Mapping natural capital and opportunities for habitat creation in Cambridgeshire

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Executive Summary

This report describes a project to produce a detailed habitat basemap for the whole of Cambridgeshire (including Peterborough), to examine habitat change over 80 years, and to identify opportunities to enhance biodiversity. It was commissioned by the Cambridgeshire Biodiversity Partnership.

The first part of the project was to produce a detailed map of the current habitats present across Cambridgeshire. 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 339,600 ha or 3,396 km^2 and contained 1.61M polygons, each of which was classified to an appropriate habitat type. It shows that Cambridgeshire is dominated by cultivated land, making up 70% of the area (238,000 ha), with much of the remaining area taken up by improved grassland (6.4%), the built environment (5.3%) and gardens (3.5%). Semi-natural and marshy grasslands make up 4.5%, while the combined cover of all woodland, scrub and tree habitat types make up just 4.8% and water makes up 2.1% of the total area. Maps were created highlighting the highest quality semi-natural habitats, and the location of sites with international, national or local nature conservation designations. Approximately 6.4% of the total area has some form of nature conservation designation. In contrast, 64.3% of Cambridgeshire is considered to be of high quality for agriculture (Grade 1 or 2) and an additional 26.5% is of moderate quality (Grade 3).

The basemap showing habitats in 2018 was then matched and compared to a map of land-use and habitats from the 1930s. Arable was the dominant habitat type even in the 1930s, occupying 60.8% of the area of Cambridgeshire, but semi-natural grassland occupied 27.3%, built-up areas and gardens occupied 5.8% and woodland 2.4%. There were no improved grasslands. By 2018 semi-natural grasslands had declined by 77,400 ha (an 84% decline), whilst arable had increased by 31,200 ha (15% increase), built-up areas and gardens had increased by 16,500 ha (84% increase) and woodland by 7,000 ha (85% increase). Improved grassland has increased from zero to 16,400 ha. This is likely to have had a major impact on biodiversity across the county.

Habitat opportunity mapping for biodiversity enhancement 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 habitats can be created that are best located in terms of their connectivity to existing habitat patches and are therefore most appropriate from an ecological point of view, whilst taking certain constraints into account. Opportunities have been mapped to enhance biodiversity for three different broad habitat types – semi-natural grassland, wet grassland and wetland, and broadleaved and mixed woodland.

For semi-natural grasslands the River Great Ouse corridor around Huntingdon and St Ives is currently providing a near-continuous habitat network, and there are also large networks around Newmarket to the east of Cambridgeshire, with other smaller patches spread across the county. There are many areas, spread fairly evenly across Cambridgeshire, where semi-natural grassland could be created to considerably enlarge and connect existing networks. Wet grassland and wetland habitat networks, are concentrated in three locations; the Nene Washes, the Ouse Washes and to a lesser extent on the River Great Ouse between Wicken Fen and Ely, and field scale habitat creation could consolidate and enlarge these existing networks. For broadleaved and mixed woodland, the most significant networks are found to the west of Peterborough and in Huntingdonshire, although many patches of woodland

remain ecologically isolated and there are no large patches of continuous habitat. Opportunities to enhance these woodland habitats exist throughout the study area (with the exception of Fenland), where field-scale habitat creation could connect many isolated woodland fragments to create a more resilient network.

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

1. As the habitat basemap is partly derived from habitat surveys carried out in the 1990s, it is recommended that new habitat surveys are carried out, focussing on the approximately 10% of Cambridgeshire containing seminatural habitats, along with areas where habitat change is known to be occurring.
2. It would be desirable to model and map the ecosystem services (the benefits to people) provided by the natural capital assets. It is also possible to produce opportunity maps for a number of different ecosystem services, highlighting the best areas to create new habitats that can deliver benefits such as reducing flood risk, enhancing air quality, increasing accessible greenspaces and other opportunities. This can highlight areas where new habitat could be created that could deliver multiple benefits and is beneficial as it opens up new revenue streams to fund habitat creation projects.
3. 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 in different locations, and to prioritise locations to take forward.

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

Contents

Executive Summary **2**

Contents **4**

1. Introduction **5**

2. The baseline – natural capital assets **6**

2.1 Approach to mapping habitats **6**

2.2 Broad habitats **8**

2.3 High quality habitats **10**

2.4 Nature conservation designations **10**

2.5 Agricultural quality **10**

3. The changing habitats of Cambridgeshire: a historical perspective over 80 years **14**

3.1 Introduction **14**

3.2 Approach **14**

3.3 Results **15**

3.4 Discussion **19**

4. Opportunity mapping for biodiversity enhancement **21**

4.1 Method **21**

4.2 Results **24**

5. Conclusions **30**

5.1 Next steps **30**

Annex 1: Additional biodiversity opportunity maps **33**

Annex 2: List of GIS data layers **41**

1. Introduction

Accurate knowledge of which habitats are present and their spatial location is an important pre-requisite in properly understanding the biodiversity of an area, how it has changed over time and the opportunities to enhance it. Cambridgeshire Biodiversity Partnership have therefore commissioned Natural Capital Solutions to undertake a project with the following three aims:

1. Create a detailed habitat basemap based on the best available existing data.
2. Compare this to a map of land-use and habitats from the 1930s to examine change over 80 years.
3. Create opportunity maps for biodiversity enhancement, showing where new habitats could be created that are most appropriate from an ecological point of view, whilst taking constraints into account.

Section 2 begins by describing how the baseline natural capital assets were mapped, before presenting the resulting habitat map and outlining the habitats present in 2018. It also highlights the most important habitats for biodiversity, maps the sites that have received international, national or local designation for their nature conservation interest, and briefly examines a map of agricultural land quality.

Section 3 compares the habitats present in 2018 with a map of land-use and habitats from the 1930s (the "Dudley Stamp" maps). It outlines the approach taken to comparing the two maps, before highlighting the land use in both periods and the change over 80 years.

Section 4 considers opportunities for enhancing biodiversity across Cambridgeshire for three different broad habitats – semi-natural grassland, wet grassland and wetland, and broadleaved and mixed woodland. Habitat opportunity mapping for biodiversity enhancement 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 habitats can be created that are best located in terms of their connectivity to existing habitat patches and are therefore most appropriate from an ecological point of view, whilst taking certain constraints into account.

Please note that the habitat basemap is based on existing data, some of which dates from the 1990s and has not been 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 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 enhance the accuracy of the basemap and move towards identifying specific projects to take forward. Potential applications and funding mechanisms are also outlined.

One of the key outputs from this project are the numerous GIS maps and layers. These are available to project partners of the Cambridgeshire Biodiversity Partnership and a list of available layers is provided in Annex 2.

2. The baseline – natural capital assets

2.1 Approach to mapping habitats

The most important part of the whole project was to produce a detailed map of the current habitats present across Cambridgeshire. This is the key component of any assessment of natural capital assets, and is required before change on land use (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 vector maps
- Phase 1 habitat data – supplied by CPERC:
    - Good coverage but excludes urban areas and SSSIs
    - Dates from the 1990s
- Natural England Priority Habitats Inventory – used for SSSIs
- County and City Wildlife Sites – supplied by CPERC
- Corrine European habitat data – modified and used primarily to distinguish arable from pasture (also helps to identify quarries, industry and golf courses)
- OS Open Greenspace data
- Layer that identified urban areas
- Ancient Woodland Inventory data
- Digital terrain model

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 Cambridgeshire (including Peterborough), and covers an area of 339,600 ha or 3,396 km^2. It contained 1.61M 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, but has not been ground-truthed and will inevitably contain errors. The Phase 1 habitat data supplied by CPERC dates from the 1990s, so some changes are inevitable and could only be partially checked. 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.

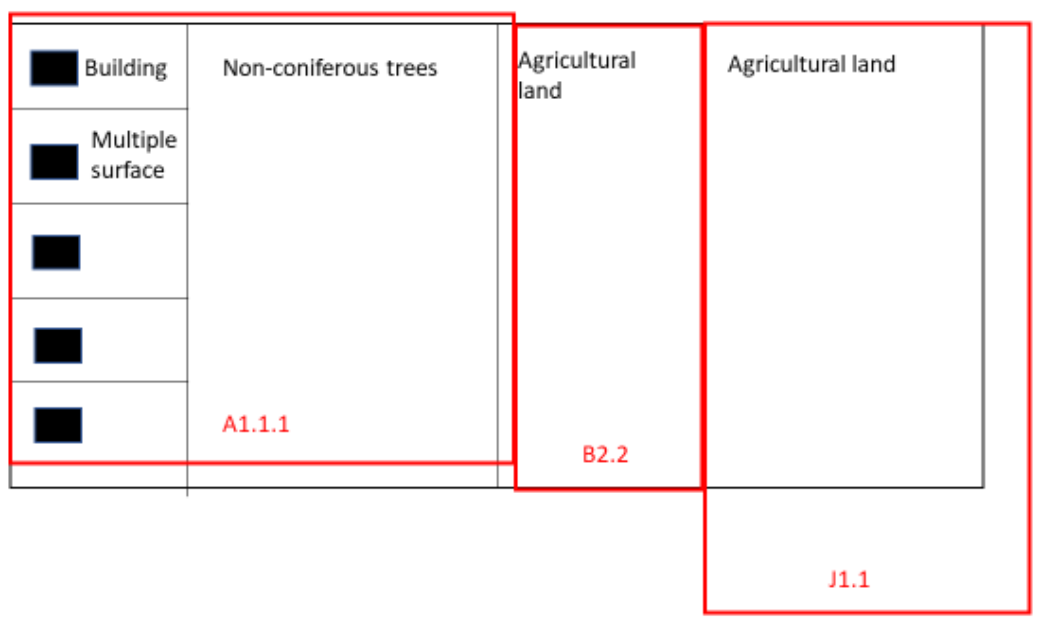
Box 2: Assigning habitats

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 Phase 1 habitat information provided by CPERC was then overlain (red layer in Fig.1) and the degree of overlap calculated using zonal statistics. This does not match precisely so, for example, if a Phase 1 polygon marked as semi-natural broadleaved woodland (A1.1.1) 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.

As the Phase 1 habitat data was collected in the 1990s, we also attempted to check that this was still accurate from additional sources, where possible. So, for example, if a Phase 1 polygon identified arable land (J1.1, red polygon on right, below), and this matched a MasterMap polygon identified as agricultural land, we would also check that the Corrine European habitat data layer (from 2012), also classified the land as arable.

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.



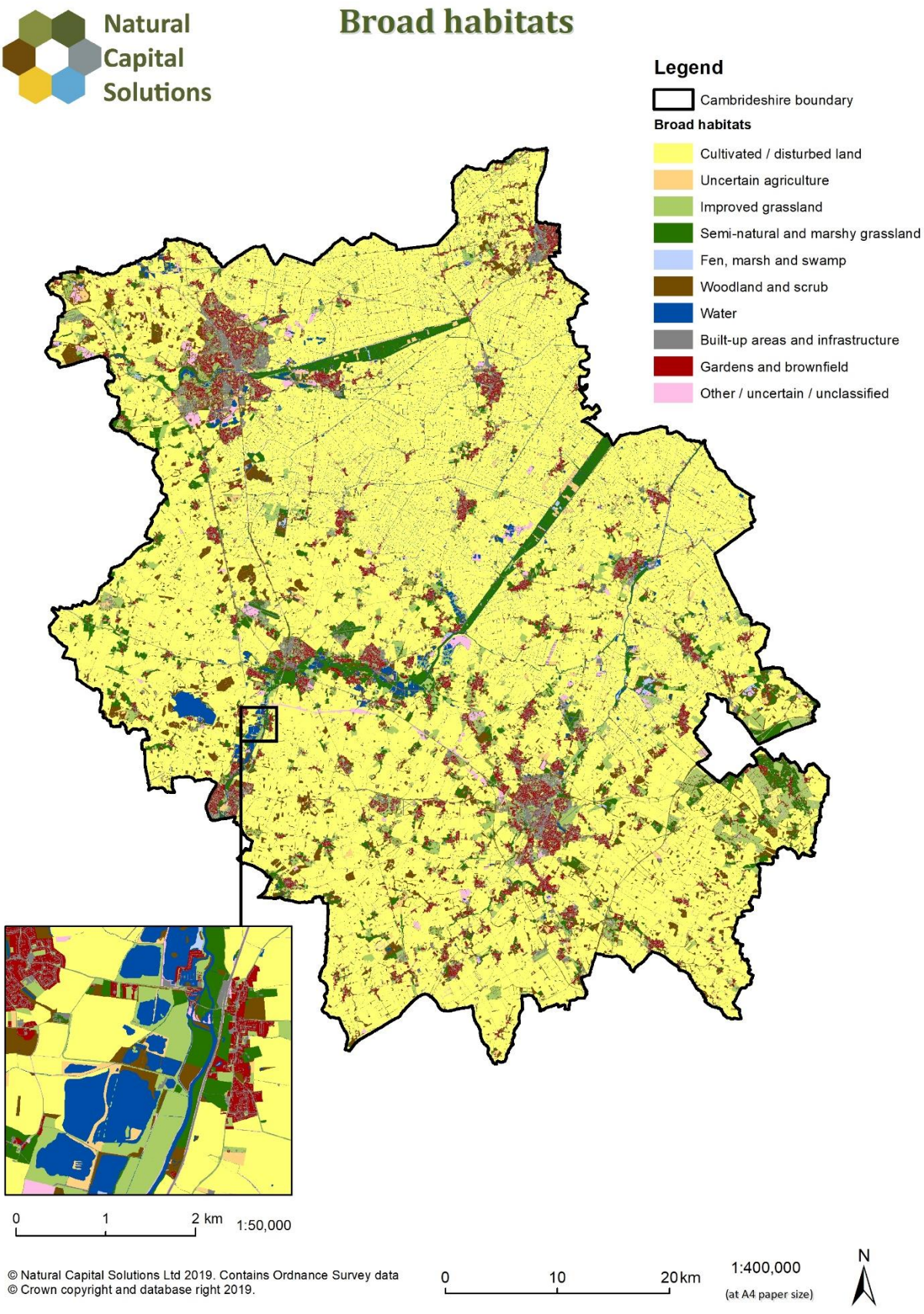
2.2 Broad habitats

Map 1 (overleaf) shows the distribution of broad habitat types across Cambridgeshire and the area and percentage cover is shown in a little more detail in Table 1. Cambridgeshire is dominated by cultivated land, making up 70% of the area (238,000 ha), with improved grassland making up an additional 6.4%. Semi-natural and marshy grasslands make up 4.5%, while the combined cover of all woodland, scrub and tree habitat types make up just 4.8% of the area (16,200 ha) and water makes up 2.1%. Built-up areas, and infrastructure (roads, railways, pavements and paths) make up 5.3% of the land area, with gardens comprising 3.5%.

