England Green Infrastructure Mapping Database. Version 2.1 Method Statement.

September 2024

Natural England Evidence Report NEER152

www.gov.uk/natural-england

NATURAL ENGLAND

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Catalogue code: NEER152

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Keywords

Green Infrastructure. Greenspace. Urban Nature Recovery. Urban Greening. Urban Habitats. Urban Heat Mitigation. Urban Air Quality. Urban Food Production.

Acknowledgements

The England Green Infrastructure Mapping Database has been created as a part of delivering the 25 Year Environment Plan aspiration to establish a National Framework of Green Infrastructure Standards for England and is also a part of the Natural Capital and Ecosystems Assessment Programme.

Learn more about the England Green Infrastructure Standards Project. Home (naturalengland.org.uk)

Learn more about the Natural Capital and Ecosystems Assessment Programme NCEA here.

The work for Version 1.1 was undertaken during 2020 – 21.

The work for Version 1.2 was undertaken during the calendar year 2022.

The work for Version 2.1 was undertaken during 2023 and early 2024 with some content that has been developing since 2021.

Some of the work for V 2.1 was undertaken by Natural England with the majority of content (updated from V 1.2 or new to V 2.1) delivered by the contractors listed below.

The work for Version 2.1 was undertaken between October 2022 and March 2024 and was commissioned and funded by the Natural Capital and Ecosystems Assessment Programme and Natural England.

Version 2.1 also contains material developed collaboratively with the University of Manchester (Urban Heat Vulnerability, Urban Air Quality and Green Infrastructure and Urban Food Production) and The Rivers Trust (Blue Infrastructure module adjustments).

Work incorporated into Version 2.1 was undertaken by;

RSK ADAS. V 1.1 and 1.2 core content.

Project Team – Ben Hockridge, George Holmes.

Westcountry Rivers Ltd (V 1.2 Blue Infrastructure Module and V 2.1 Environmental data update).

Project Team – Sarah Wigley, Emily Howard-Williams, Oakley Brunt.

Land Use Consultants (V 2.1 Census 21 import and related content and data updates).

Project Team - Kim Jones, Diana Manson, George Holmes and Izzy Grace.

The Rivers Trust (Blue Infrastructure Module adjustments).

Project Team – Chris Bean, David Johnson.

2Excel Aviation (Urban Habitat and Naturalness Maps).

Project Team – Chloe Barnes, Loreena Jaouen, Klara Halikova.

University of Manchester (Urban Heat Management, Urban Air Quality and Green Infrastructure, Urban Food Production).

Project Team – Professor Sarah Lindley, Dr Richard Figueroa Alfaro (Urban Heat).

The maps relating to Social Vulnerability to Heat were created using data available via ClimateJust.org which was commissioned by Friends of the Earth and delivered by the University of Manchester. The maps are published as OGL in V 2.1 by permission of Friends of the Earth and University of Manchester.

On the website, Version 2.1 also includes a Data Support Package Module for the Environmental Benefits of Nature Tool developed by Natural England. Guidance on the ENBT is provided separately. Learn more about EBNT.

All other new or updated content generated by Natural England.

Presentation of the mapping on the Green Infrastructure Standards website was done by Exegesis, and Idox PLC Company.

Citation

Moss, M. Greenwell, D. Hamblin, C 2024. England Green Infrastructure Mapping Database. Version 2.1 Method Statement. NEER152. Natural England.

Contents

Executive summary

The England Green Infrastructure Mapping Database is an evidence base of spatial data developed to provide consistent data at an All England or Urban England level.

The content of the database is intended to help the development of national and local policy, strategy and targeting of resources for Green Infrastructure.

The evidence base focuses on providing evidence to support national and local assessments related to the Headline Standards within the England Framework of Green Infrastructure Standards. In particular the content of the database seeks to help inform decision making for publicly accessible green spaces, urban nature recovery, urban greening (ecosystem service provision and need) and urban trees (there is currently no specific content relating to urban trees, but it is anticipated that content will be included in future releases).

Version 2.1 of the England Green Infrastructure mapping database was published online in September 2024.

This method statement for version 2.1 of the “England Green Infrastructure Mapping Database” sets out the approaches and methods used for all the content (combined V 1.1 and 1.2 and 2.1) produced by spatial assessment of combined source and core data. The individual maps or layers in the mapping are described in detail in the User Guide on the Green Infrastructure Standards website Green Infrastructure Home (naturalengland.org.uk). The website also includes a link to where the spatial data may be downloaded (Mapping Guide, Introduction, top of page 1).

Not all content has been updated to create V 2.1 and where content remains at least largely unaltered from V 1.2, the Mapping User Guide on the Green Infrastructure Standards website identifies the relevant version to which the module or map relates.

V 2.1 includes a suite of experimental modules. Experimental modules are still in development and data may only be available for limited geographies. Feedback regarding the experimental modules will be sought to inform their further development for future iterations of the mapping.

The experimental modules included in V 2.1 are for Urban Habitat Mapping, Urban Cooling, Urban Air Quality and Urban Food Production.

Section 1. England Green Infrastructure mapping approach to use of typologies.

A system of Green Infrastructure (GI) typologies was devised to enable the integration of a range of spatial datasets that sometimes describe the same physical spaces in different ways. In devising the typology system, effort was taken to mimic the descriptions in the source data as closely as possible.

Typologies are currently grouped into five "families".

1. Public and community spaces.
2. Access land.
3. Woodland.
4. Water features.
5. Functional green spaces (usually dedicated to a specific activity or use).

The system of Green Infrastructure typologies is set out in table 1.

Table 1. England Green Infrastructure Mapping Version 2.1 system of spatial typologies. Look up table for system of Green Infrastructure typologies used in version 2.1 of the mapping. The typologies are grouped in "families" and given unique numeric codes and titles.

Typology family	Typology code	Typology title
Public and Community Spaces (Family code 1)	1.1	Public Park (General)
Public and Community Spaces (Family code 1)	1.2	Public Park (Country Park)
Public and Community Spaces (Family code 1)	1.3	Millennium or Doorstep Green
Public and Community Spaces (Family code 1)	1.4	Local Nature Reserve
Public and Community Spaces (Family code 1)	1.6	Playing Fields

Typology family	Typology code	Typology title
Public and Community Spaces (Family code 1)	1.7	Other Sports Facilities
Access Land (Family code 2)	2.1	CRoW Access Land, including Section 15 Access Land
Access Land (Family code 2)	2.2	Coastal Margin
Woodland (Family code 3)	3.1	Woodland
Water Features (Family code 4)	4.1	Water courses and surface and tidal water features
Functional Green Spaces (Family code 5)	5.1	Allotments and Community Growing Spaces
Functional Green Spaces (Family code 5)	5.2	Activity Spaces Provision (including bowling greens and tennis courts)
Functional Green Spaces (Family code 5)	5.3	Cemeteries and Religious Grounds
Functional Green Spaces (Family code 5)	5.4	Golf Courses
Functional Green Spaces (Family code 5)	5.5	Play Space Provision

Green Infrastructure typologies were identified from a range of source data. Several categories from the source data were brought together into one Green Infrastructure typology to create the “Combined Green and Blue Infrastructure” map.

The relationship between source data categories for mapped polygons and the Green Infrastructure typology to which they were assigned is set out in Table 2.

Table 2. Look up table for attribution of source data to respective Green Infrastructure typologies. The table identifies which datasets (and any data attributes) were assigned to which Green Infrastructure typology (by title and numeric code) to create the "Combined Green and Blue Infrastructure" map.

Source Dataset	Attribute	License	V 2.1 Typology Code	V 2.1 Typology title
OS Greenspace	Allotments or Community Growing Spaces	OGL	5.1	Allotment and Community Growing Spaces
OS Greenspace	Bowling Green	OGL	5.2	Activity Spaces Provision
OS Greenspace	Cemetery	OGL	5.3	Cemeteries and Religious Grounds
OS Greenspace	Golf Course	OGL	5.4	Golf Course
OS Greenspace	Other Sports Facility	OGL	1.7	Other Sports Facility
OS Greenspace	Play Space	OGL	5.5	Play Space Provision
OS Greenspace	Playing Field	OGL	1.6	Playing Fields
OS Greenspace	Public Park or Garden	OGL	1.1	Public Park – General
OS Greenspace	Religious Grounds	OGL	5.3	Cemeteries and Religious Grounds
OS Greenspace	Tennis Court	OGL	5.2	Activity Spaces Provision
Local Nature Reserve	None	OGL	1.4	Local Nature Reserve
Natural England Open Access Data	None	OGL	2.1	Access Land (CRoW)
Natural England Open Access S15	None	OGL	2.1	Access Land (CRoW)
Natural England Coastal Margin	None	OGL	2.2	Coastal Margin
Millennium Greens	None	OGL	1.3	Millennium or Doorstep Green
Country Parks	None	OGL	1.2	Public Park - Country Park
Doorstep Greens	None	OGL	1.3	Millennium or Doorstep Green

Source Dataset	Attribute	License	V 2.1 Typology Code	V 2.1 Typology title
OS Localmap Open Woodland	None	OGL	3.1	Woodland
OS Localmap Open Surface Water	None	OGL	4.1	Water Courses and Surface Water Features
National Forest Inventory	None	OGL	3.1	Woodland
Ancient Woodland	None	OGL	3.1	Woodland

The combined Green and Blue Infrastructure layer is a collection of open data that is combined to identify the Green and Blue Infrastructure polygons. This map is not a comprehensive map of all green and blue land cover in England and the map has areas for which no data is presented. It is intended that the coverage of this map may expand over time to become more comprehensive as further data are added.

Data used to create the Combined Green and Blue Infrastructure layer may have overlapping geographical extents. This means that there can be multiple overlapping polygons in an area which relate to the same physical space on the ground, and which may therefore have different attributes due to different data sources. In addition, the specific polygon boundaries for the same on the ground site may have cartographic misalignments. No attempt has been made to rationalise polygon boundaries or attributes so that data integrity with the source is retained.

All polygons on the "Combined Green and Blue Infrastructure map" were assigned key attributes. These attributes are utilised to assist with spatial analysis for other maps in the database.

The key attributes used on the "Combined Green and Blue Infrastructure" map are listed below.

- Dataset. Identifies the dataset from which the polygon is derived.
- Accessible. An attribute flag to identify whether the greenspace is treated as accessible to the public.
- Accessible Greenspace. An attribute flag to determine if the greenspace is included in the Accessible Greenspace Standards (AGSt) assessment.

- Naturalness. An attribute assigned to each polygon as level 1 to 3 with 1 being most natural.
- Typology Code. The Green Infrastructure typology code assigned to each polygon.
- Typology Title. The name of the Green Infrastructure typology assigned to each polygon.
- Manmade area. The percentage of the polygon that is not vegetation, water, or soils. This attribute is derived from the Ordnance Survey MasterMap Topography (non-open) data).

Note on the treatment of “Playing Fields”.

The Town and Country Planning (Development Management Procedure) (England) Order 2015 defines “Playing Fields” as

“The whole of a site which encompasses at least one playing pitch.”

In addition, “playing pitches” are described as

“a delineated area which, together with any run-off area, is of 0.2 hectares or more, and which is used for association football, American football, rugby, cricket, hockey, lacrosse, rounders, baseball, softball, Australian football, Gaelic football, shinty, hurling, polo or cycle polo”.

In the Green Infrastructure Mapping version 2.1 source data from the Ordnance Survey (OS) “Open Green Space” data has been used to identify both “Playing Fields” and “Other Sports Facilities” which are defined in the Ordnance Survey technical specification as follows.

- Playing Fields - Large, flat areas of grass or specially designed surfaces, generally with marked pitches, used primarily for outdoor sports, i.e., football, rugby, cricket.
- Other Sports Facilities – Land used for sports not specifically described by other categories. This typology includes those facilities where participation in sport is the primary use of the area.

Please note that “Other Sports Facilities” may substantially include or be made up wholly of buildings (identifiable using the “percent manmade surface” attribute).

The Ordnance Survey depictions of “Playing Fields” may thus not be entirely in accordance with the Town and Country Planning Act definition and the Green Infrastructure mapping has used the data as provided by the Ordnance Survey source. The use of typology descriptions “Playing Fields” or “Other Sports Facilities” in the mapping is purely for the purposes of typological differentiation of spaces and in the event of any discrepancy, the depiction of “Playing Fields” and/or “Sports Facility” in the mapping does not override the definition in the Town and Country Planning Association (Development Management

Procedure) 2015 or that used in the National Planning Policy Framework which should be followed in any formal, policy or legal consideration of “Playing Fields”.

For Version 1.2 (not updated for V 2.1), in an attempt to provide some clarification on outdoor activity spaces; some limited data from the Sport England “Active Places” database has been used to supplement the information derived from the OS. The Sport England data focusses on the provision of facilities for outdoor sports and activities and does not include data on any indoor facilities. In addition, the Sport England data is “point data” that may provide either more detailed content to OS polygons or locate facilities that are missing from the OS data.

Approach to the determination of “Accessible Green Infrastructure”.

All polygons in the mapping with a greenspace “accessible” attribute flag were merged using “ArcMap GIS” into a single national vector.

Accessibility was determined primarily from the typology of the GI. The approach to assigning accessibility by typology is set out in Table 3.

For the Green Infrastructure mapping, a simple hierarchy of accessibility was used based on the formality of access provision. The hierarchy has three levels.

