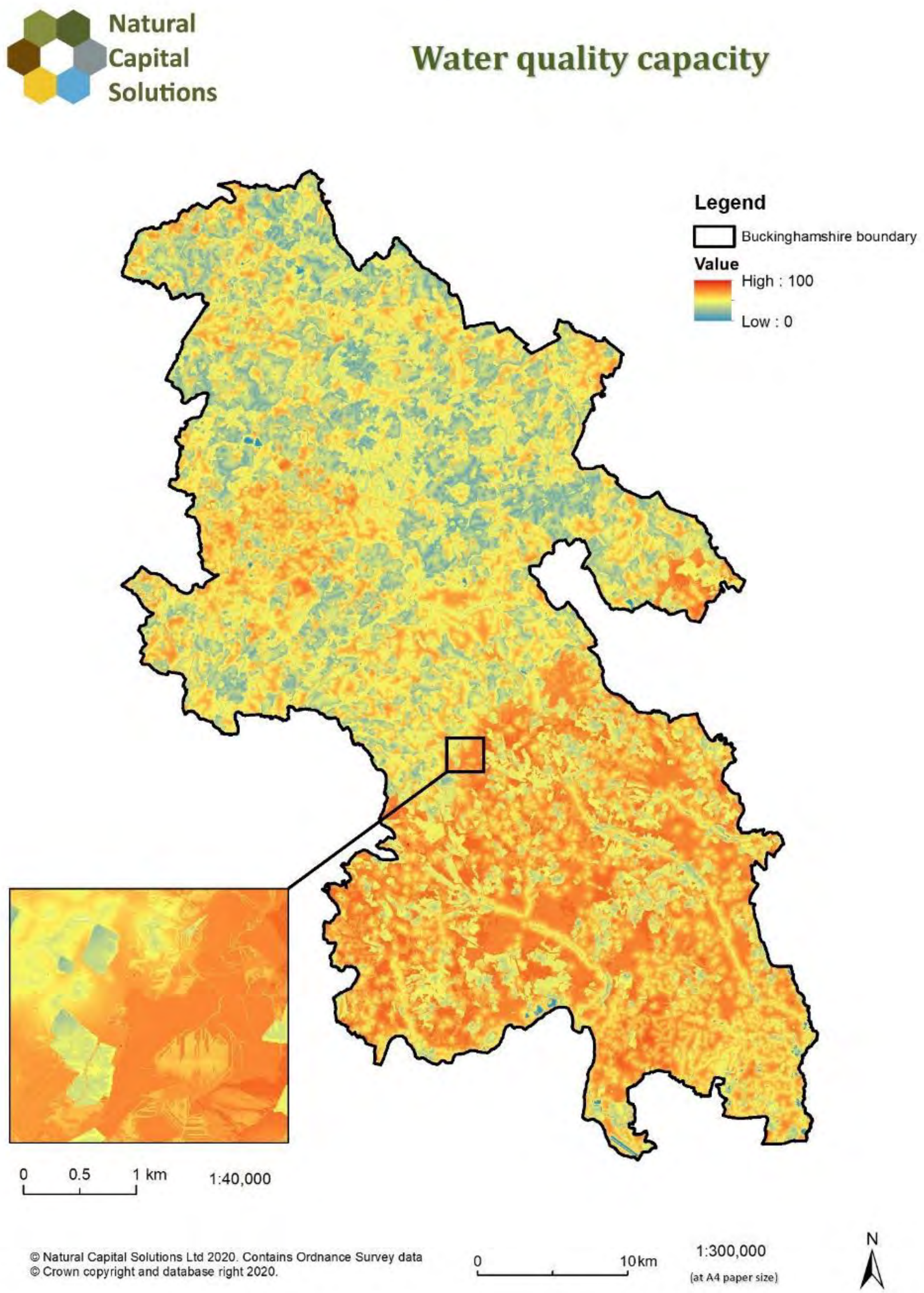



**Figure 14** Water quality regulation capacity across Buckinghamshire.

## 3.11 Food production capacity

### What is it and why is it important?

Agricultural production models the capacity of the land to produce food under current farming practices. Farming is the dominant land-use in Buckinghamshire, with an approximately equal spilt between arable and grassland for livestock. These land covers provide the largest proportion of food, however, food is produced from a range of other habitats, albeit to a lesser extent. The ability of habitats to provide food, accounting for Agricultural Land Classification, was mapped.

#### How is it measured?

The methodology follows that outlined in Smith (2020)[10] and was developed for the Ecometric tool. Broad habitats in Buckinghamshire were assigned a score based their relative ability to provide food:

- Arable, improved grassland – 10
- Orchards, allotments – 7
- Semi-natural and rough grasslands – 6
- Marshy grassland – 4
- Wood pasture and parkland – 3
- Bog/heath, domestic gardens, broadleaved and mixed woodlands - 1

This was mapped in GIS and then weighted by the Agricultural Land Class in which it occurred. The weighting was based on typical dry yield and an additional multiplier for versatility, following Smith (2020):

Grade 1 – 3.03
Grade 2 – 2.40
Grade 3 – 1.33
Grade 4 – 0.67
Grade 5 – 0.50

To maintain compatibility with the other ecosystem services maps, the weighted scores were scaled on a 0 to 100 scale, relative to values present within the mapped area.

### Results for Buckinghamshire

The majority of Buckinghamshire has a medium to low food production capacity (yellow/light blue in Figure 15). This is due to the predominant Agricultural Land Classification for the region being Grade 3, along with significant areas of Grade 4. The high (orange to red) food production areas are areas of Grade 2 and 1 land, which is predominantly down to arable 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).

[10] Smith, A. (2020) Natural Capital in Oxfordshire: Short report. Environmental Change Institute, University of Oxford.

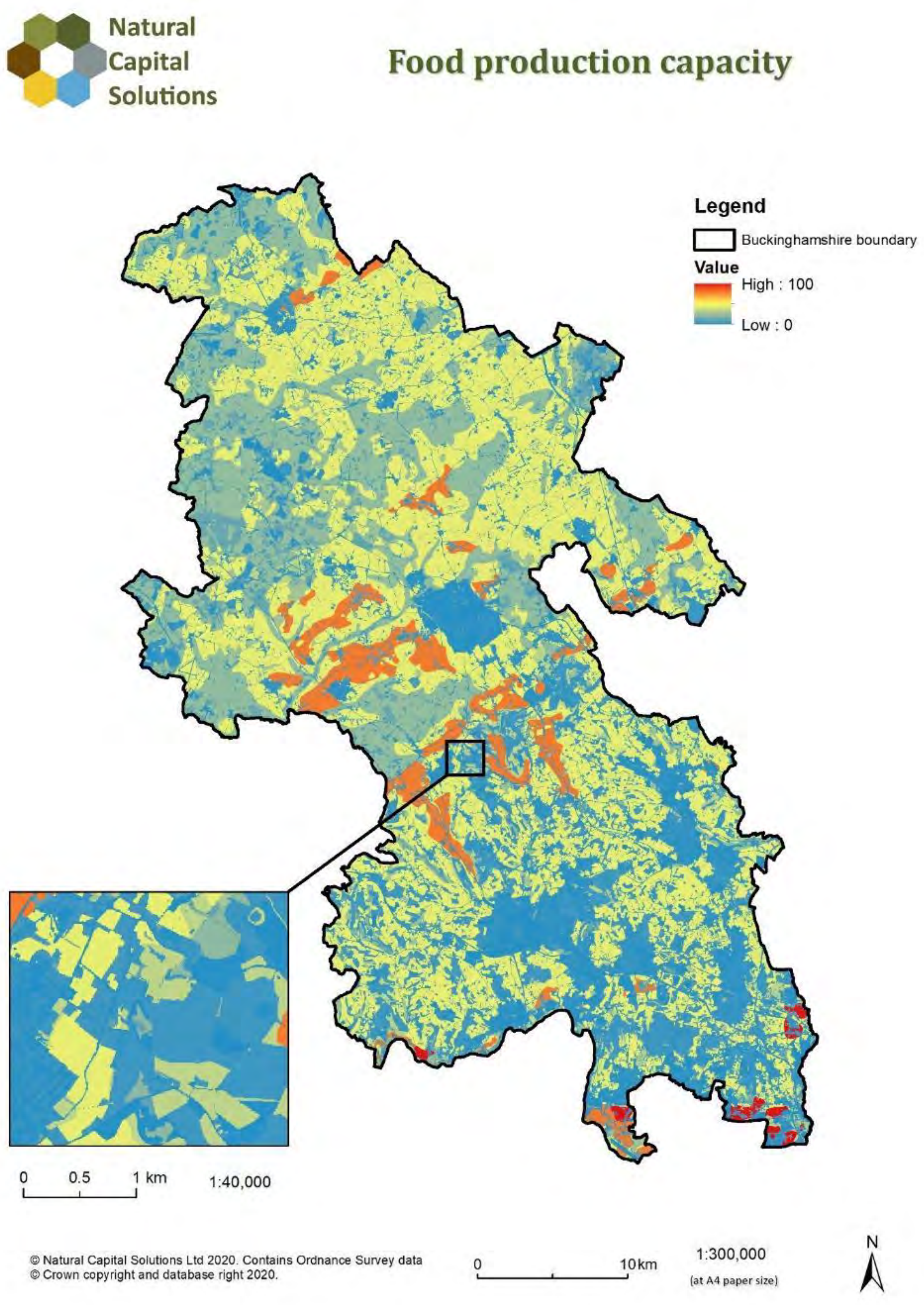



**Figure 15** Food production capacity across Buckinghamshire.

## 3.12 Timber / woodfuel capacity

### What is it and why is it important?

Forestry remains an important component of the rural economy and many areas of woodland are still valued primarily on their timber value. Timber is an important product of woodlands and is the raw resource of the timber industry. Sustainably managed woodland produces timber that is important in contributing to processing mills and factories that produce wood-based products, and also produces wood fuel for the generation of renewable heat and electricity.

### How is it measured?

Information on the species mix and yield class was obtained from the Forestry Commission's National Inventory of Woodland and Trees Regional Report for the South East (2002), and Forest Research's Ecological Site Classification tool (http://www.forestdss.org.uk/geoforestdss/). This was used to determine the average yield of timber ($m^3$) per hectare per year. This was then mapped in GIS and, to maintain compatibility with the other ecosystem services maps, the scores were scaled on a 0 to 100 scale, relative to values present within the mapped area.

### Results for Buckinghamshire

There are patches of high timber and woodfuel production capacity scattered throughout the south of Buckinghamshire and some in the west (Figure 16). 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 Buckinghamshire, although small pockets of coniferous woodland are scattered throughout the area.

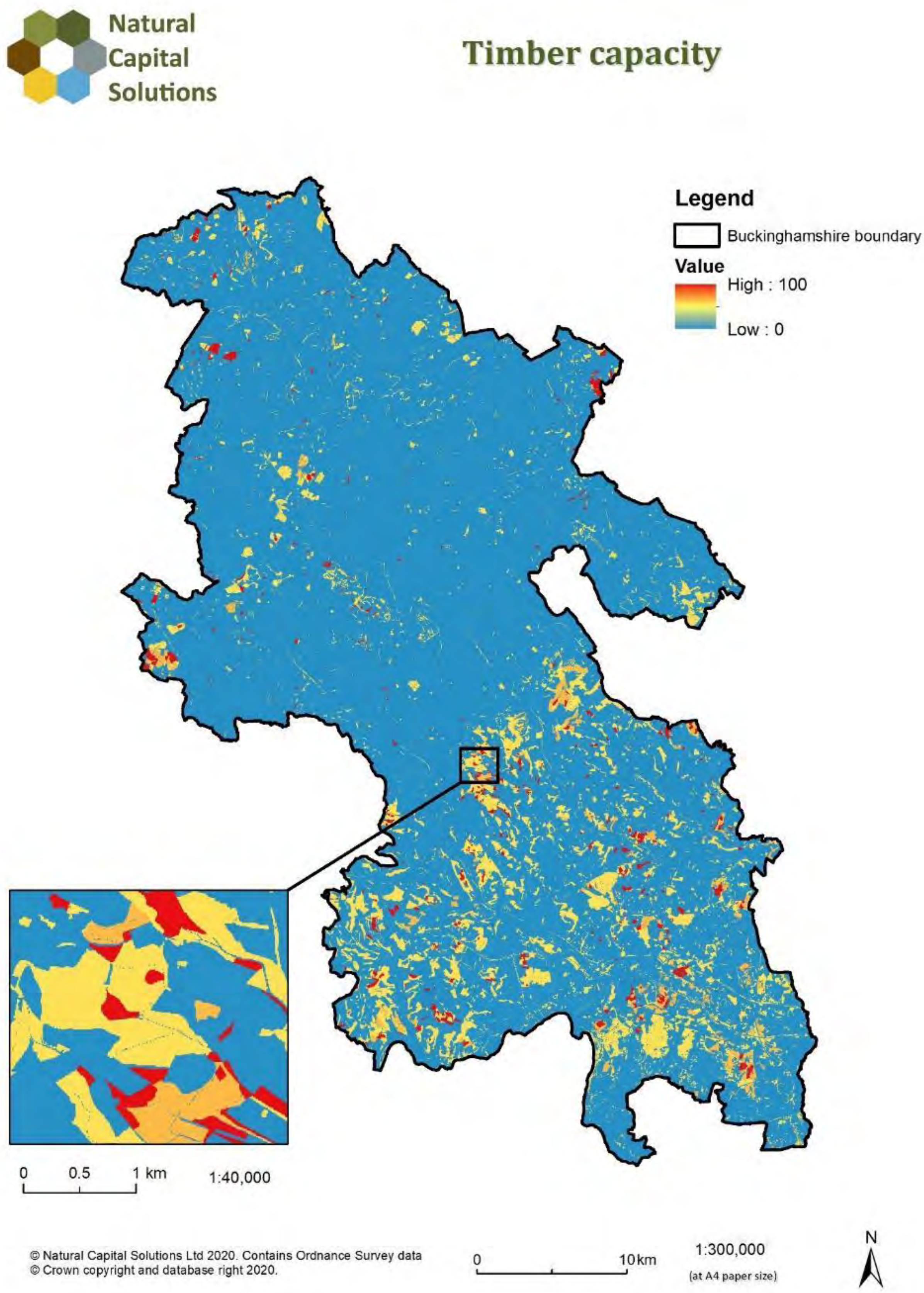



**Figure 16** Timber / woodfuel capacity across Buckinghamshire.

## 3.13 Accessible nature capacity

### What is it and why is it important?

Access to greenspace is being increasingly recognised for the multiple benefits that it can provide to people. In particular there is strong evidence linking access to greenspace to a variety of health and wellbeing measures. Research has also shown that there is a link between wellbeing and perceptions of biodiversity and naturalness. Natural England and others have published guidelines that promote the enhancement of access, naturalness and connectivity of greenspaces.

The two key components of accessible nature capacity are therefore public access and perceived naturalness. Both of these components are captured in the model, which maps the availability of natural areas and scores them by their perceived level of "naturalness".

### How is it measured?

Accessible nature capacity was mapped using an EcoServ GIS model. In the first step, accessible areas are mapped. These are defined as:

- Areas 10m either side of linear routes such as Public Rights of Way, pavements and Sustrans routes.
- Publicly accessible areas such as country parks, CRoW access land, local nature reserves and accessible woodlands.
- Areas of green infrastructure marked as accessible, including parks, playgrounds, and other amenity greenspaces.

These areas were then scored for their perceived level of naturalness, with scores taken from the scientific literature. Naturalness was scored in a 300m radius around each point, representing the visitors experience within a short walk of each point.

The resulting map shows accessible areas, with high values representing areas where habitats have a higher perceived naturalness score. Scores are on a 1 to 100 scale, relative to values present within the study area. White space shows built areas or areas with no public access.

Larger continuous blocks of more natural habitat types will have higher scores than smaller isolated sites of the same habitat type. One consequence is that linear routes, such as footpaths, that pass through land with no other access will not score highly.

### Results for Buckinghamshire

Figure 17 shows accessible nature capacity for publicly accessible land only. Accessible nature capacity is highest in Burnham Beeches, Penn Wood, Ashridge Estate and Bernwood Forest. Hotspots also occur around other large accessible sites, especially in the south.

Accessible nature capacity is moderate around the outskirts of major urban centres, especially High Wycombe, which has a number of accessible greenspaces nearby. Access is lowest in more rural areas in the northern half of the county, where public footpaths provide the only access in predominantly agricultural areas.

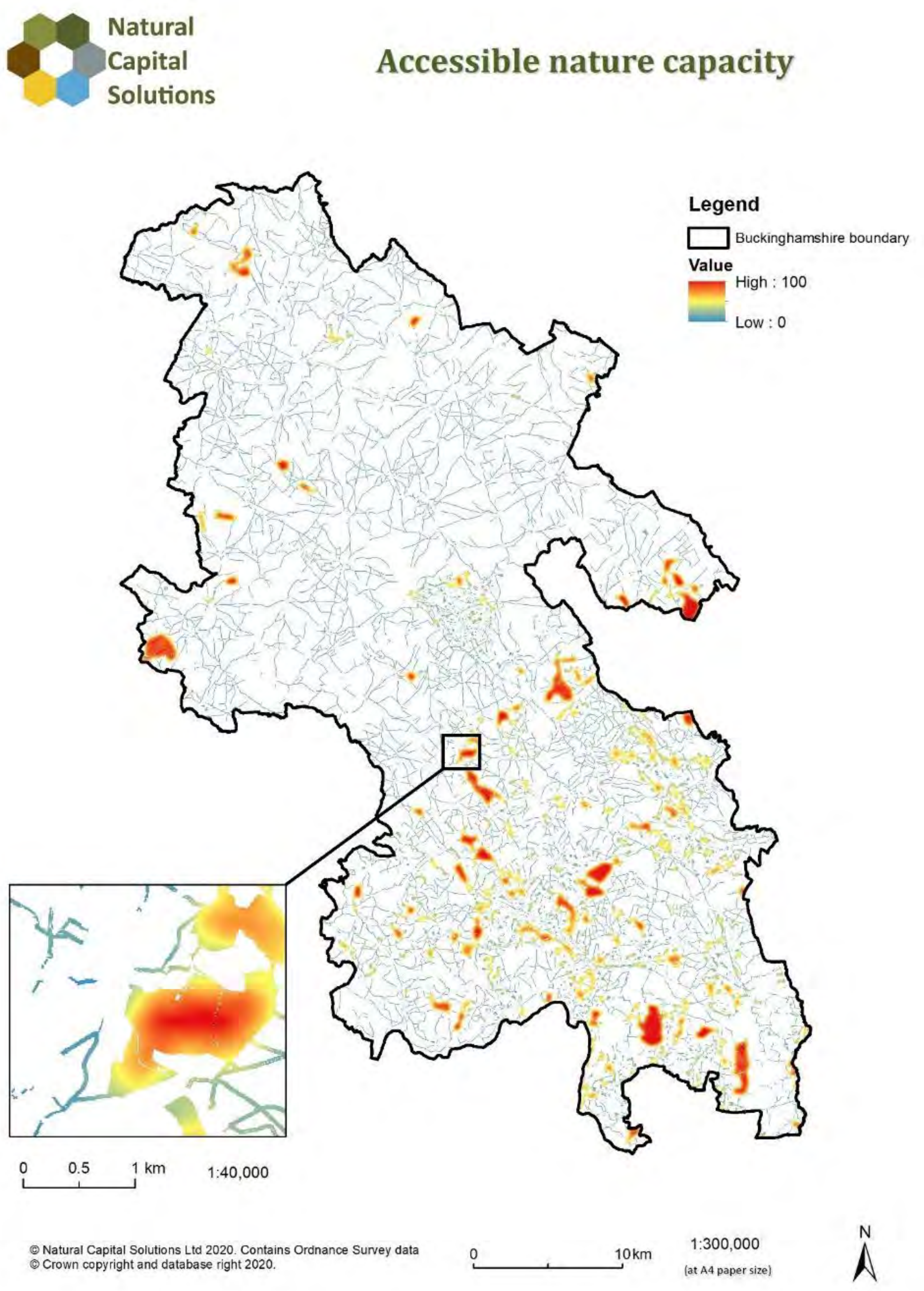



**Figure 17** Accessible nature capacity across Buckinghamshire. Areas with zero demand have been excluded to improve map legibility.

## 3.14 Accessible nature demand

### What is it and why is it important?

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

**How is it measured?**

This model maps sources of demand, taking no account of habitat, based on three indicators: population density (based on 2011 census data), health scores (from the Index of Multiple Deprivation), and distance to footpaths and access points. The three indicators are calculated at three different scales as demand is strongly related to distance. The Monitor of Engagement with the Natural Environment (MENE) survey and other literature on visit distance was used to determine appropriate distances. The distances chosen (and rationale) were: 600m (10 minutes walking distance), 3.2 Km (67% of all visits and 90% of visits by foot occur within this distance), and 16 Km (90% of all visits travelled less than this distance).

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

### Results for Buckinghamshire

Demand for accessible nature (see Figure 18) is focussed around where people live, hence Aylesbury and High Wycombe provide the largest demand across the county. There is also significant demand from the numerous other urban areas in the south of the county, with lowest demand in the north-west.

### Balancing supply and demand for accessible nature

Numerous research has shown that people travel most frequently to greenspaces very close to their homes and Natural England recommend that everyone should have access to at least some greenspace within 300m (5 minutes walk) and larger sites within 2 km. Furthermore, surveys have shown that the majority of people will typically travel less than 3.2 km to visit greenspace. Any new accessible greenspace being created should therefore be close to housing areas. New housing areas will also create increased demand for accessible greenspace, so it is important that this demand is met on-site.

There is now a vast amount of evidence showing the benefits of greenspace, particularly in built-up areas. Furthermore, research has shown that people gain greater well-being from visiting sites that they perceive to be more natural and richer in biodiversity. This shows that as well as providing access to greenspace, it is important that the greenspace is of a high quality and as natural as possible.