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

Broad habitat	Area (Ha)	% cover
Cultivated / disturbed land	237,894	70.0
Uncertain agriculture (improved grass or arable)	6,307	1.9
Grassland, improved	21,674	6.4
Grassland, semi-natural	12,543	3.7
Grassland, marshy	2,784	0.82
Grassland, unknown	249	0.07
Fen, marsh and swamp	327	0.10
Scrub	475	0.14
Trees / Parkland	3,556	1.0
Woodland, broadleaved	9,180	2.7
Woodland, coniferous	660	0.19
Woodland, mixed	2,339	0.69
Water	7,188	2.1
Built up areas	9,603	2.8
Infrastructure	8,235	2.4
Gardens and brownfield	11,866	3.5
Rock, exposure and waste	838	0.25
Other / uncertain / unclassified	3,888	1.1
TOTAL	339,607	100.0

Map 1: Broad habitats across Cambridgeshire



2.3 High quality habitats

The highest quality semi-natural habitats can be identified from the basemap and are shown in Map 2, although note that this is based on habitat type and not on condition, which was not assessed here. In total 8,960 ha, which represents 2.6% of Cambridgeshire, contain these high-quality habitats. The greatest amounts were 3,932 ha of semi-natural broadleaved woodland (A1.1.1) and 2,725 ha of floodplain grazing marsh (B4f). However, this only included certain habitat types and did not include, for example, semi-improved neutral, acid and calcareous grasslands. Note also, 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.

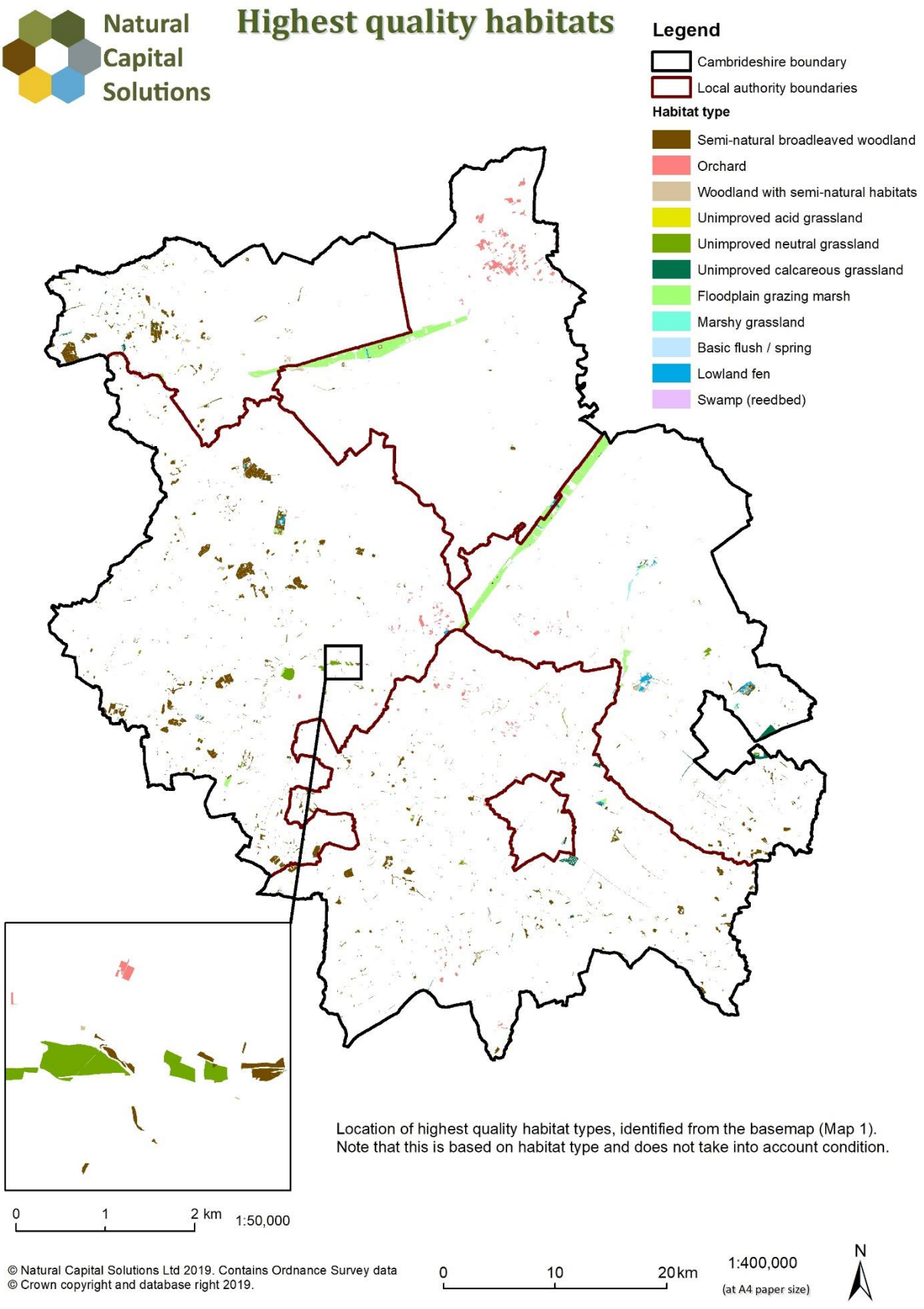
2.4 Nature conservation designations

The location of designated sites is shown on Map 3. Key sites include the Ouse Washes and Nene Washes, which are considered to be of international importance for birds and have been designated as Special Protection Areas (SPAs), Ramsar Sites and SSSIs. These predominantly consist of floodplain grazing marsh, interspersed with some fen and other habitats and are the largest designated sites in Cambridgeshire. Sites that are designated as Special Areas of Conservation (SACs) include Woodwalton Fen, Wicken Fen, and Chippenham Fen (these are a mixture of fen, wetland and woodland habitats), Portholme (unimproved neutral grassland), Eversden and Wimpole Woods (seminatural broadleaved woodland), as well as a number of other sites. In total 3,272 ha are designated as SPAs within Cambridgeshire (0.96% of the total land area), and an additional 1,272 ha (0.37%) are designated as SACs. The total amount of land designated as SSSI within Cambridgeshire is 8,097 ha, or 2.4% of the total area, with an additional 13,679 ha (4.0%) designated as a County or City Wildlife Site. All the SACs and SPAs (and Ramsar Sites) are also designated as SSSIs, hence the total amount of land receiving some level of protection amounts to approximately 6.4% of the total area of Cambridgeshire.

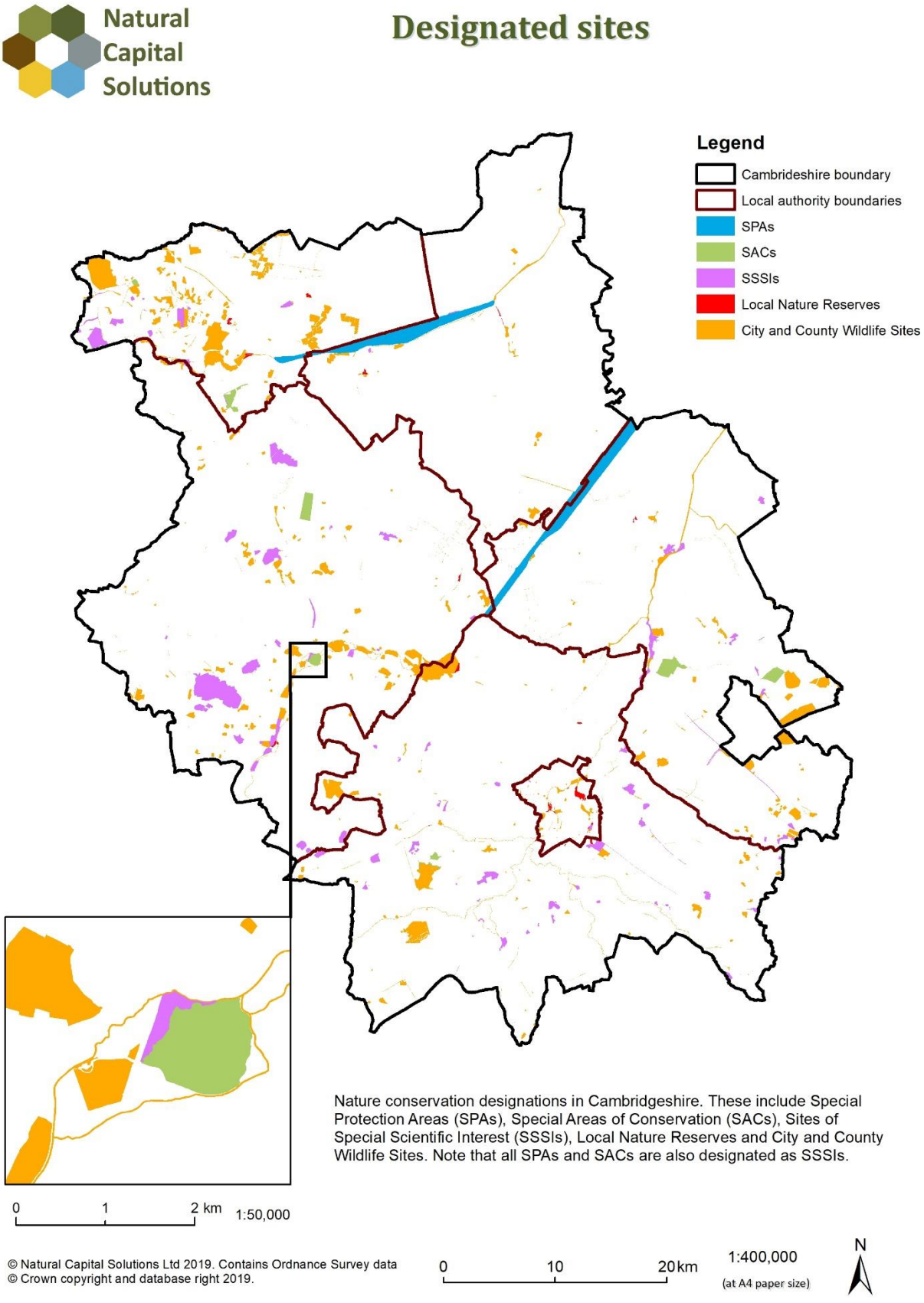
2.5 Agricultural quality

According to Natural England data, the largest amount of land in Cambridgeshire (152,000 ha or 44.8% of all land) is classified as high-quality Grade 2 agricultural land. In addition, 66,000 ha (19.5%) is considered to be Grade 1 (highest quality), and 90,000 ha (26.5%) is classified as Grade 3 (moderate quality) agricultural land. Small patches of Grade 4 (lower quality) also occur in some locations adjacent to the main waterways. The highest quality land occurs on the drained fens. Map 4 shows the spatial pattern of agricultural land classification.

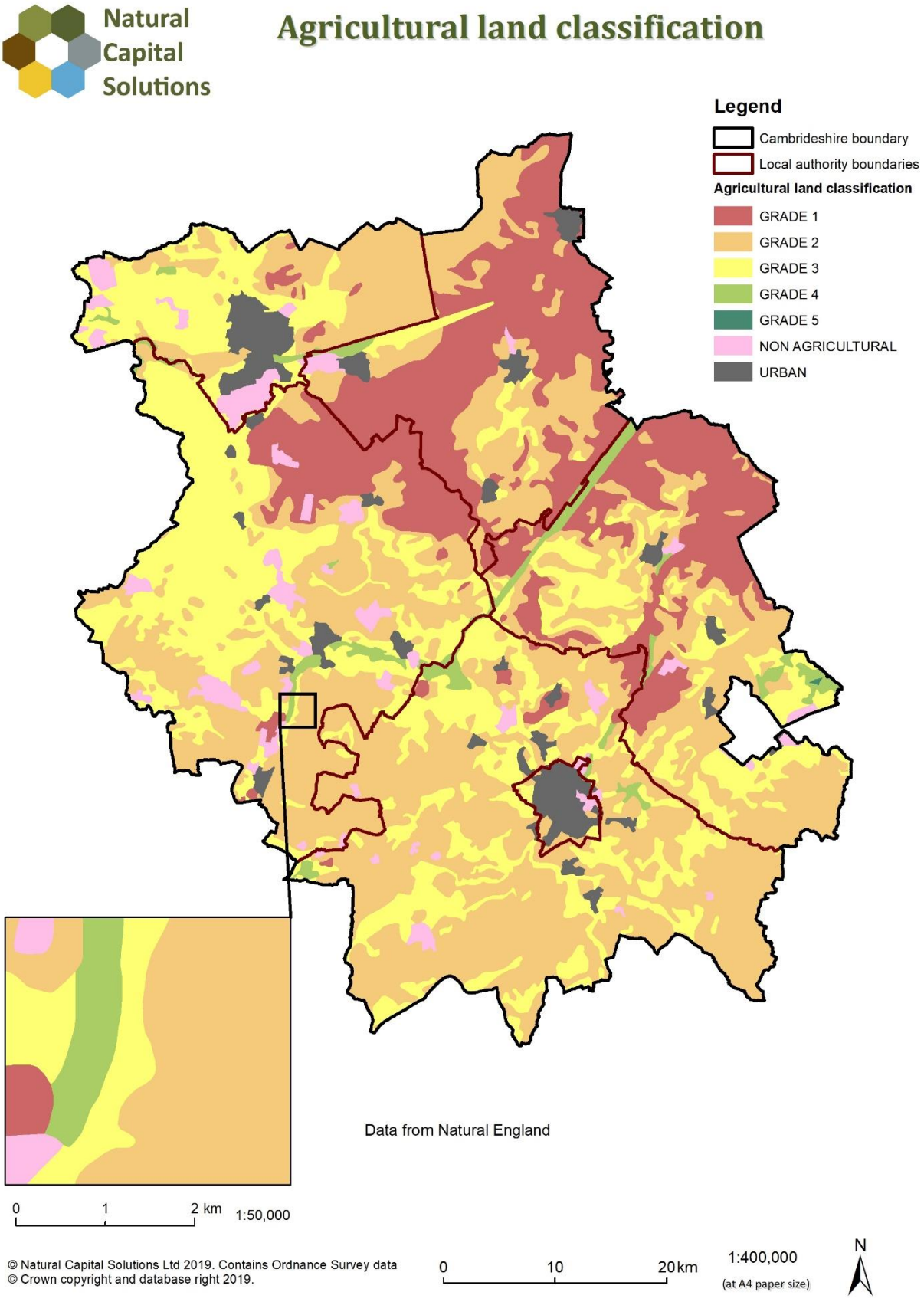
Map 2: High quality habitat types, identified from the basemap



