Mapping natural capital, ecosystem services and opportunities for habitat creation in Milton Keynes

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Executive Summary

This report describes a project to produce a detailed natural capital (habitat) basemap for Milton Keynes Unitary Authority, 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 the Buckinghamshire & Milton Keynes Natural Environment Partnership.

The first part of the project was to produce a detailed map of the current habitats present across Milton Keynes. 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 30,858 ha or 309 km^2 and contained approximately 450,000 polygons, each of which was classified to an appropriate habitat type. The LA area is dominated by the urban area of MK in the southern half of the area, with the north dominated by agriculture land. However, despite the large size of MK, built-up areas and infrastructure (roads, railways, pavements) make up only 13.1% of the total land area, with gardens comprising another 6.8% and amenity grassland 9.2%. The dominant habitats by area are cultivated land and improved grassland, together making up 55% of the area (14,900 ha). Woodland and scrub habitats take up 8.9% (2,750 ha), semi-natural and marshy grasslands make up 2.7%, while water makes up 2.0% of the area.

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 (soil erosion) regulation, food production, timber production, and accessible nature. The key importance of woodland for the provision of a range of services was highlighted.

Maps showing the demand for air purification, noise regulation, local climate regulation and accessible nature were also produced. Demand was focussed on the urban centre of Milton Keynes, which dominates the southern part of the study area. The capacity to provide these services is often quite high in urban MK, where woodland and other semi-natural habitats are integrated into the urban areas, and these areas should be protected and expanded, even if not important for biodiversity.

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

Semi-natural grasslands are present in a number of locations across the study area, although many patches remain isolated and disconnected. As such, habitat creation should aim to connect these disconnected grassland patches. Broadleaved and mixed woodland opportunities exist throughout the study area, although with particular density in the northern half of the study area where habitat creation is unconstrained by urban areas. Field-scale habitat creation in the northern part of the study area could increase the connections between woodland patches, or connect more isolated fragments to create a more resilient network. In urban MK, although the scale of opportunities is generally smaller, there are a large number of opportunities to expand and connect the existing woodland patches. For wet grassland and wetlands, opportunities are much more limited and are mostly focussed on expanding existing habitat patches along the River Great Ouse floodplain.

Opportunities to reduce surface water runoff (water flow) are present over much of the Milton Keynes area, with a large number of smaller opportunity areas identified in the urban area of MK, and fewer

but larger areas identified in the rural north, relating to areas of arable fields on sloping land. In contrast, the vast majority of opportunities to reduce soil erosion and 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 the urban centres of Milton Keynes town 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 key neighbourhoods, 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. When considering opening up access to existing sites, the habitats along the floodplain of the River Great Ouse, the Ouzel Valley as it passes through MK, and the woodland areas around Woburn were identified as presenting the best opportunities.

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 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 a Local Nature Recovery Strategy, 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 & Milton Keynes Natural Environment Partnership has identified the need for an assessment of Milton Keynes natural capital, the benefits that this provides and the opportunities to enhance it, particularly in light of the area's economic and social development ambitions. Natural capital refers to the stock of assets provided by the natural environment with the capacity to produce goods and services that are of value to people (NCC 2014)[1], often classified into provisioning, regulating and cultural ecosystem services (EEA, 2016[2], Hein et al., 2016[3]). Natural capital comprises land and minerals, fresh, tidal and marine waters, air, species and ecological systems, together with supporting natural processes and functions[3]. In many respects, it supports all forms of other capital on which human systems depend, whether man-made, human or social. However, many of the outputs produced by natural capital, such as the regulation of flooding and atmospheric gases by woodlands, are not included in the decisions of individuals or organisations. This is because they often involve non-priced public goods that are not traded in the market place and are not subject to formal property rights and entitlements (TEEB, 2010[4]). Elements of natural capital are therefore liable to be overused, degraded, depleted and eventually lost, with consequences for long term welfare and the sustainability of economic systems. There is now much greater awareness of the role of natural capital in the design and achievement of economic and social development strategies, with strong links to business and enterprise[5]. Furthermore, the central role of natural capital in delivering quality of place is being increasingly recognised.

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

Natural capital is also becoming embedded across multiple policy domains, including the mandatory requirement for biodiversity net gain for all new developments under the Town and Country Planning Act, as set out in the Environment Bill. There is further ambition, as expressed in the Government's 25 Year Plan, 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. At the same time, the recent Agriculture Act paves the way for a new Environmental Land Management Scheme (ELMs), with a

[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.

central tenet of farmers and land managers being paid public money for public 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 & Milton Keynes Natural Environment Partnership has 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 area and the demand for those benefits, where possible.
3. Create habitat opportunity maps for biodiversity enhancement and a range of ecosystem services. These maps highlight the best and most suitable habitat creation areas by considering the local ecology, the best opportunities for enhancing a range of benefits, and any constraints (e.g. infrastructure and built-up areas).

This project has proceeded in parallel with work to complete an identical assessment for Buckinghamshire, funded by Buckinghamshire Council.

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).

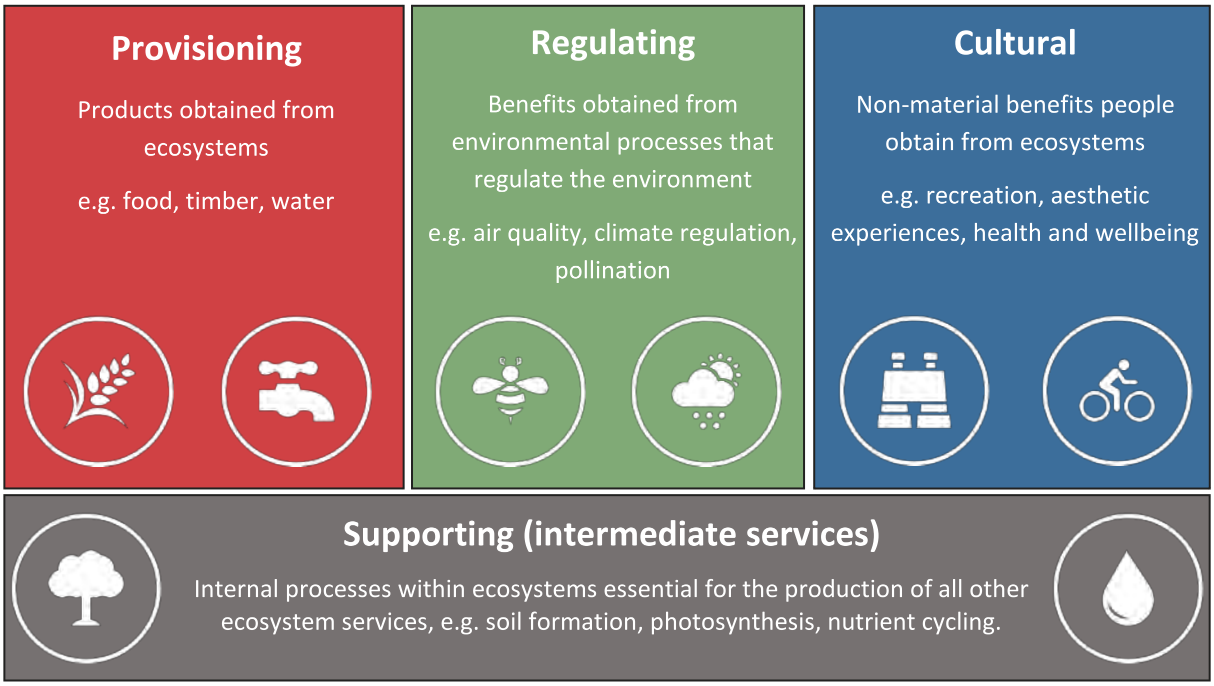


Figure 1 Key types of ecosystem services (based on MA 2005 and EEA 2016).

Much work is progressing on how to deliver the natural capital and ecosystem services approach on the ground and how to use it to inform and influence management and decision-making. One of the most important steps is to recognise and quantify ecosystem service delivery (the physical flow of services derived from natural capital). Additional insight can be gained by taking a spatial perspective on the variation in ecosystem service supply and demand across a study area using a Geographic Information System (GIS). Maps are able to highlight hotspots and cold-spots of ecosystem service delivery, and highlight important spatial patterns that provide much additional detail. They 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 objectively determine the best areas to create habitat to increase the supply of each particular ecosystem service 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 Milton Keynes. It also highlights the most important habitats for biodiversity and maps the sites that have received an 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 ten 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 Milton Keynes. We consider three broad habitats – broadleaved and mixed woodland, semi-natural grassland, 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 it 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 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 and Milton Keynes Environmental Records Centre and Milton Keynes Council.

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 Milton Keynes. 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 are 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 an area of 30,858 ha or 309 km^2 and contained approximately 450,000 polygons, each of which was classified to an appropriate habitat type.

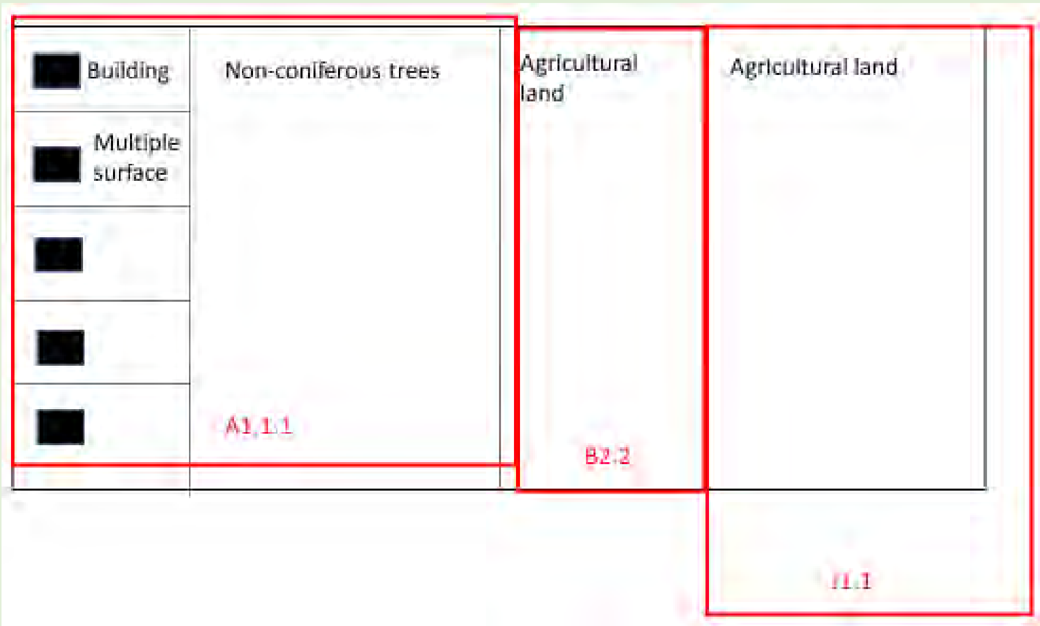
Note that the basemap provides the best approximation of habitat types that can be achieved based on available data. It was checked by experts at the Buckinghamshire and Milton Keynes Environmental Records Centre but has not been ground-truthed further and will inevitably contain errors. A particular 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. However, not all combinations of habitats could be accommodated. It was also difficult to classify areas for which there was a mismatch between data sources, or rapid land-use change had occurred.

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 layers in the figure below) 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 (A1.1.1) overlaid houses, gardens and a polygon identified as non-coniferous trees in MasterMap (red polygon on the 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 certainty.



2.2 Broad habitats

Figure 2 (overleaf) shows the distribution of broad habitat types across Milton Keynes. The area and percentage cover of broad habitats presented in Table 1 provide a little more detail. Although the Milton Keynes LA area is dominated by the town of MK, built-up areas and infrastructure (roads, railways, pavements) make up only 13.1% of the total land area, with gardens comprising another 6.8% and amenity grassland 9.2%. The dominant habitats by area are cultivated land and improved grassland, together making up 55% of the area (14,900 ha), although this is less than surrounding counties. Woodland and scrub habitats take up 8.9% (2,750 ha), semi-natural and marshy grasslands make up 2.7%, while water makes up 2.0% of the area.

Table 1 Area and percentage cover of broad habitat types across Milton Keynes

Broad habitat	Area (Ha)	% cover
Cultivated / disturbed land	12,027	39.0
Uncertain agriculture	38	0.1
Improved grassland	4,979	16.1
Amenity grassland	2,850	9.2
Semi-natural grassland	735	2.4
Marshy grassland	90	0.3
Fen, marsh and swamp	14	0.05
Scrub	82	0.3
Trees / Parkland	465	1.5
Broadleaved woodland	1,608	5.2
Coniferous woodland	300	1.0
Mixed woodland	293	0.9
Hedgerows	132	0.4
Water	608	2.0
Built-up areas	2,261	7.3
Infrastructure	1,787	5.8
Garden	2,112	6.8
Rock, exposure and waste	100	0.3
Unclassified (land currently under development)	207	0.7
Mixed / other / uncertain	169	0.5
TOTAL	**30,858**	**100.0**

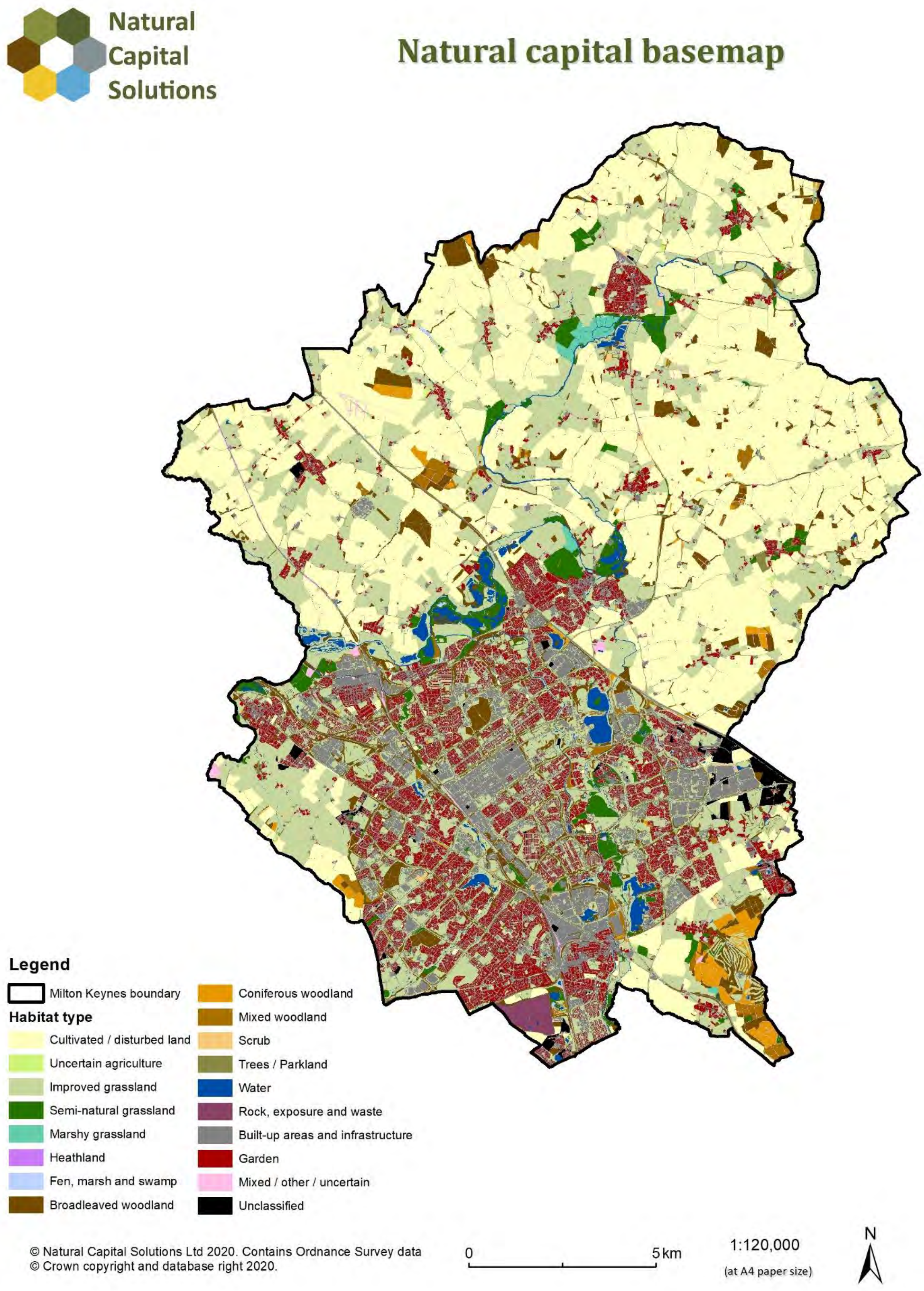


Figure 2 Broad habitats across Milton Keynes.

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 2,411 ha, which represents 7.8% of Milton Keynes, contain these high-quality habitats. The greatest amounts are 1,608 ha of broadleaved woodland, 293 ha of mixed woodland and 371 ha of neutral grassland. However, this include all broadleaved and mixed woodland, some of which will not have been high quality. There are also 30 ha of calcareous grassland, 90 ha of floodplain grazing marsh and marshy grassland, and 14 ha of fen and swamp. 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. A number of Sites of Special Scientific Interest (SSSIs) occur adjacent to the Milton Keynes LA boundary, but only two sites occur within the boundary (Howe Park Wood and Oxley Mead), totalling 27.6 ha. No international designations, such as SACs or SPAs occur in the area. On the other hand, 31 Local Wildlife Sites and one Local Nature Reserve occur across the area, which represents 684 ha, or 2.2% of the total area. The total amount of land receiving some level of protection therefore amounts to 711 ha, or 2.3% of the total area of Milton Keynes. Note that a number of additional non-statutory schemes are used to show sites of local biological interest, such as Biological Notification Sites (not shown on Figure 4).

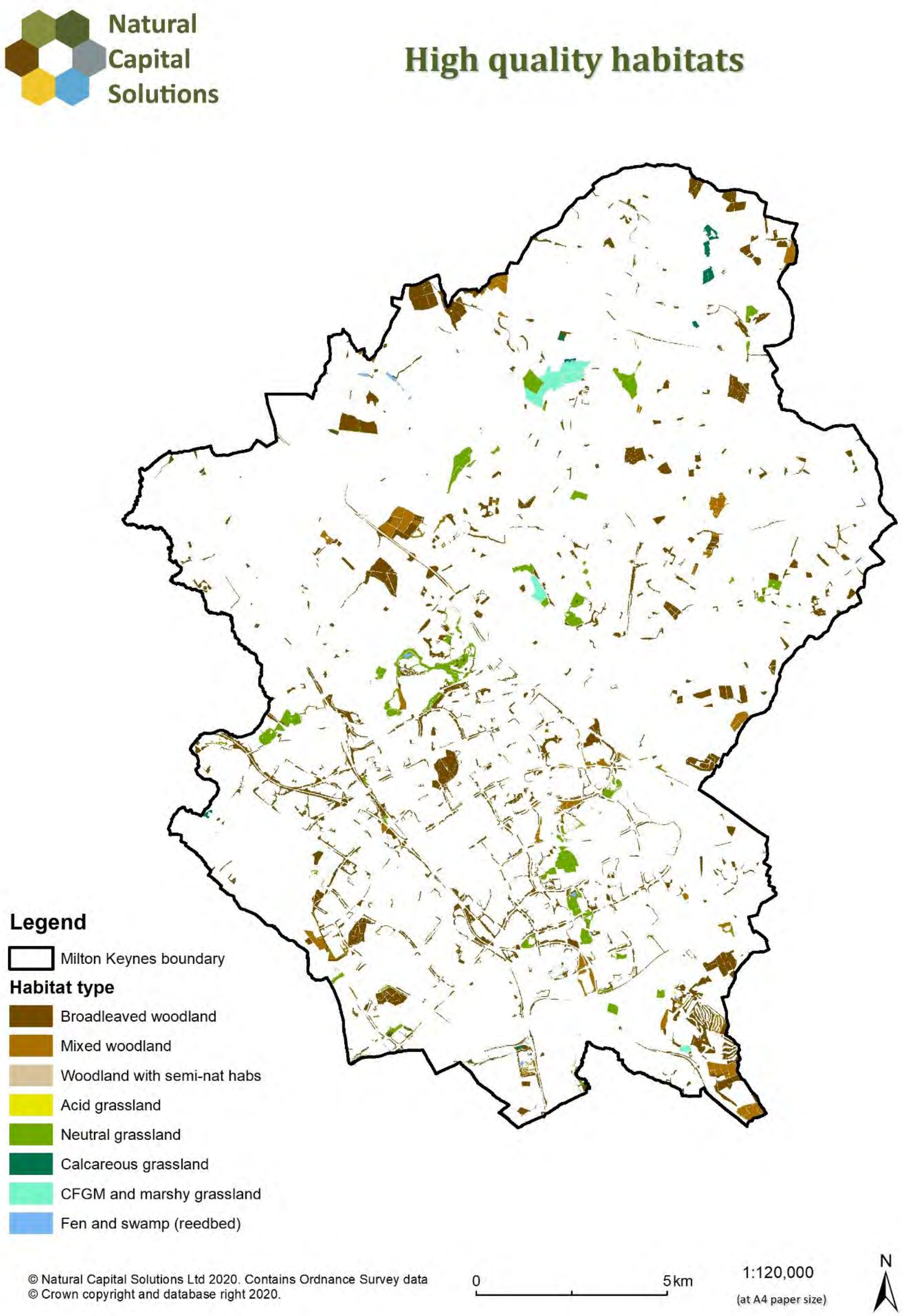


Figure 3 High-quality habitat types identified from the basemap.

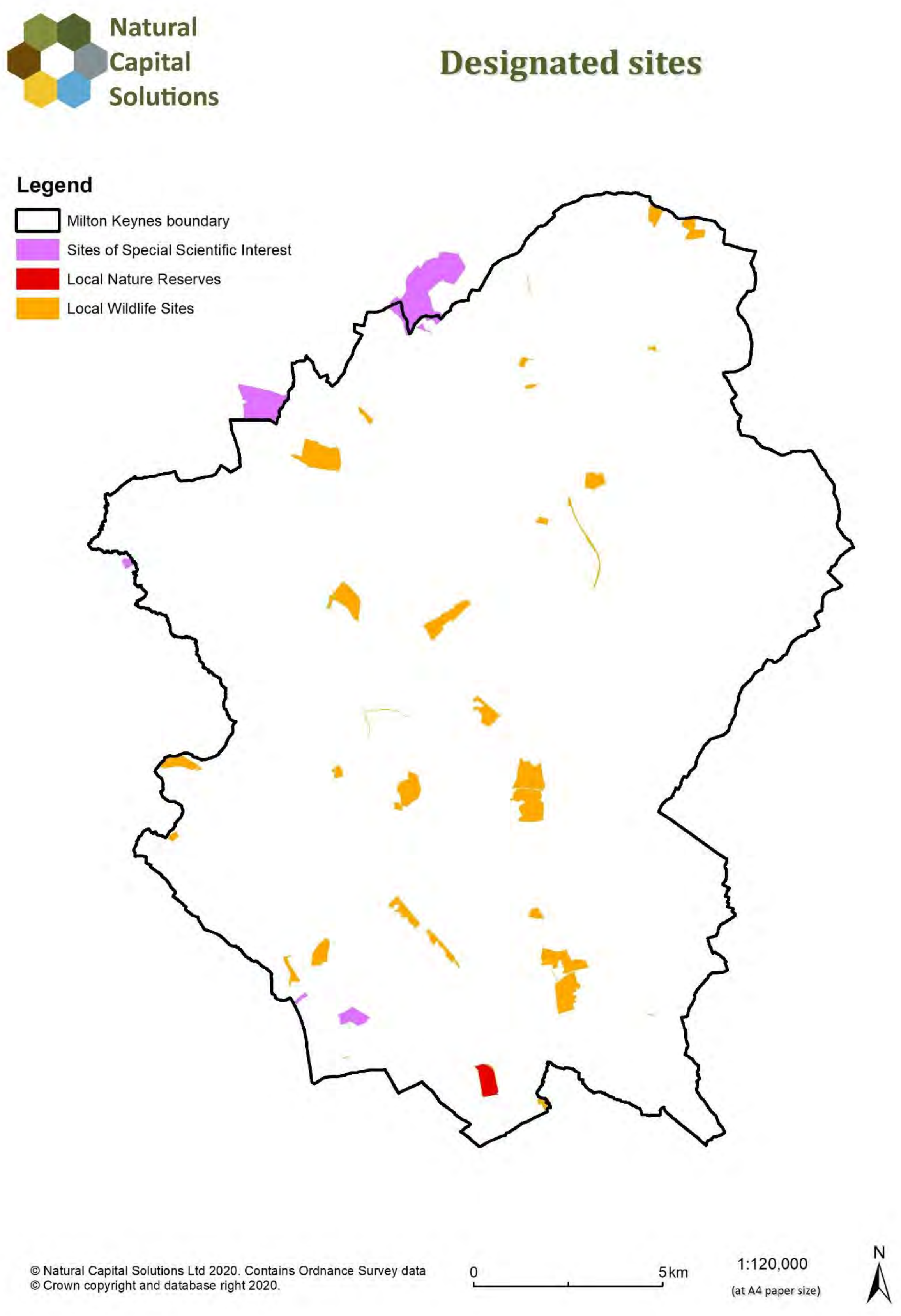


Figure 4 National and locally designated sites for nature conservation.