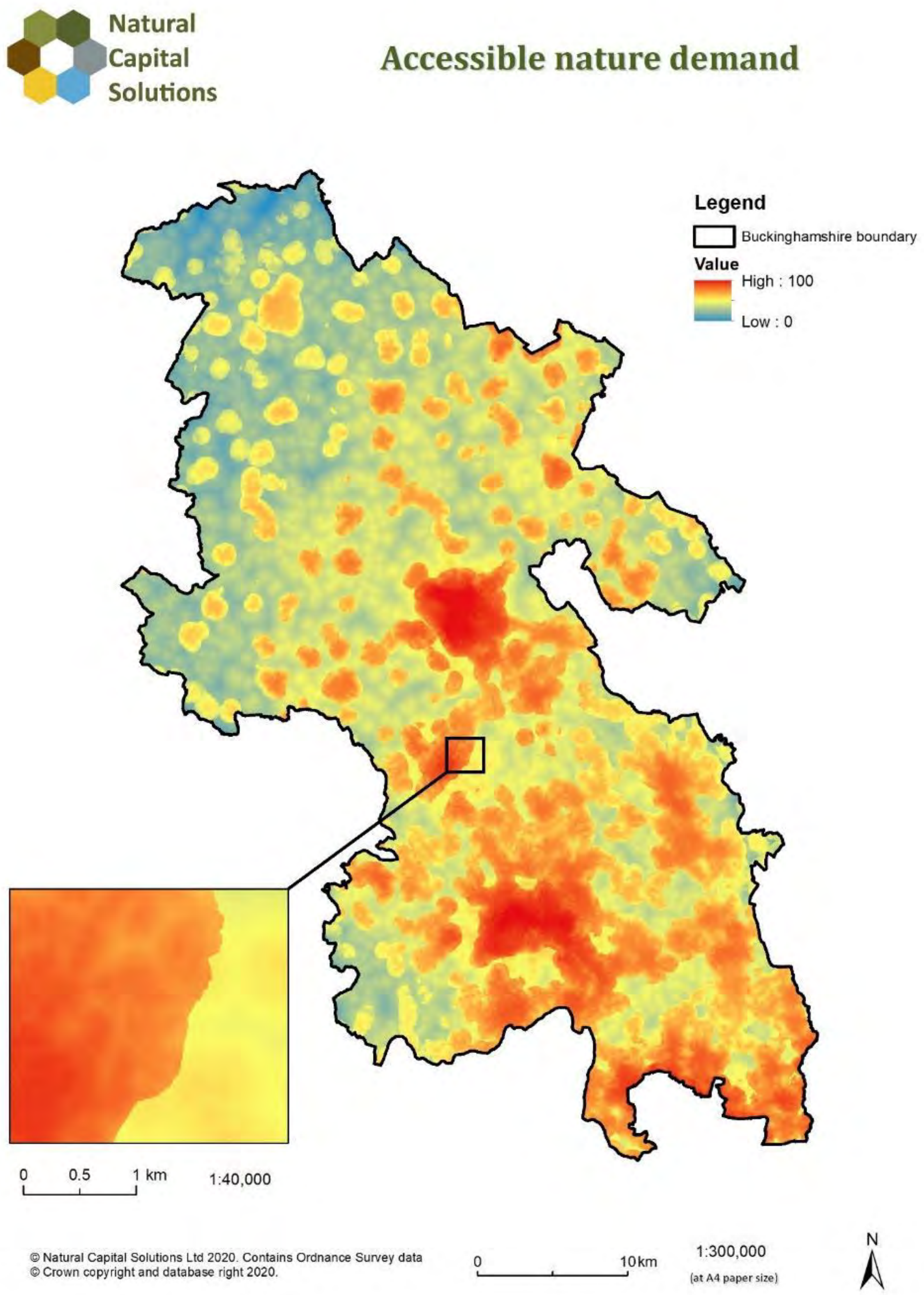



**Figure 18** Accessible nature demand across Buckinghamshire.

# 4. Habitat opportunity mapping

## 4.1 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. 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

The approach taken, and results obtained for each of these potential services are described in turn below. Maps have also been combined to show areas that could deliver multiple benefits, and this is described in Section 4.9.

Please note that the mapping identifies areas based on landscape-scale ecological principles or indicative 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. Further steps are highlighted at the end of this report (Section 5), which would move towards identifying specific projects to take forward.

## 4.2 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 Buckinghamshire. The broad habitats and their constituent types are shown in the table overleaf:

| 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)[11] and Watts et al. (2010)[12]. 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.

### 4.2.1 Method

*1. Landscape permeability*

This step involves assessing the permeability of the landscape to typical species from each habitat type and builds on work carried out by JNCC, Forest Research and others. Generic focal species are assessed for each habitat type as there is a lack of ecological knowledge to be able to repeat the process for multiple different individual species, and generic species provide an average assessment for species typical of each habitat type.

It is assumed that a species will have optimal dispersal capabilities in the habitat in which it is associated and hence the landscape is fully permeable if it consists only of this primary habitat. Each of the remaining habitat types is then assigned a permeability score that shows how likely and how far the species will travel through that habitat. Habitats are scored on a scale from 1 (most permeable) to 50 (least permeable). Permeability scores were based on expert scores compiled by JNCC and then adjusted by Natural Capital Solutions for Buckinghamshire for each habitat type. Once tables had been compiled showing permeability scores for each habitat, high (10m) resolution maps were then produced using the EcoServ GIS package showing the permeability of the landscape for generic species from each broad habitat type.

*2. Habitat networks*

Step 2 uses the permeability map created above, along with information on average dispersal distances, to map which habitat patches are ecologically connected and which are ecologically isolated from each other. Dispersal distances were obtained from JNCC, which had performed a review of the scientific literature to ascertain the dispersal distances of a range of species for each habitat type. These were typically species of small mammals, smaller birds, butterflies, and plants. The average dispersal distance for each habitat is shown in the table below:

[11] Catchpole, R.D.J. (2006). Planning for Biodiversity – opportunity mapping and habitat networks in practice: a technical guide. *English Nature Research Reports*, No 687

[12] 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.

| Dispersal distance in optimal habitat: | |
|---|---|
| Semi-natural grassland | 2.0 km |
| Wet grassland & wetlands | 2.0 km |
| Broadleaved and mixed woodland | 3.0 km |

*3. Identifying constraints*

The habitat network map created in Step 2 can be used to indicate where new habitat could be created; any habitat created within the existing network would be ecologically connected to existing patches. However, in reality a number of constraints exist that need to be taken into account when producing opportunity maps. The aim of this step, therefore, is to produce a series of maps of constraints that can be used to show where habitat cannot or should not be created. The following constraints were mapped and are shown on Figure 19 (overleaf):

- Land-use constraints – infrastructure (roads, railways, and paths), urban (all buildings), gardens, and water (standing and running), as it is highly unlikely that these would be available for habitat creation.
- High quality habitats – all existing habitats of high nature conservation interest were identified from the basemap (as described in Section 2.3), as it would not make sense to destroy existing high-quality habitat to create new habitat of a different type. A full list of these habitats is shown in Box 3 (below) and are the same as those mapped in Figure 3.
- Historic sites – data were obtained from Historic England on the location of Scheduled Monuments, Registered Parks and Gardens, and Registered Battlefields across the study area and a 30m buffer was applied around each individual site, as recommended by Historic England. This constraint was applied to woodland, and wet grassland and wetland opportunities, but not to grassland opportunities which may be possible on such sites.
- National Grid gas pipelines, overhead lines and cables – data were obtained from the National Grid and a 10m buffer was applied around both features. This constraint was only applied when woodland opportunities were being mapped, as it would not be possible to plant trees in these areas, although grassland and wetland habitats would be feasible.
- For wet grassland and wetland habitats it was assumed that hydrology (wetness) would be a limiting factor. Therefore, habitat opportunity areas were restricted to areas within the indicative floodplain, as indicated by the Environment Agency's Flood Zone 2 map.

**Box 3: High quality habitats**

The following habitats were identified from the basemap and used as constraints:

- Broadleaved woodland
- Mixed woodland
- Woodland/scrub with semi-natural habitats
- Unimproved and semi-improved acid grassland
- Unimproved and semi-improved neutral grassland
- Unimproved and semi-improved calcareous grassland
- Floodplain grazing marsh
- Marshy grassland
- Heathland
- Fen, marsh and swamp

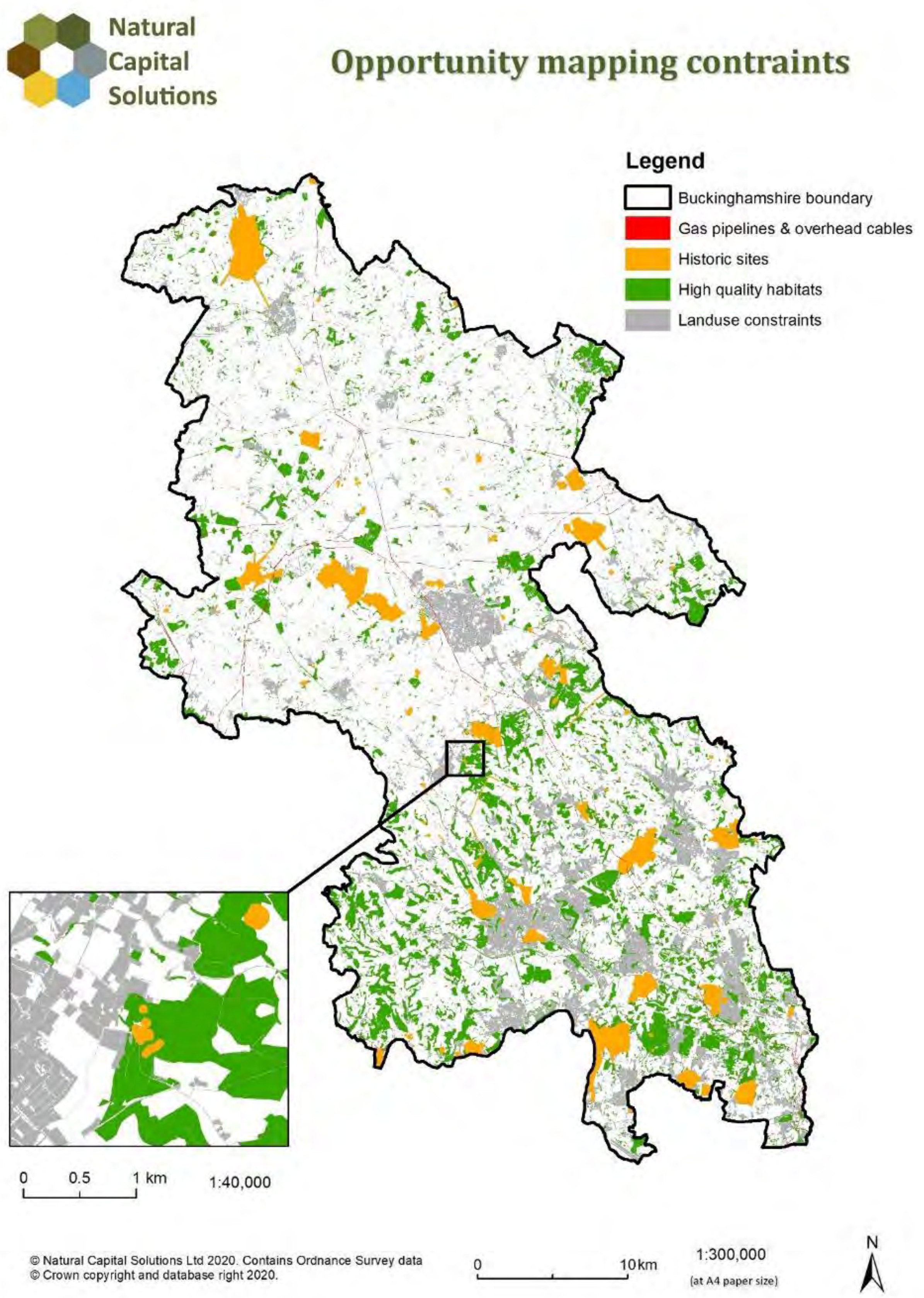



**Figure 19:** Key constraints taken into account during habitat opportunity mapping across Buckinghamshire.

4. *Habitat opportunity for biodiversity*

In the next step, the constraints map was used to exclude areas that would be unsuitable or unavailable for new habitat. A habitat opportunity layer was then created, called **buffer opportunity**. This layer identified habitat opportunity areas that are immediately adjacent to existing habitat patches and fall within the previously identified ecological network.

When creating this layer, a minimum threshold size was set at 0.1 ha, to remove tiny fragments of land and to replicate the minimum sizes of habitat creation grant schemes.

As the above map identifies portions of land in relation to the ecological network for each habitat, it often results in thin slivers of land being identified adjacent to existing habitats, which bear no relationship to existing fields and boundaries. As habitat creation or restoration projects usually operate on whole fields, an additional step was taken to identify those fields that present buffer opportunities. To do this, the buffer layer was overlain over the basemap to identify whole fields that are immediately adjacent to existing habitat patches and are not constrained by the factors described in Step 3. Parts of these fields fall within the previously identified ecological network and creating new habitat will extend the network.

### 4.1.2 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 inset map shown on each map page is included to show more clearly the detail of each layer, although the location chosen is not significant.

The permeability of the landscape for typical semi-natural grassland species is shown on Figure 20. 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.

The habitat network map for semi-natural grassland is shown on Figure 21. 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. For semi-natural grasslands (Figure 21) the area to the north-west of Aylesbury provides the greatest density of habitat. 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 other moderately large patches exist in the north-east of the county, with other smaller patches spread across the area. Broadleaved and mixed woodland habitat networks (Figure A2) are concentrated in the southern half of Buckinghamshire, where much of the area forms a near continuous patch of ecologically connected habitat. Woodland in the north half of the county is much more ecologically isolated and there are few large patches of continuous habitat. Wet grassland and wetland habitat networks (Figure A6), are much less significant in Buckinghamshire, with only a few small habitat patches along the River Thame and a few other locations in the north of the county, most of which are ecologically isolated from each other.

Once constraints have been removed, the resulting maps show biodiversity opportunity areas. Figures 22 and 23 illustrates these for semi-natural grassland habitats, with the other habitats in Annex 1. Figure 22 shows the opportunity zones as buffers around existing sites, while Figure 23 highlights whole fields where habitats could be created, as these are a more meaningful management unit for conservation action. There are many areas in the north-west of Buckinghamshire 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 through much of northern Buckinghamshire. Broadleaved and mixed woodland opportunities (Figure A4) exist throughout the study area, although with particular density in the south, where field-scale habitat creation could increase the 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 (see Section 6.1).

