Lot 2: Biodiversity Opportunity Mapping

FULL REPORT

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NATURAL ENGLAND

Nottingham City Council

ecosulis

Natural Capital Strategy
Lot 2: Biodiversity Opportunity Mapping

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NON-TECHNICAL SUMMARY

Nottingham City Council commissioned this report and GIS modelling of biodiversity opportunities within the City of Nottingham. The work is part of a wider project regarding natural capital in Nottingham involving habitat mapping, ecosystem service assessment, and a tree planting strategy.

This report acts a technical methods document for the GIS modelling work undertaken as part of the project, in addition to presenting the results of this work and providing guidance on how these may be interpreted.

The work described in this report comprises two phases, the first of these situates the biodiversity opportunity mapping within the context of Nottingham and the second presents the methodology and findings of this mapping exercise. The GIS modelling work explores the ecological networks within Nottingham and applies additional GIS data to the outputs of this modelling to identify and review biodiversity opportunities within the city. The methods applied in producing these GIS outputs and the results of this work are presented in this report and accompanying GIS data.

To model biodiversity opportunities, we apply ecological connectivity modelling to a habitat map of Nottingham developed by 4EI with support and ground-truthing undertaken by Ecosulis. Connectivity modelling used here applies cost-distance analysis - an established approach for modelling biodiversity opportunities, allowing species dispersal through ecological networks to be predicted. In turn, this allows habitats where habitat interventions (e.g., habitat enhancement and creation) may have the greatest ecological impact to be identified.

In summary, this project is grounded in established biodiversity opportunity mapping methods and seeks to apply these to identify priority areas for targeted biodiversity interventions within Nottingham.

1 INTRODUCTION

Ecosulis were commissioned by Nottingham City Council in August 2021 to undertake a series of spatial nature planning activities to allow detailed analysis of the city's natural resources, habitat networks, tree stock, and ecosystem services.

This report relates to the biodiversity opportunity mapping element (Lot 2) of the project. The aims of the biodiversity opportunity mapping are to:

- Through ecological network modelling, build an understanding of Nottingham's ecological networks, both at the regional and local scales
- Identify high-level opportunities for biodiversity enhancement, including opportunities to expand existing core habitat, watercourse daylighting opportunities (for watercourses currently flowing through culverts) and opportunities to enhance areas of modified grassland
- Develop initial priorities for biodiversity enhancement using additional data, including geology and property ownership.

This report presents the methods used to achieve these objectives. GIS outputs from the modelling have been supplied alongside this report.

2 UNDERSTANDING NOTTINGHAM'S ECOLOGICAL NETWORKS

2.1 Introduction to Ecological Network Modelling

Identifying and mapping biodiversity opportunities in Nottingham first required an understanding of the ecological networks that connect different habitat patches across the city with one another. This work seeks to highlight areas of the city in which habitats are well connected, enabling species to traverse across large areas without being cut off by large gaps in suitable habitat. It will inevitably also highlight, as in most global cities, a dominance of fragmented habitat patches that are poorly connected. This often leaves isolated pools of biodiversity that have low resilience because of the inability to move to neighbouring patches of suitable habitat when conditions change, simply because there are none to move to. To map Nottingham's ecological networks, existing ecological network modelling work was built upon, including studies undertaken in Somerset, the West of England region, and at the wider county-level in Nottinghamshire. These studies provided the basis to perform a detailed, city-level assessment of the networks using novel datasets produced for the wider Nottingham natural capital assessment project.

Ecological network modelling, as undertaken here, models habitat connectivity for a set of broad habitat types using cost–distance analysis to model species dispersal. The logic that underpins these approaches is that different habitats (e.g., vegetation or aquatic communities) support different types of species and different species vary in their ability to traverse different types of vegetation and land use (i.e., habitat permeability). The dispersal capability is estimated for an example species group, known as focal species, and the potential for their dispersal across mapped habitats is then calculated relative to modelled biodiversity hotspots.

In mapping biodiversity opportunity in Nottingham, ecological network modelling was applied to develop an accurate understanding of the connectedness of Nottingham's existing ecological networks at the city scale, acting as the basis upon which habitat enhancement and creation opportunities can be identified.

2.2 Network Modelling Methodology

An overview of the methodological steps taken to model Nottingham's ecological networks is given below, with each of these steps being detailed throughout the remainder of this section:

(i) production of input data,

(ii) definition of species dispersal parameters,

(iii) identification of core habitat sites (sources for focal species dispersal) from the habitat mapping,

(iv) assignment of permeability values to each habitat type in the habitat mapping to produce a geospatial permeability layer,

(v) cost-distance modelling to model the dispersal of species through the permeability layer from core habitat sites.

The first step taken to model Nottingham's ecological networks was to gather the input data required for this modelling. This data comprised:

(i) a full habitat map containing habitat codes for all land within the area of interest

(ii) a set of species dispersal parameters which describe the ability of a generic focal species to disperse through the landscape and the habitats they are likely to disperse from.

Habitat mapping was undertaken for the City of Nottingham under Lot 1 of this project[1], while a landcover map was also developed for a 1 km buffer of the city boundary using OS MasterMap and open-access data. More detail on the production of the input habitat data is given in Annex 1.

Second, species dispersal parameters were developed in two stages, starting with a literature review and followed by expert review. The literature review encompassed ecological network mapping projects undertaken in Somerset, the West of England Region[2], and Nottinghamshire[3]. Specifically, these parameters include: (i) a table linking habitat type to the permeability of that habitat to the focal species, (ii) a set of habitat types which constitute core habitat for the focal species, (iii) a minimum area threshold (in hectares) for a habitat to be classed as core habitat, and (iv) a maximum dispersal distance (in meters) that the focal species will travel from its core habitat. Landscape permeability values were adapted from modelling work undertaken in Nottinghamshire and Somerset and are presented in Annex 2. Dispersal distances and core habitat areas are presented in Table 1 and Table 3 later in this section.

Third, habitats which represent core habitat for a given habitat network (i.e., a permeability value of zero)[4] are selected in consideration of the habitat type and the area of the habitat. Core habitats which are within 5m of other core habitats and are not bisected by a road are considered as a single unit of core habitat[5]. Fourth, habitat permeability values are joined to each

[1] Ecosulis, 2022. *J006705 – Lot 1: Habitat Survey and Mapping - full report*.

[2] West of England Nature Partnership, 2020. *Towards a Nature Recovery Network for the West of England*. West of England Nature Partnership.

[3] Nottinghamshire Biodiversity Action Group, 2020. *Biodiversity Opportunity Mapping*.

[4] Where lower values represent low dispersal potential, and high values represent high dispersal potential.

[5] Bowe, et al. 2019. *Somerset's Ecological Network: mapping the components of the ecological network in Somerset*. Somerset Wildlife Trust, Taunton.

habitat in the habitat mapping using habitat type as a common attribute field. This allows landscape permeability to be mapped for both the woodland and open permeability networks.

Finally, species dispersal through each habitat network is modelled. Here, cost-distance analysis is applied to mapped habitat permeability to predict the ability of the focal species to move through the landscape. Dispersal distances are represented in this analysis as the maximum cumulative cost value, as raster resolution is set so that 1 cell is equal to $1m^2$. Therefore, the maximum cost that can be accumulated assuming each cell has a score of 1 (the minimum value for non-core habitat) is equal to the maximum dispersal distance in meters. The logic underpinning the cost-distance approach is presented in Figure 1.

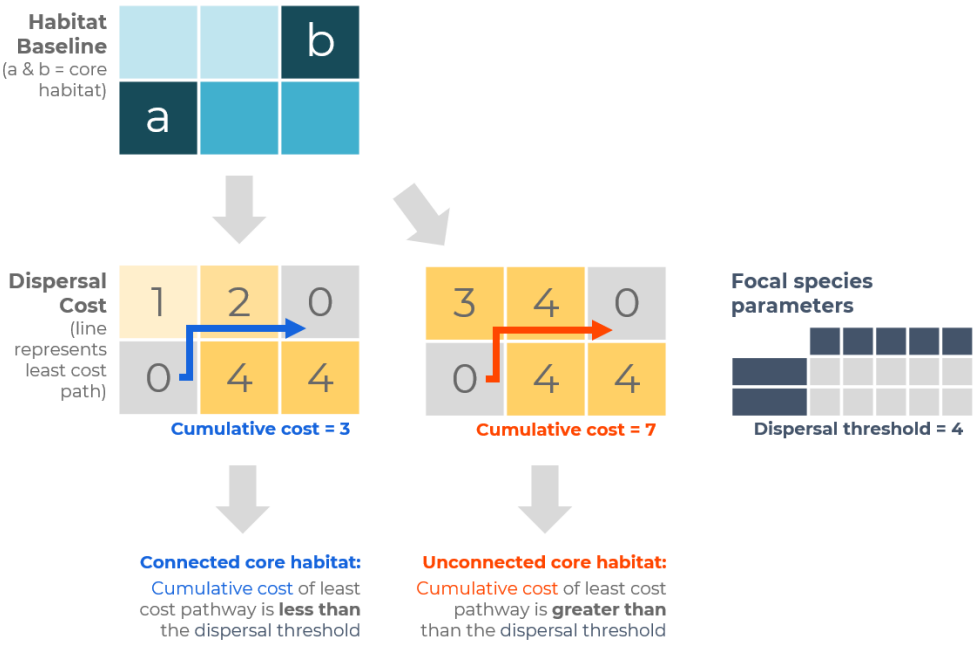


Figure 1.

Schematic illustrating use of cost–distance analysis to identify functionally connected core habitats

Ecological network modelling was run at two scales, (i) the regional scale, and (ii) the local scale. This was to develop an understanding of habitat connectivity within the City of Nottingham through local-scale network modelling and to situate these local networks in the wider context of regional habitat networks.

2.3 Regional-Scale Network Modelling

2.3.1 WHY MODEL REGIONAL-SCALE NETWORKS?

Regional-scale habitat networks were modelled initially to situate Nottingham's ecological networks within the context of the wider landscape, in turn also positioning biodiversity opportunity within these regional networks. This work sought to look at broad habitat categories and assess their interconnectedness with respect to a generic focal species. Regional-scale networks were modelled for both woodland and open (i.e., grassland and heathland) habitat networks. Heathland and grassland habitats have been grouped together into the single 'open'

habitat classification in recognition of the limited extent of heathland habitats within Nottingham.

2.3.2 INPUT PARAMETERS

Modelling regional-scale ecological networks drew upon modelling work undertaken in Somerset[6] and the West of England[7], amongst others. These models apply core habitat thresholds designed to identify large patches of core habitat throughout the landscape, which then act as points of dispersal. Cumulative cost values produced by modelling dispersal from these areas of core habitat are then grouped into four categories: (i) core habitat, (ii) 1 to 500m from core habitat, (iii) 501 to 1,000m from core habitat, and (iv) 1,001 to 5,000m from core habitat. Each of these categories represents increments of connectivity where the smaller the distance, the better connected habitats within the region are likely to be to core habitats. This allows connectivity to be understood in a series of increments, allowing a categorisation of biodiversity opportunities within each increment.

An initial run of the regional network models identified limited networks throughout Nottingham. This was found to be a result of the core habitat thresholds resulting in only a small number of core habitats to act as points of dispersal being identified within the city. To account for this, a second run of the modelling was undertaken where the core habitat thresholds were reduced by 50%. This enabled a further understanding of connectivity within the city to be gained, however, it should also be noted that this is an indicative run of the models where literature-based modelling parameters have been adapted to derive insights about urban landscape permeability. Parameters applied to regional network modelling are provided in Table 1, below. The results of this modelling have been applied to mapping biodiversity opportunity in *Section 4.2*.

