Natural Capital Solutions

Habitat Opportunity Mapping in Northamptonshire and Peterborough

Author:

Dr Jim Rouquette

Contact details:

Dr J.R. Rouquette

Natural Capital Solutions Ltd

www.naturalcapitalsolutions.co.uk

jim.rouquette@naturalcapitalsolutions.co.uk

Report prepared for and funded by:

Wildlife Trust for Bedfordshire, Cambridgeshire and Northamptonshire, Northamptonshire County Council, Peterborough City Council, North Northants Joint Planning Unit, West Northants Joint Planning Unit, River Nene Regional Park, Natural England, and Environment Agency

Version: Final

May 2018

Executive Summary

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 certain constraints into account. In this project, opportunities for new habitats have been mapped across the whole of Northamptonshire and Peterborough. Opportunities have been mapped to enhance biodiversity for three different broad habitat types (broadleaved and mixed woodland, semi-natural grassland, and wet grassland and wetland), to reduce surface water runoff, to reduce soil erosion and improve water quality, to ameliorate air pollution, and to increase access to natural greenspace.

The biodiversity opportunity maps highlight areas that are best located in terms of their connectivity to existing habitat patches and are therefore most appropriate from an ecological point of view. The remaining opportunity maps highlight the top 10% of sites for each respective service, although it would be possible to consider a wider or narrower range of sites if desired.

The different opportunity areas vary in their geographic location; broadleaved and mixed woodland biodiversity enhancement is centred around Rockingham and Salcey Forests, wet grassland and wetlands are focussed on the floodplain of the Middle Nene, whereas opportunities for semi-natural grassland are more spread throughout the study area. The greatest opportunities for reducing water flow are situated to the west of the study area on hillier terrain, whereas water quality opportunities tend to be adjacent to water courses. Air quality and accessible greenspace opportunities are focussed in and around the major towns. There is, however, some overlap between these opportunity areas.

In addition to mapping the individual opportunities, maps were also combined to highlight opportunities to enhance multiple services at the same time. Planting woodland and trees, in particular, provides opportunities to deliver multiple benefits. Key locations for delivering these multiple benefits were around the edges of the major towns.

The opportunity maps can be used to assist with the development of green infrastructure strategies and planning, locating the best places for biodiversity offsetting and natural capital net gain initiatives, for agri-environment scheme targeting, and as an important step towards producing a natural capital investment plan or strategy for the area. In addition, potential mechanisms to take this forward include natural flood risk management and catchment sensitive farming schemes, health and wellbeing initiatives, and UK Woodland Carbon Code projects. 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 opportunities in different locations, and to prioritise locations to take forward.

Contents

Habitat Opportunity Mapping in Northamptonshire and Peterborough

1. Introduction

As part of the Nene Valley Nature Improvement Area (NIA) Project, maps showing the supply of, and demand for, a whole range of ecosystem services were produced across the Nene catchment (Rouquette 2016). This showed the current situation in the Nene Valley, but an obvious next step was to consider the potential for habitat creation to enhance the provision of a range of services. Natural Capital Solutions was therefore commissioned by a consortium of partners to produce habitat opportunity maps for Northamptonshire and Peterborough. This extended the geographic coverage of the previous work to cover the whole of these two areas and focussed on the benefits deemed most important from the previous mapping work.

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 certain constraints 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 increase access to natural greenspace

The approach taken, and results obtained for each of these potential services are described in turn in Sections 3-7 of this report. Section 2 begins by describing how the baseline natural capital assets were mapped, along with a number of constraints, which show where habitat cannot or should not be created. These constrained areas were subsequently removed from the opportunity maps. Maps have also been combined to show areas that could deliver multiple benefits, and this is described in Section 8.

Please note that the mapping identifies areas based on landscape-scale ecological principles or indicative ecosystem services models and does not take into account local site-based factors that may impact on suitability. Any areas suggested for habitat creation will require ground-truthing before implementation. The maps should be seen as a tool to highlight key locations and to guide decision making, rather than an end in themselves. Further steps are highlighted at the end of this report (Section 9), which would move towards identifying specific projects to take forward. Potential applications and funding mechanisms are also outlined.

One of the key outputs from this project are the numerous GIS maps and layers. The opportunity mapping layers are being made available to all project partners and a list of available layers is provided in Annex 2.

2. The baseline – natural capital assets and constraints

2.1 Natural capital assets

The first step in producing opportunity maps is to create a detailed basemap showing habitats and other information across the study area. Although such a basemap was produced for the Nene Valley NIA Project, the study area for the current work was considerably larger, comprising the whole of Northamptonshire and Peterborough, hence it was necessary to produce a new version of the basemap. As well as covering a larger area, a further advantage of producing a new basemap was that it could be updated, using the latest data sets.

The approach taken used MasterMap polygons as the underlying mapping unit and then utilised a series of different data sets to classify each polygon to a habitat type and to associate a range of additional data with each polygon. This was done using EcoServ GIS, a toolkit developed by the Wildlife Trusts, with a number of bespoke modifications. The data that was used to classify habitats is shown in Box 1.

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

- OS MasterMap topography layer
- OS vector maps
- Open space (green infrastructure) data sets for each local council (9 local councils in total). Data highly variable from council to council, so had to be extensively pre-processed to ensure compatibility and usability in EcoServ GIS. Each open space area also checked to determine if it was publicly accessible or not.
- BAP habitat – up-to-date data supplied by Northamptonshire Wildlife Trust, which also covered the River Nene corridor in Peterborough. 24 data sets for individual habitats were merged and were then combined with data taken from the national Priority Habitats Inventory (Natural England) for areas not covered by the former. Required pre-processing to determine if each polygon was BAP quality or not, and to classify each habitat to fit with EcoServ GIS requirements.
- Corrine European habitat data – used to identify quarries, industry and golf courses, and to distinguish arable from pasture
- CEH Land Cover Map 2007
- Layer that identified urban areas
- Ancient Woodland Inventory data

Polygons were classified into Phase 1 habitat types and were also classified into broader habitat groups. Multiple modifications were made to the EcoServ GIS programme code to enable improved classification of habitats. Furthermore, upon initial completion the basemap was carefully checked and manual alterations were made in a number of places where miss-classifications had occurred. The final basemap covered the whole of Northamptonshire and Peterborough, as well as a small section of Huntingdonshire (for completeness), and covers an area of 275,000 ha or 2,750 km^2. It contained 1.72M polygons, each of which was classified to an appropriate habitat type.

2.2 Constraints

A key feature of opportunity mapping is that constraints to habitat creation are identified and these are then removed from the final 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:

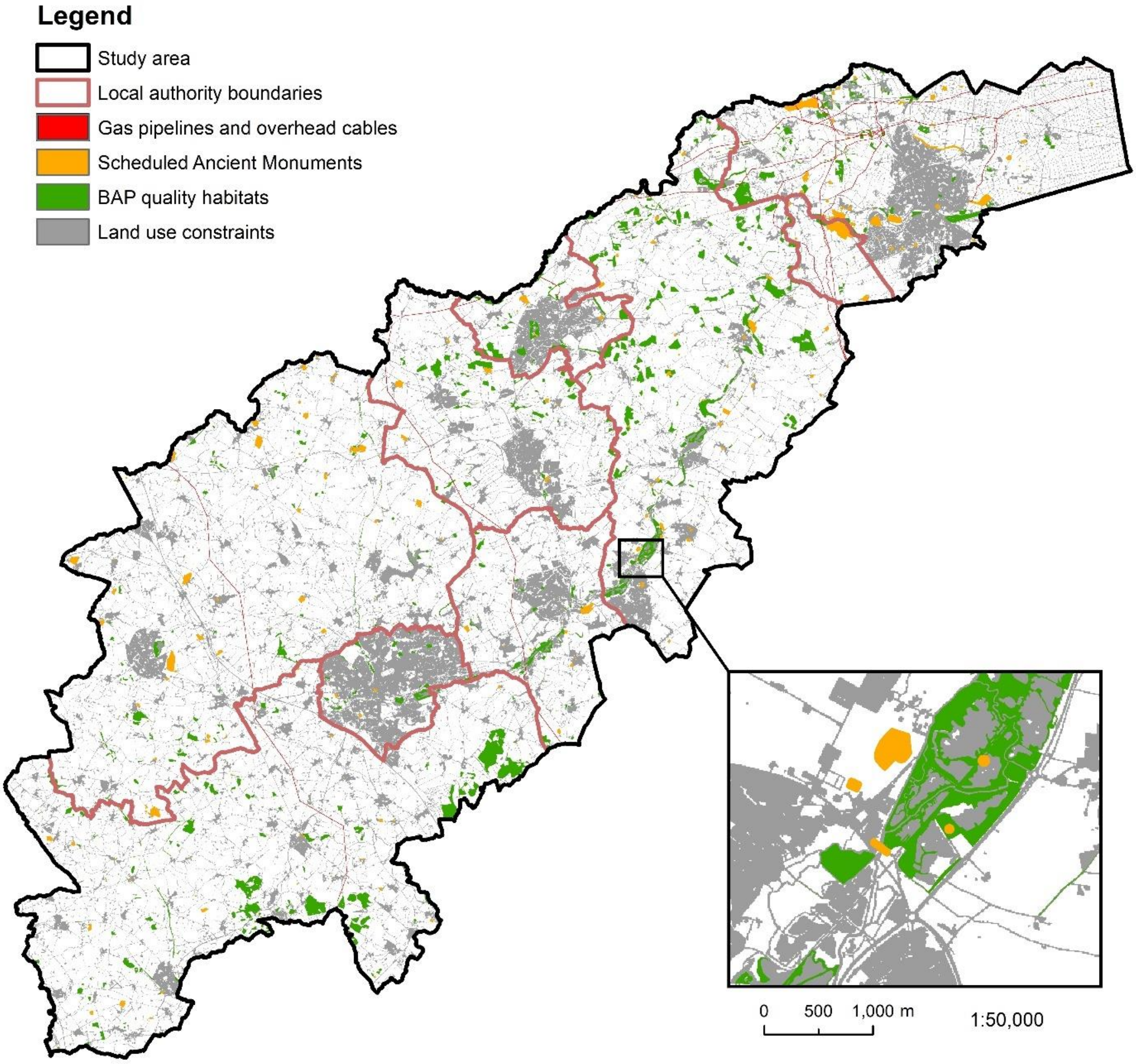
- Infrastructure – roads, railways, and paths
- Urban – including all buildings in towns and villages
- Gardens – linked to the above, it is highly unlikely that these would be available for habitat creation
- Water – standing and running water
- BAP habitats – all existing BAP quality habitat was identified. It was decided that existing high quality habitat should not be sacrificed to create new habitat of a different type. This constraint was not applied when enhancing public access with no change in habitat, although this would need to be checked on a site by site basis when taking forward particular opportunities identified.
- Scheduled Ancient Monuments (SAMs) – data was obtained on the location of SAMs across the study area and a 30m buffer was applied around each individual SAM. Again, this constraint was not applied when enhancing access only.
- National Grid gas pipelines and overhead cables – data was 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 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.

A map showing the constraints identified above is shown overleaf (Map 1). The exact constraints to be applied varied depending on the opportunity being mapped, and the combinations used for each particular opportunity map are outlined in the appropriate sections of this report.

Map 1: Key constraints taken into account during habitat opportunity mapping across Northamptonshire and Peterborough.

Natural Capital Solutions

Opportunity mapping constraints



This maps shows constraints, where new habitats cannot or should not be created. These were:
Landuse constraints - infrastructure, urban, gardens, water.
Existing Biodiversity Action Plan (BAP) quality habitats.
Scheduled Ancient Monuments (SAMs) with a 30m buffer applied.
Gas pipelines and overhead cables with a 10m buffer - note that this was only applied for woodland opportunity mapping.

0 10 20 Km

1:430,000
(at A4 paper size)

N

3. 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 Northamptonshire and Peterborough. The broad habitats and their constituent types are shown in the table below:

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

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

3.1 Method

1. <u>Landscape permeability</u>

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 Northamptonshire and Peterborough 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, birds, butterflies, and plants. The average dispersal distance for each habitat is shown in the table below:

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

3. *Identifying constraints*

The habitat network map created in Step 2 can be used to indicate where new habitat could be created; any habitat created within the existing network would be ecologically connected to existing patches. However, in reality a number of constraints exist that need to be taken into account when producing opportunity maps. The following constraints were therefore mapped for all three habitat types (more details provided in Section 2.2 and Map 1):

- Land use constraints – urban, infrastructure, gardens and water
- Biodiversity Action Plan (BAP) quality habitats
- Scheduled Ancient Monuments (SAMs), with a 30m buffer

In addition, for broadleaved and mixed woodlands only, gas pipelines and overhead cables, with a 10m buffer, were included. Wet grassland and wetland habitats opportunity areas were restricted to areas within the indicative floodplain, as indicated by the Environment Agency's Flood Zone 2 map.

4. *Habitat opportunity for biodiversity*

In the final step, the constraints map was used to exclude areas that would be unsuitable or unavailable for new habitat. Two layers of habitat opportunity were then created:

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

For both opportunity layers, a minimum threshold size was set at 0.1 ha, to remove tiny fragments of land and to replicate the minimum sizes of habitat creation grant schemes.

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

3.2 Results

The results are illustrated here for semi-natural grassland habitats, with the wet grassland and wetland, and broadleaved and mixed woodland maps following in Annex 1. The inset map shown on each map page is included to show more clearly the detail of each layer, although the location chosen is not significant.

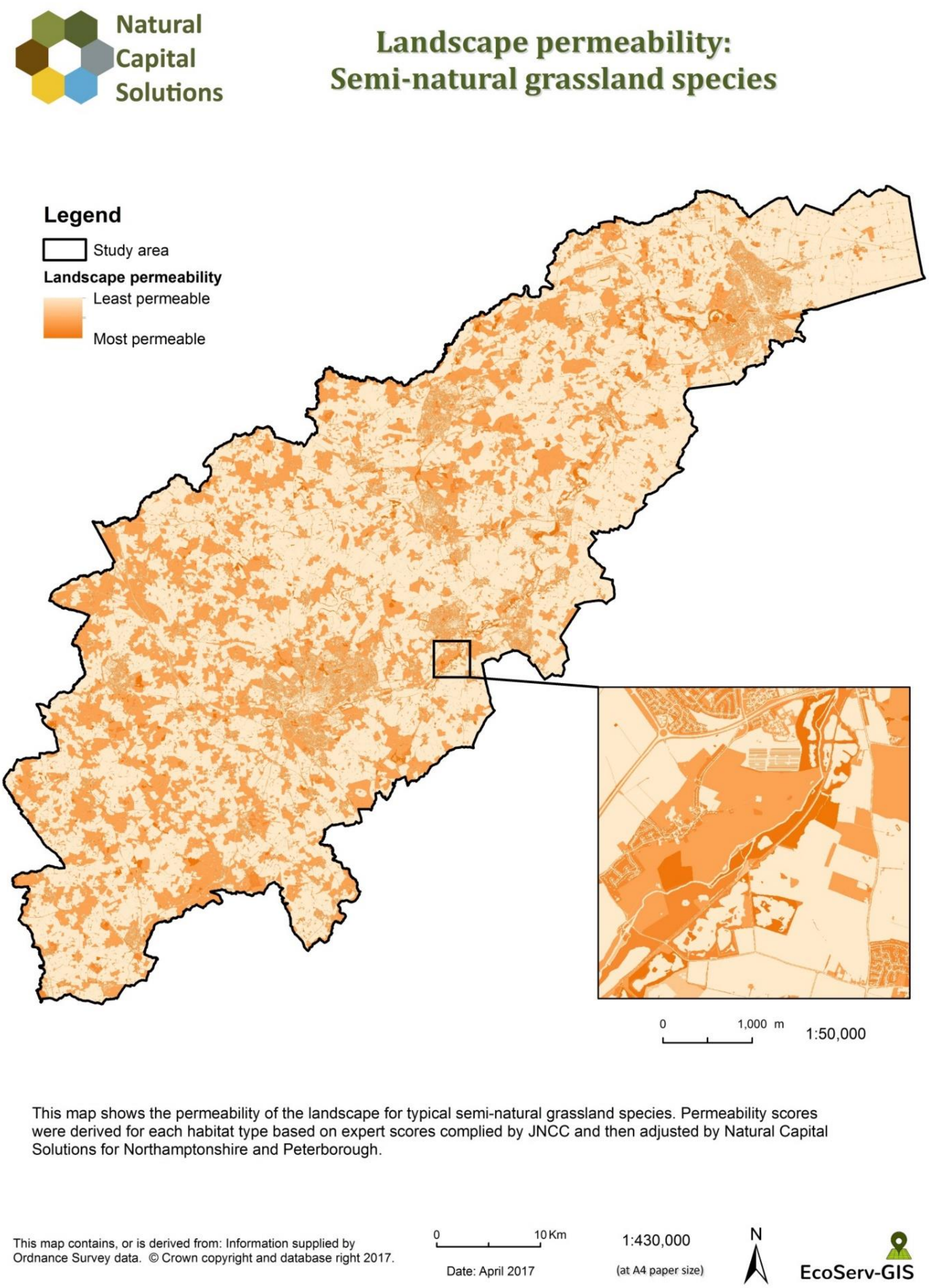
The permeability of the landscape for typical semi-natural grassland species is shown on Map 2. Darker areas are more permeable, meaning that typical species are expected to travel further across these habitats and hence will be less of a barrier to movement. For all three broad habitat types, arable fields are the most significant barrier to movement.

An example of the habitat network map for semi-natural grassland is shown on Map 3. Habitats that are ecologically connected are linked within a network shown in grey. White space between habitat patches indicate that the patches are not ecologically connected and dispersal between the patches is less likely to occur. For semi-natural grasslands (Map 3) and wet grassland (Map A2), parts of the River Nene corridor are providing a near-continuous network, although there are opportunities to enhance this further. For woodland (Map A6), the most significant networks are focussed around the Rockingham Forest area, although many patches of woodland in this area remain ecologically isolated.

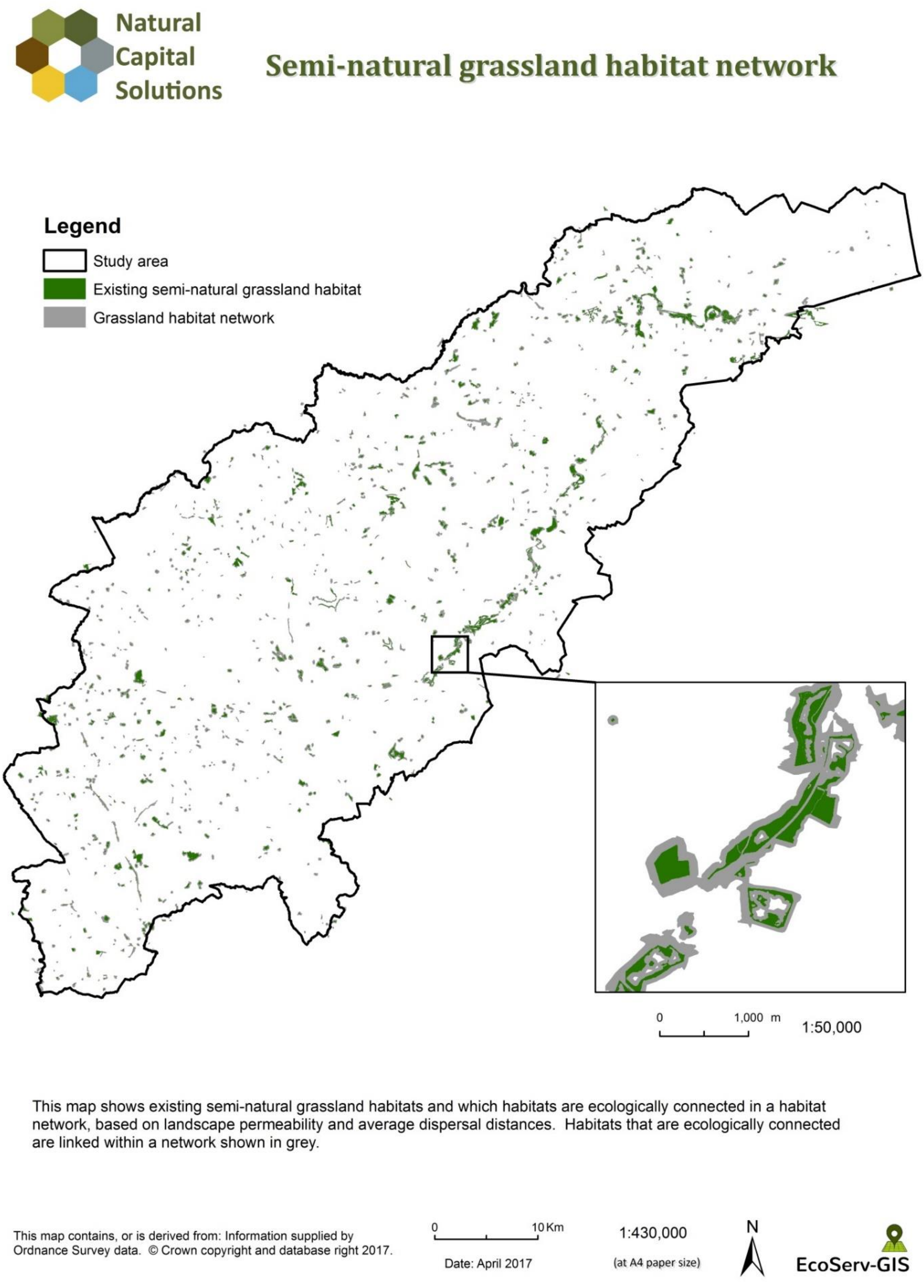
Once constraints have been removed, the resulting maps show biodiversity opportunity areas. Map 4 illustrates these for semi-natural grassland habitats, showing both buffer and stepping-stone opportunities. The fields buffer layer is shown on Map 5 for semi-natural grassland, with the other habitats in Annex 1. Note that the fields stepping-stone layer is not shown but is available as a GIS layer. These maps highlight whole fields where habitats could be created, as these are a more meaningful management unit for conservation action. There are many areas, spread fairly evenly across Northamptonshire and Peterborough, where semi-natural grassland could be created in fields to considerably enlarge and connect existing networks. For wet grassland and wetlands (Map A4), the focus is almost exclusively on the corridor of the middle Nene (with some opportunity in fenland around Peterborough), and field scale habitat creation could create a large well-connected network of this habitat. Broadleaved and mixed woodland opportunities exist throughout the study area (Map A8), but are most extensive around Rockingham Forest, where field-scale habitat creation could (re-) connect many isolated forest fragments, thereby creating a large ecologically connected forest on the site of the ancient Rockingham Forest.