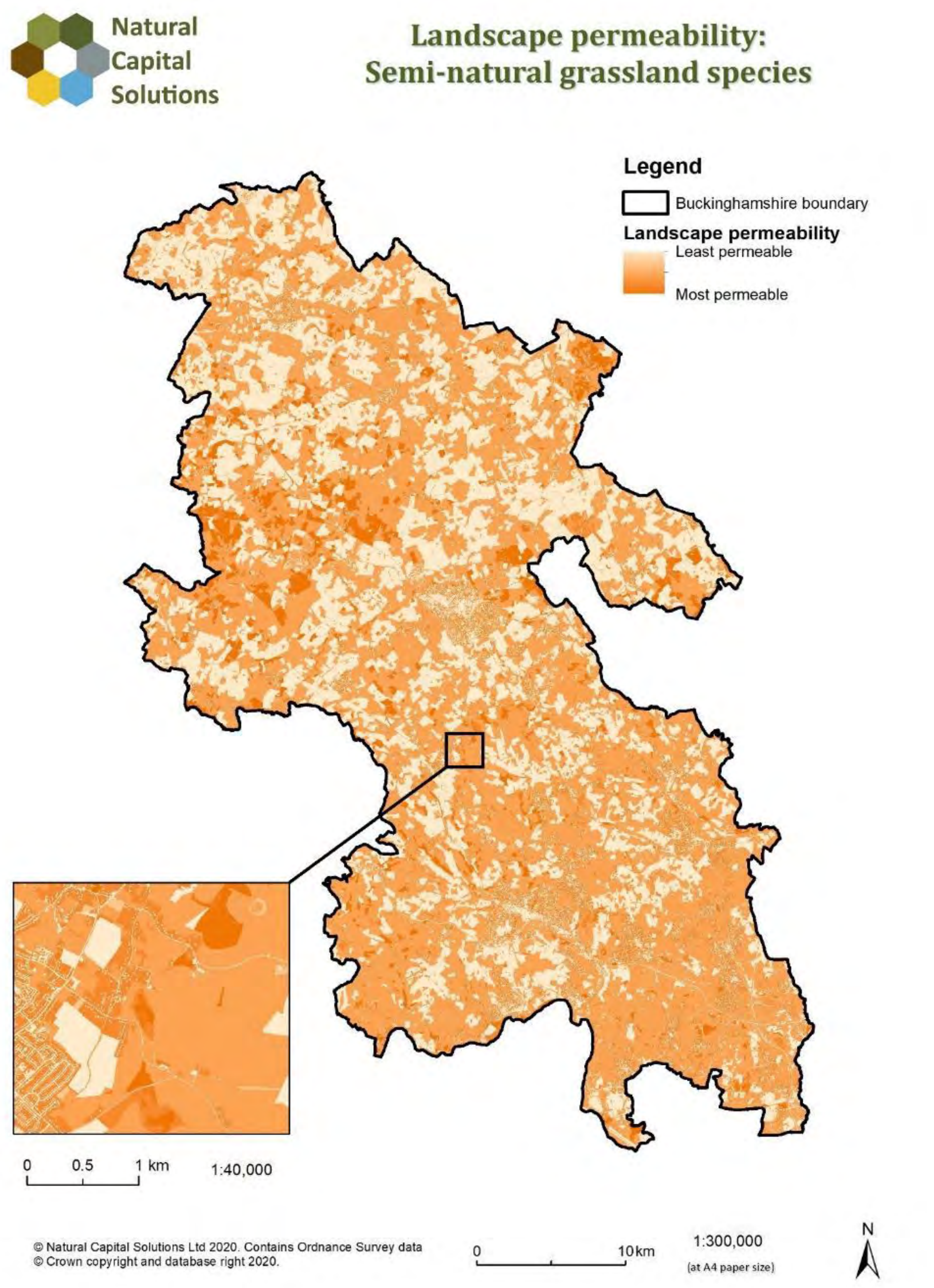



**Figure 20:** Landscape permeability for typical semi-natural grassland species across Buckinghamshire.

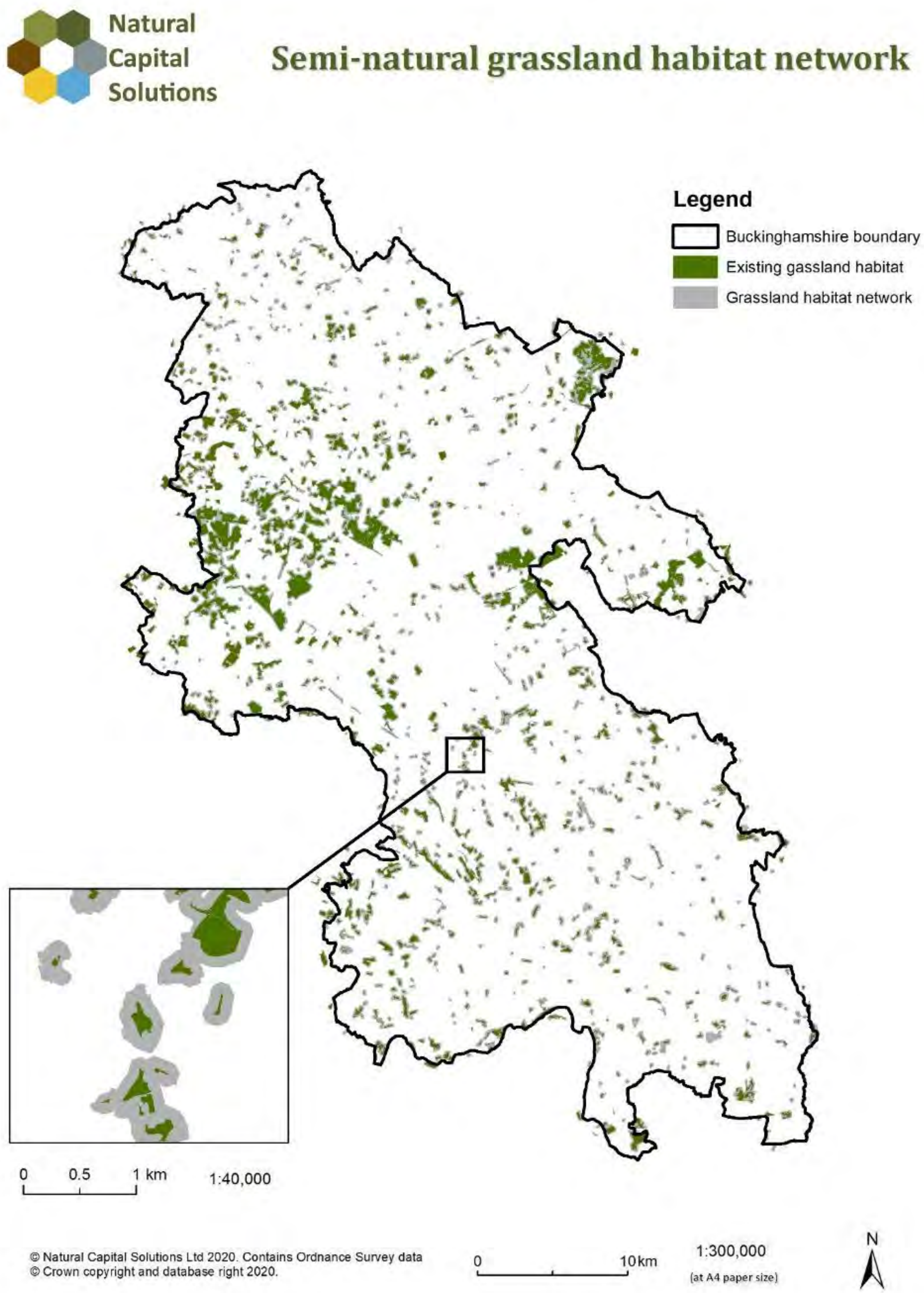



**Figure 21:** Habitat network for semi-natural grasslands across Buckinghamshire.

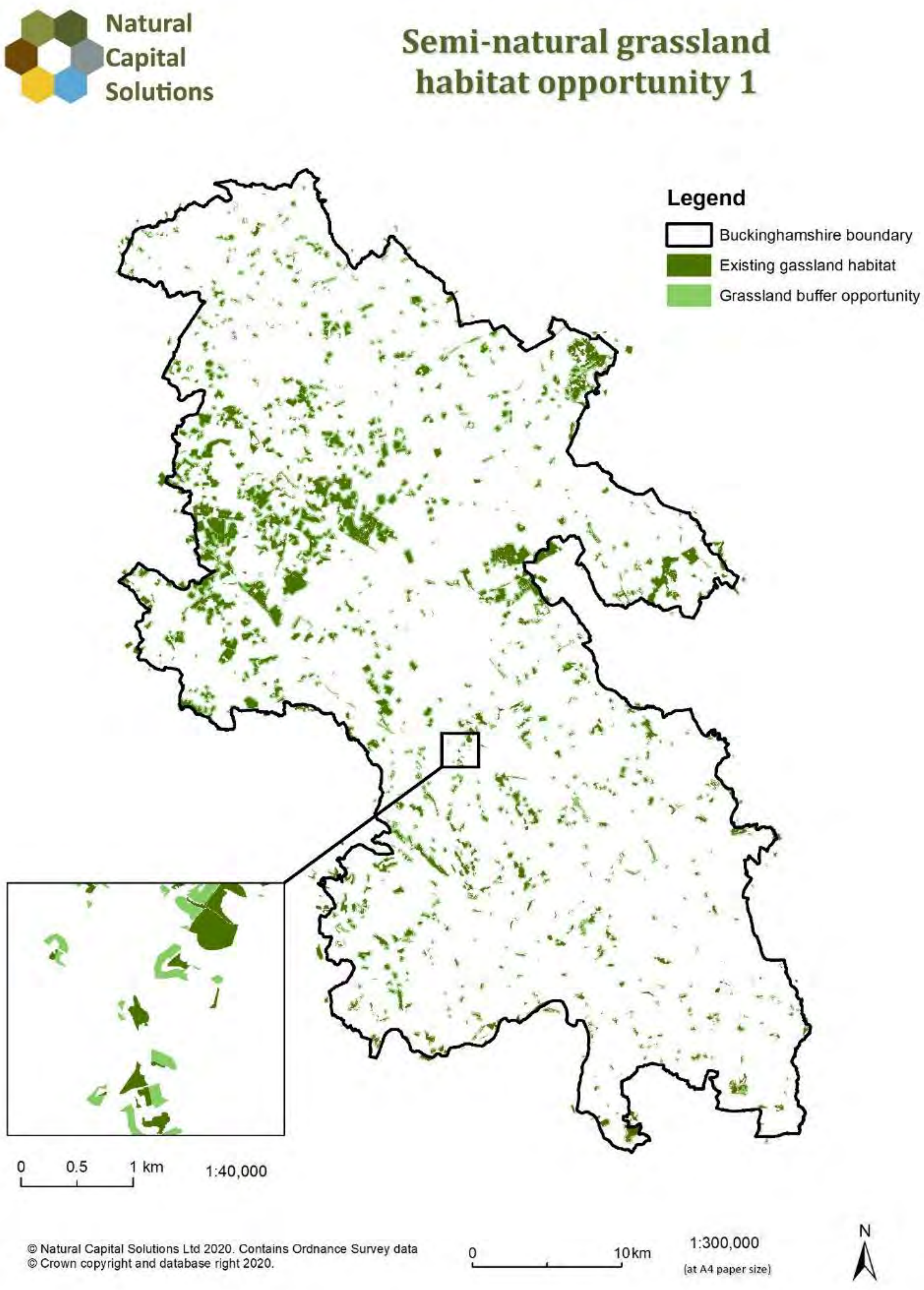



**Figure 22:** Buffer biodiversity opportunity areas for semi-natural grassland across Buckinghamshire.

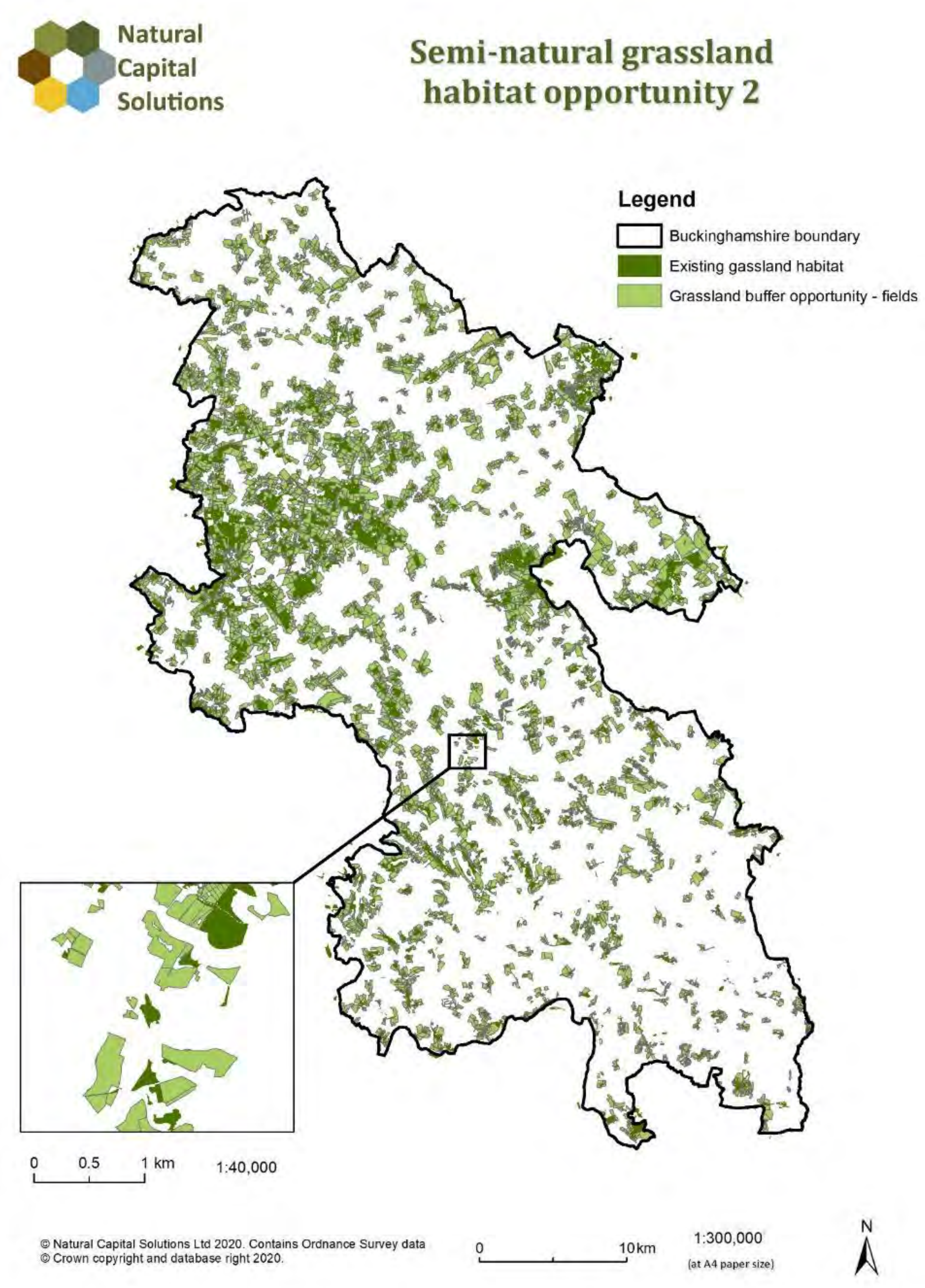



**Figure 23:** Field scale biodiversity opportunity areas for semi-natural grassland across Buckinghamshire.

## 4.3 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.

### 4.3.1 Method

Constraints were identified and mapped in the same way as described in Section 4.2.1 (Figure 19). These locations were the erased from the water flow regulation map developed in Section 3.9, to leave a map showing water flow regulation in all unconstrained locations. This was then classified into quartiles and the top quartile was extracted into a different map layer. Therefore, this shows the top 25% of areas of land across the study area where surface water runoff is currently highest and where there are no constraints on potentially altering land use. Note that it would also be possible to produce maps showing the top 10% of areas or any other value, to show a narrower range of sites, if desired.

The final opportunity map identifies a large number of very small polygons and many polygons do not coincide with fields, the scale over which management and land use change is likely to take place. Therefore, as for biodiversity opportunity areas, it was considered beneficial to identify whole fields offering the greatest opportunity to reduce surface water runoff. To do this, all the previously identified constraints were removed or erased from the underlying habitat basemap. The degree of intersection between the opportunity map and the underlying fields (polygons) in the basemap was then calculated. Fields where at least 50% of the field overlapped with the opportunity map were selected and exported to a new layer. Finally, very small polygons were deleted, so that only fields and plots at least 0.1 ha in size were included in the final map.

### 4.2.2 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 24. Opportunities are present over much of Buckinghamshire, with the exception of a flat central belt, 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 25.

Note that some of the worst areas for water flow regulation highlighted in Figure 13 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).

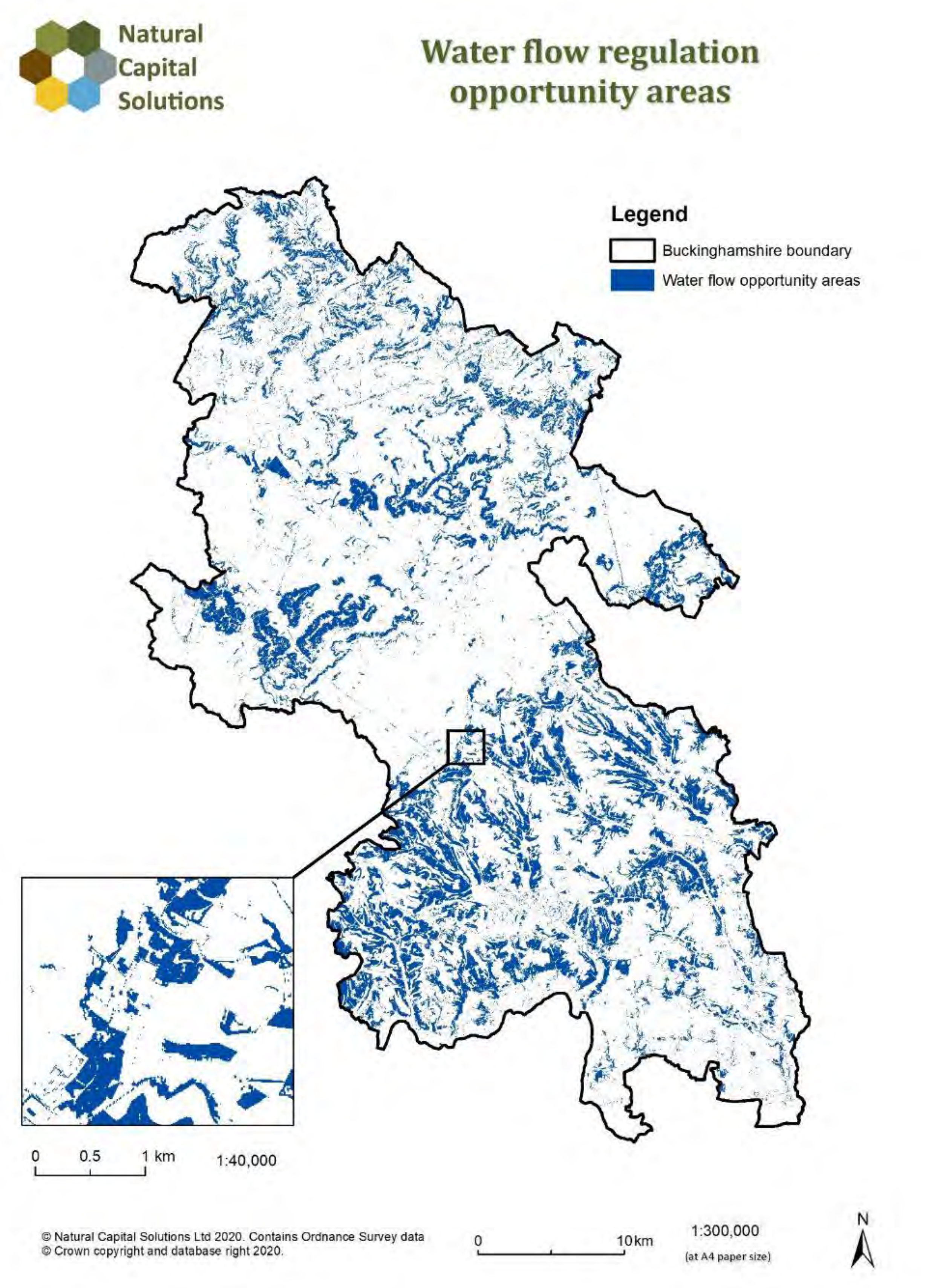



**Figure 24:** Water flow regulation opportunity areas across Buckinghamshire.

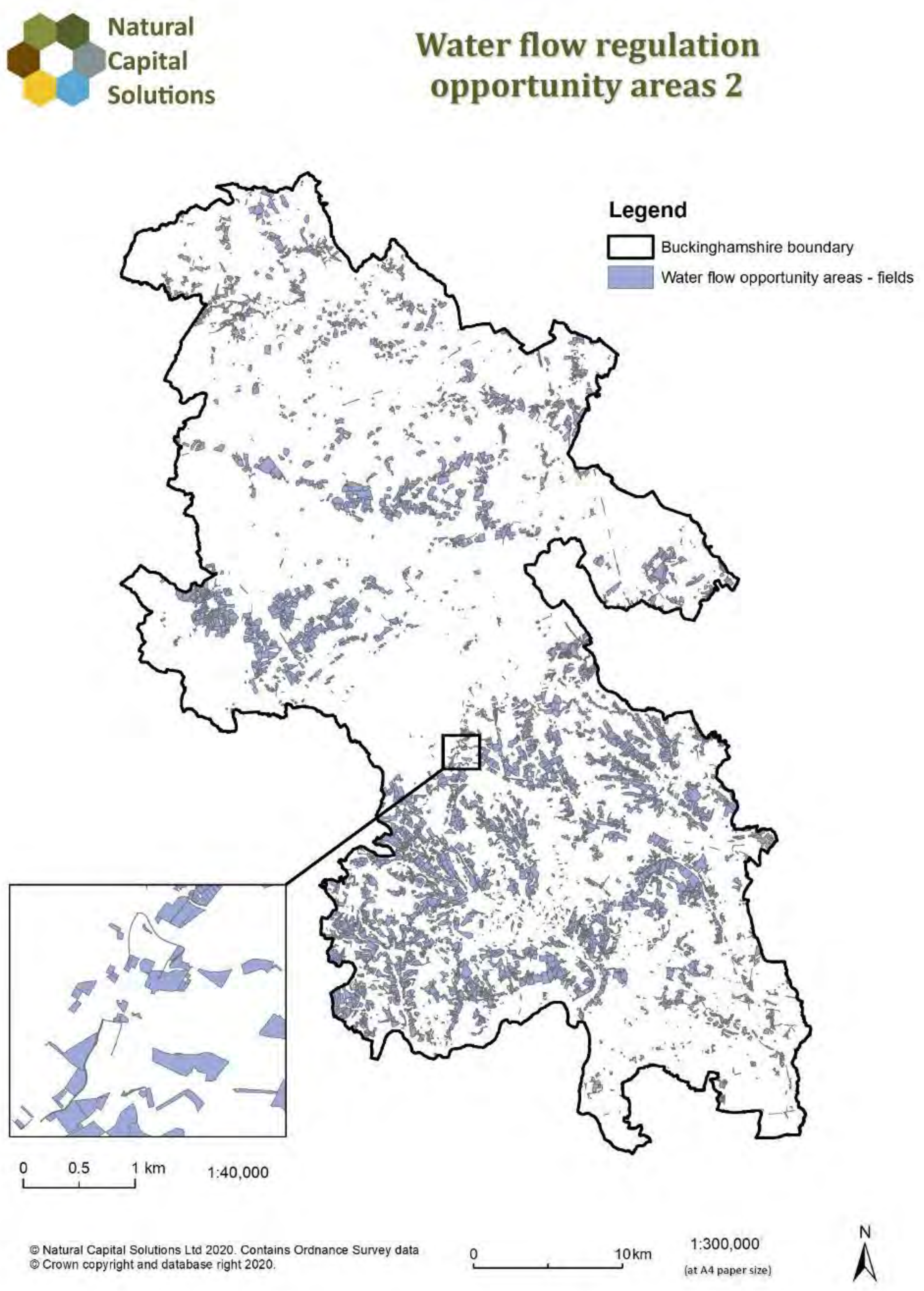



**Figure 25:** Field scale water flow regulation opportunity areas across Buckinghamshire

## 4.4 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. Hard engineered solutions such as water treatment plants are much less effective in these circumstances than when dealing with point source pollutants, and 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.

### 4.4.1 Method

Constraints were identified and mapped in the same way as before. These areas were erased from the water quality regulation map, to leave a map showing water quality regulation in all unconstrained locations. This was then classified into quartiles and the top 25% were extracted into a different map. Therefore, this shows the top 25% of areas of land across the study area where sedimentation risk and soil erosion is currently highest and where there are no constraints on potentially altering land use.

As for water flow, the final opportunity map identifies a large number of very small polygons and long thin polygons that do not coincide with fields. The long thin polygons usually follow watercourses and are useful at identifying locations where riparian buffer stirps would be appropriate. However, there may also be opportunities for whole fields to be converted to other habitats (especially woodland), therefore, whole fields offering the greatest opportunity to reduce soil erosion were identified. To do this, all the previously identified constraints were removed or erased from the underlying habitat basemap. The degree of intersection between the opportunity map and the underlying fields (polygons) in the basemap was then calculated. Fields where at least 50% of the field overlapped with the opportunity map were selected and exported to a new layer. Finally, very small polygons were deleted, so that only fields and plots at least 0.1 ha in size were included in the final map.

### 4.4.2 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 hence highlighted as the areas with greatest opportunity to reduce sediment loads and enhance water quality on the opportunity map (Figure 26). In addition, distance to watercourses is another key factor. Due to the underlying geology, the southern half of Buckinghamshire has far fewer watercourses and also less arable than the north, hence the vast majority of opportunities to improve water quality are located in the north 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.

A map of whole fields where opportunities for reducing soil erosion and enhancing water quality would be most effective has been created (Figure 27). 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 24) with water quality (Figure 26), reveals that there is little overlap between the two. The most effective locations for reducing surface water runoff tend to occur on slopes, many of which are in the south of the study area, whereas the most effective areas to enhance water quality are immediately adjacent to water courses on arable fields, almost entirely in the northern half of the study area, although there is a little overlap in the northern half of the county. It is likely that habitat features created for one will still enhance the other, it is simply that the top 25% of target areas to not overlap in many locations. Woodland would be the most effective solution to deliver these opportunities, although semi-natural grasslands, wet grasslands and wetlands would also deliver benefits.