3. Modelling and mapping ecosystem services (physical flows)

Once a detailed habitat basemap had been created for Milton Keynes, 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
- Food production
- Timber production
- Accessible nature

The list of services assessed was considered to capture the most important services provided by the natural environment, supported by expert knowledge from within the stakeholder group. 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 the 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 are 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 valuable 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 are 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 significant changes in carbon storage, as can restoration of degraded habitats. Note that carbon storage measures the stock of carbon in the natural environment. In contrast, 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 the 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 every 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 Milton Keynes

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 areas are well dispersed across the area. However, most green spaces in the region support some level of carbon storage, with much lower levels in the urban centres of MK, which are dominated by buildings and sealed surfaces.

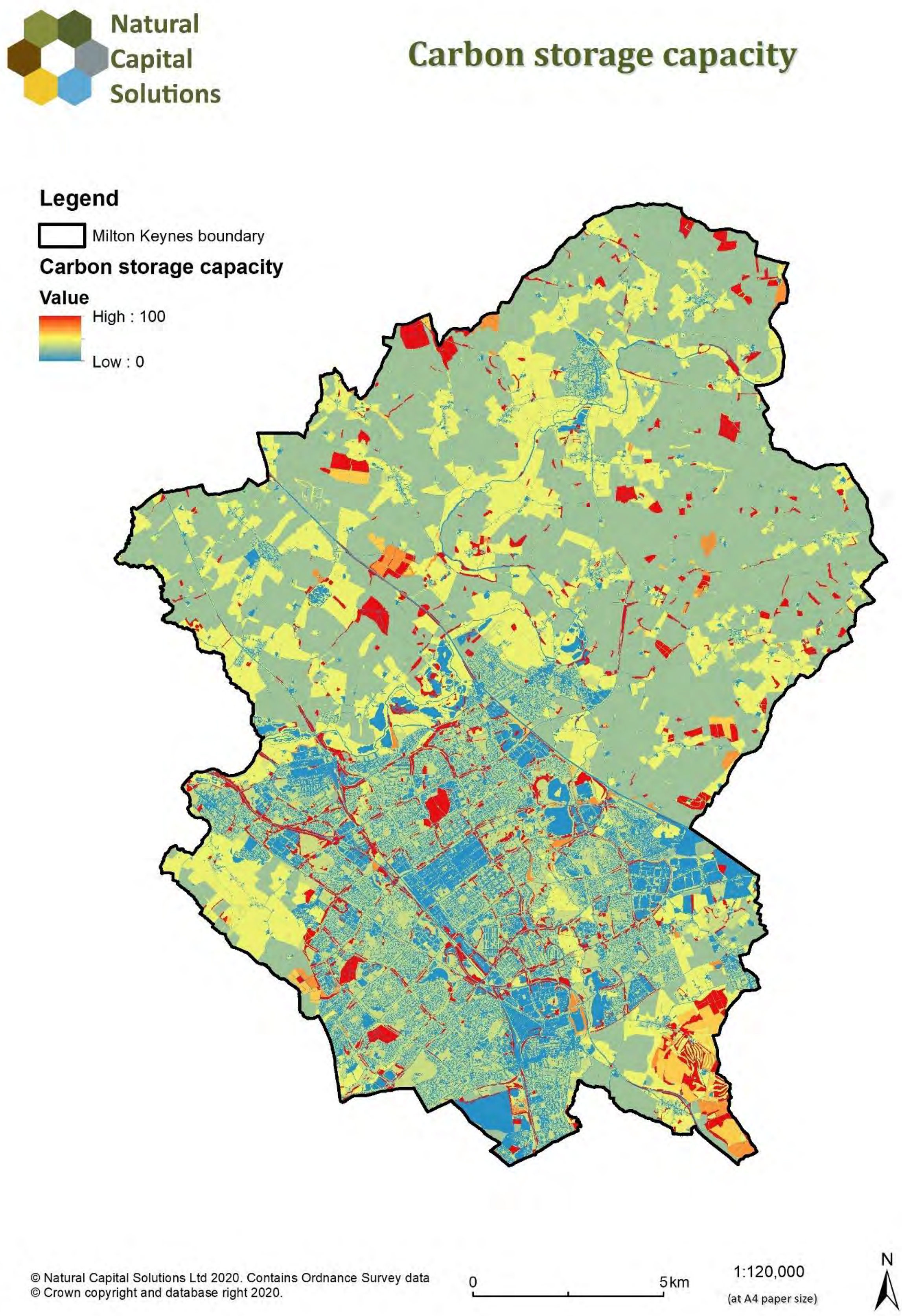


Figure 5 Carbon storage capacity across Milton Keynes.

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 Milton Keynes were derived from Forest Research's Ecological Site Classification tool (http://www.forestdss.org.uk/geoforestdss/). The 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 Milton Keynes

The baseline carbon sequestration map (Figure 6) shows areas of high carbon sequestration (in red) are present throughout Milton Keynes. These are areas of mostly broadleaved woodland. There is a large area of high to moderate (red to orange) carbon sequestration in the Woburn area to the south east of MK. 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.

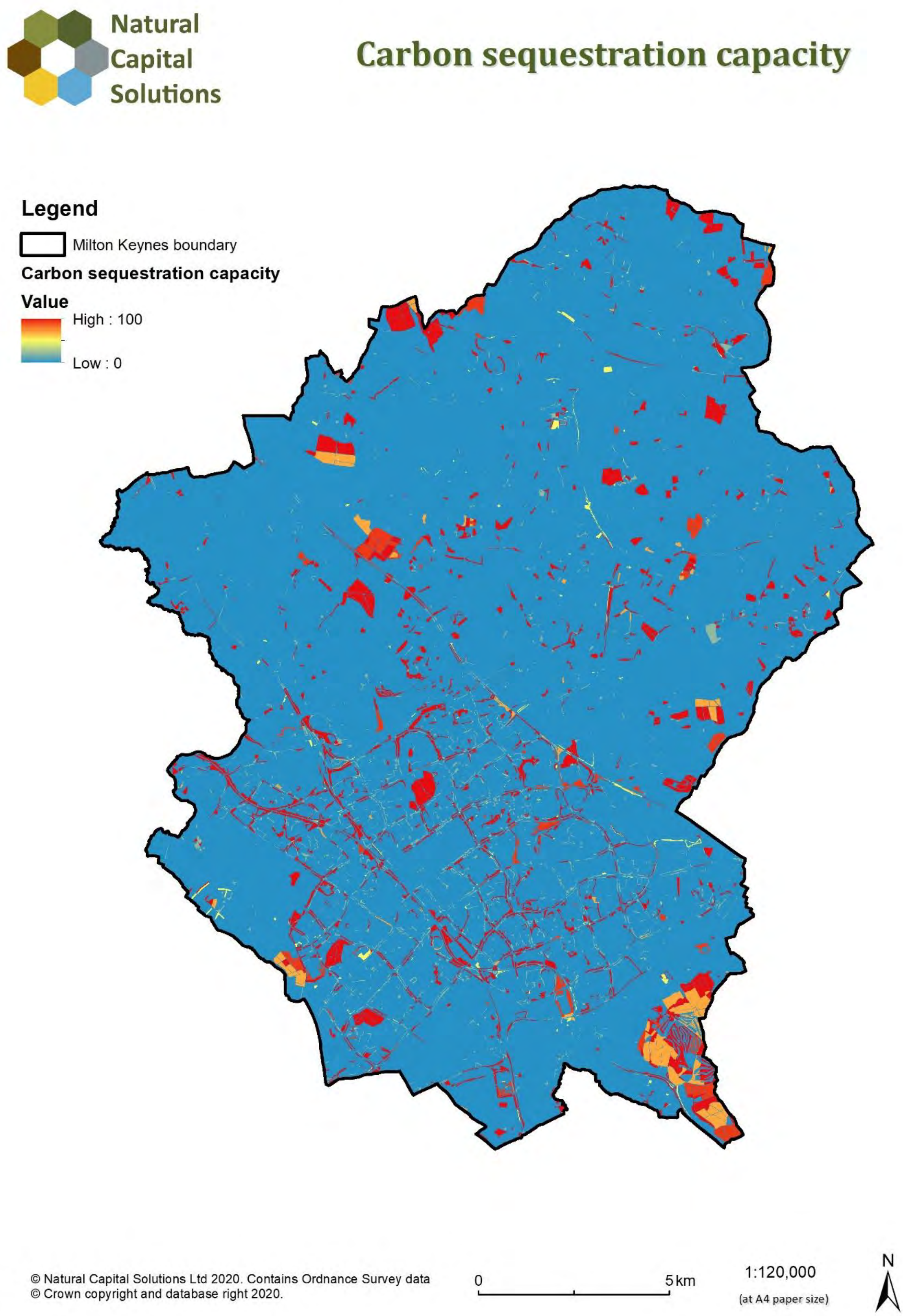


Figure 6 Carbon sequestration capacity across Milton Keynes.

3.3 Air purification capacity (air quality regulation)

What is it and why is it important?

According to the Public Health England, air pollution is the biggest environmental threat to health in the UK, with between 28,000 and 36,000 deaths a year attributed to long-term exposure, with the greatest threats from particulate matter ($PM_{2.5}$) and nitrous oxides (NO_x). Even small changes can make a big difference, just a 1µg/m^3 reduction in $PM_{2.5}$ concentrations could prevent 50,000 new cases of coronary heart disease and 9,000 new cases of asthma by 2035[8]. Air pollution also contributes to climate change, reduces crop yields, and damages habitats and 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 $PM_{2.5}$) 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 modified version of an 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 every 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 the prevailing wind direction.

The final capacity score was calculated for every 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 with the highest capacity to trap airborne pollutants and ameliorate air pollution.

Results for Milton Keynes

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 are present across Milton Keynes, with a large area of high air pollution amelioration capacity in the Woburn area.

[8] Public Health England (2018) Estimation of costs to the NHS and social care due to the health impacts of air pollution. Crown Copyright.

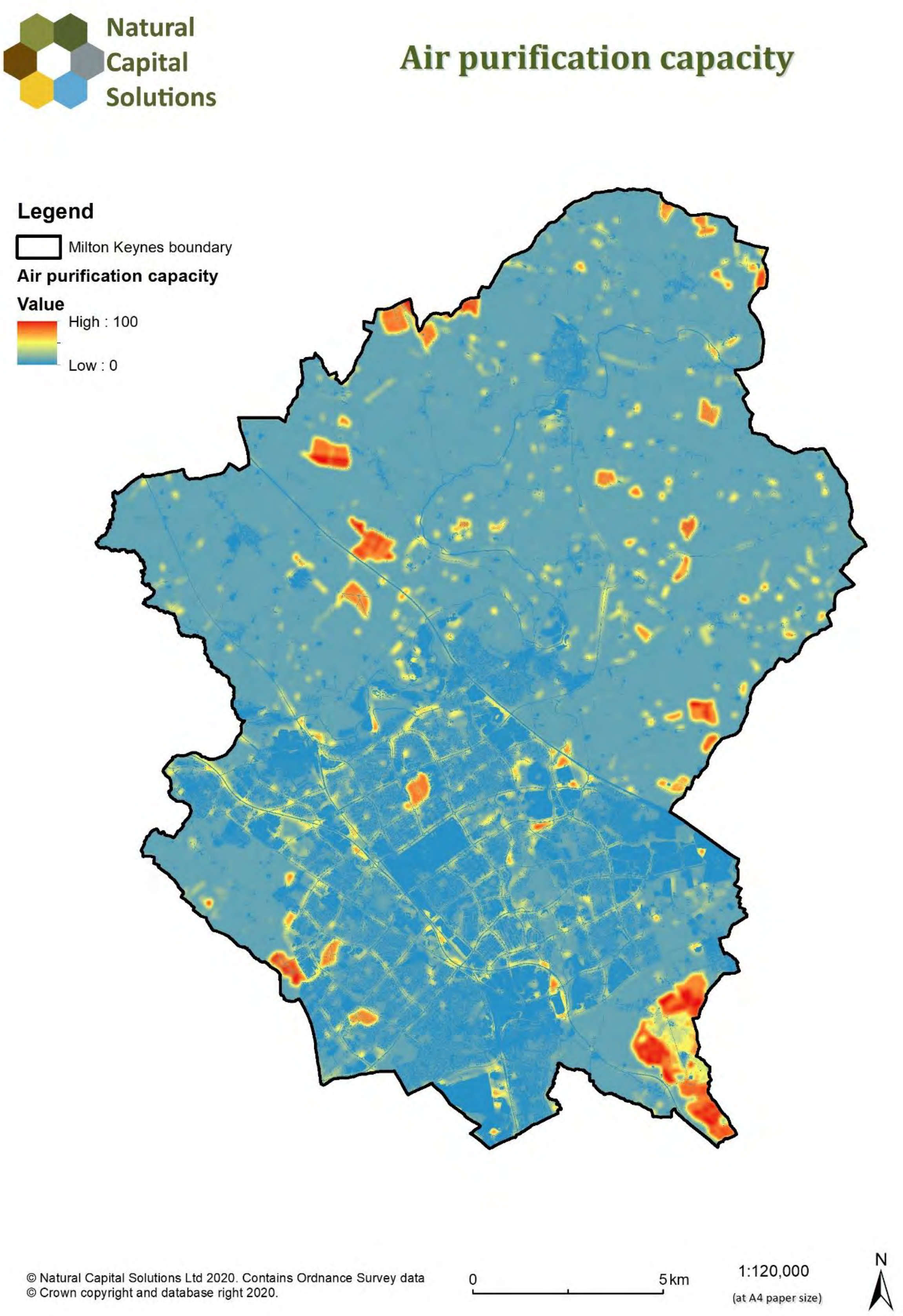


Figure 7 Air purification capacity across Milton Keynes.

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 the 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 Milton Keynes

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 a major pollution source. Where these main roads pass through built-up areas, there is increased demand for air purification. In Figure 8, the areas of highest demand are centred on a number of neighbourhoods within MK and Bletchley and the road network passing through them. The urban pattern, with large greenspace corridors and distinct neighbourhoods, can be clearly discerned from the map. Outside of the main urban conurbation, demand is relatively low across the remainder of 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 some spatial disparity in air purification capacity and demand. Indeed, air purification demand is centred on built-up areas and infrastructure. Whereas air purification capacity is centred on areas of woodland, which are often located away from built-up areas and infrastructure. However, the benefits of the urban woodland patches can be seen in the capacity map and many of these occur in areas of high demand, so will be especially important for this ecosystem service. 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 a high capacity to absorb pollution and is also situated in locations likely to have a high demand for the service.

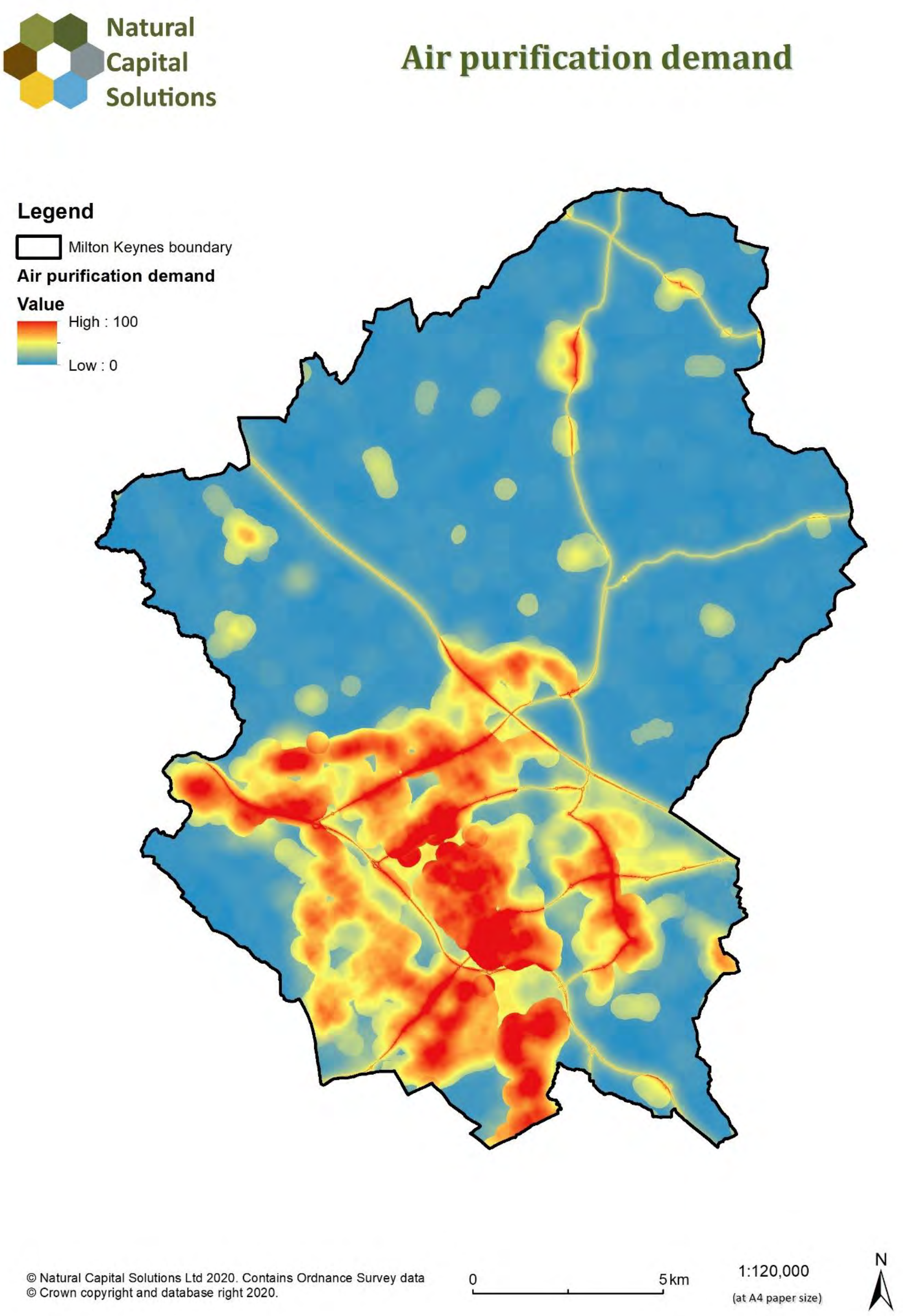


Figure 8 Air purification demand across Milton Keynes

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 health, wellbeing, productivity and the natural environment, and the World Health Organisation (WHO) has 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. However, the 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. Nevertheless, 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 every 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 Milton Keynes

This model is similar to the air purification capacity model. As such, woodland habitats are 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. Outside of these areas, noise regulation capacity is variable and there are patches of high capacity spread throughout the urban areas of MK.

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

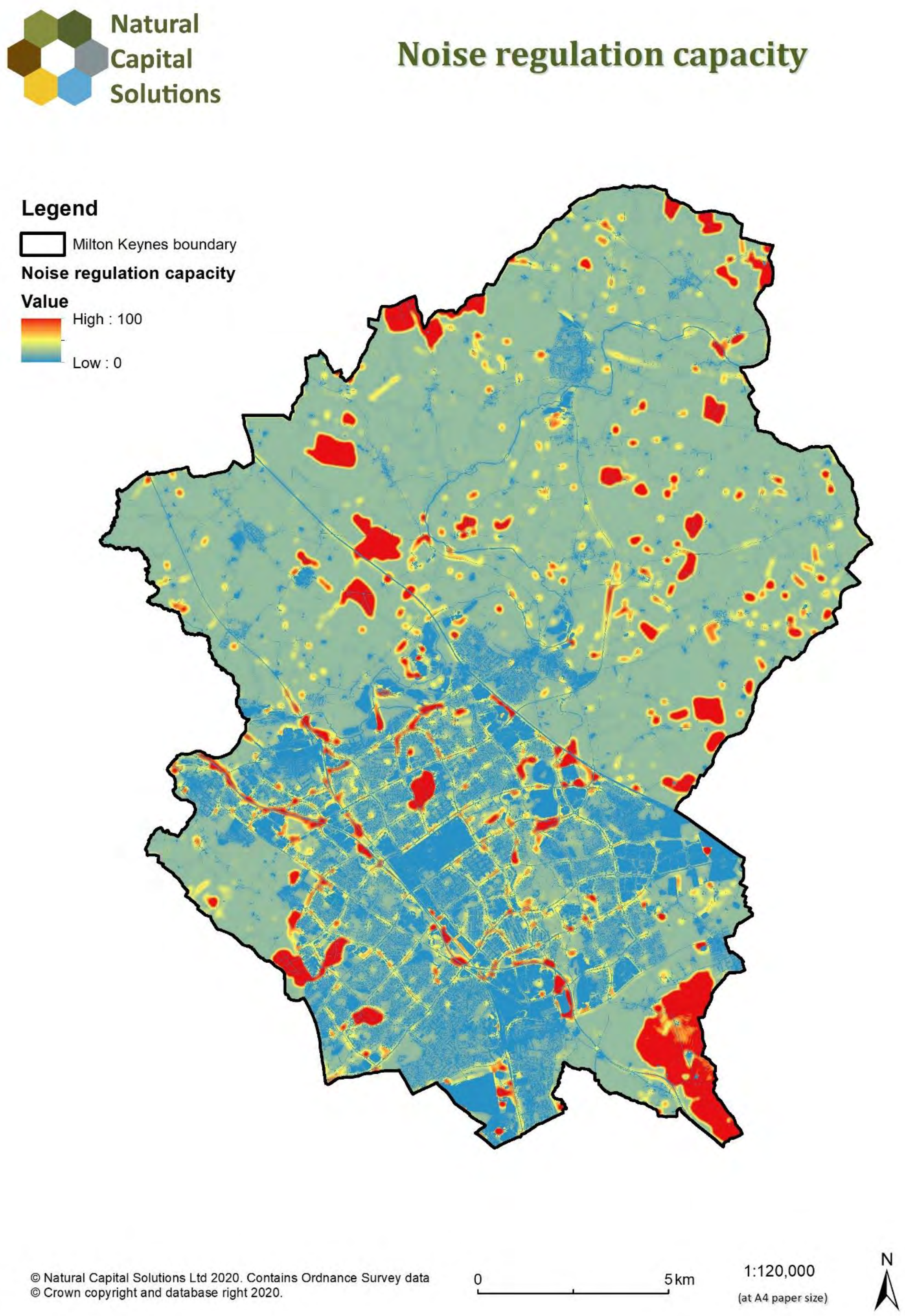


Figure 9 Noise regulation capacity across Milton Keynes.

3.6 Noise regulation demand

What is it and why is it important?

Noise regulation demand estimates the 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 Milton Keynes

Figure 10 shows noise regulation demand across the Milton Keynes 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 reduction from the main roads. Note the major impact of the A5 and other main roads running through the centre of the urban area. The spread of noise from the M1 is much greater, but there are far less houses close by.

Balancing supply and demand for noise regulation services

The pattern of supply and demand for this service is somewhat similar to that of air purification. Although larger woodland areas are concentrated in more rural areas, a large number of smaller woodland patches occur throughout the urban areas and these will be especially important, as demand is centred in these urban areas, as well as along the roads and railways. Planting thick tree belts close to main roads and other noise sources is the most effective mitigation.

Studies in many countries have shown that densely planted tree belts can reduce noise levels. Still, 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. However, any vegetation cover is more effective than artificial sealed surfaces.