1. Publicly accessible. To be considered publicly accessible, a type of Green Infrastructure had to be regarded as likely to be open to the general public, free of charge (at least mostly) and provided as a space where the public would expect to be able to access at least during daylight hours. This could either be via a formal public right of access (such as by designation as access land, but not purely by the existence of a Public Right of Way over any land) or it being a space provided for public access as a core land use purpose and likely to be providing opportunity for a broad range of activities requiring public access (including for example public parks but also places such as cemeteries or public playing fields).
2. Accessible to the public. Land to which public access is permitted by the landowner, usually free of charge (although some areas may be pay to access). Such access may be restricted in extents, times of day or year and may be subject to closure at short notice or may come with conditions. Permissive access may also be subject to removal by the landowner.
3. Accessed by the public. Land that is accessed by the public but over which no right or permissive access arrangements are known. Such access may be tolerated by the landowner, be locally accessible by tradition, be incidental in nature or be actual trespass.

A judgement was made based on a review of the source data typologies as to whether an identified space was likely to be publicly accessible as set out in the access hierarchy. Sites identified as “publicly accessible” were done on the basis of a judgement of the usual probability. This means that some sites identified as accessible may in fact not be (for example, some cemeteries are private, some Cricket Pitches (identified in the OS data as “Playing Fields”) are private sports facilities etc. The detailed determination of public access can only be done locally and the depiction of any polygon in the mapping as “publicly accessible” in error does not create access.

Table 3. Typological assignment of accessibility of Green Infrastructure. Look up table showing how datasets and relevant attributes were assigned typologically to define Green Infrastructure accessibility and further refined to identify those that were used in the England Accessible Greenspace Standards (AGSt) assessment. Sites identified as “accessible” are done so on a usual probability basis and some sites may in fact be not accessible to the public.

Database	Attribute	Classed as accessible	Used in the AGSt Assessment
OS Greenspace	Allotments or Community Growing Spaces	No	No
OS Greenspace	Bowling Green	No	No
OS Greenspace	Cemetery	Yes	No
OS Greenspace	Golf Course	No	No
OS Greenspace	Other Sports Facility	No	No
OS Greenspace	Play Space	Yes	No
OS Greenspace	Playing Field	Yes	Buffer_200 only
OS Greenspace	Public Park or Garden	Yes	Yes
OS Greenspace	Religious Grounds	Yes	No
OS Greenspace	Tennis Court	No	No
Local Nature Reserve	None	Yes	Yes
Natural England Open Access Data (including	None	Yes	Yes

Database	Attribute	Classed as accessible	Used in the AGSt Assessment
Section 15 and Coastal Margin)			
Millennium Greens	None	Yes	Yes
Country Parks	None	Yes	Yes
Doorstep Greens	None	Yes	Yes
OS Woodland	None	No	No
OS Surface Water	None	No	No
National Forest Inventory	None	No	No
OS Open Rivers	canal	No	No
OS Open Rivers	Inland River	No	No
OS Open Rivers	lake	No	No
OS Open Rivers	Tidal River	No	No

Note on exceptions.

Some typologies normally treated as “not accessible” were included as accessible if they formed part of a wider publicly accessible space. For example, woodland has been classed as usually not accessible but included as accessible if it forms part of a public park. Likewise, Tennis Courts and Bowling Greens (which on their own are deemed not accessible but are treated as accessible if within the confines of a public park).

The Ordnance Survey Open Green Space data typology of “Other Sports Facilities” was not considered accessible as they may be buildings or spaces normally providing restricted and/or private access and facilities (including pay to access).

Likewise, Golf Courses were deemed not accessible because they are usually private or have restricted access to club members or may be “pay to play” businesses.

Spaces that are usually private, pay to access, or usually accessible by permissive agreement only, were not included in the assessment of “Accessible Green Infrastructure”. However, it is possible that some outdoor sport facilities within Public Parks may have restricted access or even be pay to use. If within a broader publicly accessible space, these have nonetheless been included as accessible for simplicity.

In Version 1.2 of the mapping (not updated for V 2.1), new data on sites offering permissive access to the public (on a general basis and usually free to access) has been included. The “Permissive access” layer is based on data provided to Natural England by land owning organisations that have identified the parts of their estate to which they permit some form of public access. Such access may be restricted in extents, times of day and possibly times of year but is usually free to access (although there may be charges for parts of the site or facilities such as car parking). Data gathered so far is only for a few organisations, but more data will be added over time to build a more comprehensive dataset of sites offering permissive access to the public and are thus access hierarchy class “accessible to the public”.

In addition, for Version 1.2 of the mapping (not updated for V 2.1), OS Open Green Space data on sports, activity and play spaces (Sport, Play and Active Recreation) has been collated into one layer. The sites identified may or may not be open to the public. In addition, some sports facilities may be buildings or 100 percent “manmade surface” (that is not vegetation, water or soils). However, some sites may include significant green areas and may offer limited or significant accessibility to the public. Sport England “Active Places” data has also been used to supplement and expand on that provided from the Ordnance Survey Open Green Space data. The Sport England data gives information on those sites that provide some form of public accessibility although this may be subject to some restrictions or require payment to use.

Determination of Accessible Greenspace (AGSt) attribution.

A sub-set of “Accessible Green Infrastructure” typologies was used for the England Accessible Greenspace Standards (AGSt) assessment.

The AGSt approach aims to address differences in access to greenspaces by setting a range of accessibility benchmarks for greenspaces within easy reach of people’s homes.

Once those typologies that were judged publicly accessible had been identified, a subsequent judgement process reviewed each typology to consider its likely “naturalness score” (The approach used to “naturalness” determination is set out below).

Those with a naturalness score of 1 or 2 (likely to be of a more natural character or of a mixed character) were used to generate a sub-set of typologies that would be used in the Accessible Greenspace Standards assessment. This was done on an “on balance of probability” basis seeking to identify those spaces that were likely to be of a more “natural” character but would also generally be considered as publicly accessible green spaces.

An exception was made for “Playing Fields” (Naturalness 3). Playing Fields were included in the Doorstep AGSt assessment. In the Doorstep AGSt assessment, Playing Fields were assigned a buffer of 200 metres alongside those green spaces that had been included as likely to be of a more “natural” character. In this case it was judged that whilst their naturalness factor is likely to be 3 because they are likely to be quite highly managed for formal sport and recreation, they nonetheless are likely to be important greenspace resources at this very local level.

Formal “Sports Facilities” were completely excluded from the AGSt analysis as they are likely to be highly managed functional spaces and may be 100% man made. However, some spaces that have been identified as Sports Facilities may in fact be Playing Fields and vice versa.

Facilities such as play spaces, tennis courts or bowling greens were included only if they formed part of a larger “Public Park” with Naturalness Rank 2 (as this rank covers the fact that such sites are likely to be variable in character).

Approach to the determination of “Naturalness” attribute.

The ‘Naturalness’ attribute was determined using the Green Infrastructure typology as a proxy. A system based on that set out in Nature Nearby was devised to fit with the mapping requirements.

Please note that this is not the same approach as employed in the Urban Habitat and Naturalness Mapping which is explained in Section 12 Urban Habitat Mapping.

Using typology as a proxy for “Naturalness” introduces high levels of variability between polygons resulting in different polygons with the same typology having potentially very different naturalness qualities on the ground. This undermines its usefulness as an attribute, and it was for this reason that a new approach to Naturalness is being developed to sit alongside the development of Urban Habitat Maps. Data and maps for this new approach to Naturalness have not yet been developed for publication and are not included in V 2.1 of the mapping.

Typologies were assigned a naturalness rating based on judgement as to the average rating a particular typology was likely to attain. The meaning of “naturalness” for V 2.1 is set out below.

- Level 1 (Likely to be most natural – lowest apparent levels of land management intensity).
- Level 2 (Likely to have mixed attributes – likely to be a mosaic of areas of low and high intensity land management).
- Level 3 (Likely to be highly or intensively managed spaces – may contain an element of less intensively managed areas).

Table 4. Assignment of "naturalness factor" to source data typologies. Look up table relating source data and any relevant attributes to an assigned "naturalness factor" of between 1 (Likely to be most natural) and 3 (Likely to be least natural).

Source Dataset	Attribute (sub-title in the data where relevant)	Assigned naturalness factor
OS Greenspace	Allotments or Community Growing Spaces	3
OS Greenspace	Bowling Green	3
OS Greenspace	Cemetery	3
OS Greenspace	Golf Course	3
OS Greenspace	Other Sports Facility	3
OS Greenspace	Play Space	3
OS Greenspace	Playing Field	3
OS Greenspace	Public Park or Garden	2
OS Greenspace	Religious Grounds	3
OS Greenspace	Tennis Court	3
Local Nature Reserve	None	1
Natural England Open Access Data (including S15 and Coastal Margin)	None	1
Millennium Greens	None	2
Country Parks	None	2
Doorstep Greens	None	2
OS Woodland	None	1
OS Surface Water	None	1
National Forest Inventory	None	1
OS Open Rivers	Canal	1

Source Dataset	Attribute (sub-title in the data where relevant)	Assigned naturalness factor
OS Open Rivers	Inland River	1
OS Open Rivers	Lake	1
OS Open Rivers	Tidal River	1

The naturalness rank assignments will be full of exceptions and should only be considered as a loose fit. For example, some Golf Courses (rank 3) contain significant natural space that is not picked up whilst some cemeteries (rank 2) will be more or less intensively managed than others meaning they could rank 1 or 3. Likewise, the management regimes for public parks are likely to be highly varied but they have been given a general rank of 2. In addition, all watercourses and bodies were assigned a rank of 1, but some will be highly engineered reservoirs, formal water features and canals with a substantial man-made character.

Approach to the determination of the "Percent Manmade Surface" attribution.

The "Percent manmade surface" attribution shows the percentage of the total area of each Green Infrastructure polygon or "Greenness Grid" square that is covered by a manmade surface (not vegetation, water, or soils). It is intended as a companion indicator to naturalness and can indicate some Green Infrastructure areas which were mapped in this process as Green Infrastructure but are in fact substantially or even entirely manmade.

For example, some sport facilities which appear in this dataset as Green Infrastructure may be buildings and indoor sports areas, and this can be determined using the percentage manmade area. The manmade area was calculated using a manmade surface dataset for the whole of England which was extracted from the Topography Layer from the Ordnance Survey's (OS) 'MasterMap' data.

The broader greenness grid (see section 4) registers the existence of Green Infrastructure that does not appear in the mapping because the data relating to it is not open, cannot be shown in the Open Government Licence (OGL) mapping or has no specific typological attribution due to a lack of land use data. Greenness itself is the inverse of the total "manmade surface" area and is therefore a broad measure of the total amount of aggregated "green cover" both accessible and non-accessible. The Urban Habitat and Naturalness Mapping is attempting to provide more detail on the actual constituency of the "green cover" within the Urban Ecosystem overall.

The Greenness data does not however include any tree canopy data. The impact of trees (as opposed to woods) on local greenness will therefore not be taken account of in the Greenness Grid.

In addition, the OS source data treats gardens as “mixed” surfaces. Most gardens will include some “manmade surface”, but this will not be accounted in the Greenness Grid “% manmade surface”. The “% manmade surface” will therefore likely be an underestimate of variable size depending on total amount of garden space present within he grid square and the actual amount of that space that is manmade surface. This means that actual “greenness” is conversely likely to be over-estimated to some degree.

Section 2. The assessment of publicly Accessible Green Infrastructure (AGI).

The “Accessible Green Infrastructure” layer was generated by creating a subset of polygons from the “Combined Green and Blue Infrastructure” layer.

Polygons from the “Combined Green and Blue Infrastructure” layer were retained based on the accessibility flag attribute. This means that private greenspaces such as golf courses, allotments, private sports facilities, gardens etc are not included in the Accessible Green Infrastructure layer.

Public accessibility was assigned using the Access Hierarchy as set out in “Approach to determination of Accessible Green Infrastructure (AGI)”.

To be flagged as “Publicly Accessible” a typology had to be (on the basis of usual probability), formally open to the general public (at least during daylight hours), free to access and available for at least informal recreation and visiting (although many accessible spaces will provide for a range of formal and informal recreation and activities).

All polygons flagged as accessible were dissolved to create a single vector dataset. The process of dissolving the polygons into one vector dataset removes the problem of overlapping polygons from different datasets seen in the “Combined Green and Blue Infrastructure” layer. This is because it joins adjacent greenspace polygons and creates a single, larger polygon where two or more polygons intersect.

A look up table matching dataset typologies with their treatment as “accessible” and whether used in the Accessible Greenspace Standards Assessment is set out in Table 3.

Section 3. Woodlands and access.

The Woodlands and Access module has not been updated for V 2.1 and remains as set out for Version 1.2. It is anticipated that work currently being done by Forest Research on the England Woodland Access Implementation Plan will ultimately provide the basis of any future update.

Find out more about the England [Woodland Access Implementation Plan].

There has been a limited change to the incorporation of woodlands into the Woodlands and Access module by removing Ancient Woodlands. This has been done to simplify the Combined Green and Blue Infrastructure Map and Ancient Woodlands are still included in the Biodiversity layer of the “Designated and Defined Areas” module.

It has not proved possible to yet include data on urban trees. It is still planned to incorporate tree data in a future iteration of the mapping.

In addition, the assessment of access to woods has been limited and high level and the resulting “Woodlands and Access” map should be regarded as a limited initial product only. Current work being undertaken by Forest Research on woodlands and access will expand data in due course.