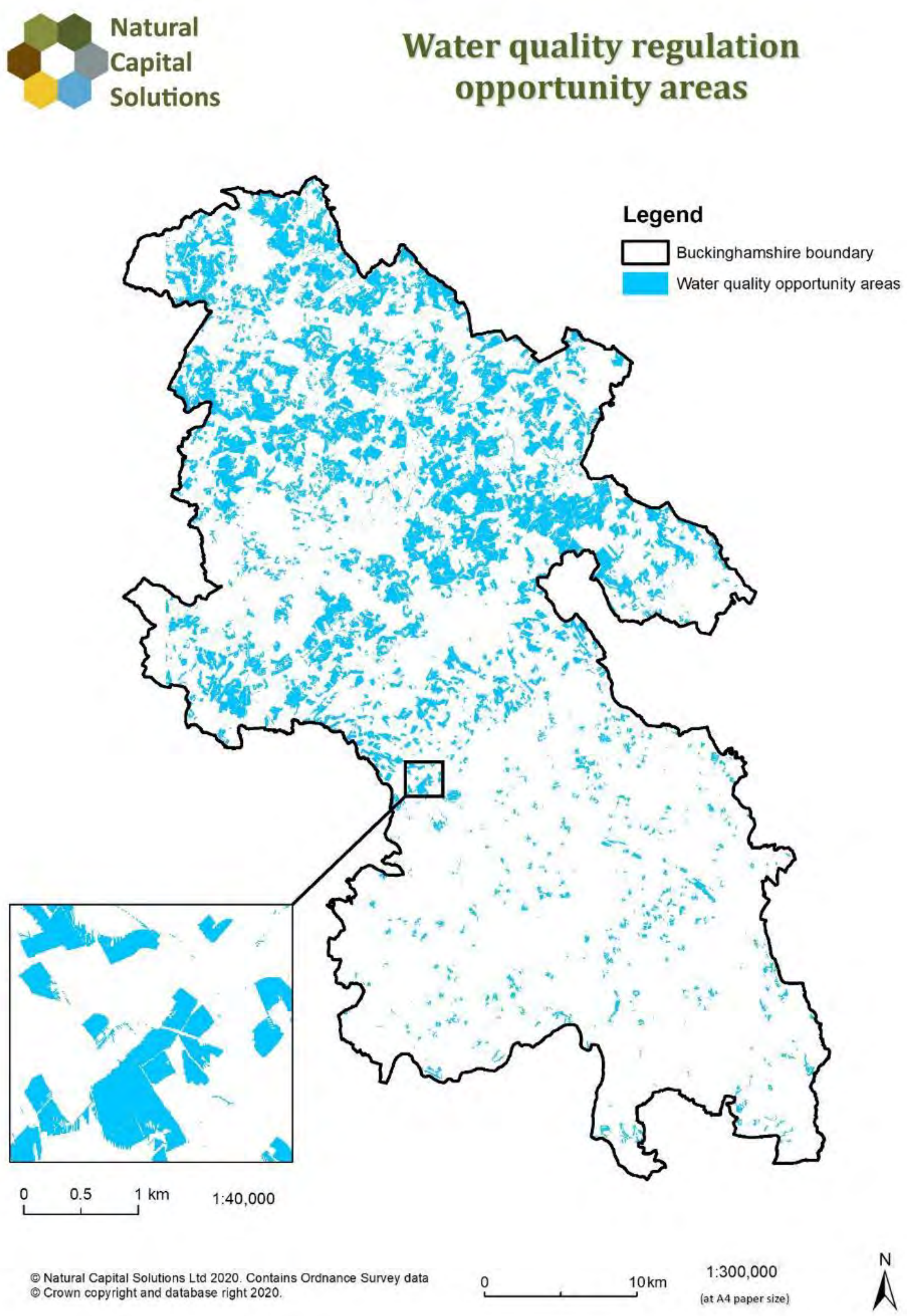



**Figure 26:** Water quality regulation opportunity areas across Buckinghamshire.

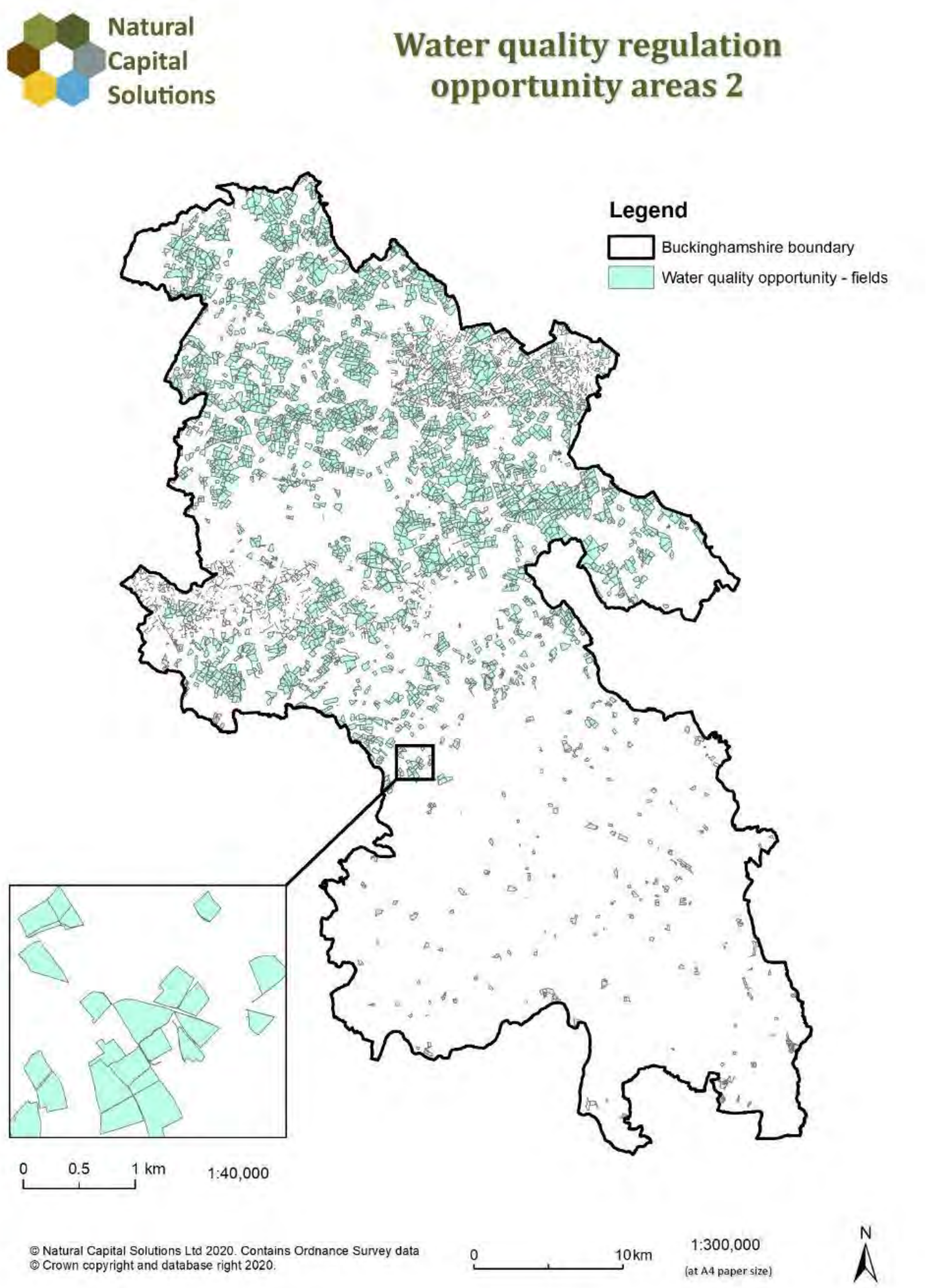



**Figure 27:** Field scale water quality regulation opportunity areas across Buckinghamshire.

## 4.5 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.

### 4.5.1 Method

The constraints identified previously were erased from the air quality regulation demand map, to leave a map showing demand in all unconstrained locations. As before, this was then classified into quartiles and the top quartile was extracted into a different map. This map therefore highlights the top 25% of areas of land across the study area where demand for air quality amelioration is greatest and where there are no constraints on potentially altering land use. As previously it would also be possible to produce maps showing the top 10% or 5% (or any other value), to focus on the worst pollution hotspots with the greatest demand.

To match the other ecosystem services, the opportunity map was used to identify whole plots and fields in the basemap where the degree of intersection was at least 50% and a new layer was created. On this occasion very small polygons were not deleted, as it may be possible to plant an individual tree in very small plots of land.

### 4.5.2 Results

As described previously, demand for air quality regulation (Figure 8) 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 28). Opportunity areas along the main roads were also highlighted. Whole plots were also identified (Figure 29), 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.

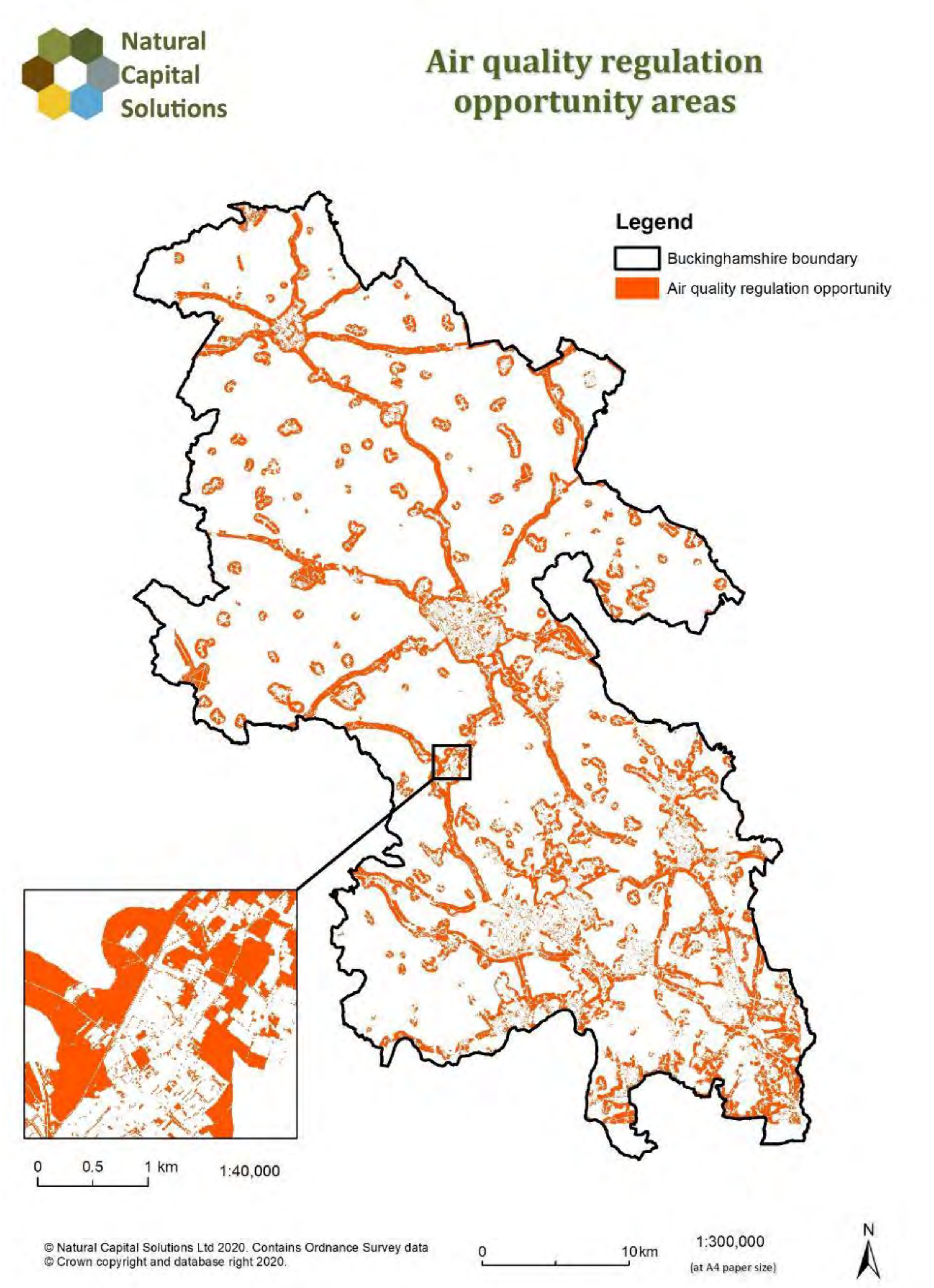



**Figure 28:** Air quality regulation opportunity areas across Buckinghamshire.

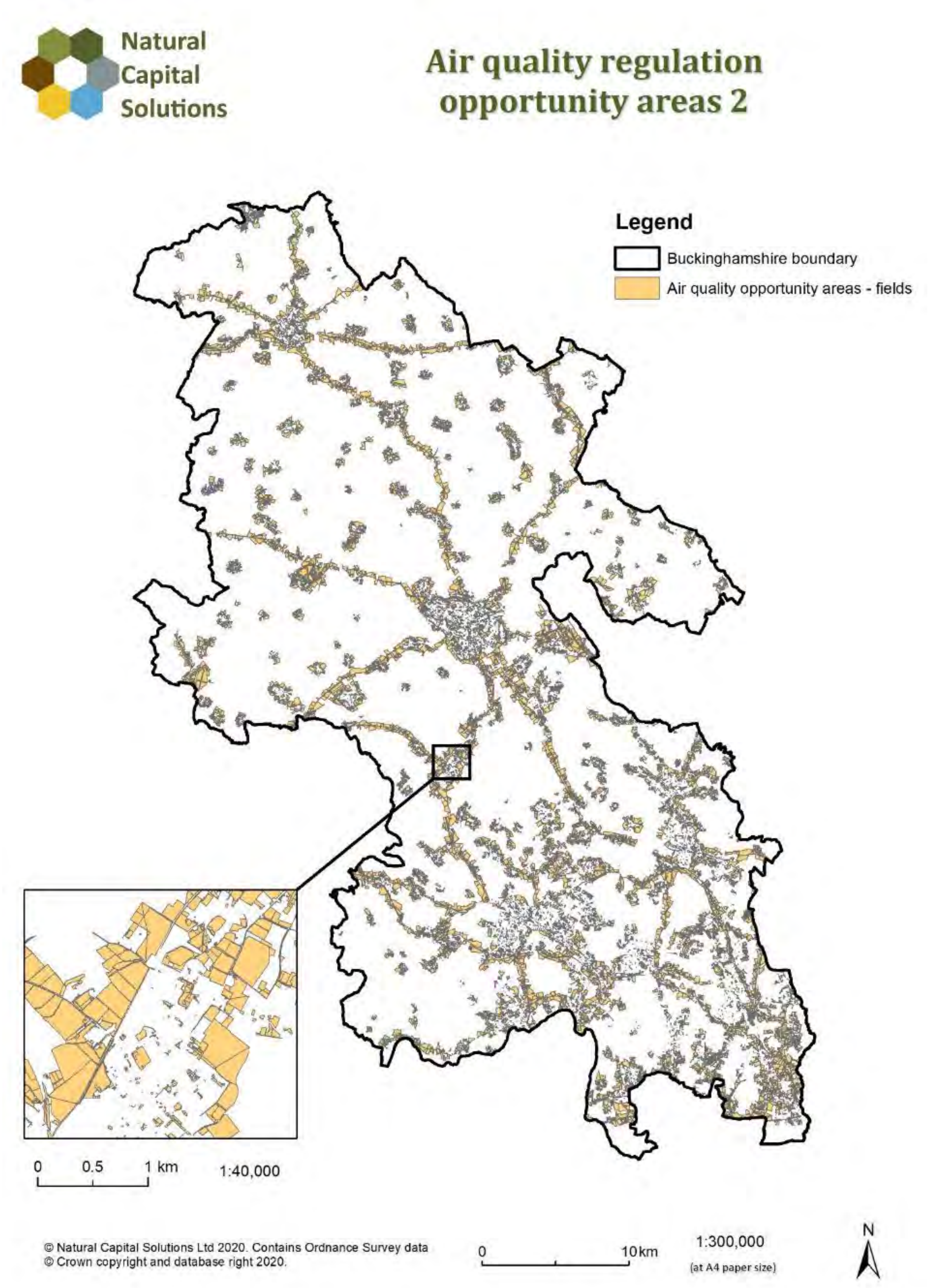



**Figure 29:** Field (plot) scale air quality regulation opportunity areas across Buckinghamshire.

## 4.6 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.

### 4.6.1 Method

The constraints identified previously were erased from the noise regulation demand map, to leave a map showing demand in all unconstrained locations. As before, this was then classified into quartiles and the top quartile was extracted into a different map. This map therefore highlights the top 25% of areas of land across the study area where demand for noise regulation is greatest and where there are no constraints on potentially altering land use.

As before, the opportunity map was used to identify whole plots and fields in the basemap where the degree of intersection was at least 50% and a new layer was created. As individual trees or very small groups of trees are largely ineffective at blocking noise, polygons less than $200m^2$ were deleted.

### 4.6.2 Results

Similarly to air quality regulation, demand for noise regulation (Figure 10) is highest in the main urban centres and adjacent to the road and rail network, especially the motorways, 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 30). Whole plots were also identified and shown in Figure 31. These locations potentially provide the opportunity to plant trees and scrub belts that could help to block and screen noise pollution.

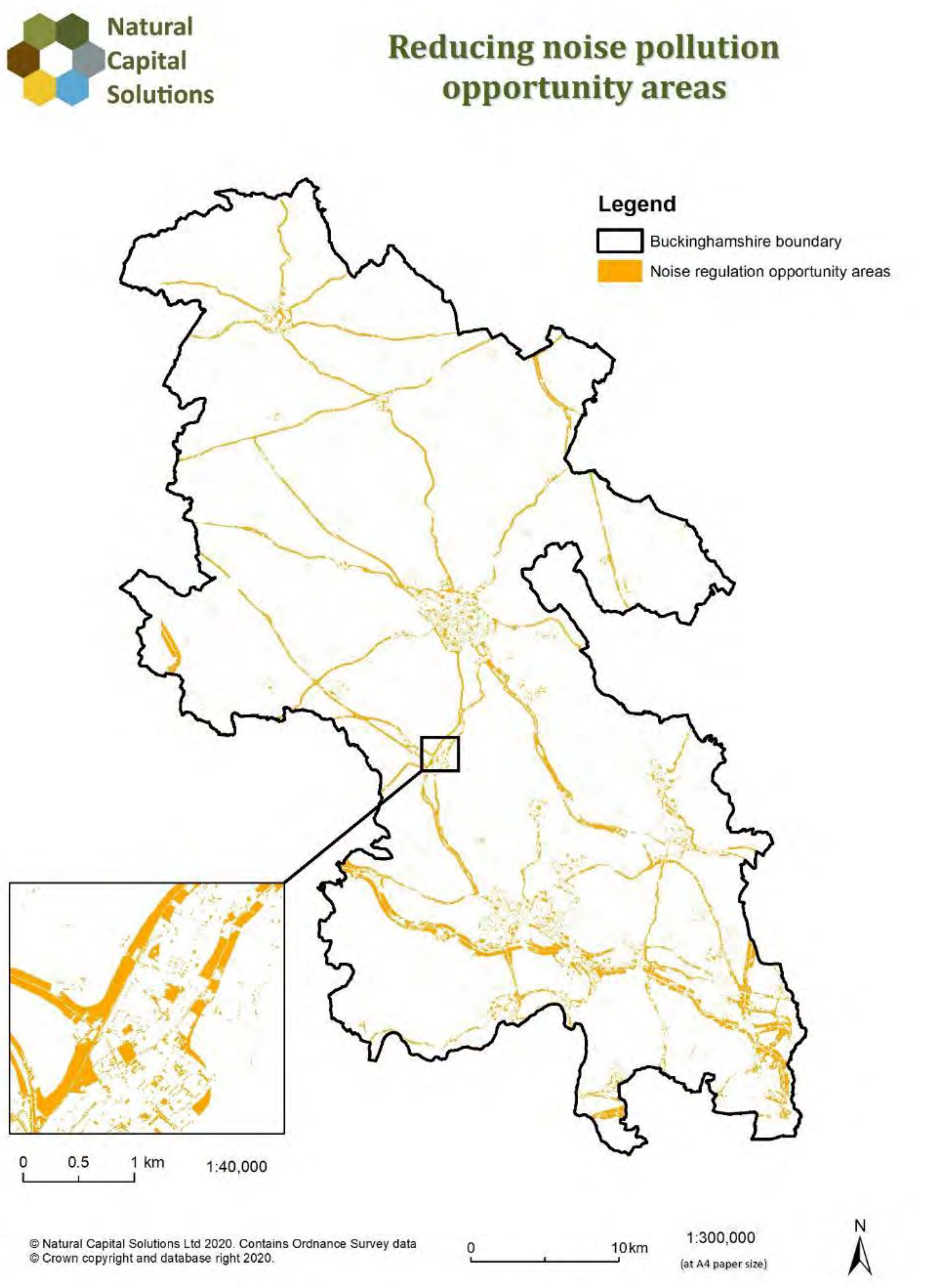



**Figure 30:** Noise regulation opportunity areas across Buckinghamshire.

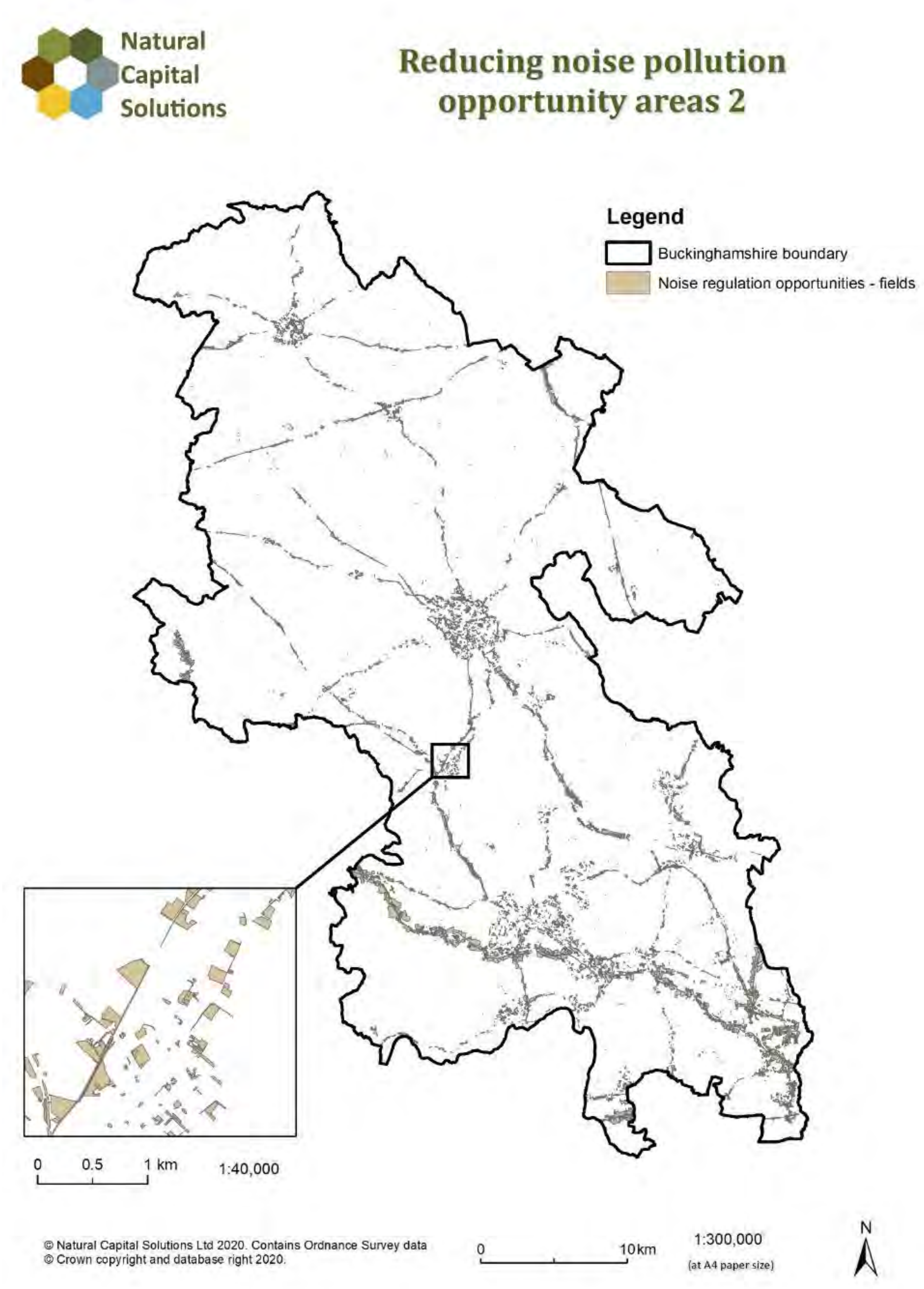



**Figure 31:** Field (plot) scale noise regulation opportunity areas across Buckinghamshire.

## 4.7 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.

### 4.7.1 Method

The constraints identified previously were erased from the local climate regulation demand map (Section 3.8), to leave a map showing demand in all unconstrained locations. As before, this was then classified into quartiles and the top quartile was extracted into a different map. This map therefore highlights the top 25% of areas of land across the study area where demand for local climate regulation is greatest and where there are no constraints on potentially altering land use.

As before, the opportunity map was used to identify whole plots and fields in the basemap where the degree of intersection was at least 50% and a new layer was created. All polygons were retained, as evn planting an individua tree could be beneficial, although will have a smaller effect.

### 4.7.2 Results

Demand for local climate regulation (Figure 12) 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 urban centre location have also been identified (Figure 32). As for the other services, whole plots were also identified and shown in Figure 33. 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.