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 9.2).

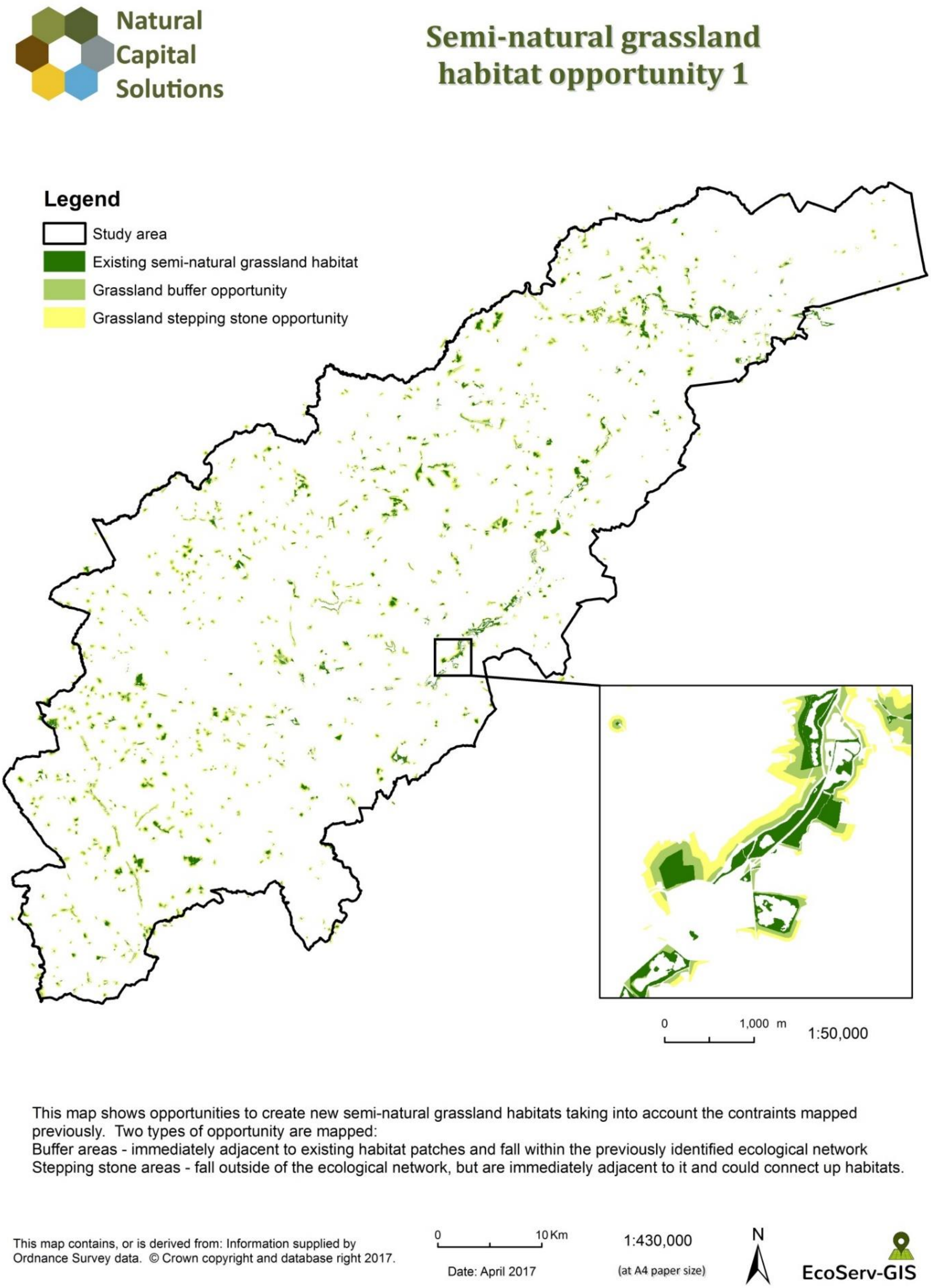
Map 2: Landscape permeability for typical semi-natural grassland species across Northamptonshire and Peterborough.



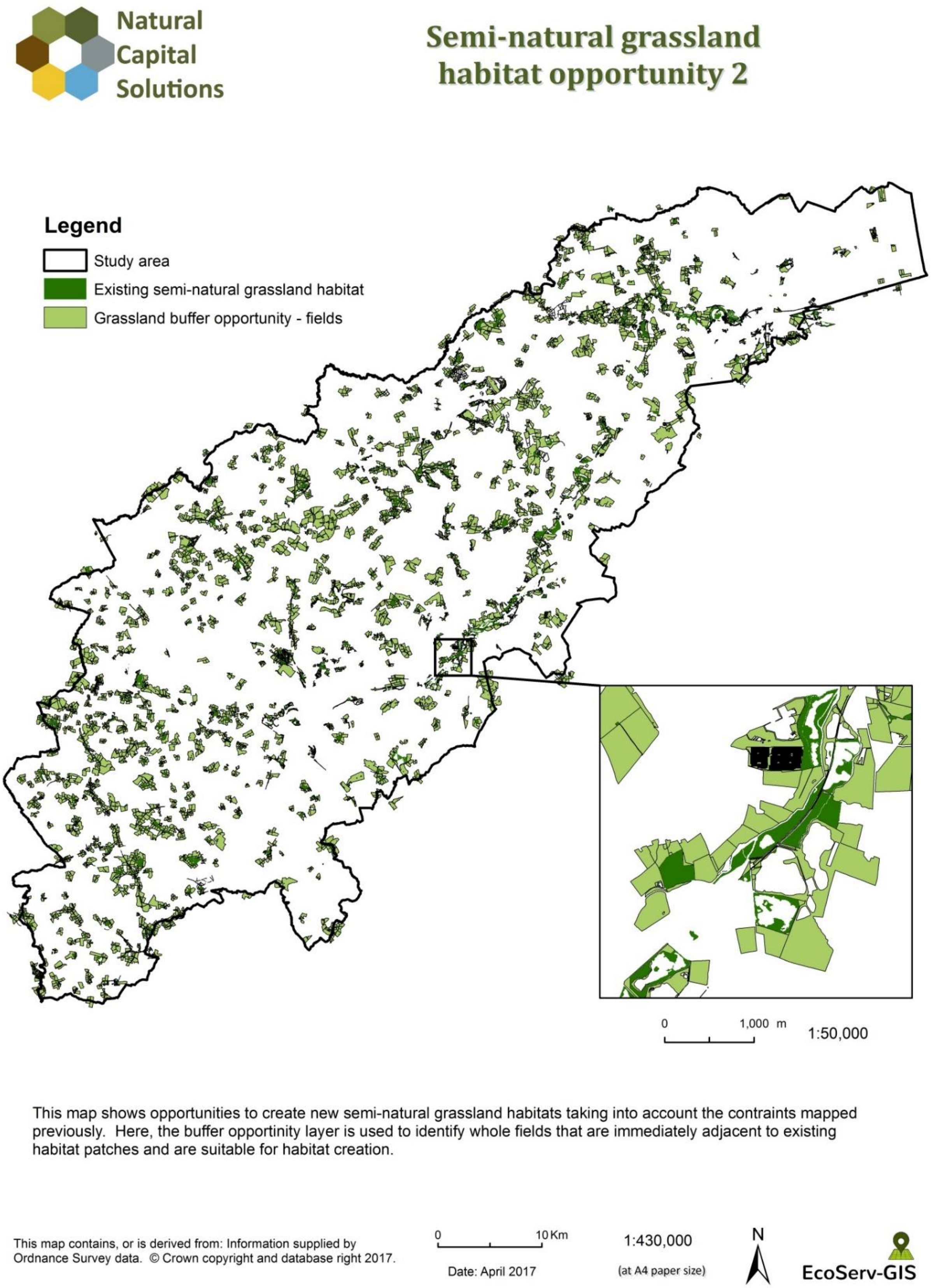
Map 3: Habitat network for semi-natural grasslands across Northamptonshire and Peterborough.



Map 4: Buffer and stepping-stone biodiversity opportunity areas for semi-natural grassland across Northamptonshire and Peterborough.



Map 5: Field scale biodiversity opportunity areas for semi-natural grassland across Northamptonshire and Peterborough.



4. Opportunity mapping to reduce surface runoff

Following a number of recent flooding events in the UK and the expectation that these will become more frequent over the coming years due to climate change, there is growing interest in working with natural process to reduce downstream flood risk. These projects aim to "slow the flow", 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 using two methods:

- **Slowing the flow across the catchment** – this was based on a previously developed water flow regulation model, taking into account slope, soil type, sealed surfaces and existing land-use. It highlights areas across the whole catchment where changing land-use would have the greatest impact on reducing runoff.
- **Floodplain woodland opportunity** – this was based on methods developed by Forest Research for the Midlands Woodlands for Water project (Broadmeadow et al 2013), with additional constraints applied to make it most relevant to Northamptonshire and Peterborough. It identifies areas where woodland could be planted in areas at risk of flooding, to slow surface water runoff, absorb water and reduce sediment and pollutant loads flowing into the river network.

4.1 Slowing the flow across the catchment - Method

1. *Modelling and mapping water flow regulation*

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 (EA 2008) and SEPA's natural flood management (runoff reduction) maps (SEPA 2013). Runoff can generally be assessed based on three factors: land use, slope and soil type and so the following indicators were developed and mapped for each 10m by 10m cell across the study area:

- **Roughness score** – Manning's Roughness Coefficient provides a score for each land use type based on how much the land use will slow overland flow.
- **Slope score** – based on a detailed digital terrain model, slope was re-classified into a number of classes based on the British Land Capability Classification and others.
- **Standard % runoff** – was obtained from soil data and modified to reflect soil hydrological properties and their sensitivity to structural degradation from agricultural use (from Broadmeadow et al 2013). This was integrated with a layer showing impermeable areas where no soil was present (sealed surfaces, water and bare ground).

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

2. *Identifying constraints*

Constraints were identified and mapped in the same way as described in Section 2.2. The following constraints were included and joined together onto one map:

- Land use constraints – urban, infrastructure, gardens and water
- Biodiversity Action Plan (BAP) quality habitats
- Scheduled Ancient Monuments (SAMs), with a 30m buffer
- Gas pipelines and overhead cables, with a 10m buffer

3. *Identifying opportunity areas*

All locations where it would be difficult to change habitats (the constraints map above) were erased from the water flow regulation map developed in step 1, to leave a map showing water flow regulation in all unconstrained locations. This was then classified into 10 percentiles (i.e. the top 10% were identified, 10-20%, 20-30% and so on) and the top 10% were extracted into a different map layer. Therefore, this shows the top 10% 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 25% of areas or the top 5% (or any other value), to show a wider or narrower range of sites respectively, if desired.

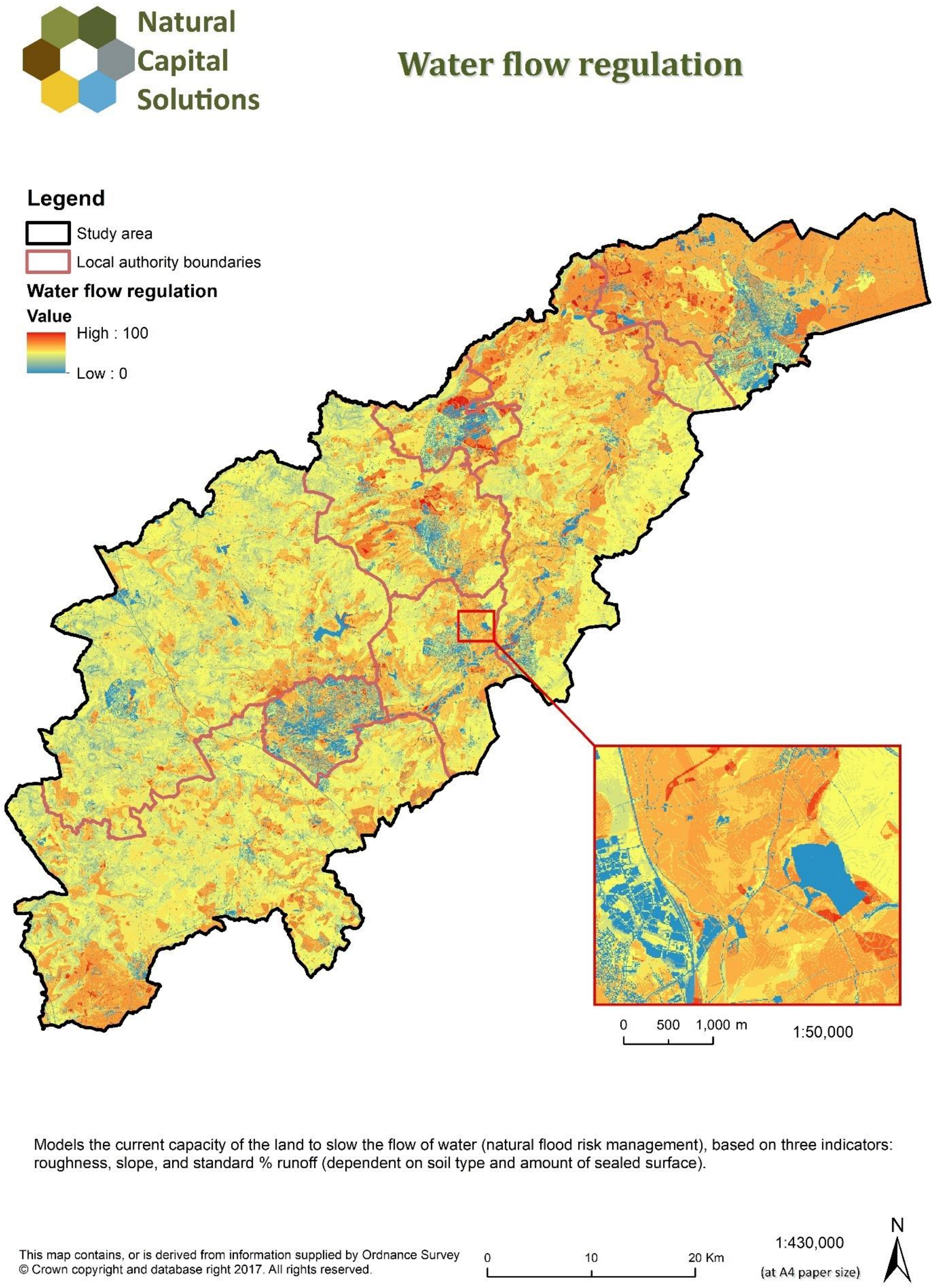
The final opportunity map identifies a large number of very small polygons and many polygons do not coincide with fields, the scale over which management and land use change is likely to take place. Therefore, as for biodiversity opportunity areas, it was considered beneficial to identify whole fields 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 Slowing the flow across the catchment – Results

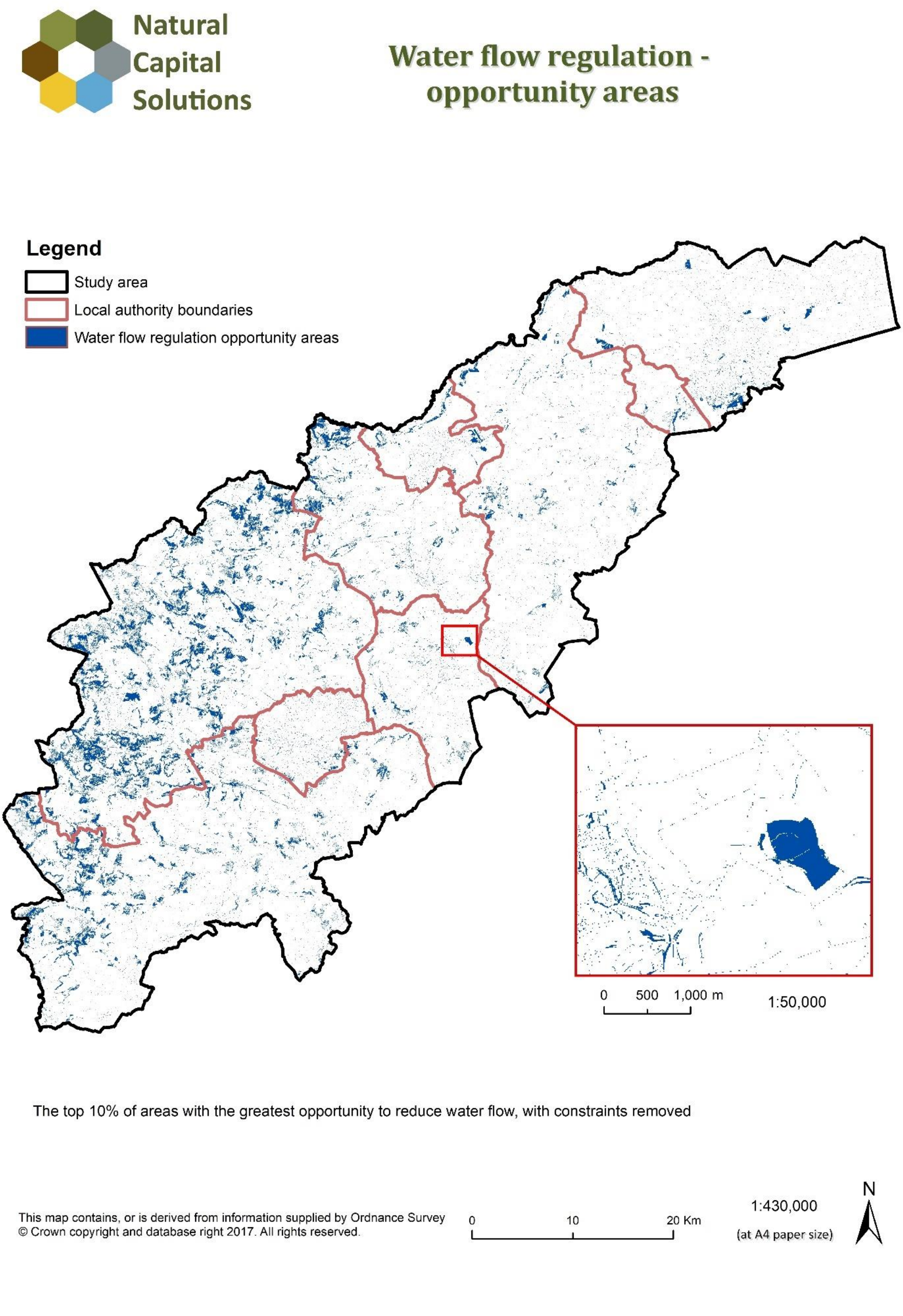
Map 6 models water flow regulation across the study area. The worst areas (shown in blue on the map) are generally related to impermeable land surfaces, especially in urban areas. Many of these are buildings and infrastructure, which were not assessed as part of this project, although could be suitable for the installation of green roofs and other types of retrofitted Sustainable Drainage Systems (SuDS).

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 Map 7. The most striking feature was the west-east split, with the majority of best opportunities being located in the west of Northamptonshire, especially in Daventry and South Northamptonshire local authority areas. These are often areas of arable fields on sloping land. In the east of the study area, where there are very few slopes, some of the larger opportunity areas are highlighting bare soil related to quarries. The opportunity areas have been displayed in relation to fields and plots of land in Map 8.

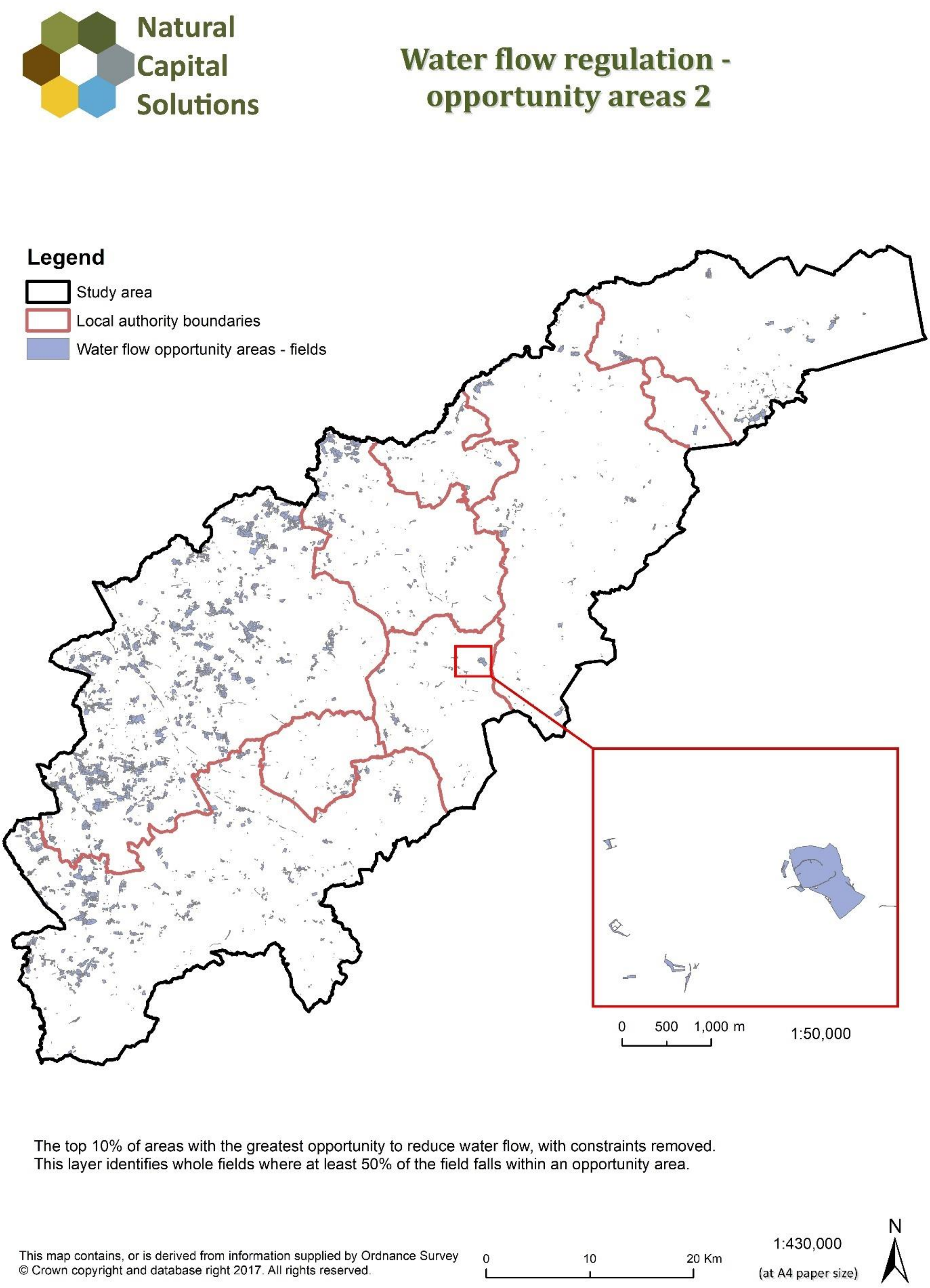
Map 6: Water flow regulation across Northamptonshire and Peterborough.