Woodland access standards have not been incorporated into V 1.2, however; a limited “Woodlands and Access” assessment was undertaken to identify those woods that are either:

1. Accessible because they fall within a publicly accessible green infrastructure polygon.
2. Are partially accessible because of the existence of a Public Right of Way (PRoW) either within or along the edge of a woodland which creates a linear route with a woodland character. The route of the Public Right of Way is depicted as a linear corridor of 20m width.
3. Are not part of a publicly accessible green infrastructure polygon and are not crossed by a Public Right of Way and are thus, for the purposes of this exercise, deemed as “not accessible”. However, some woods deemed in this way may offer some form of permissive access and thus be “accessible to the public” in the access hierarchy.

No data relating to permissive access or incidental access to woodlands is included in this analysis.

Data for the “Woodlands and Access” map was extracted from the “Combined Green and Blue Infrastructure” map. Polygons were extracted if they were classed as having woodland typology code.

There are gaps in the Public Rights of Way network layer where data could not be sourced for inclusion in V 2.1 (PRoW has been updated for V 2.1 but there are still gaps in coverage). Where this is the case, woodlands with a Public Right of Way through or adjacent to them will not be identified as “linear accessible”.

Public Rights of way within or adjacent to woodlands are identified using an indicative 20m wide corridor to highlight the corridor within which the Public Right of Way exists. The existence of a Public Right of Way within or adjacent to a woodland does not give any rights of access except along the route of the right of way itself.

Section 4. The Greenness Grid.

Greenness is mapped with respect to the percentage of a polygon/area that is not vegetation, water, or soils. Greenness is expressed as a "percentage manmade surface" in the mapping. Actual greenness can be expressed as the inverse proportion statistically (see note on gardens below).

Greenness is used to permit two things.

1. At a site level (for each polygon), greenness is a means of understanding the amount of any given space mapped as Green Infrastructure that is actually man-made surface.
2. On an area basis (each Greenness Grid square), a simple measure of general environmental quality as derived from understanding how much of an area is manmade surface as opposed to vegetation, water, or soils.

The manmade area was calculated using the "manmade surface" dataset for the whole of England which was extracted from the "topography layer" from Ordnance Survey's (OS) 'MasterMap' data.

The percent manmade surface and Greenness Grid data presented in V 2.1 is a derived product because OS MasterMap Topography Layer is not open data and not available under Open Government License.

Approach to the use of greenness in the "Combined Green and Blue Infrastructure" map.

Within the Combined Green and Blue Infrastructure layer, Greenness exists as an attribute attached to each mapped Green Infrastructure polygon.

The attribute field shows the percentage of the total area of each green infrastructure polygon that is covered by manmade surface (not vegetation, water, or soils). It is intended as a companion indicator to naturalness and can indicate those areas mapped as green infrastructure in the data that are in fact entirely or mostly buildings and other manmade surfaces. For example, some sport facilities which appear in the OS Greenspace dataset may be indoor sport areas and this can be determined using the percentage manmade area.

Approach to the creation of the "Greenness Grid" map.

There is also a specific "Greenness Grid" map which shows the percentage of land surface that is manmade as opposed to vegetation, water or soils using a 250-metre square grid (aligned with the OS Grid).

This national map purely shows the estimated amount (derived from the source data) of surface within a grid square that is not vegetation, water, or soils. A 250-metre square grid was chosen as it strikes a balance between detailed geographical area coverage, processing requirements to create the data and overall size of the data.

The Greenness Grid was updated for V 2.1. Please note, there was an error with the V 1.2 Greenness Grid that meant it did not align with the OS National Grid. This has been corrected for V 2.1 but this means that individual grid squares cannot be compared between versions.

In addition, the OS source data treats gardens as “mixed” surfaces. Most gardens will include some “manmade surface”, but this will not be accounted in the Greenness Grid “% manmade surface”. The “% manmade surface” will therefore likely be an under-estimate of variable size depending on total amount of garden space present within the grid square and the actual amount of that space that is manmade surface. Conversely, the estimate of actual greenness is likely to have a degree of over-estimation.

Section 5. England Accessible Greenspace Standards Assessment (AGSt).

The Accessible Greenspace Standards assessment uses the system of 6 AGSt Standards that now form the structure of the England Green Infrastructure Standards for accessible greenspace (see table below).

The England Accessible Greenspace assessment was updated for Version 2.1 using OS Greenspace data (from autumn 2022).

The England AGSt assessment was undertaken using a subset of the data for the "Accessible Green Infrastructure" layer (see table 3) and utilised a system of AGSt criteria as set out in table 5.

Table 5. Table setting out the parameters for the system of Accessible Greenspace Standards (AGSt) used in the England AGSt assessment. Each Accessible Greenspace Standard is set out with the threshold values for minimum green space size, and its associated width of proximity buffer. Information on generalised time estimates for walking and cycling to undertake a journey of distance equivalent to the respective buffer width is also given.

Name of ANGSt Standard	Size and distance criteria
Doorstep Greenspace	At least 0.5 ha within 200 metres
Local Greenspace	At least 2 ha within 300 m
Neighbourhood Greenspace	10 ha within 1 km
Wider Neighbourhood Greenspace	At least 20ha within 2km
District Greenspace	100 ha within 5 km
Sub-regional Greenspace	500 ha within 10 km
Local Nature Reserves	LNRs of at least 1 ha per 1000 population

Approach to establishing AGSt buffers (Straight line versus network approaches).

The V 2.1 AGSt assessment uses a “straight line” method to creating buffers around those green spaces that meet the minimum threshold size for each AGSt standard.

A buffer of the respective distance was generated around all polygons (that meet the size and naturalness thresholds) in the “Accessible Green Infrastructure” map.

Because the “straight line” method assumes an “as the crow flies” distance measurement, actual distances walked are likely to be longer. Comparison with assessments using network analysis suggest that actual walking distances may be significantly longer than the straight-line distance due to barriers within the route network between journey origin (usually home) and destination (greenspace). Such barriers may be railways, rivers, and roads. In addition, the position of access points to greenspace will affect workable routes and thus actual distances traversed.

Best practice is to measure actual walking routes in applying the AGSt standards (at least for the 200m, 300m and 1km buffers). Such approaches are often called “network analysis”. But there are data size and comprehensiveness issues (especially for access points) that have meant that an England level network style of analysis has not been attempted for this version of the mapping. This means that the “straight line buffer” method was used for this assessment.

In the context of the England AGSt assessment, “accessibility” thus in practice refers to the creation of distance buffers around publicly accessible greenspaces. The buffer thus more correctly creates a “zone of proximity” to the relevant spaces. However, the ability of people to physically access the space will be affected by a range of factors including physical barriers and those created through personal circumstances such as personal health issues. Proximity to a space may thus not directly lead to an ability to easily physically access it.

In the England AGSt assessment, straight line buffers have been used with no corrections to understand the impact of major barriers (such as motorways, railways, or rivers etc) on local buffers. Such corrections can be applied locally.

However, V 2.1 includes layers of information that may help understand major features that could affect routes and thus distances have been included.

There are layers showing:

- Major barriers (for V 2.1 these are all railways and motorways although potential barriers created by rivers and water bodies can also be seen when combining this layer with the “Blue Infrastructure Network” map to identify water courses that may also be physical barriers).

- Access Points. This layer incorporates access points derived from OS Open Greenspace data but has also identified access points where the edge of an accessible greenspace intersects a Public Right of Way (see PRoW Network layer) where it is assumed that there will be an access point. Where PRoW data is missing, access points will not have been identified. In addition, any access points that occur where the PRoW or other track/road etc are in parallel with the Access Land may not have been picked up.

Selection of polygons to include in the England Accessible Greenspace (AGSt) assessment.

The Accessible Greenspace (AGSt) approach aims to aid the understanding of differences in access to the local greenspaces across the country.

Accessible green infrastructure polygons of size 0.5 ha and above that also have a "naturalness" score of 1 or 2 were used in the England AGSt assessment. These typologies and their source data are set out in table 3.

An exception was made for "Playing Fields" (Naturalness 3) which were included in the AGSt assessments if they were an integral part of a wider public open greenspace.

In addition, Playing Fields were included within the 'Doorstep' AGSt standard buffer of 200m. This was because it was judged that whilst their Naturalness factor is 3 (likely to be highly managed for formal sport and recreation) they nonetheless are likely to be important greenspace resources at this very local level.

Formal "Sports Facilities" were completely excluded from the AGSt analysis as they are likely to be highly managed functional spaces and may be 100% man made.

Polygons identified as activity spaces (such as tennis courts and bowling greens etc) were included if they were part of a wider public greenspace (given a Naturalness rank of 2) but not if standalone facilities.

All features flagged to be included in the AGSt assessment were dissolved to create a single feature where individual layers overlapped. The area of each of the spatially isolated polygons was calculated to determine the size of the buffer that was created around them based on the standards set out in table 5.

Note on the difference of approach for the "Doorstep" AGSt criterion.

For the Doorstep standard, a different approach was taken by including Playing Fields (Naturalness 3) in the assessment. This means that the Doorstep Standard is actually a measure of wider access to greenspace rather than those used for the other AGSt buffers where only polygons with Naturalness factor 1 or 2 were used.

This was because the Doorstep standard includes spaces down to 0.5 ha where it may be difficult to determine a robust view of what “Natural” means at such a small scale. In addition, the rationale for this standard relates to the provision of very local greenspace assets and more formal spaces are likely to be valued resources at community level irrespective of actual Naturalness qualities.

Note on the generation of the “AGSt Profile” map.

Maps were generated to show overlaps of the different buffers (combined buffers map) to create an “AGSt Profile” for each area. The AGSt profile identifies the number of buffers that are present at any given location of the map. The specific buffers present can be identified by cross reference to the AGSt maps.

Note on the generation of the “AGSt” population data.

In order to estimate the population that is within the AGSt buffer “zone of proximity”, the percentage and area of each Lower Layer Super Output Area (LSOA) that was covered by the zones meeting each of the AGSt size and distance criteria was multiplied by the population density in that output area. This analysis had to assume that the population is evenly spread within each LSOA. This will not be the case for all LSOA, especially those of a more rural or dispersed character.

For most rural LSOA (where population is likely to be nucleated within settlements and where accessible greenspace is more likely to be located) the population within buffer measure is likely to be an underestimate.

The population within the “zones of proximity” to a greenspace was then aggregated to England level and expressed as a percentage of the total population within each AGSt buffer.

Specific data at an individual LSOA level using this method may be at variance with the situation on the ground due to the methodological assumptions that were made for the calculation. Aggregated data at larger scales is likely to smooth out any variances. This means that population data at LSOA level must be treated with caution as it is at this fine grain of detail that margins for error will be most acute. Data at Local Authority level is likely to be more robust.

Note on barriers affecting people movement across buffers.

No account of the impact of major barriers has been attempted in the mapping.

However, some information in the mapping has been included showing the presence of major barriers in the form of the rail network and motorways. When used in conjunction with the “AGSt Buffers” layers it is possible to detect where substantial barriers within the buffers are likely to create a network interruption. Potential crossing points are not included in the mapping and other more local barriers are not mapped. Such information can be generated locally and incorporated as required.

In addition to motorways and railways, the “Blue Infrastructure Network” map can also be used to identify potential barriers created by water courses or water bodies. Again, crossing points are not included in the mapping, although some may be identifiable on the “Public Rights of Way Network” map which includes bridges that form part of a Public Right of Way.

Section 6. Accessible Greenspace Inequalities Mapping.

The original assessment of greenspace inequalities for Version 1.1 was undertaken using two approaches.

- A nature close to home (Nature Close to Home) assessment was undertaken for selected age cohorts of population using a unique 300m buffer that incorporates all greenspaces with a naturalness factor of 1 or 2 and above 0.5 ha in size.
- Accessible Greenspace Inequalities maps were created for LSOAs comparing levels of accessibility with other socio-economic variables.

For Version 1.2 an additional assessment of access inequalities was undertaken that identifies variations in the combined provision of greenspace and Public Rights of Way that is presented using a 5km square grid.

Version 1.2 of the mapping thus provided information on.

- The potential variation of the supply of “more natural” greenspaces with respect to the population cohorts for people of ages under 16 (children) or 65 and over (older people) at LSOA level.
- The relative provision of accessible greenspace compared to either the Index of Multiple Derivation (IMD) or population density at Lower Super Output Area (LSOA) level.
- The relative variation in the combined provision of access infrastructure (measured as amounts of accessible greenspace and density of the Public Rights of Way network) using a 5km grid square.

These modules have been updated for V 2.1 as follows.

The Nature Close to Home data was updated using updated OS Greenspace data (Autumn 2022) and Census 21 population data.

The Access Inequalities and IMD module has been updated with the Census 21 LSOAs. It is important to note that interim IMD deciles have been created for all LSOA that are new and would thus not have existed in the V 1.1 or V 1.2 assessment. A note on how this was done is set out below.

The Access Inequalities and Population Density module has been updated to use the new LSOA and Census 21 population figures.

The Combined Greenspace and Public Rights of Way Inequalities module has been updated to incorporate updated OS Greenspace data and the expanded Public Rights of Way data.

Nature rich spaces close to home. The “Close to Home” assessment.

The “Nature Close to Home” assessment aims to understand the supply of publicly accessible greenspaces that are likely to be moderate to high in terms of providing opportunity for “contact with nature” (wildlife) on a regular, daily, and local basis.

The assessment focusses on the supply of greenspaces of at least 0.5 ha size and with a naturalness rank of either 1 or 2. However, this is a general approach to assessing naturalness which means some of the level 1 or 2 spaces may not be that “nature rich” at current time, although many may have potential for biodiversity enhancement.