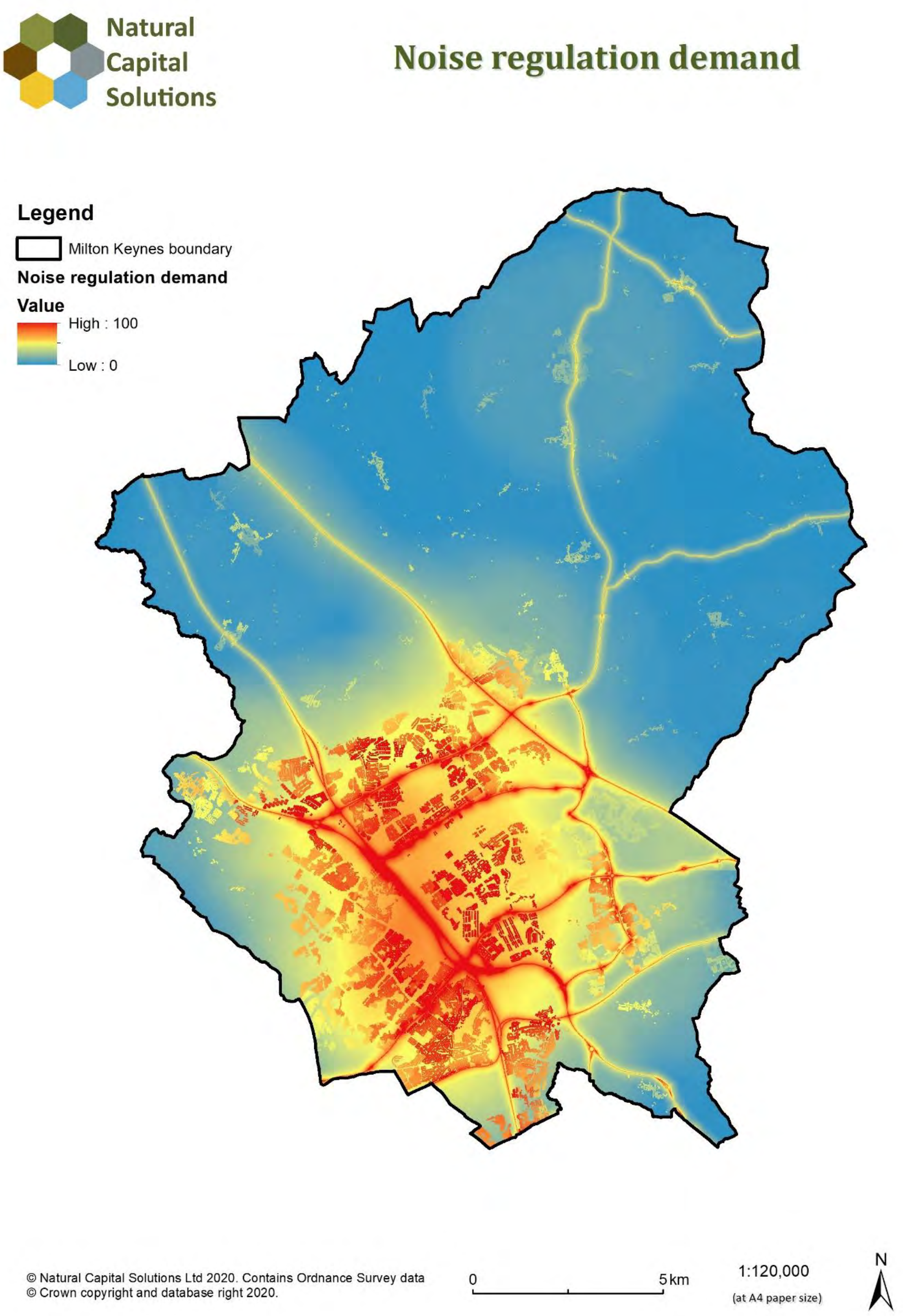


Figure 10 Noise regulation demand across Milton Keynes.

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 the 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, can have a moderating effect on the 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 every 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 every 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 with the highest capacity to regulate temperatures, keeping them cool in the summer and warmer in the winter.

Results for Milton Keynes

Figure 11 shows local climate regulation capacity across Milton Keynes. Large bodies of water, such as Willen Lake and Caldecote Lake, and larger areas of woodland such as Linford Wood and the woodlands in the Woburn area, provide the highest local climate regulation capacity in the region. These benefits can extend into adjacent built up areas. In much of the remaining region, away from woodland and water bodies, capacity is significantly lower.

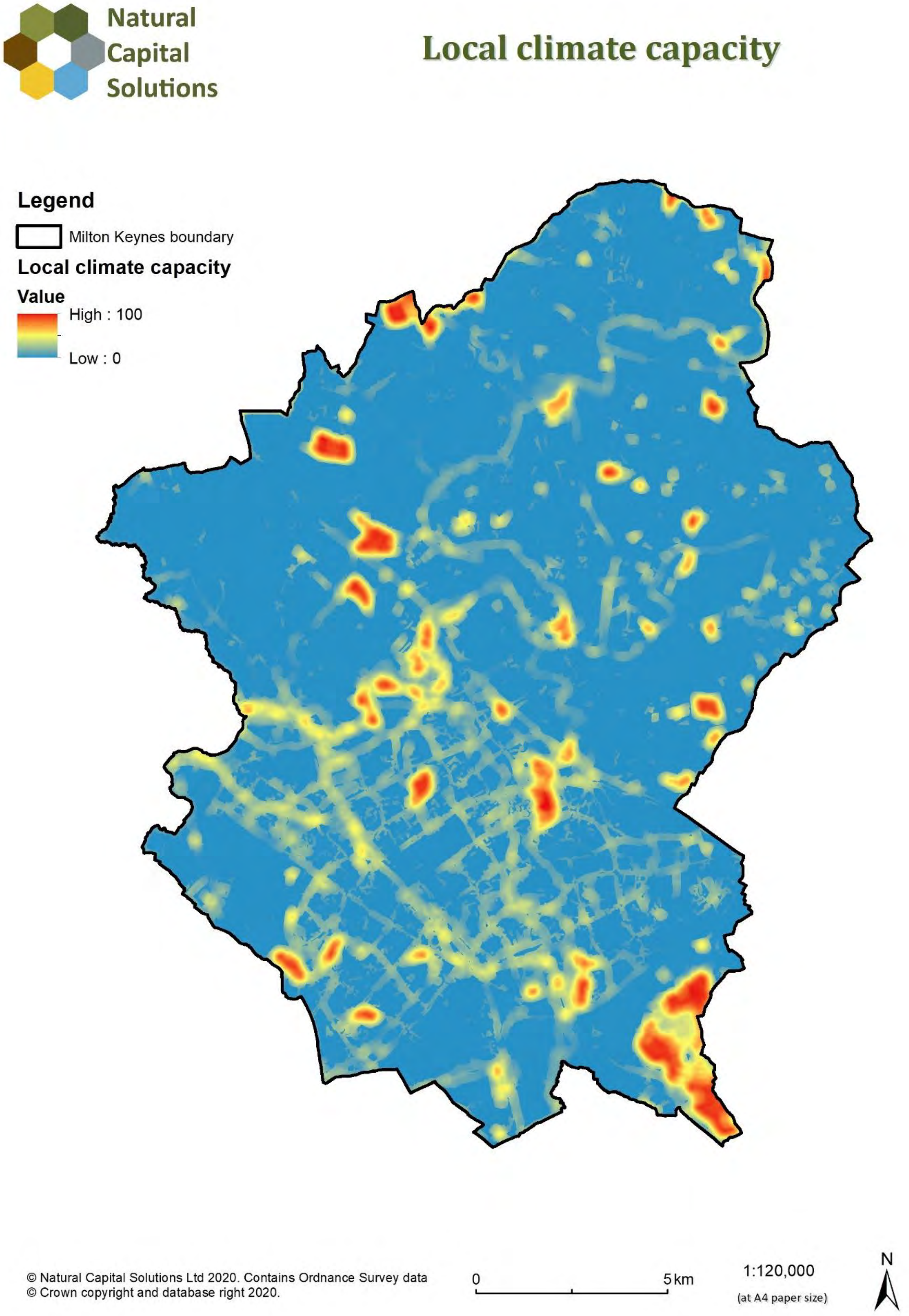


Figure 11 Local climate regulation capacity across Milton Keynes.

3.8 Local climate regulation demand

What is it and why is it important?

Local climate regulation demand estimates the 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 an adapted version of an EcoServ GIS model. 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 the 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 with the highest demand for local climate regulation as a service.

Results for Milton Keynes

Figure 12 shows local climate regulation demand across the Milton Keynes region. By removing areas of zero demand, it is immediately clear that demand is heavily clustered around urban areas, with the built up areas of MK, and especially Bletchley, Newport Pagnell, Stony Stratford and Wolverton providing the largest areas of high demand. Demand for local climate regulation is effectively zero outside of these centres. 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. Large water bodies, and large areas of woodland in or adjacent to towns are particularly beneficial to local climate regulating services as they can bring moderating conditions into the heart of these urban areas. Further promoting 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.

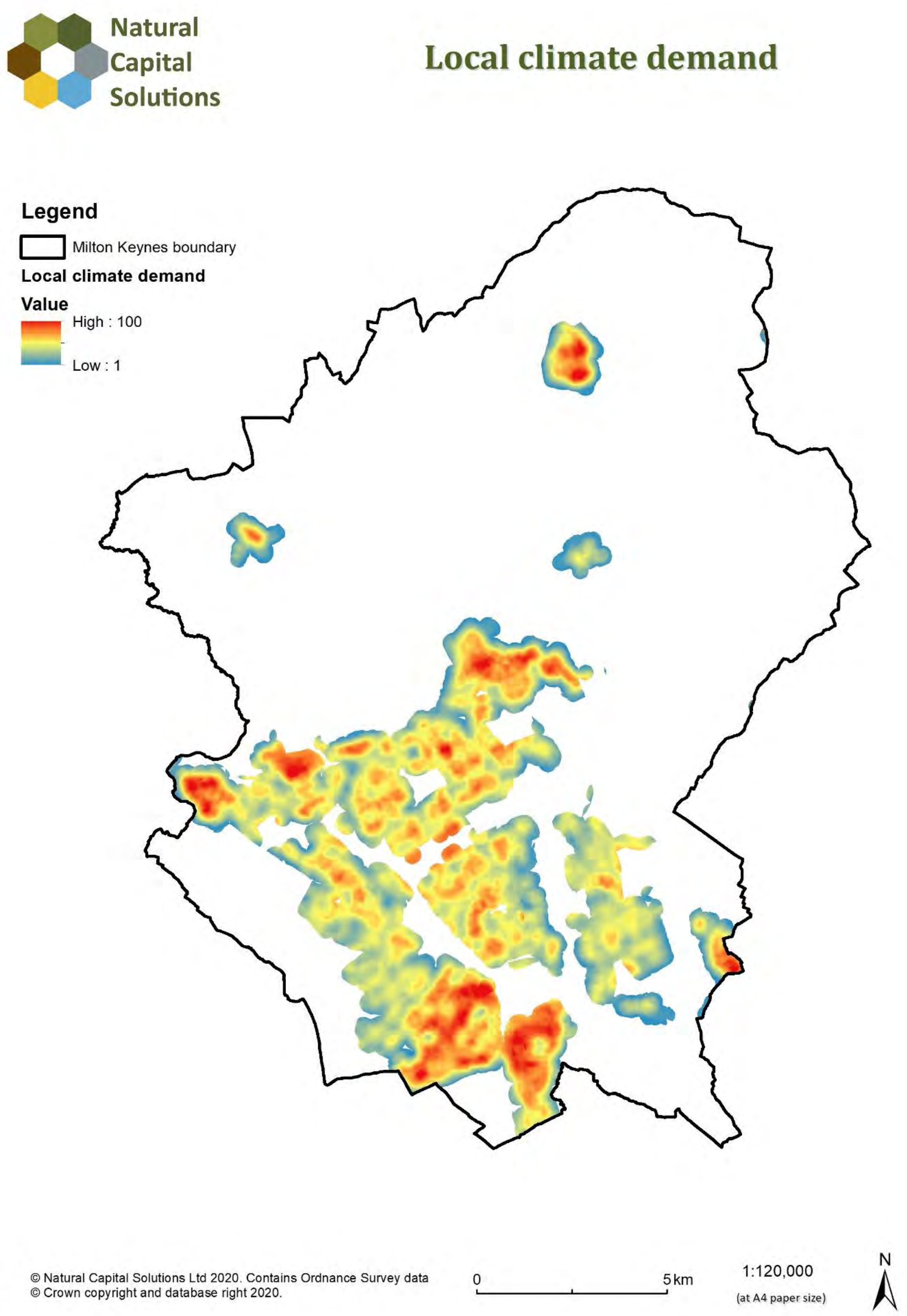


Figure 12 Local climate regulation demand across Milton Keynes. Areas with zero demand have been excluded to improve map legibility.

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 the 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 several 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 generally have high or low capacity and is not a hydrological model. High values (dark orange and red) indicate areas with the highest capacity to slow water runoff.

Results for Milton Keynes

The best locations for slowing water runoff are areas of woodland on flat land (red and orange areas in Figure 13). The worst areas (blue areas in Figure 13) are impermeable surface and slopes. Thus, the lowest areas of water flow capacity regulation in the study area are centred on built-up areas in MK, with the very worst area, being a landfill site south of Bletchley. In contrast, the highest areas of water flow capacity regulation in the study area are found within the woodlands, which are generally on gently sloping ground.

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.

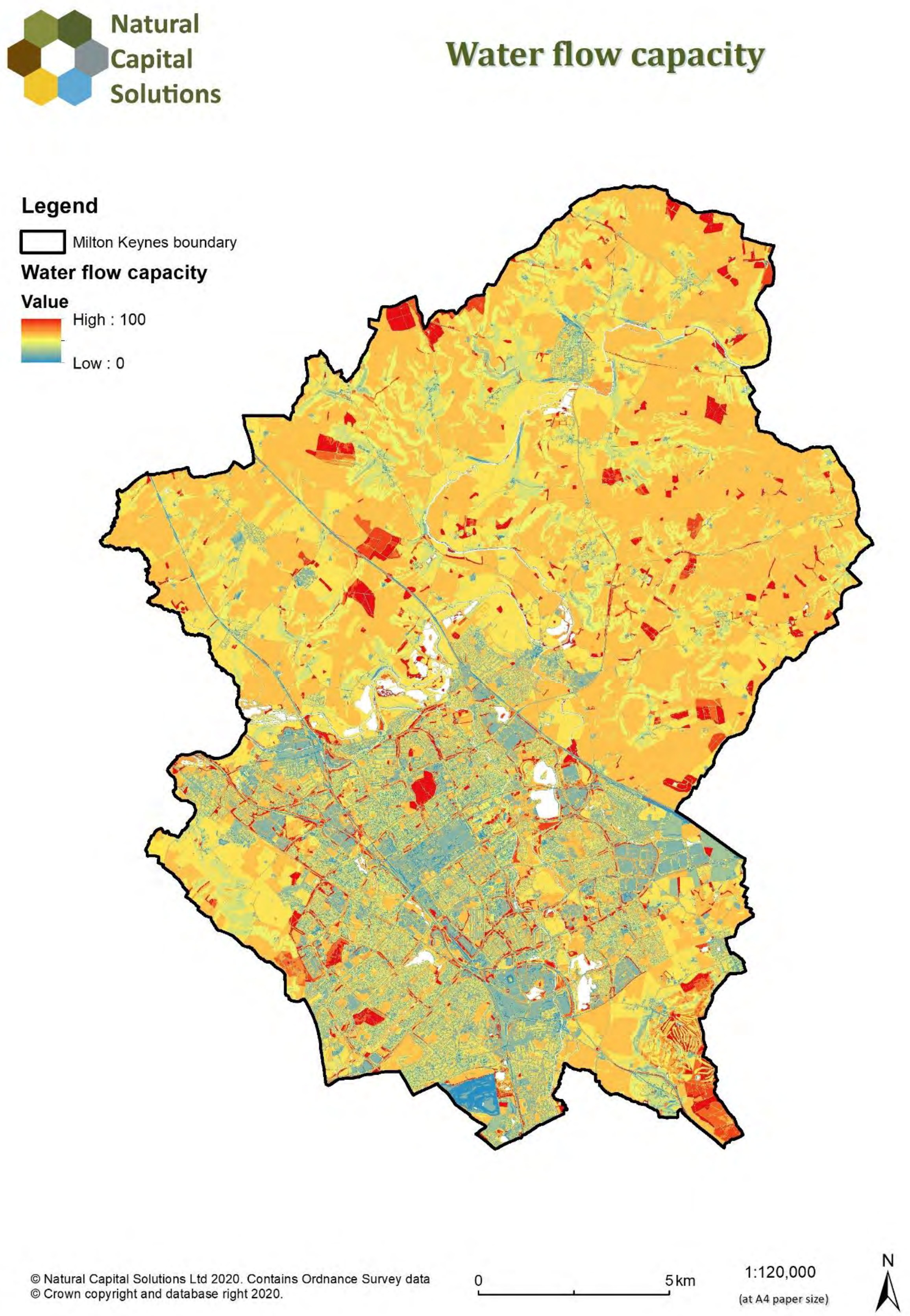


Figure 13 Water flow regulation capacity across Milton Keynes. Water areas are not given a score and appear as white (blank) on the map.

3.10 Water quality (soil erosion reduction) capacity

What is it and why is it important?

Water quality capacity maps the risk of surface runoff becoming contaminated with high sediment loads before entering a watercourse, with a higher water quality capacity indicating that water is likely to be less contaminated. Note that although diffuse urban pollution is partially captured in the model at the catchment scale, the focus is on sedimentation risk from agricultural land; 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 susceptible 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 a 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 was 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 generally have high or low capacity and is not a process-based model. High values (red) indicate areas with the greatest capacity to deliver high water quality (least sedimentation risk).

Results for Milton Keynes

Scores are generally lowest (blue areas in Figure 14) within arable fields, with those parts close to watercourses scoring least well. The arable areas to the north east of the area are the worst scoring locations. Scores are generally higher in areas away from watercourses with woodland land covers (Figure 14).

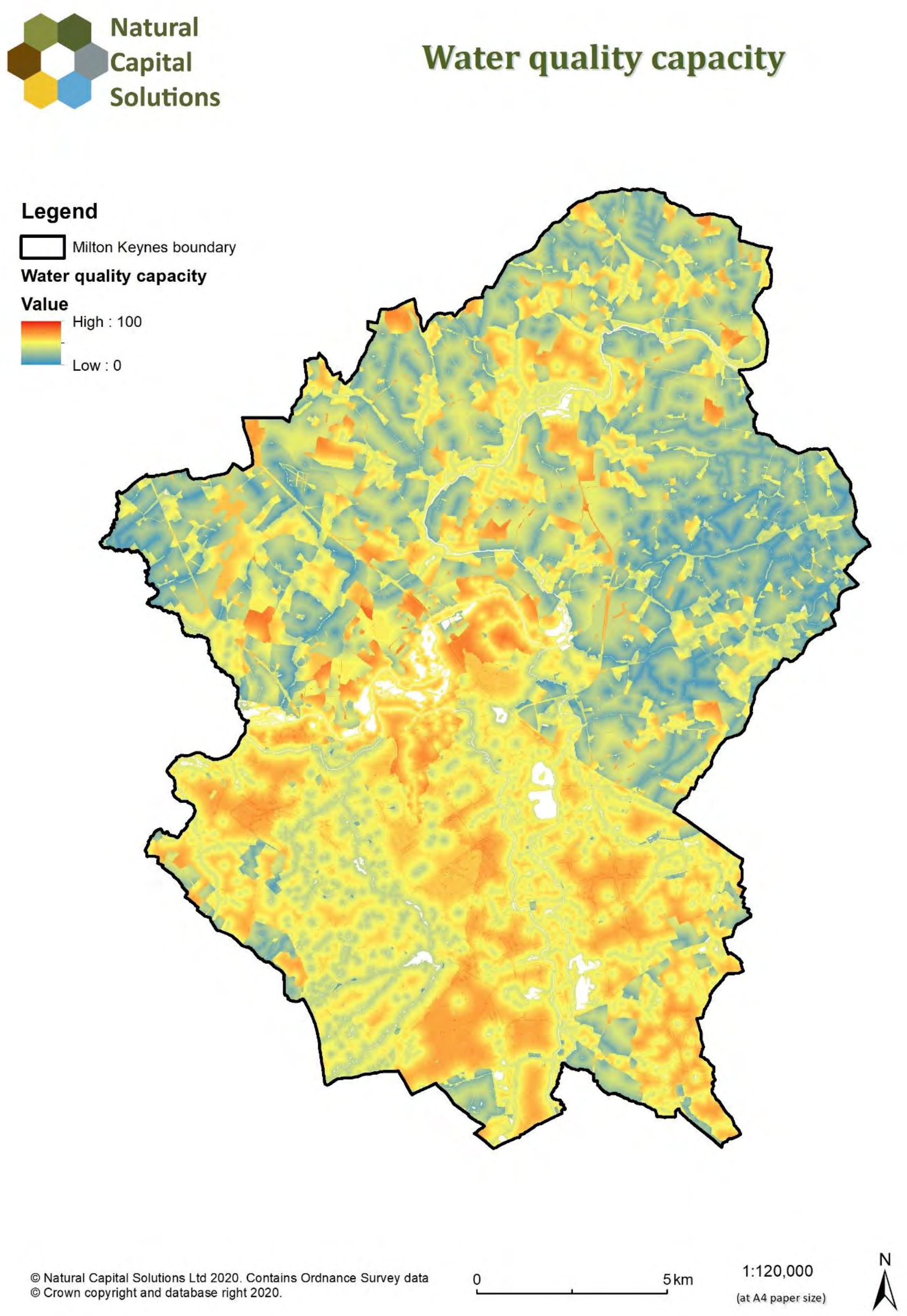


Figure 14 Water quality regulation capacity across Milton Keynes. Water areas are not given a score and appear as white (blank) on the map.

3.11 Food production capacity

What is it and why is it important?

Food production models the capacity of the land to produce food under current farming practices. Farming is the dominant land-use in Milton Keynes, with a 70:30 split 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 followed that outlined in Smith (2020)[10] and was developed for the Ecometric tool. Broad habitats in Milton Keynes were assigned a score based on 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 Milton Keynes

Food production is low in the south (blue areas in Figure 15), an area dominated by the urban centre of Milton Keynes town. In contrast, food production is medium to high in the northern part of the study area (yellow and orange areas in Figure 15), where arable and improved grassland dominates. This is due to the predominant Agricultural Land Classification for the region being Grade 3, along with significant areas of Grade 2. The relatively high (orange) food production areas are areas of Grade 2 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.

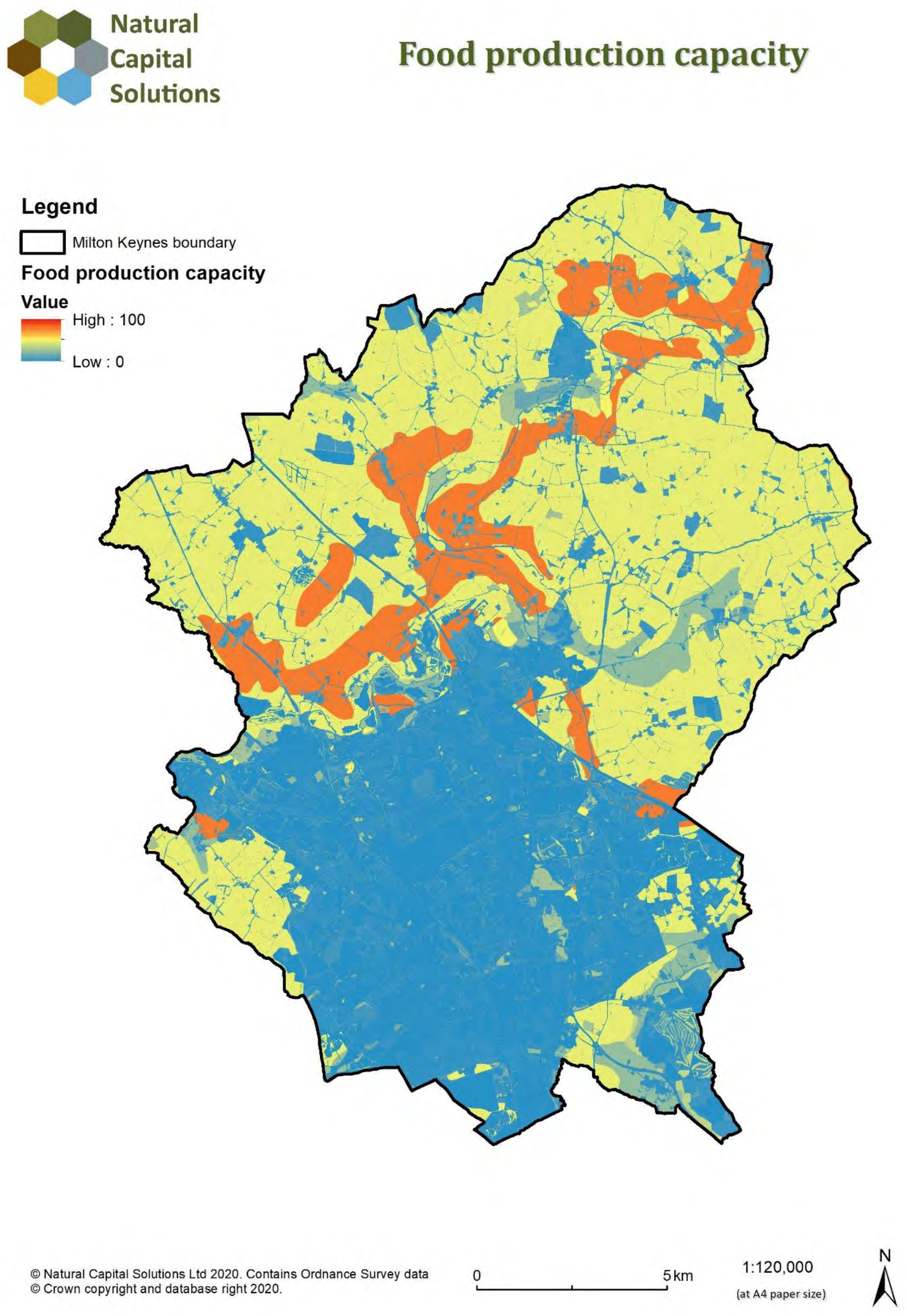


Figure 15 Food production capacity across Milton Keynes.