Map 7: Water flow regulation opportunity areas across Northamptonshire and Peterborough.



Map 8: Field scale water flow regulation opportunity areas across Northamptonshire and Peterborough.



4.3 Floodplain woodland opportunity – Method

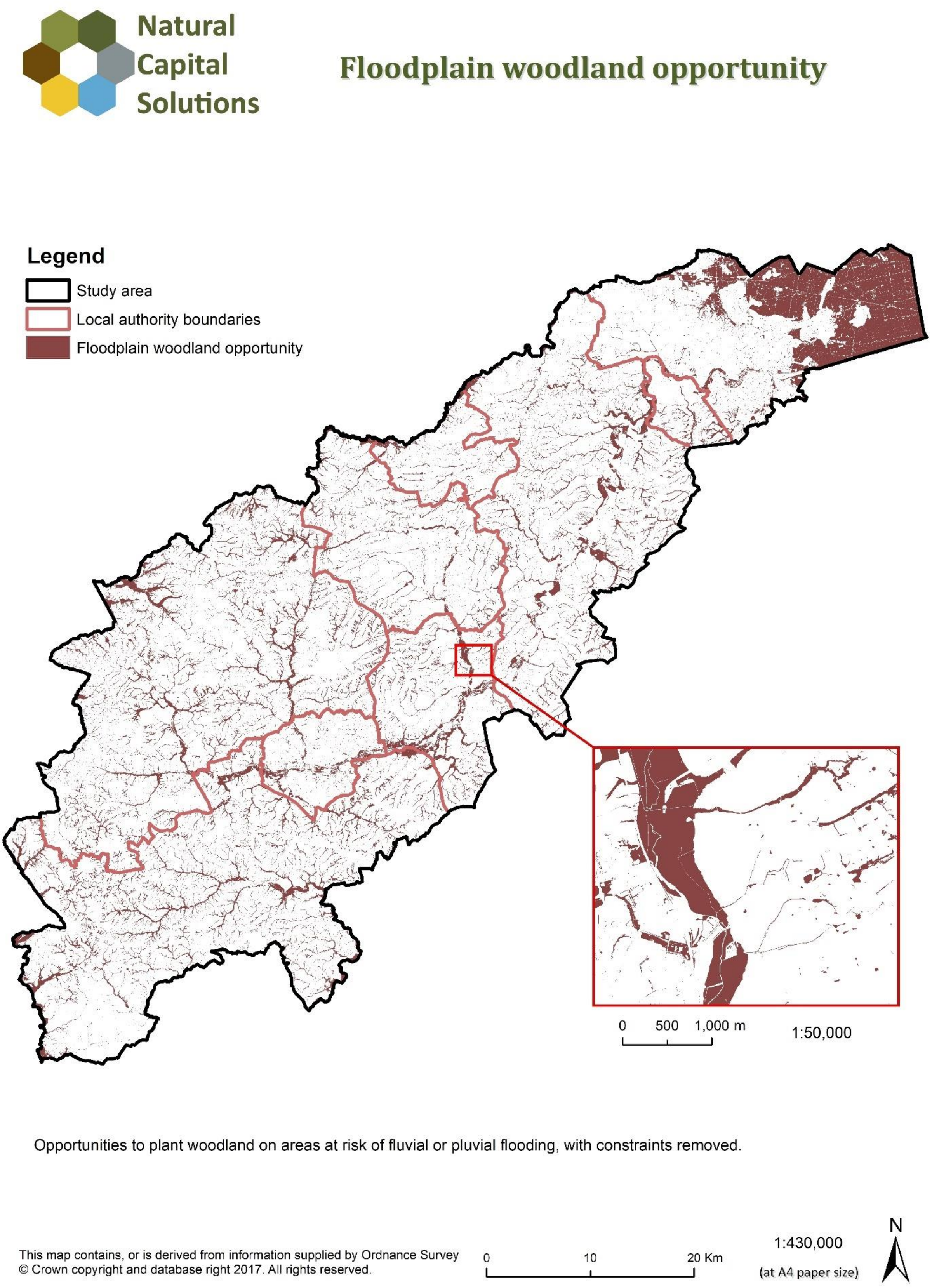
This followed the approach developed by Forest Research for the Midlands Woodlands for Water project (Broadmeadow et al 2013). The following steps were undertaken to map floodplain woodland opportunity across the study area:

1. A map was produced that identified areas that are susceptible to either river (fluvial) or surface water (pluvial) flooding with a greater than 1 in 1000 risk. To do this, the Environment Agency's updated Flood Map for Surface Water (uFMfSW) showing flooding extent at 0.1% risk, was combined with a map of Flood Zone 2 (river flooding extent at 0.1%).
2. A constraints layer, showing where it would be inappropriate or impossible to plant floodplain woodland was created, exactly as described in Section 4.1. This therefore contained all the constraints recommended in the Midlands Woodland for Water Project, with the addition of existing BAP habitats, as it was decided that it would be inappropriate to plant new woodland on locations that contained high quality habitats.
3. The two maps were then combined and areas identified as being subject to constraints were erased.

4.4 Floodplain woodland opportunity – Results

The output is shown on Map 9 on the next page. It shows the opportunity areas for floodplain woodland planting, after constraints and habitat sensitivities have been taken into account. It is focussed largely on the floodplain of the River Nene. This map highlights mostly different areas to the map based on water flow regulation (Map 8) and there is only a small amount of overlap between the two maps.

Map 9: Opportunities to plant floodplain woodland across Northamptonshire and Peterborough.



5. 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.

5.1 Method

1. <u>Modelling and mapping water quality (soil erosion) regulation</u>

A modified version of an EcoServ GIS model was developed, which combines a coarse and fine-scale assessment of erosion / sedimentation 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 river waterbody catchment (identified by the Environment Agency for Cycle 2 of the Water Framework Directive) was calculated and the values were re-classified into a number of risk classes. There is a strong link between the percentage cover of these land uses and pollution levels, with water quality particularly sensitive to the percentage of sealed surface in the catchment.

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

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

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

2. <u>Identifying constraints</u>

Constraints were identified and mapped in the same way as for water flow. The following constraints were therefore included and joined together onto one map:

- Land use constraints – urban, infrastructure, gardens and water
- Biodiversity Action Plan (BAP) quality habitats
- Scheduled Ancient Monuments (SAMs), with a 30m buffer
- Gas pipelines and overhead cables, with a 10m buffer

A map of high quality agricultural land (Grades 1 and 2) was also created from Natural England's agricultural land classification map. Initially it was considered using this as an additional constraint, as it is unlikely that such areas would be converted to other land uses. However, it would still be possible to install riparian buffer strips in these fields, while maintaining the majority of the field under agriculture, hence this layer was used to highlight areas rather than constrain them.

3. Identifying opportunity areas

All locations where it would be difficult to change habitats (the constraints map above) 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 10 percentiles (i.e. the top 10% were identified, 10-20%, 20-30% and so on) and the top 10% were extracted into a different map. Therefore, this shows the top 10% 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 before, it would also be possible to produce maps showing the top 25% of areas or the top 5% (or any other value), to show a wider or narrower range of sites, if desired.

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

5.2 Results

Water quality regulation was mapped across Northamptonshire and Peterborough (Map 10). Arable farmland scores particularly badly at both a coarse and a fine scale of assessment and sub-catchments with a high proportion of arable farmland have the lowest scores (they are delivering the highest pollutant and sediment loads to watercourses). These areas are hence highlighted as the areas with greatest opportunity to reduce sediment loads and enhance water quality on the opportunity map (Map 11).

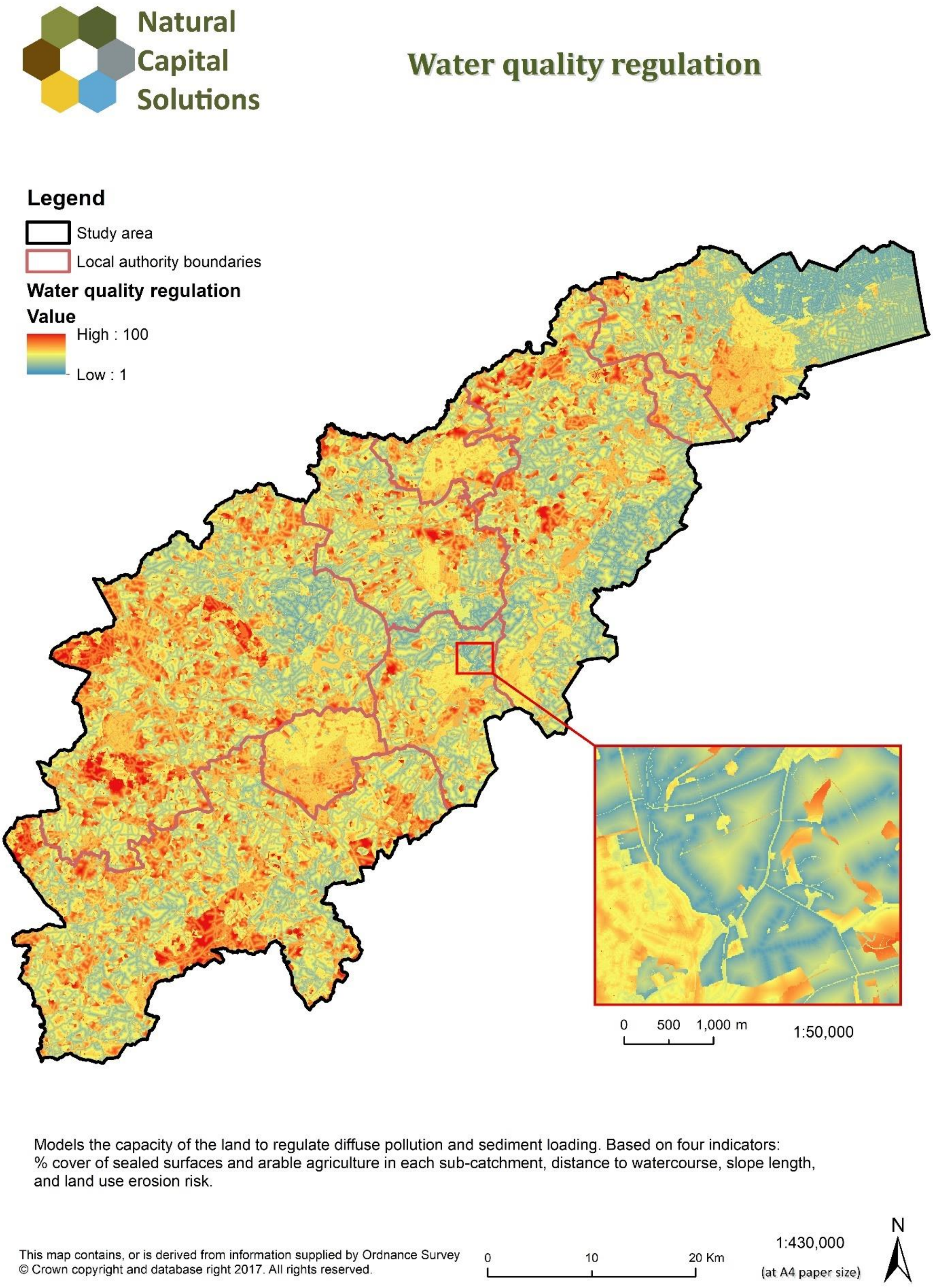
Sediment loads, and therefore opportunity areas, can be variable across short distances as it is partly dependent upon slope and distance to water course, which change rapidly over short spaces, and is why many of the identified areas are linear stretches adjacent to watercourses. These areas would be ideal places to install riparian buffer strips, ideally of woodland, but any habitat offering year-round cover would help. The area to the north-east of Peterborough appears as the location with the greatest density of opportunity areas, as it is an area of intensive arable farmland and also has a large number of drainage ditches located at the boundary of every field, hence distance to water is always short.

A map of whole fields where opportunities for reducing soil erosion and enhancing water quality would be most effective has been created (Map 12), although on this occasion this map may be less useful than the previous map. 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.

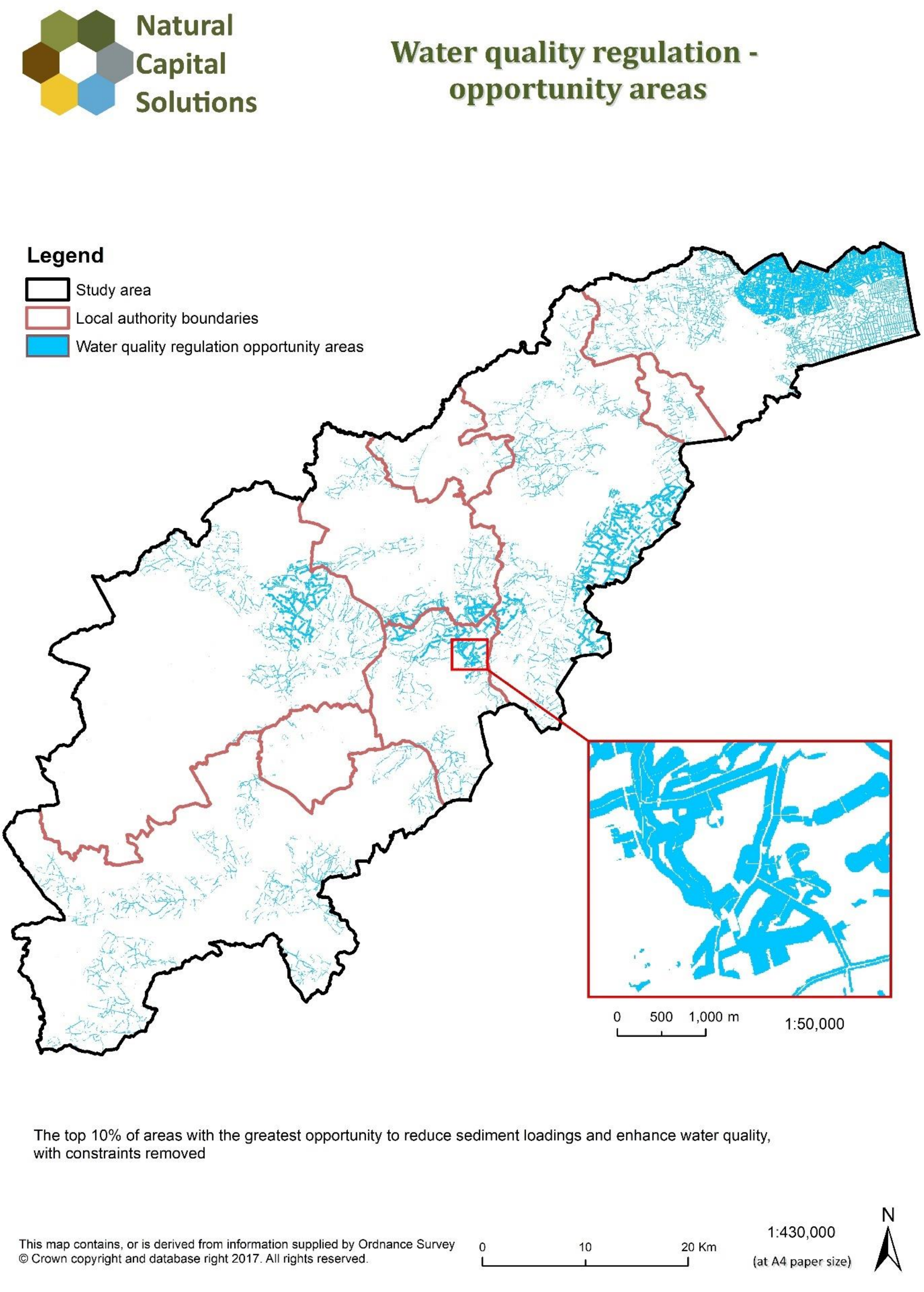
A map of agricultural land classification (Map 13) shows that the vast majority of the study area is classified as Grade 3, which is of intermediate quality for agriculture. This would not be expected to be a constraint to land use conversion. There are, however, a number of areas of Grade 2 agricultural land (and a very small amount of Grade 1), especially in the fens to the east of Peterborough and this coincides with the area highlighted above as providing some of the greatest opportunities for enhancing water quality. This is an example of a location where wholesale habitat change may be unrealistic, but it could still be an area where it would be worth targeting the installation of riparian buffer strips.

Comparing the opportunity maps for water flow (Map 7) with water quality (Map 11), reveals that there is virtually no overlap between the two. The most effective locations for reducing surface water runoff tend to be in the west of the study area on slopes in arable fields, whereas the most effective areas to enhance water quality are immediately adjacent to water courses on arable fields, especially in the lower lying areas and in the east. It is likely that habitat features created for one will still enhance the other, it is simply that the top 10% of target areas to not overlap. Indeed, there are a number of areas of overlap spread across the study areas when comparing the top 25% of both opportunity areas (not shown). Woodland would be the most effective solution to deliver these opportunities, although semi-natural grasslands, wet grasslands and wetlands would also deliver benefits.

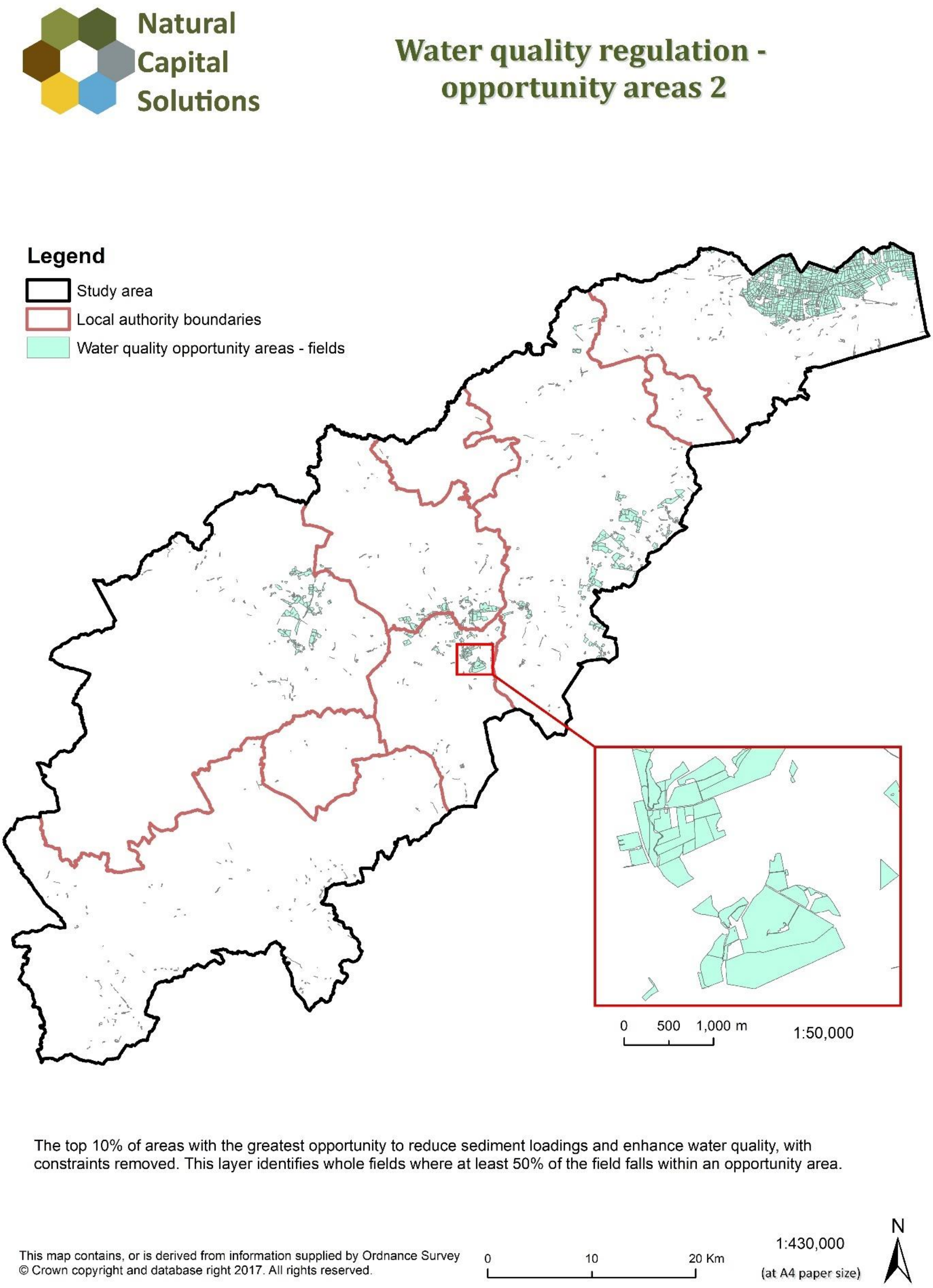
Map 10: Water quality (soil erosion) regulation across Northamptonshire and Peterborough.



Map 11: Water quality regulation opportunity areas across Northamptonshire and Peterborough.