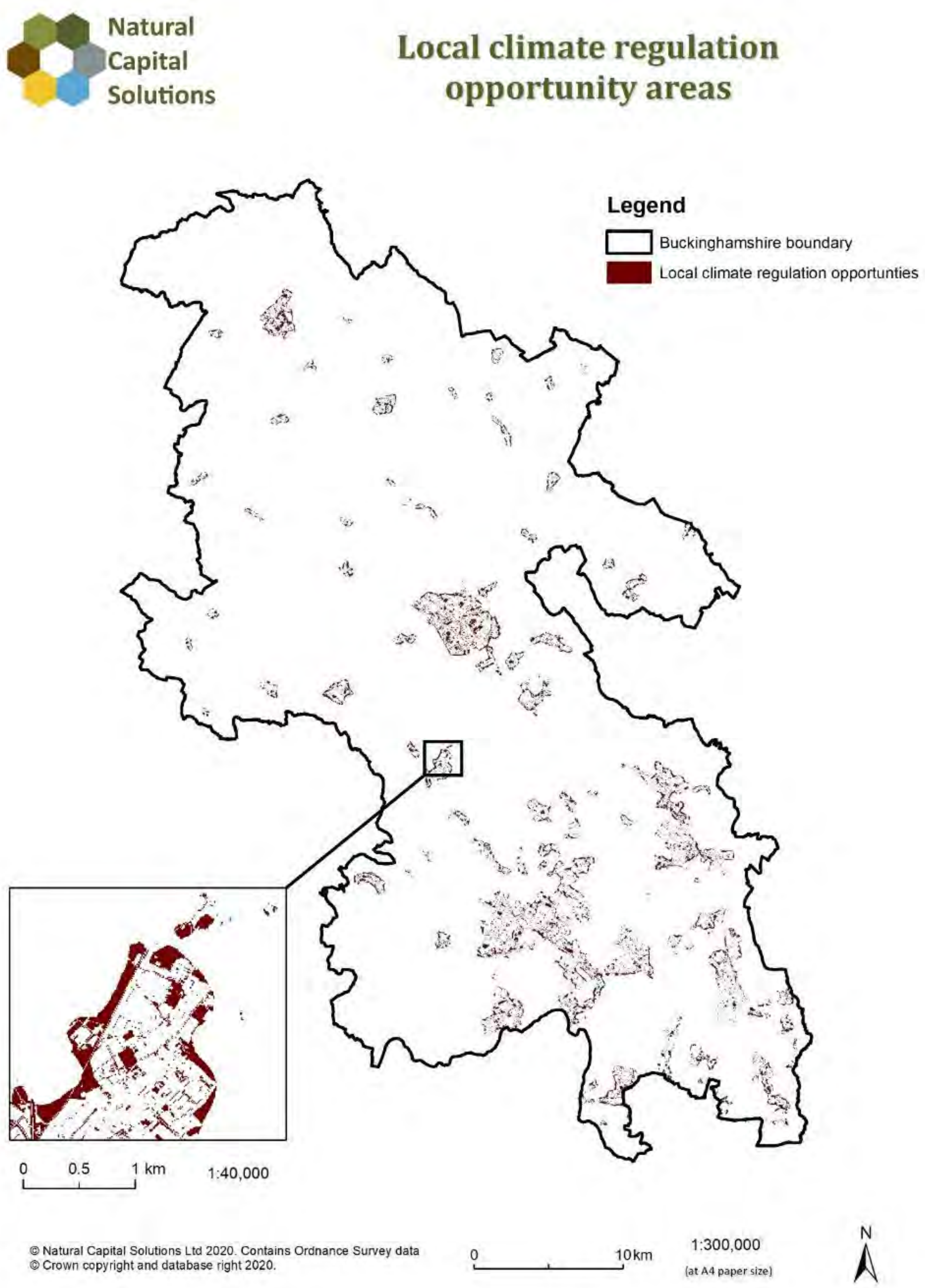



**Figure 32:** Local climate regulation opportunity areas across Buckinghamshire.

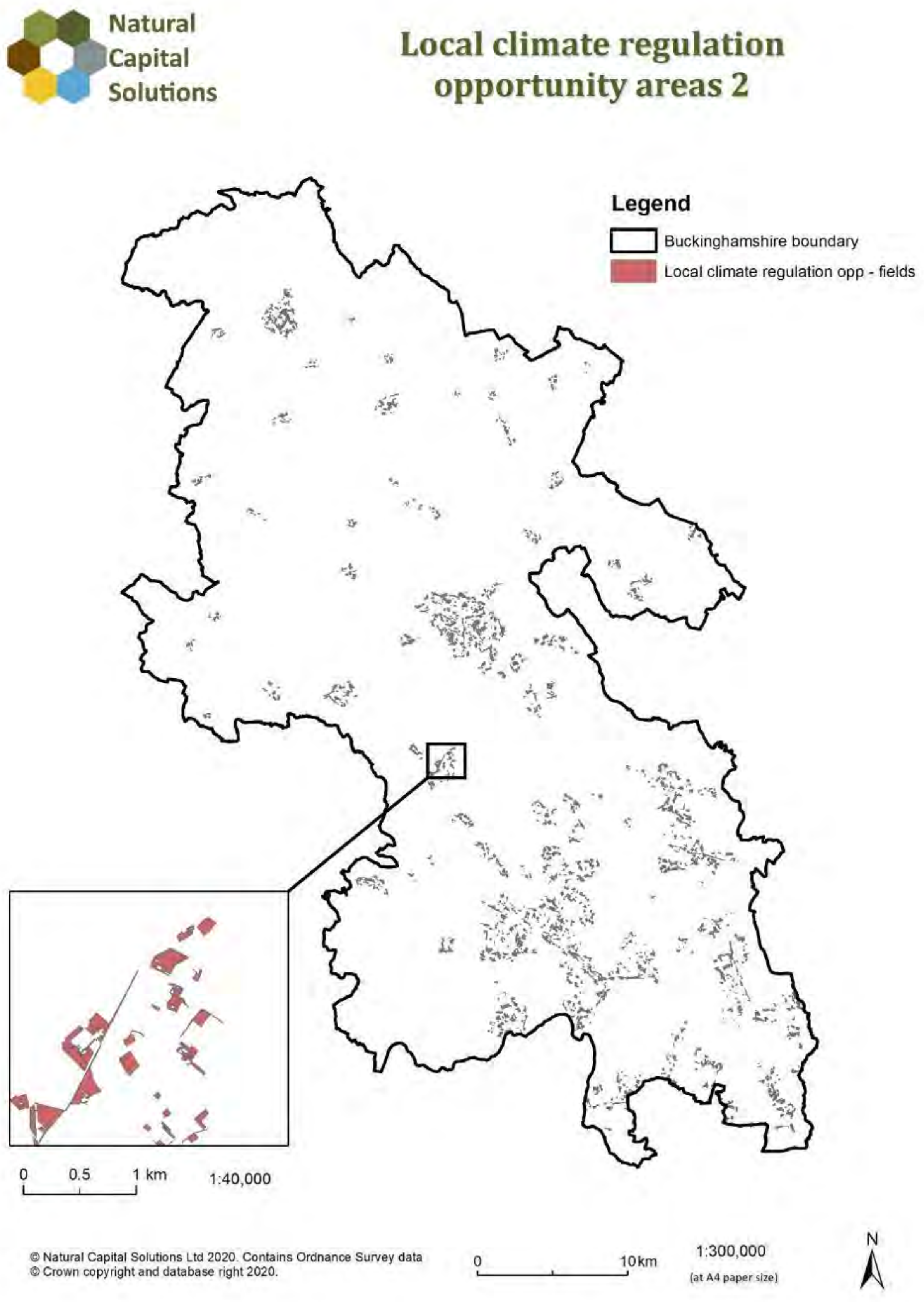



**Figure 33:** Field (plot) scale local climate regulation opportunity areas across Buckinghamshire.

## 4.8 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.

### 4.8.1 Method

*1. <u>Identifying constraints</u>*

It may be possible to create accessible natural greenspace simply by opening up public access to existing areas, rather than changing habitats. Therefore, many of the constraints that would need to be taken into account when planting new habitats for water flow, water quality or air quality regulation, do not need to be taken into account. For example, opportunities do not need to be constrained by existing high quality habitats and historic sites, although these areas would need to be carefully considered on a case-by-case basis to avoid any damage to existing features. The only constraints taken into account were therefore the land use constraints identified previously – buildings, infrastructure, gardens and water. It would be possible to include water features as part of larger sites, but that was not investigated here. A map was created showing all the land use constraints on one map.

In addition to these constraints, a map was created from the basemap showing all areas of green infrastructure currently existing across Buckinghamshire. This was based predominantly on the OS Mastermap Greenspace data layer, with some modifications. This included sites that were both publicly accessible (e.g. public parks, amenity greenspace, play facilities, natural and semi-natural greenspaces) and green infrastructure that is not fully publicly accessible (includes golf courses, allotments, and institutional (e.g. school) grounds).

*2. <u>Identifying opportunity areas</u>*

The land use constraints identified above were erased from the accessible natural greenspace demand map, along with the existing areas of green infrastructure, to leave a map showing demand in all unconstrained locations where there is currently no green infrastructure. As before, this was then classified into quartiles and the top quartile were extracted into a different map. This map highlights the top 25% of areas of land across the study area where demand for accessible natural greenspace is greatest and where there are no constraints on potentially creating this. As before, the opportunity map was used to identify whole plots and fields in the basemap where the degree of intersection was at least 50%.

*3. <u>Mapping the perceived naturalness of existing habitats</u>*

As well as mapping opportunities based purely on demand, it’s also possible to look at the link between demand and the current capacity of the landscape to supply that demand if access were improved. In other words, determining which existing areas would be best to open up to public access with no change of habitats. As stated previously, there is a link between perceptions of naturalness and wellbeing, hence more natural areas are able to deliver accessible natural greenspace of greater value.

Perceived naturalness was therefore mapped using an EcoServ GIS model. All habitats were scored for their perceived level of naturalness, with scores taken as a mean from the scientific literature. Naturalness was scored in a 300m radius around each point, representing the visitors experience within a short walk of each point. This means that larger continuous blocks of more natural habitat types will have higher scores than smaller isolated sites of the same habitat type. Scores are on a 1 to 100 scale, relative to values present within the study area.

4. *Identifying opportunity areas to enhance access to existing sites*

The land use constraints identified in Step 1 were erased from the perceived naturalness map, along with the existing areas of green infrastructure, to leave a map showing the perceived naturalness of all unconstrained locations where there is currently no green infrastructure. This was then classified into 10 percentiles (i.e. the top 10% were identified, 10-20%, 20-30% and so on) and each pixel reclassified from 1-10. The demand map (from step 2) was also re-classified in exactly the same way into 10 percentiles. The two maps were then joined together so that each pixel was given a score based on the naturalness score (out of 10) plus the demand score (out of 10). Finally, the top 25% of combined scores were identified and extracted into a different layer. This map therefore highlights the top 25% of areas of land across the study area where there is both high demand for accessible natural greenspace and the perceived naturalness of the current habitats are greatest (plus there are no constraints). As before, the opportunity map was used to identify whole plots and fields in the basemap where the degree of intersection was at least 50%.

### 4.8.2 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 34 & 35) are centred around the major towns across the study area. As opportunities for new greenspaces are usually highly constrained within towns, opportunity areas tend to form a ring around the edges of these towns. 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 36. 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 37 & 38). 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.