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 Milton Keynes

There are patches of medium to high timber and woodfuel production capacity scattered throughout the Milton Keynes LA area (orange and red in 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 orange. Broadleaved woodland is the dominant woodland cover type in Milton Keynes, although patches of coniferous woodland are scattered throughout the area, with large standings around Woburn being particularly prominent.

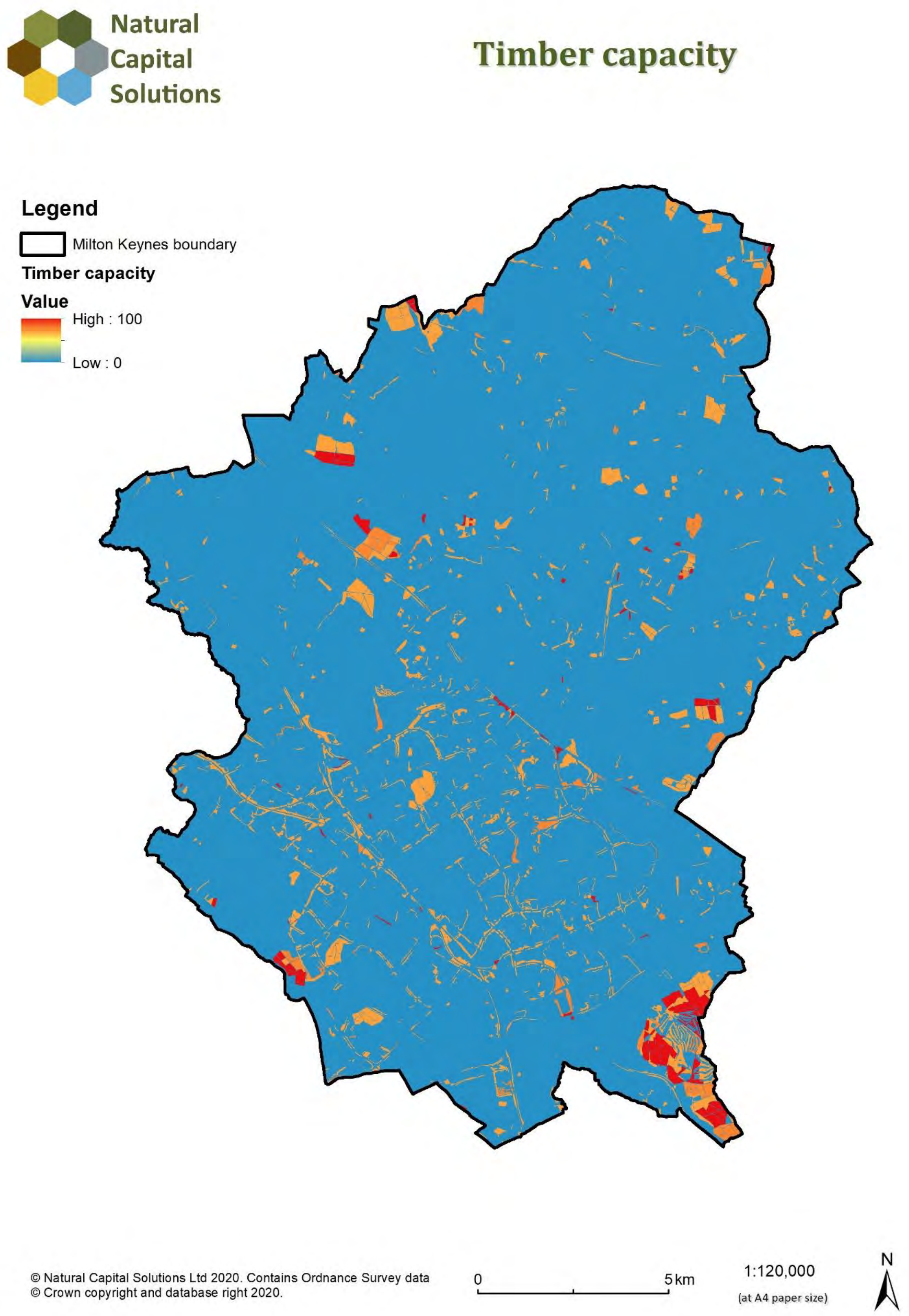


Figure 16 Timber/woodfuel capacity across Milton Keynes.

3.13 Accessible nature capacity

What is it and why is it important?

The importance of access to greenspace is increasingly recognised due to 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 visitor's 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 the land with no other access will not score highly.

Results for Milton Keynes

Figure 17 shows accessible nature capacity for publicly accessible land only. Accessible nature capacity is highest in the parks in and around Milton Keynes town (red areas in Figure 17), such as Willen Lake, Ouzel Valley Park, Woughton Park, Caldecote Lake, Bury Field and a number of the other linear parks spread across the urban area. A few hotspots occur in the northern and more rural parts of the study area, away from MK (the primary northern hotspot being Emberton Country Park).

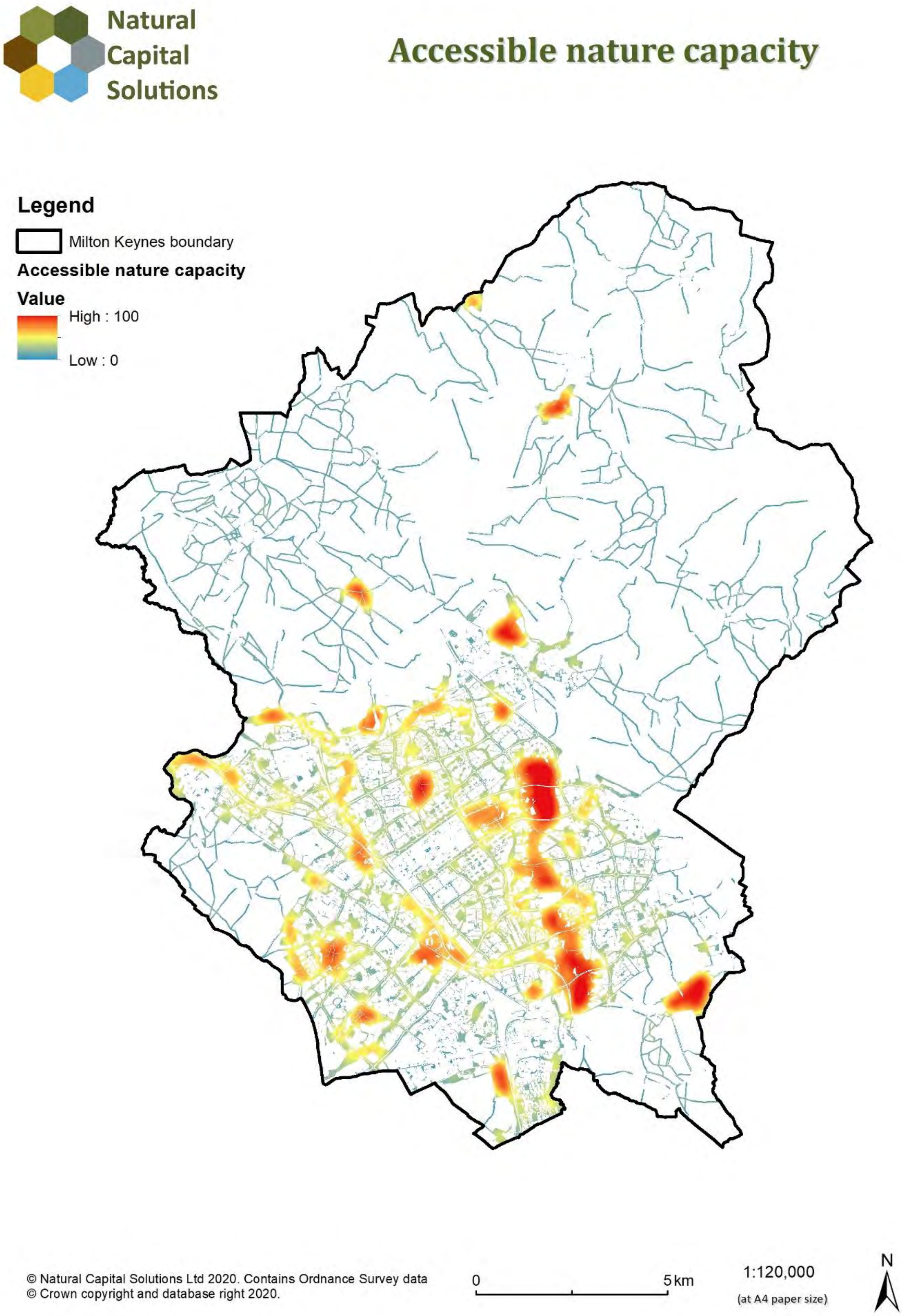


Figure 17 Accessible nature capacity across Milton Keynes. Areas with zero demand have been excluded to improve map legibility.

3.14 Accessible nature demand

What is it and why is it important?

This indicates where there is the 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 the 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 Milton Keynes

Demand for accessible nature (see Figure 18) is focussed on where people live. Hence, most of the demand across the study area is centred on MK itself and the adjoining urban areas. Demand is much reduced in the more rural northern half of the study areas, although is still apparent from some of the larger settlements.

Balancing supply and demand for accessible nature

Numerous researchers have shown that people travel most frequently to greenspaces very close to their homes, and Natural England recommends 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 most 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 this demand must be 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 high quality and as natural as possible.

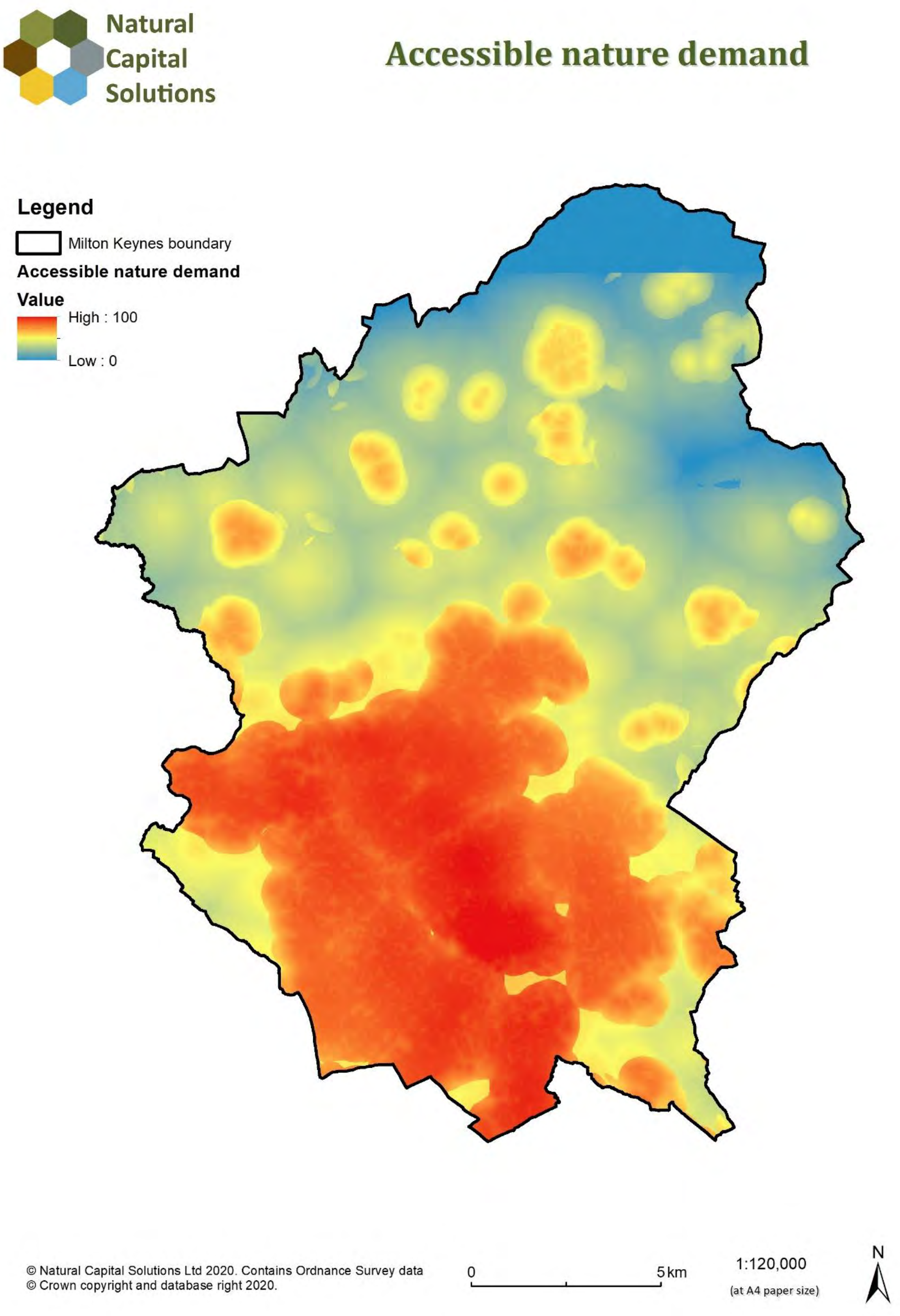


Figure 18 Accessible nature demand across Milton Keynes.

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 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 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 Milton Keynes. 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 Milton Keynes 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 in 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 a 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

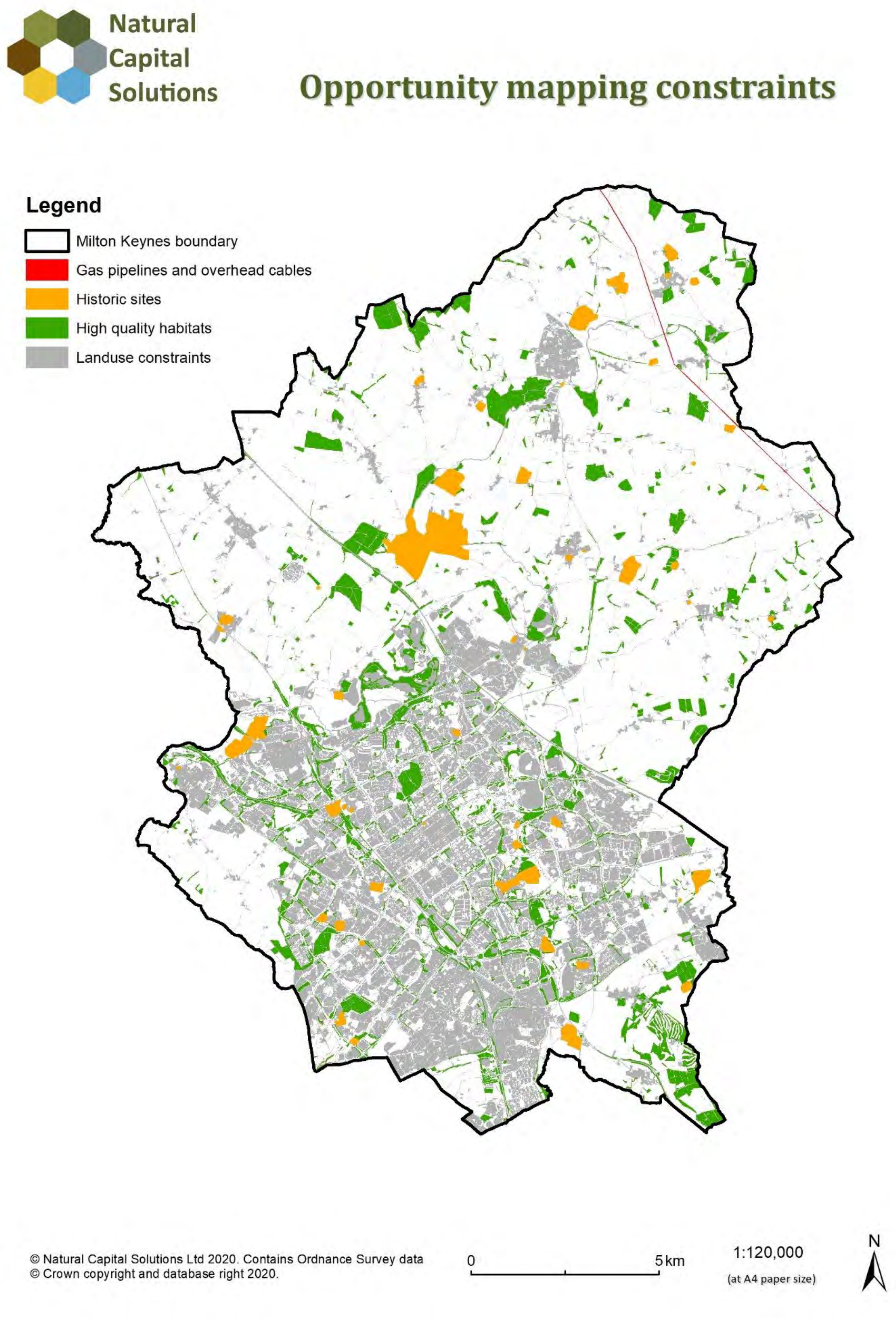


Figure 19 Key constraints taken into account during habitat opportunity mapping across Milton Keynes.

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 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 overlaid 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 permeability of the landscape for typical semi-natural grassland species is shown in 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 in Figure 21. Habitats that are ecologically connected are linked within a network shown in grey. White space between habitat patches indicates that the patches are ecologically unconnected, and dispersal between them is less likely to occur. Semi-natural grasslands (Figure 21) occur in a number of places across the study area, and many habitat patches are ecologically connected with patches nearby but unconnected from more distant semi-natural grasslands (as indicated by the large amount of white space in Figure 21). Broadleaved and mixed woodland habitat networks (Figure A2) are present throughout. In MK itself, although the woodland patches are generally small, much of the area forms a near-continuous patch of ecologically connected habitat. Woodland in the northern half of the study area generally occurs in larger patches, but is more ecologically isolated and there are few large areas of continuous habitat. Wet grassland and wetland habitat networks (Figure A6), are much less significant across the study area, with only a few small habitat patches along the River Great Ouse, most of which are ecologically isolated from each other. The largest of these wet grassland patches is in between Olney and Emberton

Once constraints have been removed, the resulting maps show biodiversity opportunity areas. Figures 22 and 23 illustrate these for semi-natural grassland habitats, with the other habitats in Annex 1. Figure 22 shows the opportunity zones as buffers around existing sites. In contrast, Figure 23 highlights whole fields where habitats could be created; fields are a more meaningful management unit for conservation action. There are a number of areas throughout the Milton Keynes LA area, around the previously identified habitat network, where semi-natural grassland could be created to considerably enlarge and connect existing networks, along with smaller and scattered opportunities. Broadleaved and mixed woodland opportunities (Figure A4) exist throughout the study area, although with particular density in the northern half of the study area where habitat creation is unconstrained by urban areas. Field-scale habitat creation in the northern part of the study area could increase the connections between woodland patches, or connect more isolated fragments to create a more resilient network. In urban MK, although the scale of opportunities is generally smaller, there are a large number of opportunities to expand and connect the existing woodland patches. 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).

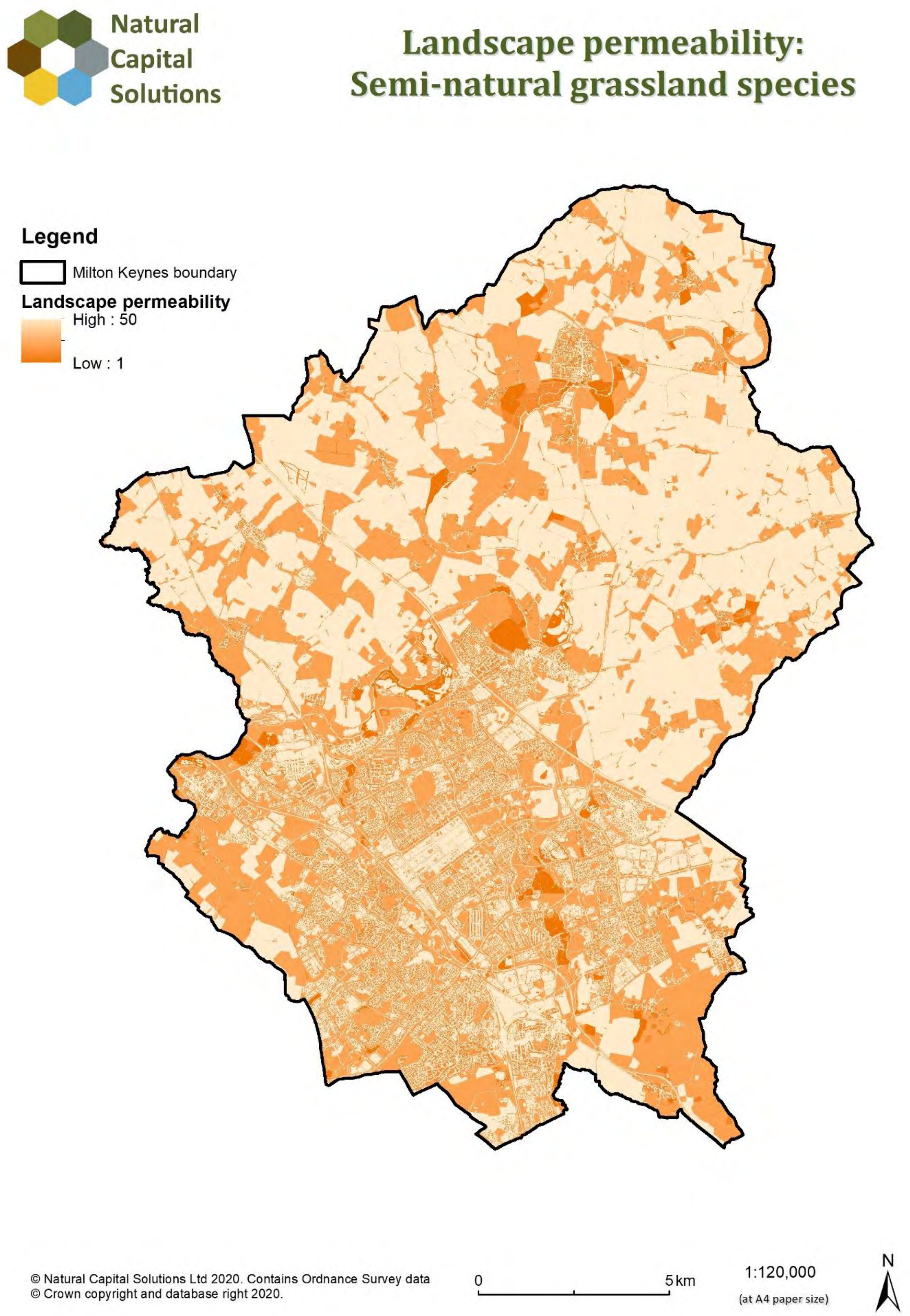


Figure 20 Landscape permeability for typical semi-natural grassland species across Milton Keynes.