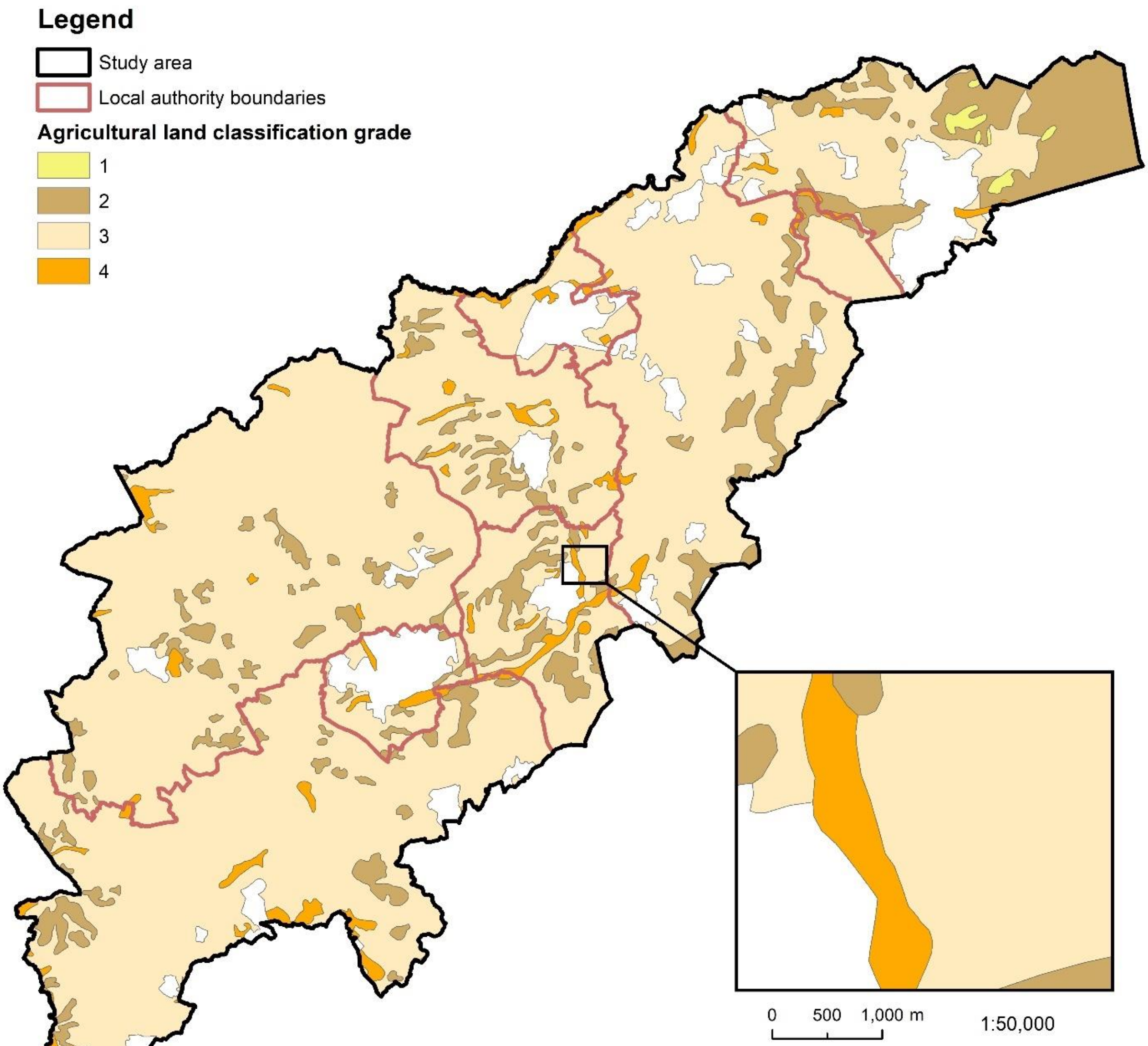
Map 12: Field scale water quality regulation opportunity areas across Northamptonshire and Peterborough.



Map 13: Agricultural land classification across Northamptonshire and Peterborough.

Natural Capital Solutions

Agricultural land classification



Agricultural land classification. Blank areas are non-agricultural land. Data from Natural England.

0 10 20 Km

1:430,000 (at A4 paper size)

N

6. Opportunity mapping to ameliorate air pollution

Exposure to air pollution in the UK causes around 40,000 deaths each year and plays a major role in cancer, asthma, stroke, heart disease, diabetes, obesity, and changes linked to dementia (RCP 2016). The cost has been estimated at more than £20 billion per year (RCP 2016) and the government is under increasing pressure to tackle the problem more effectively (e.g. House of Commons 2018). Although policies to implement clean air zones and encourage the uptake of electric vehicles, will have much the greatest impact on air pollution, the natural environment can also play a role. Vegetation can be effective at mitigating the effects of air pollution, primarily by intercepting particulates, especially PM_{10} (particulate matter 10 micrometres or less in diameter), but also by absorbing ozone, SO_2 and NO_x. Trees are much more effective than grass or low-lying vegetation, although effectiveness varies greatly depending on the species.

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

6.1 Method

1. *Modelling and mapping demand for air quality regulation*

Air quality regulation demand was mapped using a modified EcoServ GIS model. Four indicators were developed and mapped for each 10m by 10m cell across the study area; two indicators that gave an approximate indication of air pollution levels (environmental need) and two indicators of societal demand for air purification:

- **Distance to roads** – maps a key source of air pollution by applying a log distance decay function to main roads, with a maximum distance set at 300m.
- **Sealed surface cover** – maps % cover of sealed surfaces over 400m radius around each point as this has been shown to be correlated with pollution levels in scientific studies.
- **Population density** – maps societal need for air purification based on population density from 2011 UK census figures in the adjacent area (300m radius around each point).
- **Health score** – maps societal need for air purification based on Index of Multiple Deprivation health scores in the adjacent area (300m radius), with worse health indicating greater need.

The scores for each indicator were normalised and combined with equal weighting. The final score was then projected on a 0 to 100 scale. High values (red) indicate areas that have the highest demand for air pollution amelioration.

2. *Identifying constraints*

Constraints were identified and mapped in a similar way to the previous sections. The following constraints were therefore included and joined together onto one map:

- Land use constraints – urban, infrastructure, gardens and water
- Biodiversity Action Plan (BAP) quality habitats
- Scheduled Ancient Monuments (SAMs), with a 30m buffer
- Gas pipelines and overhead cables, with a 10m buffer

In urban areas, large blocks of land adjacent to pollution sources such as main roads are often not available for tree planting. In these situations, street trees can be an effective option and should be planted where pavement or verge width allows. An attempt was therefore made to identify pavements that were over 2m in width and so might be suitable for planting street trees. However, Mastermap (which provides the underlying polygons in the maps used in this study) is not accurate enough to determine pavement width at the level of detail required, so this could not be taken forward. This is an area that could be investigated further if detailed maps were available.

3. Identifying opportunity areas

The constraints identified above 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 10 percentiles (i.e. the top 10% were identified, 10-20% and so on) and the top 10% were extracted into a different map. This map therefore highlights the top 10% 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. It is also possible to produce maps showing the top 5% or 2% (or any other value), to focus on the worst pollution hotspots with the greatest demand.

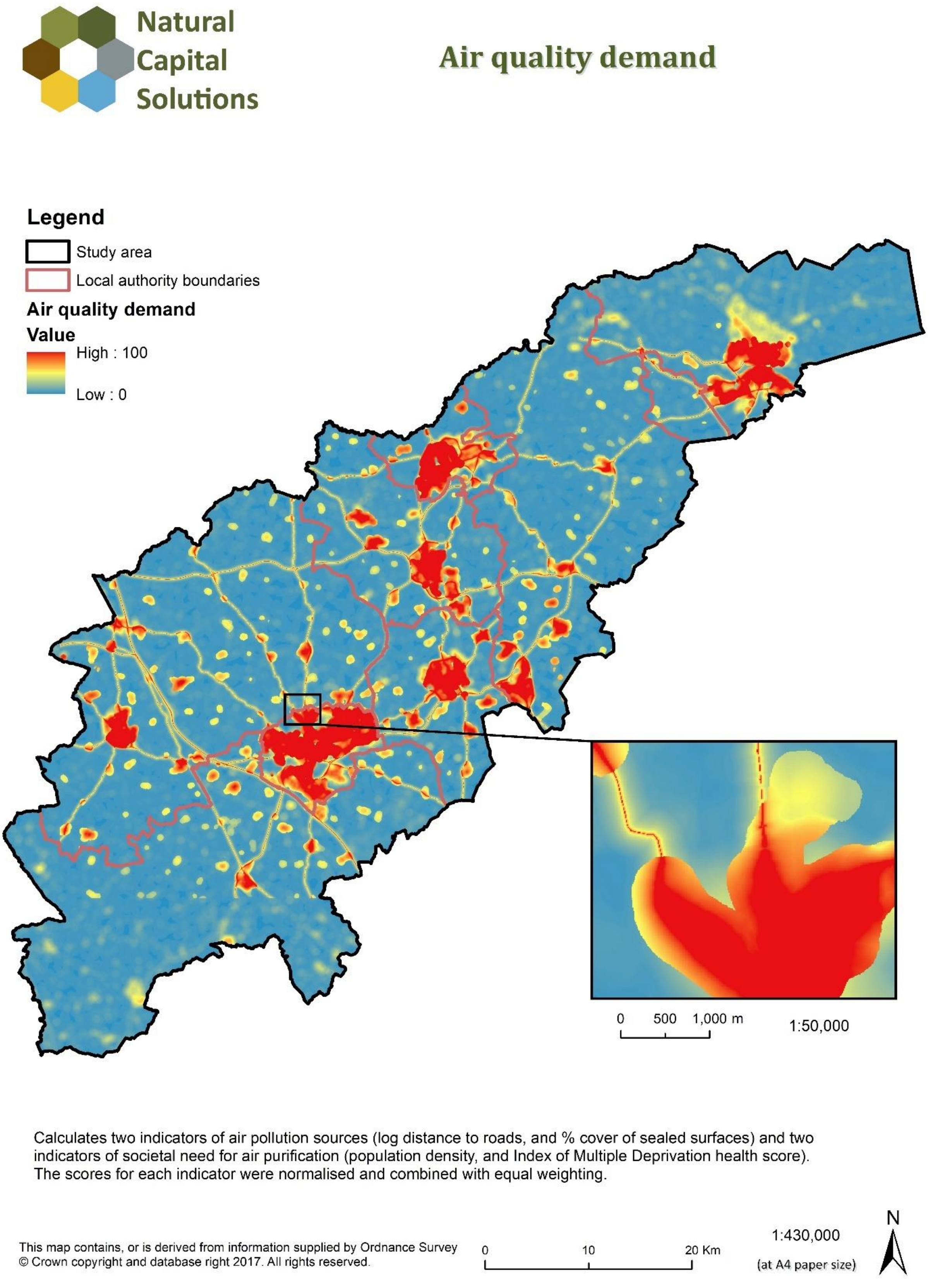
To match the other ecosystem services, the opportunity map was used to identify whole plots and fields in the basemap where the degree of intersection was at least 50% and a new layer was created. On this occasion very small polygons were not deleted, as it may be possible to plant an individual tree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

6.2 Results

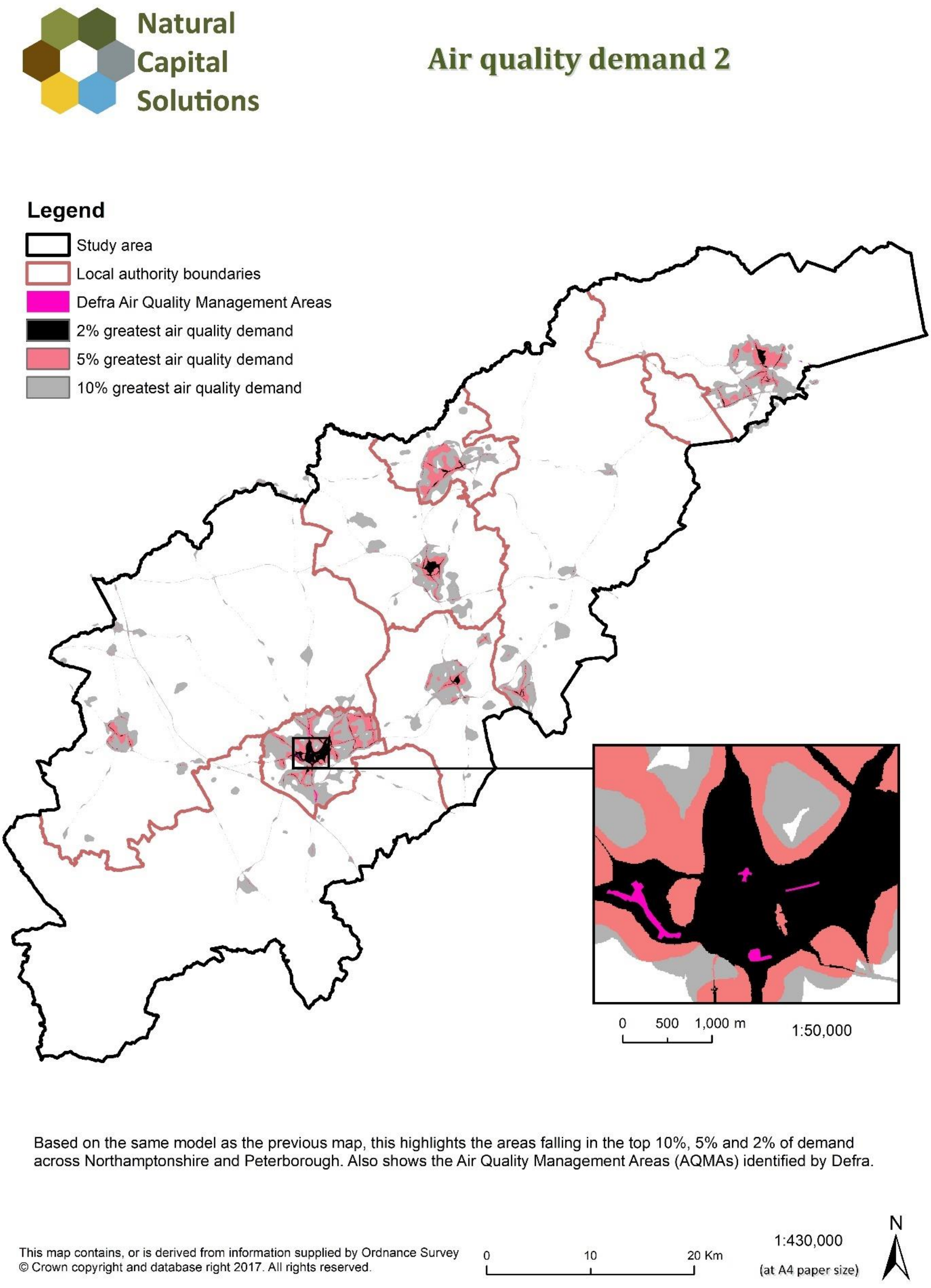
Demand for air quality regulation (Map 14) is highest in the main urban centres as these have both higher air pollution levels and higher populations that would benefit from better air quality. The main road network is also clearly visible as a major pollution source, and where these main roads pass through built up areas, there is increased demand for air quality regulation. Map 15 is based on the same model, but here the highest 10%, 5% and 2% of demand is highlighted. The very highest demand occurs in the centres of the major towns around the major road networks, with the largest area of very high demand located in Northampton town centre (marked in black on Map 15). Interestingly, this corresponds very closely with the location of Air Quality Management Areas (AQMAs, Map 15), which are locations identified by Defra where national air quality objectives are not being achieved

Inevitably, when the focus on air quality regulation is in the major towns, large areas are constrained, where it would not be possible to plant trees or other green infrastructure. However, unconstrained areas do remain, and these are highlighted on the opportunity map (Map 16). Whole plots are also identified (Map 17), although on this occasion this is similar to the previous map. These locations potentially provide the opportunity to plant trees that could absorb air pollution in areas where there is the greatest need for this service. As noted above, this does not include pavements, where further opportunities may be present, if pavements are sufficiently wide.

Map 14: Air quality regulation demand across Northamptonshire and Peterborough.



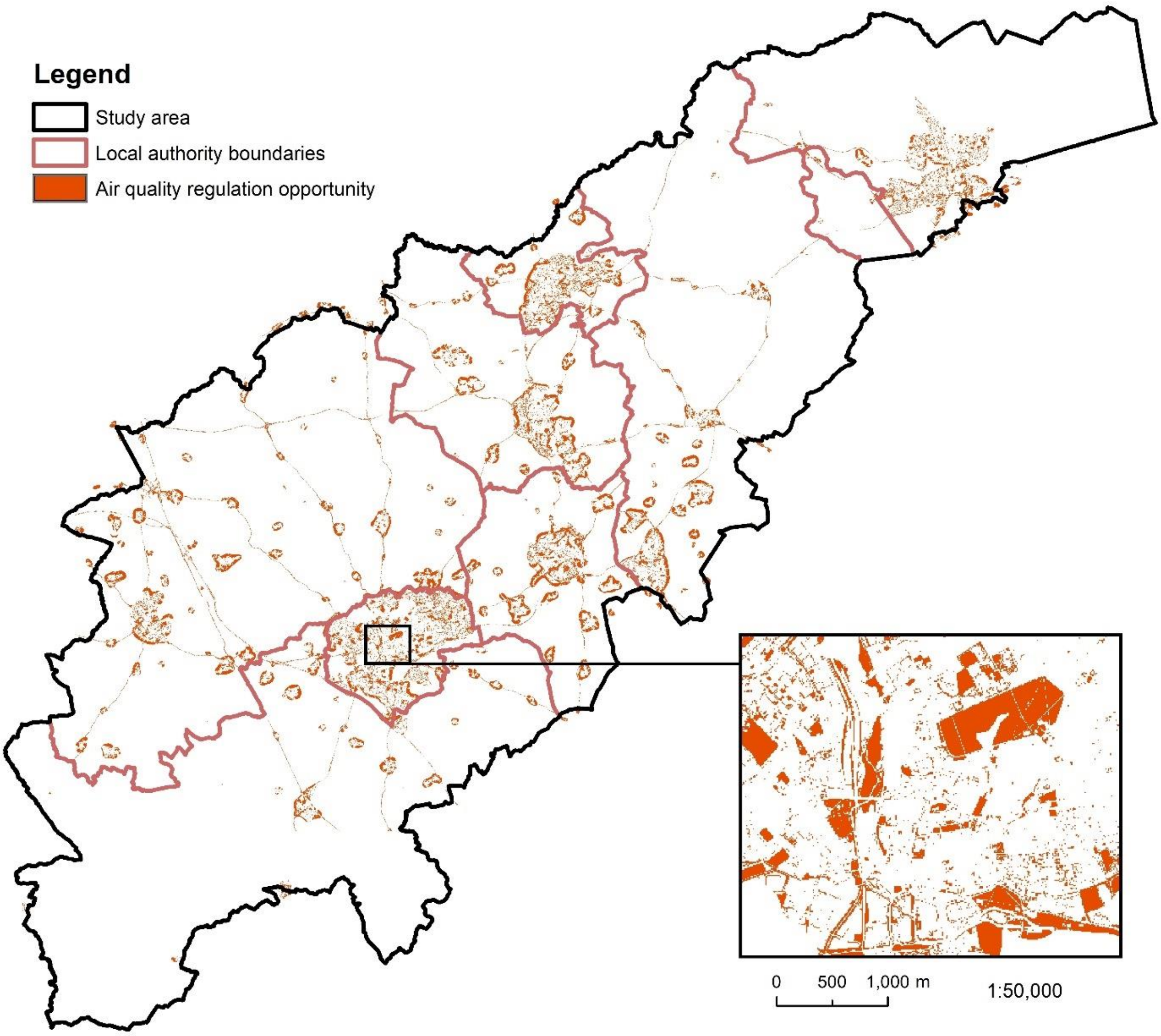
Map 15: Air quality regulation demand across Northamptonshire and Peterborough, highlighting areas with the greatest 10%, 5% and 2% of demand, and Defra Air Quality Management Areas.



Map 16: Air quality regulation opportunity areas across Northamptonshire and Peterborough.

Natural Capital Solutions

Air quality regulation - opportunity areas



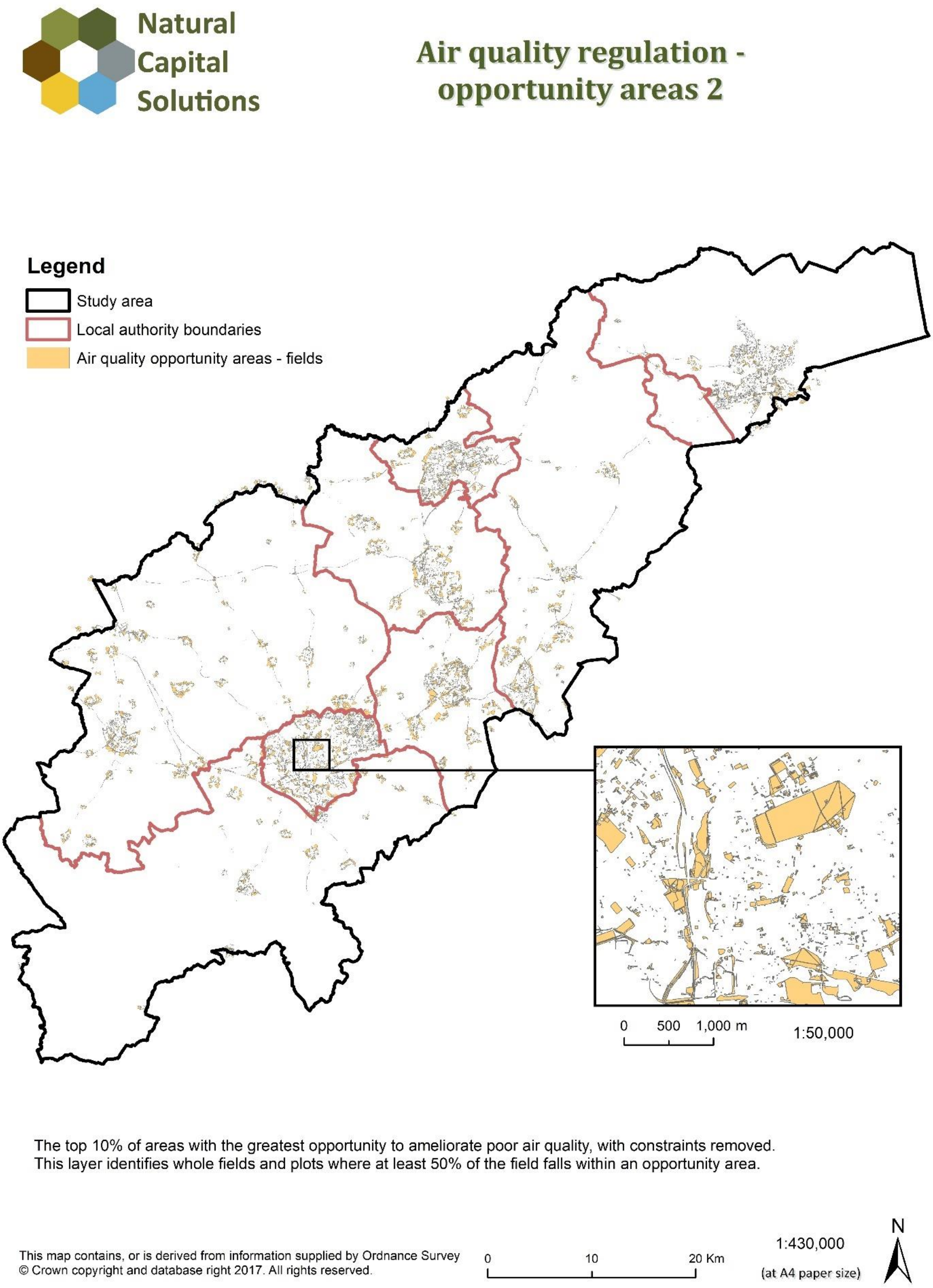
The top 10% of areas with the greatest opportunity to ameliorate poor air quality, with constraints removed

0 10 20 Km

1:430,000
(at A4 paper size)

N

Map 17: Field (plot) scale air quality regulation opportunity areas across Northamptonshire and Peterborough.