Map 3: International, national and locally designated sites for nature conservation



Map 4: Agricultural land classification across Cambridgeshire



3. The changing habitats of Cambridgeshire: a historical perspective over 80 years

3.1 Introduction

Land-use and habitats in the UK have changed drastically since the Second World War. During this time period the countryside underwent a period of major intensification and industrialisation, with a rapid rise in the use of artificial fertilizers, pesticides, and machinery, as well as increases in field sizes, drainage of wetlands, reduction in rotations, simplification and homogenization of farm types, and altered cropping patterns from spring sown to autumn sown crops. At the same time there has been a rapid expansion of urban areas and an increase in plantation forestry. These factors taken together have led to the loss of much of the semi-natural habitats of lowland UK, and the fragmentation of remaining patches, resulting in major declines in biodiversity. It has also resulted in changes to the ecosystem services delivered by the land, with a primary focus on agricultural and timber production, but a decline in other ecosystem services.

Here, the land-use and habitats of Cambridgeshire have been mapped using data from the 1930s and compared this to the current situation (2018). The primary aim has been to establish how land-use has changed and the amount of change of different habitats.

3.2 Approach

Although historic maps are available dating back several centuries and with newer editions appearing at regular intervals in more recent times, these do not provide any information on habitats, apart from identifying woodlands. Indeed, only one source of habitat information is available prior to the 1980s and that is The Land Utilisation Survey of Great Britain, 1933-49. These resulting maps are known as the “Dudley Stamp Maps” after the organiser and instigator of the survey.

A scanned and digitised version of the survey was obtained. The digital version of the Land Utilisation Survey classifies habitats into eight different categories. A key challenge when comparing maps from very different sources is the difficulty of matching land cover types between the different surveys. The original definitions of the Dudley Stamp categories were used and compared to the habitat types produced in the basemap described in Section 2, and matched as closely as possible. Nine final categories were chosen, and Table 2 describes how the habitats from both time-periods fit into these categories.

All “meadowland and permanent grass” identified in the Dudley Stamp map was classified as “semi-natural grassland” and no areas were classified in the “improved grassland” category. This is based on the assumption that no agricultural grasslands were improved at that time as they were not receiving inorganic fertilizers. This has been shown to be true in areas with detailed botanical data from the 1930s.

Urban areas presented a particular difficulty as these areas were not mapped in any detail in the Dudley Stamp survey. In the Dudley Stamp maps, dense urban areas were classified as “land agriculturally unproductive”, with suburban areas classified as “gardens”, and only large greenspaces within urban areas were marked separately. As there was no obvious way to match this with the categories on the modern map, a new category was created of “built-up areas and gardens” containing both the Dudley Stamp categories. For the present-day map, all urban and garden

categories were combined, along with amenity grassland (e.g. road verges) that were less than 1 ha in size. Note that ditches between fields were not recorded on the Dudley Stamp maps and the width of larger rivers and drainage channels was not recorded accurately, hence the change in the amount of water between the two time periods should be interpreted with caution.

Table 2: Final habitat categories chosen, and the corresponding categories from the Dudley Stamp maps (1930s) and the basemap (2018)

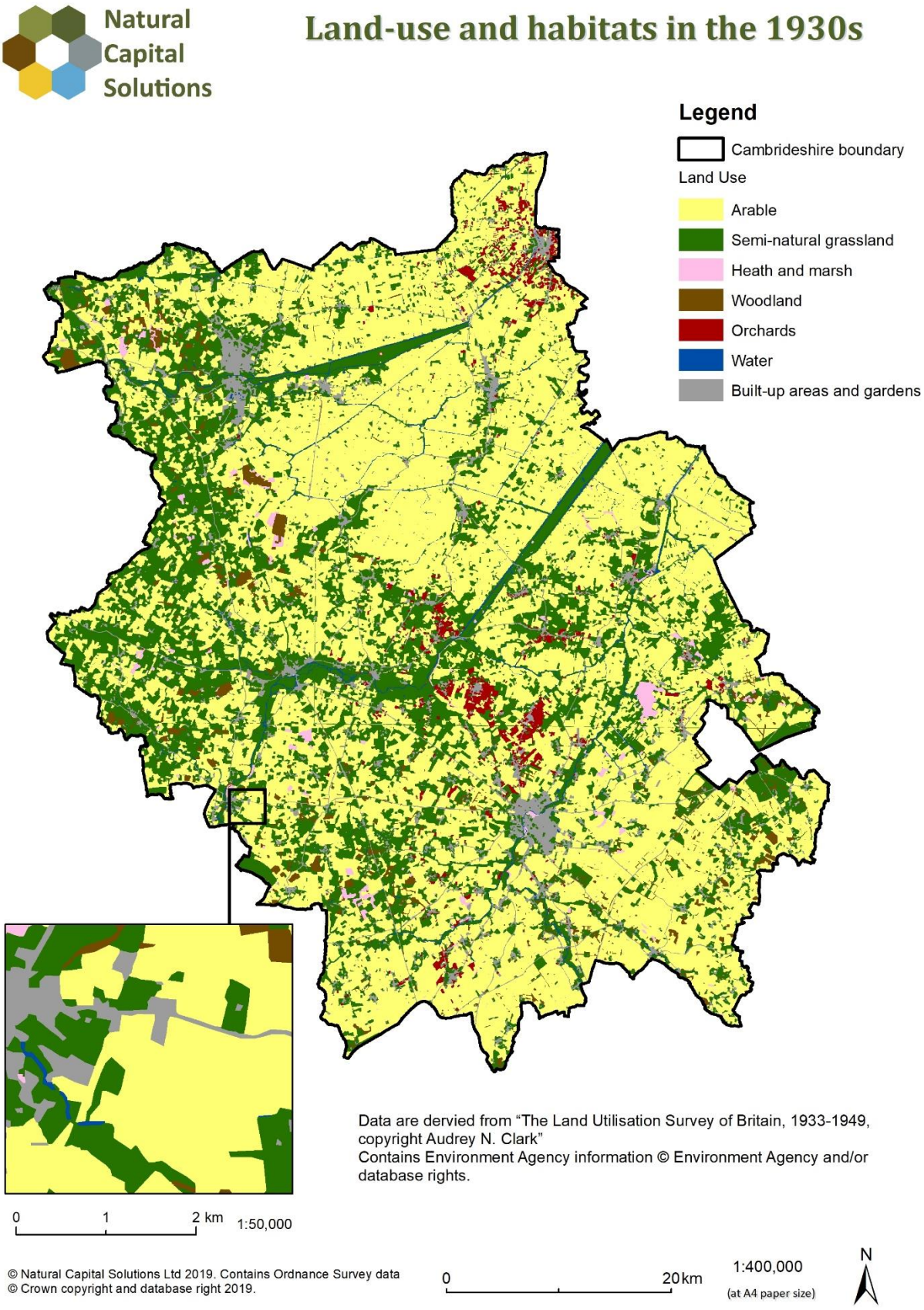
Final categories	Dudley Stamp categories	Basemap habitats
Woodland	Forest and woodland	Broadleaved woodland Coniferous woodland Mixed woodland Scrub Parkland
Arable	Arable land	Cultivated / disturbed land (excluding allotments)
Semi-natural grassland	Meadowland and permanent grass	Semi-natural grassland (includes neutral, acid, calcareous and rough grasslands), Floodplain grazing marsh
Improved grassland	-	Improved grassland (excluding floodplain grazing marsh), Amenity grassland > 1 ha
Heath and marsh	Heaths and moorlands	Marshy grassland, Heathland, Mire Swamp
Built-up areas and gardens	Land agriculturally unproductive (includes buildings, roads, industry) Gardens (includes allotments)	Built-up areas Infrastructure Gardens & brownfield Allotments Amenity grassland < 1 ha Railway and road verges
Orchards	Orchards	Orchards
Water	Water	Water
Other / unclassified	-	Other Uncertain Unclassified

Using the new categories, two maps were created representing the 1930s and 2018 and clipped to the study area boundary. Data were then extracted on the cover of each habitat in each time period and the change in habitat area was calculated.

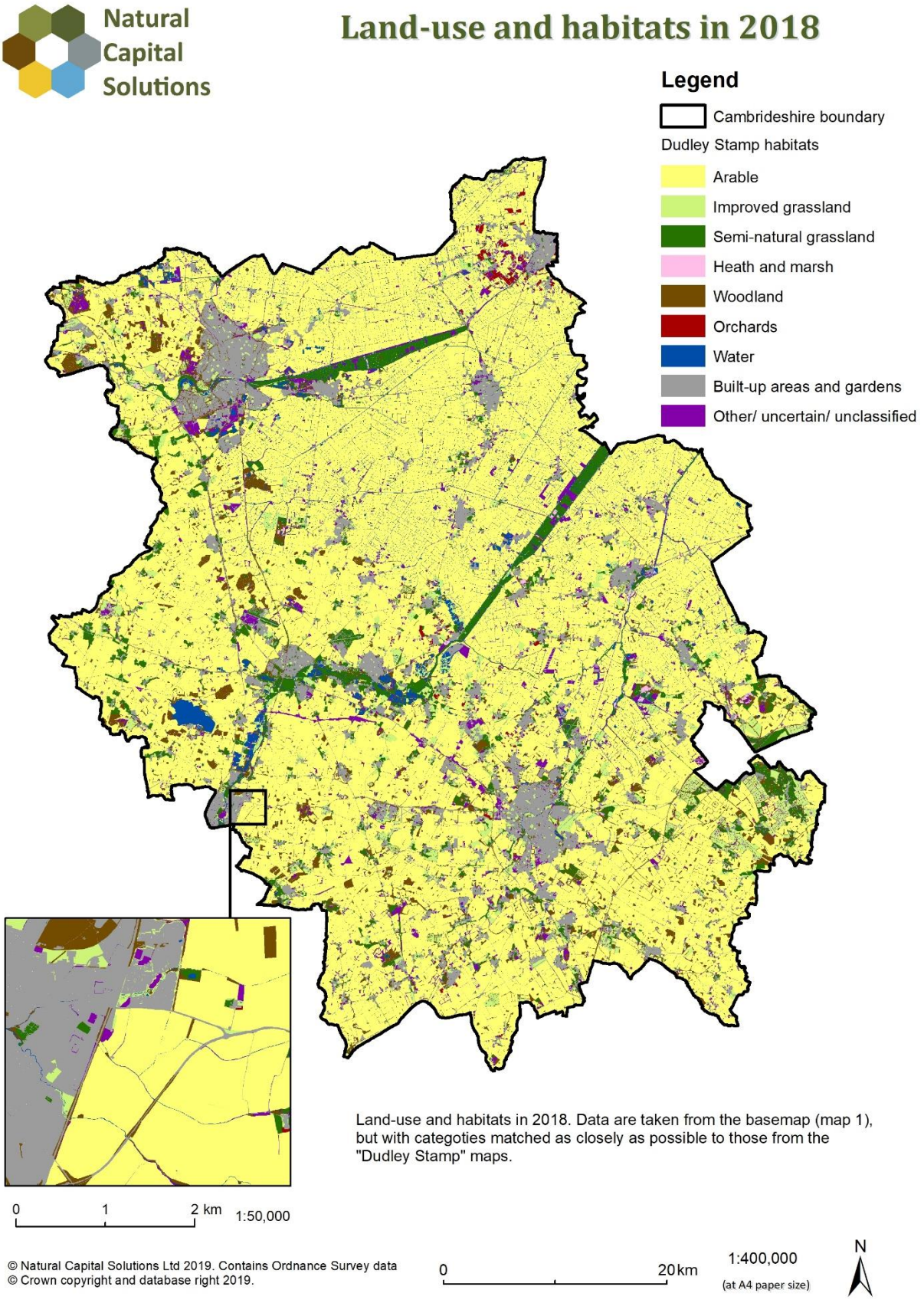
3.3 Results

A map of habitats in the 1930s is shown as Map 5, with the corresponding map from 2018 as Map 6.

Map 5: Land-use and habitats in the 1930s, derived from the "Dudley Stamp" maps



Map 6: Land-use and habitats in 2018, derived from the basemap, but with categories matched as closely as possible to the “Dudley Stamp” maps.