To assess the supply of “nature rich” spaces close to home, a new 300m “Close to Home” buffer was created around all greenspaces with a minimum 0.5 ha size and naturalness rank 1 or 2. This excludes “Playing Fields” and is thus different to both the Doorstep and Local AGSt buffers.

The spaces included are thus those that are likely to be currently offering the most local opportunity to have contact with nature on a regular or routine daily basis.

The “Nature Close to Home” assessment has focussed on two key age groups. These are:

- Children and young people (under 16).
- Older people (65 and older).

Population data from ONS (2021 census) was gathered which provides a breakdown of population for all different age cohorts (0-5, 5-10, 10-15, 65-75 and 75+). Relevant cohort populations were summed together to define new “children” and “older people” population groups.

The new “Close to Home” buffer was intersected with LSOA to calculate the percentage area of LSOA within at least 300 m of a “Close to Home” natural greenspace”. This percentage area was then used to calculate the percentage of total population and percentage of Children (ages 15 and under) and older people (Age 65 plus) which were within this “Close to Home” buffer.

This calculation assumes cohort populations are evenly distributed across LSOA which is probably true for some, but not for all. This assumption introduces a level of distortion into the statistics and maps at an individual LSOA level which means the actual figures must be treated with some caution. Estimates are likely to underestimate actual populations, especially in rural areas where population is likely to be highly nucleated in settlements and where most green spaces are likely to occur.

The age cohort data was then used to create maps of greenspace provision showing area in hectares of accessible greenspace per head of population for Children and Older people at Lower Tier Local Authority, MSOA and LSOA level. Maps were colour coded after sorting into 10 equal sized bands (deciles) based on area of greenspace per head for each cohort.

Accessible Greenspace Inequalities Mapping.

The “Accessible Greenspace Inequalities” mapping looks at the relative disparity between LSOA when it comes to levels of access to Greenspaces.

The measure of accessibility used is “percent of output area covered by selected AGSt Standard Greenspace and attendant buffer”. This measure of accessibility is thus essentially an estimate of proximity to greenspace which is then compared using bivariate analysis with another key indicator of interest.

Two comparator variables were selected for analysis. They were:

- Index of Multiple Deprivation (IMD) by decile (IMD 2019 with amendments for Census 21 new LSOA – see below).
- Population Density (by square km).

The resulting maps give an overview of LSOA across England showing the differential between the greenspace “demand factors” of IMD and population density against a proxy supply factor of “% LSOA covered by the AGSt buffer including the associated greenspace”. The assessment was undertaken for the full set of 6 AGSt Standards.

A method of bivariate colour mapping was used to assign Access Inequalities codes to LSOA. Bivariate analysis is where 2 factors are identified and mapped at the same time, with different colour gradients. Overall, this gives a spatial measure of relative accessible natural green space inequalities between different places.

The approach is outlined in Figure 2.

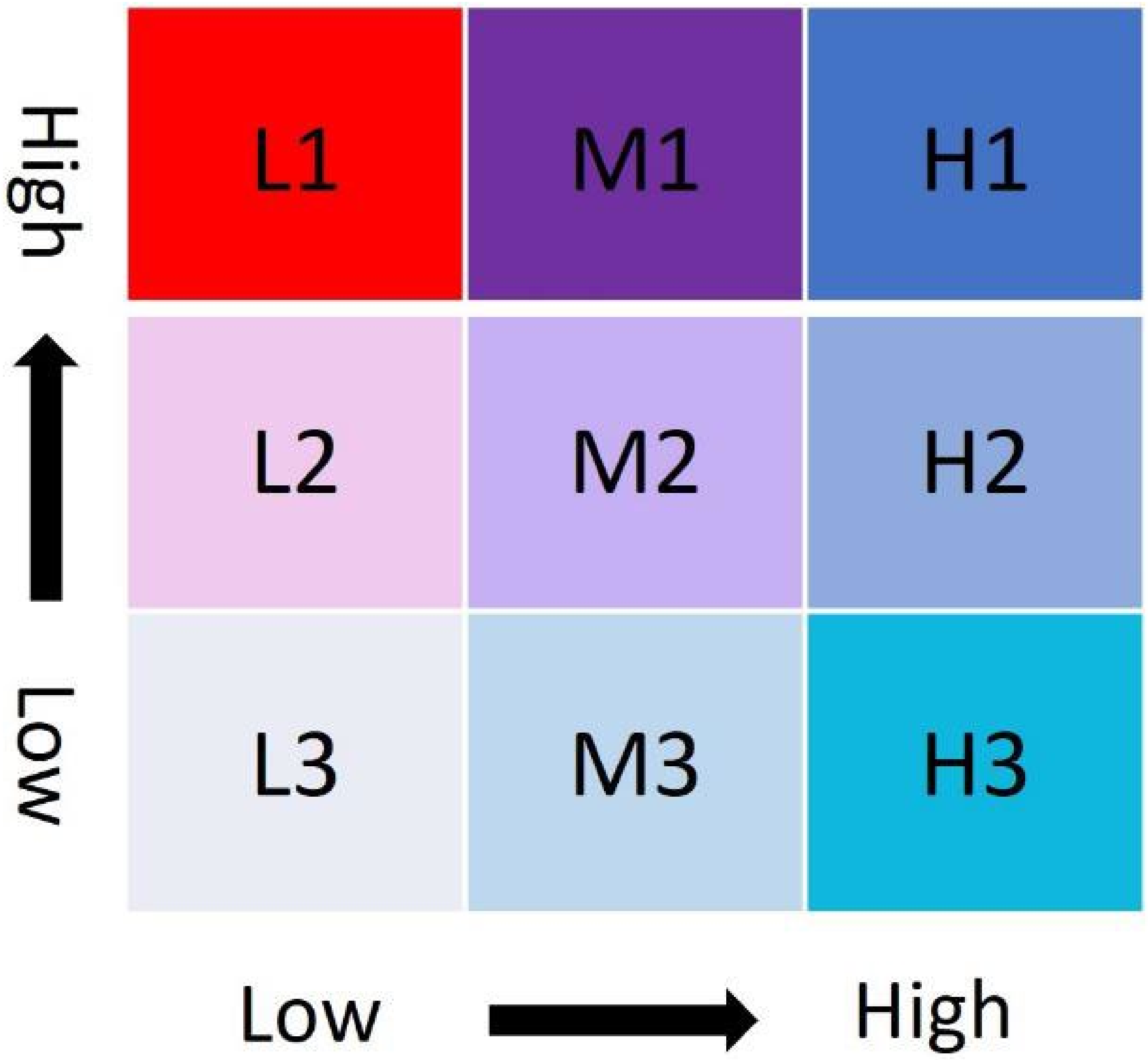

Figure 2. Graphic showing how a bivariate analysis is built up. Each axis is from low to high. This creates an analysis box containing 9 compartments in a grid. A system of alphanumeric codes is used to define the 9 accessible greenspace inequalities classes. Unique alphanumeric codes are assigned to each sector of the grid. In this system, the assessment classes represent the different scenarios as defined by the mix of variables to create an "Access Inequalities Class" ranging from L1 to H3. Each assessment class is colour coded for the purposes of mapping but has its' individual alpha-numeric code attached as an attribute.

In this system the letters L, M and H represent Low, Medium, and High for "Percent AGSt Buffer Coverage".

In addition, the numbers 1, 2 and 3 represent High, Medium, and Low for level of deprivation or Population Density.

This creates a range of Access Inequalities Classes with.

- L1 = Being the Least Favourable Scenario (i.e.: lowest buffer coverage and highest level of IMD/Population Density.
- H3 = Being the Most Favourable Scenario (i.e.: highest buffer coverage and lowest level of IMD/Population density).

Please note that these are relative not absolute measures and that H3 as a scenario does not mean that the situation on the ground necessarily fulfils local greenspace requirements.

In addition, the assessment can take no account of the quality of greenspaces.

To run the analysis, band widths were selected to allow the two variables to be co-mapped. The band widths of the variables are not equal. This is to simplify the outputs of the analysis and permit a focus on those places considered to be in the “least favourable scenario”.

The selected approach to band widths is set out in Figures 3 and 4.

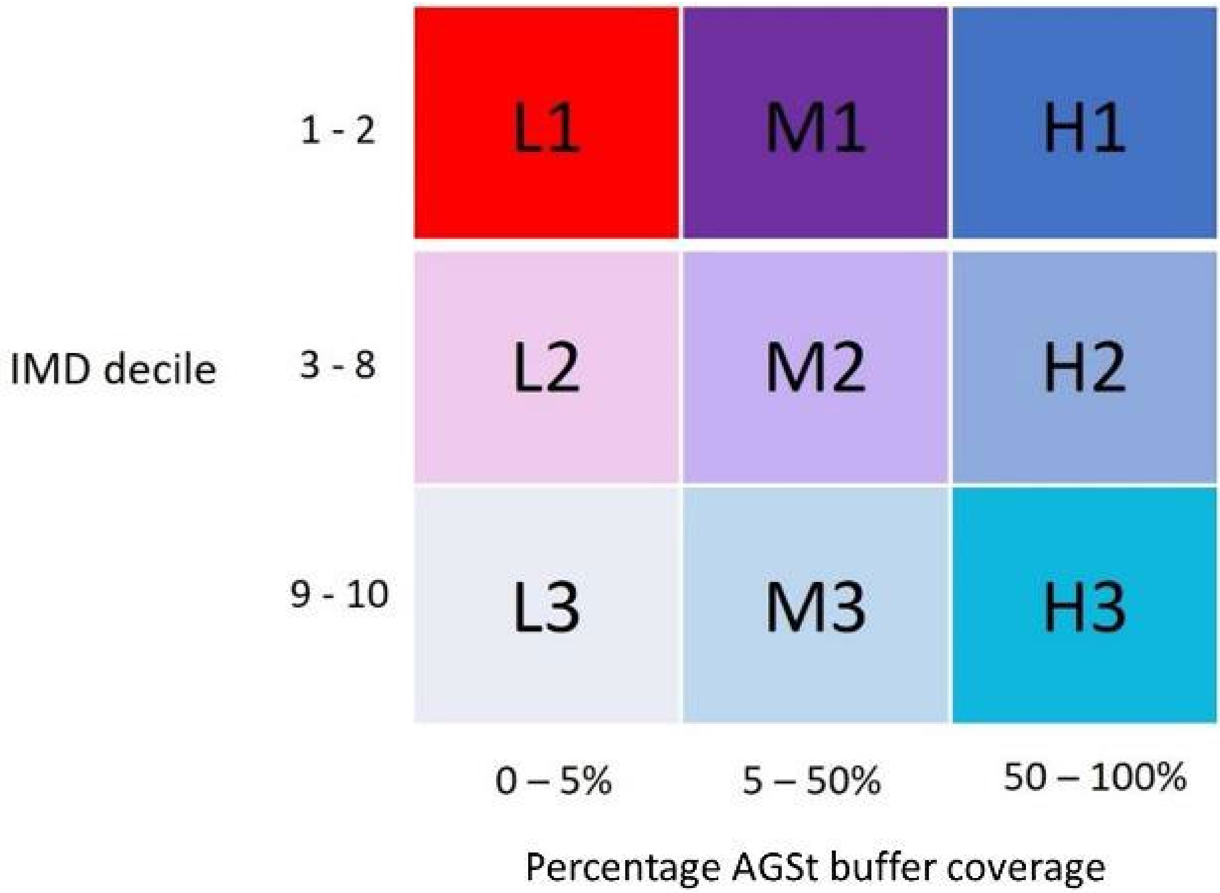

Figure 3. Band width selection incorporating IMD Deciles. Bivariate analysis box for percent AGSt buffer coverage along the horizontal axis and IMD decile along the vertical. Band widths for AGSt buffer coverage (from low to high) are 0 to 5%, 5% to 50% and 50 to 100%. The percent AGSt buffer coverage is the percentage of the area covered by both the accessible greenspace and its attendant buffer. Band widths for IMD deciles are inverted so that the highest IMD deciles (least deprived) are presented as low. Therefore, band widths are IMD deciles 1 and 2 (most deprived) are highest, 9 and 10 (least deprived) are lowest.