7. Opportunity mapping to enhance recreation in the natural environment

Access to greenspace is being increasingly recognised for the multiple benefits that it can provide to people. In particular, there is strong evidence linking access to greenspace to a variety of health and wellbeing measures, and the opportunities for physical exercise that the natural environment provides has been shown to reduce diseases related to lack of exercise (for example, heart disease, stroke, diabetes and certain types of cancers). Research has also shown that there is a link between wellbeing and perceptions of biodiversity and naturalness, with people reporting greater wellbeing from sites that they consider to be more natural. Natural England and others have published guidelines that promote the enhancement of access, naturalness and connectivity of greenspaces (e.g. Natural England 2010).

Research, including large surveys such as the Monitor of Engagement with the Natural Environment (MENE), has shown that there is greatest demand for accessible greenspace close to people's homes, especially for sites within walking distance. Furthermore, Natural England have published Accessible Natural Greenspace Standards (ANGSt), which set out guidelines on the size and proximity of greenspace in relation to where people live (Natural England 2010). As part of the Nene Valley NIA project, a visitor access study was performed across multiple locations within the Upper Nene Valley Gravel Pits SPA (Liley *et al.* 2014). This provided data on the distance that people travelled to visit sites within the SPA and mode of transport and confirmed that the vast majority of visits were of local origin.

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 purely on demand, and then by also taking into account the naturalness of existing habitats.

7.1 Method

1. *Modelling and mapping demand for accessible natural greenspace*

Accessible natural greenspace demand was mapped using a modified EcoServ GIS model. This is based on the location of the demand, taking no account of habitat, determined using three indicators:

- **Population density** – based on 2011 census data, as the larger the population the greater demand for accessible nature.
- **Health scores** – taken from the Index of Multiple Deprivation general health scores, with the assumption that those in worse health have the greatest need and would benefit most from access to greenspace.
- **Distance to footpaths and access points** – maps all pavements, Public Rights of Way, Sustrans routes and other paths, and combines with public transport stops and access points to parks / country parks, and calculates distance from these.

The three indicators are calculated at **three different scales** as demand is strongly related to distance. The Visitor Access Study of the Upper Nene Valley Gravel Pits SPA (Liley *et al.* 2014) was used to determine appropriate distances. The distances chosen (and rationale) were: 800m (the median distance travelled by people walking to sites), 3.2 km (median distance travelled by all visitors using all modes of transport), and 14 km (90% of all visitors 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, also with equal weighting and projected on a 0 to 100 scale. High values (red) indicate areas (sources) that generate the greatest demand for accessible natural greenspace.

2. Identifying constraints

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 woodland 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 Biodiversity Action Plan habitats and Scheduled Ancient Monuments, 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 – urban habitats (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 showing all areas of green infrastructure currently existing across Northamptonshire and Peterborough. This was created by combining open space and green infrastructure data sets for each local council (9 local councils in total). 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).

3. Identifying opportunity areas

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 10 percentiles (i.e. the top 10% were identified, 10-20%, 20-30% and so on) and the top 10% were extracted into a different map. This map highlights the top 10% 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%.

4. Mapping the perceived naturalness of existing habitats

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. There is a link between perceptions of naturalness and wellbeing, hence more natural areas are able to deliver accessible natural greenspace of greater value.

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

5. Identifying opportunity areas that balance supply and demand

The land use constraints identified in Step 2 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 and each pixel reclassified from 1-10. The demand map (from step 1) was also re-classified in exactly the same way. 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 10% of combined scores were identified and extracted into a different layer. This map therefore highlights the top 10% 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%.

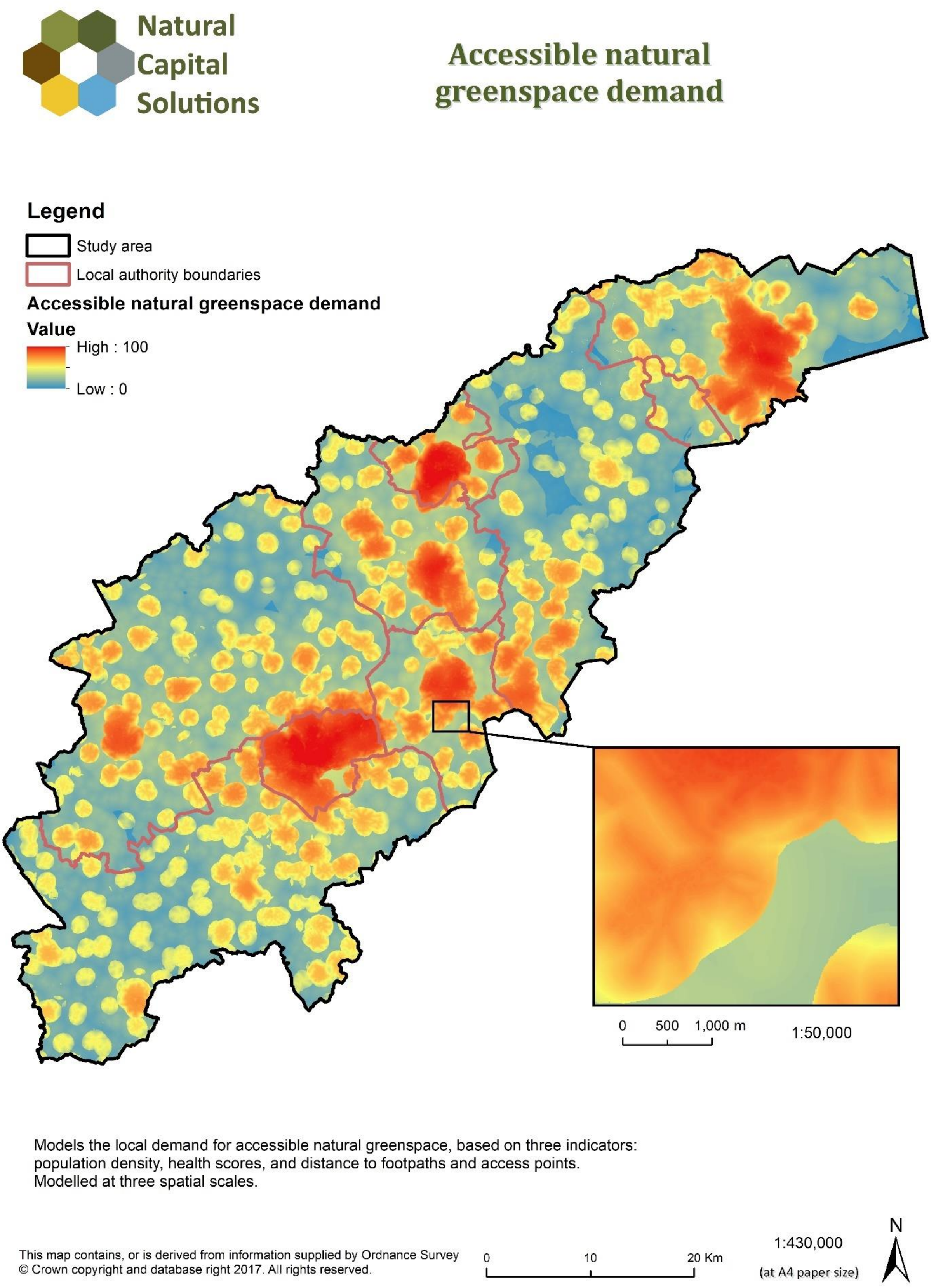
7.2 Results

Demand for accessible natural greenspace is shown on Map 18. It is strongly focussed around the urban areas in the study area, especially Northampton, Peterborough and Corby. There is still some demand throughout the study area, although local demand will be lower in areas that are further away from population centres. Due to the strong demand arising from urban areas, it is perhaps unsurprising that the majority of the opportunity areas identified (Maps 19 & 20) are centred around the major towns across the study area. As opportunities for new greenspaces are usually highly constrained within towns, opportunity areas tend to form a ring around the edges of these towns. These are also often locations that have been targeted for sustainable urban extensions and other development, so it is important that planners and developers take into account the strong demand for greenspace at these sites from both the new developments and from the existing population.

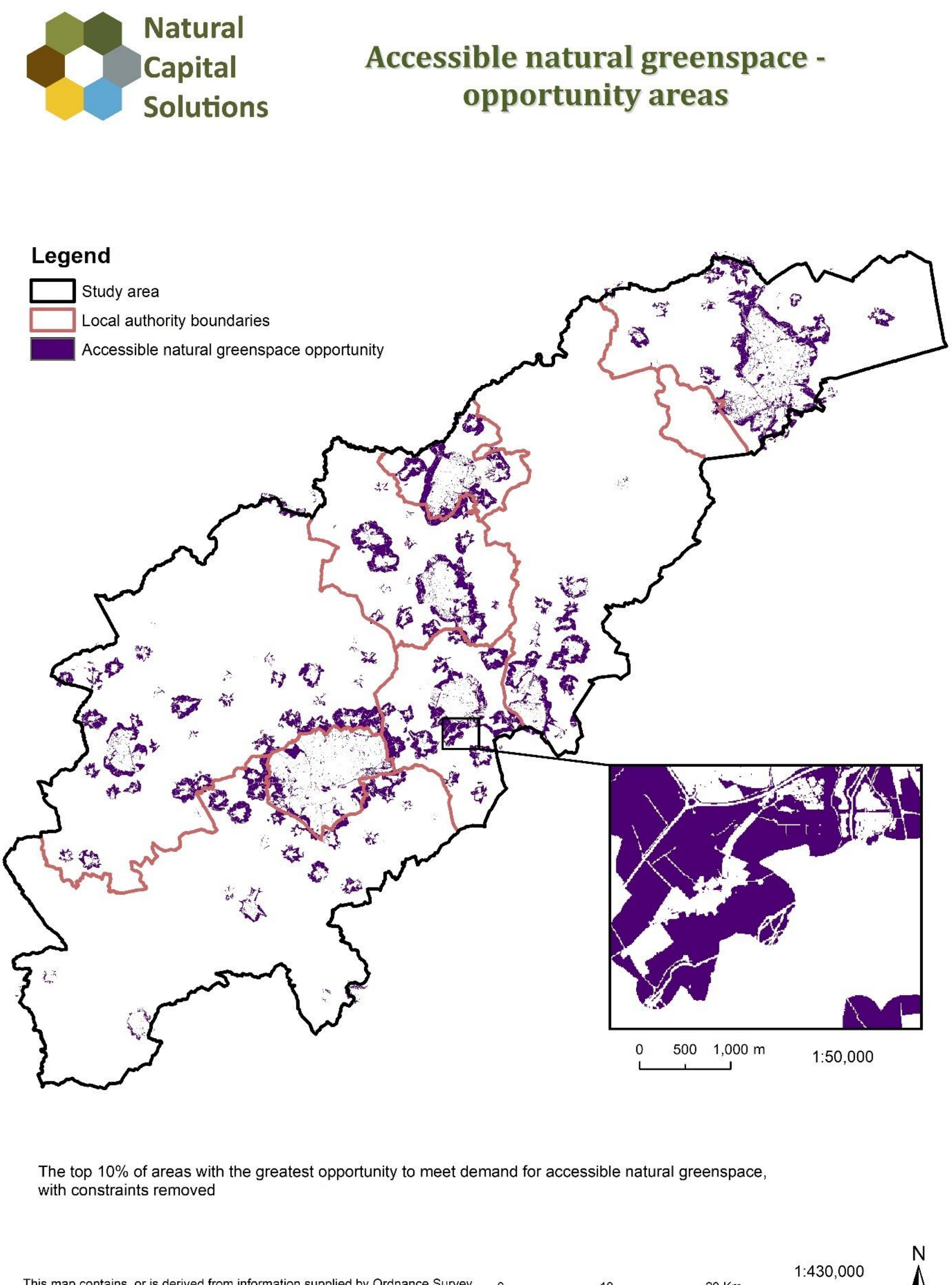
Although demand is greatest around the larger towns, these locations often do not contain the most natural habitats, and the perceived naturalness of habitats throughout the study area is shown on Map 21. Woodland and water features are considered to be the most natural habitats in the area and can be clearly identified in red on the map, especially the larger blocks of these habitats. When demand is balanced against the naturalness of the existing habitats, a different pattern of opportunity areas emerges (Map 22 & 23). The association with the larger towns is now much weaker, although still present, as areas of poor habitat adjacent to towns are not selected. Areas of higher quality habitat are now more likely to be selected, especially when those are relatively close to towns.

To illustrate the difference between the two approaches, the inset map on each of Maps 18-23 shows the area immediately to the south of Wellingborough. When considering only demand, opportunities to enhance accessible natural greenspace are highlighted immediately adjacent to the town (Map 19), predominately on arable fields and improved grassland. This is an ideal location for access from Wellingborough, but 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, the area slightly further away from the town and adjacent to the River Nene is shown as being much more natural (Map 21), and it is this area that is highlighted as an opportunity area on Map 22. This area has slightly poorer access but already contains natural habitats.

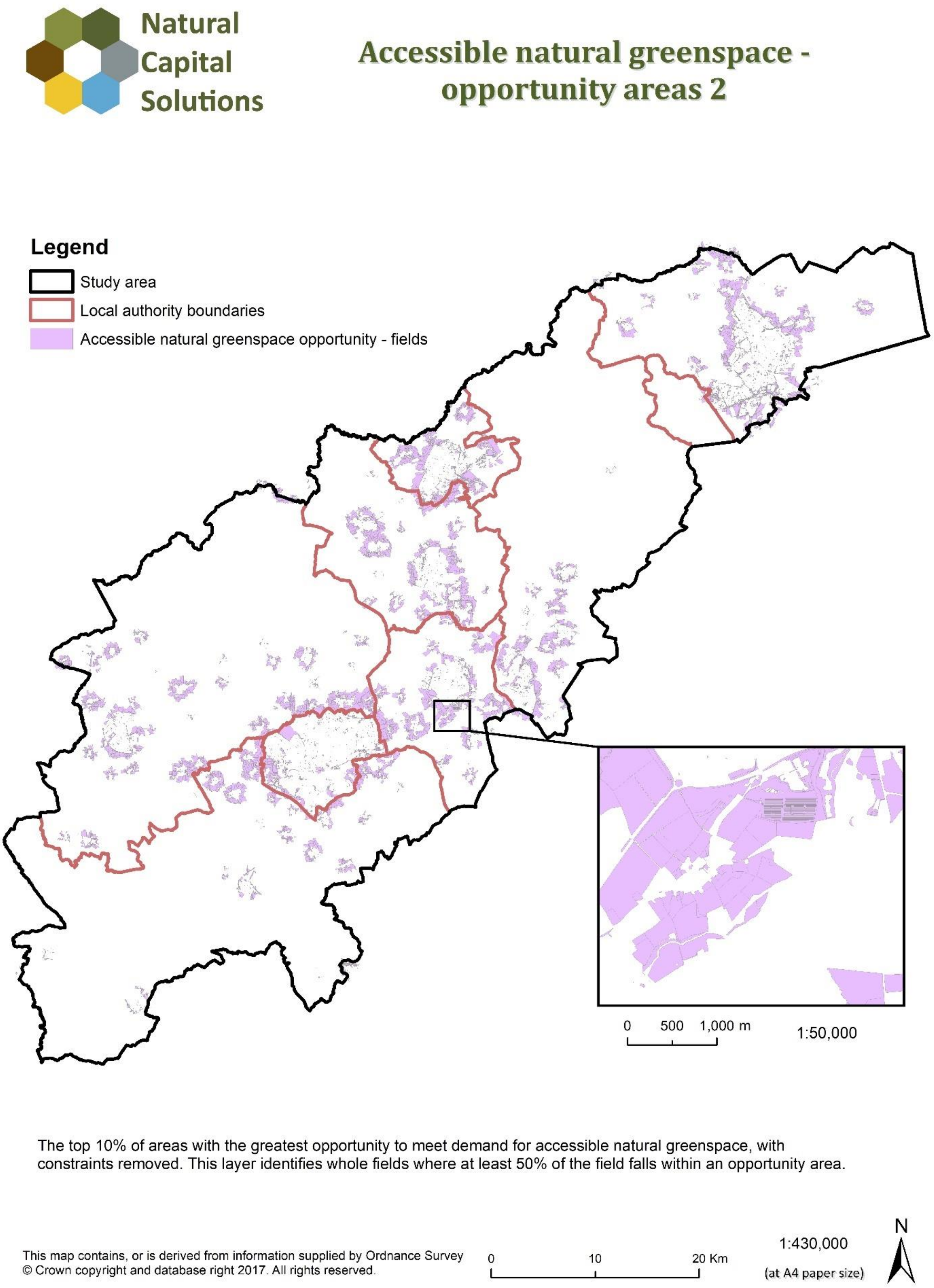
Map 18: Demand for accessible natural greenspace across Northamptonshire and Peterborough.



Map 19: Accessible natural greenspace opportunity areas across Northamptonshire and Peterborough.



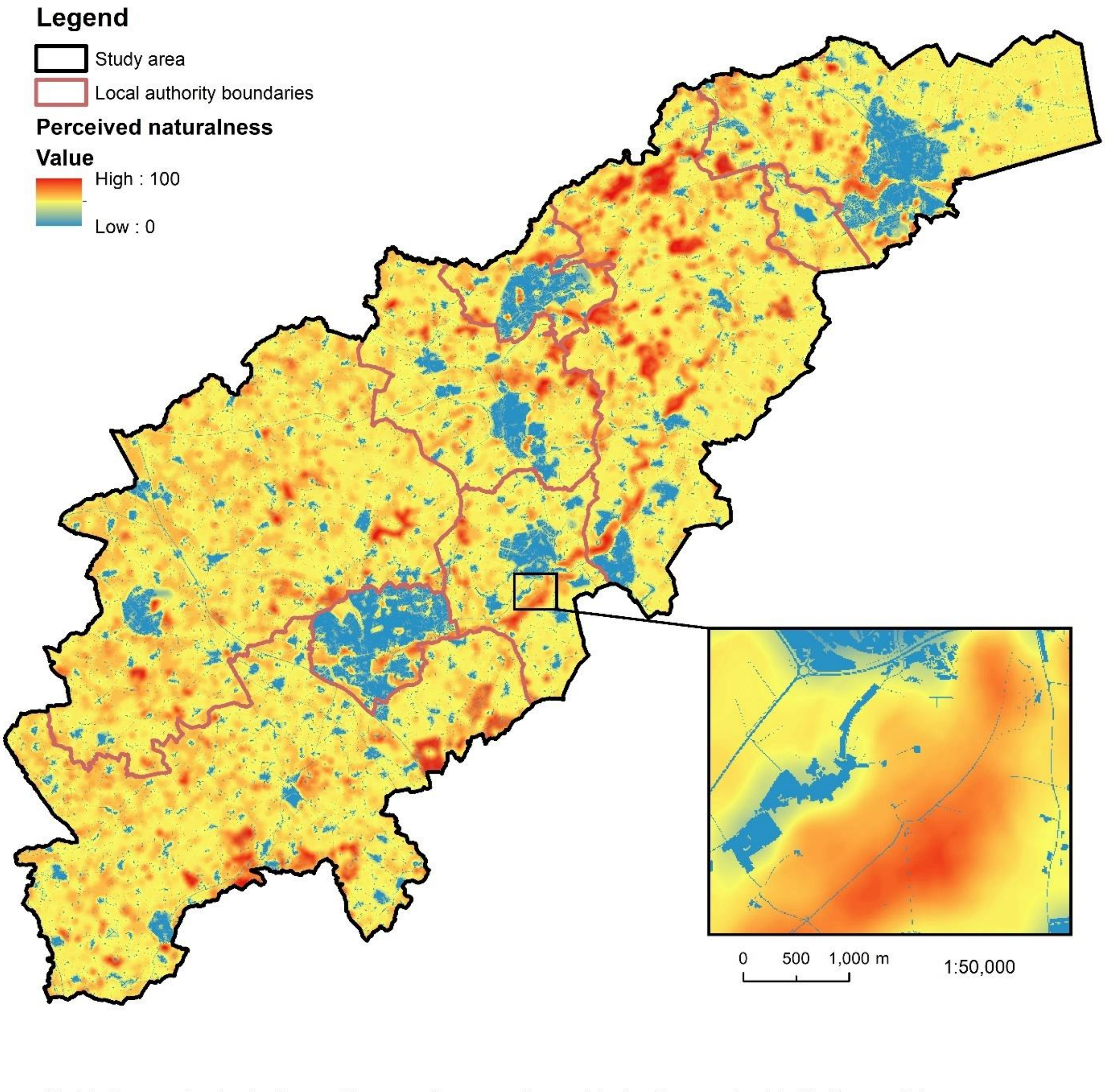
Map 20: Field (plot) scale accessible natural greenspace opportunity areas across Northamptonshire and Peterborough.