Arable was the dominant habitat type even in the 1930s, occupying 60.8% of the area of Cambridgeshire, with semi-natural grassland occupying 27.3% (Figure 1). Built-up areas and gardens occupied 5.8% and woodland 2.4%. There were no improved grasslands.

By 2018 arable had increased to 69.9% of the land area, with improved grasslands occupying a further 4.8%. Semi-natural grassland had declined to just 4.5%, whilst built-up areas and gardens had increased to 10.7% and woodland had increased to 4.5% (Figure 1).

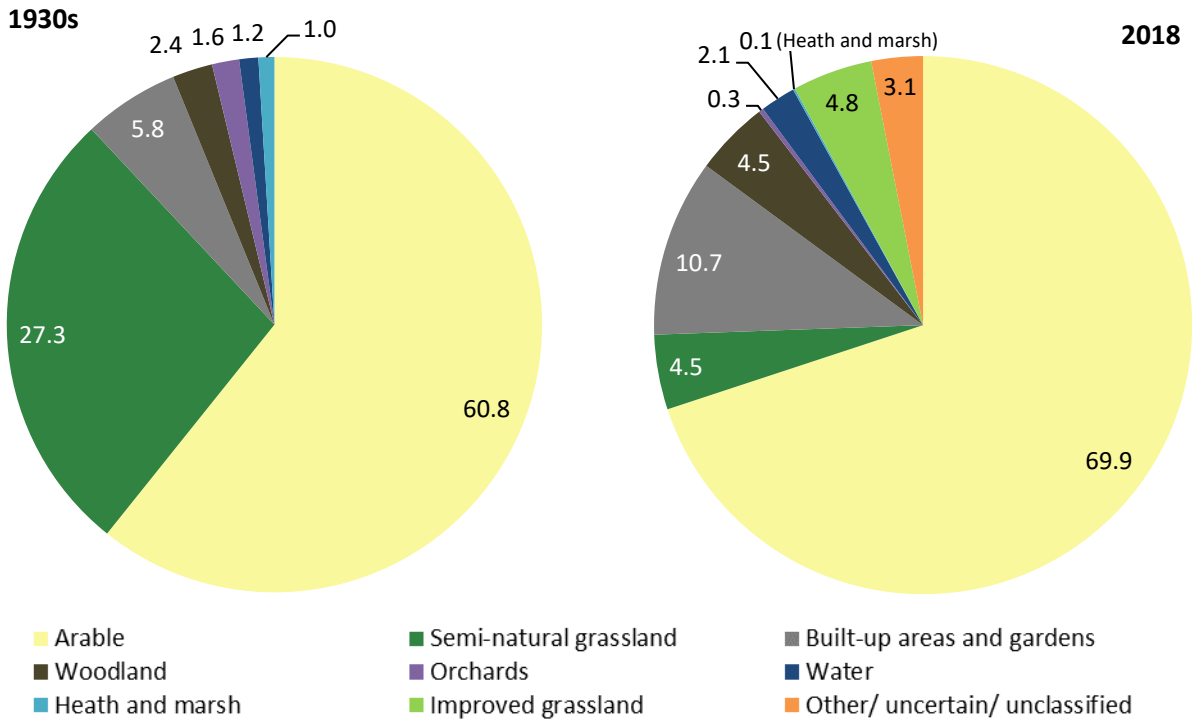


Figure 1: Percentage cover of habitat types in the 1930s (left) and 2018 (right).

The overall change in cover between the two time periods is shown in Figure 2. This shows that there has been a loss of 77,400 ha of semi-natural grasslands (an 84% decline) and 2,900 ha of heath and marsh (wetland) habitats (an 88% decline) across Cambridgeshire. On the other hand, arable has increased by 31,200 ha (an increase of 15%), built-up areas and gardens by 16,500 ha (84% increase) and woodland by 7,000 ha (85% increase). Improved grassland has increased from zero to 16,400 ha. The amount of water has also increased, due to the proliferation of gravel pits and the construction of Grafham Water, although the exact change recorded here is unreliable, as smaller drainage ditches were not recorded in the 1930s map.

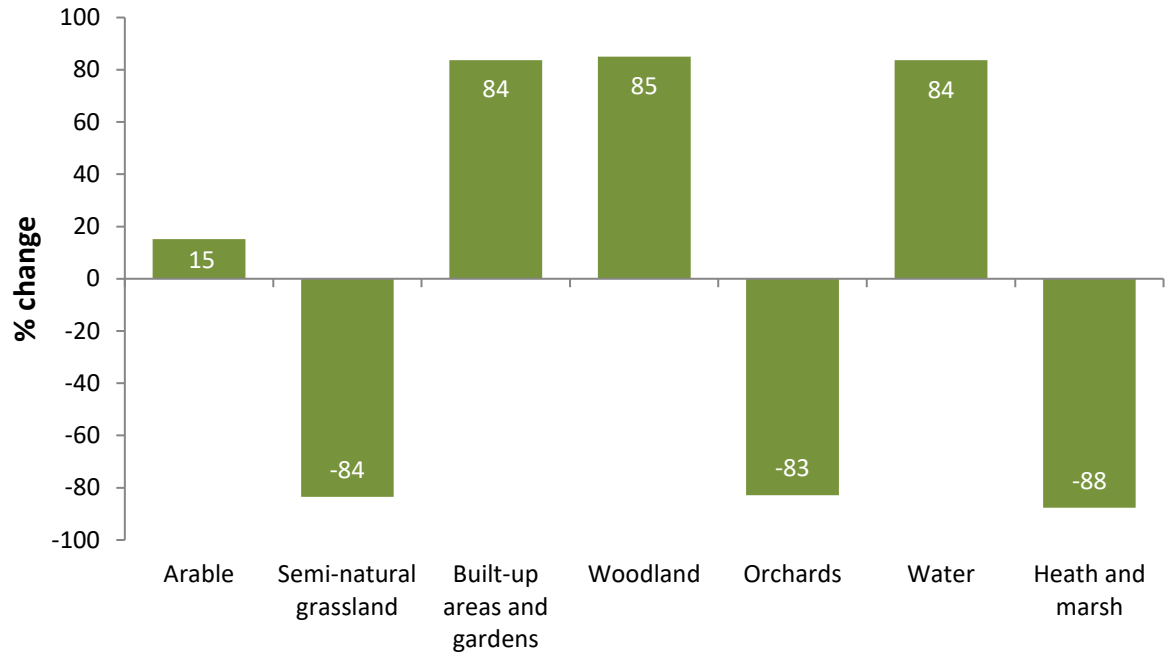


Figure 2: Percentage change in habitat types between the 1930s and 2018.

3.4 Discussion

The maps and data paint a picture of significant habitat change over the last 80 years. Although the dominant habitat type was arable in the 1930s and this land cover has increased by a relatively modest 15%, large amounts of semi-natural habitats have been lost, replaced predominantly by further arable, improved grassland and built-up areas. There has also been an expansion of woodland, particularly of plantation forestry in the 1950-60s. Similar changes have been seen throughout the UK. Nationally, it has been estimated that 97% of enclosed semi-natural grasslands in England and Wales were lost between 1930 and 1984, whereas woodland in the UK increased by almost 100% over similar periods[1], figures that are not dissimilar to the 84% decline and 85% increase seen here. In neighbouring Northamptonshire, which was less dominated by arable in the 1930s, the change has been even larger, with a 94% decline in semi-natural grasslands.

Such significant losses of semi-natural habitats are almost certain to have had an impact on biodiversity in Cambridgeshire. As well as direct loss of habitat, remaining habitat patches are smaller and more fragmented with reduced connectivity between wildlife populations. This reduces dispersal between populations, and small and isolated populations are more prone to local extinction. The exceptions to this are perhaps the Nene and Ouse Washes, which provide continuous areas of habitat of high nature conservation value.

Efforts were made to match the habitats recorded in the 1930s to those from the present day, but there will inevitably be some discrepancies. Habitats were recorded at a much higher resolution in the present study, capturing very small habitat patches. This was not the case in the 1930s, particularly in urban areas, and water was also mapped with less accuracy. In addition, the digitization process led to some further loss of detail for small habitat patches. It is likely that both the built-up / garden and

[1] UK NEA (2011) The UK National Ecosystem Assessment. UNEP WCMC, Cambridge.

water categories will have been slightly over-simplified in the 1930s map compared to the present day, and some smaller habitats such as orchards will have been underrepresented. The exact habitat areas and percentage change reported here are therefore prone to some error. Nevertheless, the overall picture of change is accurate.

There are likely to have been major changes in the ecosystem services delivered by the natural environment over the last 80 years. Clearly agricultural production will have increased, along with timber production. However, a number of regulatory services are likely to have declined. The ability of the land to retain water will have decreased, and the positive impact of habitats filtering pollutants and enhancing water quality will also have declined. The impact on carbon storage and sequestration is more difficult to predict without a detailed assessment, as gains in carbon through increasing woodland cover will have been offset by losses due to conversion of semi-natural grasslands to arable and improved grassland, which store less carbon and give rise to emissions from agricultural activities. The supply of pollination services is likely to have declined with the loss of semi-natural habitats, but the demand for pollination will have increased considerably as oil-seed rape has become a major component of the farming landscape but was not planted at all in the 1930s. Cultural services will also have been impacted although it is impossible to assess these due to cultural and other changes over the period.

Mapping and comparing land use and habitats over 80 years is a powerful way of demonstrating the changing landscape of Cambridgeshire and the loss of semi-natural habitats. Additional uses of the maps could be to assess changes in the degree of fragmentation and connectivity of habitat patches, and to identify previous land-use configurations to aid with the identification of the most suitable locations for habitat restoration. This could work particularly well in combination with the habitat opportunity mapping described in the next section.

4. 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 Cambridgeshire. The broad habitats and their constituent types are shown in the table below:

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

Biodiversity opportunity mapping followed a four-step process, as explained below, and was based on the approach developed by Catchpole (2006)[2] and Watts et al. (2010)[3]. 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.

4.1 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

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

[3] 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.

adjusted by Natural Capital Solutions for Cambridgeshire 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:

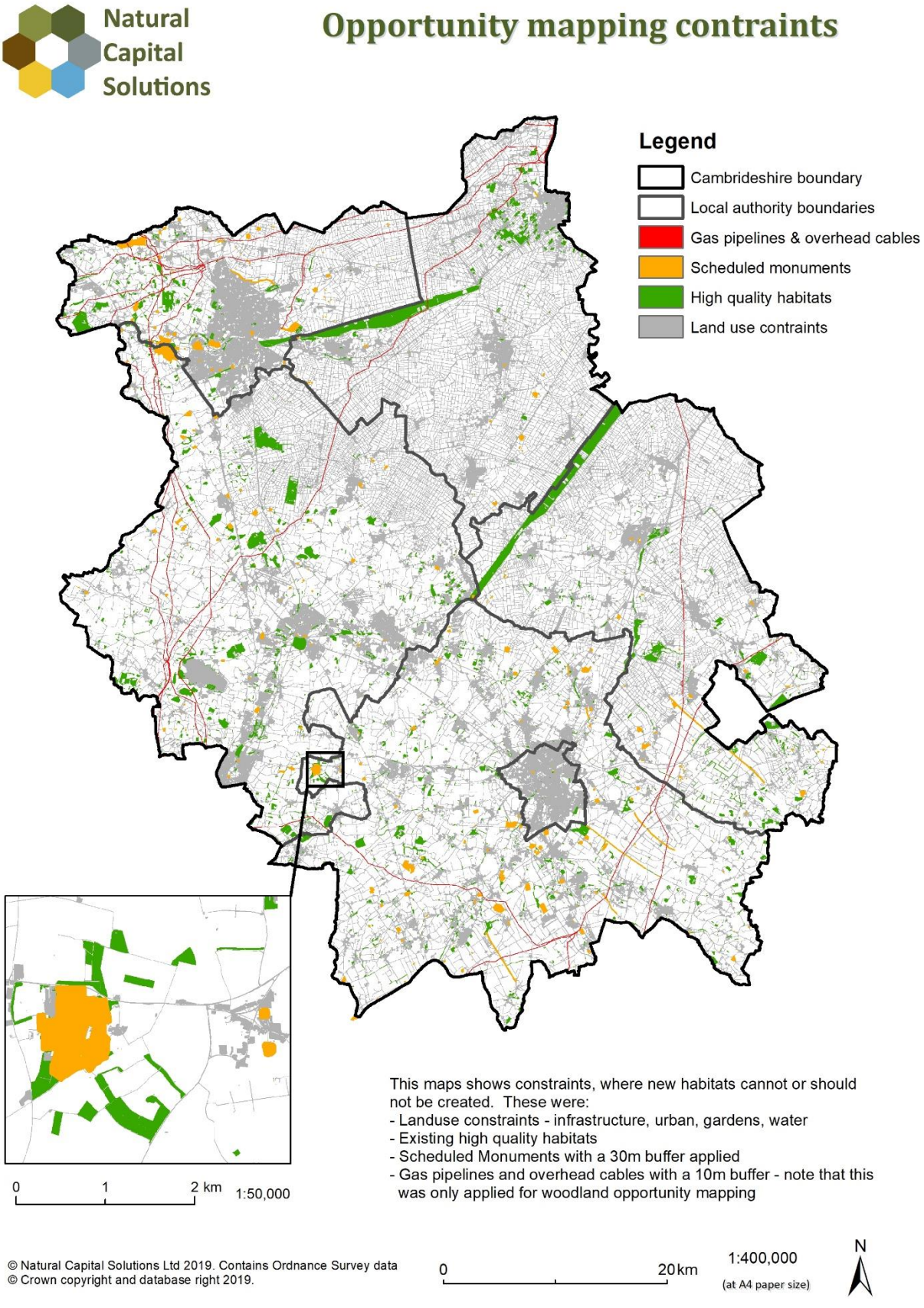
Dispersal distance in optimal habitat:	
Semi-natural grassland	2.0 km
Wet grassland & wetlands	2.0 km
Broadleaved and mixed woodland	3.0 km

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 Map 7 (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 (overleaf) and are the same as those mapped in Map 2.
- Scheduled Monuments (SAMs) – data was obtained on the location of SAMs across the study area and a 30m buffer was applied around each individual SAM, 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 and overhead 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.