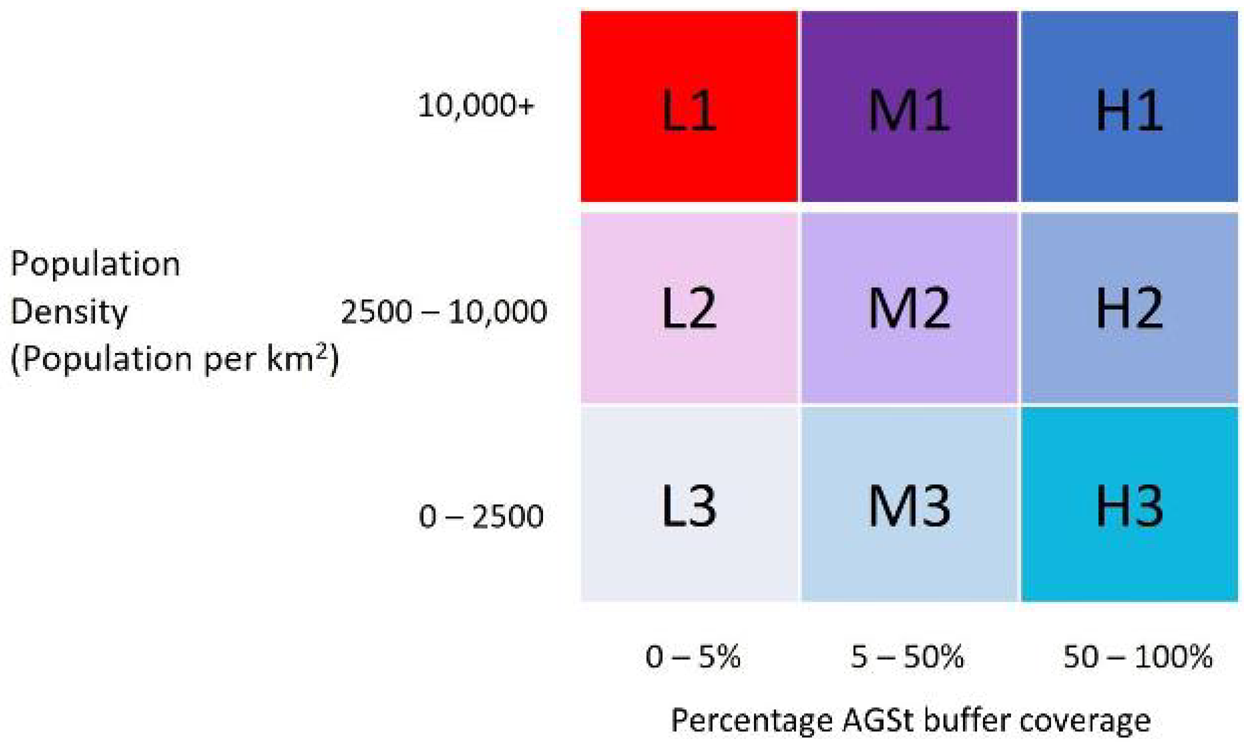

Figure 4. Band width selection incorporating population density. Bivariate analysis box for percent AGSt buffer coverage along the horizontal axis and population density along the vertical. Band widths for AGSt buffer coverage (from low to high) are 0 to 5%, 5% to 50% and 50 to 100%. The percent AGSt buffer coverage is the percentage of the area covered by both the accessible greenspace and its attendant buffer. Band widths for population density (from low to high) are 0 to 2500, 2500 to 10,000 and 10,000 and above people per square kilometre.

Note on implications of boundary changes for Census 21 LSOA and IMD Deciles.

The assessment of accessible greenspace inequalities was undertaken at an LSOA scale and each LSOA assigned its respective Access Inequalities Code based on the respective data for "percent of LSOA covered by the greenspace and associated buffer for each AGSt Standard" and IMD Decile or level of population density.

Both the Access Inequalities and IMD and Population density assessments have been updated for V 2.1. This means that the population data used is now from Census 21. For the IMD related assessment, the maps have been updated to use the new LSOA resulting from the ONS update for the release of the Census 21 population data. However, the IMD deciles have not been updated to reflect the new LSOA as yet and remain as at 2019.

As an interim measure therefore, the V 2.1 Access Inequalities and IMD map has assigned “Interim IMD” decile values using lookup tables to join the 2011 LSOAs and the 2019 IMD decile values to 2021 LSOA boundaries.

The boundary changes between 2011 and 2021 have resulted in the number of LSOA increasing from 32844 to 33755.

In order to avoid LSOA “gaps” appearing on the maps, the IMD data has been amended as set out below.

- Where a new 2021 LSOA was created by merging 2 or more 2011 LSOAs, the lowest decile (most deprived) from the 2011 LSOAs was assigned to the new 2021 LSOA.
- Where a 2011 LSOA was split to create two or more new 2021 LSOAs, both the new LSOAs were given the 2011 IMD decile value.
- There are a few cases (about 10) where the ONS say 'The relationship between 2011 and 2021 LSOA is irregular and fragmented. This has occurred where 2011 LSOA have been redesigned because of local authority district boundary changes, or to improve their social homogeneity. These can’t be easily mapped to equivalent 2021 LSOA like the regular splits (S) and merges (M), and therefore like for like comparisons of estimates for 2011 LSOA and 2021 LSOA are not possible', but the ONS provide a best fit in their lookup tables and this “best fit” LSOA IMD has been followed.

Access inequalities for combined greenspace and Public Rights of Way access infrastructure.

A new assessment for Version 1.2 (updated for V 2.1) looked at the relative disparity between total greenspace area (ha) compared to the total length of Public Rights of Way (PRoW) (m) across England. As total area and length values have been used the results are displayed in 5 km grid squares across England and not by LSOA or other geographic area as the variable size of these areas would affect the amounts of each variable they contain thus creating outputs that could not be easily compared across boundaries.

Again, a method of bivariate colour mapping was used. This is where 2 factors are identified and mapped at the same time, with different colour gradients. To run the analysis, band widths were selected to allow the two variables to be co-mapped. In this instance the ‘Natural Breaks’ method of classification was used to generate the different band widths.

“Natural Breaks” (also known as “Jenks Natural Breaks”) is a data clustering method of data classification that partitions data based on natural groups in the data distribution. The method is considered particularly suitable for use with data that has high ranges. Natural Breaks aims to normalise data in the most accurate way by minimising average deviation from the class mean while maximising the deviation from the means of other groups within the data. This creates classes with different numbers of observations within each class.

“Natural Breaks” splits up ranges to create like areas that are grouped together. The method minimizes the variation within each range, so that areas within each range are as close as possible in value to each other.

The assessment has thus used thresholds that are not even and based on specific numbers that may not look intuitive. This is because of the high range in the “amounts” for each variable and the heavy skewing or bunching in the data that is seen across that range.

Figure six shows the bivariate analysis box for total greenspace area and total PRoW length. To aid the display and assessment of the inequalities between greenspace and PRoW each sector of the grid has an alphanumeric code. The values for both greenspace area and total PRoW length for each 5 km grid square in England were then assessed together and assigned an alphanumeric code. The classes and codes can be seen in Figure 5.

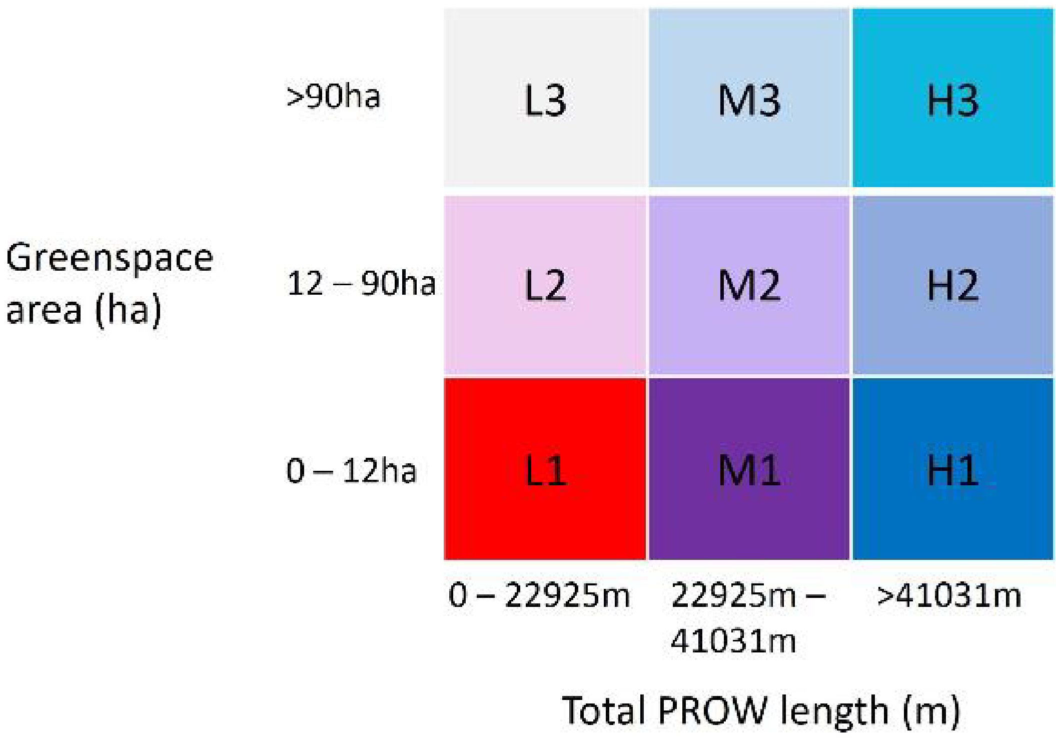

Figure 5. The bivariate colour grid used in the access inequalities for combined greenspace and PRoW access infrastructure. Unique alphanumeric codes are assigned to each sector. In this system, the assessment classes represent the different scenarios as defined by the mix of variables to create an “Access Inequalities Class” ranging from L1 to H3. Each assessment class is colour coded for the purposes of mapping but has its’ individual alpha-numeric code attached as an attribute.

In this system the letters L, M and H represent Low, Medium, and High for ‘total PRoW length (m)’.

In addition, the numbers 1, 2 and 3 represent Low, Medium and High for Greenspace area (ha)

This Creates a range of Access Inequalities Classes with:

- L1 = Being the Least Favourable Scenario (i.e., Lowest PRoW length and lowest Greenspace Area)
- H3 = Being the Most Favourable Scenario (i.e., Highest PRoW length and Highest Greenspace Area)

Thresholds used were;

For Greenspace, L = up to 12 ha, M = between 12 and 90 ha and H = over 90 ha.

For Public Rights of Way, L = up to 22925 m, M = between 22925 and 41031 m and H = over 41031 m.

Section 7. Blue Infrastructure Network Map.

In Version 2.1 of the England Green Infrastructure Mapping Database, the term “Blue Infrastructure” is used as a general description for those elements of the wider Green Infrastructure that are water dominated (water courses, water bodies and tidal water bodies). The Blue Infrastructure Network brings together data to identify and highlight the water courses, water bodies and tidal water elements of the overall Green Infrastructure.

The Combined Green and Blue Infrastructure layer includes some Blue Infrastructure data on inland water courses and bodies. However, the Blue Infrastructure Network layer is more detailed.

To create a more detailed Blue Infrastructure Network (Open) map, a range of data options were reviewed.

It was decided that the Ordnance Survey (OS) OpenMap Local Surface Water Area dataset (already utilised in the Combined Green and Blue Infrastructure map) was the most suitable dataset for mapping inland water in terms of balancing spatial resolution and data accessibility.

The spatial resolution of this dataset is not too dissimilar from OS MasterMap Topographic Area - Surface Water (the most detailed dataset that exists) but has the advantage of being openly accessible. It includes rivers, canals, lakes, and reservoirs.

However, this polygon dataset omits smaller streams and therefore for the Blue Infrastructure Network map it was decided to also include the equivalent polyline dataset of OS OpenMap Local Surface Water Line.

Furthermore, tidal sections of rivers are not included, therefore the equivalent tidal water dataset was also included, being OS OpenMap Local Tidal Water.

The resulting map represents a comprehensive collation of Blue Infrastructure data but will nonetheless omit the smallest of water bodies and courses.

Section 8. Access to waterside (all England) assessment.

The Blue Infrastructure module has not been updated for V 2.1 except that the Accessible Waterside assessments for the All England and Urban assessments (which were done separately) have now been combined into one map showing Likely Accessible Waterside by Accessible Green Infrastructure, Public Right of Way and Urban Paths. No other changes have been made. The detailed methodologies for the two assessments have been retained as they were done separately.

In addition, this assessment uses the Public Rights of Way network data for V 1.1 of the mapping and takes no account of the subsequent addition of data undertaken for V 1.2 or V 2.1. This means that for local authorities for which no data had been secured for V 1.1 Access to Waterside will not be identified by Public Rights of Way proximity and will thus be an overall underestimate.

The “Access to Waterside” assessment aims to map the level of (probable) public access to the side of water courses and bodies across England. Limitations in the mapping method mean that the depiction on the map of accessible waterside is only indicative. Waterside mapped as accessible may in fact not be and that mapped as not accessible may also in fact be accessible. Local inspection is required to confirm the access to waterside data and the depiction in the mapping is only intended to be broadly indicative.

The inclusion of waterside in the mapping as accessible does not create any right or provision of access.

Likewise, the mapping of waterside as not accessible does not affect the existence of any rights or provision of access.

The assessment focussed on access via off road routes and on foot only, to inland water bodies.

The results are displayed at different administrative scales (Upper and Lower Tier Local Authority, MSOA and LSOA – using Census 2011 boundaries) to be able to sit alongside the access to greenspace assessments.

The access to waterside assessment only maps the likelihood that the edges of water bodies and course are accessible. The accessibility is created purely by proximity of water edge to publicly Accessible Green Infrastructure, Public Right of Way or Urban Path.

The access to waterside maps do not consider any access to the actual water body itself and the existence of accessible waterside does not create or imply any such rights of access to the water for any purpose.

No attempt has been made to create standards relating to access to waterside.

The approach uses the V 1.1 "Public Rights of Way Network" (PRoW) dataset that was compiled using data made openly accessible by Local Authorities across England. However, there are some gaps. PRoW data for Version 1.1 of the PRoW Network map was unavailable for 54 local authorities. The lack of data for these areas is highlighted on the resulting maps. Whilst updating of the PRoW Network map was undertaken for version 1.2 and V 2.1, the Access to Waterside Analysis was not updated and remains that included in Version 1.1.

Access to waterside was assessed using proximity buffers which may contain local barriers not picked up in the assessment. Not all of the waterside mapped as accessible may therefore be physically accessible on site.