Map 21: Perceived naturalness of habitats across Northamptonshire and Peterborough.

Natural Capital Solutions

Perceived naturalness



Models the perceived naturalness of the area. Larger continuous blocks of more natural habitat types will have higher scores than smaller isolated sites of the same habitat type.

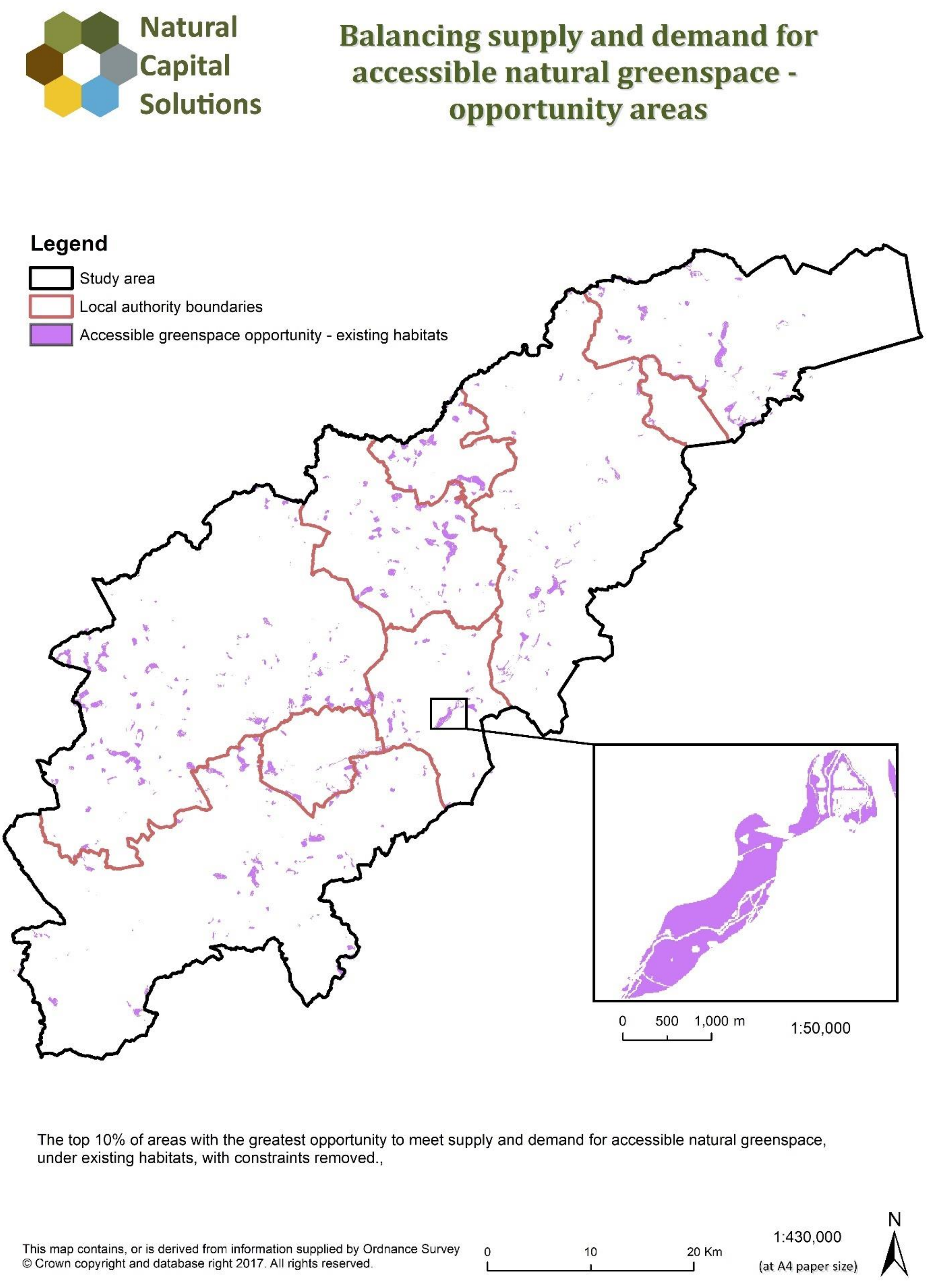
0 10 20 Km

1:430,000

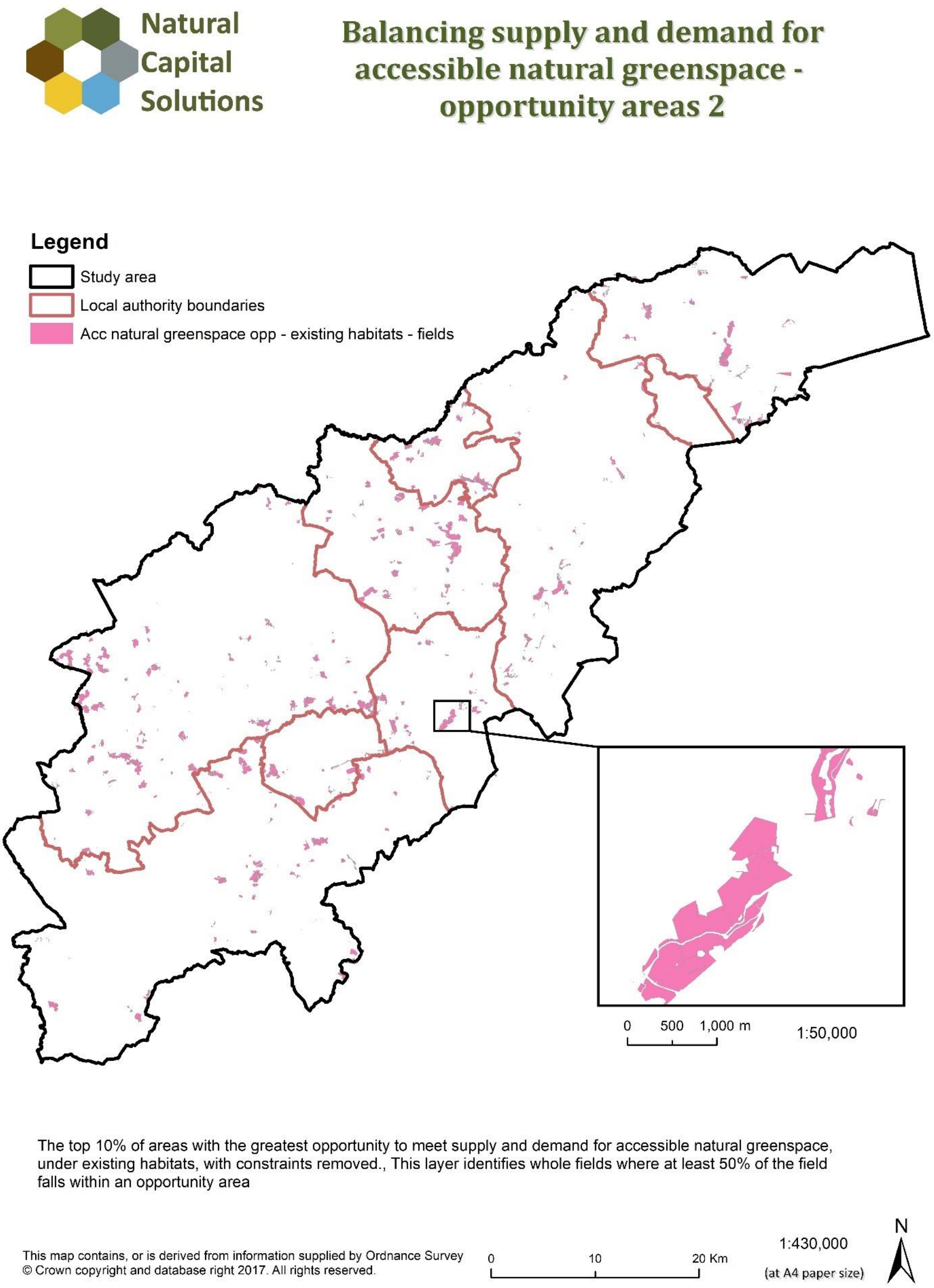
(at A4 paper size)

N

Map 22: Accessible natural greenspace opportunity areas, based on demand and naturalness of existing habitats, across Northamptonshire and Peterborough.



Map 23: Field (plot) scale accessible natural greenspace opportunity areas, based on demand and naturalness of existing habitats, across Northamptonshire and Peterborough.



8. Combined opportunities for new habitats

In addition to mapping the individual opportunities presented in Sections 3-7, it is also possible to examine multiple opportunities, which are areas where new habitat can be created that provides opportunities to enhance more than one of the services mapped previously. This is assessed by overlaying each individual opportunity map already created to determine the degree of overlap, examining each of the main habitat types in turn. This is focussing on the top 10% of opportunity areas for each ecosystem service, so is only considering the very highest 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 10%. It would be possible to examine broader overlaps by considering the top 25% of areas (or any other value), although that is not presented here. Note that as the assessment below is concerned with creating new habitats, the opportunity map for accessible natural greenspace based solely on demand (Map 19), was used rather than the one that examined existing habitats alongside demand (Map 22).

8.1 Combined opportunities for new broadleaved and mixed woodland

Opportunities to reduce surface runoff (water flow), reduce soil erosion (enhance water quality) and enhance air quality, can all be best achieved through planting trees and woodland, and woodland is also one of the best habitats for creating high quality accessible natural greenspace. Therefore, the opportunity maps for these services were overlain with the opportunity map for biodiversity enhancement through the creation of broadleaved and mixed woodland.

The results are shown on Map 24, which maps the existing areas of broadleaved and mixed woodland and an overlay of all the five different opportunity areas. The map highlights the number of different opportunity areas that overlap (out of a maximum of five) for each 10m by 10m pixel across the study area. The results show that while there are large areas that only offer one opportunity, there are many areas that offer two or more opportunities. Locations at the edges of the main towns are most often highlighted as being able to deliver multiple services. 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.

8.2 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 (although better than sealed surfaces). Hence combined opportunities were examined for four out of the five services: water flow, water quality, accessible natural greenspace, and biodiversity enhancement, while air quality was not included.

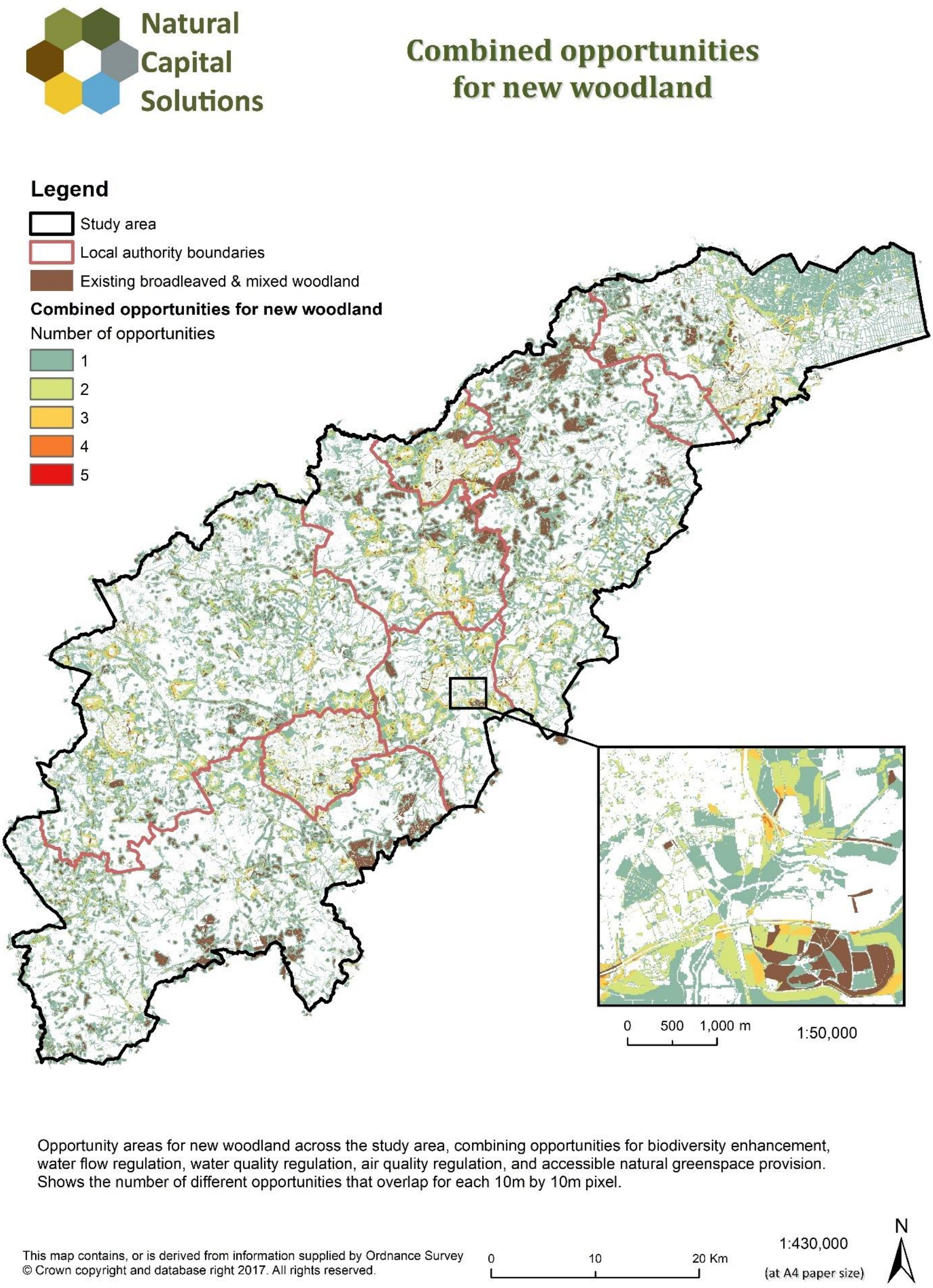
Combined opportunities for new semi-natural grasslands are not as extensive as for woodland, but are still spread across all local authority areas (Map 25). Similarly to woodland, while the greatest number of opportunity areas are only in the top 10% for one service, there are nevertheless many areas that support two or more opportunities, with the majority of these being close to the towns.

8.3 Combined opportunities for new wet grassland and wetlands

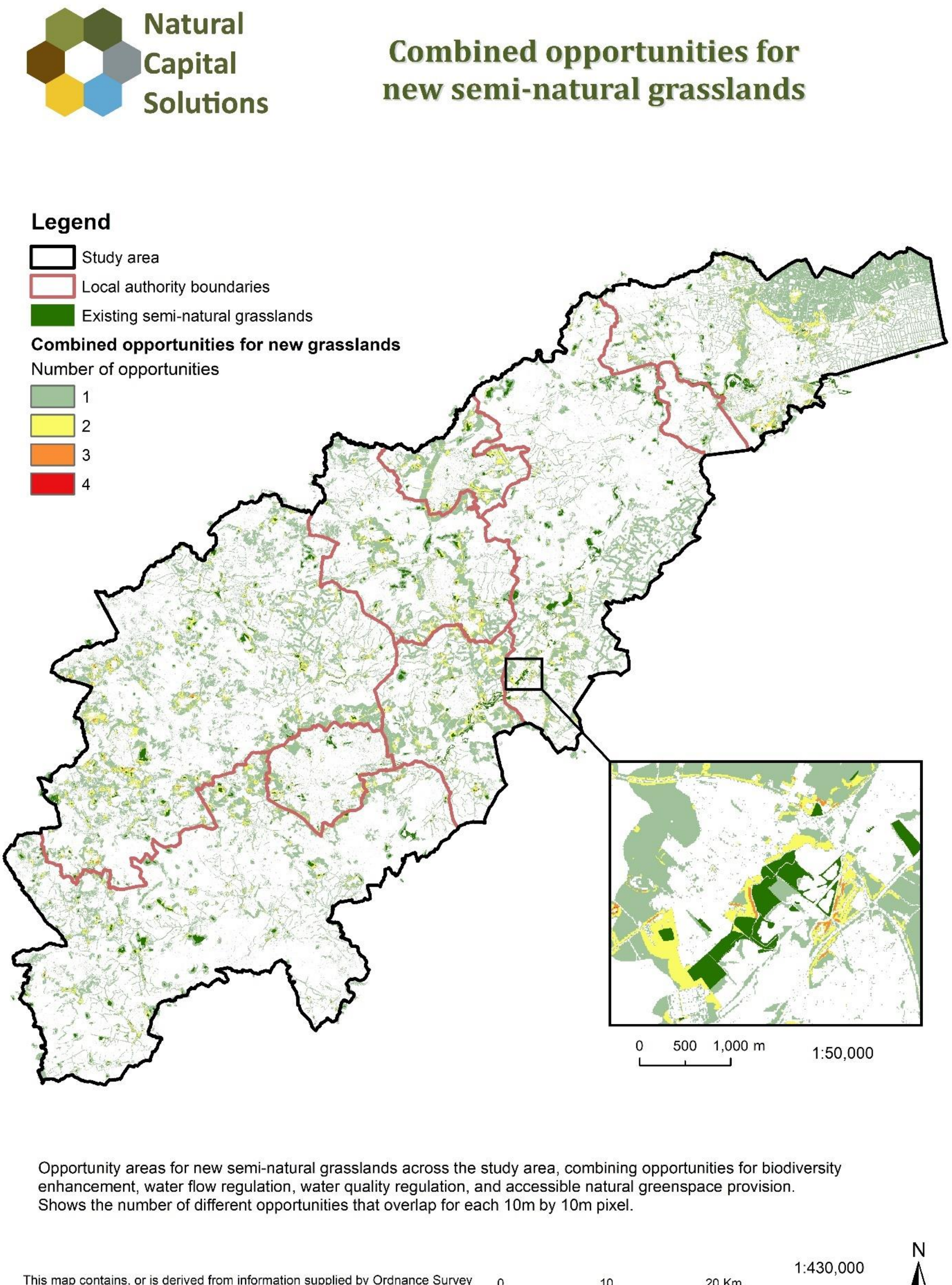
Opportunities for new wet grassland and wetlands were mapped in the same way as for semi-natural grassland, except that all opportunities were restricted to areas within the indicative floodplain. Thus four out of the five services were included, with air quality excluded. Wetland habitats can be effective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

The location of opportunities for this habitat type is much more restricted than for the previous two (Map 26), due to the requirement for being located on the floodplain. The River Nene corridor between Northampton and Peterborough offers the greatest number of opportunities, with opportunities also apparent on the Brampton Branch of the Nene, the River Ise, and on the River Tove in South Northamptonshire. A few of these locations are opportunity areas for two or three services.

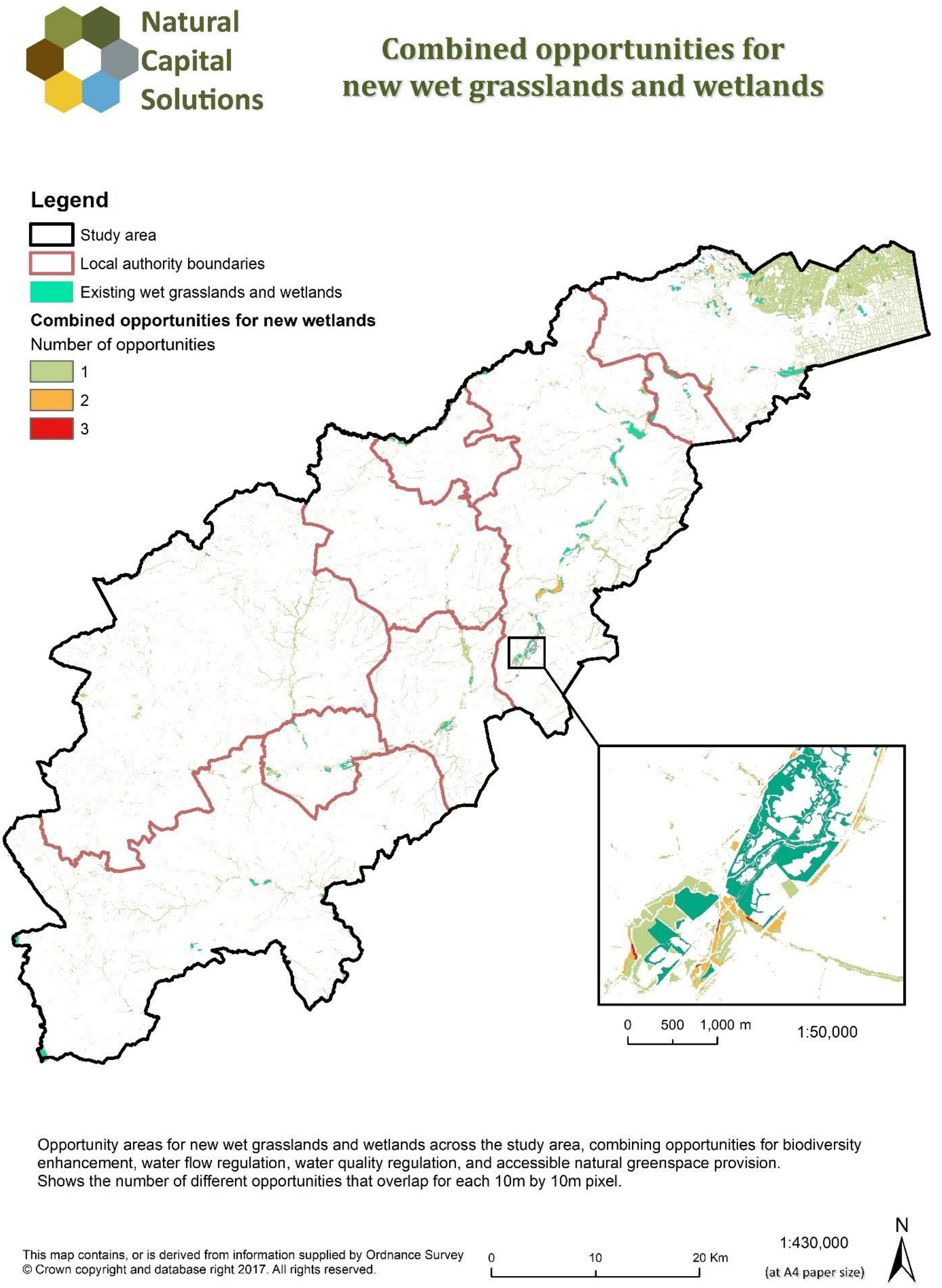
Map 24: Existing broadleaved and mixed woodland, and combined opportunities for new woodland, across Northamptonshire and Peterborough.