Table 1. *Regional network modelling dispersal distances and minimum core habitat areas*

	Maximum Dispersal Distance (m)	**Minimum Core Habitat Area** (ha)
Woodland	5,000	4
Open	5,000	1.5

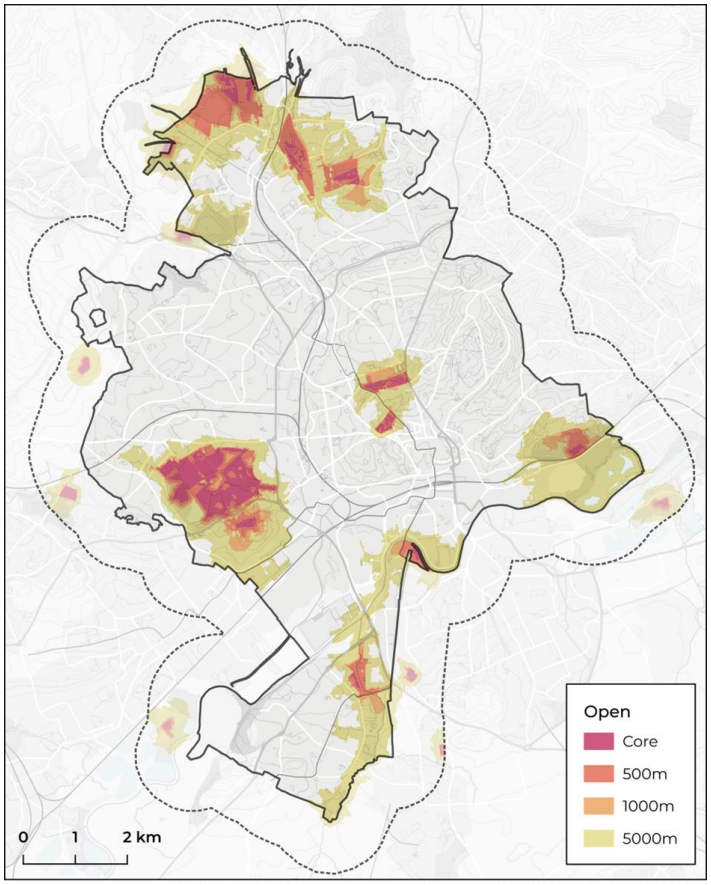
2.3.3 RESULTS

Modelled woodland and open habitat networks are presented in Figure 2 below. Areas of core habitat are generally located around the periphery of the city. The lighter colours – representing habitats which are connected to these core habitats – indicate opportunities for the enhancement or creation of habitats to better connect existing networks. The modelling also indicates that areas of open habitat within Nottingham are more likely to be disconnected from

[6] Bowe, et al. 2019. *Somerset's Ecological Network: mapping the components of the ecological network in Somerset*. Somerset Wildlife Trust, Taunton.

[7] West of England Nature Partnership, 2020. *Towards a Nature Recovery Network for the West of England*. West of England Nature Partnership.

wider networks than woodland networks. Woodland core habitats, however, are more likely to be connected to wider networks. The role of linear expanses of habitat (e.g., along rivers and rail lines) in connecting core habitats is also evident from the regional network modelling presented in Figure 2.

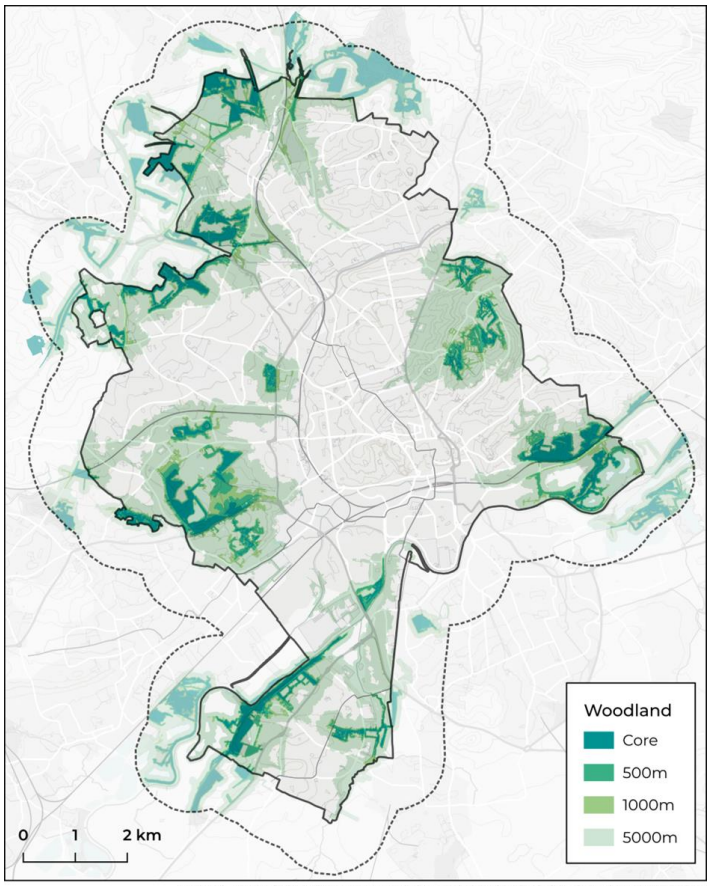


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Figure 2.

(a)

Modelled regional scale open habitat networks, displaying core habitats and dispersal increments.



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Figure 2.

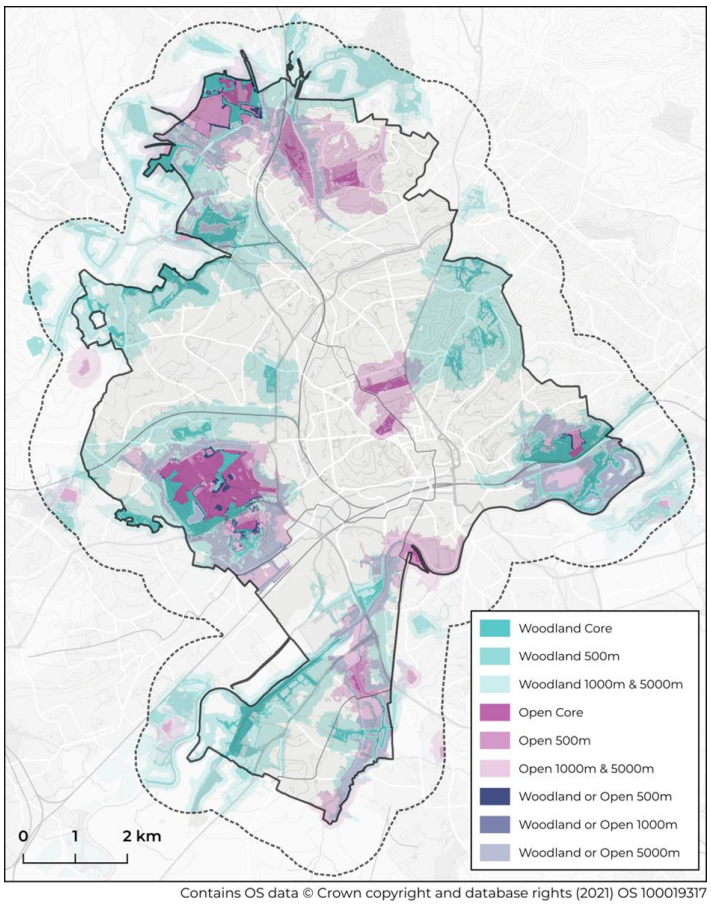
(b)

Modelled regional scale woodland habitat networks, displaying core habitats and dispersal increments.

In many places, the woodland and open habitat networks overlap. Here, a combined woodland and open habitat network map has been produced using raster calculation. The raster calculation process prioritises a network (where an overlap is present) by selecting the network which is better connected to its core habitat. Cells where overlapping networks are equally well connected are classified separately. These logics are illustrated as a matrix in Table 2.

Table 2. *Matrix illustrating how modelled regional open and woodland networks are processed to produce a combined network*

		Open Network			
		Core	**500m**	**1,000m**	**5,000m**
Woodland Network	**Core**	No overlap	Woodland	Woodland	Woodland
	500m	Open	Open or Woodland	Woodland	Woodland
	1000m	Open	Open	Open or Woodland	Woodland
	5000m	Open	Open	Open	Open or Woodland



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Figure 3.

Modelled regional scale combined ecological networks displaying core habitats and dispersal increments.

The combined habitat network mapping is presented in Figure 3. The figure illustrates habitat equally connected to both open and woodland core habitat (highlighted in blue) and where habitats are better connected to either the open or woodland habitat networks. This indicates areas of habitat which may be better suited to open or woodland habitat creation, alongside overlapping areas where opportunities are present to enhance both open and woodland networks.

2.4 Local-Scale Network Modelling

2.4.1 WHY MODEL LOCAL-SCALE NETWORKS?

The rationale for undertaking local-scale ecological network modelling was to identify smaller, more fragmented wildlife sites with greater potential for enhancement alongside the existing good quality wildlife sites identified by the regional-scale modelling. Local-scale habitat networks were modelled for four broad habitat groups: (i) woodland, (ii) wetland, (iii) heathland

and acid grassland, and (iv) calcareous and neutral grassland. These four habitat groups were selected for consistency with the county-level biodiversity opportunity modelling[8].

2.4.2 INPUT PARAMETERS

To identify local networks within Nottingham as areas for improvement, the modelling parameters specified below were applied to the ecological network models. These values apply shorter maximum dispersal distance, and smaller minimum core habitat areas. Maximum dispersal distances applied were adapted from ecological network modelling undertaken in Somerset. Permeability values applied for woodland networks are the same as those applied to regional networks, while permeability scores applied for 'calcareous and neutral grassland', 'heathland and acid grassland', 'woodland', and 'wetland' networks are presented in Annex 2.