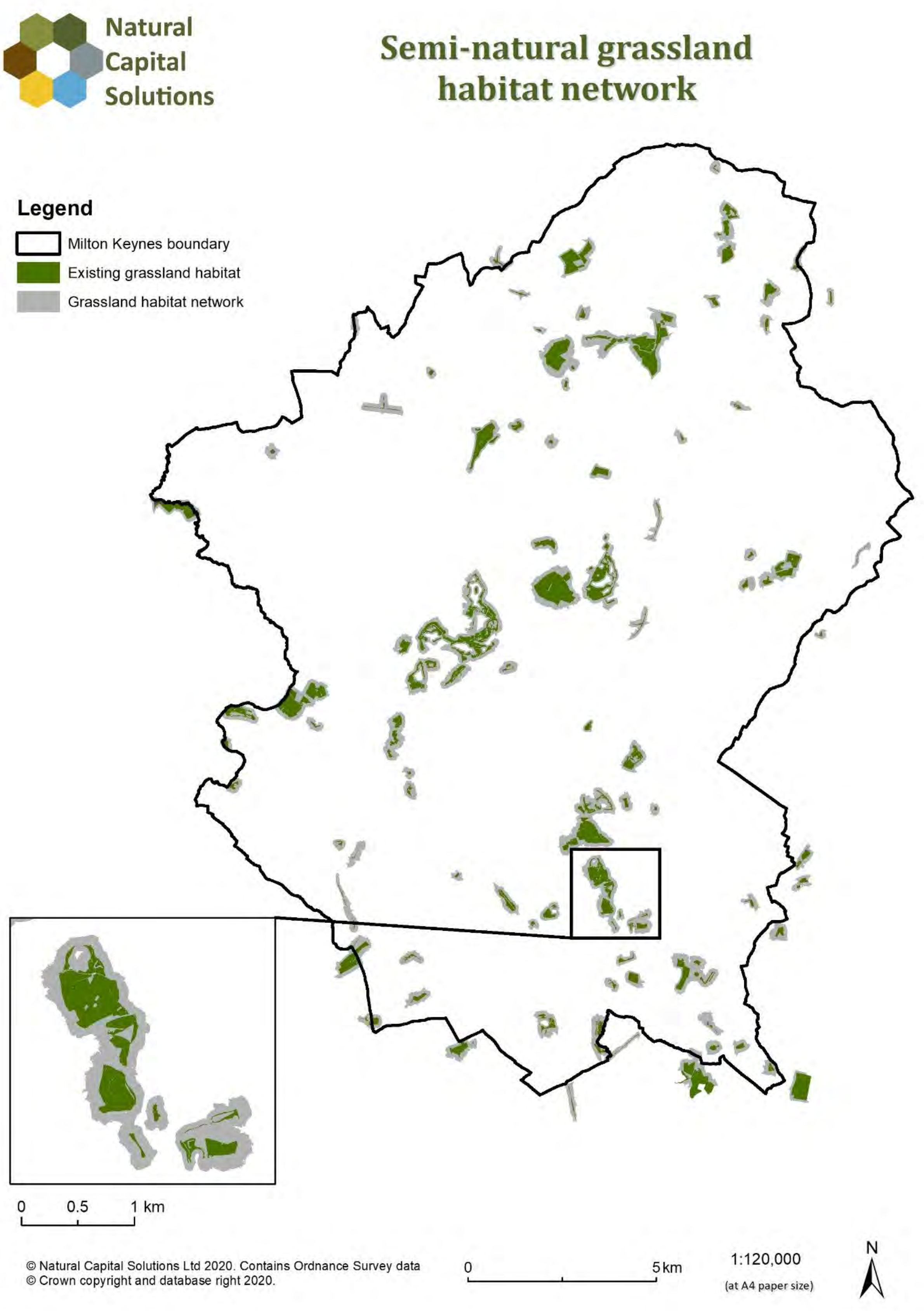


Figure 21 Habitat network for semi-natural grasslands across Milton Keynes.

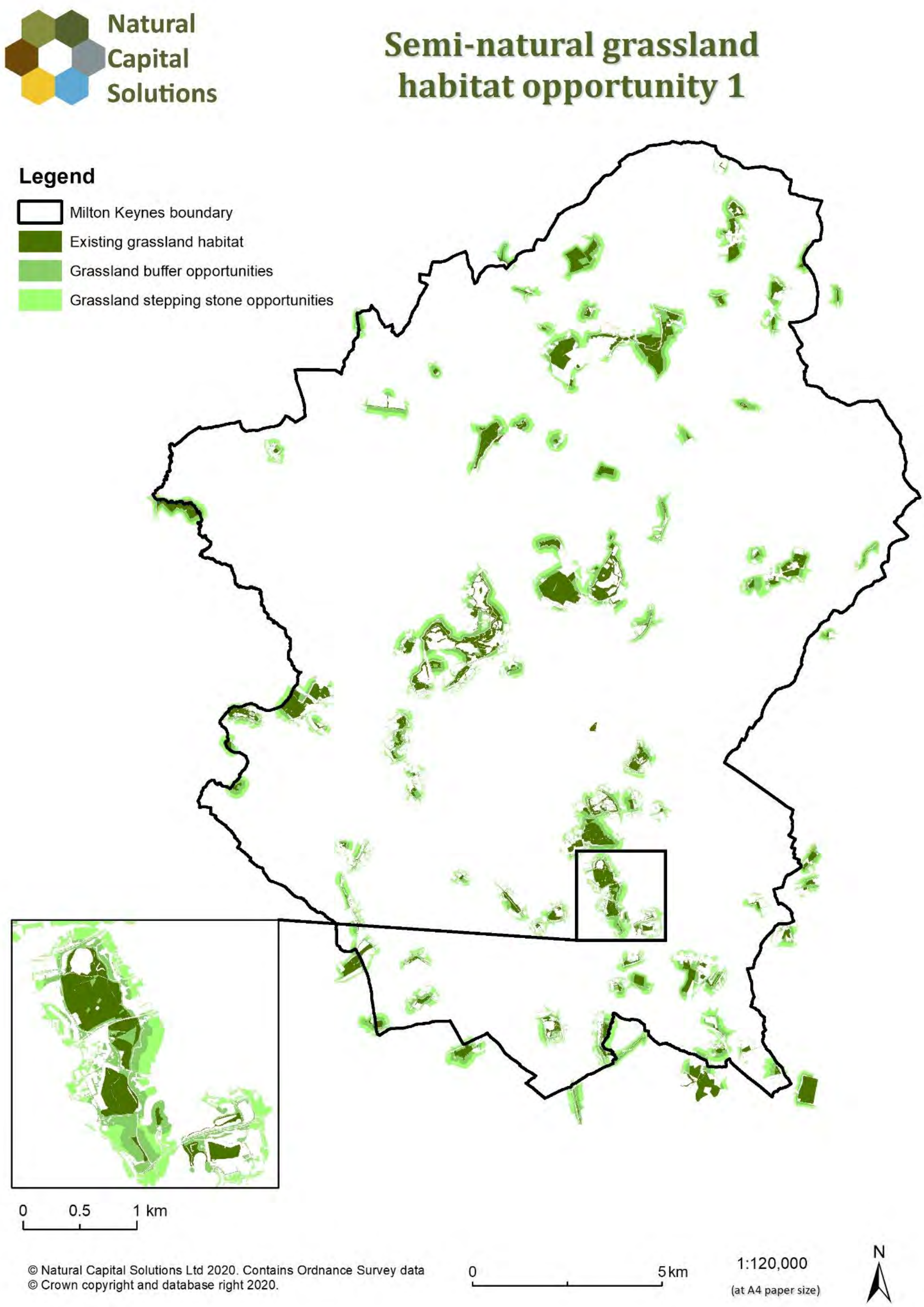


Figure 22 Buffer biodiversity opportunity areas for semi-natural grassland across Milton Keynes.

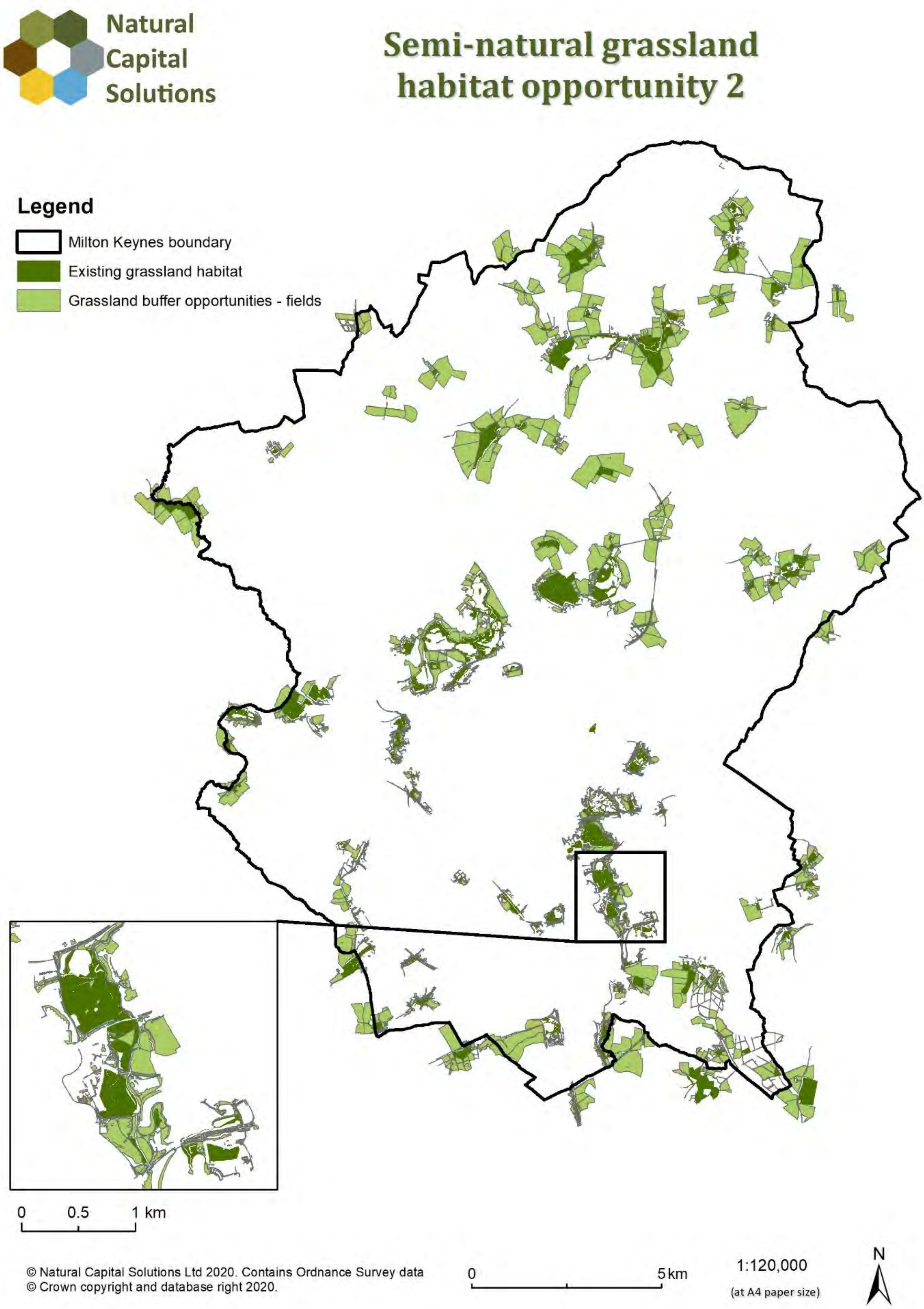


Figure 23 Field-scale biodiversity opportunity areas for semi-natural grassland across Milton Keynes.

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 then 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 Milton Keynes, but are more concentrated in the rural north, with the majority of opportunities relating to areas of arable fields on sloping land. The landfill site to the south of Bletchley has also been highlighted as a particular opportunity for improvement. 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).

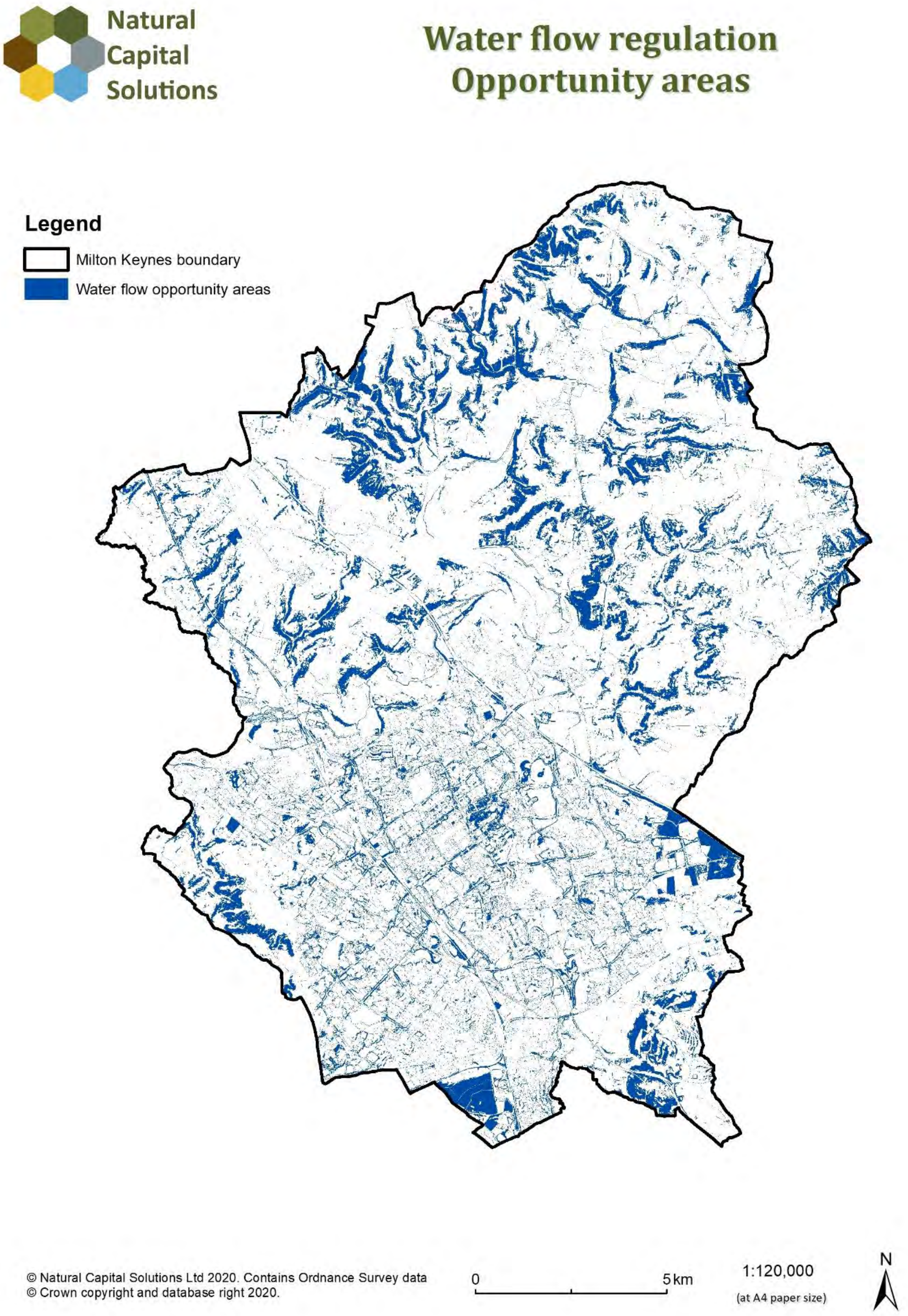


Figure 24 Water flow regulation opportunity areas across Milton Keynes.

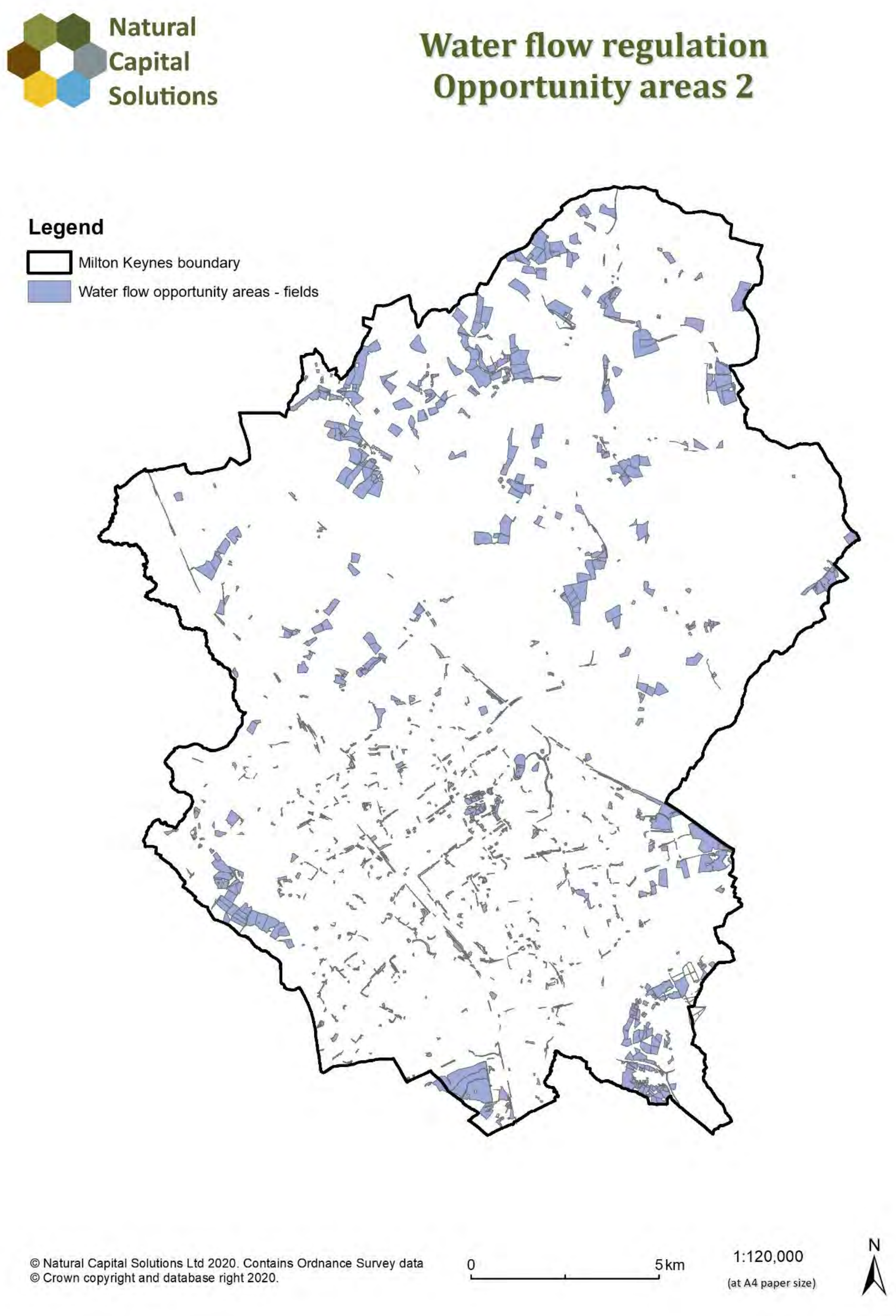


Figure 25 Field scale water flow regulation opportunity areas across Milton Keynes

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 strips 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, therefore, 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. The southern half of the study area is dominated by Milton Keynes town and there is very little arable land present when compared to the rural and agricultural northern part of the study area. Consequently, the vast majority of nature-based intervention opportunities to improve water quality are located in the northern half of the study area.

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, potentially of woodland if permitted, 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 do 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.

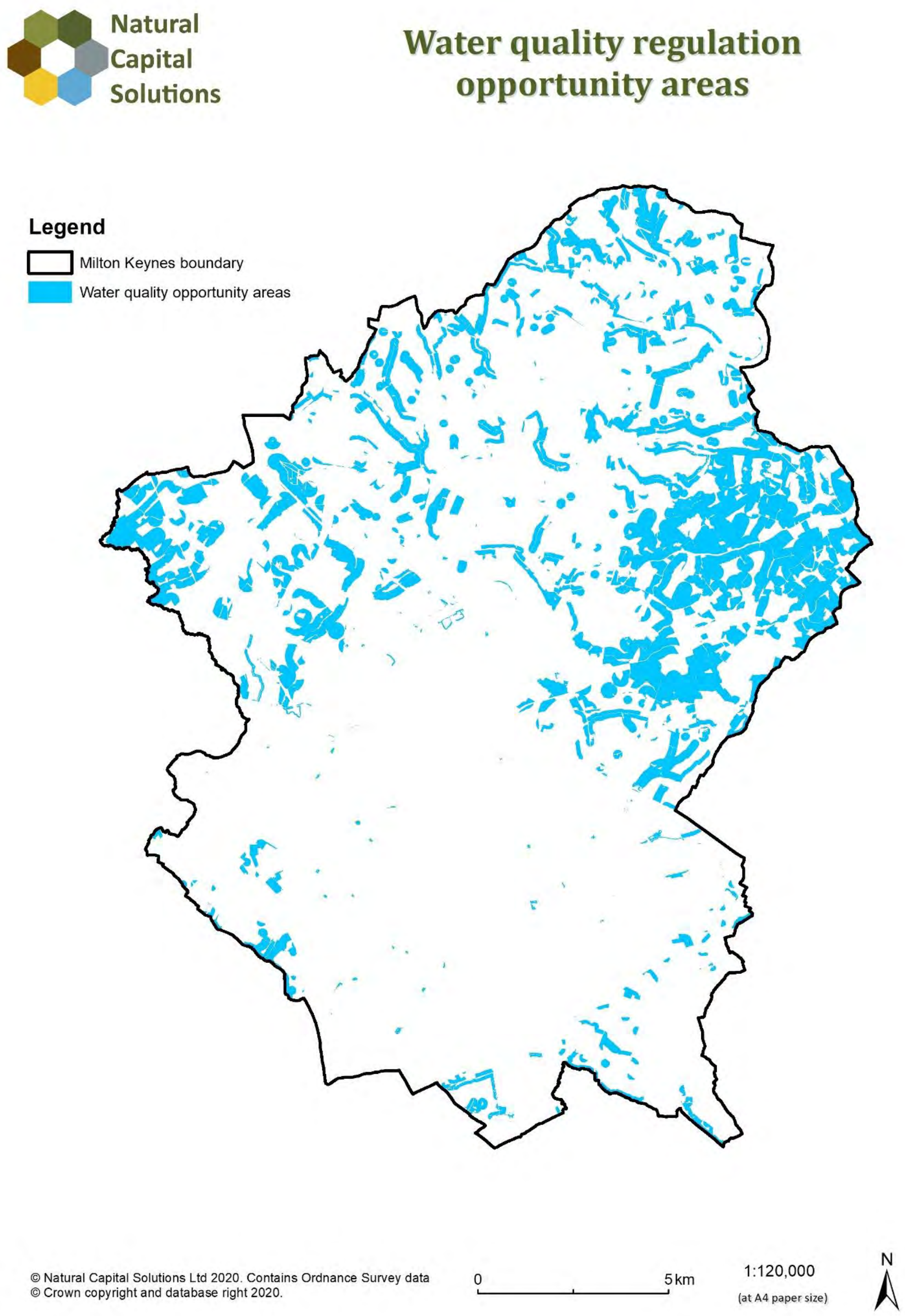


Figure 26 Water quality regulation opportunity areas across Milton Keynes.