Map 25: Existing semi-natural grasslands, and combined opportunities for new grasslands, across Northamptonshire and Peterborough.



Map 26: Existing wet grasslands and wetlands, and combined opportunities for new wetlands, across Northamptonshire and Peterborough.



9. Conclusions

Opportunity maps have been presented for biodiversity enhancement for three broad habitat types, along with maps showing the top 10% of opportunity areas to enhance water retention, water quality, air quality, and accessible natural greenspace provision. They highlight areas that can be targeted to enhance natural capital with respect to any of these individual goals, or in combination, to target areas where multiple objectives can be delivered at the same location. Note, however, that the maps have not been ground-truthed or checked against other data, and so individual locations will need to be assessed further before being taken forward. The maps should be considered as a resource to highlight potential locations for habitat creation or restoration projects, rather than as an end in themselves. The maps are best examined on a Geographic Information System, and GIS layers are available for project partners.

The biodiversity opportunity maps highlight areas that are best located in terms of their connectivity with existing habitat patches and are therefore most appropriate from an ecological point of view. Enhancing connectivity and expanding habitat networks is a key priority for biodiversity conservation and climate change adaptation at present, and these maps go a long way to identifying appropriate locations. The remaining opportunity maps highlight the top 10% of sites for each respective service, but it would be possible to consider a wider or narrower range of sites if desired.

The different opportunity areas do vary in their geographic location; broadleaved and mixed woodland biodiversity enhancement is centred around Rockingham and Salcey Forests although is present to some extent across the study area, wet grassland and wetlands are focussed on the floodplain of the Middle Nene, whereas opportunities for semi-natural grassland are more spread throughout the study area. The greatest opportunities for reducing water flow are situated to the west of the study area on hillier terrain, whereas water quality opportunities tend to be adjacent to water courses. Air quality and accessible greenspace opportunities are focussed in and around the major towns. There is, however, some overlap between these opportunity areas. In addition, any new habitats created on sites that are currently arable or improved grassland, are likely to provide benefits for each of the services assessed, regardless of whether these fall in the top 10%.

9.1 General principles of investing in natural capital

The benefits of investing in natural capital are considerable. Access to greenspace for people can be highly beneficial for physical and mental health and well-being and the monetary value of these benefits can be extremely high. Green infrastructure (GI) can also make important contributions to air quality regulation, natural flood risk management, water quality enhancements, and additional services such as climate change mitigation, local climate amelioration, and noise screening. GI is 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.

The location and type of GI should be related to demand, which varies considerably across an area. In addition, investing in green infrastructure can help to address issues of social inequality when located within or close to deprived communities. Mapping the spatial location and distribution of benefits (especially in relation to demand) provides valuable additional information. This has formed the basis of the opportunity mapping presented here, which is a valuable tool for targeting areas for habitat creation and investment.

9.2 Next steps

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 previous opportunity mapping completed by the Northamptonshire Wildlife Trust for some areas, green infrastructure plans, and national maps created by Natural England, alongside local knowledge to remove errors, and target particular areas to take forward.
- It is recommended that a workshop is held with local stakeholders to consider priorities for different zones within the study area. For example, the current biodiversity opportunity maps overlap, which means that in some areas two or three of the different habitats appear in the opportunity maps for the same location. Simple rules could be created to target certain habitats or certain opportunities in different locations. The workshop could also be used to assess how sensible the mapped areas are compared to local knowledge, to examine quality control and to consider prioritising certain areas to take forward.
- Priority locations can be taken forward in a number of different ways. This includes:
  - A number of specific habitat creation projects could be worked up into costed proposals and offered as biodiversity offsetting and biodiversity or natural capital net gain projects. These could be funded through the development process.
  - It is hoped that the Nenescape project will be able to take forward some of the opportunities for semi-natural and wet grassland creation.
  - Opportunity areas could be targeted through agri-environment schemes. This will be particularly relevant post-Brexit when there is expected to be a further move towards paying farmers for environmental enhancements.
  - Woodland areas could be taken forward through the UK Woodland Carbon Code.
  - A number of projects could be taken forward through a range of mechanisms such as projects focussing on working with natural processes for slowing the flow (natural flood risk management) and water quality, such as catchment sensitive farming. Opportunities for planting trees to enhance air quality could be part of air pollution reduction strategies, and increasing public access to natural greenspace could be incorporated into wellbeing initiatives and ideas around green prescribing.
- It would be possible to take forward this work through a **Natural Capital Investment Strategy or Plan**. This would involve identifying key projects / locations to take forward, determining the costs and monetary benefits of habitat creation at these sites and hence the return on investment, and then presenting the plans in the form of a prospectus, potentially considering appropriate financial mechanisms.

References

Broadmeadow, S., Thomas H. & Nisbet, T. (2013) *Midlands Woodland for Water Project Phase 1: Opportunity Mapping Final Report*. Forest Research.

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

EA (2008) 2008. Delivery of Making Space for Water: Identification of catchments sensitive to land use change. *Report NA788*, Environment Agency.

House of Commons (2018). *Improving air quality*. Report of the Environment, Food and Rural Affairs, Environmental Audit, Health and Social Care, and Transport Committees, House of Commons.

Liley, D., Floyd, L., Cruickshanks, K. & Fearnley, H. (2014) *Visitor Access Study of the Upper Nene Valley Gravel Pits SPA*. Footprint Ecology. Unpublished report for the NIA partnership.

Natural England (2010) *'Nature Nearby' Accessible Natural Greenspace Guidance*. Natural England.

RCP (2016) *Every breath we take: the lifelong impact of air pollution*. Report of a working party, Royal College of Physicians.

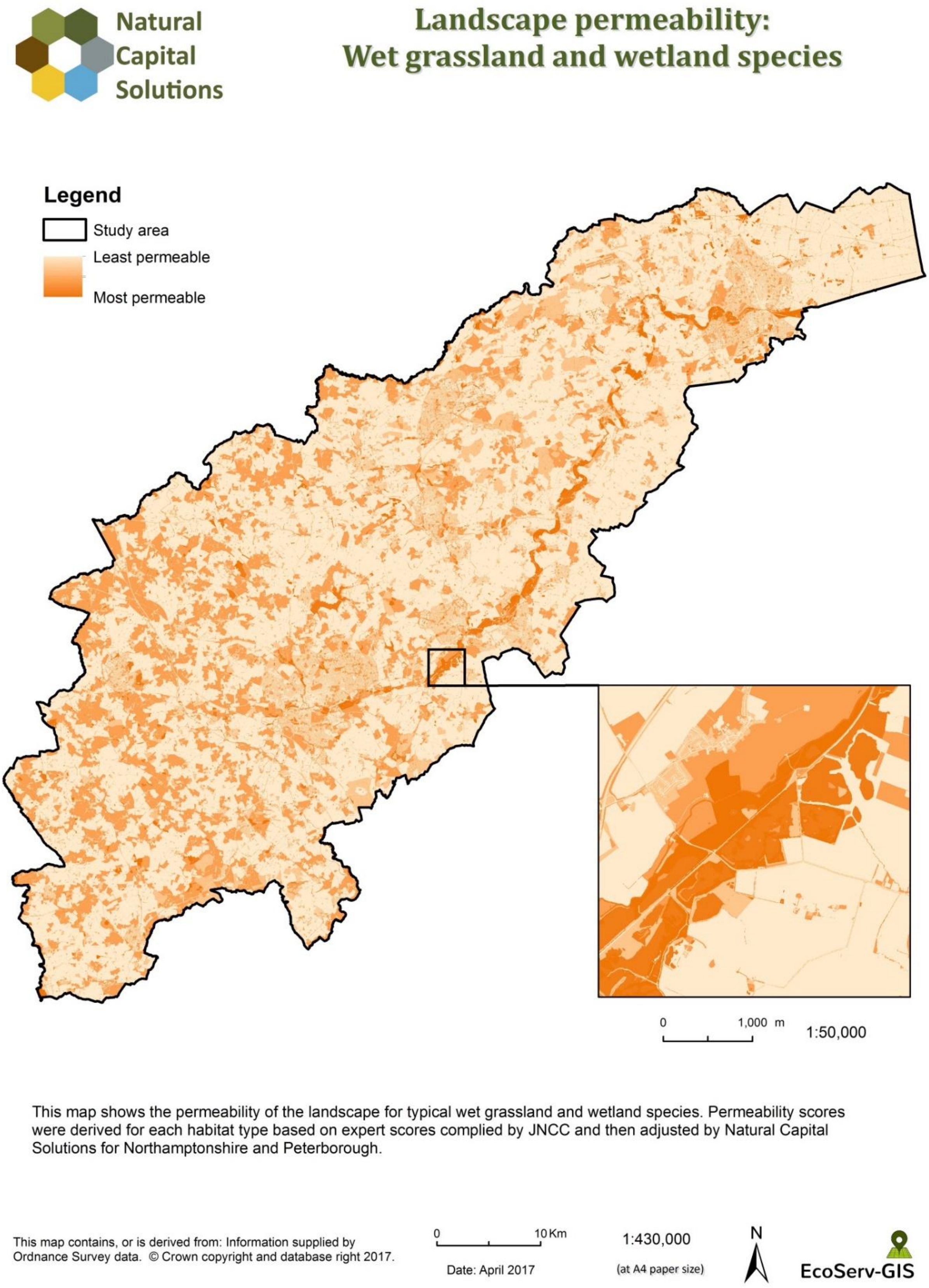
Rouquette, J.R. (2016). *Mapping Natural Capital and Ecosystem Services in the Nene Valley*. Report for the Nene Valley NIA Project, Natural Capital Solutions

SEPA (2013). *Identifying Opportunities for Natural Flood Management*. Scottish Environment Protection Agency.

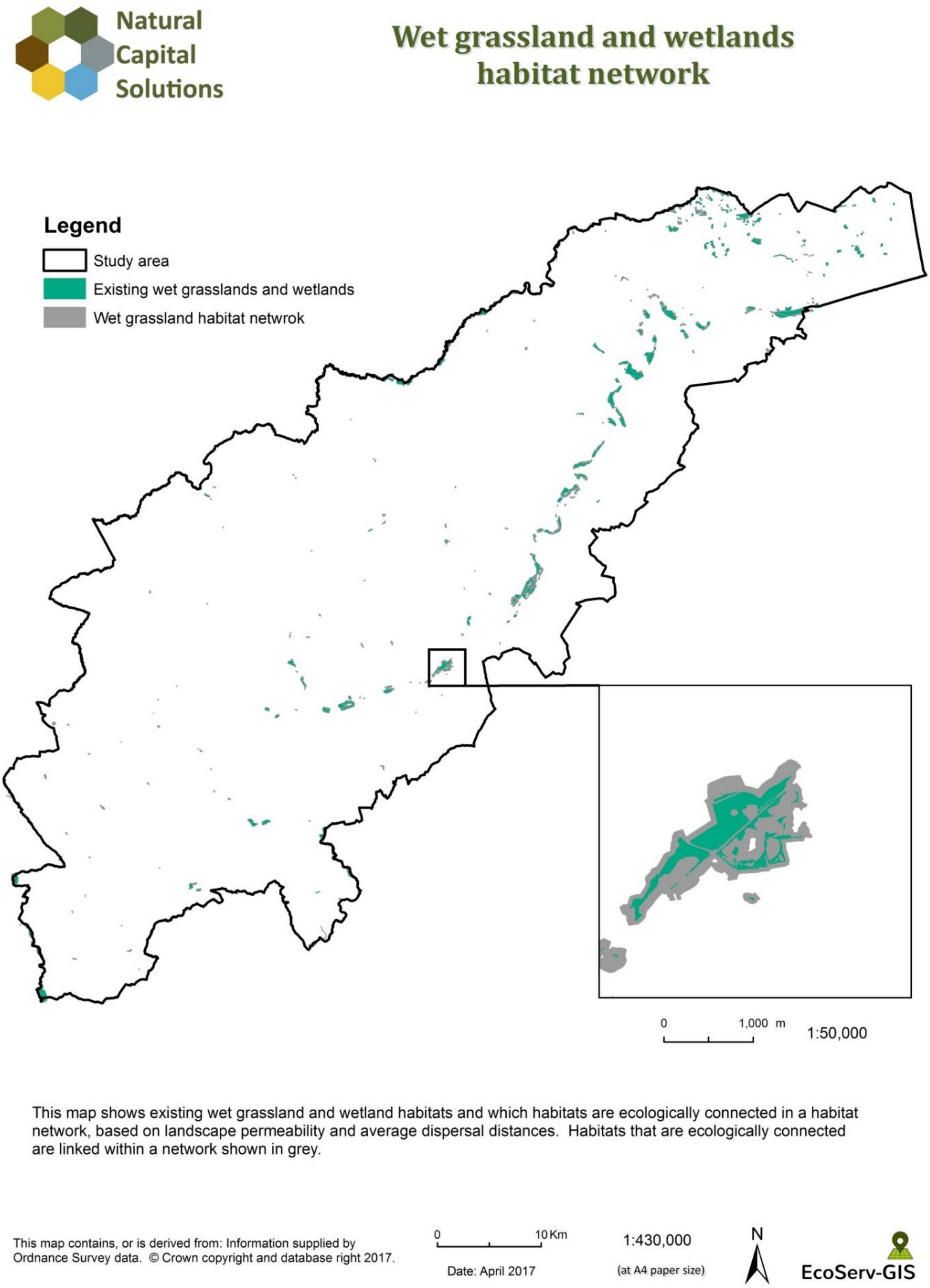
Watts, K., Eycott, A.E., Handley, P., Ray, D., Humphrey, J.W. & Quine, C.P (2010). Targeting and evaluating biodiversity conservation action within fragmented landscapes: an approach based on generic focal species and least-cost networks. *Landscape Ecology,* 25: 1305–1318.

Annex 1: Additional biodiversity opportunity maps

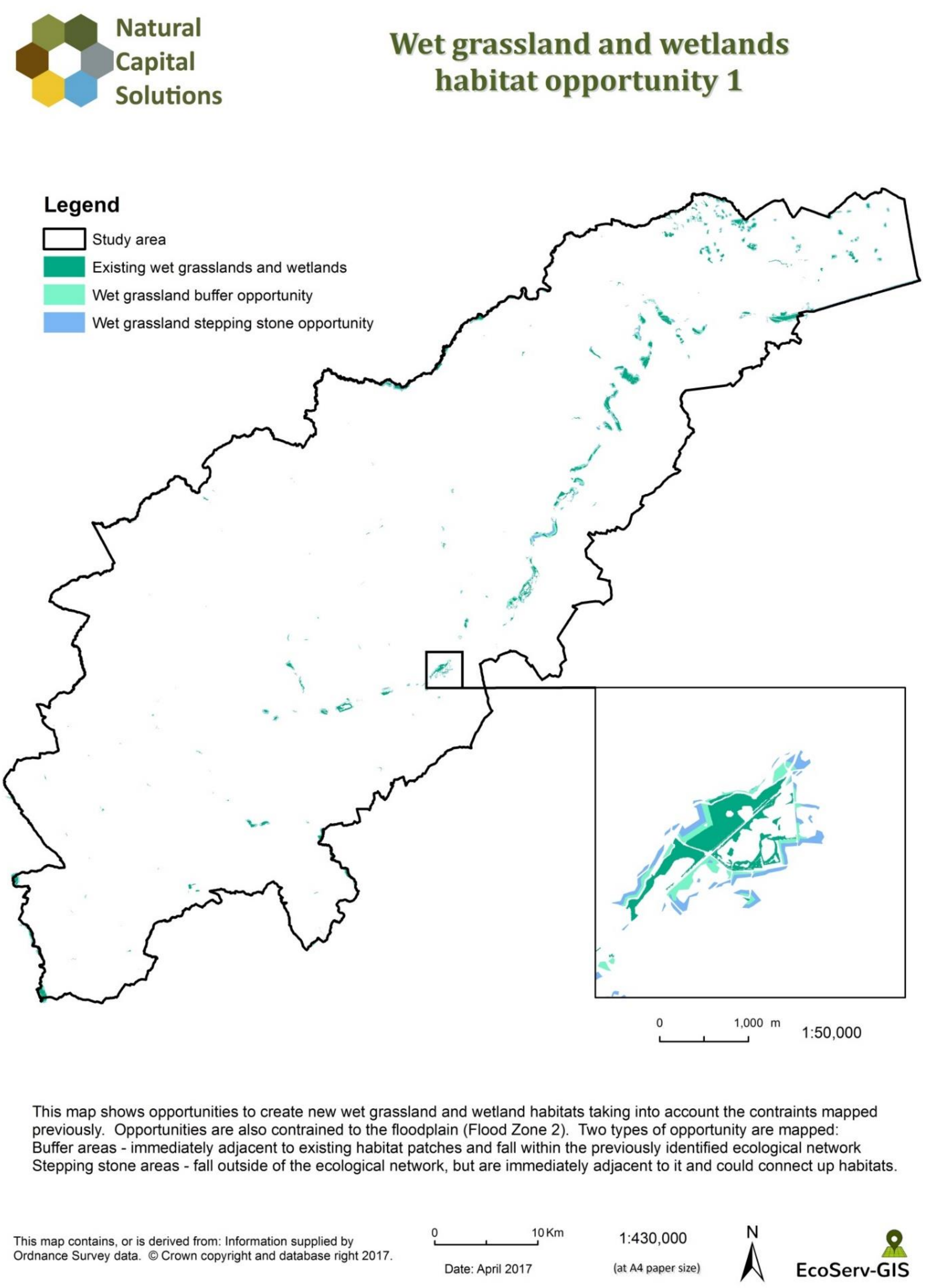
Map A1: Landscape permeability for typical wet grassland and wetland species across Northamptonshire and Peterborough.



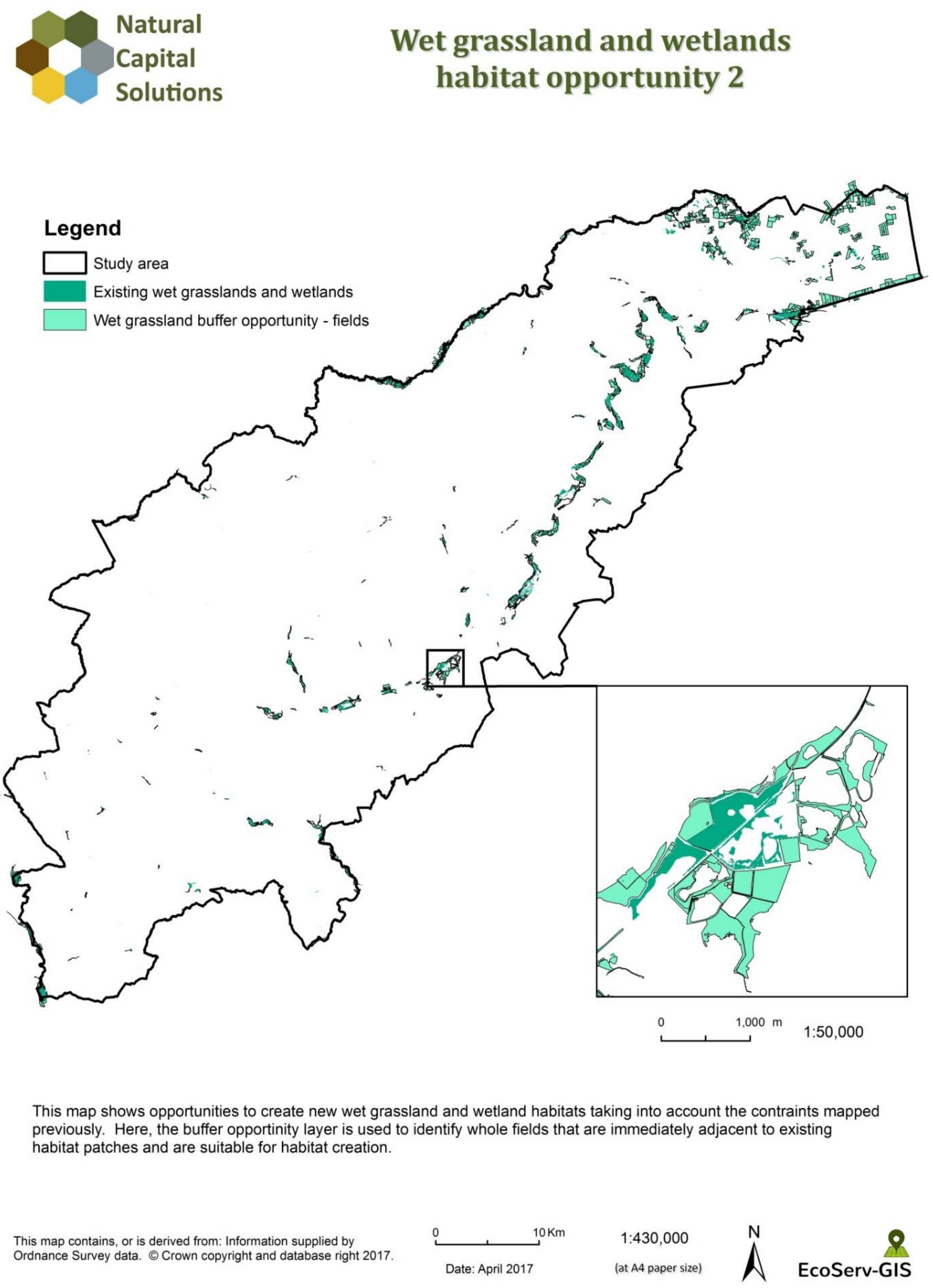
Map A2: Habitat network for wet grassland and wetlands across Northamptonshire and Peterborough.