Table 3. *Local network modelling dispersal distances and minimum core habitat areas*

	Maximum Dispersal Distance (m)	**Minimum Core Habitat Area** (ha)
Woodland	750	0.5
Calcareous and Neutral Grassland	500	0.1
Heathland and Acid Grassland	600	0.1
Wetland	400	0.01

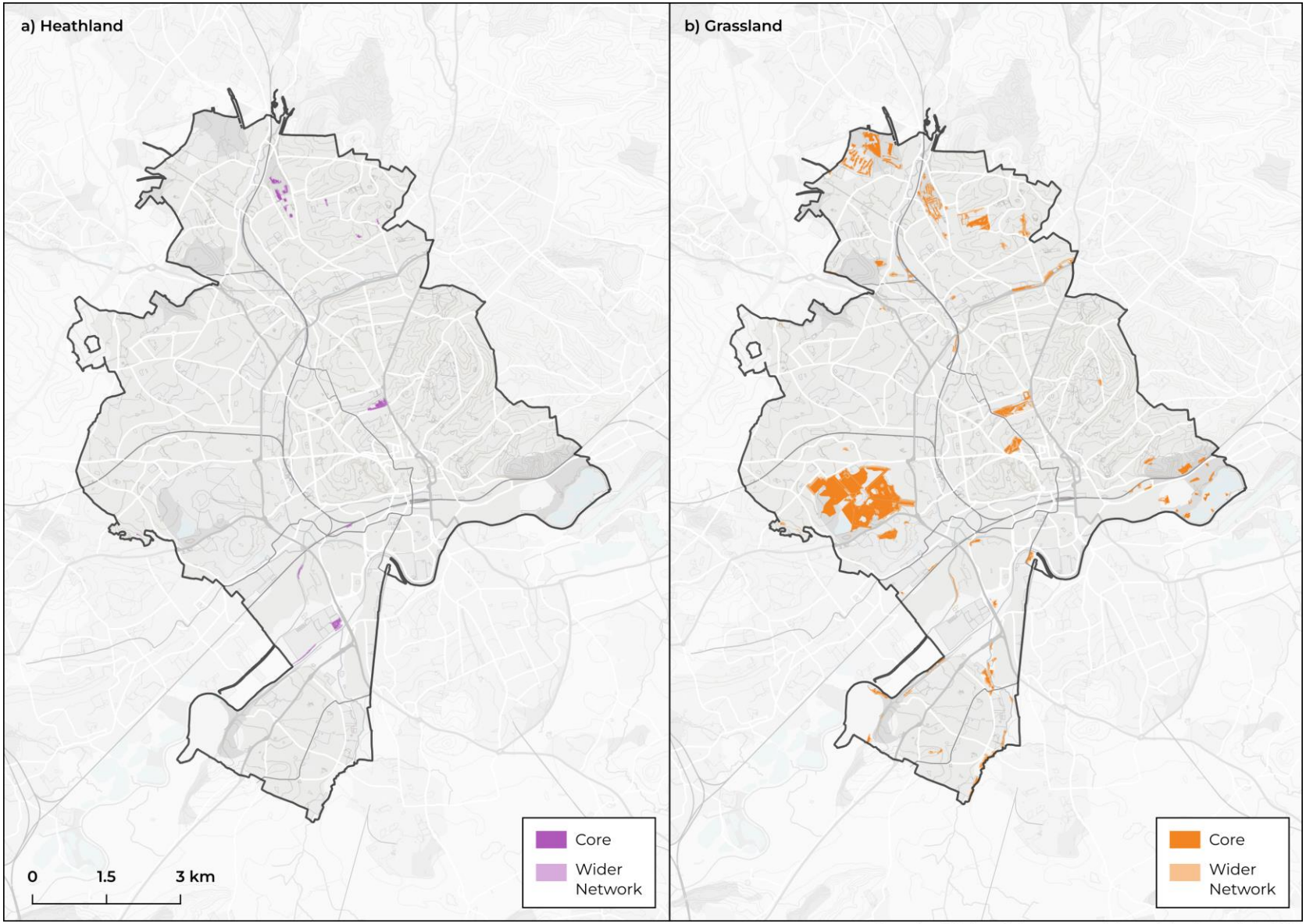
2.4.3 RESULTS

Modelled local-scale networks for each of the four habitat networks are presented in Figure 4. Larger maps are presented in Annex 4, alongside the biodiversity opportunities presented in this report. Figure 4 shows core habitat and the wider habitat networks. Parts of the wider habitat networks outside of the Nottingham city council area are included where suitable habitat types are found within the maximum dispersal distance from a core habitat patch that falls within the council area.

The modelled networks show the prominence of woodland habitats in Nottingham and its surroundings, as well as the concentration of wetland habitats along the River Trent and its flood plain. Similarly, neutral and calcareous grassland habitats are shown to be distributed throughout the city. Analysis of bedrock geology shows that heathland and acid grassland habitats occur predominantly in the areas of sandstone geology found across central Nottingham.

[8] Nottinghamshire Biodiversity Action Group, 2020. *Biodiversity Opportunity Mapping*.

There is some overlap between the wider habitat networks for different networks. This is a result of some habitats being within the maximum dispersal distance of core habitat from different habitat networks (e.g., woodland, wetland). As a result, these habitats may be functionally connected to multiple habitat networks.

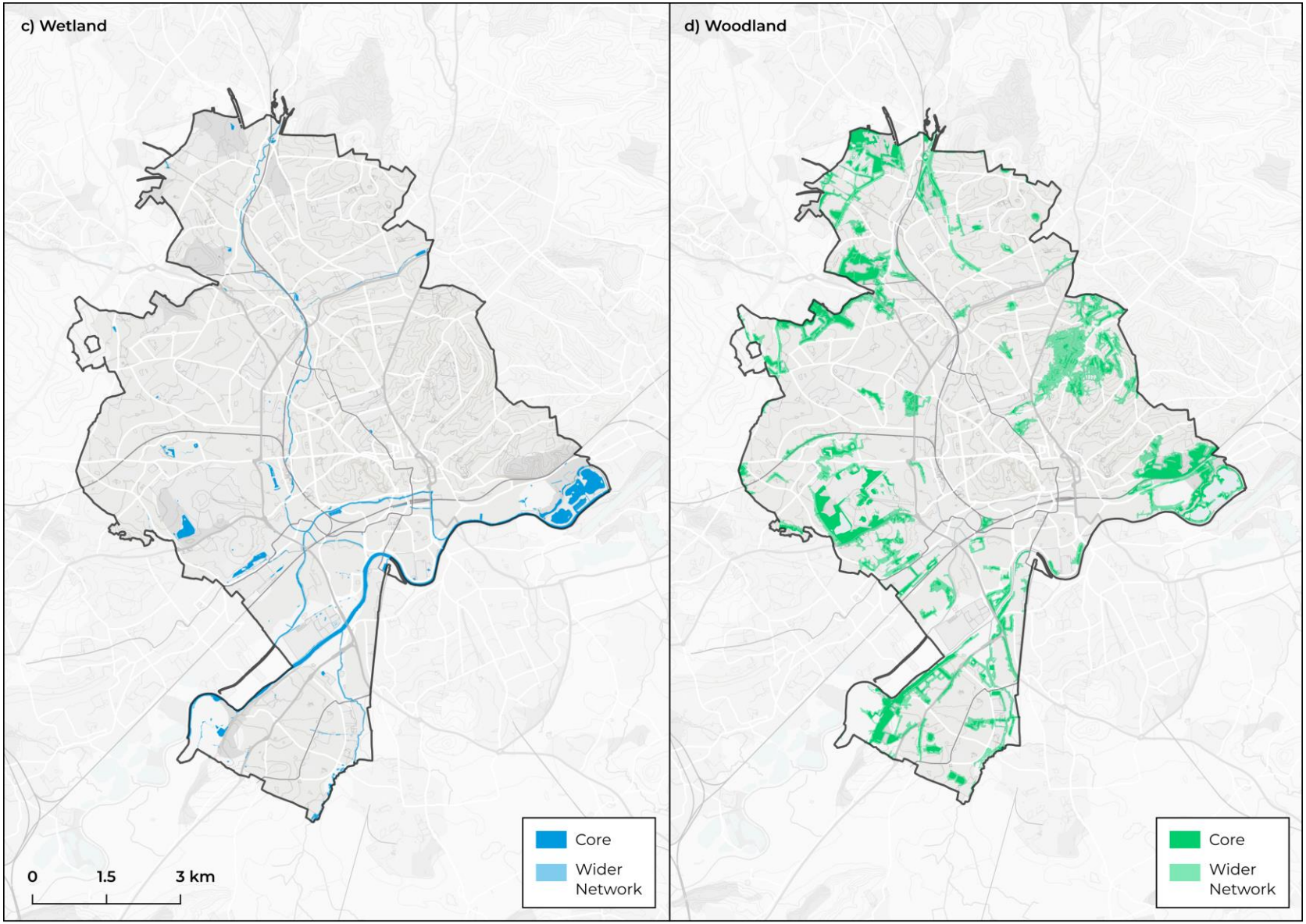


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Figure 4.

(a - b)

Modelled local scale networks displaying core habitats and the connected wider network for the heathland, grassland, wetland, and woodland networks



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Figure 4.

(c - d)

Modelled local scale networks displaying core habitats and the connected wider network for the heathland, grassland, wetland, and woodland networks

3 MAPPING BIODIVERSITY OPPORTUNITY IN NOTTINGHAM

3.1 Introduction

Biodiversity opportunity areas are those that have been found to be located in areas that appear to be most suitable for interventions such as habitat creation or habitat enhancement. Suitability for habitat creation could result from an area currently being of a habitat type that would easily be converted or reverted to a different type that supports greater biodiversity. An area could be suitable for habitat enhancement where currently there is, for example, poor quality grassland that could be recovered to provide a diverse and rich grassland capable of supporting myriad species. A multi-level GIS approach has been taken to map biodiversity opportunity in Nottingham. Each of these levels seeks to map opportunities associated with different geographical features of the landscape. These are presented in Table 4.

Prior to the mapping of biodiversity opportunities, the locations of features that could constrain acting on those opportunities were identified and any adjacent biodiversity opportunity areas were adjusted to refine the mapping further. Examples of constraints are power lines impacting tree planting, existing land uses that have community value (e.g., sport facilities) and existing areas of ecological value. These constraints, described in Section 3.2, were specified for each network and represent areas where habitat enhancement for biodiversity gain is constrained by other landscape features.

Initial opportunities have been identified through a review of the modelled ecological network outputs presented in Section 2. This review was undertaken during a workshop held with local specialists and stakeholders in March 2022. Opportunity identification was supplemented using secondary data that identifies both additional biodiversity opportunities and constraints that restrict acting on some of the opportunities. Opportunity mapping presented in this section includes:

Table 4. *Technical description and ecological justification of biodiversity opportunity mapping phases*

Technical Description	Ecological Justification
Core habitat expansion opportunities	Identifies core habitats which are likely to have the greatest potential to be expanded through habitat creation or enhancement
Intersection of urban networks and improved grassland	Identifies grassland of low ecological value which is likely to have potential to support habitat creation or enhancement
Intersection with calcareous / acid geology and grassland opportunity	Identifies grassland of low ecological value which is likely to have potential for creation of either calcareous or acid grassland

Technical Description	Ecological Justification
Culvert daylighting opportunities	Identifies culverted watercourses which are likely to have potential for daylighting to enhance and support wetland networks

3.2 Constraint Removal

Constraints represent areas where the physical environment and existing infrastructure constrain opportunities for habitat enhancement and creation that were identified by the network modelling. Prior to modelling of biodiversity opportunities, these constraints were removed from each of the associated networks, as described in Table 5, prior to further analysis of biodiversity opportunity.

Table 5. *List of constraints applied to biodiversity opportunity mapping and the networks to which constraints were applied*

Constraint	Relevant Networks	Justification
Overhead powerlines (10m easement)	Wetland, Woodland	Conflict between large trees and the requirement to ensure infrastructure is visible and unobstructed.
Sports facilities	All	Sports facilities are likely to limit ecological network enhancement opportunities despite often consisting of large patches of grassland.
Core habitats of different habitat networks	All	These habitats are important to their respective habitat networks so there may not be a wish to change them.
Priority Habitat Inventory	All	Habitats that are recognised as being threatened and therefore changes in habitat type are unlikely to be appropriate

3.3 Opportunities to Expand Existing Core Habitats

3.3.1 METHODS

This phase of modelling sought to identify core habitats which are likely to have the greatest potential to be expanded through habitat creation or enhancement. Opportunities to expand existing core habitats were modelled for both existing green spaces in Nottingham and private gardens. To identify existing green spaces, the "make" classification of the Ordnance Survey's MasterMap data was used – indicating "*whether the real-world nature of the feature is man-made or natural*"[9]. Here, land parcels classified as 'Natural' were taken to represent existing green space. To identify gardens the 'Primary function' classification of Ordnance Survey's MasterMap Greenspace dataset was used to extract land parcels described as 'Private Garden'.