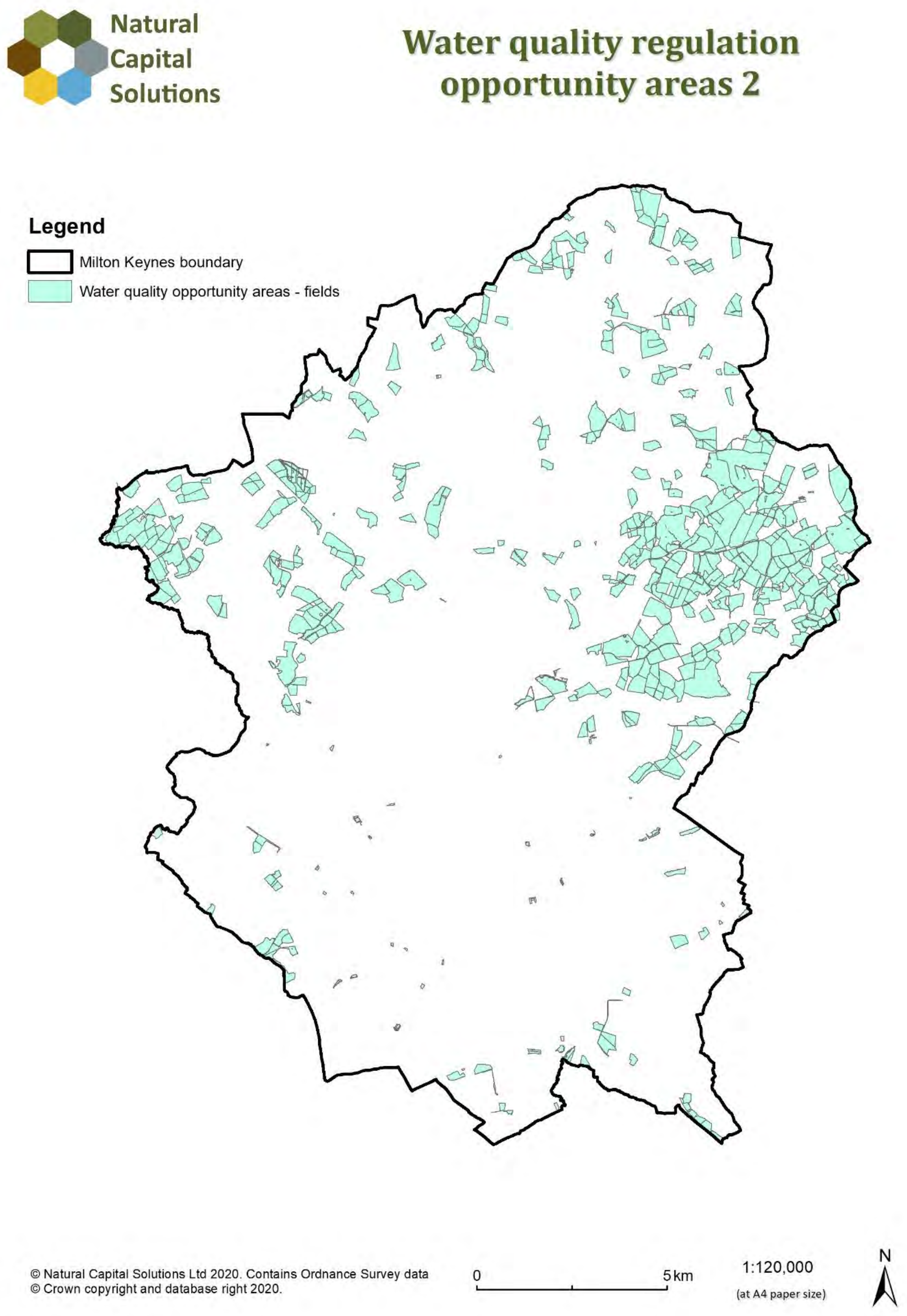


Figure 27 Field scale water quality regulation opportunity areas across Milton Keynes.

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 the 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. Therefore, the opportunity maps 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 areas as these have both higher air pollution levels and higher populations that would benefit from better air quality, and also along with the main road networks. Inevitably, when the focus on air quality regulation is in urban areas, there are areas where it is not possible to plant trees or other green infrastructure (i.e. constraints). However, unconstrained areas remain, which 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 (or additional 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.

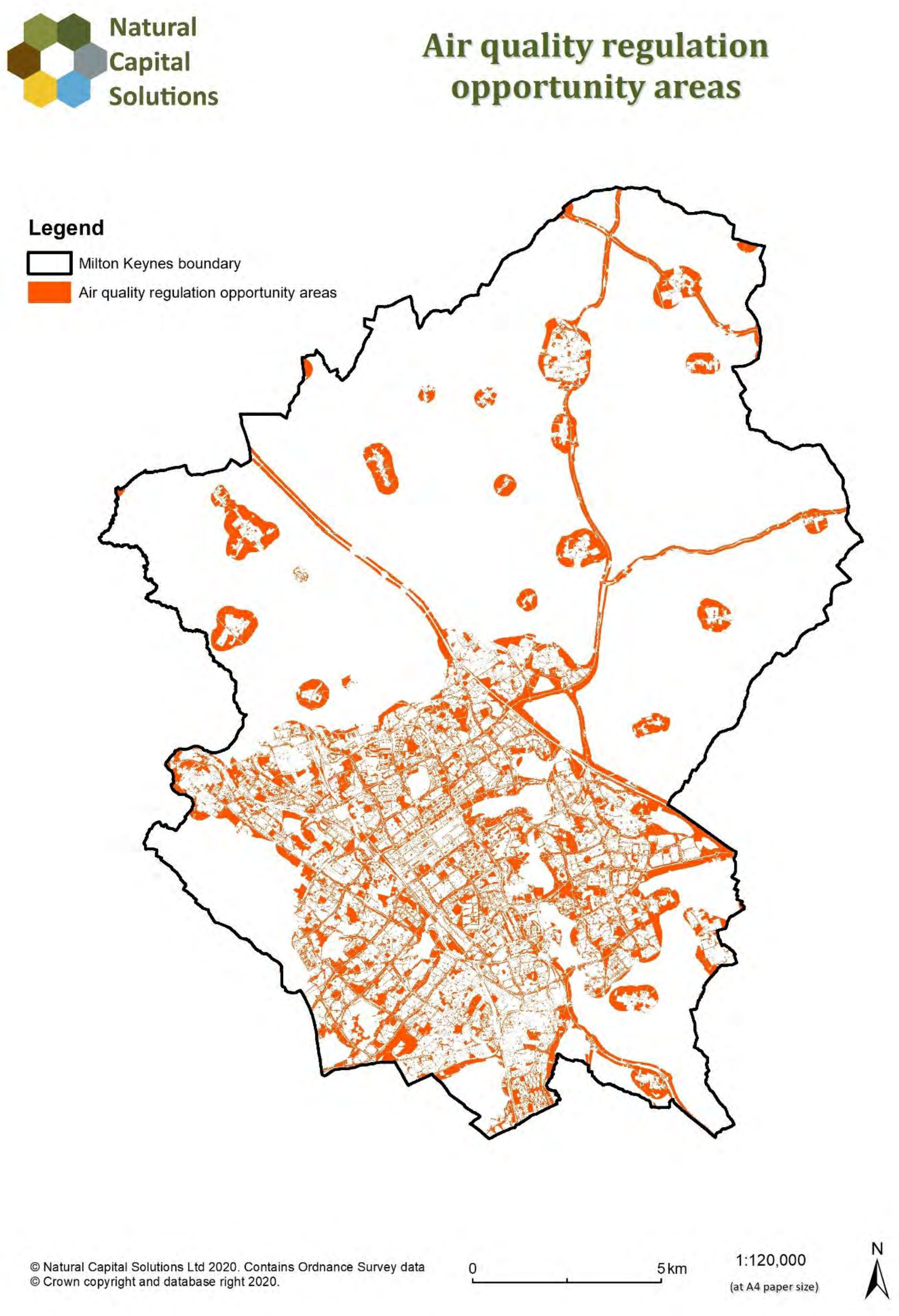


Figure 28 Air quality regulation opportunity areas across Milton Keynes.

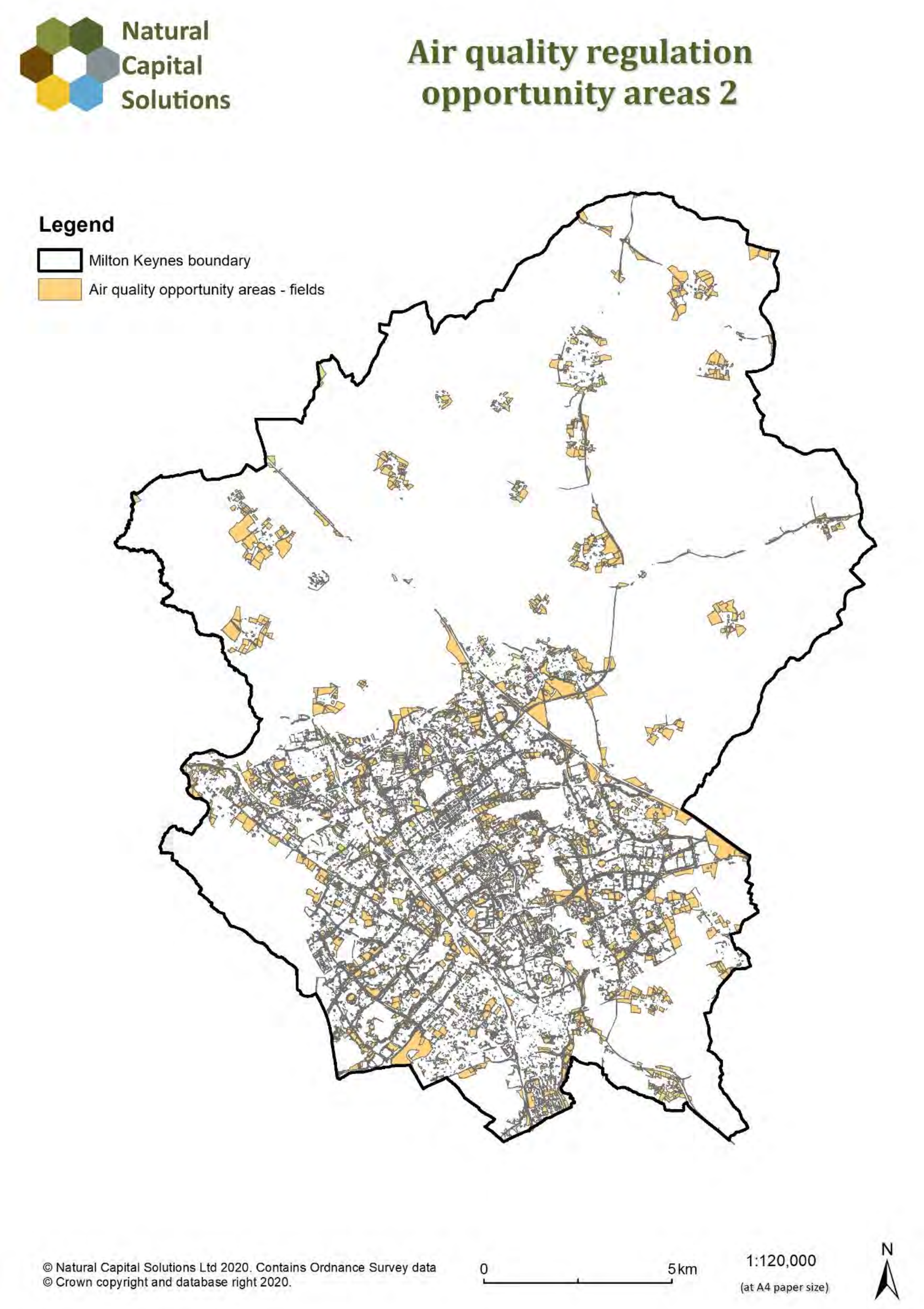


Figure 29 Field (plot) scale air quality regulation opportunity areas across Milton Keynes.

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 on areas with the 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

As with 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 A5 and main road in central MK; since these areas have higher noise pollution levels and higher populations that would benefit from noise screening. Given a large number of constraints in urban centres, many of the opportunity areas identified fall on the outer fringes of neighbourhoods and adjacent to the road network. However, several urban centre locations have also been identified (Figure 30). Whole plots were also identified and shown in Figure 31. These locations potentially provide the opportunity to plant or expand tree and scrub belts that could help to block and screen noise pollution.

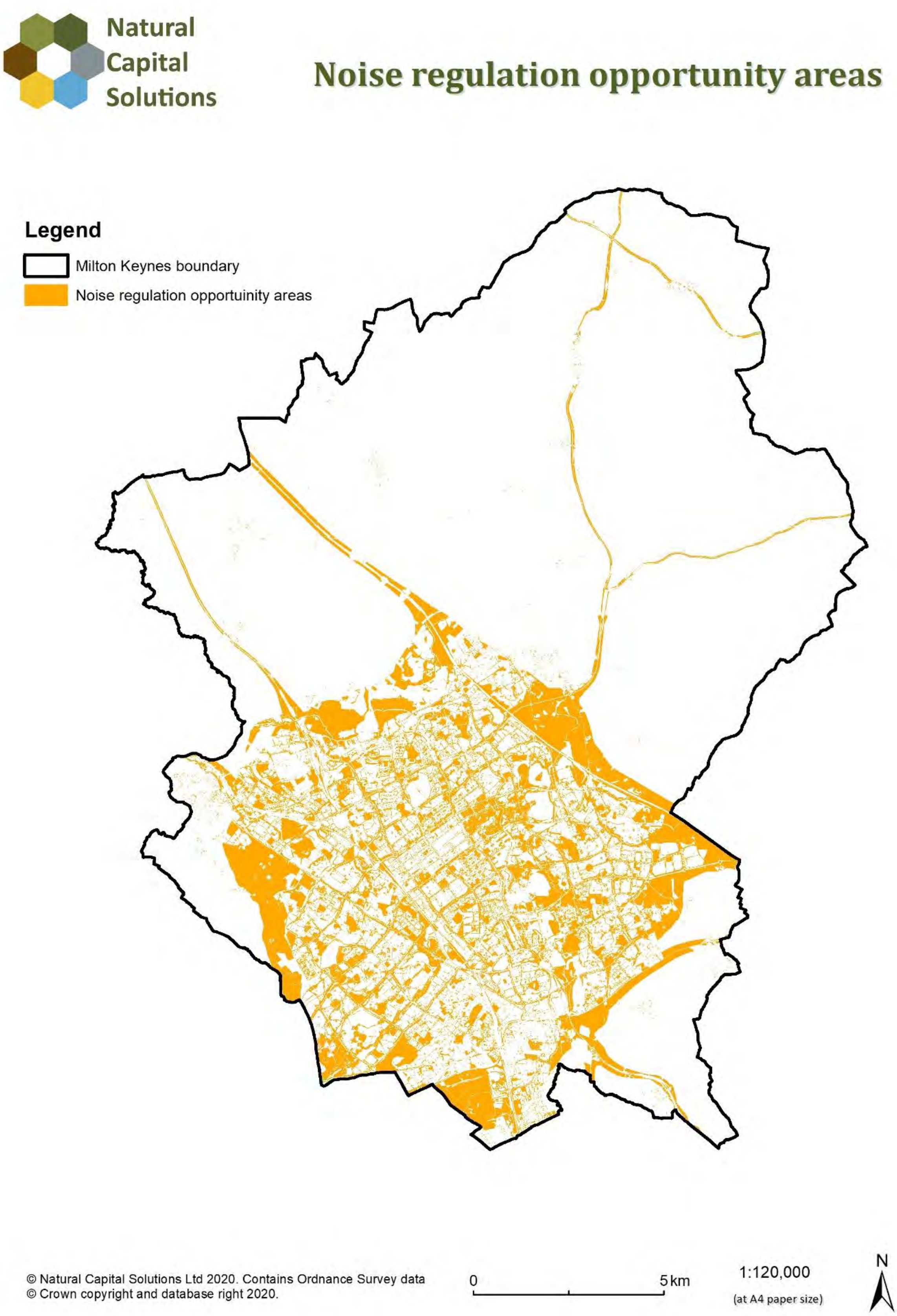


Figure 30 Noise regulation opportunity areas across Milton Keynes.

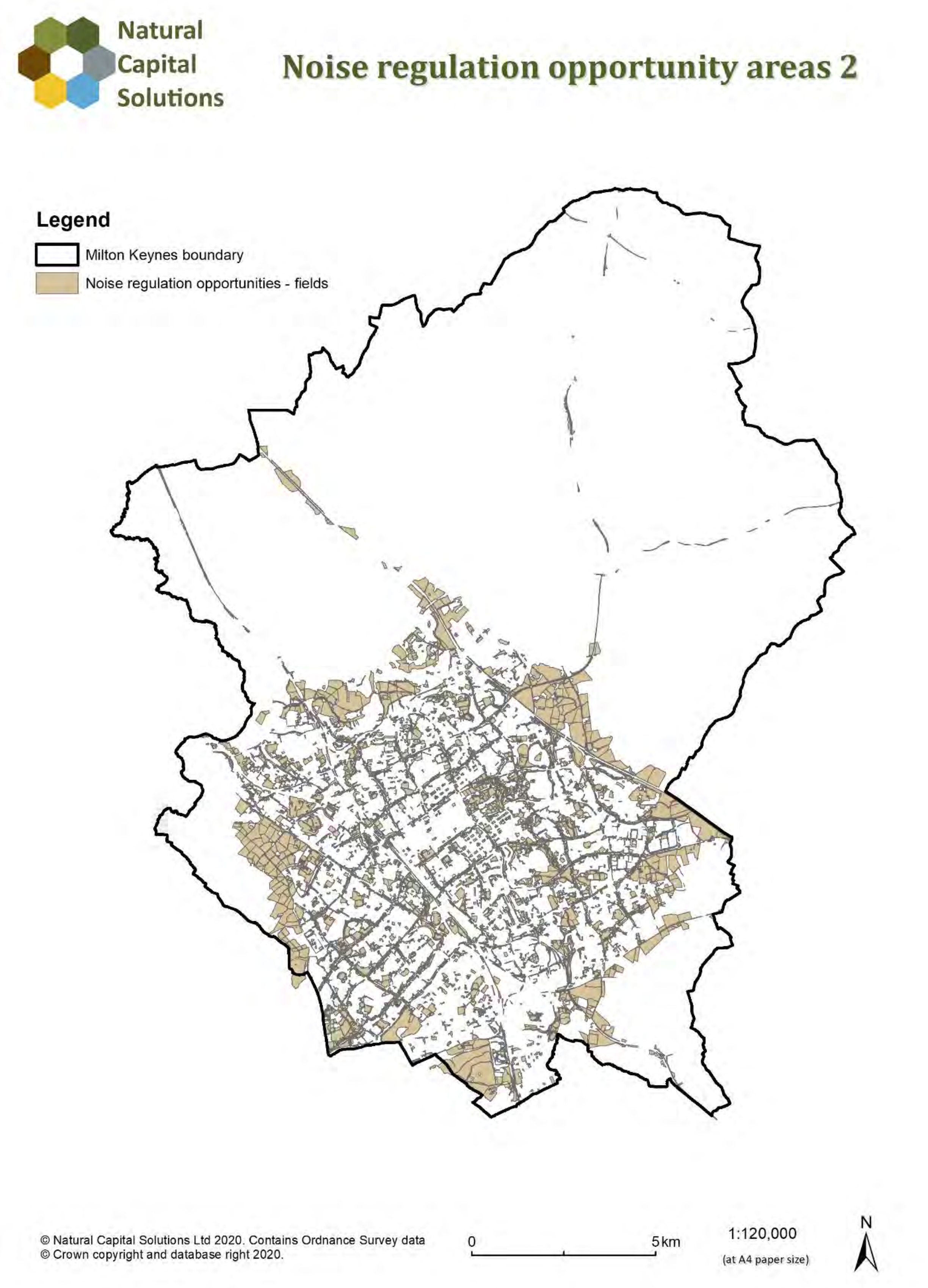


Figure 31 Field (plot) scale noise regulation opportunity areas across Milton Keynes.

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

Opportunities to regulate local climate were mapped using the same approach 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 planting 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. However, 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 even planting individual trees could be beneficial, although they will have a smaller effect.

4.7.2 Results

Demand for local climate regulation (Figure 12) is focused in the main urban areas, and the size of the urban heat island effect increase with the size of the urban area and the amount of sealed surface. As with air pollution regulation and noise regulation, most of the opportunity areas identified fall on the outer fringes of key neighbourhoods due to the many constraints in urban centres, although some of the urban centre locations 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.

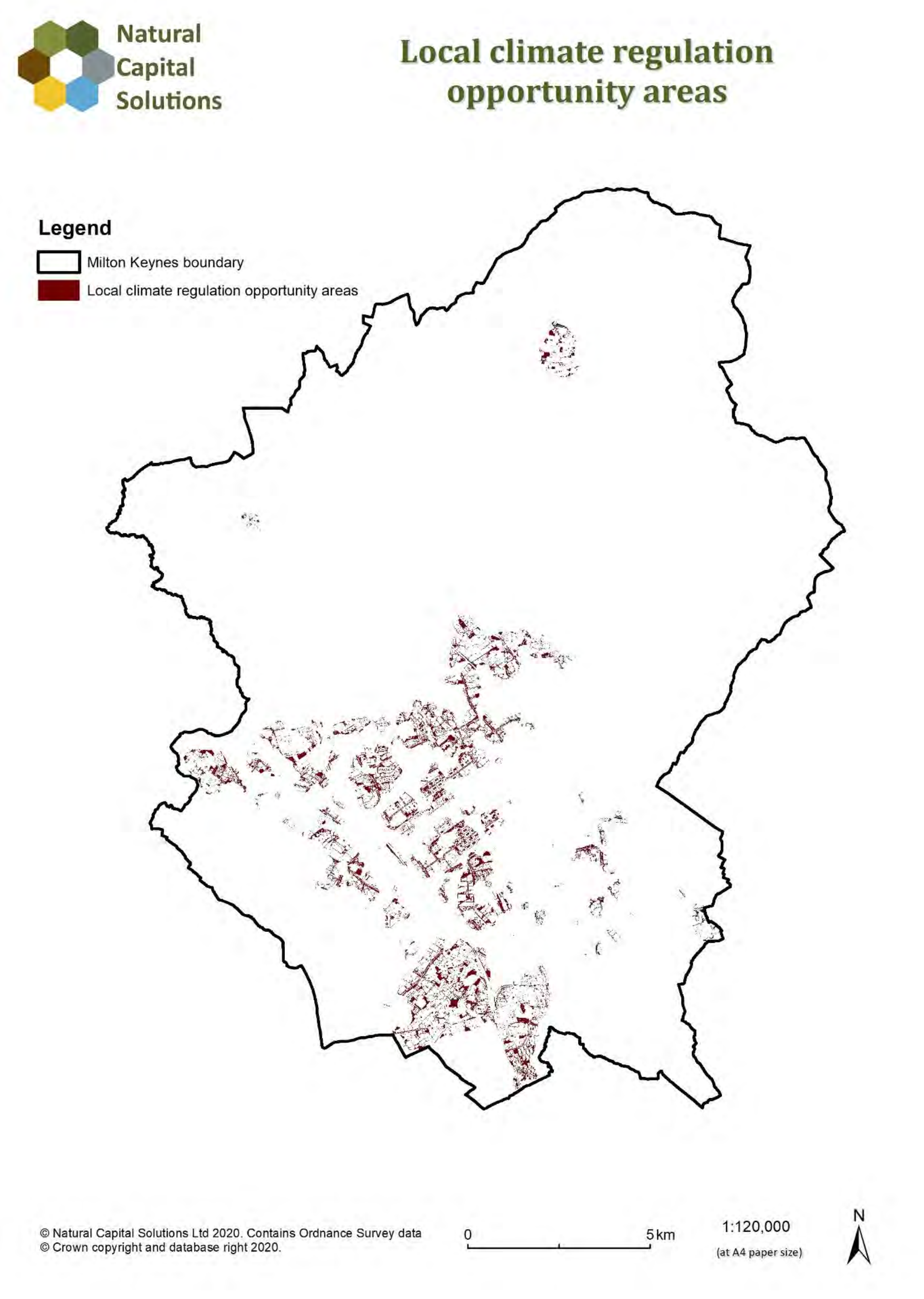


Figure 32 Local climate regulation opportunity areas across Milton Keynes.