Map 7: Key constraints taken into account during habitat opportunity mapping across Cambridgeshire.



Box 3: High quality habitats

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

- Semi-natural broadleaved woodland (A1.1.1)
- Orchards (A1.1.2o)
- Woodland/scrub with semi-natural habitats
- Unimproved acid grassland (B1.1)
- Unimproved neutral grassland (B2.1)
- Unimproved calcareous grassland (B3.1)
- Floodplain grazing marsh (B4f)
- Marshy grassland (B5)
- Basic flush and spring (E2.2)
- Lowland fen (E3/F1)
- Swamp (reedbed) (F1)

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. Two layers of habitat opportunity were then created:

- **Buffer opportunity** – this layer identified habitat opportunity areas that are immediately adjacent to existing habitat patches and fall within the previously identified ecological network.
- **Stepping-stone opportunity** – this layer identified potential sites that fall outside of the ecological network, but are immediately adjacent to it. These areas could potentially be used to create stepping-stone habitats that could link up more distant habitat patches.

For both opportunity layers, 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 maps identify 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 and stepping stone 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. To remove spurious results where only a tiny fraction of a field fell within a buffer zone, fields where less than 10% of the whole field overlapped with the buffer zone were removed. In the same way, the stepping stone layer was also overlain to identify whole fields that fall outside of the ecological network, but are immediately adjacent to it.

4.2 Results

The results are illustrated here for semi-natural grassland habitats, with the wet grassland and wetland, and broadleaved and mixed woodland 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.

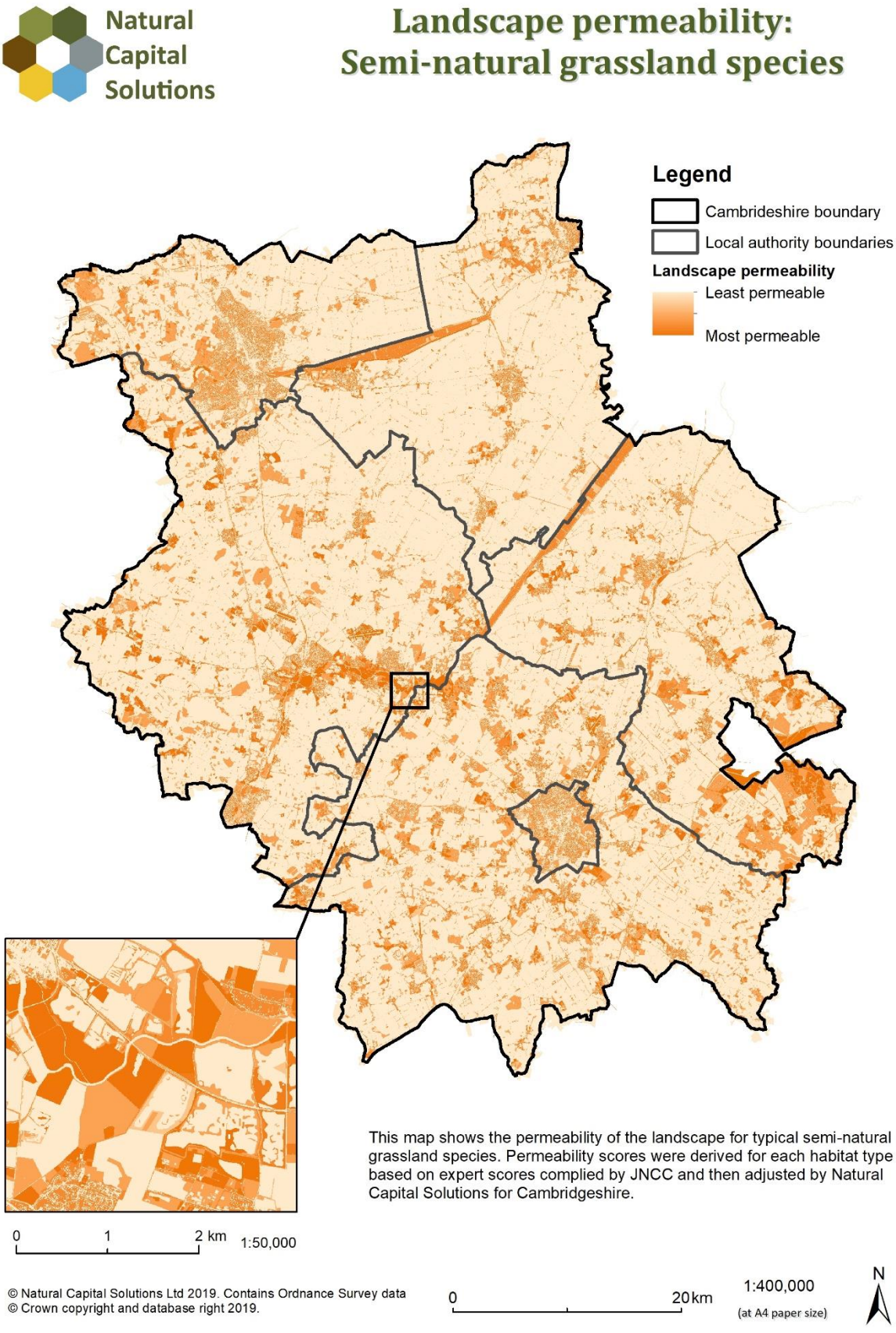
The permeability of the landscape for typical semi-natural grassland species is shown on Map 8. Darker areas are more permeable, meaning that typical species are expected to travel further across these habitats and hence will be less of a barrier to movement. For all three broad habitat types, arable fields are the most significant barrier to movement.

The habitat network map for semi-natural grassland is shown on Map 9. 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 (Map 9) the River Great Ouse corridor around Huntingdon and St Ives is providing a near-continuous network, although there are opportunities to enhance this further. There are also large networks around Newmarket to the east of Cambridgeshire, with other smaller patches spread across the county. Wet grassland and wetland habitat networks (Map A2), are concentrated in three locations; the Nene Washes, the Ouse Washes and to a lesser extent on the River Great Ouse between Wicken Fen and Ely. For broadleaved and mixed woodland (Map A6), the most significant networks are found to the west of Peterborough and in Huntingdonshire, although many patches of woodland remain ecologically isolated and there are no large patches of continuous habitat.

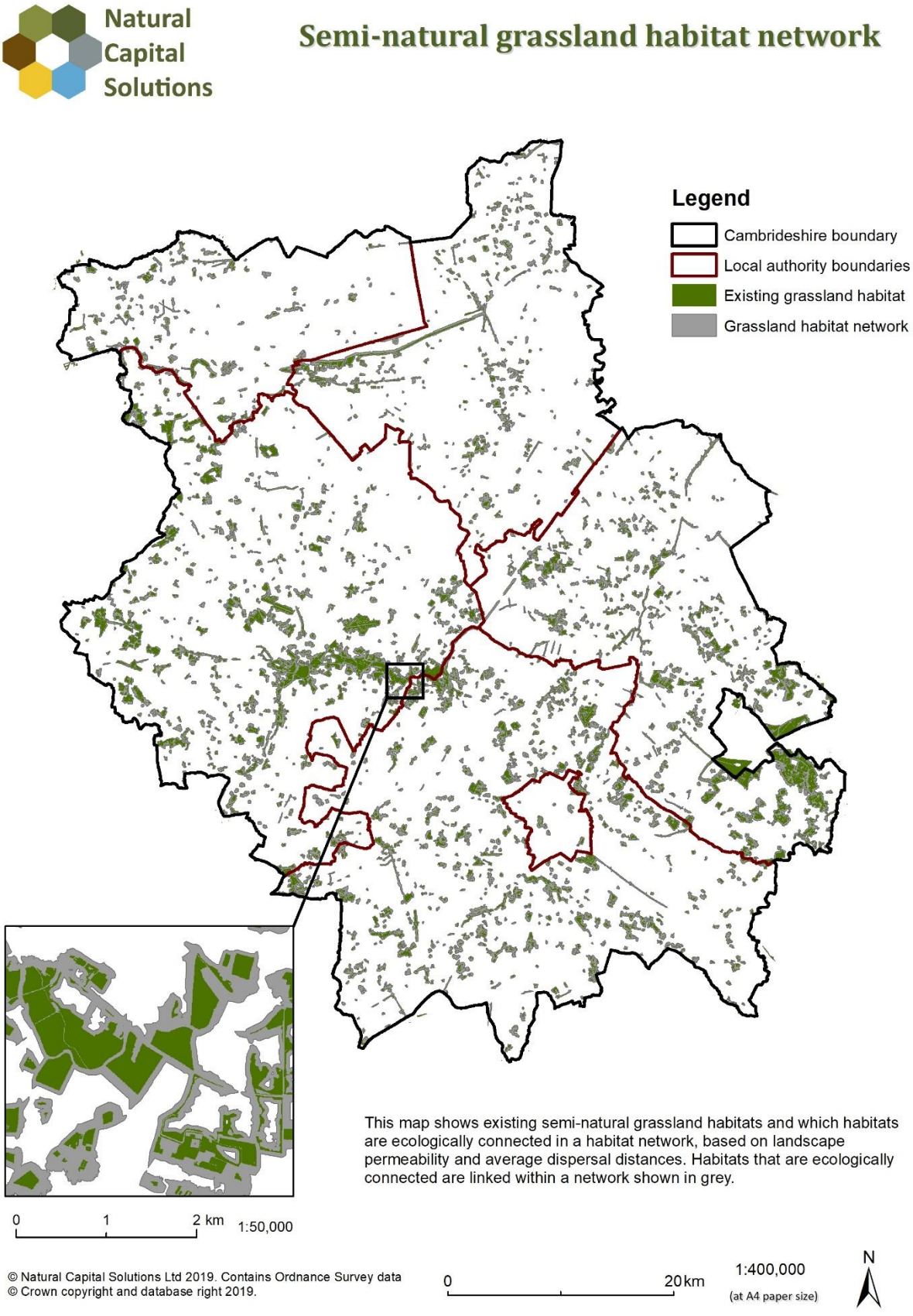
Once constraints have been removed, the resulting maps show biodiversity opportunity areas. Map 10 illustrates these for semi-natural grassland habitats, showing both buffer and stepping-stone opportunities. The fields buffer layer is shown on Map 11 for semi-natural grassland, with the other habitats in Annex 1. Note that the fields stepping-stone layer is not shown but is available as a GIS layer. These maps highlight whole fields where habitats could be created, as these are a more meaningful management unit for conservation action. There are many areas, spread fairly evenly across Cambridgeshire, where semi-natural grassland could be created to considerably enlarge and connect existing networks. For wet grassland and wetlands (Map A4), the focus is almost exclusively on the three areas highlighted above (Nene and Ouse Washes and the Wicken Fen to Ely corridor), and field scale habitat creation could consolidate and enlarge these existing networks. Broadleaved and mixed woodland opportunities (Map A8) exist throughout the study area (with the exception of Fenland), where field-scale habitat creation could connect many isolated woodland fragments to create a more resilient network.

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 5.1).

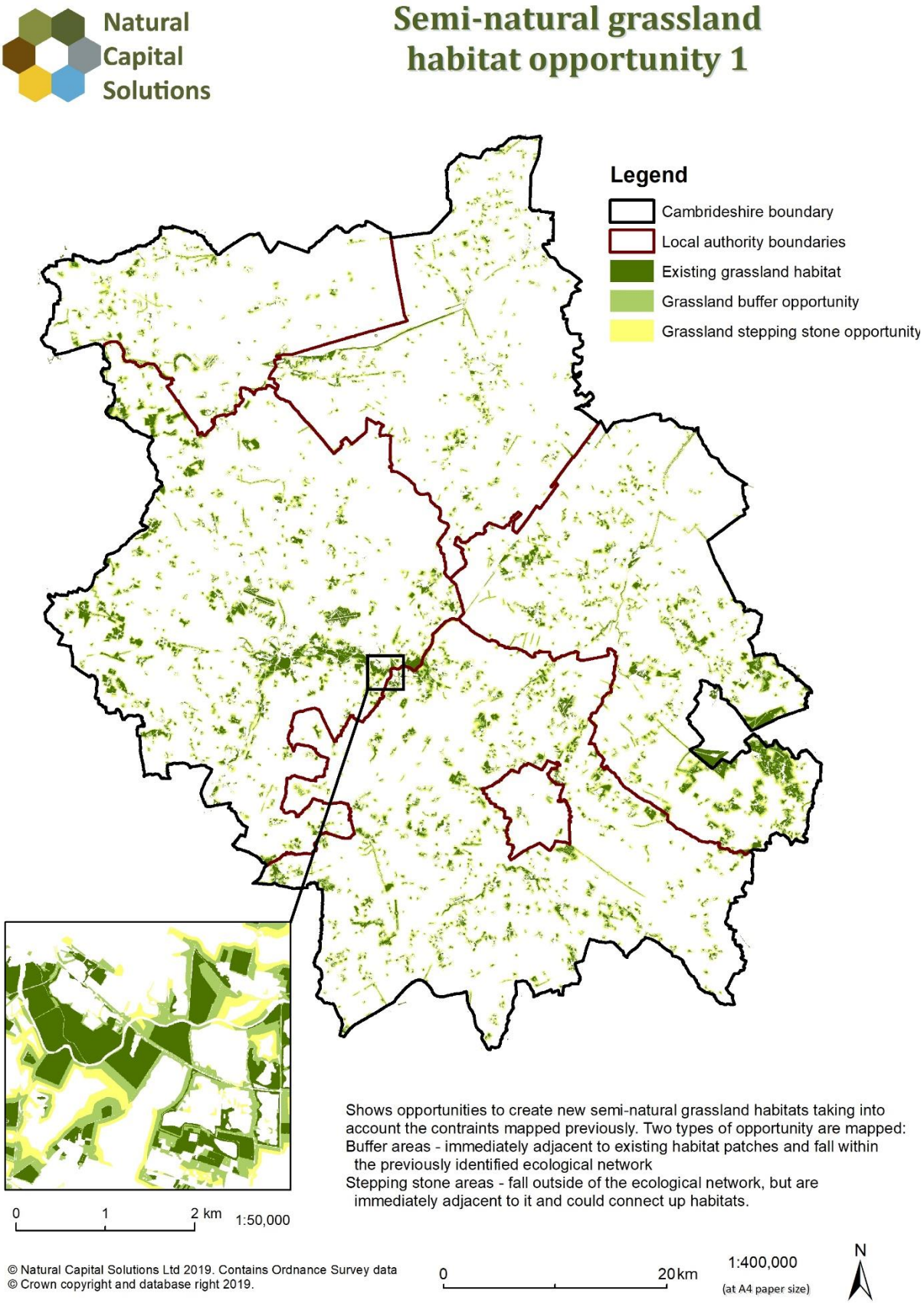
Map 8: Landscape permeability for typical semi-natural grassland species across Cambridgeshire