[9] Ordnance Survey, 2017. *OS MasterMap Topography Layer Technical Specification v2 08/2017*.

This logic was used to create one subset of data representing green spaces and another representing gardens. Next, both datasets were overlayed over the modelled local-scale ecological networks to highlight only the green spaces and gardens that fall within an ecological network. After removing core habitats areas (for each of the four modelled networks), this process produced a map of opportunities to enhance existing core habitat by including all green spaces and gardens with the local-scale habitat networks.

It was recognised that these opportunities are not limited – and should not be constrained – by the limits of existing networks. As such, the area of the wider parcel of green space or garden within which the opportunity was located was also calculated. The result of this analysis is a GIS layer containing polygons where each feature is an area of core habitat expansion potential within either land used as green space or gardens. Each feature contains two area values:

(i) the area of modelled local network which intersects the opportunity green space or garden land parcel, and

(ii) the area of continuous green space or garden within which the opportunity is located.

3.3.2 RESULTS

The opportunities to expand core habitats are presented in Figure 5 below. For clarity, modelled areas of opportunity for both continuous natural surfaces and private gardens have been displayed as points. In the figure, green points represent areas of core habitat with high potential to expand due to being surrounded by large areas of natural greenspace and gardens in proportion to the existing core habitat area, while red points represent areas of core habitat with low potential to expand. This overview map highlights the city-wide distribution of habitats in networks where dispersal is less constrained by the built environment. Full sized opportunity maps can be viewed in Annex 4 and a full list of GIS attributes for the model output files are available in Annex 3.

The figures show that there are widespread opportunities to expand existing core habitats across all habitat networks if some natural spaces and gardens are managed to support greater biodiversity. The model outputs show that natural surfaces offer the greatest opportunities, with the spatial distribution of those opportunities aligning closely with the distribution of each habitat group across the city. Wetland habitat expansion opportunities remain closely tied to the river networks whilst opportunities for grassland and woodland habitat expansion are spread throughout suburban Nottingham with more limited opportunities closer to the city centre where urban land uses dominate.

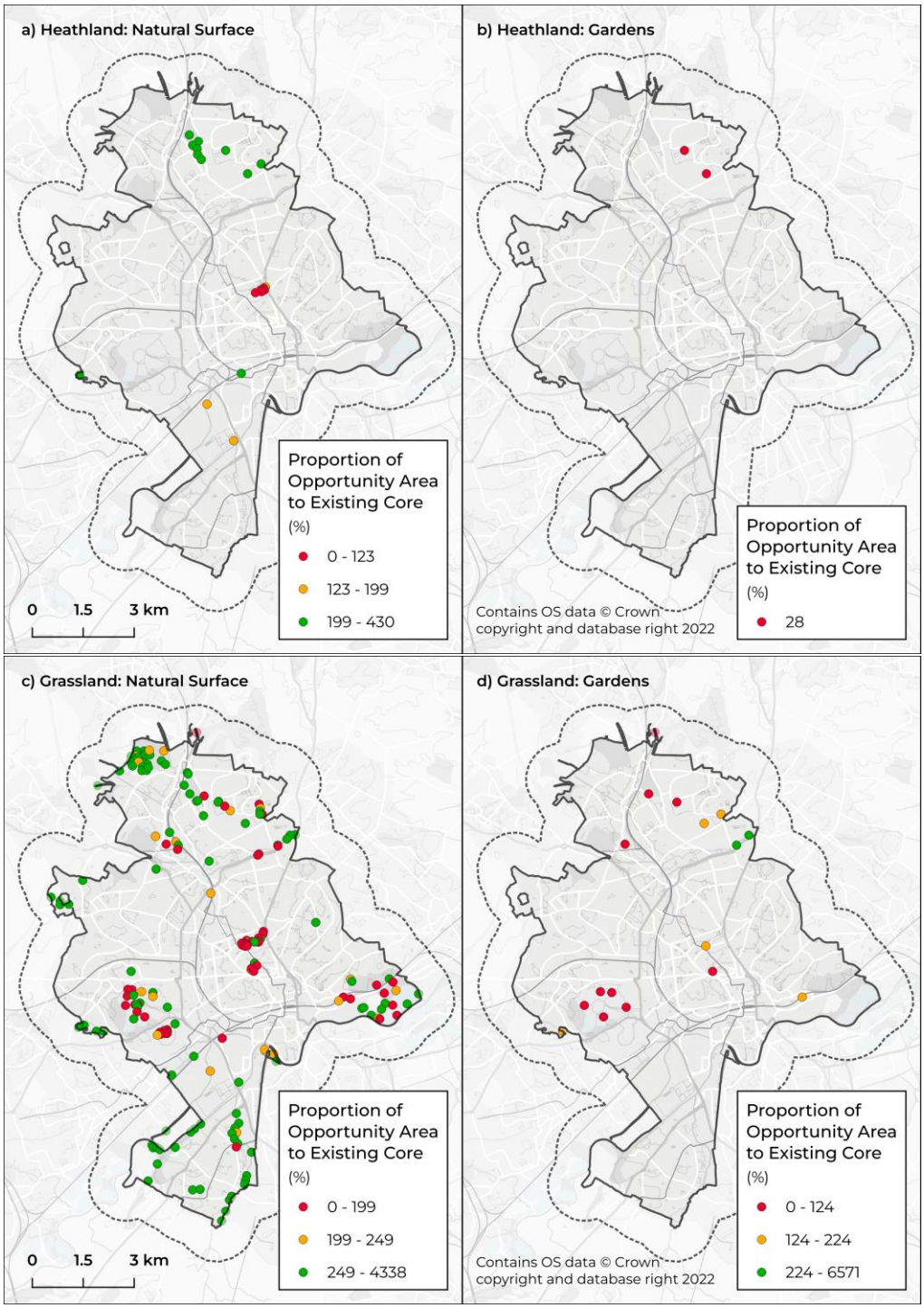


Figure 5.

(a – d)

Core habitat expansion opportunities displayed by area for both natural surfaces and private gardens for heathland and grassland habitat networks

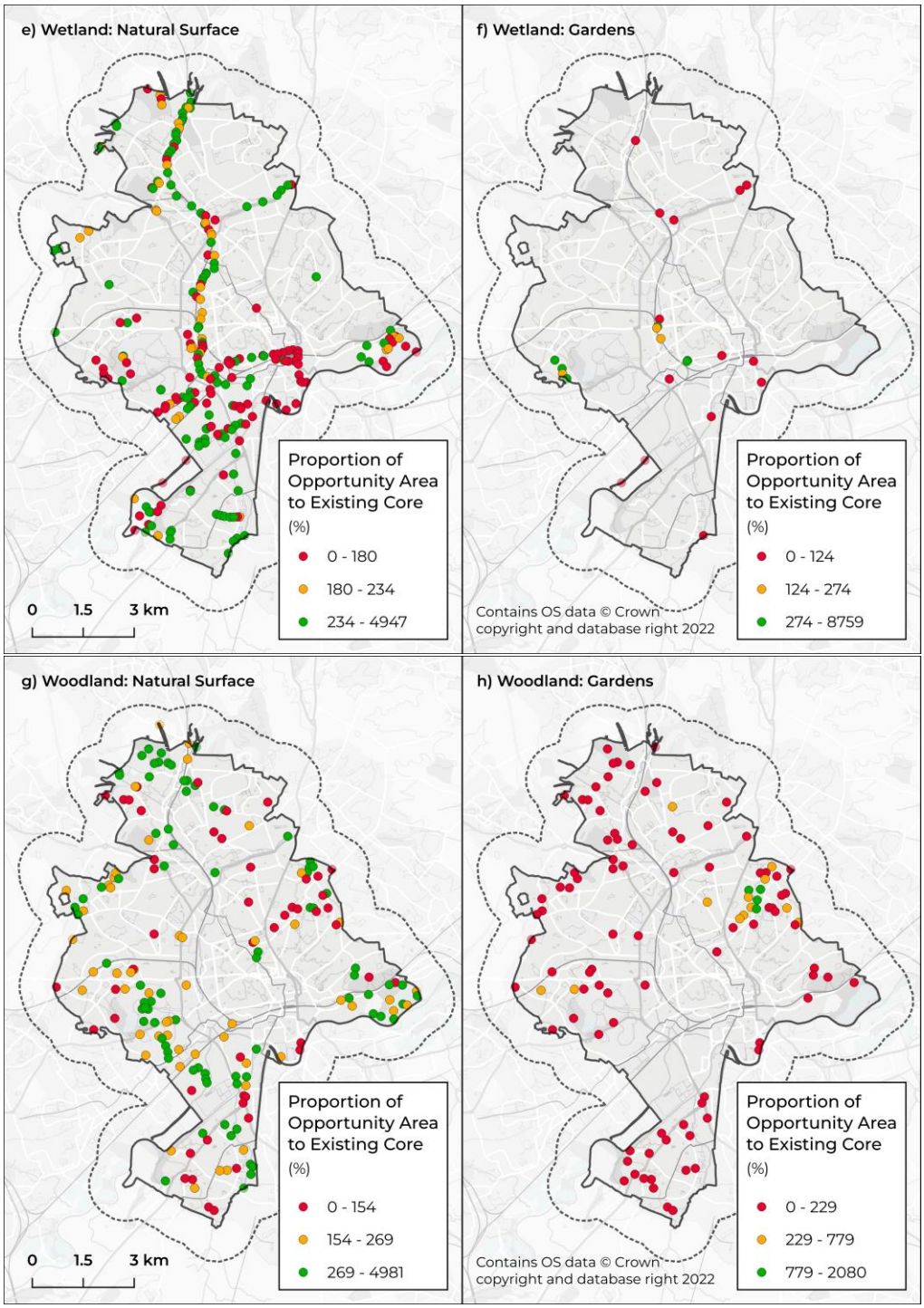


Figure 5.

(e - h)

Core habitat expansion opportunities displayed by area for both natural surfaces and private gardens for wetland and woodland networks

3.4 Grassland Enhancement Opportunity

3.4.1 METHODS

Much of the UK's 'improved' grasslands could be enhanced through different management styles to support greater biodiversity and make ecological networks of all types more extensive. Using the habitat mapping and OS MasterMap Greenspace datasets it was possible to show areas of grassland that are likely to be of low ecological value and therefore represent opportunities for grassland habitat enhancement or creation of alternative habitats of higher ecological value. To provide strategic guidance on habitat interventions for the sites identified in this modelling, improved grassland patches which intersect modelled habitat networks were mapped.

To achieve this, areas of improved grassland were extracted from the habitat mapping and those that intersect with modelled habitat networks were deemed to pose an opportunity to extend the network with which they spatially align. In some cases, improved grassland is found adjacent to multiple habitat networks (i.e., woodland and grassland habitats). The result of this analysis is a dataset containing habitat patches that represent areas of improved grassland habitat which adjoin modelled ecological networks. This dataset has had areas that could constrain opportunities for grassland enhancement removed (as detailed in Section 3.2). The GIS model includes a threshold area to allow polygons below a certain area to be filtered from the results. For the outputs presented in this report, this has been set to 10m^2.