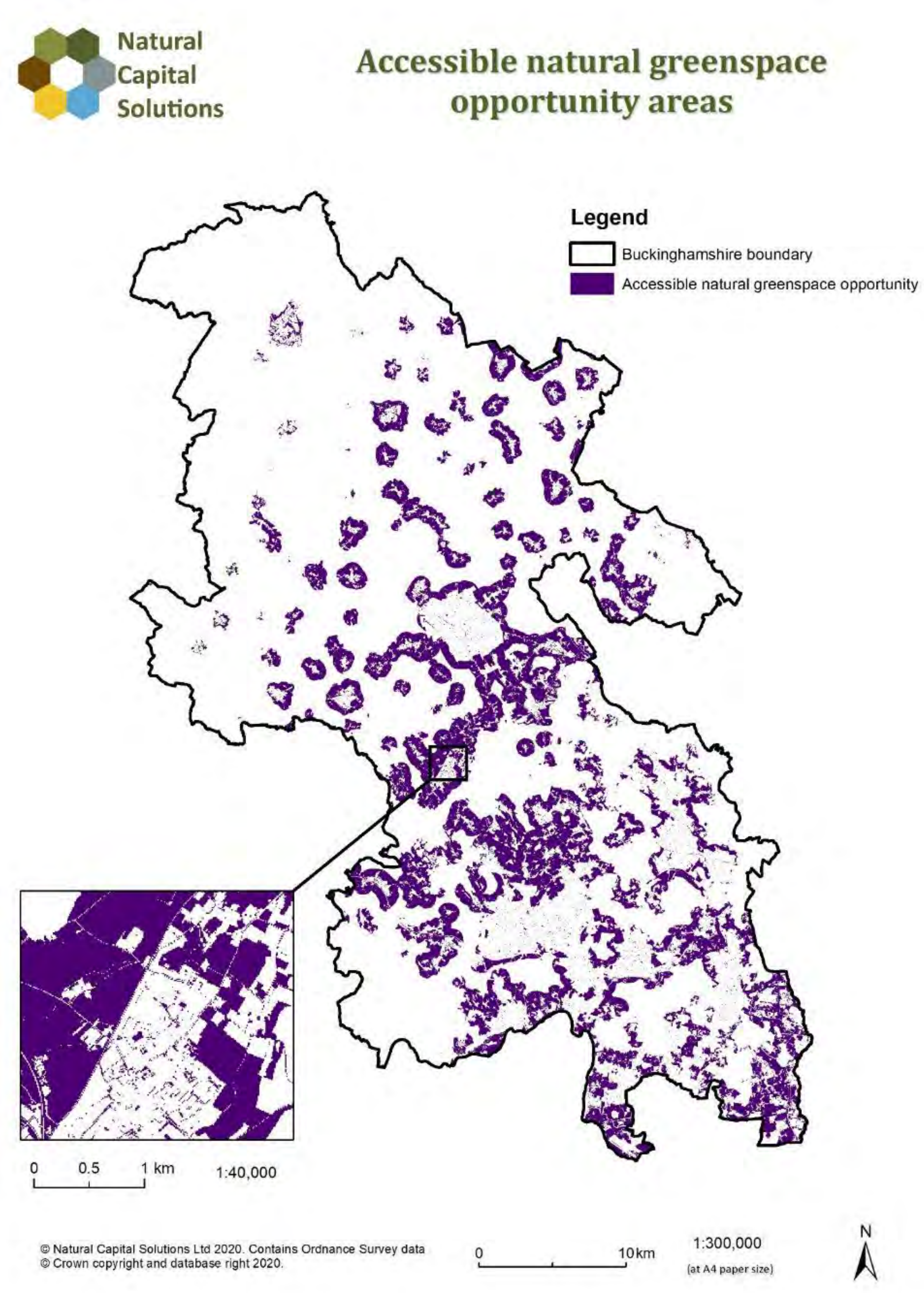



**Figure 34:** Accessible natural greenspace opportunity areas across Buckinghamshire.

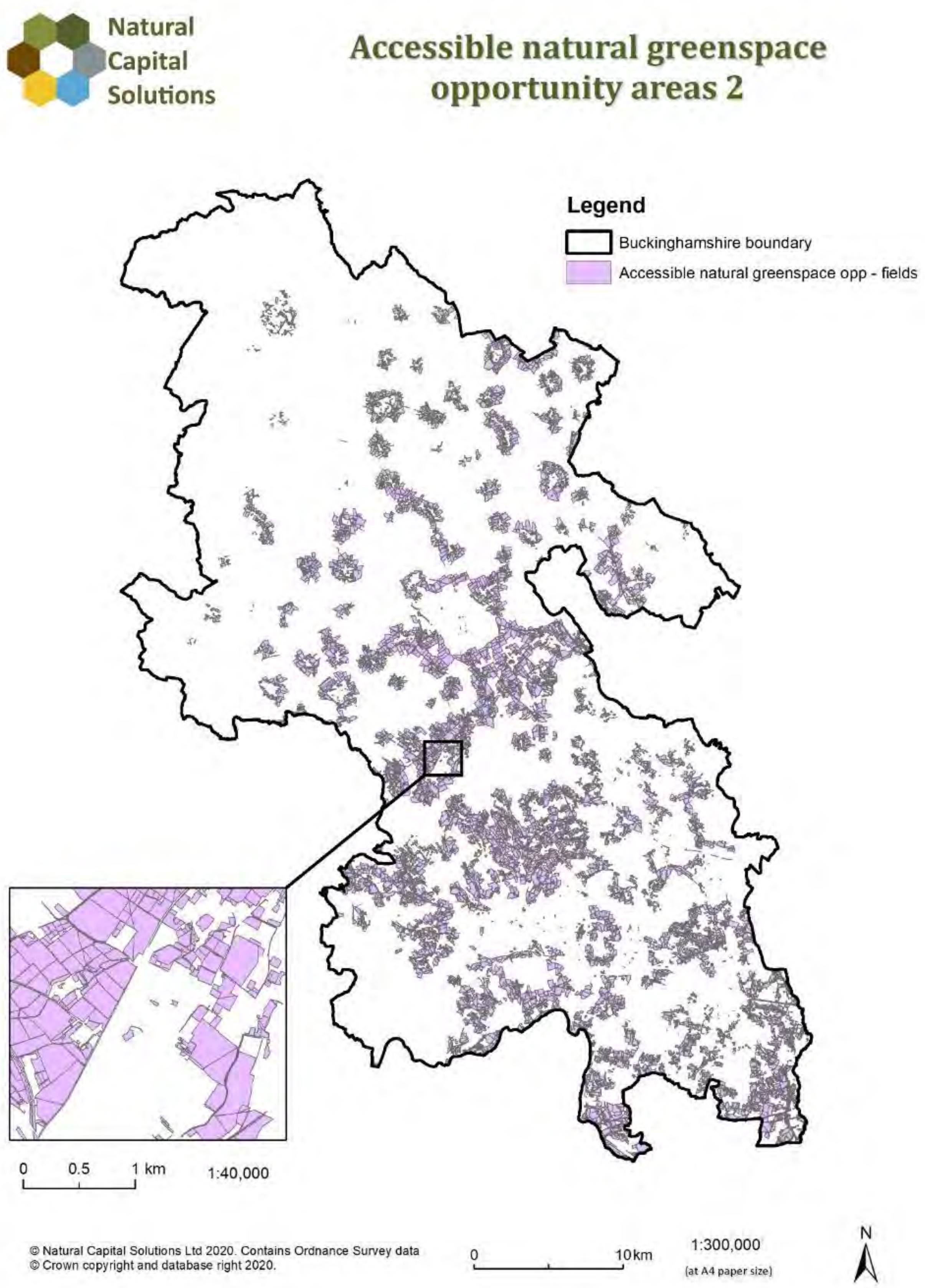



**Figure 35:** Field (plot) scale accessible natural greenspace opportunity areas across Buckinghamshire.

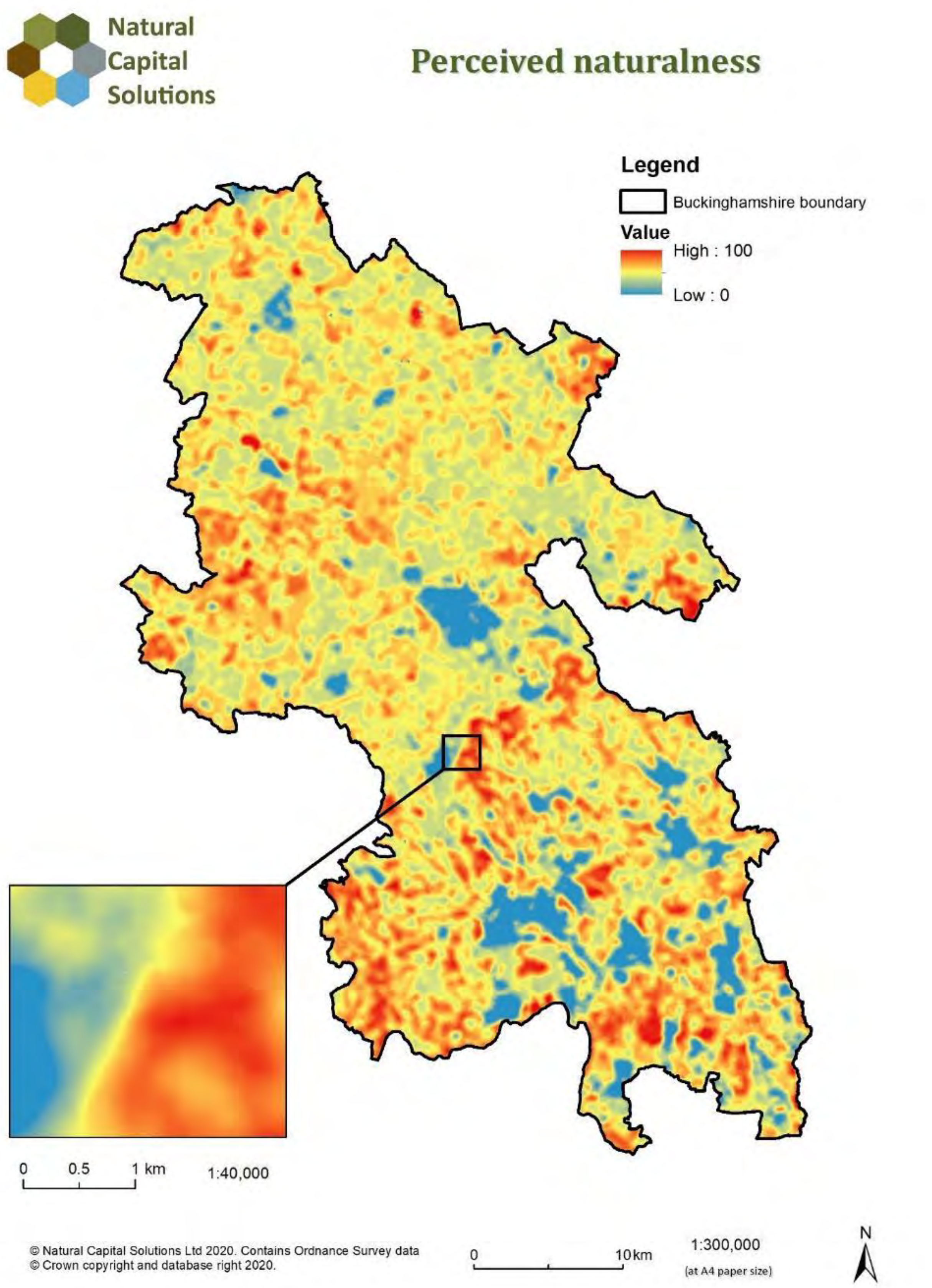



**Figure 36:** Perceived naturalness of habitats across Buckinghamshire.

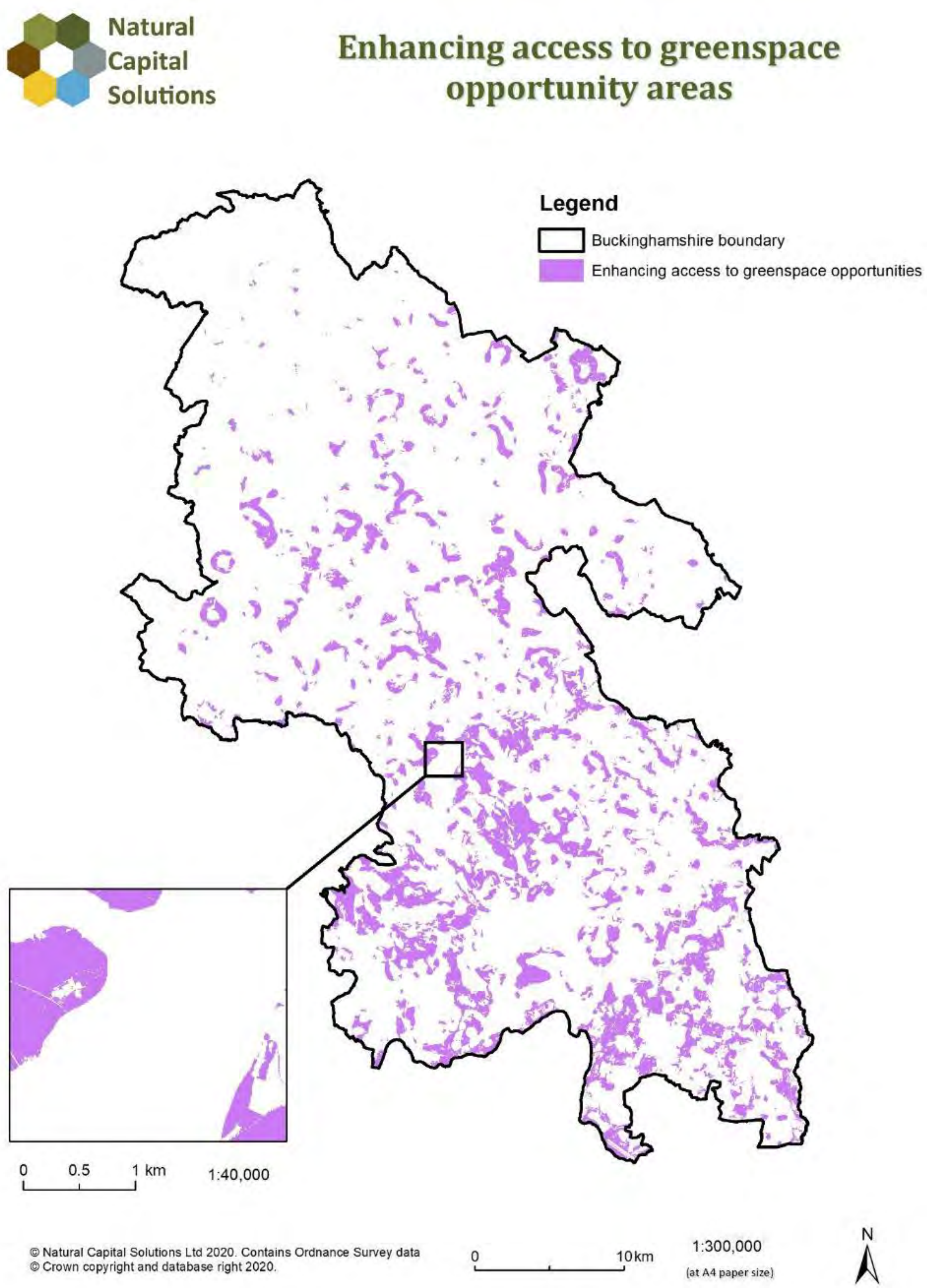



**Figure 37:** Opportunities for enhancing access to existing natural greenspaces across Buckinghamshire.

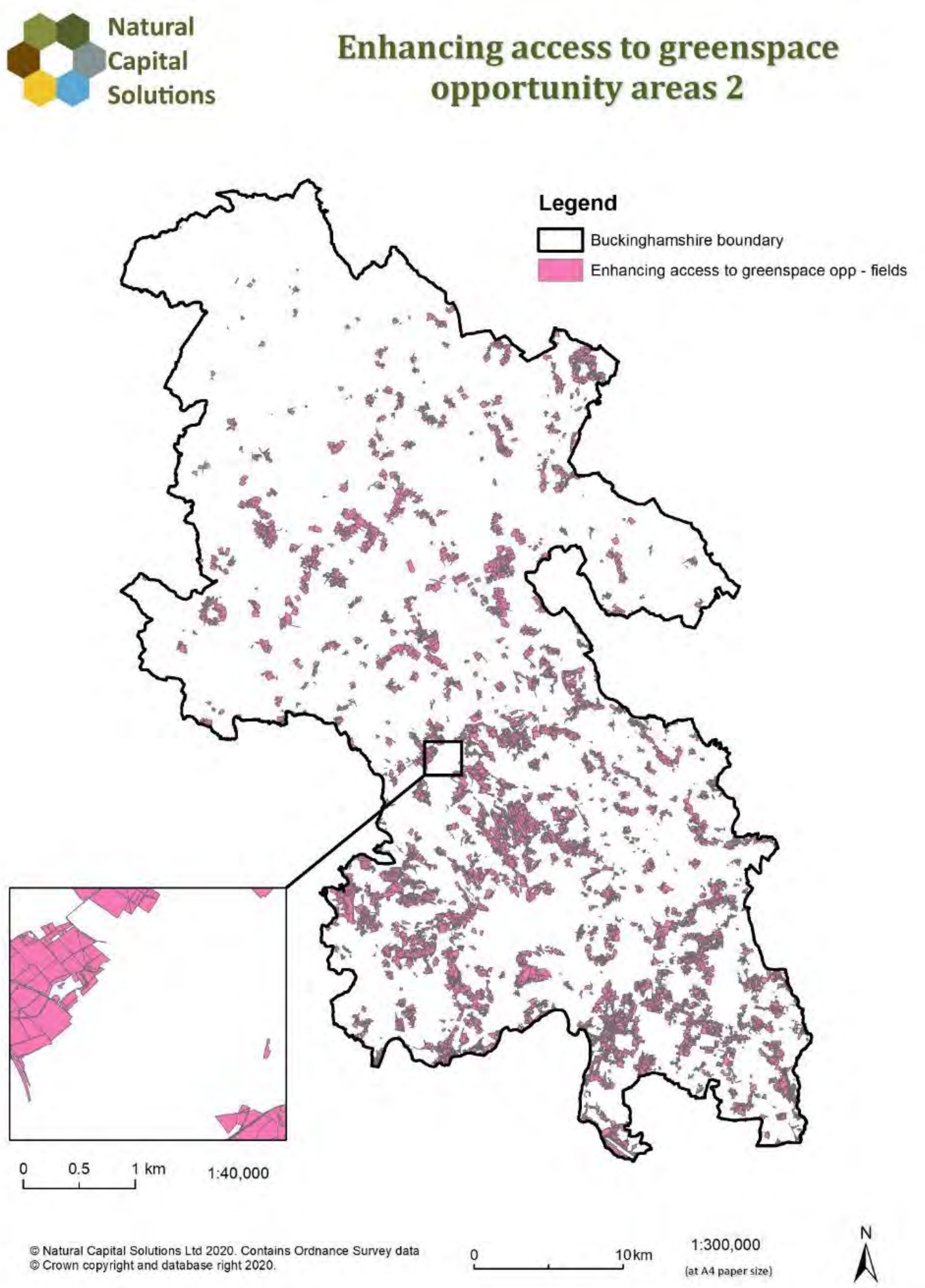



**Figure 38:** Field (plot) scale Opportunities for enhancing access to existing natural greenspaces across Buckinghamshire.

# 5. Combined opportunities for new habitats

In addition to mapping the individual opportunities presented in Sections 4, 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 o 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 34), was used rather than the one that examined existing habitats alongside demand (Figure 37).

## 5.1 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 4.3-4.7), 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 4.8). 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 39, which maps the existing areas of broadleaved and mixed woodland and an overlay of all the seven different opportunity areas, and on Figure 25 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 39. 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 40), the number of locations is reduced, but there remain many, particularly in the southern 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.

## 5.2 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 41). 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 42), opportunity areas are reduced, although still extensive, and are particularly focussed in an area to the north-west of Aylesbury that contains a reasonable amount of existing semi-natural grasslands.

## 5.3 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 43), due to the requirement for being located on floodplains. The river networks in the north of the county offer some opportunities, but there are very few opportunities in the south of Buckinghamshire. A few of these locations are opportunity areas for two or more services. When considering opportunity close to existing habitats (Figure 44), there are very few opportunity areas.

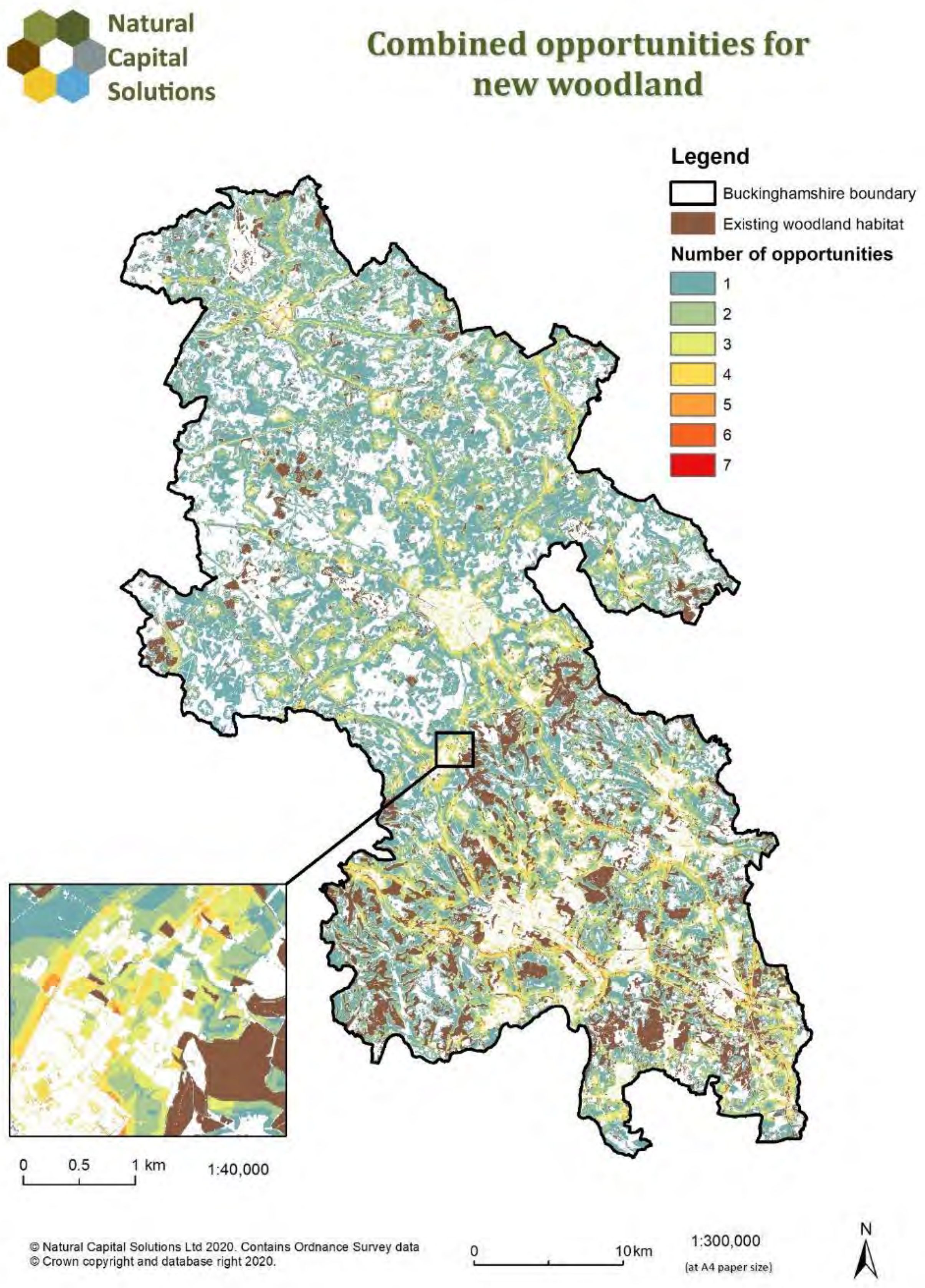



**Figure 39:** Existing broadleaved and mixed woodland, and combined opportunities for new woodland, across Buckinghamshire.

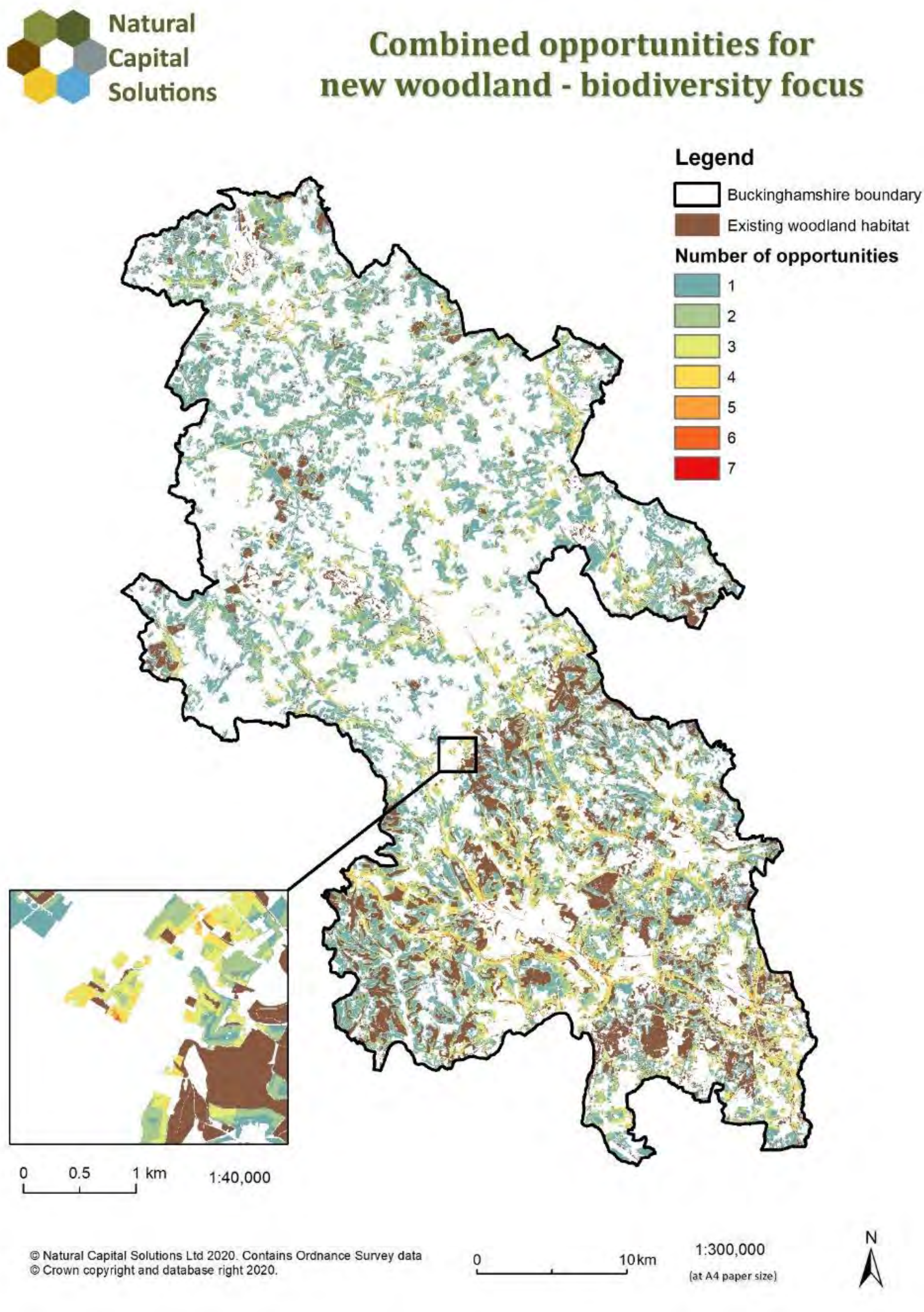



**Figure 40: C**ombined opportunities for new woodland across Buckinghamshire, restricted to areas that are ecologically connected to existing woodlands.

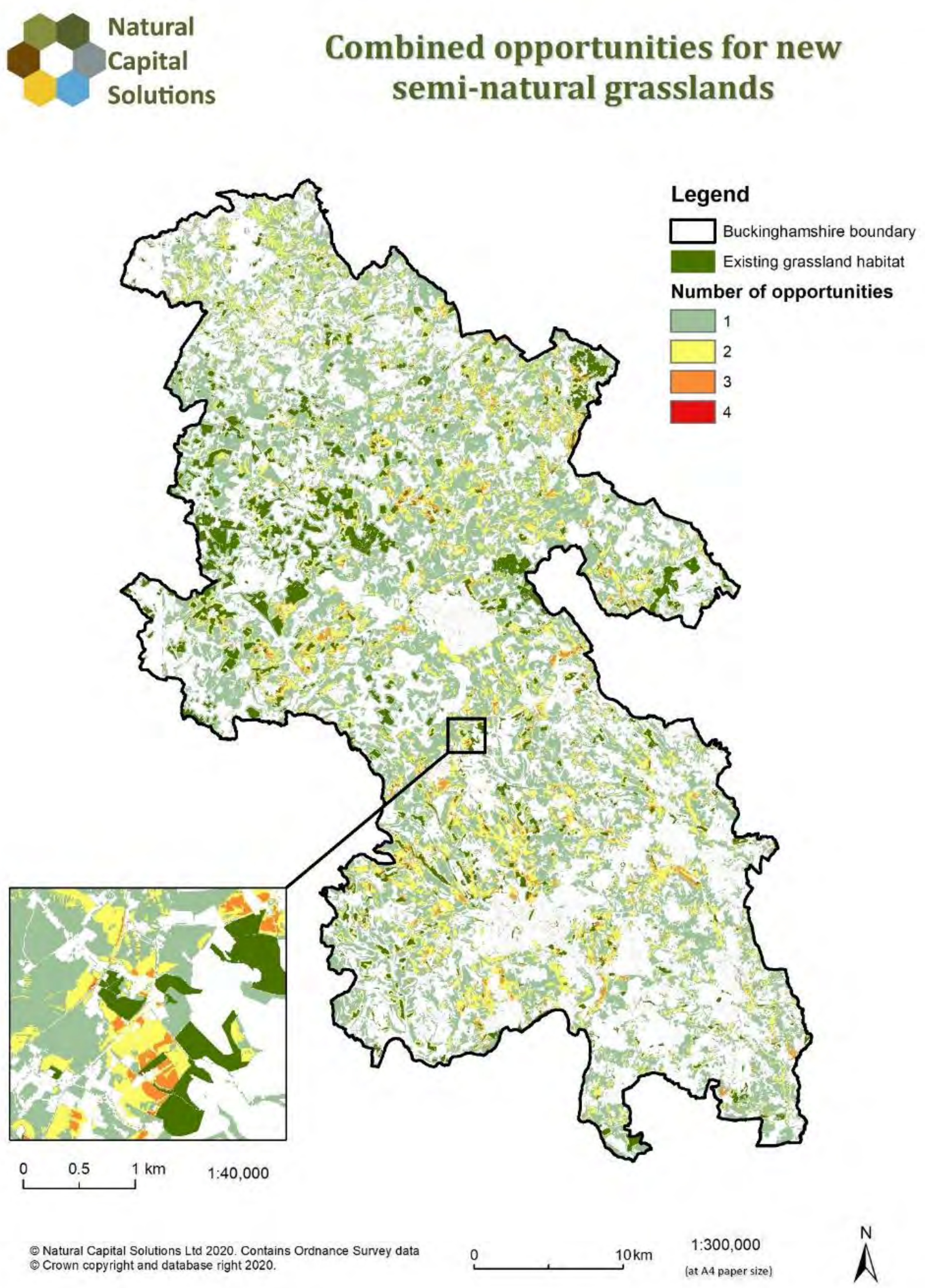



**Figure 41:** Existing semi-natural grasslands, and combined opportunities for new grasslands, across Buckinghamshire.

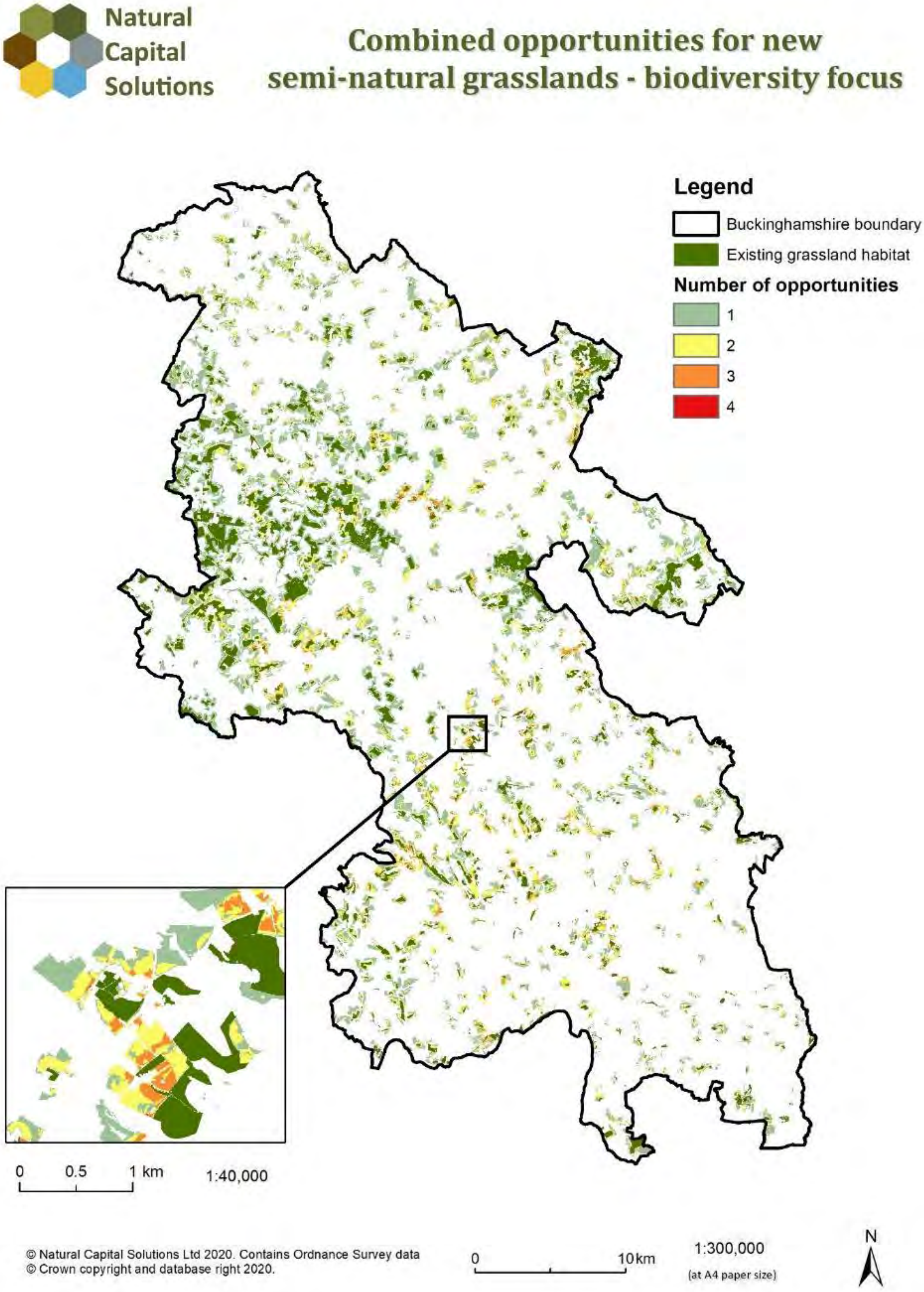



**Figure 42: C**ombined opportunities for new semi-natural grasslands across Buckinghamshire, restricted to areas that are ecologically connected to existing grasslands.