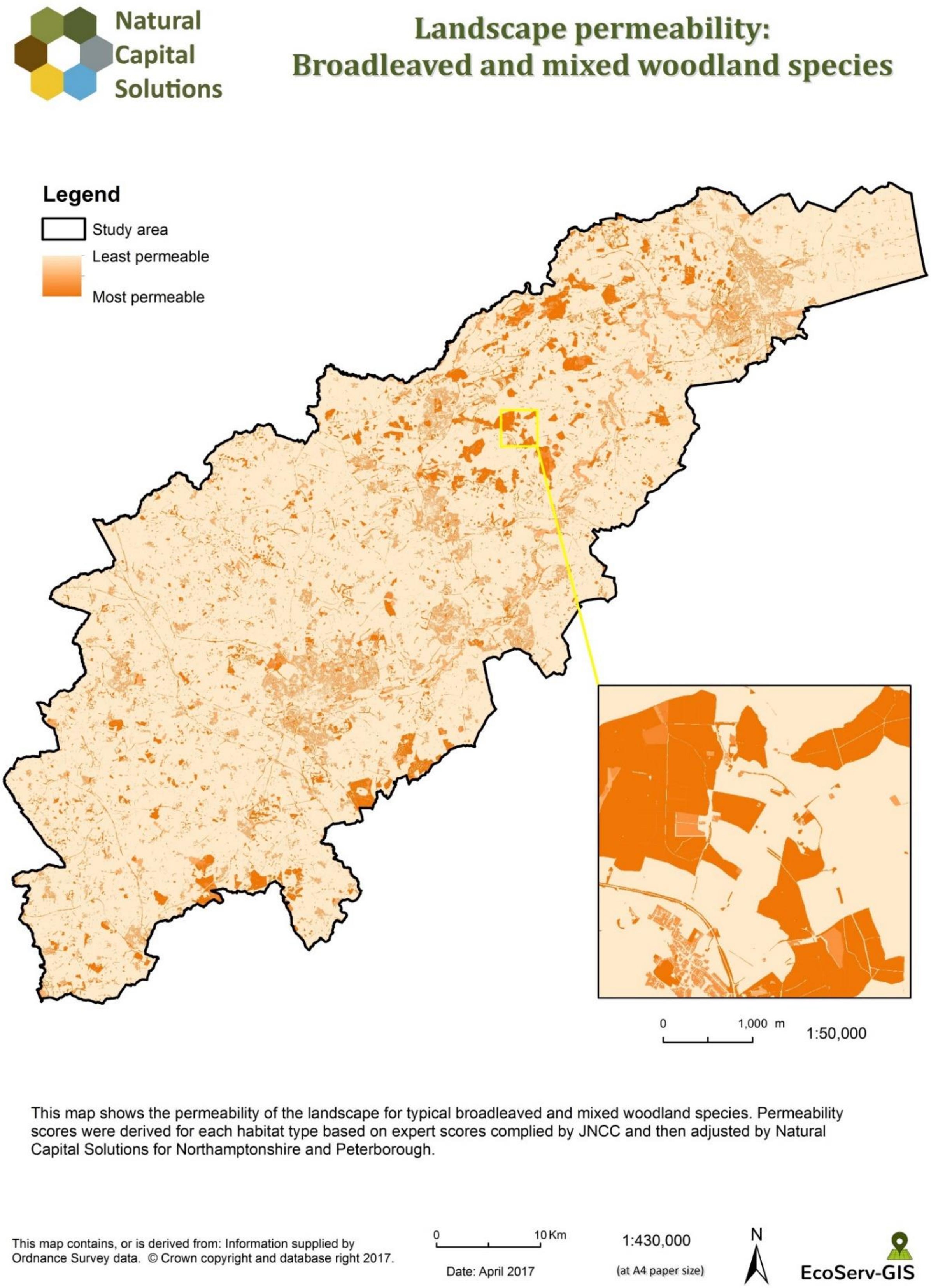
Map A3: Buffer and stepping-stone biodiversity opportunity areas for wet grassland and wetlands across Northamptonshire and Peterborough.



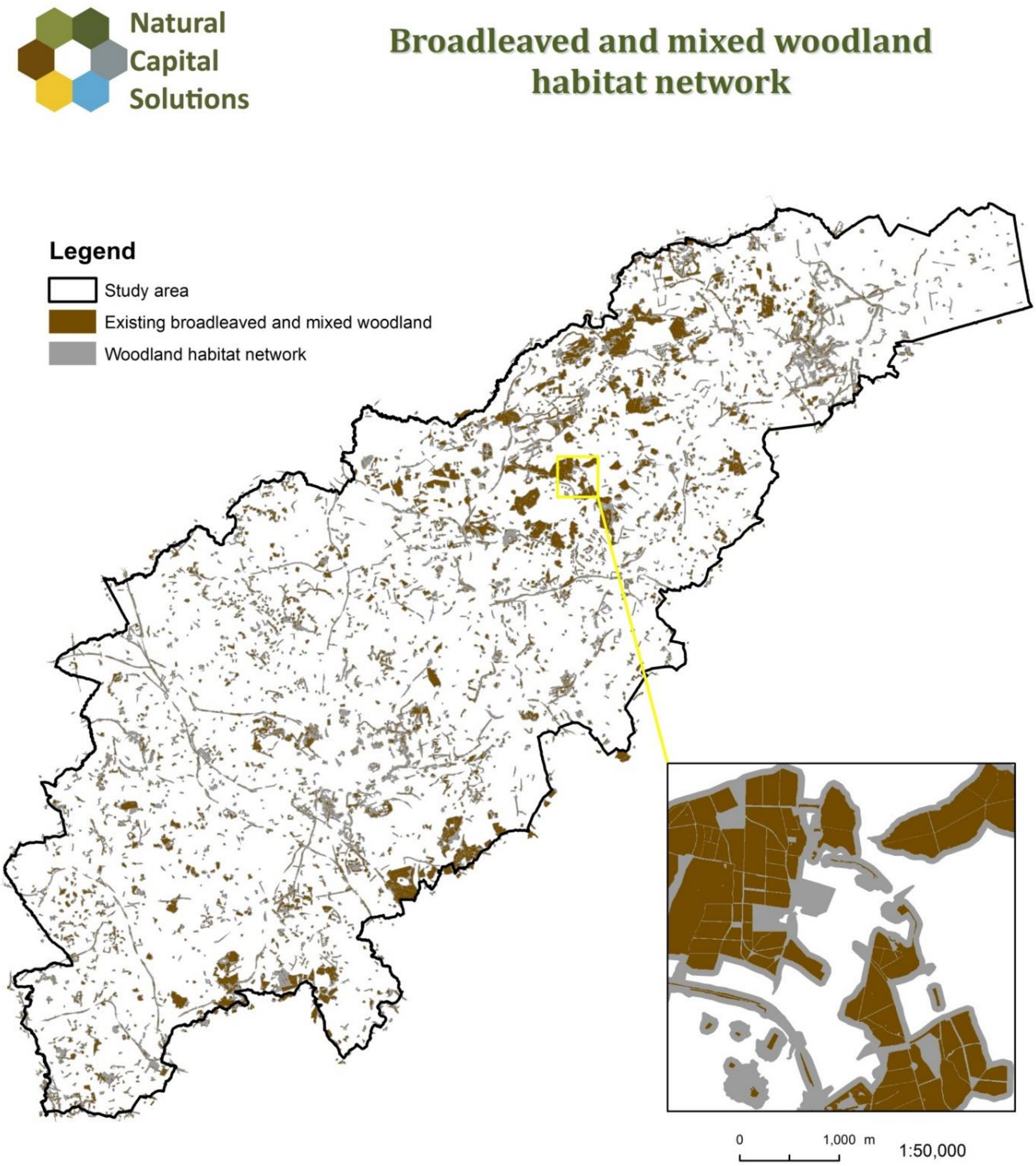
Map A4: Field scale biodiversity opportunity areas for wet grassland and wetlands across Northamptonshire and Peterborough.



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



Map A6: Habitat network for broadleaved and mixed woodlands across Northamptonshire and Peterborough.



This map shows existing broadleaved and mixed woodlands and which habitats are ecologically connected in a habitat network, based on landscape permeability and average dispersal distances. Habitats that are ecologically connected are linked within a network shown in grey.

0 10 Km

Date: April 2017

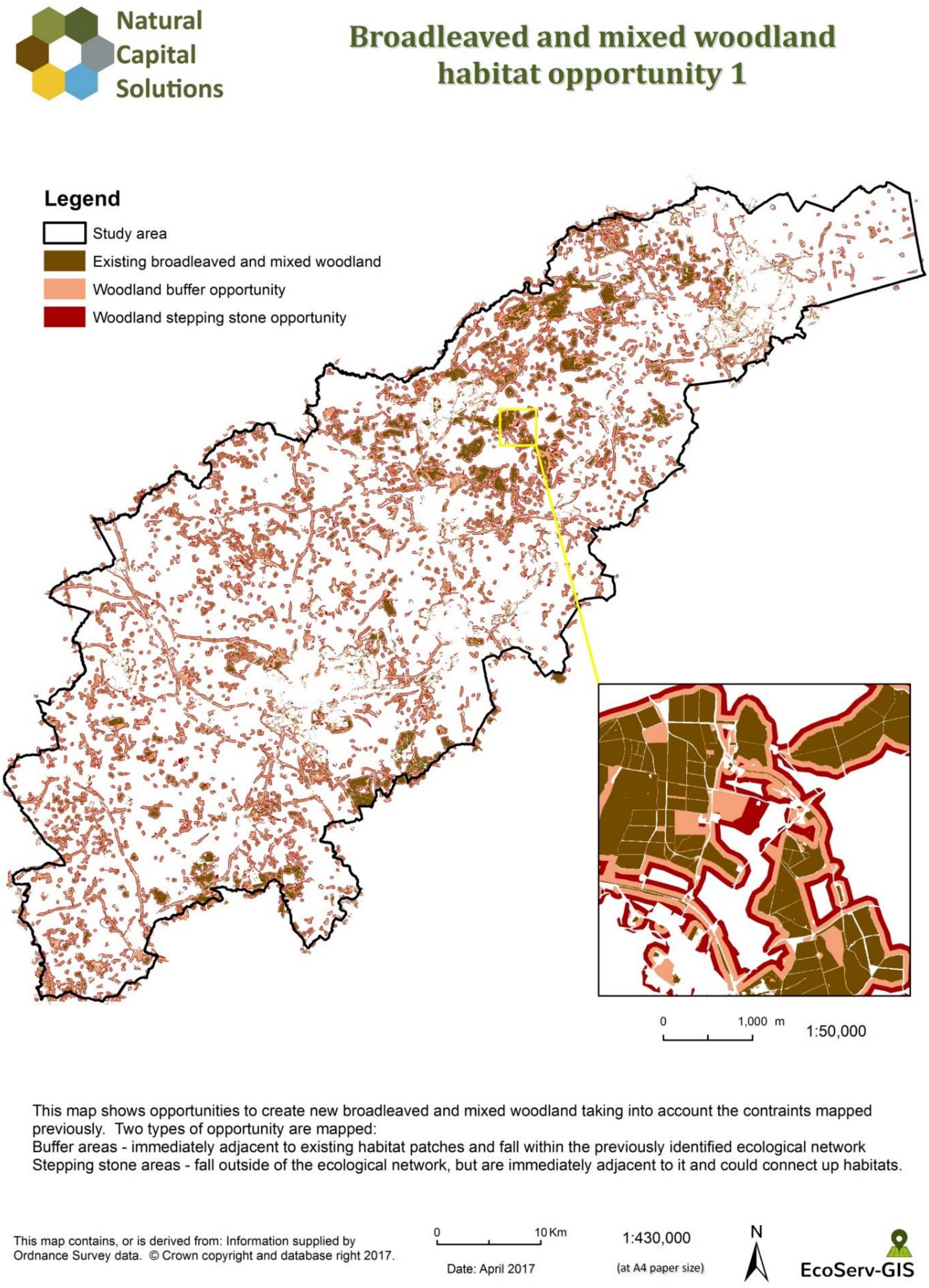
1:430,000

(at A4 paper size)

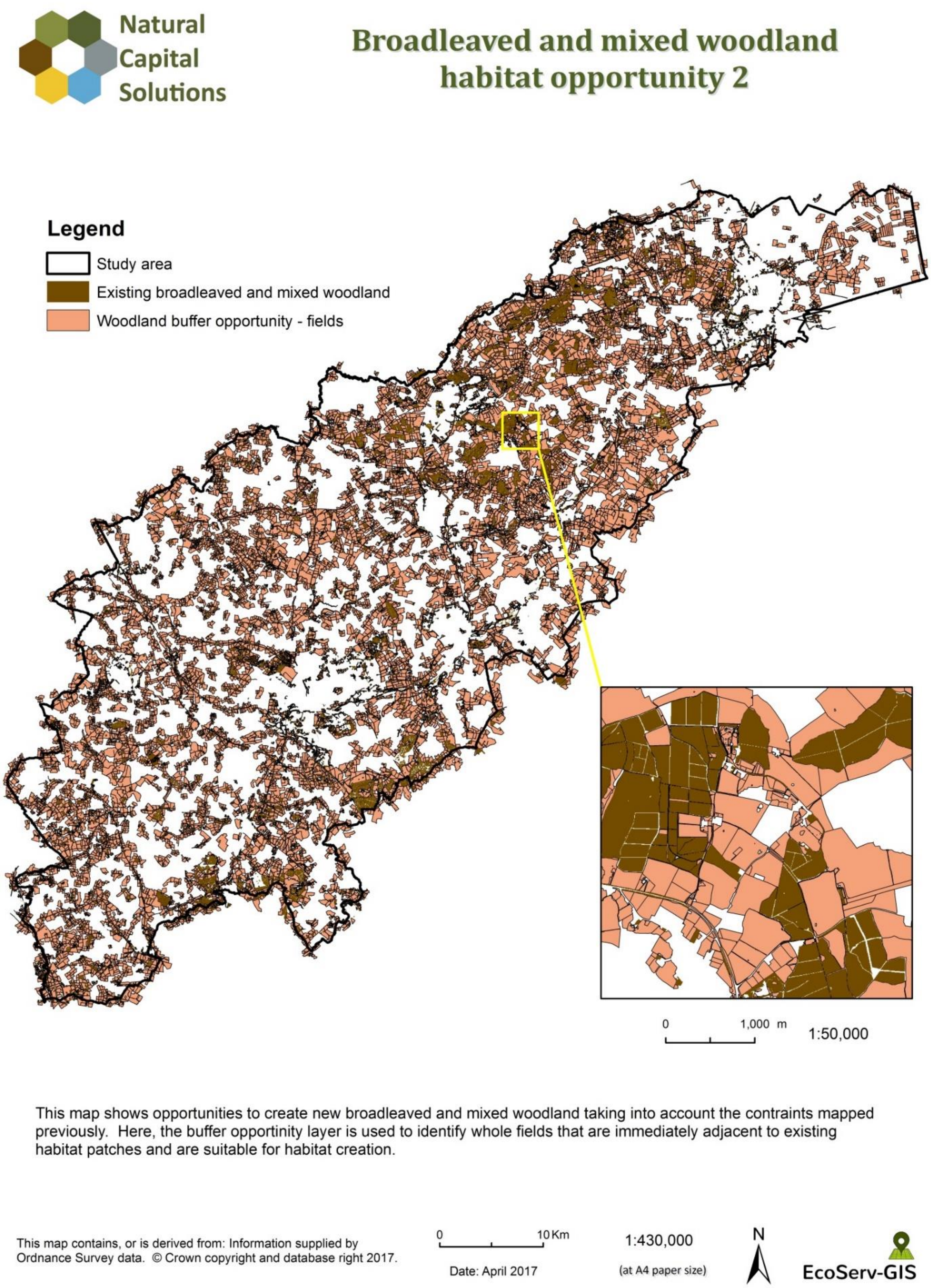
N

EcoServ-GIS

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



Map A8: Field scale biodiversity opportunity areas for broadleaved and mixed woodlands across Northamptonshire and Peterborough.



Annex 2: List of GIS data layers

List and brief description of GIS data layers supplied by Natural Capital Solutions to the Northamptonshire and Peterborough Habitat Opportunity Mapping project partners. Numbers shown in the layer name match the map number in this report wherever possible.

LAYER NAME	DESCRIPTION
Study area	Study area boundary – includes whole of Northamptonshire, Peterborough, and a small patch of Huntingdonshire.
Local authority boundaries	Local authority boundaries
1a: Constraints – land use	Comprises infrastructure, urban, gardens, water.
1b: Constraints – BAP habitats	BAP quality habitats.
1c: Constraints – SAMs	Scheduled Ancient Monuments (with 30m buffer).
1b: Constraints – gas & electricity	Gas pipelines & overhead cables (with 10m buffer).
2: Landscape permeability: semi-natural grassland	Shows the landscape permeability for typical semi-natural grassland species (scored from 1 to 50).
3a: Existing semi-natural grasslands	Existing semi-natural grasslands in Northamptonshire and Peterborough.
3b: Semi-natural grassland habitat network	Semi-natural grassland habitat network.
4a: Semi-natural grassland buffer opportunity	Opportunities for habitat creation at sites that are immediately adjacent to existing habitat and fall within the ecological network.
4b: Semi-natural grassland stepping-stone opportunity	Identifies 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.
5a: Semi-natural grassland buffer opportunity - fields	Whole fields that present opportunities for habitat creation immediately adjacent to existing habitat and fall within the ecological network.
5b: Semi-natural grassland stepping-stone opportunity - fields	Whole fields that present opportunities for habitat creation that fall outside the ecological network, but are immediately adjacent to it.
7a: Water flow regulation opportunity areas – top 10%	Top 10% of opportunities to reduce surface water runoff, taking into account roughness, slope and soil type, and removing constraints.
7b: Water flow regulation opportunity areas – top 25%	Top 25% of opportunities to reduce surface water runoff, taking into account roughness, slope and soil type, and removing constraints.
8: Water flow regulation opportunity areas - fields	Whole fields where at least 50% of the field falls within an opportunity area for reducing surface water runoff.
9: Floodplain woodland opportunity	Opportunities for woodland planting in the floodplain of the watercourses, to slow surface water runoff, absorb water and reduce sediment and pollutant loads flowing into the river network.
11a: Water quality regulation opportunity areas – top 10%	Top 10% of opportunities to reduce soil erosion and enhance water quality, taking into account sub-catchment land cover characteristics, distance to watercourse, slop length, and land use erosion risk, and removing constraints.
11b: Water quality regulation opportunity areas – top 25%	Top 25% of opportunities to reduce soil erosion and enhance water quality, taking into account sub-catchment land cover characteristics, distance to watercourse, slop length, and land use erosion risk, and removing

	constraints.
12: Water quality regulation opportunity areas - fields	Whole fields where at least 50% of the field falls within an opportunity area for reducing soil erosion and enhancing water quality.
13: Agricultural land classification	Agricultural land classification, scored from 1 (highest quality) to 5 (lowest quality). Data from Natural England.
15a-c: Air quality regulation demand – top 10%, 5% & 2%	Three layers highlighting the top 10%, 5% and 2% of areas of greatest demand for air quality regulation, based on two indicators of air pollution sources and two indicators of societal need for air purification.
15d Air Quality Management Areas	Air Quality Management Areas (AQMAs) identified by Defra.
16: Air quality regulation opportunity areas	Top 10% of opportunities to ameliorate poor air quality, taking into account air pollution sources and societal need, and removing constraints.
17: Air quality regulation opportunity areas - fields	Whole plots where at least 50% of the plot / field falls within an opportunity area for ameliorating poor air quality.
19: Accessible natural greenspace opportunity areas	Top 10% of opportunities to meet demand for accessible natural greenspace, taking into account population density, health scores and distance, and removing constraints.
20: Accessible natural greenspace opportunity areas - fields	Whole fields where at least 50% of the field falls within an opportunity area for meeting demand for accessible natural greenspace.
22: Balancing supply & demand for accessible natural greenspace opportunity areas	Top 10% of opportunities for accessible natural greenspace based on balancing demand with naturalness of exiting habitats, and removing constraints.
23: Balancing supply & demand for accessible natural greenspace opportunity areas - fields	Whole fields where at least 50% of the field falls within an opportunity area for accessible natural greenspace based on balancing demand with naturalness of exiting habitats.
24: Combined opportunities for new broadleaved and mixed woodland	Opportunity areas for new woodland, combining opportunities for enhancing biodiversity, water flow regulation, water quality regulation, air quality regulation, and accessible natural greenspace provision.
25: Combined opportunities for new semi-natural grassland	Opportunity areas for new semi-natural grassland, combining opportunities for enhancing biodiversity, water flow regulation, water quality regulation, and accessible natural greenspace provision.
26: Combined opportunities for new wet grassland and wetlands	Opportunity areas for new wet grassland and wetlands, combining opportunities for enhancing biodiversity, water flow regulation, water quality regulation, and accessible natural greenspace provision, and falling within the indicative floodplain.
A1: Landscape permeability: wet grasslands & wetlands	Shows the landscape permeability for typical wet grassland and wetland species (scored from 1 to 50).
A2a: Existing wet grassland and wetlands	Existing wet grasslands and wetlands across Northamptonshire & Peterborough.
A2b: Wet grassland and wetland habitat network	Wet grassland habitat network.
A3a: Wet grassland and wetland buffer opportunity	Opportunities for habitat creation at sites that are immediately adjacent to existing habitat and fall within the ecological network.
A3b: Wet grassland and wetland stepping-stone opportunity	Identifies 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.
A4a: Wet grassland and wetland buffer opportunity - fields	Whole fields that present opportunities for habitat creation immediately adjacent to existing habitat and fall within the ecological network.

A4b: Wet grassland and wetland stepping-stone opportunity - fields	Whole fields the present opportunities for habitat creation that fall outside the ecological network, but are immediately adjacent to it.
A5: Landscape permeability: broadleaved and mixed woodland	Shows the landscape permeability for typical broadleaved and mixed woodland species (scored from 1 to 50).
A6a: Existing broadleaved and mixed woodland	Existing broadleaved and mixed woodland across Northamptonshire and Peterborough.
A6b: Broadleaved and mixed woodland habitat network	Habitat network for broadleaved and mixed woodland.
A7a: Broadleaved and mixed woodland buffer opportunity	Opportunities for habitat creation at sites that are immediately adjacent to existing habitat and fall within the ecological network.
A7b: Broadleaved and mixed woodland stepping-stone opportunity	Identifies 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.
A8a: Broadleaved and mixed woodland buffer opportunity - fields	Whole fields that present opportunities for habitat creation immediately adjacent to existing habitat and fall within the ecological network.
A8b: Broadleaved and mixed woodland stepping-stone opportunity - fields	Whole fields the present opportunities for habitat creation that fall outside the ecological network, but are immediately adjacent to it.