To enable further examination and filtering of opportunities within this layer, an attribute of the GIS dataset indicates the current land use of the improved grassland, based on the OS MasterMap Greenspace layer. Full attributes of the GIS output of this modelling are available in Annex 3.

3.4.2 RESULTS

Figure 6 shows the distribution and relative size of the opportunities to enhance grassland habitats across Nottingham. Full sized and more detailed mapping of the outputs are presented in Annex 4. The figures indicate that generally, opportunities adjoining core heathland and grassland habitats tend to be larger than those adjacent to core woodland and wetland habitats, yet there are many more opportunities for woodland expansion in grassland areas compared to the other opportunity habitat types. This is likely a result of the greater coverage of core woodland habitats across the city giving more opportunities for connection relative to other network types, particularly wetland habitats.

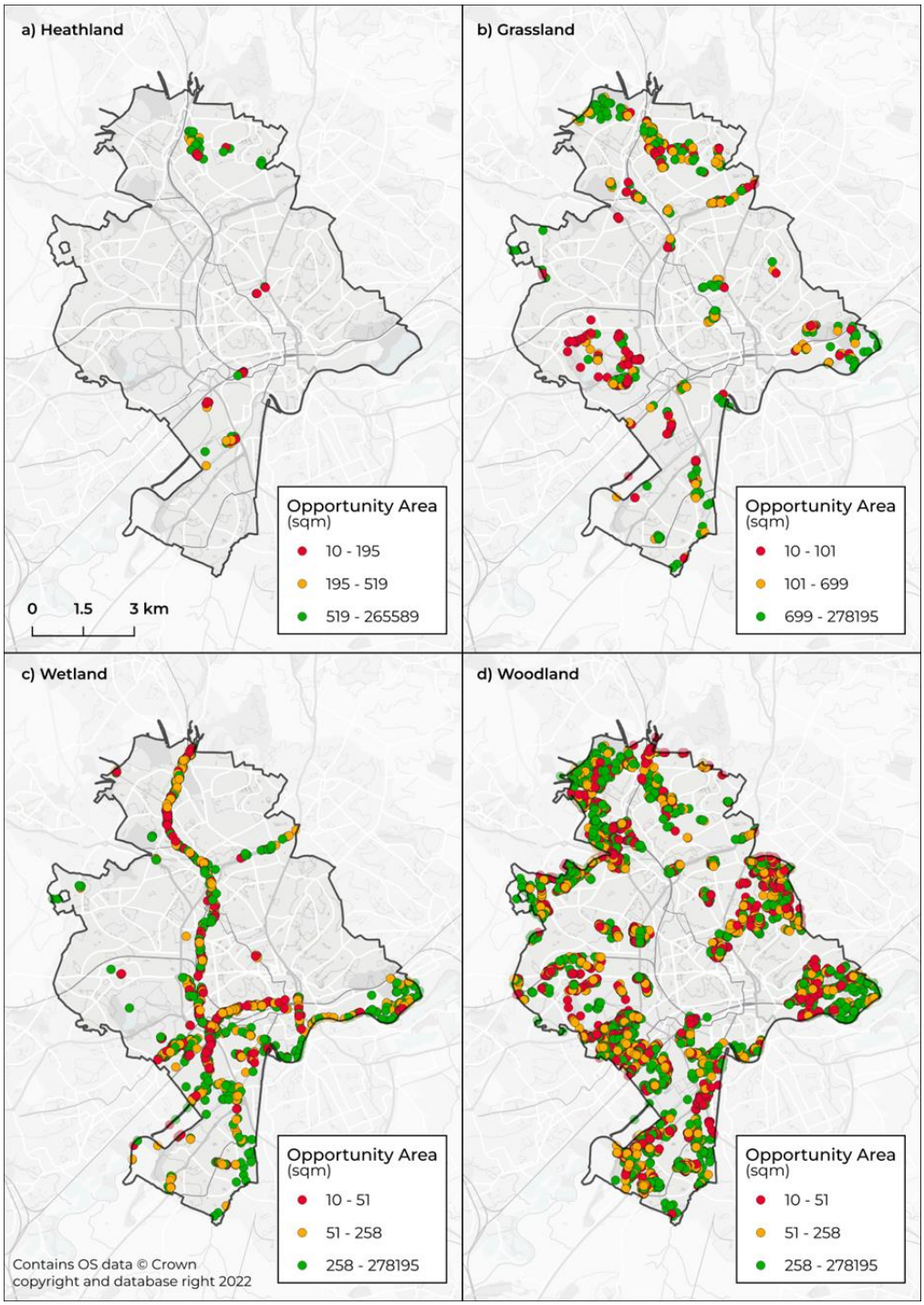


Figure 6.

Modelled modified grassland enhancement opportunity displayed by area

3.5 Culvert Daylighting Opportunities

3.5.1 METHODS

Open watercourses provide myriad ecological and cultural benefits. In many cases, city culverts provide conduits for watercourses as they pass beneath transport infrastructure and buildings yet in other cases culverts are in place beneath parks and other green spaces. Removing sections of culvert in areas of green space to produce open streams and pools - so-called culvert daylighting - could extend the wetland habitat network and bring about some of the benefits of open watercourses. Identifying the locations where culverts sit beneath green spaces shows potential opportunities for culvert daylighting that could be investigated through urban drainage and flood risk assessment.

Opportunity areas were identified through further analysis of the wetland networks, applying OS MasterMap topographic data. Natural surface features were extracted along with the locations of covered watercourses and where underground watercourses coincide with natural surfaces the watercourse was selected as having the potential for daylighting. Only natural surfaces are included here due to the additional constraints that need consideration when daylighting watercourses below sealed surfaces in the urban environment (e.g., presence of buildings or key infrastructure). The result of this analysis is a GIS line layer where features represent culverted water flows located beneath open or green space.

The culvert daylighting opportunity GIS model incudes a threshold area to allow areas of greenspace below a certain size to be filtered from the results. For the outputs presented in this report, the minimum size has been set to 1m to show all locations where daylighting could be considered alongside other works in the area. Full attributes of the GIS output of this modelling are available in Annex 3.

3.5.2 RESULTS

An overview of the results of culvert daylighting opportunity mapping are presented in Figure 7, with the results fully presented in Annex 4. The modelling indicates that most culvert daylighting opportunities are concentrated in the north of the city. Specific opportunities are present in Broxtowe Country Park, east of Bulwell Cemetery, and in green space between Phoenix Park and the River Leen. It may only be a small sub-set of these locations at which culvert daylighting is feasible once a more detailed assessment is carried out.

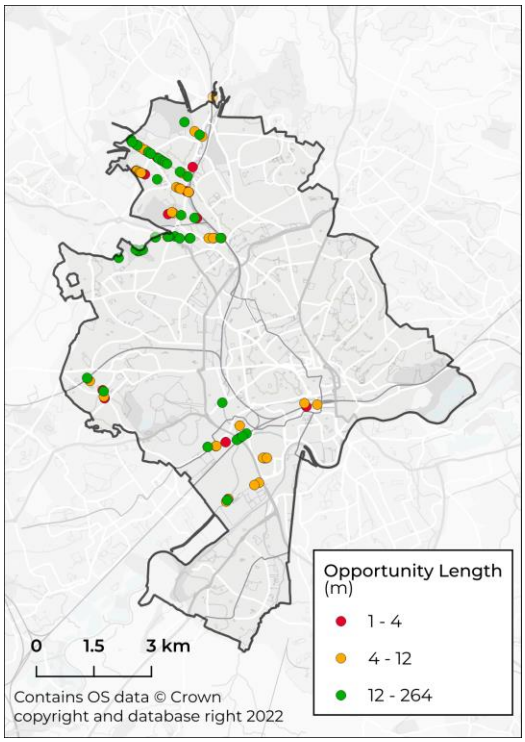


Figure 7.

Modelled culvert daylighting opportunity displayed by the length of watercourse that could be exposed

4 PRIORITISING BIODIVERSITY OPPORTUNITIES

4.1 Summary

Following the initial identification of biodiversity opportunities, additional data was used to provide contextual information that can be used to assign priority to biodiversity opportunities. This has been approached using three additional datasets:

(i) modelled regional-scale networks

(ii) superficial and bedrock geology (British Geological Survey)

(iii) NCC property ownership

The methods and results relating to the application of these two layers in prioritising biodiversity opportunity are presented in the remainder of this section.

4.2 Intersection of Local-Scale and Regional-Scale Networks

Initial opportunities for the enhancement of local-scale networks were identified through analysis in conjunction with the modelled regional-scale networks. This was to identify areas for the enhancement of networks within the city which may also strengthen and increase the resilience of the wider regional networks. Here, the local networks which intersected either the woodland or open regional networks were identified. To record this, each mapped opportunity was attributed with a value describing the network(s) it is situated within. Where the local networks were not intersected by a landscape network, this was also recorded.

The result of this analysis is a GIS dataset with an attribute detailing how far away from a patch of core habitat the local and regional networks coincide (i.e., 1 to 500m, 501 – 1,000m in line with the description of the regional-scale network modelling methodology given in section 2.3.2) and the habitat network (woodland, open, or both) intersected by the overlapping regional scale network. An overview of the output data is presented in Figure 8.

Areas of core habitat that fell below the minimum core habitat threshold area for both regional and local-scale ecological networks are included because as part of a wider network they may contribute more than their small area suggest. These maps have been designed to identify how biodiversity opportunities within Nottingham may fit with a wider landscape-scale strategy for the enhancement and creation of habitats.