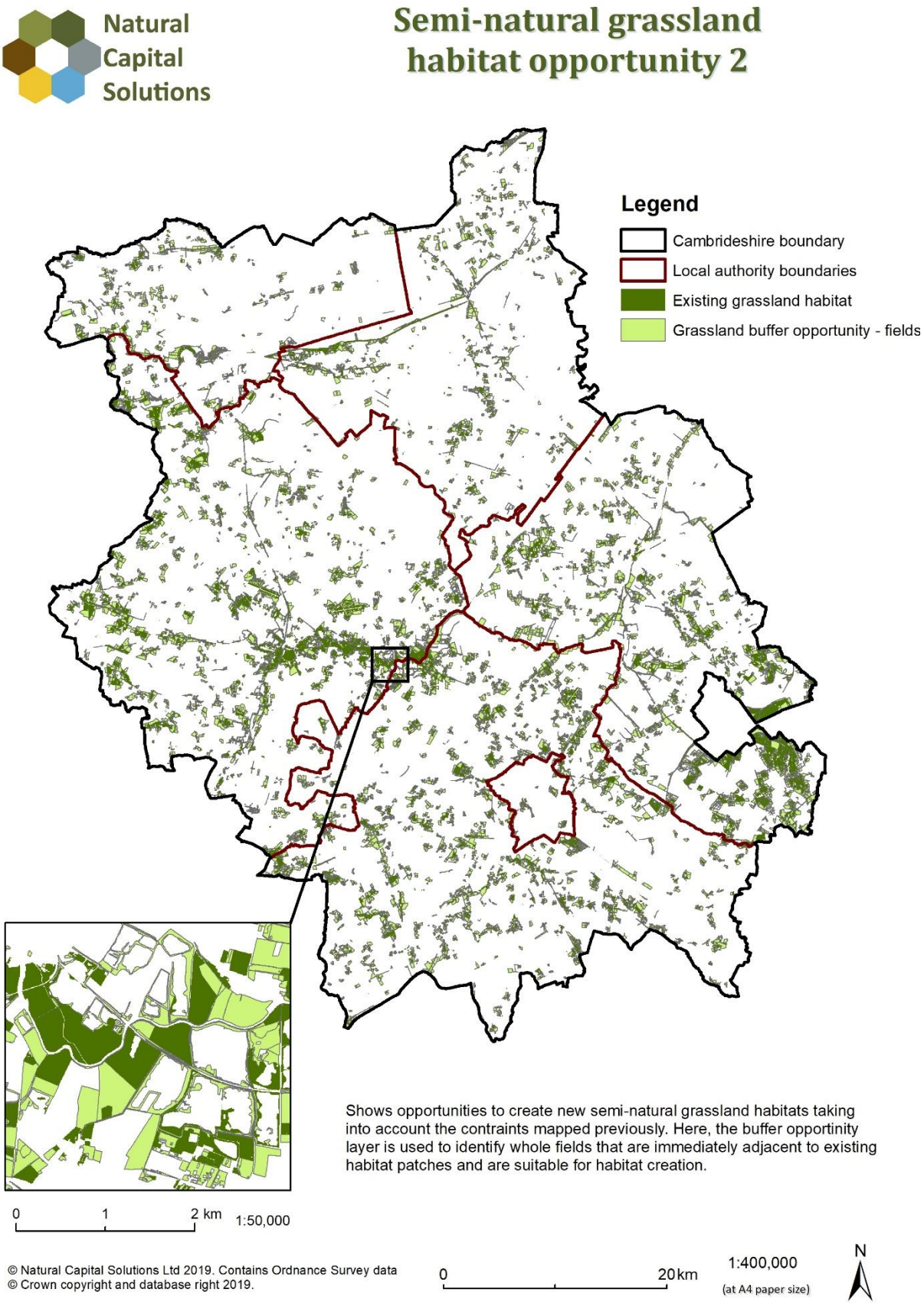
Map 9: Habitat network for semi-natural grasslands across Cambridgeshire.



Map 10: Buffer and stepping-stone biodiversity opportunity areas for semi-natural grassland across Cambridgeshire.



Map 11: Field scale biodiversity opportunity areas for semi-natural grassland across Cambridgeshire.



5. 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 Cambridgeshire (including Peterborough). It provides the most comprehensive and detailed coverage that is possible at this time and should have a wide range of applications. However, the basemap should be used with care, as it has not been ground-truthed and some of the data on which it is dependent is quite old. It shows that Cambridgeshire is dominated by arable land, with much of the remaining area taken up by improved grassland, the built environment and gardens. Semi-natural grasslands, wet grassland and wetlands, broadleaved and mixed woodland, and running and standing water take up a combined total of about 10% of the area of Cambridgeshire, whilst about 6.4% of the total area has some form of nature conservation designation.

One application of the basemap has been to compare it to historic land-use maps from the 1930s, to look at habitat change since that time. This confirms that there has been considerable loss of semi-natural habitats, particularly of semi-natural grasslands, and loss of connectivity of the remaining semi-natural habitats over the last 80 years. This is discussed in much more detail in Section 3.4.

The basemap has also been used, along with additional data, to produce opportunity maps showing where new habitats could be created for biodiversity enhancement for three broad habitat types. 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 are available for project partners. The opportunity maps 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 go a long way to identifying appropriate locations.

There are considerable additional benefits of investing in habitat creation for biodiversity. 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 air quality regulation, natural flood risk management, water quality enhancements, and additional services such as climate change mitigation, local climate amelioration, and noise screening. 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. Opportunities for enhancing ecosystem services, or of delivering multiple benefits, could be the subject of further mapping and is described further below.

5.1 Next steps

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

1. Update habitat survey

As described previously, the habitat basemap is partially dependent on data collected in the 1990s, so will be prone to some error. Wholesale land-use change will have been picked up through other data layers, but more subtle changes to habitat types is likely to have occurred and is unlikely to have been detected. Improving the accuracy of the basemap through conducting ground-based habitat surveys would seem to be a useful undertaking and this would then lead to increased confidence in the outputs and the other analyses carried out. To reduce time and cost of such a survey, it would be possible to focus on the approximately 10% of Cambridgeshire containing seminatural habitats, along with areas where habitat change is known to be occurring (e.g. the Great Fen Project area). It would then be a good idea to repeat such a habitat survey every few years, or continue on a rolling basis, so that the basemap is kept up-to-date.

2. Map ecosystem services and opportunities to enhance these services

It is possible to use the basemap, combined with a variety of other data, to model and map the ecosystem services (the benefits to people) provided by the natural capital assets. This could include benefits such as carbon sequestration, water retention, water quality, air quality, noise regulation, temperature regulation, agricultural production, timber production, access to nature, recreation, and health and wellbeing. This is useful at highlighting the wider benefits of nature and the spatial pattern of these benefits, which can also be mapped in relation to demand. These benefits can also be valued if desired.

Furthermore, it is also possible to produce opportunity maps for a number of different ecosystem services. In a similar way to the biodiversity opportunity maps included here, these highlight the best areas to create new habitats that can deliver benefits such as further reducing flood risk, enhancing air quality, increasing accessible greenspaces and so on. It then becomes possible to combine opportunity maps to highlight areas where new habitat could be created that could deliver multiple benefits. This is particularly useful as it opens up new revenue streams to fund habitat creation projects (see below) and provides additional support for plans with a biodiversity focus.

3. 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:

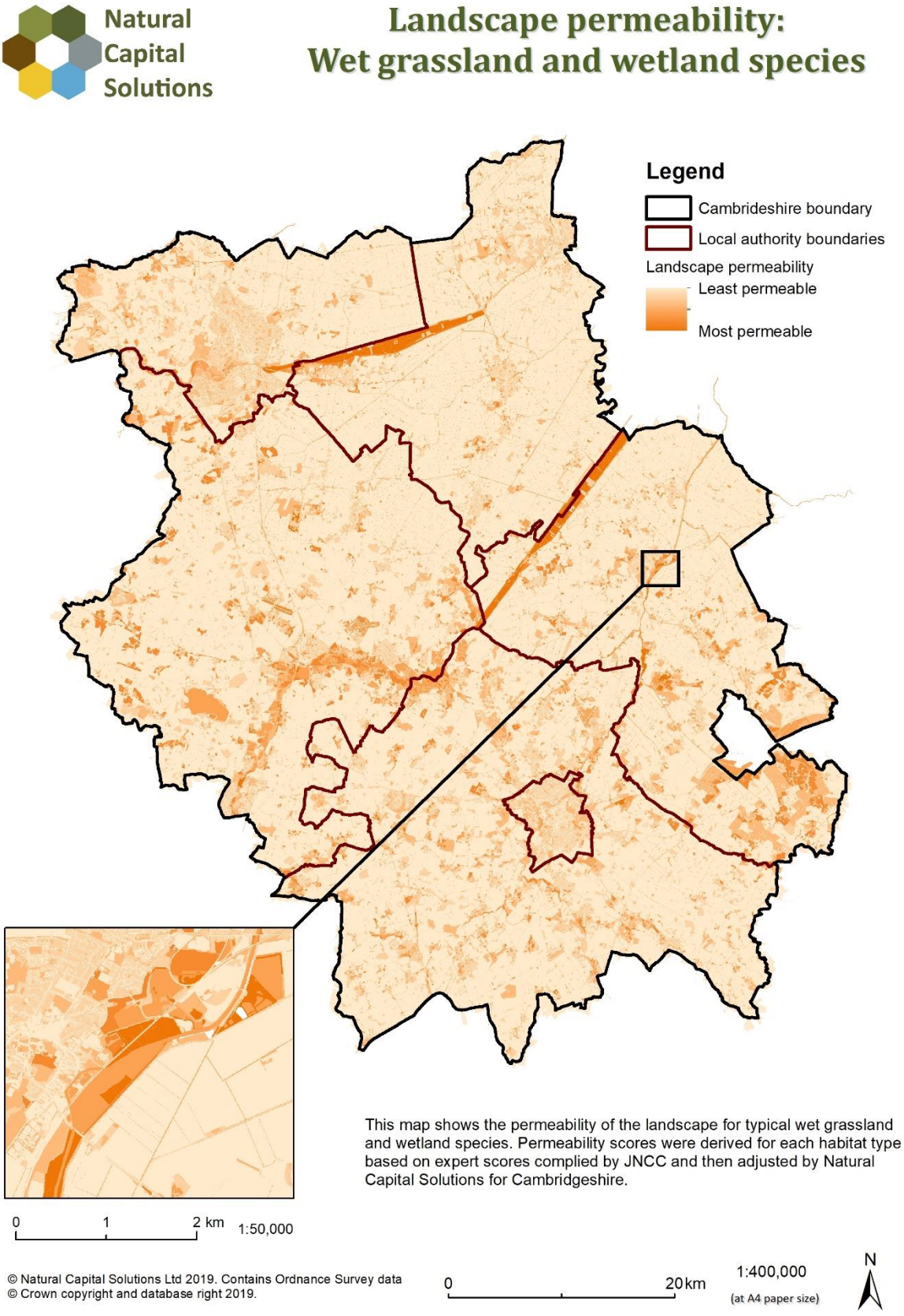
- The maps should be compared to other studies such as green infrastructure plans, and national maps created by Natural England, alongside local knowledge to remove errors, and target particular areas to take forward.
- It is recommended that a workshop is held with local stakeholders to consider priorities 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. Simple rules could be created to target certain habitats in different locations. The workshop could also be used to examine quality control and to consider prioritising certain areas (projects) to take forward.
- 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 and potentially incorporated into Local Plans and strategies. These could either be funded in the traditional way (e.g. grants from HLS etc.) or offered as biodiversity offsetting and biodiversity net gain projects funded through the development process. Biodiversity net gain has just been made mandatory for all new developments, so there is huge potential to use this as a source of funding.
  - Opportunity areas could be targeted through agri-environment schemes. This will be particularly relevant post-Brexit when the new Environmental Land Management Scheme will be moving towards paying farmers for environmental enhancements that deliver a range of public goods.
  - Woodland areas could be taken forward through the UK Woodland Carbon Code as well as more traditional woodland grant schemes.
  - If the biodiversity opportunity maps are combined with opportunity mapping for other ecosystem service, projects could be taken forward through a range of additional mechanisms. 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.