Other potential access infrastructure includes footpaths that are not designated as PRoW and small/quiet roads that are suitable for walking. In addition, access infrastructure in urban areas is more likely to be dominated by streets and paths and these have not been included in this assessment. This is likely to result in a marked underestimation of access to waterside in built up areas. Rural footpaths that are not designated as PRoW may also be locally used viable access routes. Unfortunately, these are not mapped for most of the country and the conditions of access (assuming it is by some form of permissive agreement) are also unknown.

Waterside access created by permissive agreement or other non-statutory access behaviour, or informal arrangements are thus not included in this assessment.

Approach to mapping access to waterside.

The "Blue Infrastructure Network" map was used to create a map of all watersides around water bodies and along water courses.

However, the smaller water courses are mapped as lines with unknown widths, meaning the water's edge cannot be accurately delineated. This causes complications when considering how close a person can get to the water's edge.

The access to waterside assessment does not include any factors describing the physical condition or aesthetic qualities of the watercourse or suitability of the waterside for access.

The assessment also presumes that the surface water bodies are visible; underground rivers and culverts are not included in the dataset.

Note on access criteria used to identify accessible waterside.

The analysis considered access to waterside on foot only.

Access to waterside was deemed to be possible (and therefore likely) if the edge of a water body/course was within 10 metres of a Public Right of Way or adjacent to, or within 1 metre of an area of Accessible Green Infrastructure (AGI).

Mapping access by proximity to PRoW was affected by a lack of data for 54 Local Authorities (V 1.1) which creates gaps on the maps.

The accessible green infrastructure typologies used to generate the 1m buffer were:

- Cemeteries and religious grounds.
- Playing fields
- Public parks and gardens.
- Local Nature Reserves
- Access Land (including Section 15)
- Millennium and Doorstep Greens.
- Country Parks

Footpaths that are not designated as PRoW potentially provide access to waterside. However, many of these are not consistently mapped for most of the country and they are not included in this assessment.

Spatial analysis approach used to identify accessible waterside.

The Access to waterside assessment looked at the likelihood of PRoW and Accessible Green Infrastructure providing direct access to waterside only. No attempt has been made to map any form of access to the water bodies themselves.

For PRoW, access to waterside was deemed probable if the route of the PRoW (as depicted on the Public Rights of Way Network map) was within a 10m buffer created around the edges of all water bodies and courses in the Blue Infrastructure Network Layer.

Note that any changes to the routes of Public Rights of Way after April 2021 (or the date of the appropriate Highway Authority published PRoW data used as source) will not have been picked up by the Version 1.1 of the PRoW Network map. This may introduce a source of local error.

A 10m buffer was used because a distance allowance had to be made for four reasons.

1. There may be a gap between the water and the path.

2. The width of the path may vary.

3. The width of the riverbank zone (e.g., mudbanks, vegetation etc) may vary.

4. The potential for there being a low spatial resolution of the PRoW data.

A buffer of less than 10m was thought to exclude a large number of genuine waterside paths, while more than 10m has greater potential to include paths that have no access to the waterside itself (e.g. there could be buildings between the path and water body, especially in urban or developed areas).

For Accessible Green Infrastructure, any edge of a water body located within such a space was assumed to be accessible. A 1m buffer on the accessible space was used in order to capture the edge of water bodies (e.g., rivers) that border the space where differences in spatial resolution and/or mapping depiction may cause them to slightly misalign. However, some waterside thus identified may in practice be fenced off or be otherwise inaccessible.

Note that the use of buffers can create an effect called “weaving” where a route (especially alongside large waterbodies) dips in and out of a 10m proximity. This can result in waterside access appearing more fragmented than it is on the ground.

Modification used for tidal waters.

Some rivers are tidal for a long distance inland and therefore much of this tidal stretch of river should be included in the inland access to waterside analysis (using a 10m buffer). The tidal water dataset (OS OpenMap Local Tidal Water) includes these sections of river but also includes coastal waters (water on the seaward side of the mouth of the river and along the coastline). These seaward polygons were removed from the ‘inland water’ analysis, in order to focus on inland waters.

To do this, the tidal waters dataset was clipped by the GB boundary (OS BoundaryLine – GB region) with a 250m landward buffer to remove coastal waters. The landward buffer was used to exclude numerous tidal water polygons/slivers along the coast. This generally worked well, splitting the tidal rivers at the river mouth (retaining tidal rivers but excluding coastal waters), but it does retain some additional coastal polygons. This is a limitation of the method. If a PRoW comes within 10m of one of these coastal polygons, they will be included in the ‘inland surface water’ statistics for each administrative scale.

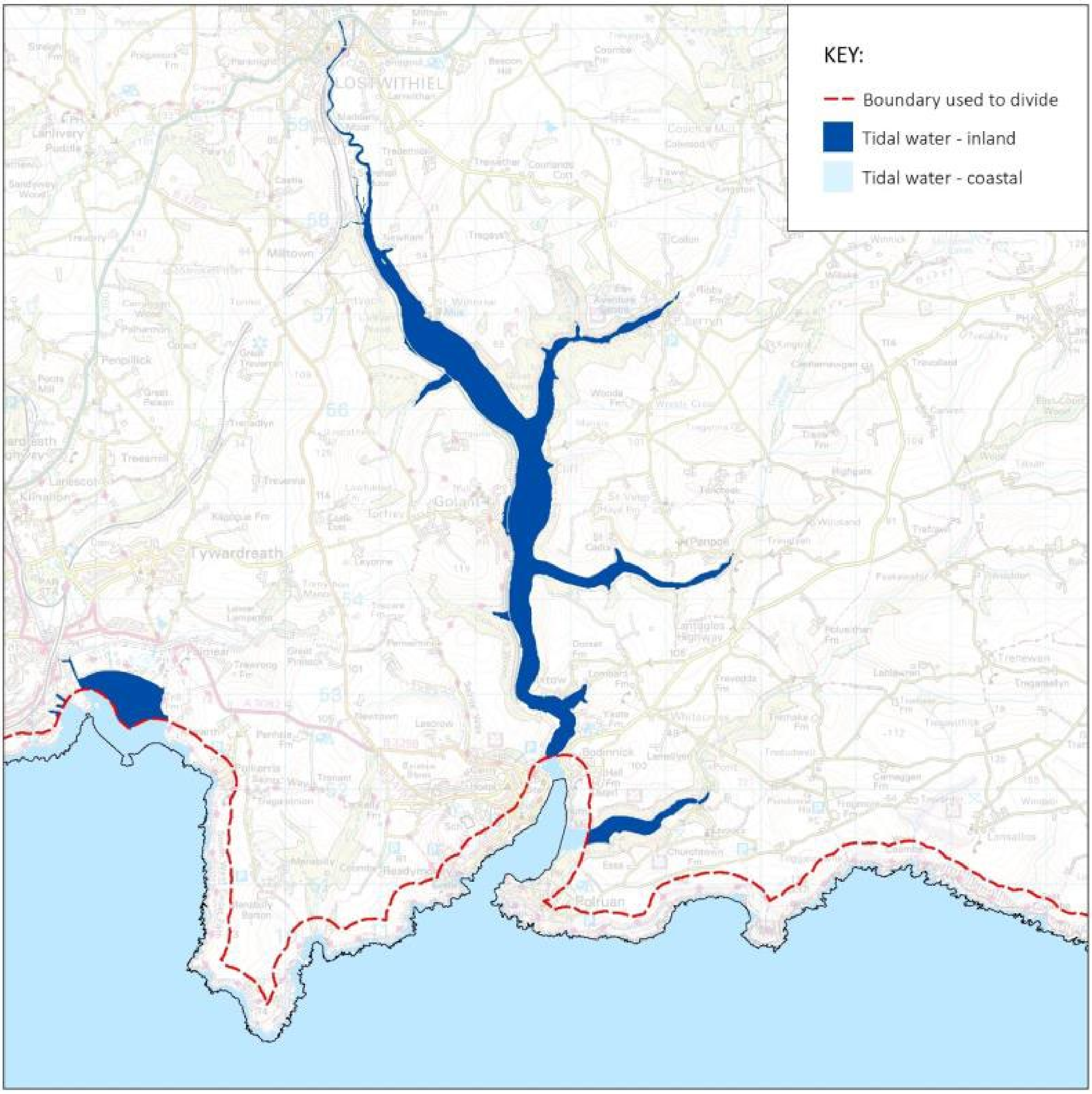

Figure 6. Use of landward cut off to exclude coastal waters. Map showing example of tidal waters ‘inland’ and ‘offshore’, with 250m cut-off boundary highlighted. Dark blue = tidal water inland. Light blue = tidal waters offshore. Red dotted line – cut off boundary used to differentiate in the mapping.

Note on access criteria used to identify accessible waterside.

The main statistics calculated from the assessment are related to the length of accessible waterside**,** not the area or length of the water body itself. Water bodies that were mapped as polygons were converted to lines (i.e., lines delineating their perimeter) in order to measure the length of the waters' edge.

This approach has four main benefits.

1. The inclusion of both sides of a river if a PRoW is present on both sides.
2. A clearer statistic for water bodies (e.g., lakes) that are only partially within an accessible area.
3. A more accurate measurement of water's edge (as opposed to river centrelines).
4. A singular statistic type (length) as opposed to a mixture of area and lengths for the different water body types and dataset shapes.

However, this method has limitations. For example, when a PRoW is within close proximity of a narrow river/stream, both sides of the river fall within the 10m buffer zone skewing any "length of waterside" analyses. It was decided that both sides of the river should be counted when a PRoW is present on both sides. However, there may be stretches of waterside that are depicted as accessible because of the narrowness of the water body. This introduces some over-estimation of accessible waterside.

When a PRoW crosses a river, a 10m stretch of waterside is selected (5m upstream and 5m downstream) for both sides of the river. Furthermore, the smaller streams that were mapped as lines from the start (centreline of stream as opposed to a polygon) produce statistics describing the length of the river only, not the length of individual banks.

These sources of error may distort local statistics.

Section 9. Access to urban waterside assessment.

Please note that this assessment uses the Public Rights of Way network data for V 1.1 of the mapping and takes no account of the subsequent addition of data undertaken for V 1.2 or for V 2.1.

An access to urban waterside assessment was undertaken as a part of the version 1.2 development process.

The version 1.1 approach to mapping accessible waterside had several limitations, especially in terms of its application to the urban environment. In particular, the relative lack of Public Rights of Way in urban areas limited the identification of potentially accessible waterside. In the urban environment, roads, paths, and public realm are of greater significance as access infrastructure relative to Public Rights of Way.

Work for version 1.2 reviewed the access to waterside mapping approach in version 1.1 and explored solutions to the urban limitations. It tested the accuracy of modified mapping methods, including the use of different distance thresholds between access infrastructure and waterside, as well as including additional datasets. It then applied a modified approach to the urban domain in England.

The main difference from the version 1.1 mapping approach was the addition of the “OS MasterMap Highways – Paths” dataset to the access infrastructure. Summarised statistics were then produced at the LSOA scale and additional analyses were also carried out describing distance to accessible waterside and length of accessible waterside per 1000 people.

In addition, data validation was undertaken through 120 field validation surveys at seven different locations (Bristol, Cheltenham, Exeter, Reading, Salisbury, Dartmoor, and Cornwall) to assess the accuracy of the “Access to Waterside” analysis both in urban and rural areas.

When present, the length of over-estimation and under-estimation was recorded by field survey, as well as the suspected causes of error.

Whilst the field validation exercise has limitations due to the survey locations being located mostly in the South-West of England, nonetheless it provides some evidence of the margins for error in the data.

Field validation found that overall, 64% of the sites were described as having ‘high’ overall accuracy, 27% as ‘medium’ accuracy and 9% as ‘low’ accuracy.

Overall, the field validation identified that the length of accessible waterside was over-estimated by 3.8% in parts and under-estimated by 4.6% in parts, the net result being a 0.8% under-estimation. However, the results showed that there was a high level of variability in accuracy rates from location to location. This means that at local scales, the actual accessibility of the waterside should be subject to ground truthing.

Geographical scope of the access to urban waterside mapping. Defining the urban domain.

There are several spatial datasets that describe the extent and distribution of the urban domain in England. Each differs in its method, level of detail and the size of urban areas mapped. Datasets that were considered for the access to urban waterside mapping were:

- OS Strategic Urban Regions (includes very small towns and villages, as well as cities)
- ONS Built-Up Areas (includes small towns, as well as cities)
- ONS Urban Audit Core Cities (includes medium to large cities)
- ONS Rural-Urban classifications for different administrative scales (e.g., Output Areas, LSOAs, MSOAs, Local Authorities, counties)

It was decided to use the LSOA rural-urban classification dataset (Census 2011) for consistency with existing content in the Green Infrastructure database.

All urban LSOAs were extracted from the national dataset and dissolved to show the outer boundary of urban areas. LSOA were considered urban if they had one of the following RUC 2011 LSOA classifications.

- Urban Major Conurbation.
- Urban Minor Conurbation.
- Urban City and Town.

This created an “Urban Mapping Domain” of about 25,000 square kilometres across England (approximately 20% of the country). The edges of the “Urban Mapping Domain” were then buffered by 200m before carrying out the mapping analysis to include waterside that lies adjacent to the boundary (the large buffer distance ensured all tidal waters were included, allowing for inconsistencies between the LSOA and the tidal water boundaries). Despite these efforts to include tidal waters in the mapping analysis, in the end they were not fully captured in the LSOA summary statistics due to complexities in the mapping method and boundary inconsistencies. There is therefore some under-representation in affected LSOAs.