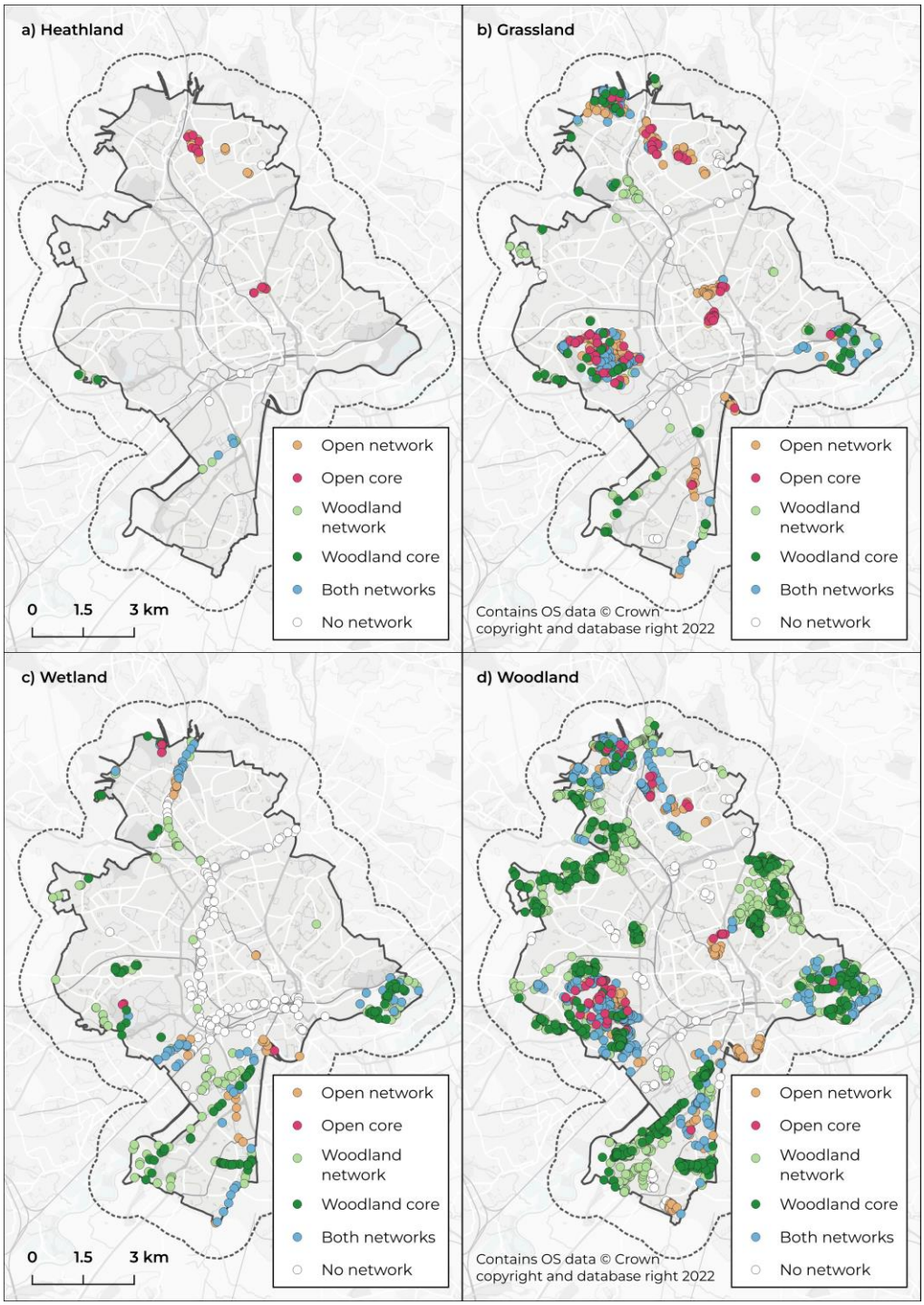


Figure 8.

Modelled core habitat expansion opportunities displayed by the regional habitat networks in which they are located

4.3 Intersection of Grassland Biodiversity Opportunities with Geological Data

Underlying bedrock geology can have an important influence on soil chemistry that can ultimately affect the plant species most suited to a particular environment. Opportunities presented by Nottingham's geology for enhancing grassland habitats were modelled using British Geological Survey (BGS) data[10] to establish where acid or calcareous grassland should naturally prevail. The developed GIS model takes modelled grassland biodiversity opportunities and BGS data as an input. Figure 9 shows habitat enhancement and habitat creation opportunities for the grassland habitat network classified into opportunity for acid or calcareous grassland. The distribution of different grassland types across the city reflects the sandstone which underlies central areas of Nottingham, in addition to the areas of dolomitic and mudstone located closer to the city's boundary. Rather than generating a separate data layer, the model that creates this dataset updates grassland opportunity layers with an additional attribute, containing the potential to enhance grassland to acid or calcareous grassland, as indicated by the underlying geology.

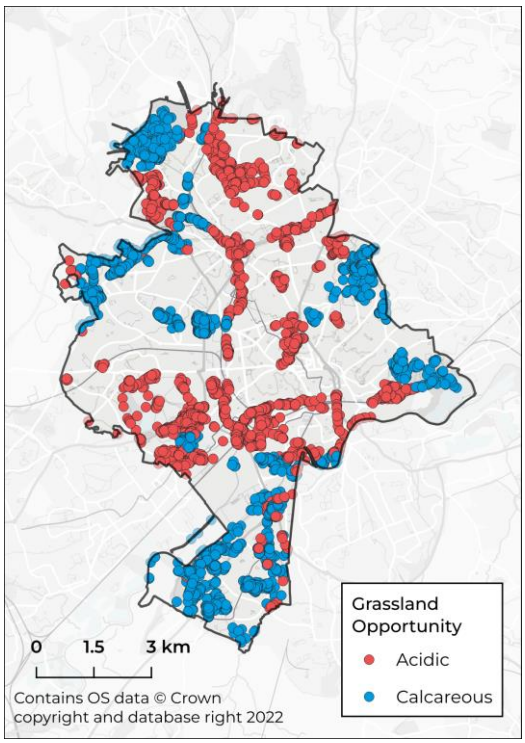


Figure 9.

Modelled grassland core habitat expansion opportunities that are located above geology which indicates suitability for acidic or calcareous grasslands

4.4 Biodiversity Opportunities on NCC Land

A final biodiversity opportunity mapping stage was carried out to identify which of the previously mapped opportunities fall upon certain types of land owned by NCC, and therefore represent

[10] BGS, 2022. *BGS Detailed Bedrock and Superficial geology.* GIS Data, used under licence.

opportunities to enhance networks which may be more accessible in the short-term than other mapped opportunities. To achieve this, a property-ownership dataset provided by NCC was intersected with mapped biodiversity opportunities. Property ownership was grouped according to the values listed in Table 6.

Table 6. *Property ownership groups used to identify biodiversity opportunity*

	Nottingham City Council Ownership Class
Education	'Education', 'Education Primary Schools', 'Education Secondary Schools', 'Education Special Schools'
Parks	'Highfields Leisure Trust', 'NCCW GM (Parks & Leisure)'
Housing	'Housing Committee', 'Housing Revenue'
Other	All other ownership classes

The result of this analysis is an updated version of NCC property ownership data containing the area of the land parcel which is intersected by modelled biodiversity opportunities for each of the four habitat networks analysed. An overview of these results is presented in Figure 10 below and more fully in Annex 4. The presence of opportunities within the 'Housing' category, is in part a reflection of the fact that these ownership parcels tend to be much smaller in area than 'Parks' and 'Education' property. The distribution of these opportunities broadly reflects the distribution of the modelled local networks, indicating that biodiversity opportunities on NCC property are present throughout the city.

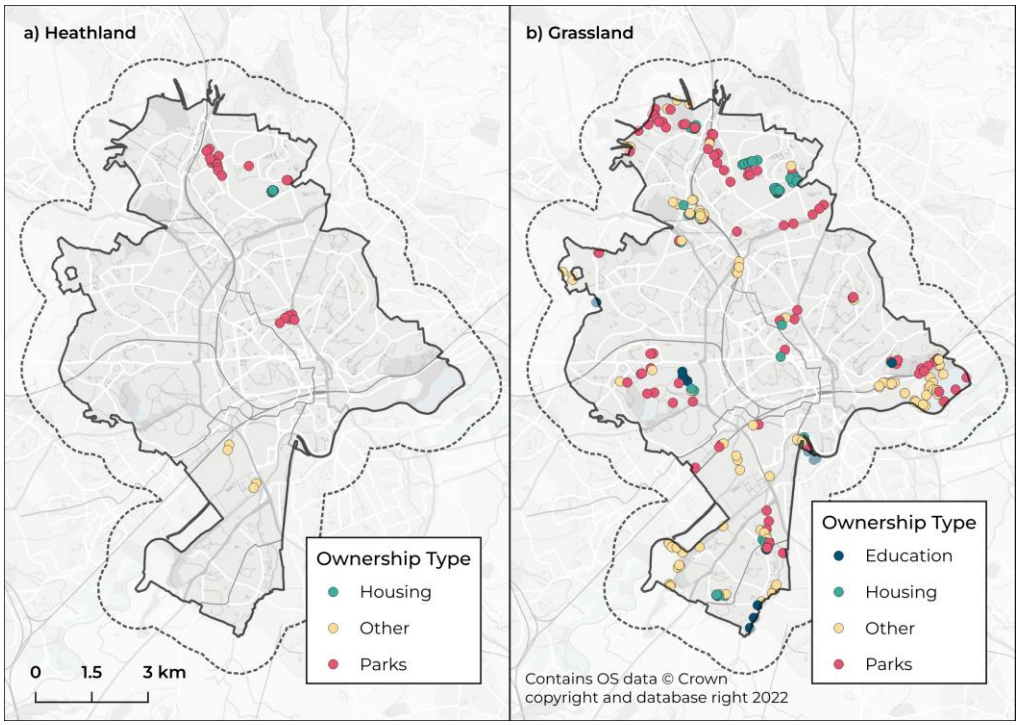


Figure 10.

(a – b)

Modelled core habitat expansion opportunities which are located within NCC-owned land, and the category of land ownership they fall within.

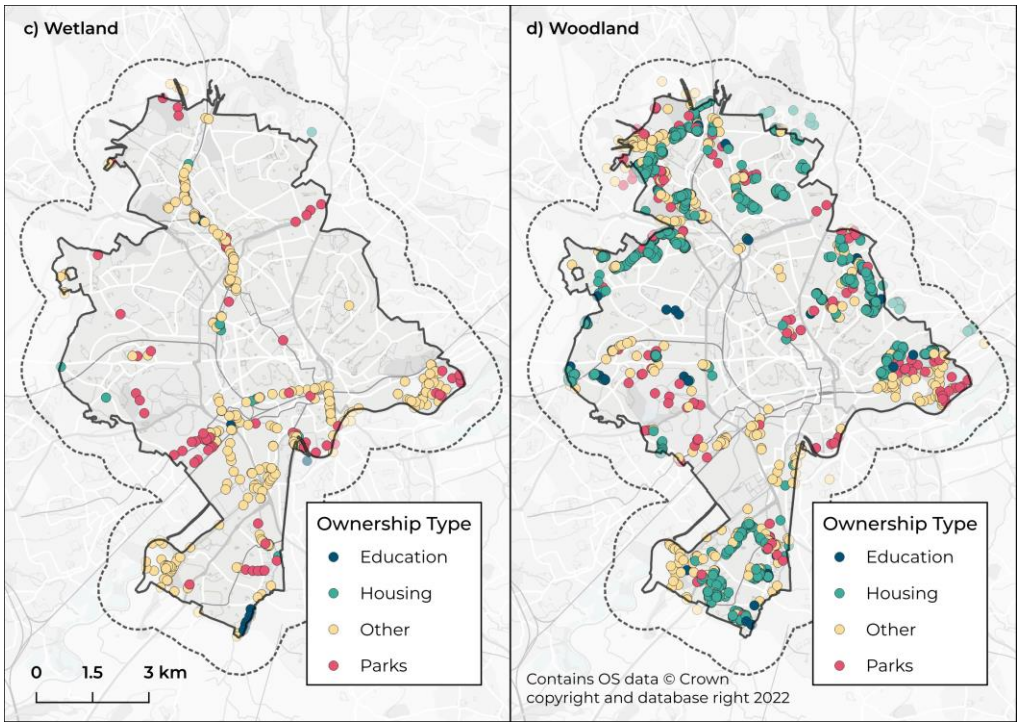


Figure 10.

(c – d)

Modelled core habitat expansion opportunities which are located within NCC-owned land, and the category of land ownership they fall within.

5 LIMITATIONS AND FURTHER WORK

5.1 Limitations

Species dispersal parameters are not currently standardised nationally. However, work is ongoing to standardise these and the GIS models have been built in a manner which enables these parameters to be readily updated as needed (by input comma separated value files).

There are several limitations with the process of mapping habitats beyond the NCC boundary that should be recognised. Firstly, OS MasterMap data is not a habitat map but describes landcover and topography. Generally, this allows a high-level of attribution to be made for urban areas, but non-urban landcover types are far more general in their attribution. Priority Habitat Inventory data has been applied to mitigate the lower level of detail to add in the locations of priority habitats (those of principal importance according to a 2006 study). However, there is a lower level of detail present in the habitat classification in this extended region compared to habitats within the City of Nottingham boundary.