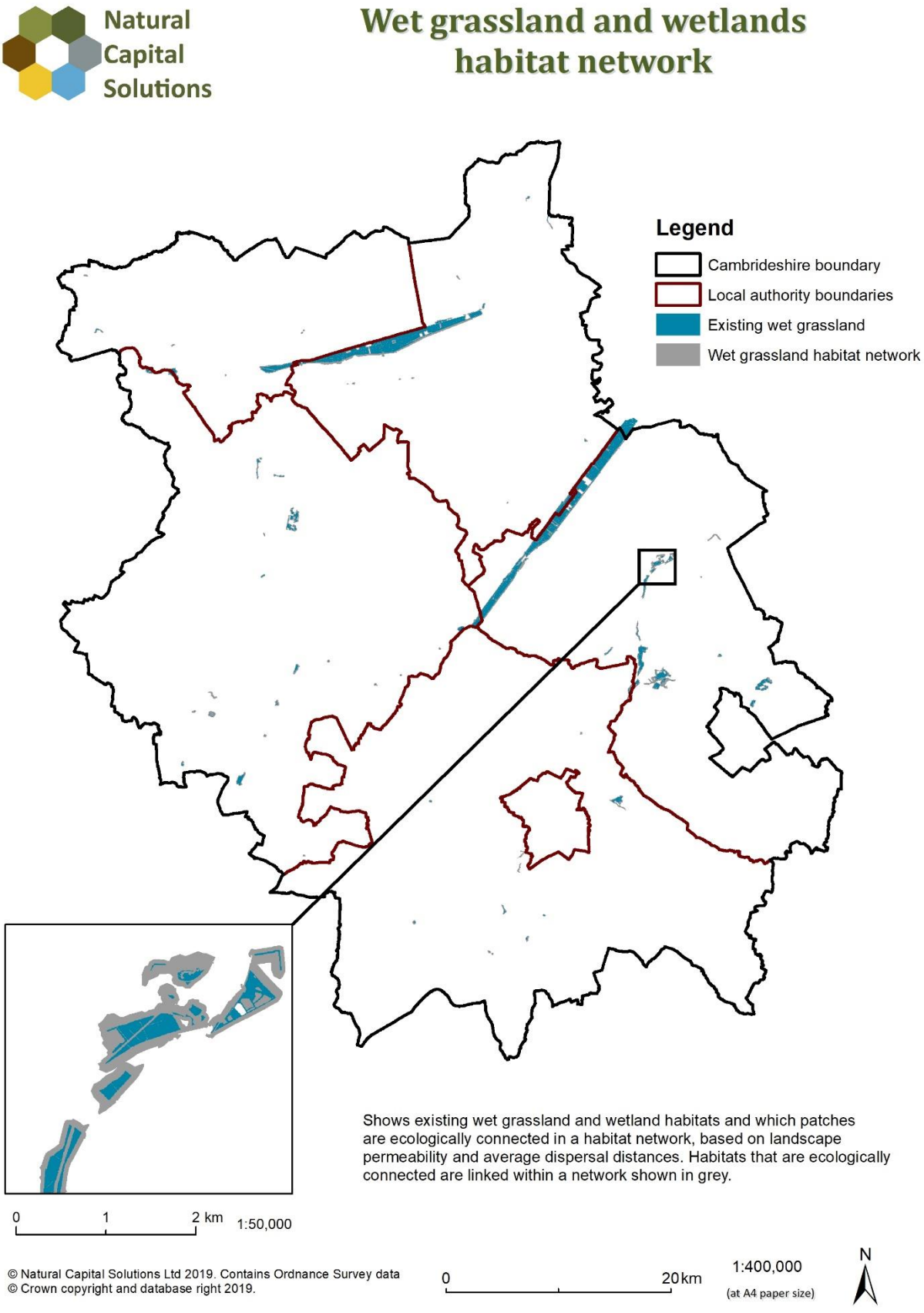
- It would be possible to take forward this work through a **Natural Capital Investment Strategy or Plan**. This would involve identifying key projects / locations to take forward, determining the costs and monetary benefits of habitat creation at these sites and hence the return on investment, and then presenting the plans in the form of a prospectus, potentially considering appropriate financial mechanisms. Note also, that Highways England and Defra have recently commissioned a Local Natural Capital Plan to be produced for the Oxford-Cambridge Arc, which will include stand-alone plans for Cambridgeshire and for each of the Local Authorities. Many of the potential projects identified here could be taken forward as part of that process.

Annex 1: Additional biodiversity opportunity maps

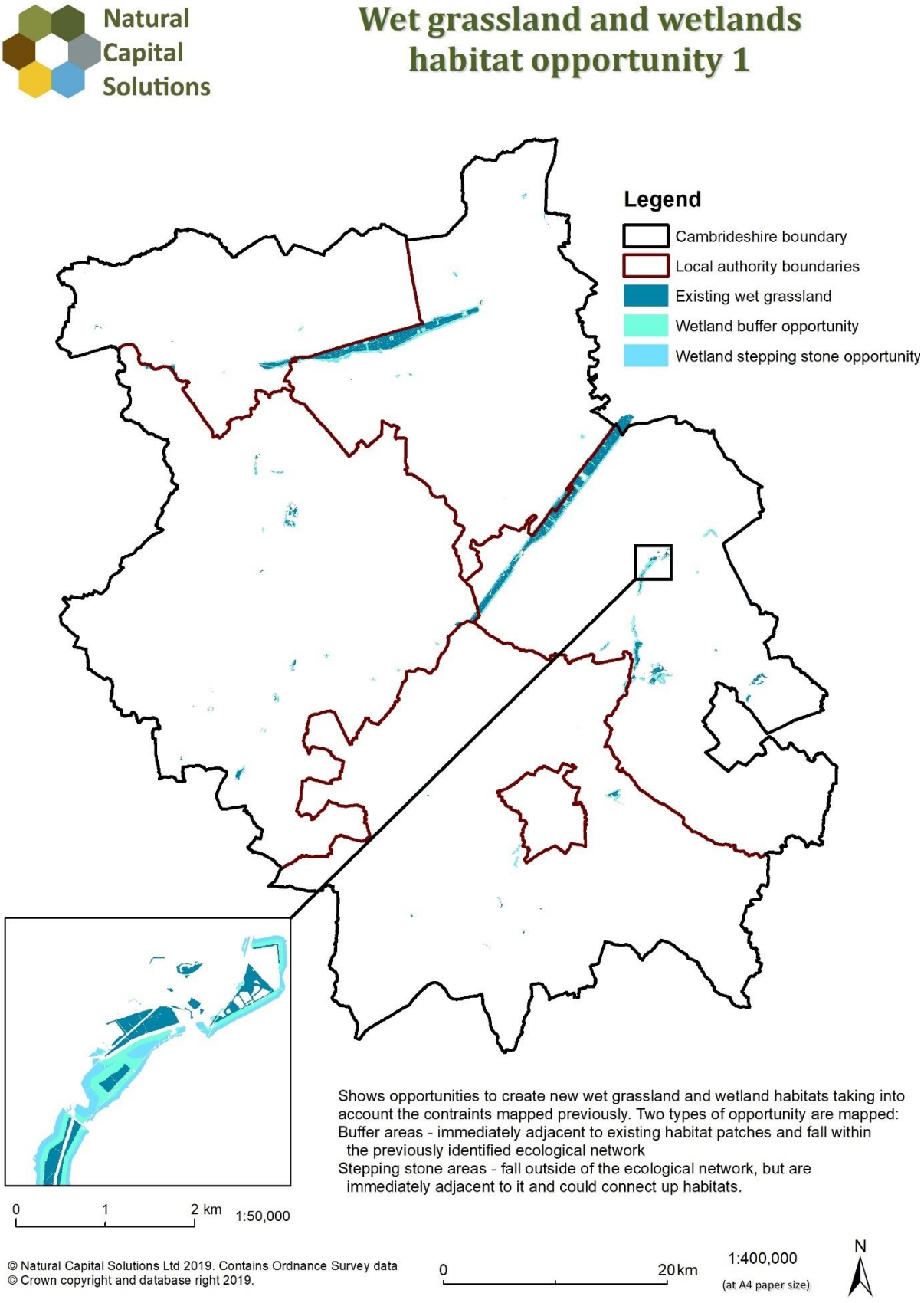
Map A1: Landscape permeability for typical wet grassland and wetland species across Cambridgeshire.



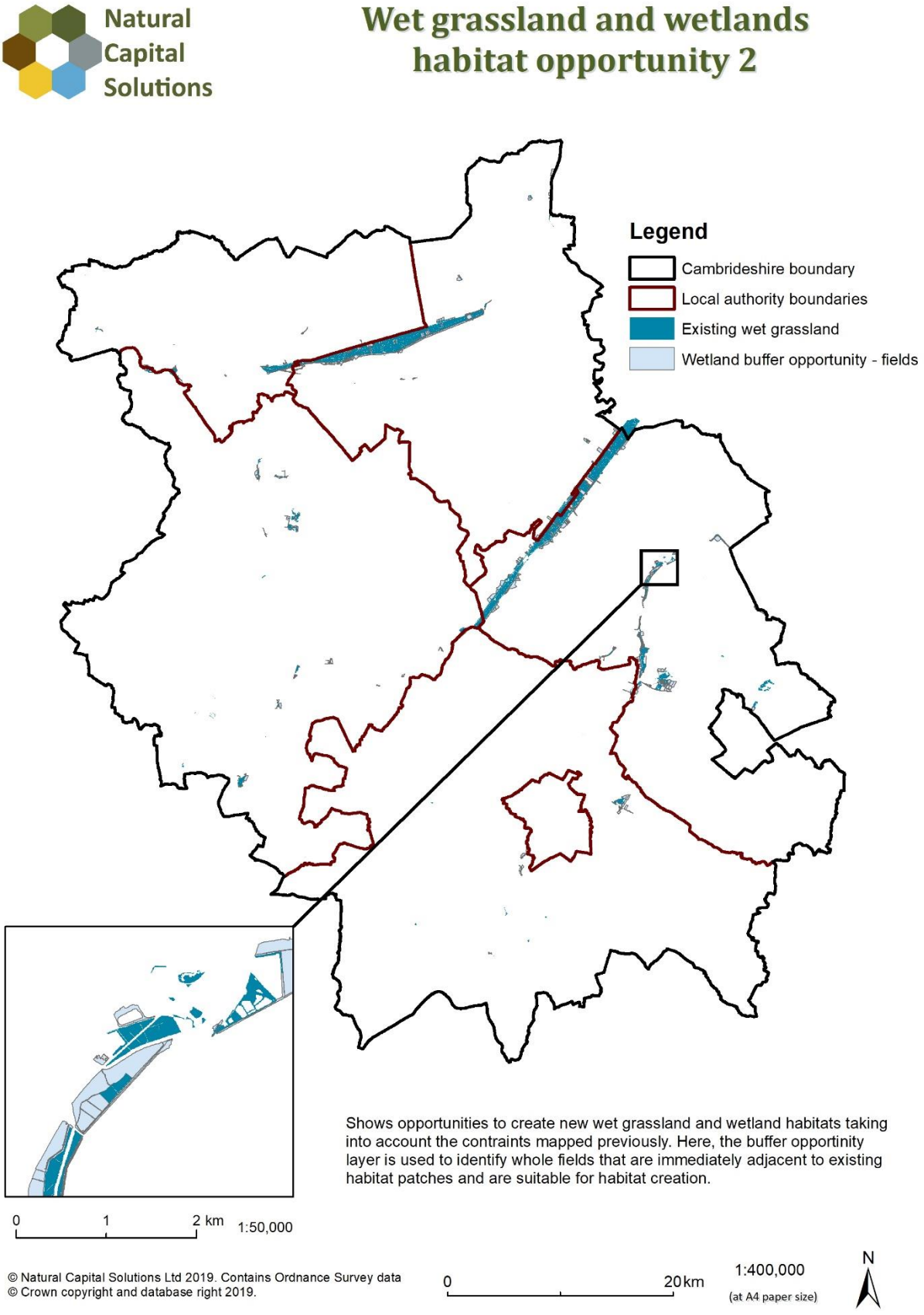
Map A2: Habitat network for wet grassland and wetlands across Cambridgeshire.



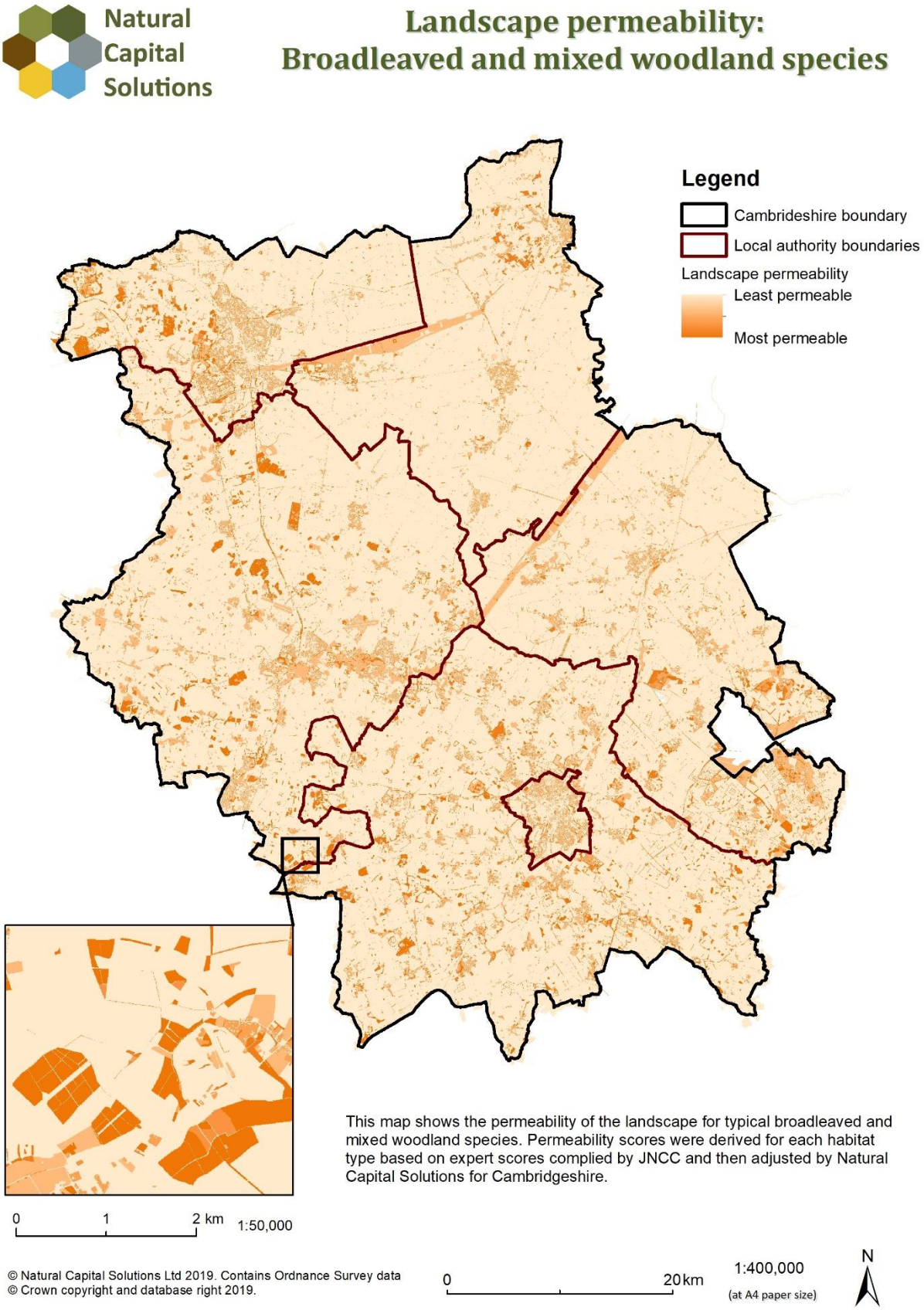
Map A3: Buffer and stepping-stone biodiversity opportunity areas for wet grassland and wetlands across Cambridgeshire.