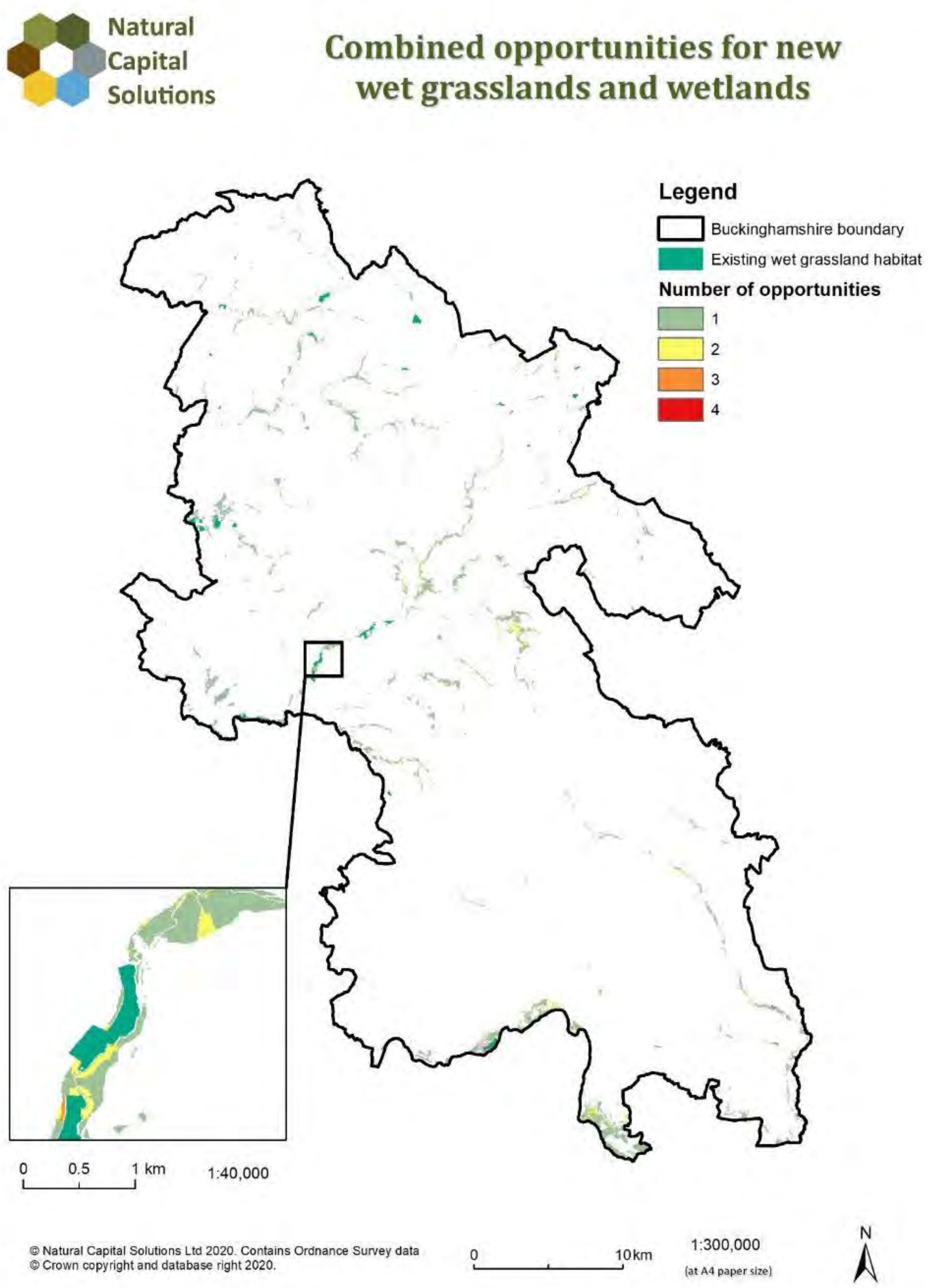



**Figure 43:** Existing wet grasslands and wetlands, and combined opportunities for new wetlands, across Buckinghamshire.

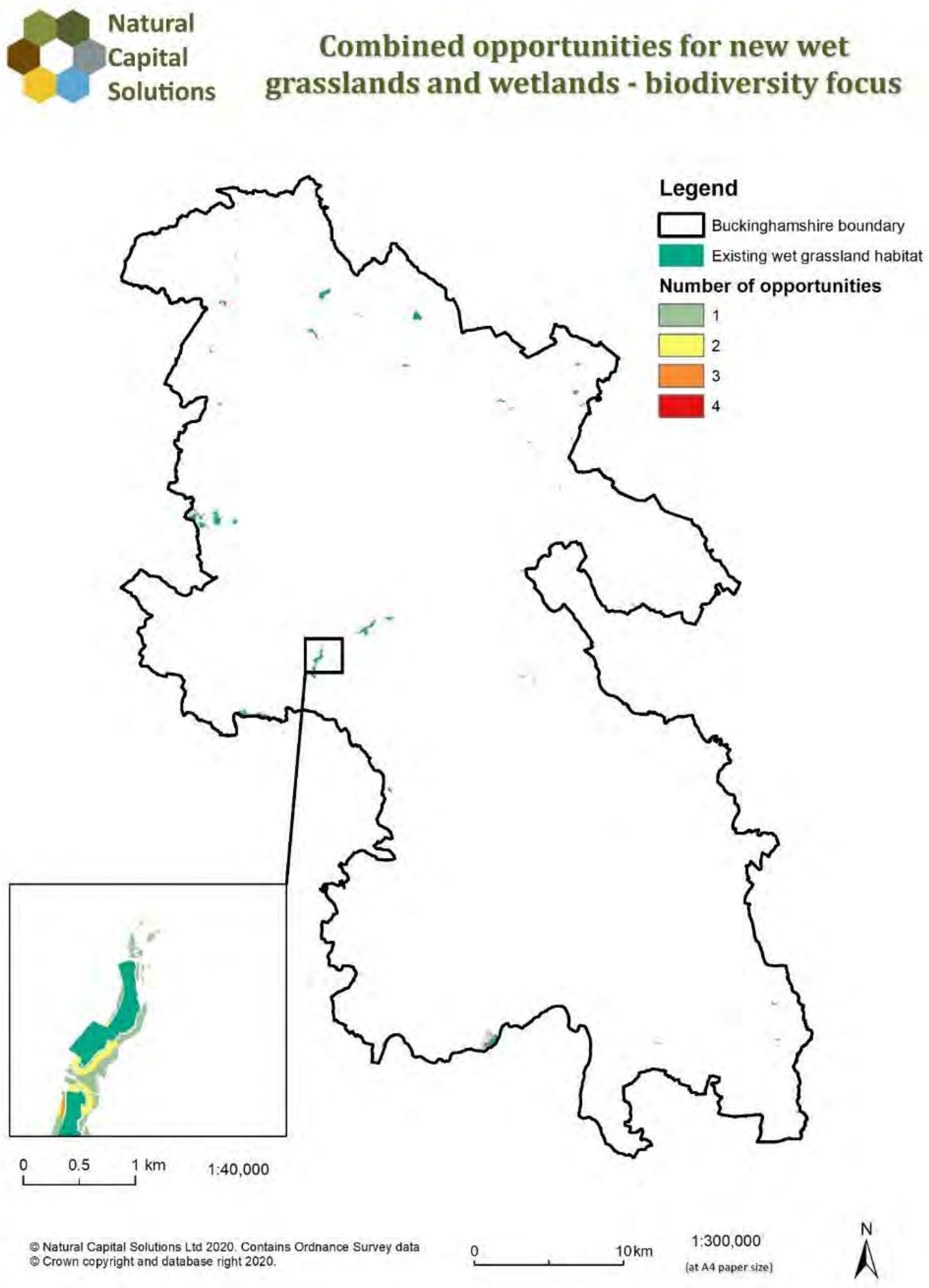



**Figure 44: C**ombined opportunities for new wet grasslands and wetlands across Buckinghamshire, restricted to areas that are ecologically connected to existing wetlands.

# 6. 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 the whole of Buckinghamshire. It provides the most comprehensive and detailed coverage that is possible at this time and should have a wide range of applications. Buckinghamshire is dominated by arable land and improved grassland, but there are also extensive areas of woodland in the southern half of the county (predominantly in the Chilterns). Tree and woodland categories take up 13.0% of the county, which is greater than any other county in the OxCam Arc. Semi-natural and marshy grassland is also reasonably widespread, taking up 5.6% of the area. Built up areas, infrastructure and gardens make up a combined 12.2% 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, particularly Burnham Beeches, Penn Wood, Ashridge Estate and Bernwood Forest. Ecosystem delivery is greatest in the southern half of the county, where the majority of woodland is located, but is still high in pockets in the northern half of the county. Food production is also greater in the north, and especially in central Buckinghamshire.

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 Buckinghamshire, with the highest demand in Aylesbury and High Wycombe. 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 southern Buckinghamshire, where woodland and other semi-natural habitats occur on the fringes of towns, and these areas should be protected and expanded, even if not important for biodiversity. In the northern half of the county there is much more of a mismatch between demand and supply.

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.

## 6.1 Next steps

The maps and GIS layers produced for this project have a wide range of potential applications, but here we outline two possible projects for taking this work forward:

1. *Map habitat quality*

The basemap presented in Section 2 provides a detailed map of habitats across Buckinghamshire, enabling an assessment of the type, extent and spatial attributes of habitats. However, it does not include an assessment of habitat quality (condition). It would be possible to create such a map based on existing data, combined with a number of careful assumptions developed recently for a project for the OxCam Arc Local Natural Capital Plan Project. The opportunity maps presented in Sections 4 and 5 are focussed on creating new habitats, rather than enhancing existing ones, hence mapping habitat quality would provide a more complete understanding of Buckinghamshire's natural capital assets by highlighting requirements for habitat restoration. The data could also be used to create a baseline biodiversity assessment using the Biodiversity Metric 2.0 tool (that assigns the number of biodiversity units to each habitat parcel based on the condition and distinctiveness of the habitat). This is a new approach to enable local authorities to monitor whether they are achieving net gain in biodiversity.

2. *Refine most promising sites to take forward*

As stated above, the opportunity maps should be considered as a tool to guide decision making regarding the best locations to target for habitat creation projects. A number of steps are recommended in terms of taking this process forward:

- The maps should be compared to other studies such as green infrastructure plans, national maps created by Natural England, as well as Local Plan policies and strategies, to target particular areas to take forward.
- It is recommended that a workshop is held with local stakeholders to consider priorities for different zones within the study area. For example, the current biodiversity opportunity maps overlap, which means that in some areas two or three of the different habitats appear in the opportunity maps for the same location. In addition, different ecosystem services may be considered more important in particular areas. Simple rules could be created to target certain habitats or certain ecosystem services in different locations. The workshop could also be used to consider prioritising particular areas (projects) to take forward or to weight criteria to assess projects.
- Priority locations can be taken forward in a number of different ways. This includes:
  - A number of specific habitat creation projects could be worked up into costed proposals. These could be offered as biodiversity offsetting and biodiversity net gain

projects funded through the development process. Large and ambitious projects could potentially be put forward as part of the OxCam Arc proposals.

- Opportunity areas could be targeted through agri-environment schemes, particularly the new Environmental Land Management Scheme which will be paying farmers for environmental enhancements that deliver a range of public goods.
- Woodland areas could be taken forward through the Carbon Guarantee Scheme or other carbon offsetting initiatives, as well as more traditional woodland grant schemes.
- A range of additional mechanisms exist for taking forward project that deliver ecosystem services benefits. This includes projects that focus on working with natural processes for slowing the flow (natural flood risk management) and water quality, such as catchment sensitive farming. Opportunities for planting trees to enhance air quality could be part of air pollution reduction strategies, and increasing public access to natural greenspace could be incorporated into wellbeing initiatives and ideas around green prescribing.

- It would be possible to take forward this work through a **Local Natural Capital Plan** (also sometimes called a Natural Capital Investment Plan). This would involve identifying key projects / locations to take forward, determining the costs and monetary benefits of habitat creation at these sites and hence the return on investment, considering appropriate financial mechanisms and funding sources, and then presenting the plans in the form of a prospectus.