Detailed mapping methodology.

The method set out below was applied to the developed England "Urban Mapping Domain". The spatial analyses focus was on the length of accessible urban waterside.

The Blue Infrastructure (BI), for which access is measured, comprises rivers, lakes, canals, reservoirs, and inland tidal waters.

The access infrastructure includes Public Rights of Way (PRoW), urban paths and accessible green infrastructure.

A seven-step process for undertaking the mapping was developed as set out below.

Step 1. Data collation.

The datasets used were:

- Inland Waterside. (Note, this is based on OS OpenMap Local Surface Water Area (polygon), Surface Water Line (line) and Tidal Waters (polygon), where the polygons are converted to lines and the tidal waters are clipped to exclude coastal waters).
- Public Rights of Way (PRoW).
- Accessible Green Infrastructure.
- OS MasterMap Highways – Paths**.** (Obtained by extracting and merging the *PathLink* feature classes).

Step 2. Creation of "Urban Mapping Domain".

LSOA boundaries (ONS Lower Super Output Areas 2011) and urban-rural classification data (ONS LSOA Urban-Rural Classification 2011) were obtained. The urban-rural data was joined with the LSOA boundaries and urban LSOAs were extracted (Urban LSOAs as defined above). All identified "Urban LSOA" were then dissolved to produce the outer extent of urban areas (the 'urban domain') and buffer by 200m.

Note that due to the way that LSOA are built up from Output Areas by the ONS, some urban edge LSOA can include large Output Areas with low population densities and a rural character. This inflates the extent of "urban" in the Urban Mapping Domain.

Step 3. Data clipping.

The selected datasets were clipped to the buffered urban domain.

Step 4. Linear access infrastructure buffering.

Linear routes in the “Public Rights of Way” (PRoW) and “OS Paths” datasets were buffered by 10m and the “accessible green infrastructure” dataset by 1m.

Step 5. Accessible waterside lines generation.

The PRoW, OS Paths and accessible green infrastructure buffers were merged and then intersected with the inland waterside dataset to identify accessible waterside.

Step 6. Generation of map attributes.

Attribute fields were added to the urban LSOA dataset to record the accessible waterside statistics, namely:

- Area of LSOA in hectares.
- Total length of Public Rights of Way (all classes).
- Total length of “paths” (OS Paths data).
- Total area of accessible green infrastructure in hectares.
- Total length of waterside.
- Total length of waterside accessible by PRoW proximity in metres.
- Total length of waterside accessible by proximity to “paths” in metres.
- Total length of waterside accessible by adjacency or inclusion within an accessible green infrastructure in metres.
- Total length of waterside accessible (PRoW, OS Paths, and accessible green infrastructure).
- Percentage of waterside within the LSOA accessible by the above access infrastructure types.

Step 7. Statistics generation.

Statistics were calculated for the LSOA boundary dataset.

Note on the use of the “OS Paths” data to increase access infrastructure data used in the accessible urban waterside assessment.

This analysis extracted from the “OS Highways – Paths” dataset, the location of paths suitable for pedestrians (using the PathLink feature class). These paths are defined as “linear features that represent the general alignment of a route used by pedestrians”. That is, they show urban pedestrian routes, such as footpaths and alleys, that Local Authorities have captured in their “Local Street Gazetteer” (excluding single paved footpaths along roads). Upon clarification of their public accessibility, the OS stated that it can be assumed these paths are mostly publicly accessible. Some paths may be private, but most will be owned by the Local Authority they sit within. It has therefore been assumed for this exercise that pedestrians will have access to these paths. However, some may in practice be private.

The source data for urban paths is not open. The vector data lines of the paths themselves cannot be published in the mapping. However, metrics describing their length have been included in summarised maps using administrative boundaries.

As well as paths, some other datasets were considered for inclusion in the refined urban analysis. They focused on expanding the access infrastructure to include more types of urban public walkways. These included: small lanes, pavements, bridges, and cycle routes.

It is possible to map all these features in some way. However, several reasons meant that these datasets were less suitable for the national analysis (but may be practicable to include in more local assessments).

Firstly, small lanes can be mapped using different OS data products (e.g.,OpenMap Local or MasterMap Highways); however, it is not possible to know which small lanes are suitable for walking or unsuitable due to the presence of road related hazards.

Pavements can be mapped fairly accurately using OS MasterMap Topographic Layer (roadside, manmade); however, in addition to pavements this method identifies numerous other types of manmade roadside, which would not be suitable for walking. Also, the data processing requirements for including all pavements (detailed polygons) across all urban areas in England would be considerable and were considered beyond scope for this work.

Road bridges can be mapped quite accurately by intersecting roads with surface water (various OS datasets). However, once mapped, it is necessary to identify which bridges are suitable for pedestrians. Mapping pavements on bridges would have the same issue as already stated. Foot bridges are generally included when a PRoW or path (“OS Paths”) crosses a water body, and these datasets are included in the analysis. Other bridges are not included.

Local cycle routes can also be important access routes; however, they are not mapped consistently across the country. Some information is included in the “OS MasterMap Highways” dataset and some Local Authorities have mapped these routes, but the data is not comprehensive and has not been collated at England level. Cycleways have thus not been specifically included in the access infrastructure for the urban waterside accessibility mapping.

In addition, consideration was given to the inclusion of non-green open spaces (e.g., public realm and open areas or spaces such as shopping precincts) which can sometimes include waterside access. There is a persuasive argument that these areas should be included and could potentially have a significant impact on the overall length of waterside that is deemed accessible in some places. However, these areas are not consistently mapped across the country and therefore could not be included in the analysis at this time. Many Local Authorities have published ‘Open Spaces’ data meaning that such data may be available locally.

Note on methodological limitations.

The main statistics produced from these analyses describe the length of waterside that is likely to be accessible within the “urban domain” LSOA.

However, there are several limitations which introduce some uncertainty. This means that some waterside identified as accessible may in fact not be whilst other sections identified as non-accessible may, in reality; be accessible. The depiction of waterside as either accessible or not accessible should only be considered as indicative. Local confirmation of the actual access is required to confirm the position on the ground. The depiction of waterside in the mapping does not create, extinguish, or affect the status of any existing access (or lack of) in reality.

There are four main sources of mapping error in the assessment that need to be taken account of when considering the map outputs at a local level.

1. Small streams error. Small streams are mapped as centrelines, not polygons. This can lead to an under-estimation of the length of accessible waterside in areas where these small streams are accessed from both sides. This is because only one length of the watercourse is being counted as opposed to the length of each bank, which is the case for larger rivers.
2. Opposite bank error. In some places, the bank of a watercourse may be incorrectly mapped as accessible when the river or water body polygon is narrow. This can lead to an over-estimation of the length of accessible waterside.
3. Data missing error. There are gaps in the PRoW network dataset for some urban areas. Data gaps are highlighted on the maps. This lack of access infrastructure data may lead to an under-estimation of accessible waterside in affected urban areas.
4. Mapping method error. The mapping method can introduce complexities with regards to waterside that falls outside, but adjacent to, the LSOA boundary. When summarising the results at LSOA scale, only waterside that falls within each LSOA boundary is counted. It does not include lengths of waterside that lie outside the LSOA border, even if they are accessed from a path within the LSOA. This length of accessible waterside is counted within the neighbouring LSOA. This approach is logical and straightforward to calculate, but complications can occur in the tidal regions. The LSOA boundaries are drawn to exclude tidal waters leading to a spatial misalignment between the LSOA and tidal water boundary lines. This means that many stretches of accessible tidal waterside are not included in the LSOA statistics.

Limitations of the distance to nearest waterside assessment.

For urban LSOAs that had no detectable accessible waterside present, the distance to nearest accessible waterside was calculated. Note, if an LSOA contains accessible waterside then this value is zero.

Furthermore, the length of waterside per 1000 people was calculated using the 2018 population estimate for LSOAs provided by ONS and not the 2011 population data used in the broader Green Infrastructure mapping. This is the only element of version 1.2 of the Green Infrastructure mapping that uses population data other than Census 2011 outputs.

The distance to nearest waterside calculation has some limitations, including the fact that the value describes the shortest distance between any point on the edge of the LSOA and the surrounding accessible waterside, not the distance from households within the LSOA. Therefore, residents that live at the opposite end of the LSOA would have to travel further to the identified accessible waterside or may in fact be closer to a different accessible water body. Furthermore, it currently only includes urban accessible waterside, not rural accessible waterside. Therefore, if no accessible waterside is present in the entire urban area the distance to the accessible waterside in the next urban area is calculated, which can be very large in some cases. Further refinement of the method in future may resolve these issues.

Field data verification exercise.

A field data verification exercise was undertaken to provide information on the data confidence of the accessible waterside data.

Seven locations in England were selected for field data verification, each measuring approximately 20 square kilometres. Each location had multiple sites that covered all the waterside mapped as accessible (divided into 300m stretches of manageable lengths to survey). A surveyor spent a day at each location, surveying as many of the sites as possible (ranged between 11 and 26 sites). After a training session, each surveyor was provided with an overview map; a list of site coordinates; individual site maps showing the accessible waterside and the access infrastructure. At each site, the surveyor walked the length of the accessible waterside, making notes on the paper maps and taking photos as required, then completed a survey on a mobile app (ArcGIS Survey123).

Of the seven locations, five were urban and two were rural. While the focus was to validate the urban mapping method, the opportunity was taken to gain some understanding of the accuracy of the rural method also.

A key limitation to note, is that the surveys focus on waterside that is mapped as accessible, identifying whether it is truly accessible or whether the map over-estimates or under-estimates the length that is accessible. The surveys do not actively assess waterside that is mapped as inaccessible (though many stretches are present within the surveyed sites). Therefore, if a stretch of waterside has been wrongly mapped as inaccessible (and is not adjacent to waterside mapped as accessible) it was not actively surveyed. The survey form had the option to record notes about these sites if the surveyor came across them, however, they were captured in a much more ad-hoc way than the waterside mapped as accessible. This was due to time constraints and impracticalities. In an ideal situation, the surveys would capture information about all the waterside present across the location. However, inaccessible waterside is often very difficult to validate because it is exactly that; inaccessible. To be certain that inaccessible waterside is truly inaccessible, the surveyor would have to explore all possible access routes to the site. Sometimes, on the ground, this can be difficult due to obstructions or uncertainty about whether land/paths are public or private, etc.

Field data verification locations.

To thoroughly assess the accuracy of the method, locations were selected to represent a range of settings with different types of Blue Infrastructure (BI) and means of accessing it. However, logistical practicalities also had to be considered and therefore the selected locations cover a wide area but were to be reachable by a team of surveyors based in SW England. There were thus no field verification sites in the North, East, Southeast or Midlands.

The locations where surveys took place were:

Urban areas.

- Exeter (smaller city; tidal)
- Bristol (large mixture)
- Cheltenham (small historic town)
- Salisbury (chalk rivers)
- Reading (large river through a city centre)

Rural areas.

- Dartmoor (access land)
- Cornwall (a coastal stream)

For each of these locations, a 20 square kilometre portion of land was selected, usually focusing on the city centre and/or areas with considerable waterside mapped as accessible. All surveys took place between February and April 2022, by six different surveyors.

Table 6. Table of field verification survey contexts, locations, survey dates and number of sample locations.

Urban or rural	Location name	Date surveyed	Number of sites surveyed
Urban	Bristol	04/03/2022	26
Urban	Cheltenham	25/02/2022	11
Urban	Exeter	30/04/2022	25
Urban	Reading	11/03/2022	15
Urban	Salisbury	07/03/2022	15
Rural	Dartmoor	19/03/2022	18
Rural	Cornwall	23/03/2022	10

Out of the 120 sites surveyed, 77 were described as having ‘high’ overall accuracy (64%), 32 as ‘medium’ accuracy (27%) and 11 as ‘low’ accuracy (9%). Though it should be noted that despite 77 sites described as having high overall accuracy, 32 of these still recorded a minor level of over-estimation and/or under-estimation in the length of accessible waterside mapped.

Over estimation of accessible waterside.

Out of the 120 sites surveyed, 37 sites (31%) recorded an over-estimation of accessible waterside at part or all of the site. That is, the waterside mapped as accessible was not deemed to be accessible in reality. Of these sites, the length of over-estimation ranged between 10m and 300m. As the length of accessible waterside varies from site to site, it is more meaningful to use the percentage of mapped accessible waterside that is deemed to be inaccurate. At sites where over-estimation was recorded, this ranged from 1% to 100%, with an average of 20%.

However, the impact of over-estimation on the length of accessible waterside across all sites (including those where no over-estimation was recorded) was relatively low; with only 3.8% of the mapped accessible waterside regarded as inaccessible in reality.

Under estimation of accessible waterside.

50 out of the 120 sites surveyed (42%) recorded an under-estimation of accessible waterside at part or all of the site. That is, accessible waterside existed in reality but was not included on the map. Note, that surveyors could record both over-estimation and under-

estimation at a site, if different parts of the site could be described as such. Of these 50 sites, the length of under-estimation ranged between 10m and 400m. When comparing these lengths with the waterside that was already mapped as accessible at each site, the under-estimation varied between 1% and 400% of the mapped accessible waterside, with an average of 26%.

However, the impact of under-estimation on the length of accessible waterside across all sites (i.e., including those where no under-estimation was recorded) was relatively low; with the mapped accessible waterside underestimated by an overall 4.6%.