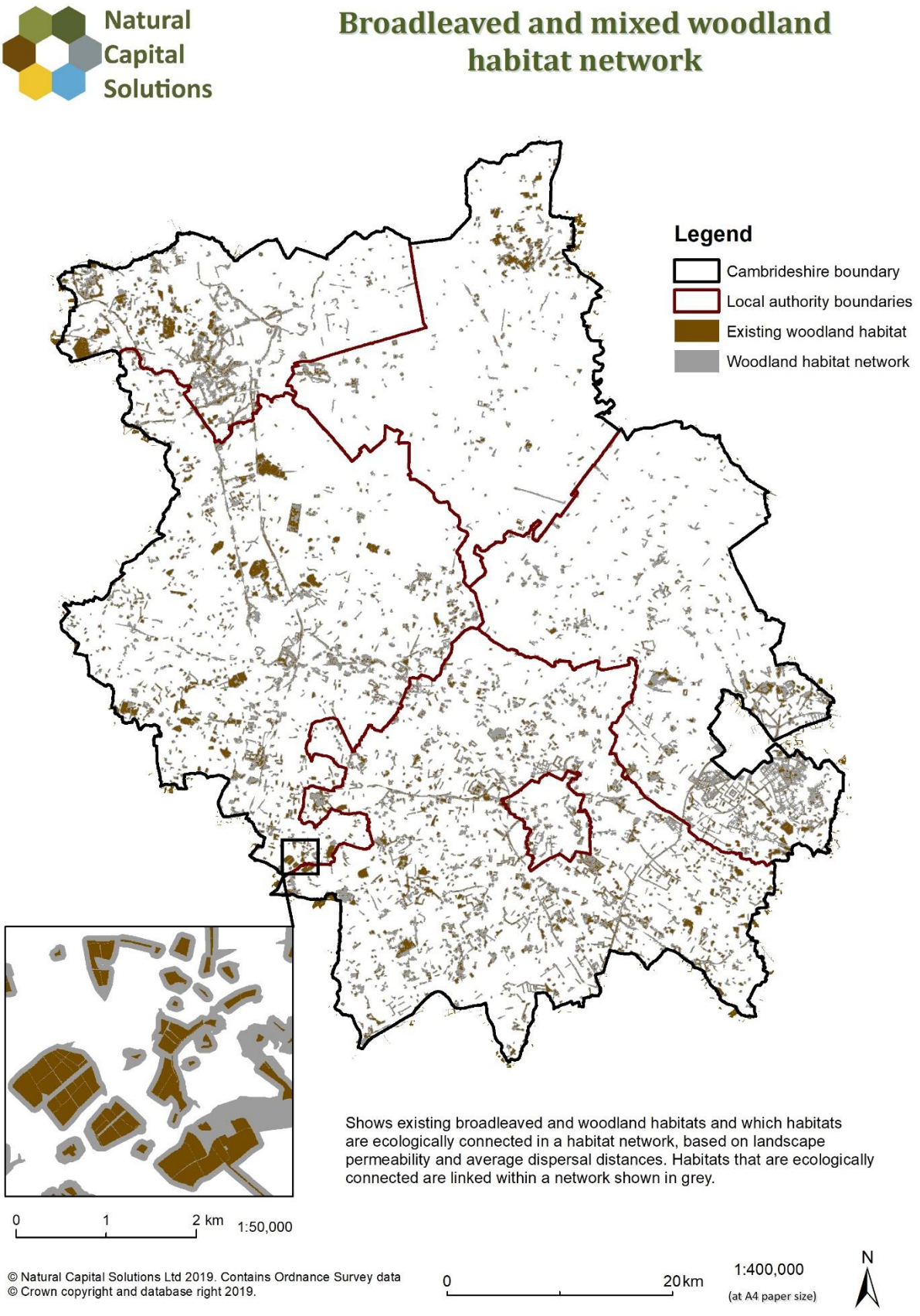
Map A4: Field scale biodiversity opportunity areas for wet grassland and wetlands across Cambridgeshire



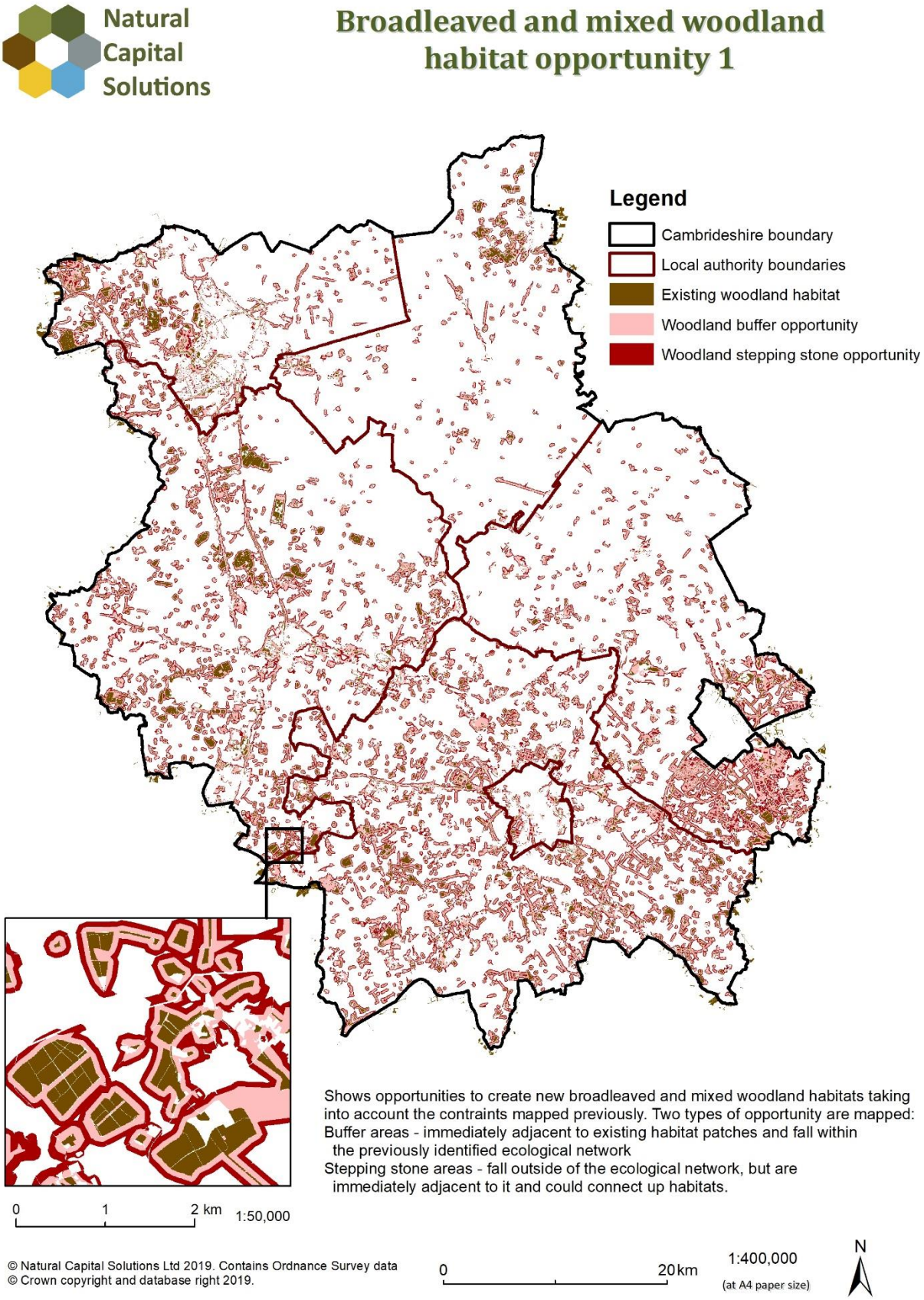
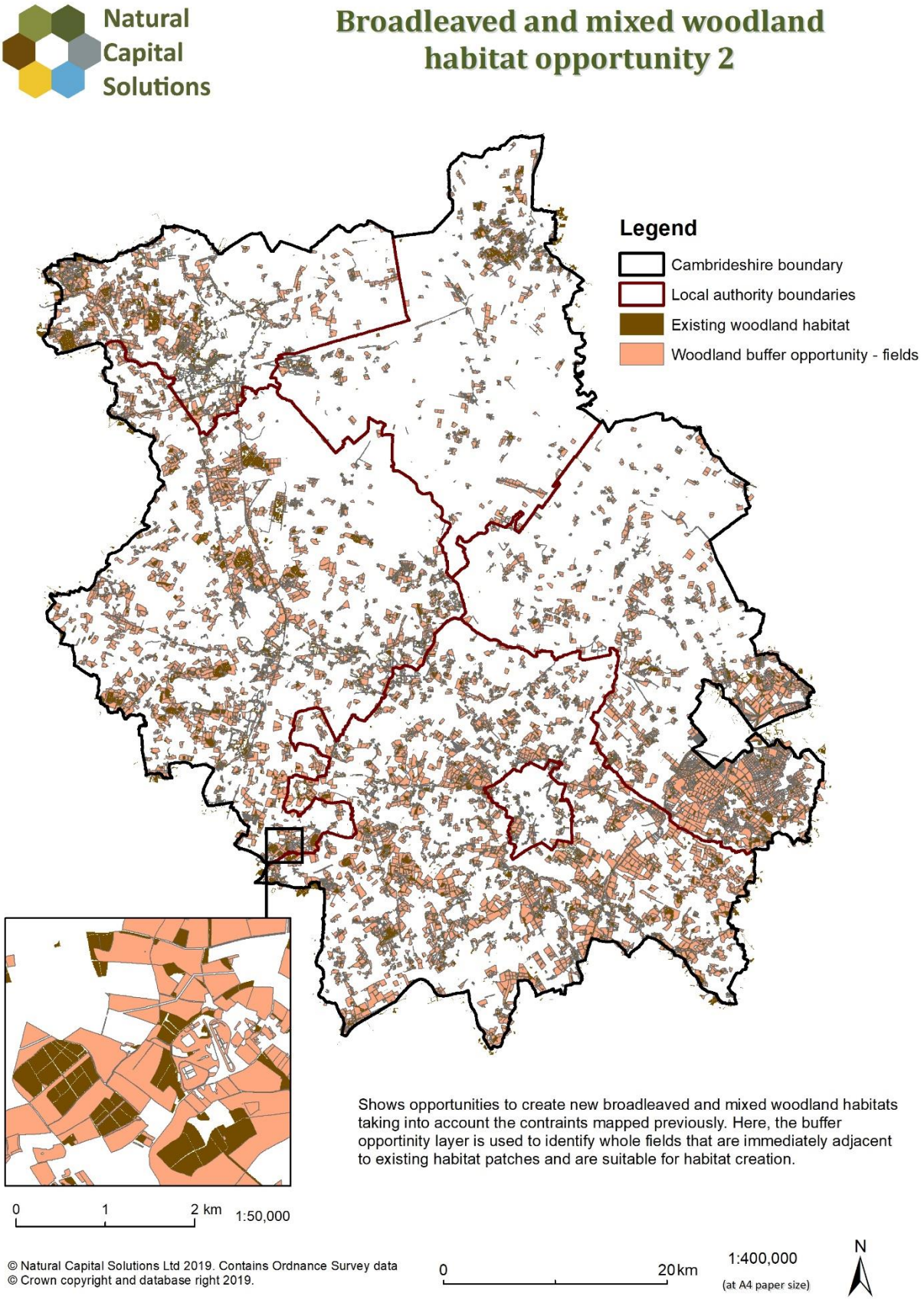
Map A5: Landscape permeability for typical broadleaved and mixed woodland species across Cambridgeshire.



Map A6: Habitat network for broadleaved and mixed woodlands across Cambridgeshire



Map A7: Buffer and stepping-stone biodiversity opportunity areas for broadleaved and mixed woodlands across Cambridgeshire



Map A8: Field scale biodiversity opportunity areas for broadleaved and mixed woodlands across Cambridegeshire