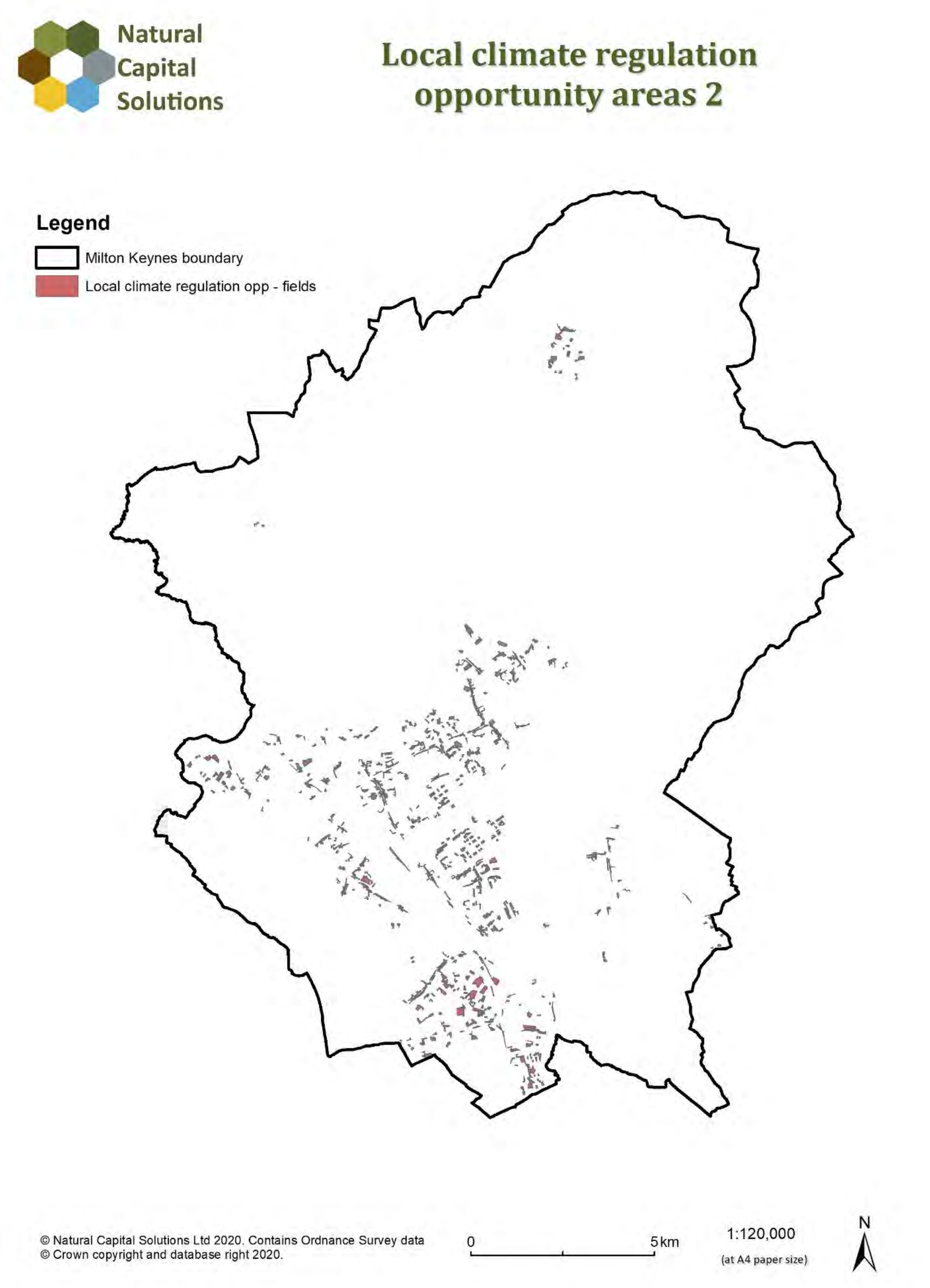


Figure 33 Field (plot) scale local climate regulation opportunity areas across Milton Keynes.

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 Milton Keynes. 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 was 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 can deliver accessible natural greenspace of greater value.

Therefore, perceived naturalness was 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 visitor's experience within a short walk of each point. This means that larger contiguous 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 on the urban areas in the study area. Therefore, it is perhaps unsurprising that most of the opportunity areas identified (Figures 34 & 35) are centred around the urban areas across the study area. As opportunities for new greenspaces are usually highly constrained within urban areas, opportunity areas tend to form a ring around the edges of these areas. These are also often locations that have been targeted for sustainable urban extensions and other development, so it is important that planners and developers take into account the strong demand for greenspace at these sites from both the new developments and from the existing population.

Although demand is greatest closest to urban areas, these locations do not necessarily contain the most natural habitats, and the perceived naturalness of habitats throughout the study area is shown on Figure 36. Woodland, semi-natural grassland, wetland 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. In the Milton Keynes area, the habitats along the floodplain of the River Great Ouse are particularly prominent, along with the Ouzel Valley as it passes through MK, and the woodland areas around Woburn. As a number of these more natural sites are immediately adjacent to the urban areas of MK, when demand is balanced against the naturalness of the existing habitats, the pattern of opportunity areas is not very different (Figures 37 & 38). Some more natural areas further away from built up areas are now highlighted, along with large areas along the River Great Ouse that were highlighted on the previous maps. In general, when considering only demand for access to greenspace, opportunities are selected that are immediately adjacent to urban areas, but some of these are on arable fields, improved grassland, and a landfill site, where 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 in some cases slightly further from urban areas so with slightly poorer access, but more natural habitats, such as woodland, are often selected.

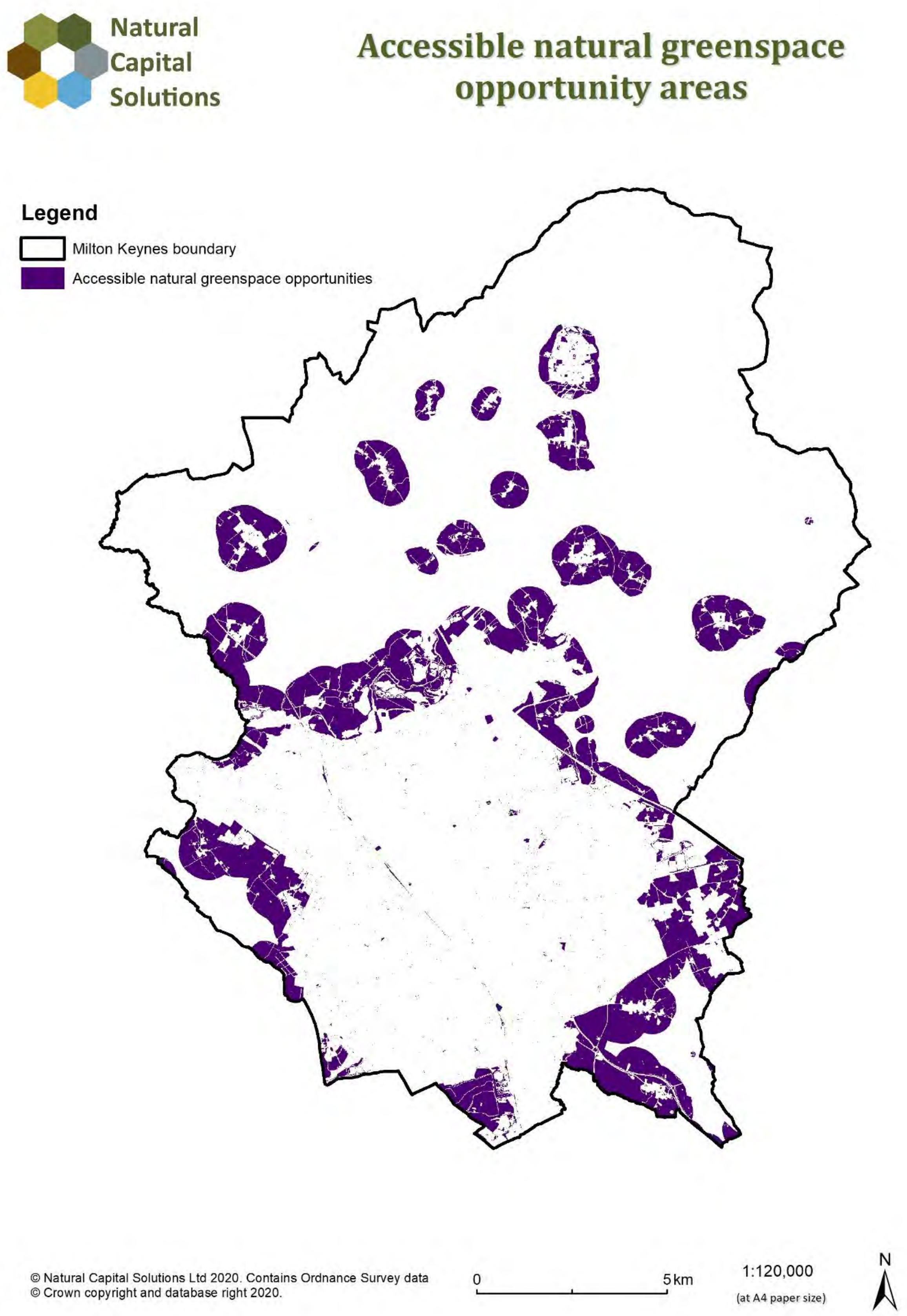


Figure 34 Accessible natural greenspace opportunity areas across Milton Keynes.

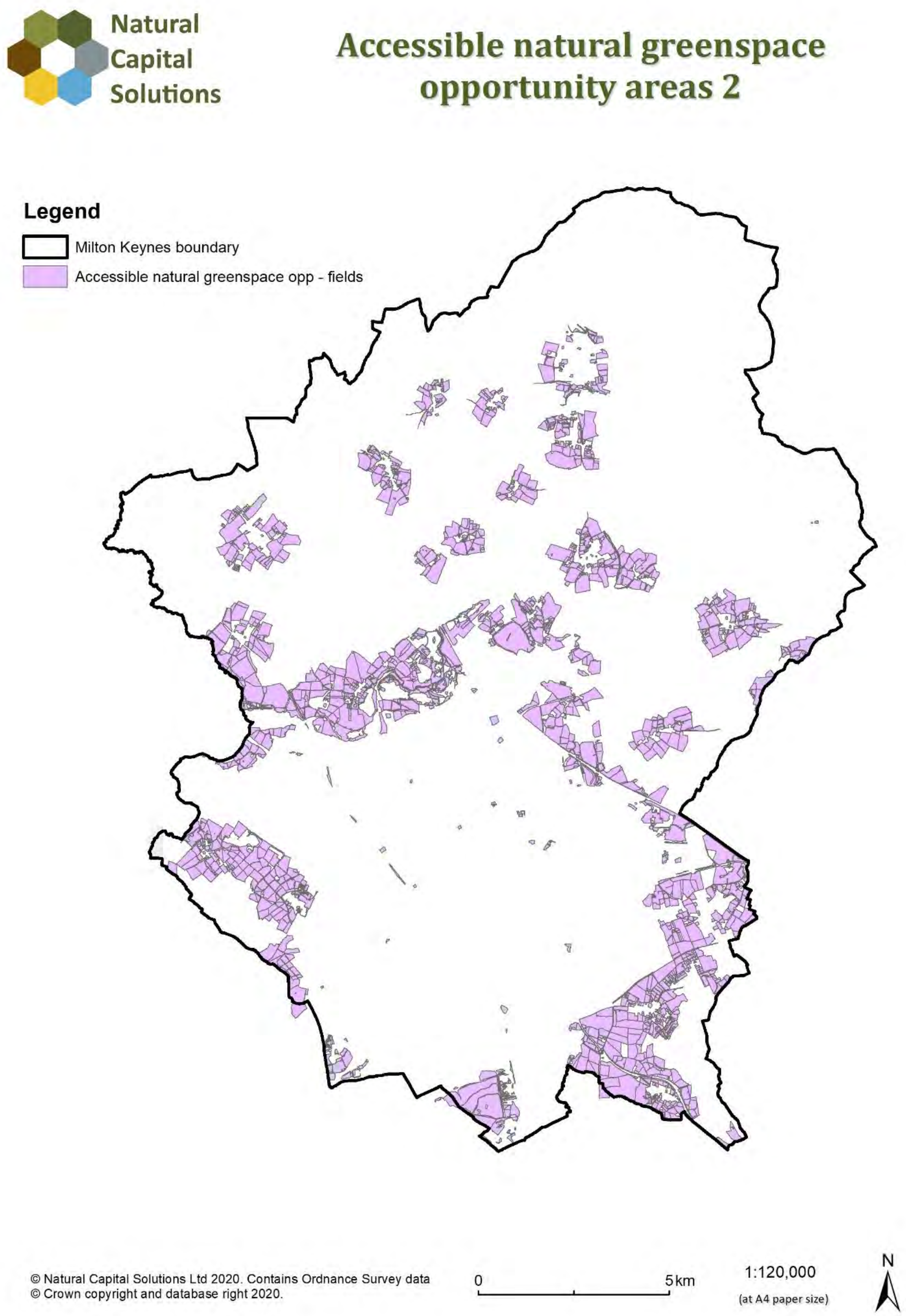


Figure 35 Field (plot) scale accessible natural greenspace opportunity areas across Milton Keynes.

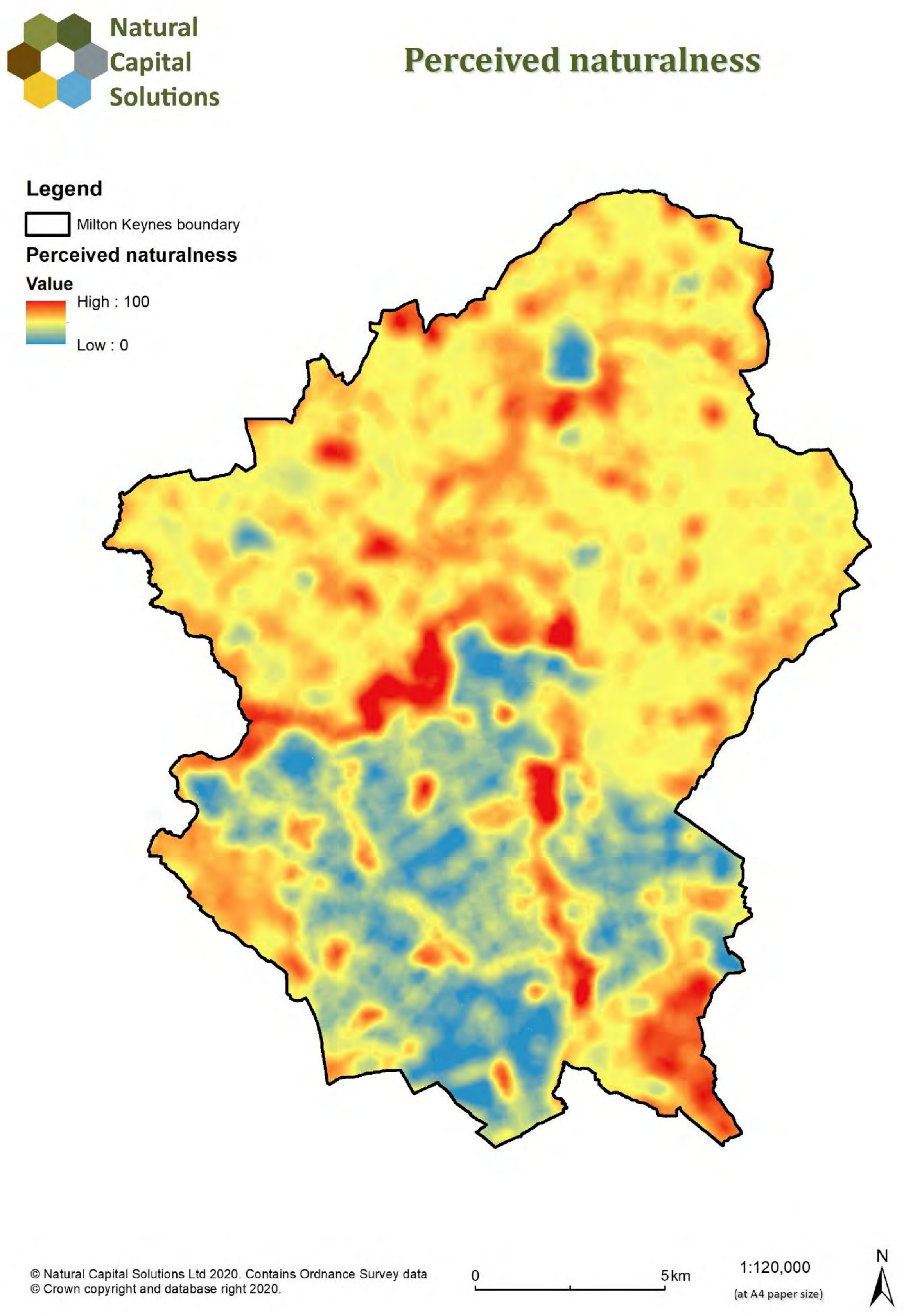


Figure 36 Perceived naturalness of habitats across Milton Keynes.

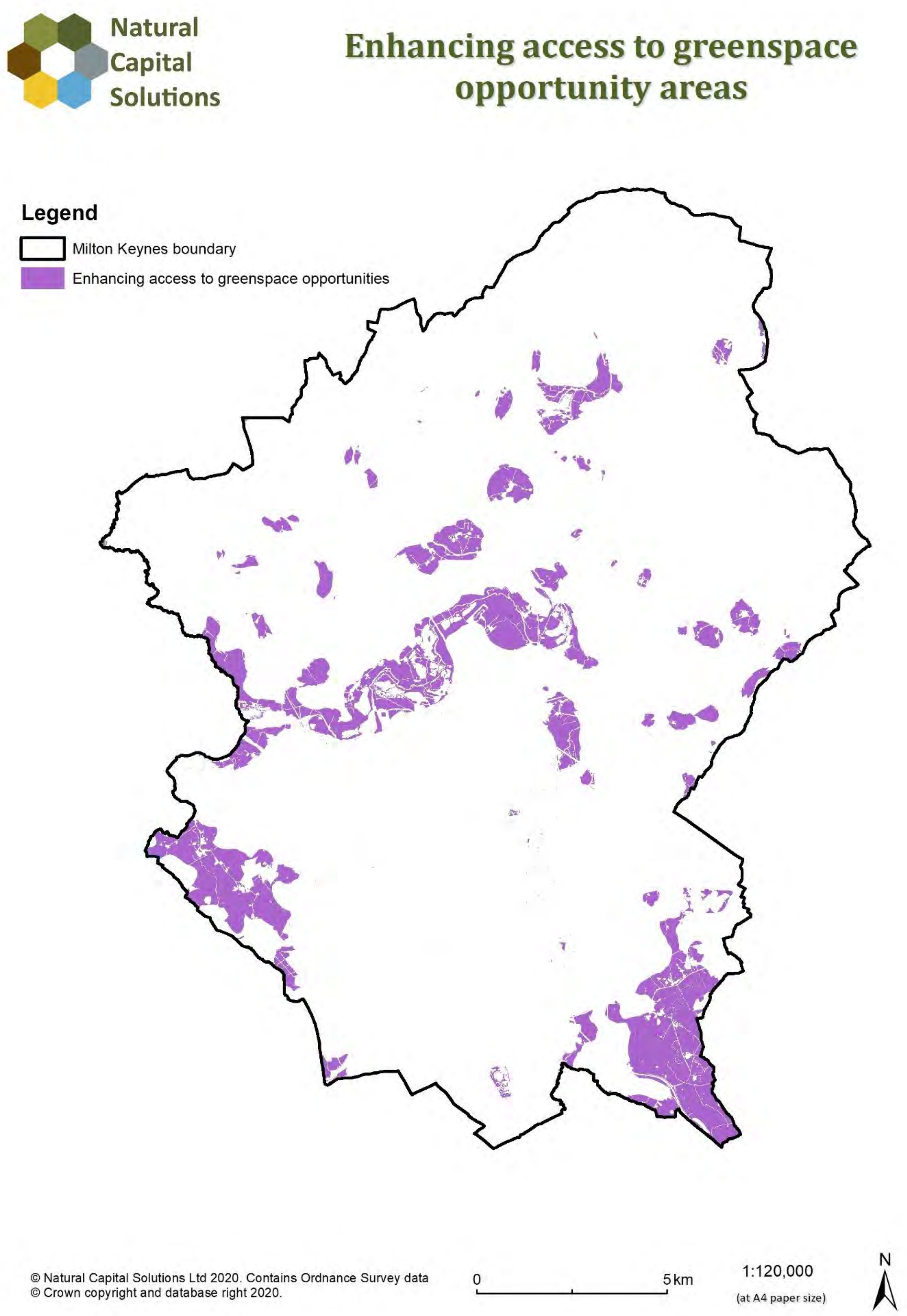


Figure 37 Opportunities for enhancing access to existing natural greenspaces across Milton Keynes.

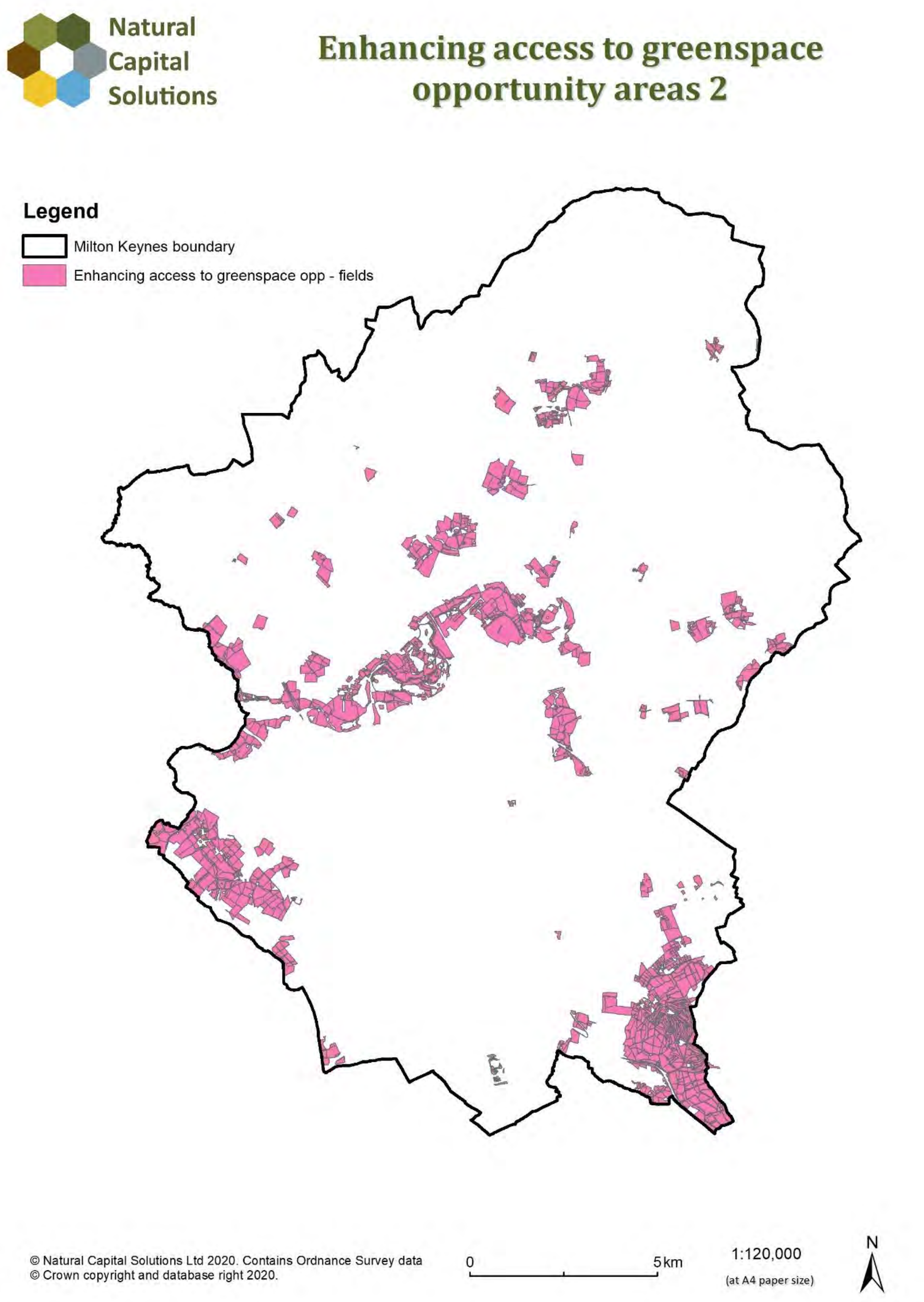


Figure 38 Field (plot) scale Opportunities for enhancing access to existing natural greenspaces across Milton Keynes.

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 provide 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 it 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 a greater weighting. This has not been attempted here, but it would be possible to combine the maps in any way wanted. Note that as the assessment below is concerned with creating new habitats, the opportunity map for accessible natural greenspace based solely on demand (Figure 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. 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 overlaid 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 the 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 in 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 every 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 urban areas are most often highlighted as being able to deliver multiple services in 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. Areas close to the main urban areas 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 (Figure 41). Indeed, opportunities are limited within the large urban area of MK. However, similarly to woodland, many areas support multiple opportunities. 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 along the river valleys, which contain a reasonable amount of existing semi-natural grassland.

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 study area offer some opportunities, but there are very few opportunities in the south of Milton Keynes (especially the south-west). A few of these locations are opportunity areas for two or more services. There are very few opportunities close to existing habitats (Figure 44).