# Annex 1: Additional biodiversity opportunity maps

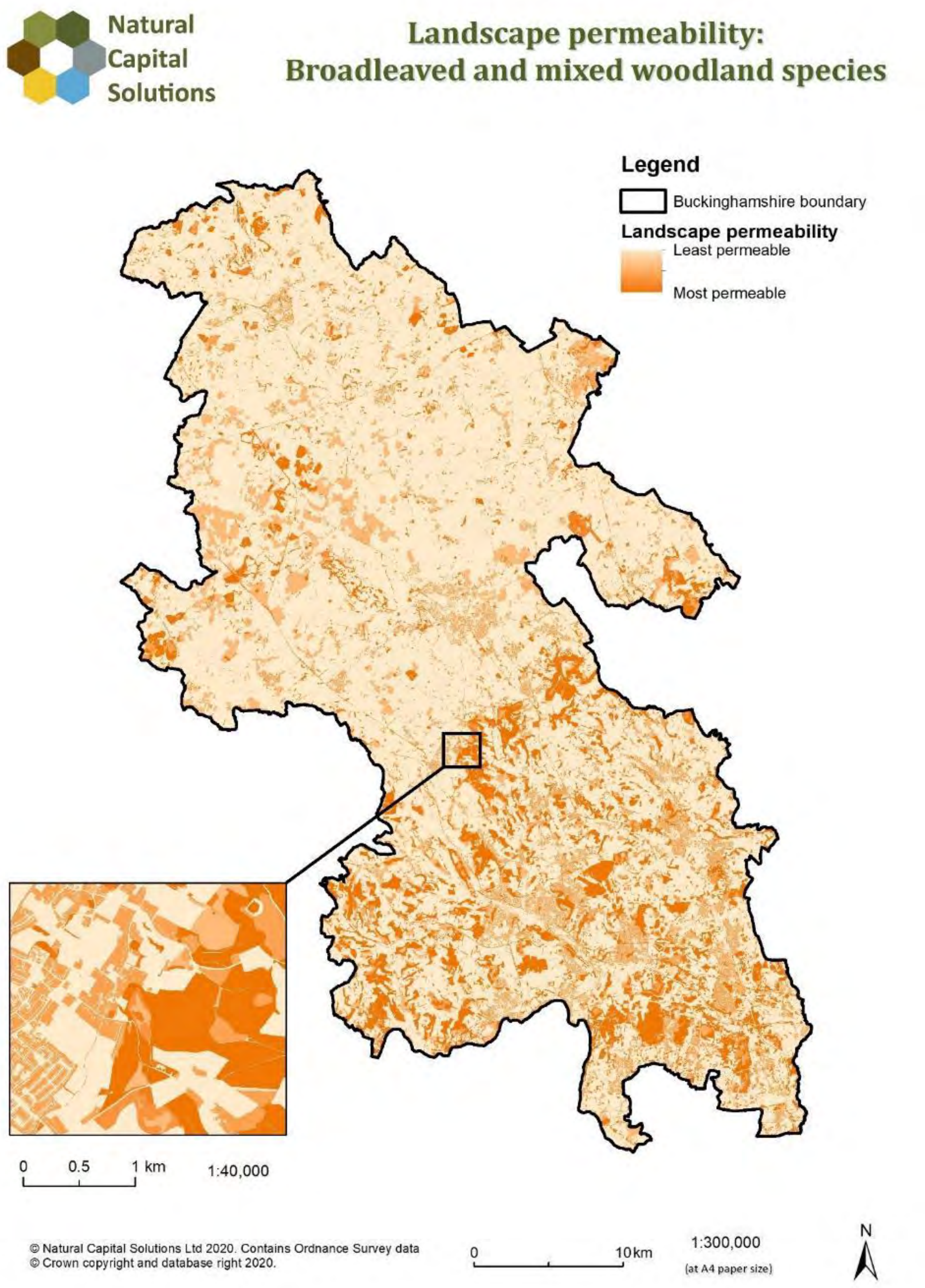



**Figure A1:** Landscape permeability for typical broadleaved and mixed woodland species across Buckinghamshire.

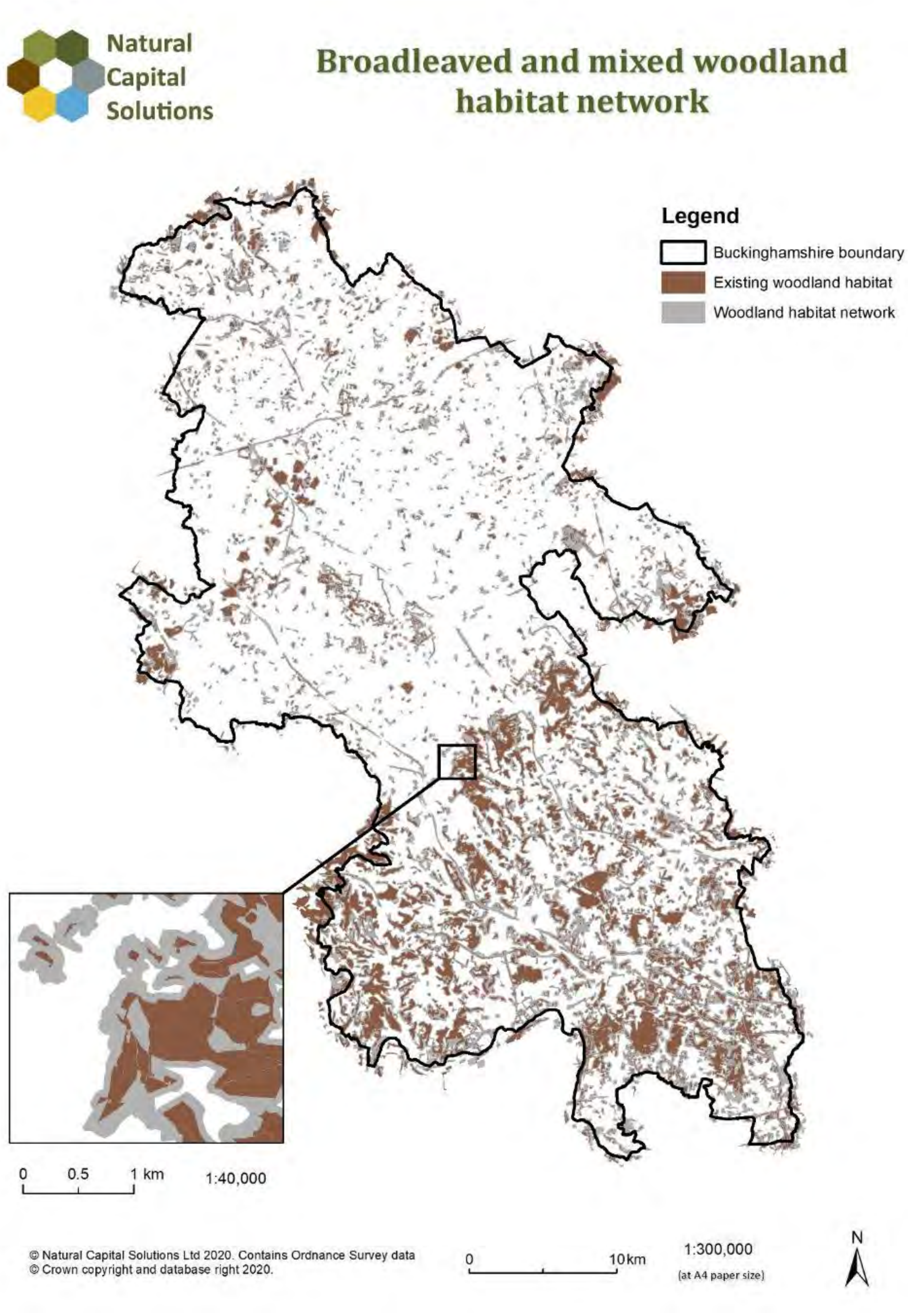



**Figure A2:** Habitat network for broadleaved and mixed woodlands across Buckinghamshire.

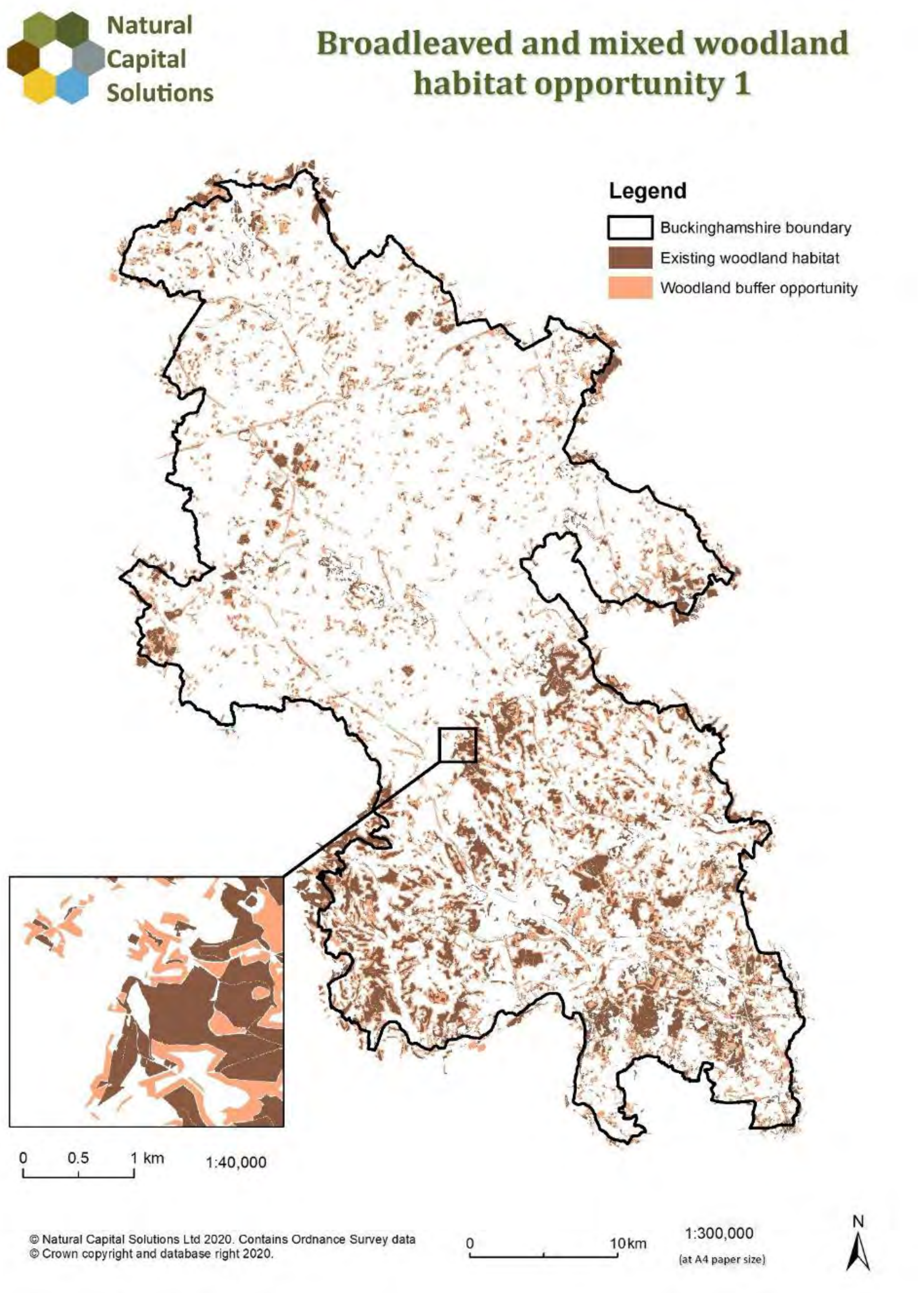



**Figure A3:** Buffer biodiversity opportunity areas for broadleaved and mixed woodlands across Buckinghamshire.

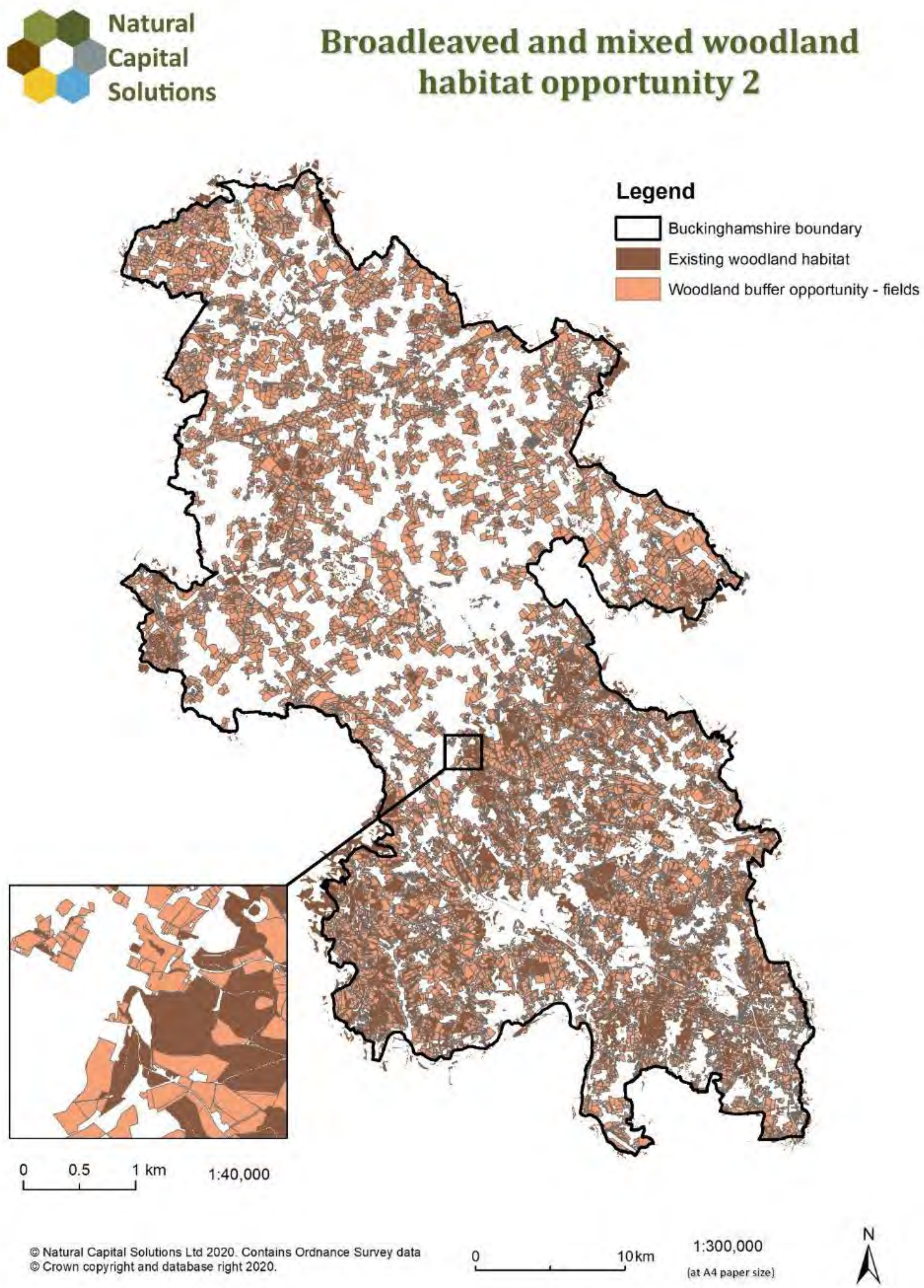



**Figure A4:** Field scale biodiversity opportunity areas for broadleaved and mixed woodlands across Buckinghamshire.

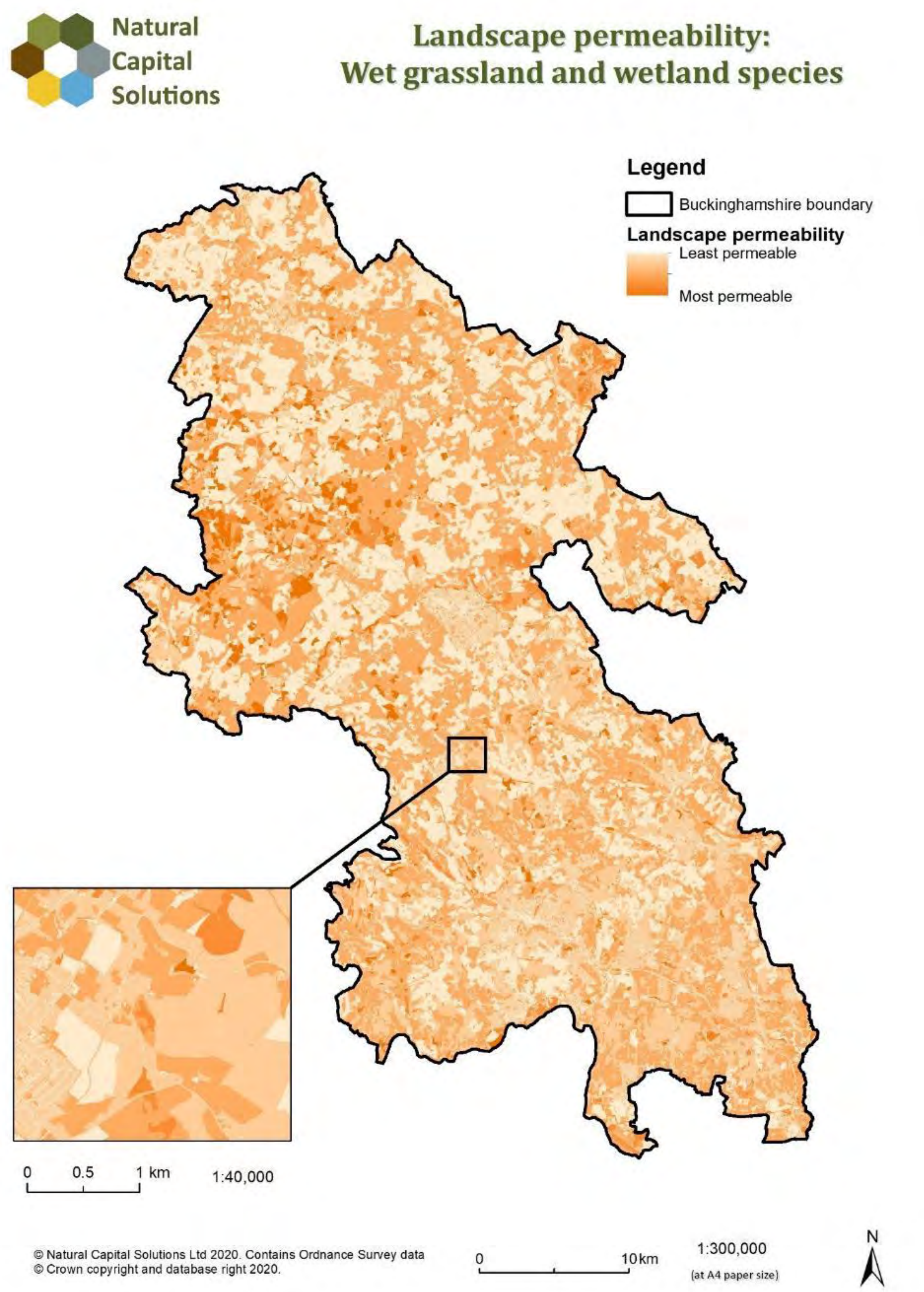



**Figure A5:** Landscape permeability for typical wet grassland and wetland species across Buckinghamshire

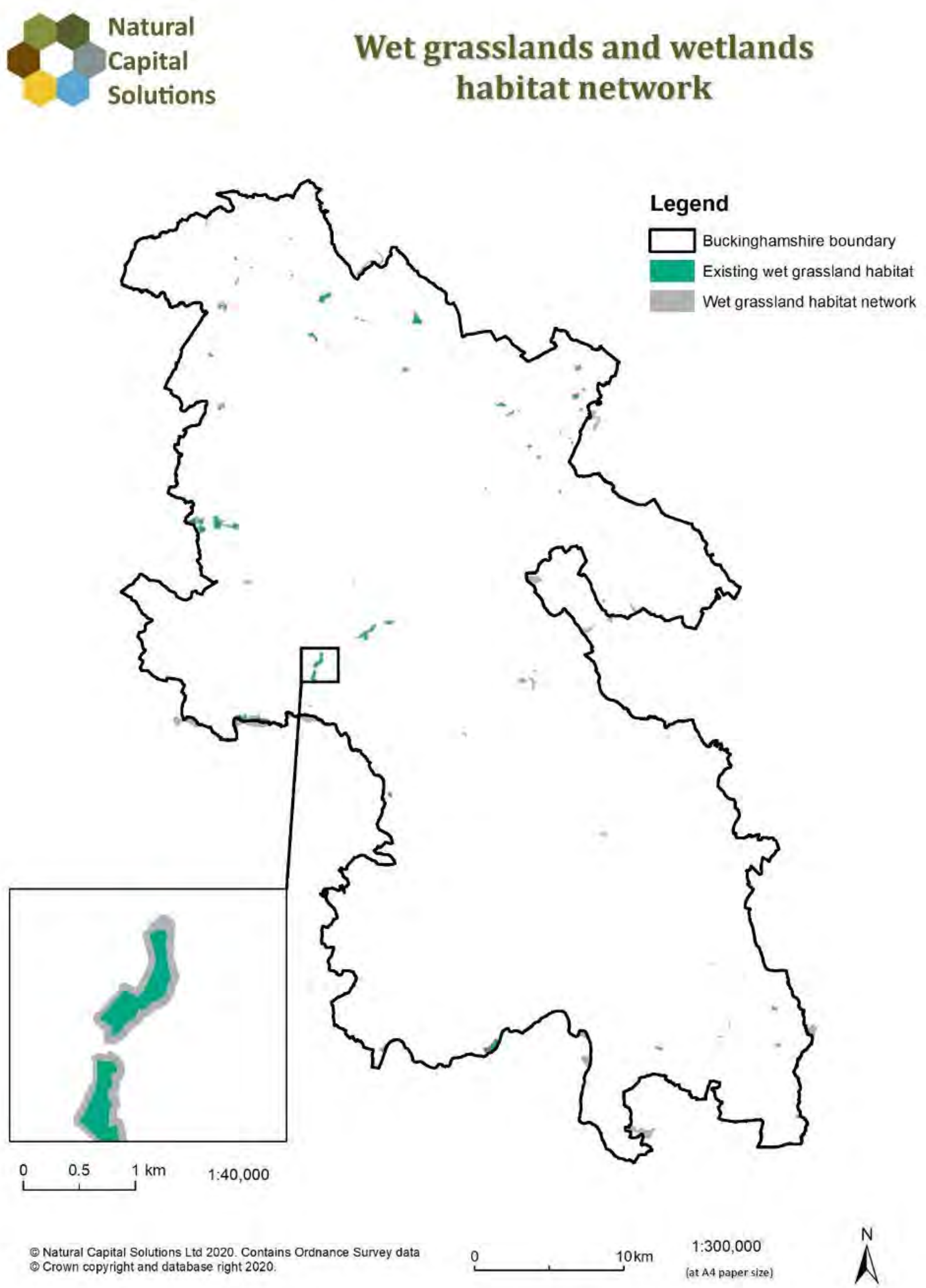



**Figure A6:** Habitat network for wet grassland and wetlands across Buckinghamshire.

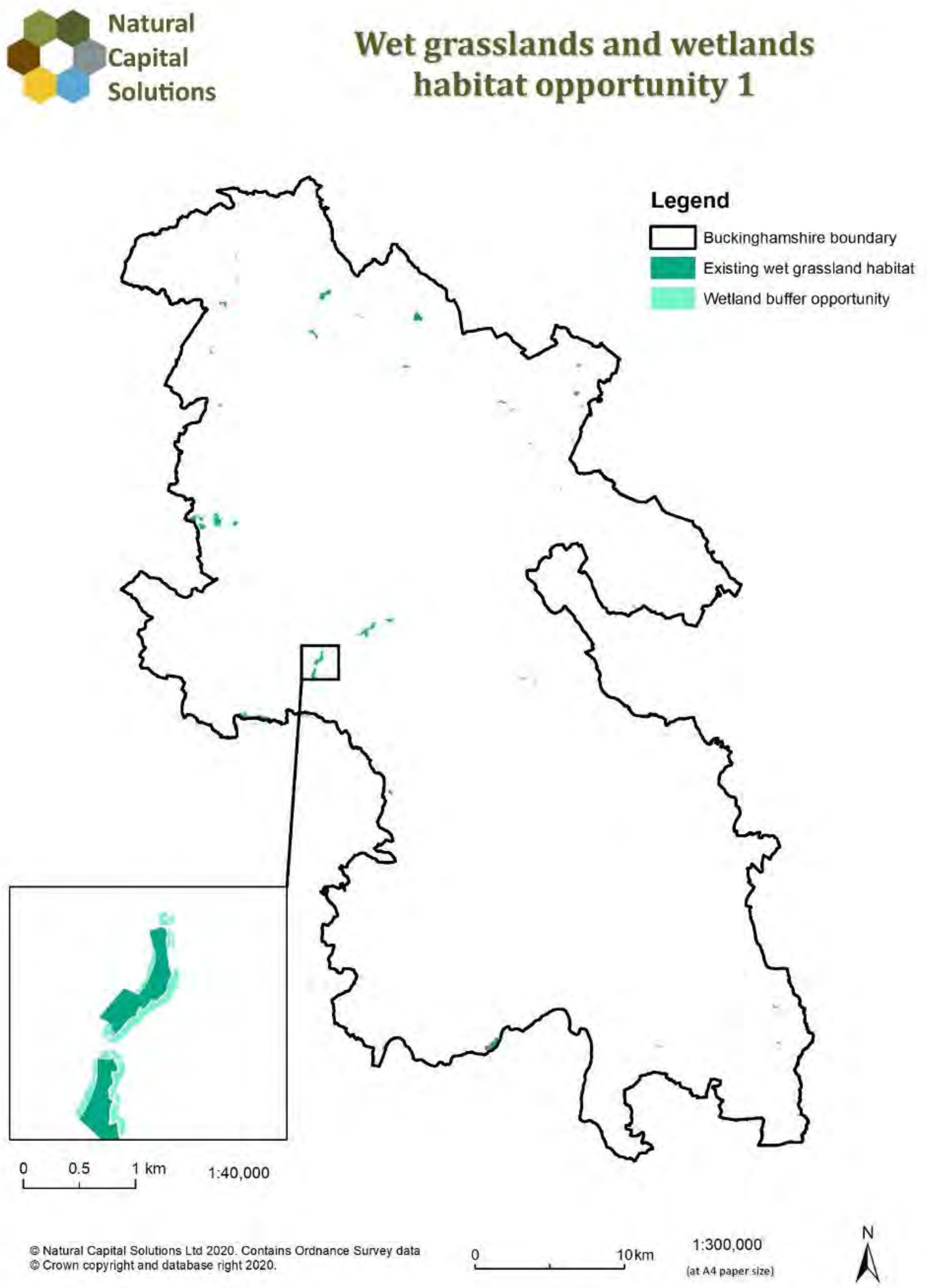



**Figure A7:** Buffer and stepping-stone biodiversity opportunity areas for wet grassland and wetlands across Buckinghamshire.

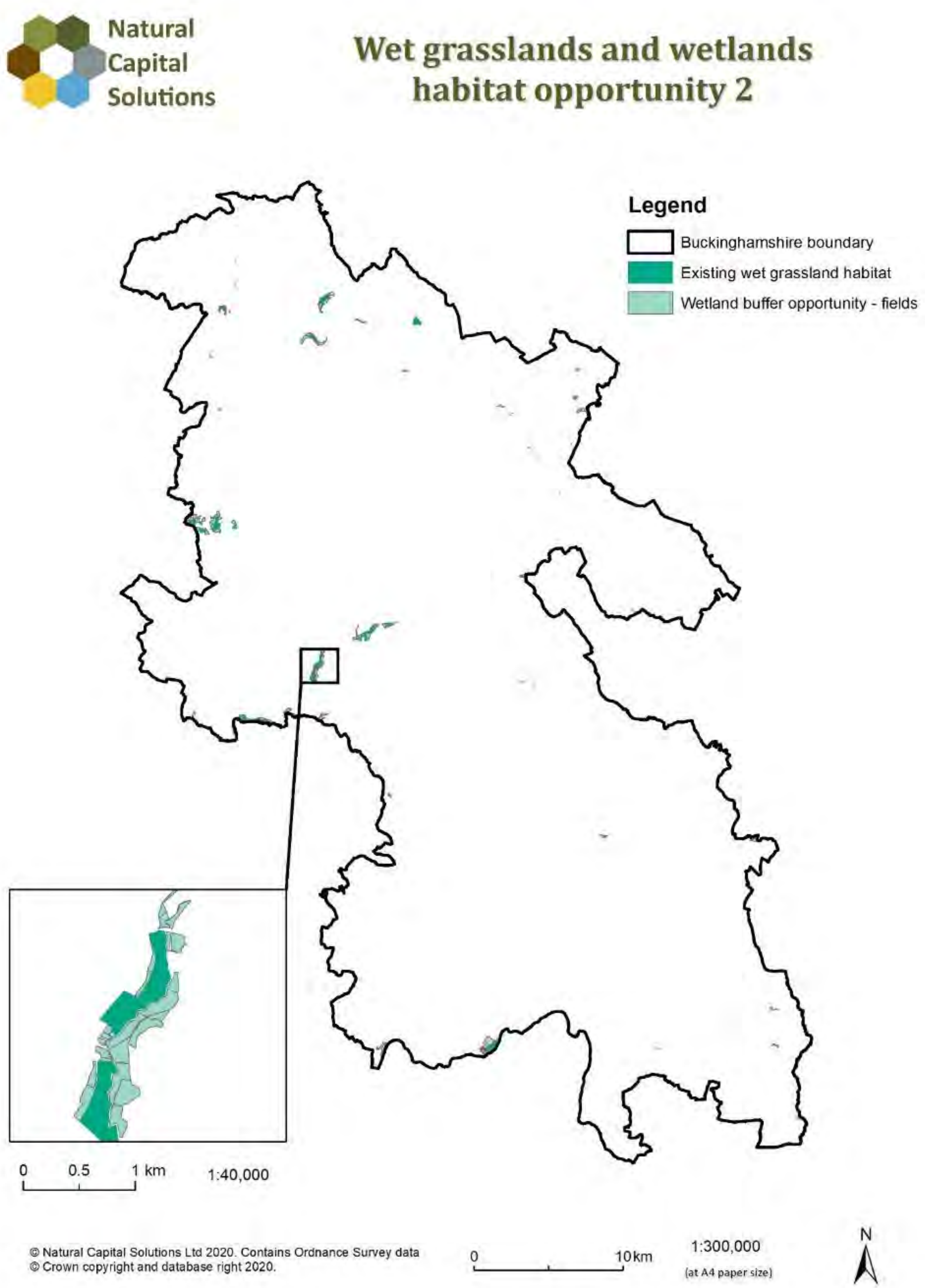



**Figure A8:** Field scale biodiversity opportunity areas for wet grassland and wetlands across Buckinghamshire.