5.2 Recommendations for Further Work

A workshop may be undertaken with local stakeholders to review the outputs of this modelling exercise. This would enable specific on the ground opportunities to be derived from those identified by the computer modelling undertaken for this project. This could be undertaken as a participatory mapping exercise whereby participants review mapped biodiversity opportunities and annotate the map with their insights into how each of the mapped opportunities relates to practical interventions.

To further build on the ecological network modelling, future steps could be taken to apply next-generation data streams to build further insights. These data streams could include LiDAR data that can be applied to model vegetation structure, an indicator of micro-habitat variety. Greater micro-habitat variety generally infers greater ecosystem complexity and a more abundant nature when compared to lower levels of structural diversity. Insights may also be garnered from analysis of day/night band remote sensing imagery which can be applied to model dark corridors in urban environments - something that is being taken increasingly seriously in some councils' efforts to understand and benefit nature recovery.

Annex 1: MAPPING NOTTINGHAM'S HABITATS

Within the NCC Boundary

Network modelling within the NCC boundary has been undertaken using the habitat mapping produced by 4EI and supplemented by ecological surveys, completed under Lot 1 of this scope of works. The habitat baseline was produced by 4EI by applying a semi-automated approach to classify habitats within the City of Nottingham to a minimum of UKHab Level 3. This approach applied a series of datasets which are either openly available or have been provided by Nottingham City Council. The process is outlined below:

- Produce GIS layer containing contiguous topographic boundaries
- Development of an automated decision tree to attribute polygons in topographic layer to a minimum of UKHab Level 2
- Analysis of automated classification to apply additional data to further attribute habitats to a minimum of UKHab Level 3.

The full methodology for producing the habitat basemap for Nottingham has been supplied within[11].

Within the 1km Buffer

Network modelling outside of the NCC boundary has been undertaken using landcover derived from OS MasterMap and Priority Habitat Inventory data.

Landcover classification has been derived from OS MasterMap in several steps. First, a list of the highest-level descriptive codes available in OS MasterMap attributes was selected for the areas not covered by habitat mapping. Second, each of these descriptive codes was assigned to the network components used to assign the permeability codes. Third, features described as "Cliffs" or "Slopes" were merged with the polygon they shared the largest common boundary, to provide a feature more descriptive of the landcover in these areas. Fourth, each OS MasterMap feature was assigned both a network component class and subsequently, a permeability score.

Core habitats have been derived from the Priority Habitat Inventory using the following process. First, the features of the Priority Habitat Inventory data intersected the OS MasterMap data and were outside of the City of Nottingham boundary were extracted. Second, a list of all extracted Priority Habitat Inventory habitat types (using the "*main_habit*" field) was retrieved. Third, each of the habitat types within the area covered by OS MasterMap were also assigned to the network

[11] Ecosulis, 2022. *J006705 – Lot 1: Habitat Survey and Mapping - full report*.

components used to assign the permeability codes. Finally, these were merged with the OS MasterMap data, with Priority Habitat Inventory data being used as landcover where present and OS MasterMap data being used elsewhere. This process produced a landcover dataset which was merged with the 4EI habitat mapping to give a single permeability input dataset for the network models to model networks for the City of Nottingham and a 1km buffer.

Annex 2: FULL SPECIES DISPERSAL PARAMETERS

Habitat Type	Calcareous and Neutral Grassland	Heathland and Acid Grassland	Woodland	Wetland	Source Value Adapted From
Neutral grassland	0	30	30	20	Nottinghamshire [a]
Calcareous grassland	0	40	30	40	Nottinghamshire
Scattered trees	0	30	5	30	Nottinghamshire
Shrub heath	10	0	25	5	Nottinghamshire
Acid grassland	2	0	30	20	Nottinghamshire
Broadleaved mixed and yew woodland	20	35	0	50	Nottinghamshire
Coniferous woodland	20	20	0	40	Nottinghamshire
Bog	20	3	30	0	Nottinghamshire
Fen and marsh	5	30	20	0	Nottinghamshire
Standing open water and canals	50	50	50	0	Nottinghamshire
Rivers and streams	50	50	50	0	Nottinghamshire
Reedbeds and swamp	20	40	20	0	Nottinghamshire
Modified grassland	50	50	50	50	Nottinghamshire
Arable and horticulture	50	50	50	50	Nottinghamshire
Buildings	20	50	40	50	Nottinghamshire
Suburban mosaic of developed or natural surface	10	50	25	50	Nottinghamshire
Built linear features	50	50	50	50	Nottinghamshire
All other features	50	50	50	50	Somerset [b]
Bracken	10	20	20	30	Nottinghamshire
Hedgerow	20	10	1	30	Nottinghamshire
Dense scrub	20	10	1	30	Nottinghamshire

[a] Nottinghamshire Biodiversity Action Group, 2020. *Biodiversity Opportunity Mapping*.

[b] Bowe, *et al.*, 2019. *Somerset's Ecological Network: mapping the components of the ecological network in Somerset*. Somerset Wildlife Trust, Taunton.

Annex 3: GIS DATA REFERENCE

1. Regional Network (Open & Woodland)

Attribute	Description
fid	Unique feature ID
connectivity	Habitat type and functional distance from core

2. Local Networks Unconstrained

Attribute	Description
fid	Unique feature ID
habitat	Habitat type of opportunity feature

3. Local Networks Constrained

Attribute	Description
fid	Unique feature ID
habitat	Habitat type of opportunity feature

4. Local Networks Core

Attribute	Description
fid	Unique feature ID
area	Feature area
habitat	Habitat type of opportunity feature

5. Network Buffer Opportunities

Attribute	Description
fid	Unique feature ID
area	Feature area
habitat	Habitat type of opportunity feature
surface	Type of surface, either 'Natural' or 'Private Garden' (joined from OS MasterMap)

6. Core Buffer Opportunities

Attribute	Description
fid	Unique feature ID
area	Feature area
bufferPotential_gardensNetwork	Area of modelled core buffer potential in gardens
bufferPotential_naturalNetwork	Area of modelled core buffer potential in natural surfaces

Attribute	Description
habitat	Habitat type of opportunity feature

7. Culvert Daylighting Opportunities

Attribute	Description
fid	Unique feature ID
length	Feature length

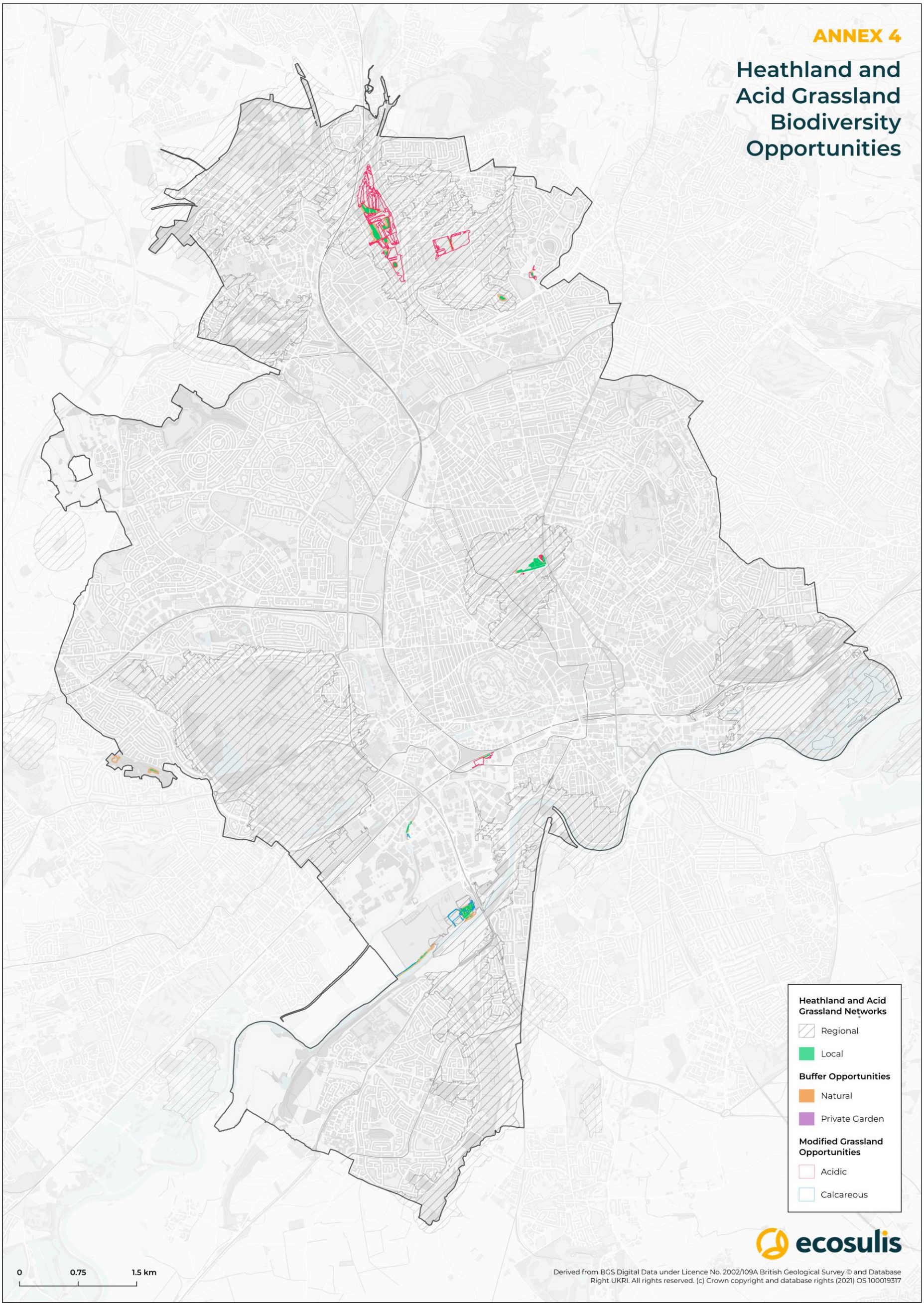
8. Modified Grassland & Geological Opportunities

Attribute	Description
fid	Unique feature ID
area	Feature area
function	Land use of modified grassland (derived from OS MasterMap)
indicative_pH	Grassland pH indicated by underlying geology (derived from BGS data)
woodland	Boolean value indicating whether feature intersects woodland network
grassland	Boolean value indicating whether feature intersects grassland network
heathland	Boolean value indicating whether feature intersects heathland network
wetland	Boolean value indicating whether feature intersects wetland network

9. Property Ownership Opportunities

Attribute	Description
fid	Unique feature ID
ownershipArea	Feature area
ownershipCategory	Category of property ownership represented (e.g., 'Parks', 'Education')
opportunityArea_heathland_sum	Total area of heathland opportunity overlapping land ownership parcel
opportunityArea_grassland_sum	Total area of grassland opportunity overlapping land ownership parcel
opportunityArea_wetland_sum	Total area of wetland opportunity overlapping land ownership parcel
opportunityArea_woodland_sum	Total area of woodland opportunity overlapping land ownership parcel