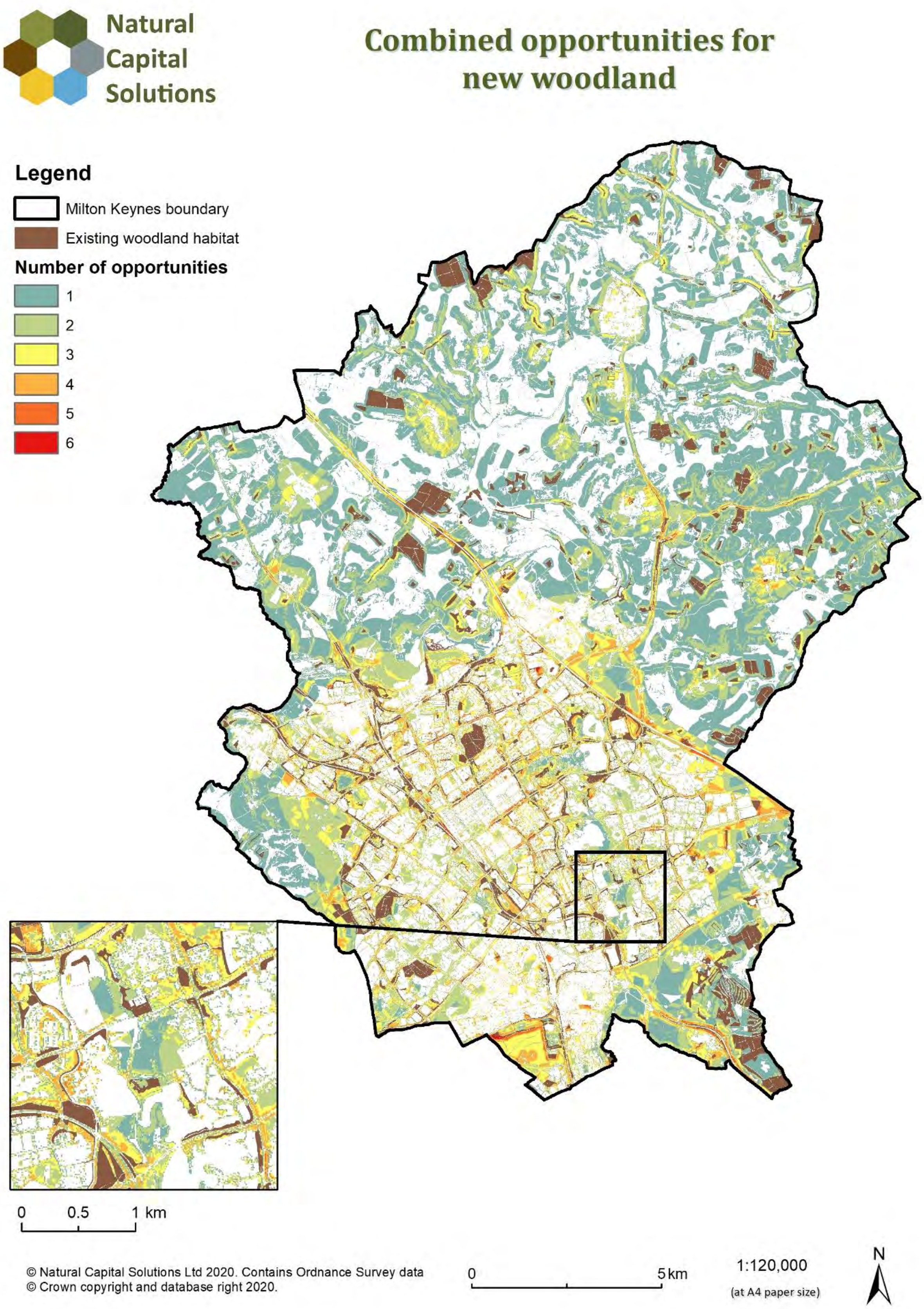


Figure 39 Existing broadleaved and mixed woodland, and combined opportunities for new woodland, across Milton Keynes.

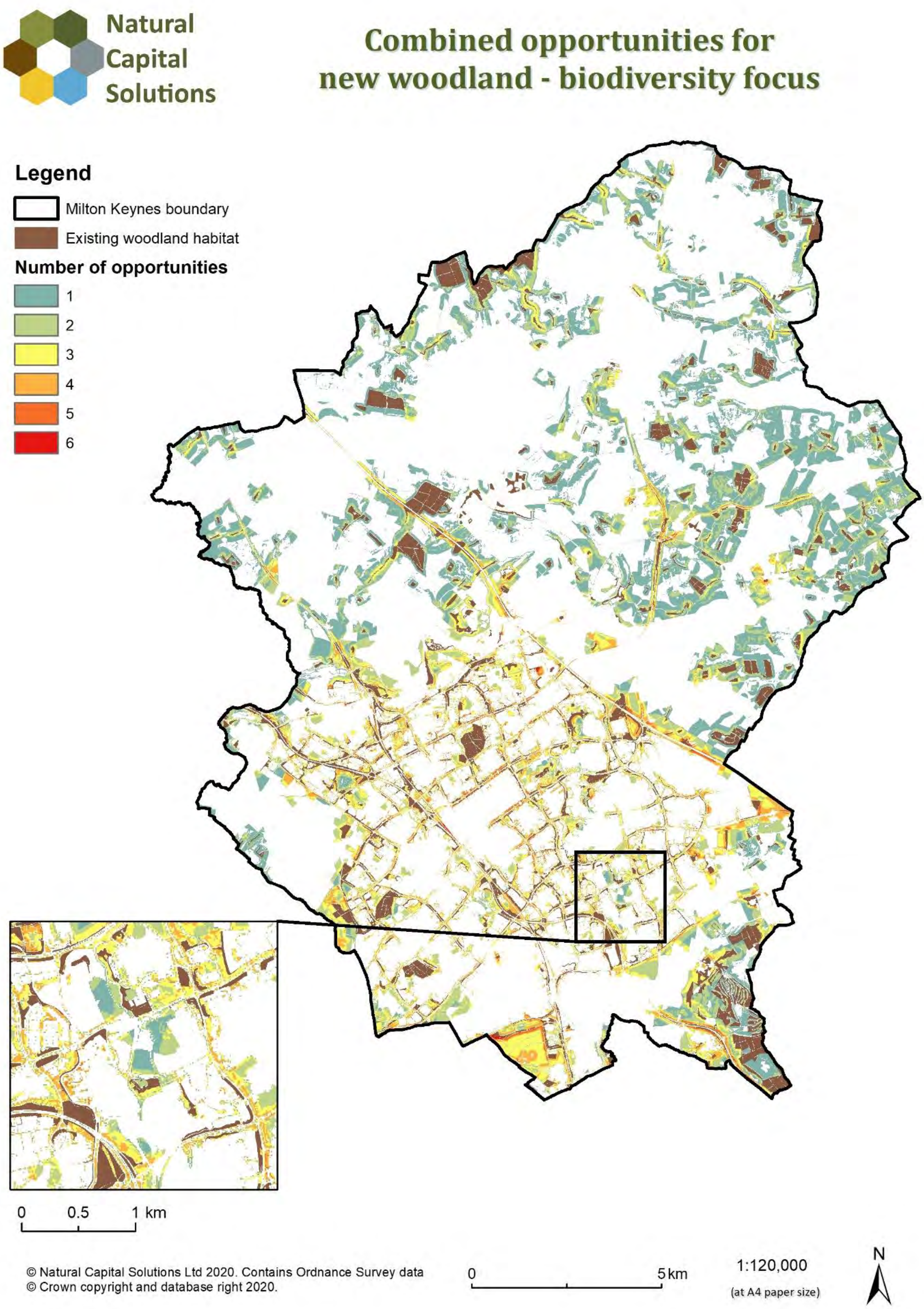


Figure 40 Combined opportunities for new woodland across Milton Keynes, restricted to areas that are ecologically connected to existing woodlands.

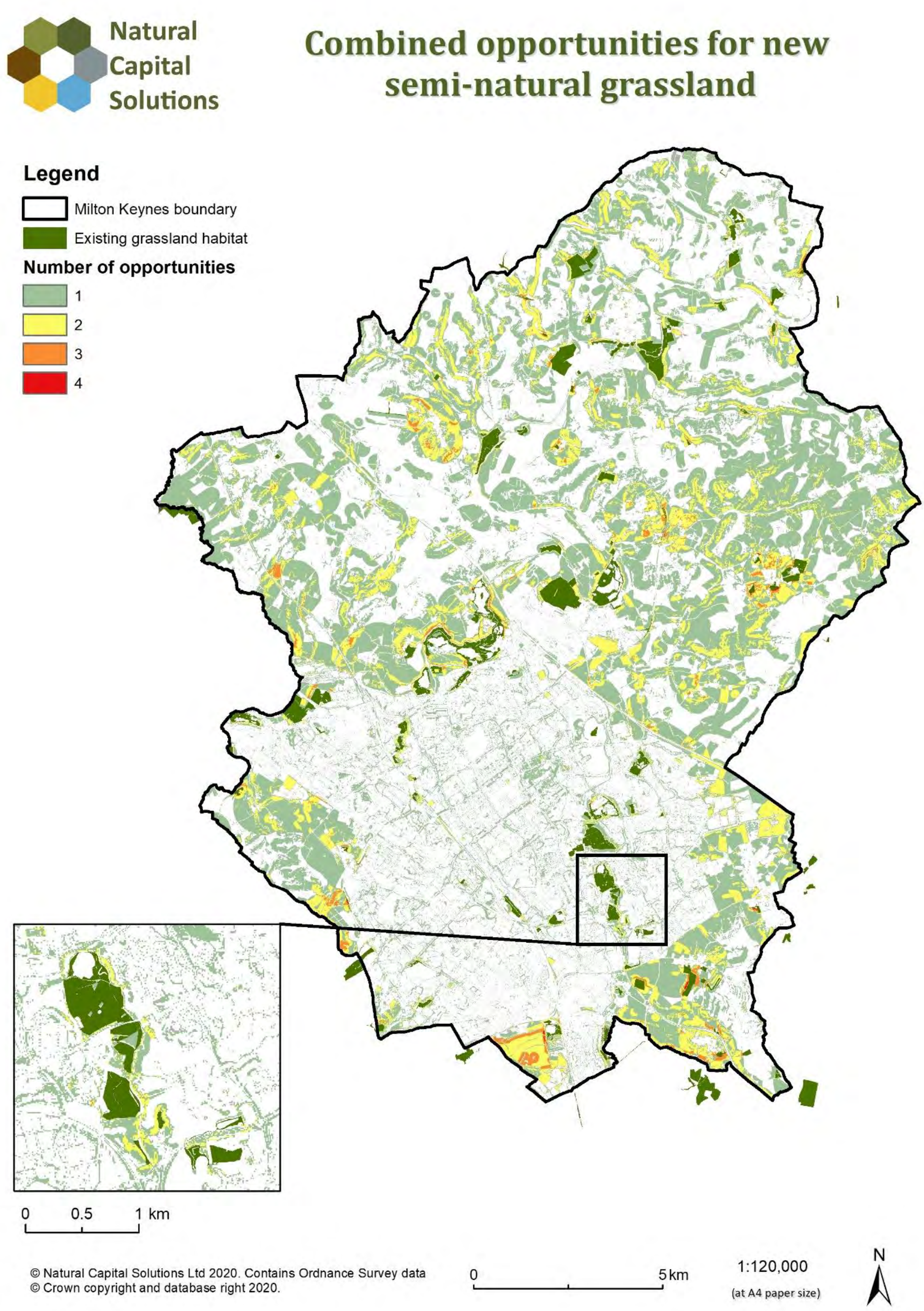


Figure 41 Existing semi-natural grasslands, and combined opportunities for new grasslands, across Milton Keynes.

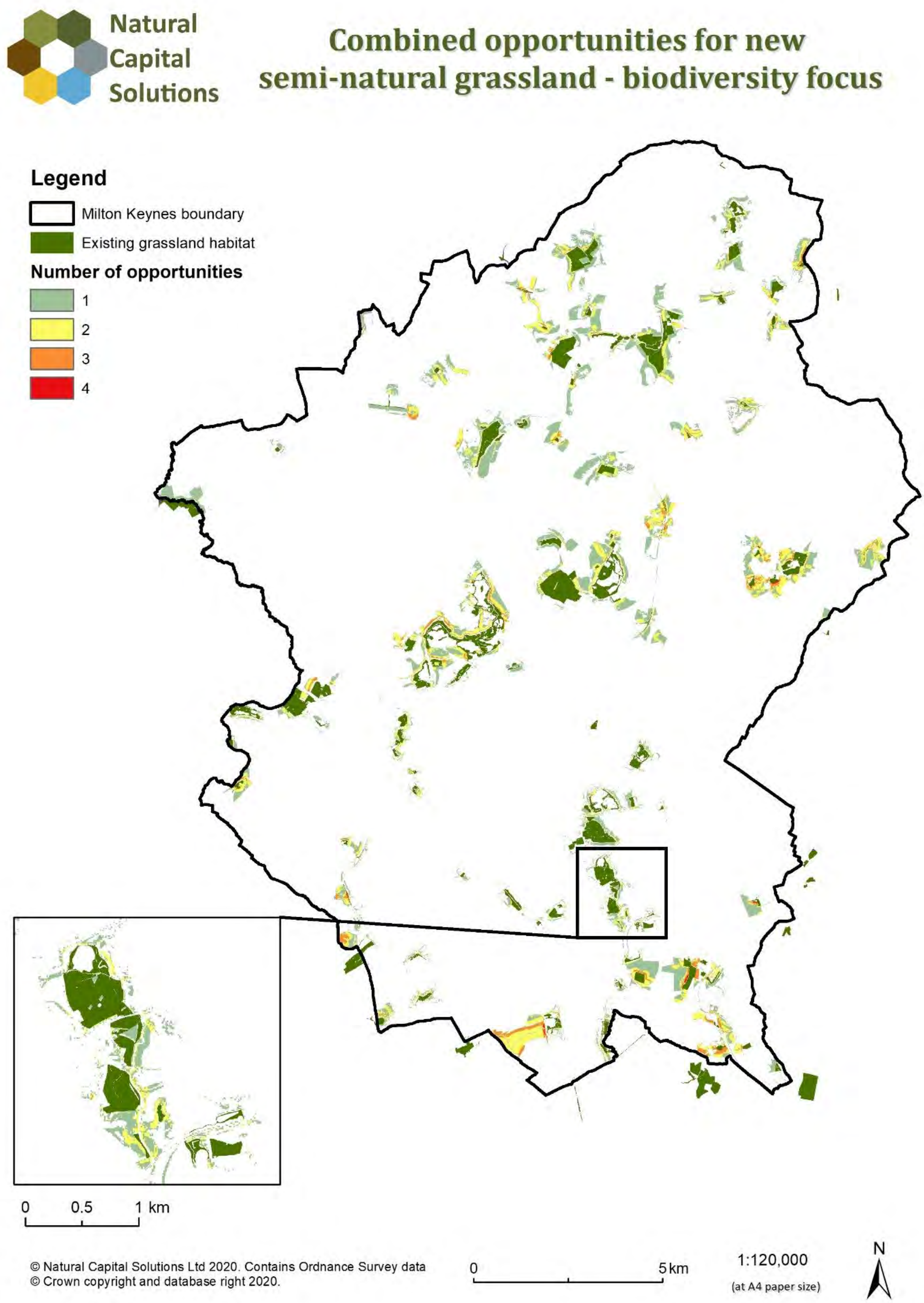


Figure 42 Combined opportunities for new semi-natural grasslands across Milton Keynes, restricted to areas that are ecologically connected to existing grasslands.

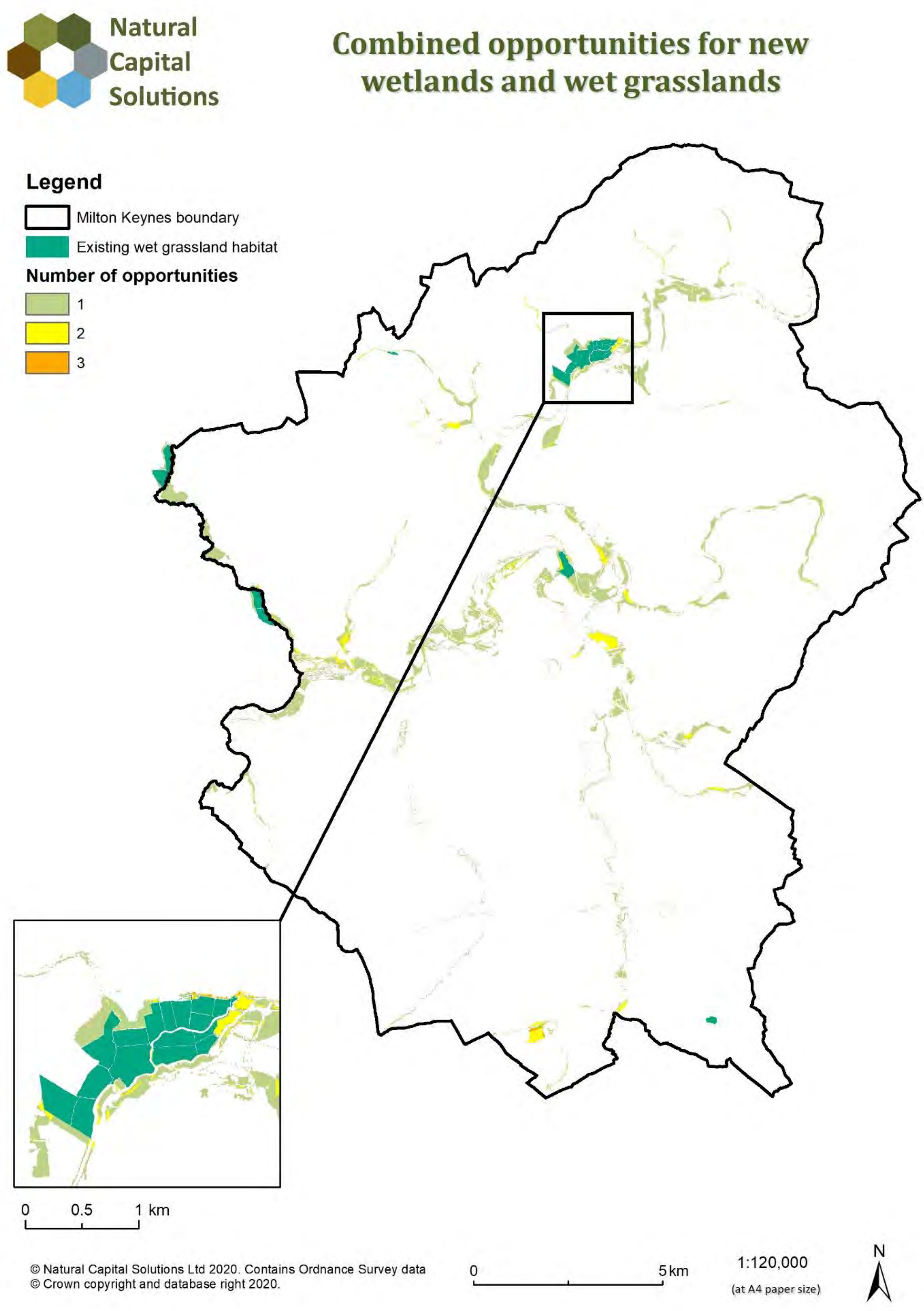


Figure 43 Existing wet grasslands and wetlands, and combined opportunities for new wetlands, across Milton Keynes.

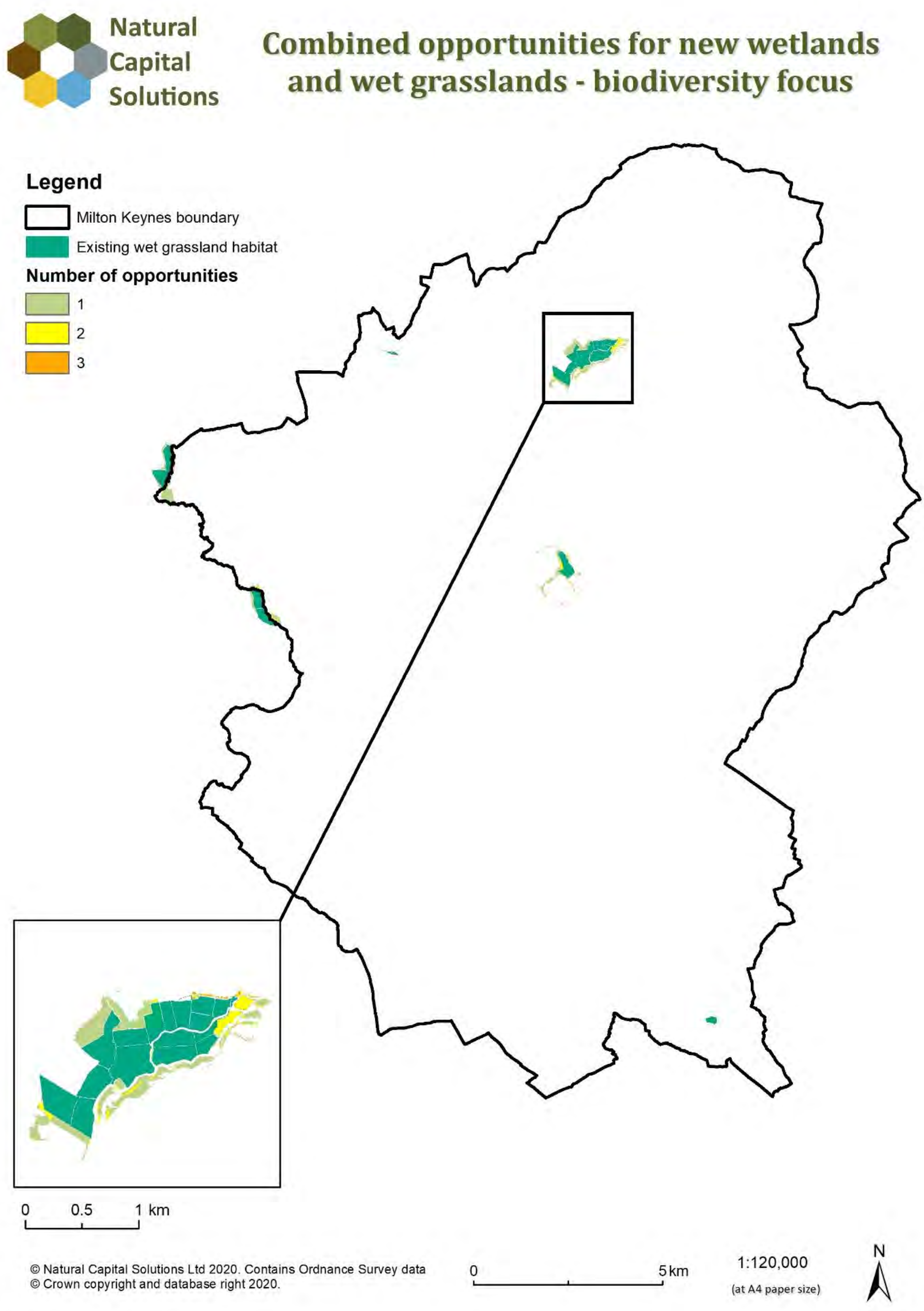


Figure 44 Combined opportunities for new wet grasslands and wetlands across Milton Keynes, restricted to areas that are ecologically connected to existing wetlands.

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 the Milton Keynes LA area. It provides the most comprehensive and detailed coverage that is possible at this time and should have a wide range of applications. The Local Authority area is dominated by arable land and improved grassland, but there are also extensive corridors of woodland and other semi-natural habitats that stretch into the heart of the urban areas of MK. Despite the apparent dominance of MK in the southern half of the area, built up areas and infrastructure only make up 11.4% of the area, with gardens comprising an additional 5.9% and amenity grassland 9.2%.

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 particularly 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. Like the woodland habitats, ecosystem delivery is well distributed across the study area and the extensive pockets and corridors of woodland spread across the urban area bring ecosystem services benefits into the heart of the built-up area. However, food production is greater within the rural north (dominated by arable and improved grassland). In contrast, the mapping also suggests that accessible nature capacity is concentrated in the southern half of the study area within the many parks located within and around MK. Notably, Willen Lake, Ouzel Valley Park, Woughton Park, Caldecote Lake, Bury Field and a number of the other linear parks spread across the urban area.

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

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 area. They also highlight areas where biodiversity offsetting should be focussed, under the forthcoming 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 projects to deliver additional benefits. Access to greenspace for people can be highly beneficial for physical and mental health and well-being and the monetary and social 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 Milton Keynes, 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. A similar project is currently underway in Buckinghamshire. 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 Milton Keynes'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 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 opportunity 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 projects 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.
- There is a strong degree of overlap between the approach described in this report and the steps above, with the forthcoming requirement for **Local Nature Recovery Strategies** (LNRS). For a LNRS, biodiversity is the primary driver, but there is a requirement to also consider multiple ecosystem services benefits. Therefore, the opportunity mapping presented in Section 5, where biodiversity opportunities are the focus, but with multiple benefits also mapped, can form the basis for producing a strategy, backed up by stakeholder engagement and further refinement based on local priorities.