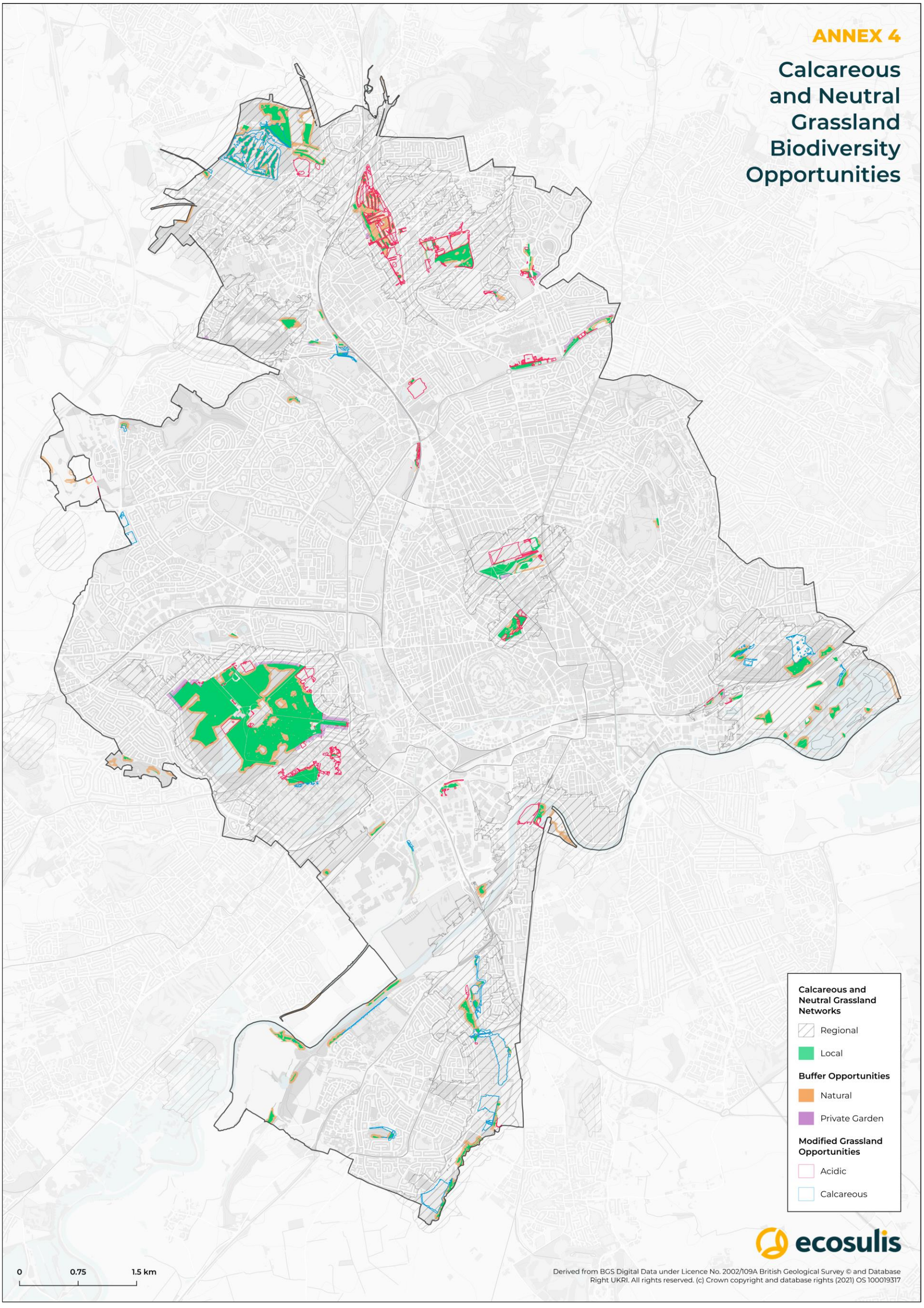
Annex 4: FULL SIZE OPPORTUNITY MAPS



* Combined heathland and acid, calcareous, and neutral grassland networks.

ANNEX 4

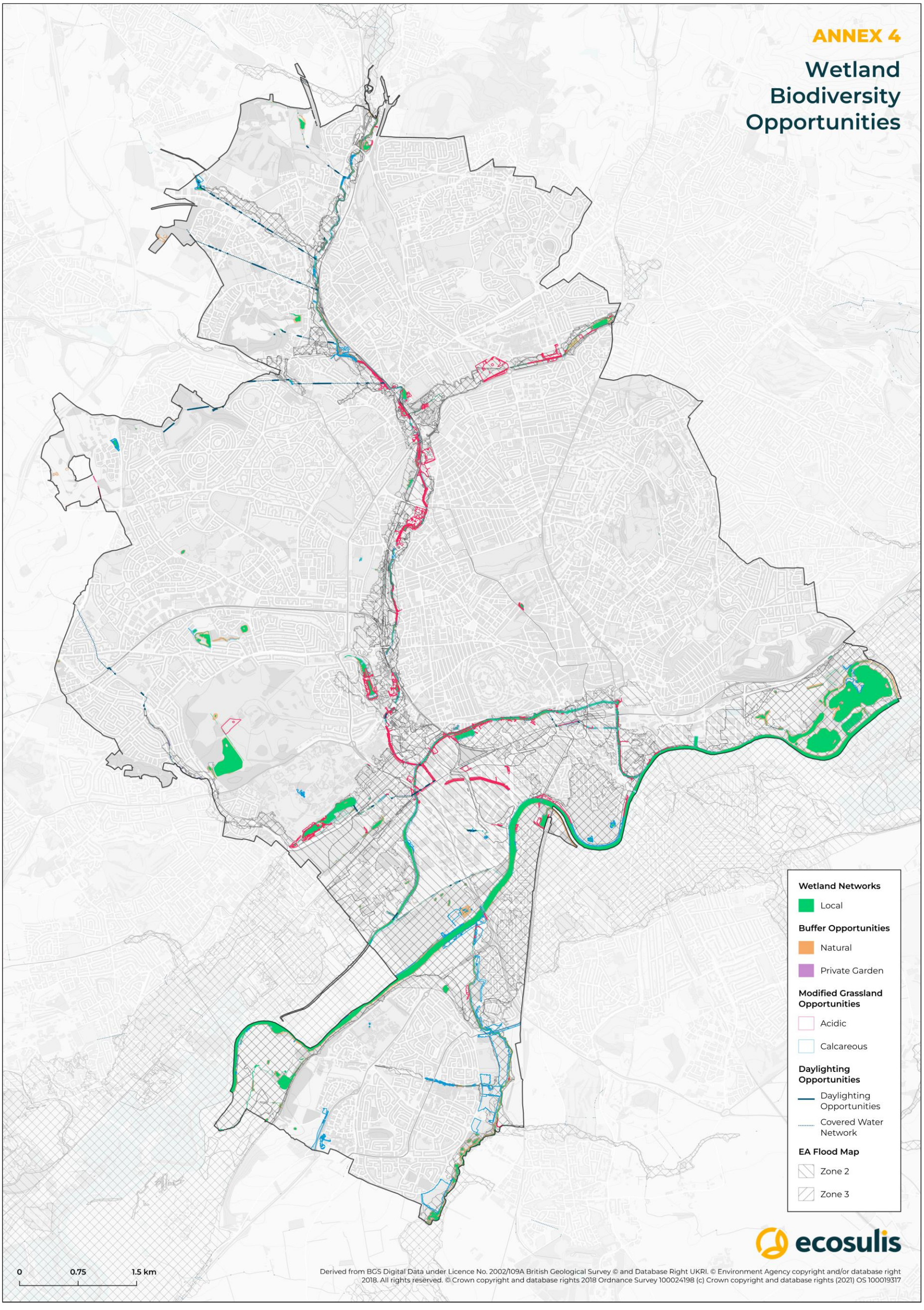
Calcareous and Neutral Grassland Biodiversity Opportunities



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ANNEX 4

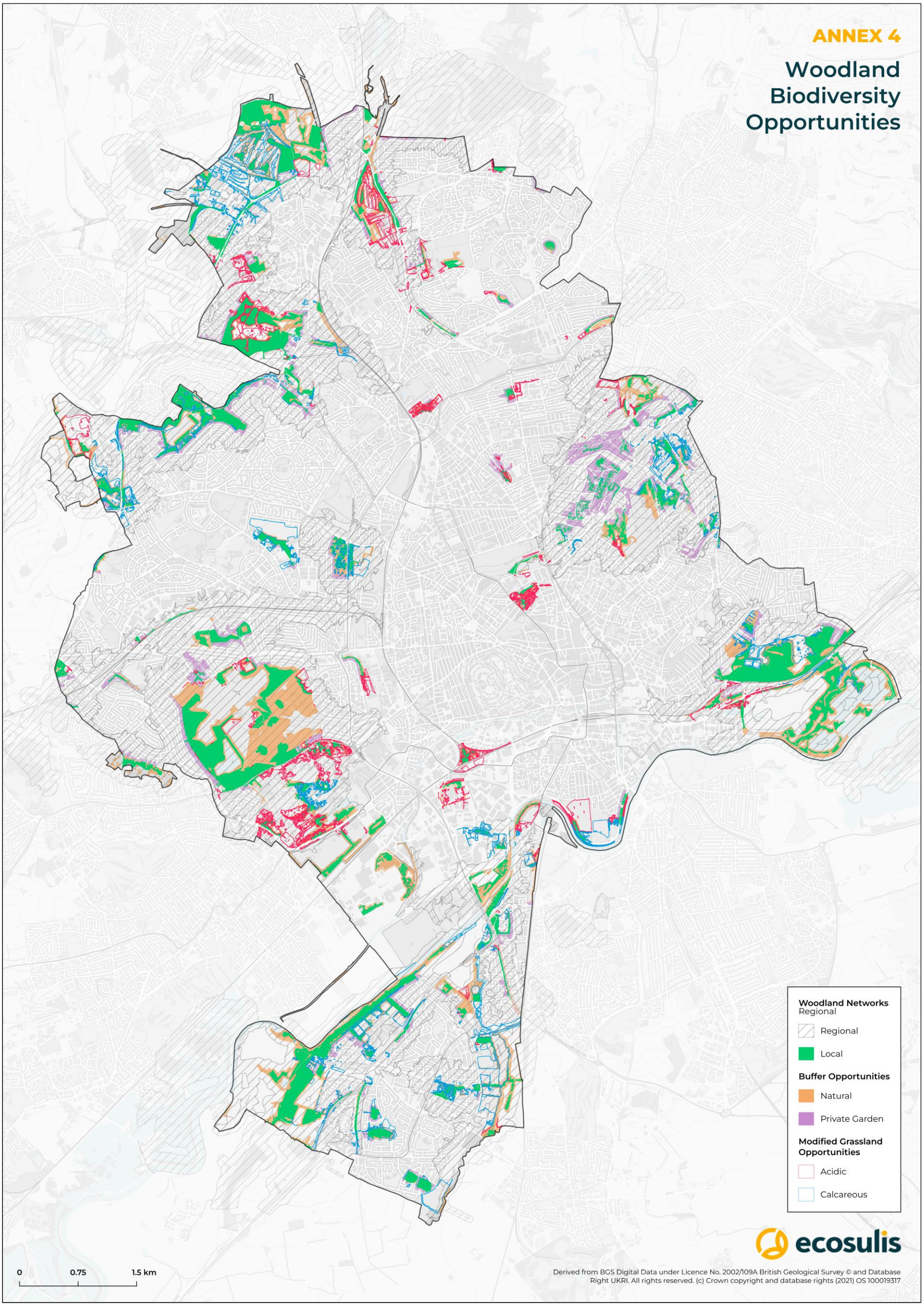
Wetland Biodiversity Opportunities



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ANNEX 4

Woodland Biodiversity Opportunities



ANNEX 4

Geology and Modified Grassland Biodiversity Opportunities