The surveys show that under-estimation appears to be marginally more wide-spread and impacting on mapped accuracy of accessible waterside than over-estimation. With the results showing that, overall, the length of accessible waterside is over-estimated by 3.8% in parts and under-estimated by 4.6% in parts, the net result being a 0.8% under-estimation.

There are caveats with generalising the figures in this way. An important one being that the surveys focused on sites where waterside was mapped as accessible. Sites where waterside was mapped as inaccessible were not actively surveyed (except the segments that fell within or adjacent to accessible waterside).

Table 7. Variations in survey results of under and over estimation of accessible waterside by survey location. Table showing field data survey locations giving statistics for levels of over and under estimation of accessible waterside. The figures show the range of variation of both over and under-estimation and the estimated overall impact on net accuracy. Overall net accuracy in the field assessment was a 0.8% under-estimation with a range between 11.2% under-estimation to 10.5% over estimation.

Field location	Urban or rural	Number of sites surveyed	Percent of accessible waterside over estimated	Percent of accessible waterside underestimated	Difference (Positive numbers = under-estimation. Negative numbers = over-estimation.
Bristol	Urban	26	4.4	14.9	10.5
Cheltenham	Urban	11	17.1	5.9	-11.2
Exeter	Urban	25	3.7	4.0	0.3
Reading	Urban	15	0.3	1.6	1.3
Salisbury	Urban	15	1.1	0.2	-0.9
Dartmoor	Rural	18	3.6	0.0	-3.6
Cornwall	Rural	10	4.2	0.4	-3.8
All	Mix	120	3.8	4.6	0.8

Section 10. Public Rights of Way density mapping.

All Public Rights of Way.

Public Rights of Way density is mapped using a 1 km grid covering the whole of England. The 1 km grid is in alignment with the OS National Grid.

Calculations were made for total length within the grid square for all PRoW and each PRoW type (footpath, bridleway, byways, and restricted byway).

A 'Data_Available' field was added to the 1 km grid dataset and, where no PRoW data was available within a grid square; the grid square was assigned 'no' in this field and each length field was left as 'null'. This was done to distinguish those grid squares where data is available but there is 0m of PRoW within that grid square from those without available data. The areas of Highway Authorities for which no data could be included in version 1.2 have been cut out of the map. This cuts across and truncates some grid squares and will affect the accuracy of the statistics (as the lengths do not cover the whole of the truncated square).

There are a total of 134,486 1km grid squares. There are 4,055 grid squares where no PRoW data was available (3%). Some grid squares include coastal waters and may only have a small amount of land within them.

Higher Public Rights of Way only.

A separate Public Rights of Way density mapping exercise was conducted for routes that are more than Public Footpaths. These routes are sometimes referred to as "higher rights" and include Bridleways, Byways Open to all Traffic and Restricted Byways.

For version 2.1 "higher rights" density mapping, a 1 km square grid was used. This differs from the version 1.2 assessment which used a 5 km grid.

Section 11. Public Rights of Way Experiential Terrain mapping.

The "Public Rights of Way (PRoW) Experiential Terrain" mapping aims to give a broad indication of the physical environment (landscape terrain) and likely "underfoot" land surface that the route of a PRoW exhibits. These two factors are designed to give an indication of the likely physical experience that might be encountered along the route.

The England PRoW network map data was buffered by 10m either side of the right of way. This distance was deemed to be wide enough to provide a good overall indication of the experience of the environment through which the PRoW passes. This buffered PRoW network was then intersected with two further datasets to provide contextual information about the areas which intersect the PRoW.

Use of Living England Map data.

The first of these datasets was the Living England Phase 4 Habitat Map. The Living England habitat map is a satellite-derived national habitat layer in support of the Environment Land Management (ELM) system and the Natural Capital and Ecosystem Assessment (NCEA) Pilot. Living England is a habitat probability map created using machine learning. The habitat probability map displays modelled likely broad habitat classifications trained on earth observation data from 2021 as well as historic data layers. Thus, Living England should be seen as an indicative probability-based map and is not a definitive habitat survey.

The habitat probability map has some known under mapping (under representation) of urban areas, with major roads, airports, car parks and dockland areas being classified under several other habitat types. This mainly affects habitat predictions around urban areas for the following broad habitat types: Broadleaved, Mixed and Yew Woodland; Coastal Sand Dunes; Bare Sand; Dwarf Shrub Heath; Acid, Calcareous and Neutral Grasslands. The Living England Technical User Guide and Confusion Matrices provide further information.

Prior to intersection with the buffered PRoW network the Living England habitat classifications were aggregated to create a simplified system of experiential classes. The Moorland Line dataset was used to differentiate between upland and lowland Heathland, Grasslands and Wetlands. The aggregation classes create the mapped "Experiential Terrain Classes" and are set out in Table 8.

Table 8. Experiential Terrain Classes used in the Public Rights of Way Experiential Terrain Mapping and their constituent Living England habitat probability classes.

Experiential Terrain Class	Constituent Living England Class
Grasslands	Acid, calcareous and acid grassland, or improved grassland.
Woodland and scrub	Broadleaf, mixed and Yew woods, coniferous woods, scrub, or bracken.
Arable	Arable and horticultural.
Urban	Built up and gardens.
Wetlands	Bog, Fen, Marsh, and Swamp.
Heath	Dwarf shrub heath.
Coastal	Coastal salt marsh and coastal sand dunes.
Water	Water.
Bare ground	Bare ground and bare sand.
Upland grasslands	Acid, calcareous and acid grassland, or improved grassland above the Moorland Line.
Upland wetlands	Bog, Fen, Marsh, and Swamp above the Moorland line.
Upland heath	Dwarf shrub heath above the Moorland line.

Use of Landscape Description Units (LDU) data.

The second dataset that was intersected with the buffered PRoW network was the Landscape Descriptor Unit dataset. This is a non-open data product from which broad geological and landscape feature information was derived to add contextual information relating to the physical character of the landscape of the Experiential Terrain Corridors. However, the LDU data is not always comprehensive in this respect so that some corridors lack specific physical character information and provide basic geological information only.

The PRoW type attribute was retained alongside the new Experiential Terrain Corridor and LDU derived dataset attributes.

Section 12. Urban Habitat and Naturalness Mapping.

Urban Habitat and Naturalness Mapping is an Earth Observation based approach to generating detailed data on the constituency of the greenness of the urban ecosystem. It uses a new developing approach to Naturalness as a means of trying to understand the broad environmental quality of the constituent elements of the urban ecosystem from the perspective of "apparent degree of management intensity".

The Urban Habitat and Naturalness maps identify;

- The "Broad Habitats" within the urban areas.
- The "Detailed Habitats" within the urban areas.
- The distribution of "Naturalness" as a measure of broad environmental quality across an urban area.
- The "naturalness" of each Accessible Green Infrastructure space within the urban area using a "Combined Naturalness Factor" based on the mix of urban habitats within any given space and their relative proportions.

Urban Habitat Maps are created using an Earth Observation based approach blending a variety of source data to create maps of the spatial location and extents of a system of Broad and Detailed Urban Habitat Classes.

The data sources used are;

- England Green Infrastructure and Blue Infrastructure Mapping (Open Government Licence). Accessible Green Infrastructure. Please note that all Urban Habitat and Naturalness Mapping done to date (April 2024) uses version 1.2 of the Green Infrastructure Mapping.
- Aerial Photography for Great Britain (Not open data).
- Ordnance Survey British National Grid (Open Government Licence).
- Ordnance Survey Master Map (Not open data).
- National Forest Inventory (Open Government Licence).
- Environment Agency National LiDAR Programme (Open Government Licence).
- OS Open Built-Up Areas (Open Government Licence).
- Priority Habitat Inventory. Coastal Habitats, Wetland Habitats (Open Government Licence).
- Moorland Line (Open Government Licence).

Urban Habitat Map coverage is intended to be urban only. Data outside Built-Up Areas is for context only.

The Urban Habitat mapping approach is specifically designed to work within Built Up Areas (BUA). The maps also provide information on the land outside of the BUA, but this is provided very generally and is for context only. Other data sources should be used to understand areas outside of the BUA, such as the Living England maps.

Note that the Naturalness maps are still developmental and whilst the emthoid to their development is included in this section, no maps have yet been published and they do not form part of the V 2.1 release.

History of the development of Urban Habitat and Naturalness Maps.

Methodological development for Urban Habitat and Naturalness Mapping was conducted during 2021/22 and focussed on the pilot cities: Plymouth, Cambridge and City of Manchester.

Following successful piloting, a second phase of work was undertaken during 2022/23 that further developed the methodology and then developed approaches to upscaling its application to large city conurbations. This phase resulted in the creation of Urban Habitat and Naturalness Maps for Tyneside, Greater Manchester and Greater Birmingham using an amended approach that was more streamlined and more applicable to desk-based application for large scale urban areas.

Further work is being undertaken to expand coverage.

Purpose and use.

Urban Habitat and Naturalness Mapping data is intended to improve our understanding of;

- The physical composition of the urban ecosystem (Urban Habitats).
- It's quality using "Naturalness" as a proxy.
- Change in these parameters of the Urban Ecosystem in England over time.

Overall approach developed as initial mapping for Cambridge, Plymouth and City of Manchester.

The data processing approach to developing Urban Habitat and Naturalness Maps is complex and cannot reasonably be presented in this report.

However, a detailed step by step user guide to developing Urban Habitat and Naturalness Maps using Trimble eCognition software has been developed and is available on request to Natural England.

The overall approach to undertaking the process of developing Urban Habitat and Naturalness maps is set out in figure 8.

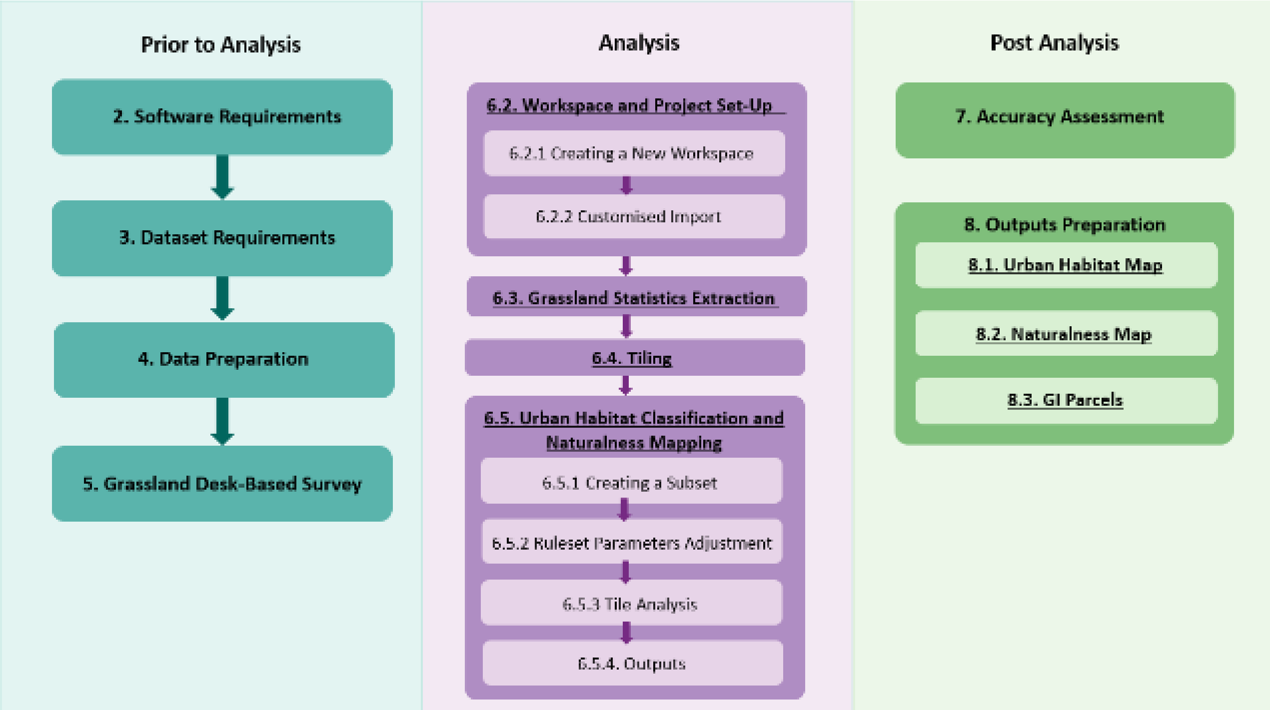

Figure 8. Steps in the Urban Habitat and Naturalness Mapping approach.

The Aerial Photography for Great Britain (APGB) imagery was the primary dataset used in the classification workflow. It provided spectral features in the red, green, blue and near-infrared (NIR) parts of the electromagnetic spectrum at a spatial resolution of 50 cm. Additionally, the APGB Digital Terrain Model (DTM) and Digital Surface Model (DSM) were downloaded. Other supplementary datasets were also used, including the Ordnance Survey Master Map (OSMM) to extract building and private garden footprints, the National Forest inventory (NFI) to extract information about woodland types, and the Environment Agency (EA) DTM and point cloud (LAZ). Following a short investigation, the EA LiDAR DTM and point cloud were preferred to the APGB DTM and DSM, due to higher spatial resolution and enhanced details in vegetation mapping. Despite the higher spatial resolution of some of the data sources, the minimum mappable unit for the final classified map was 5 sqm.

For the pilot, the broad and detailed habitat classification maps achieved accuracies ranging from 73% to 87% and 60% to 75% respectively, with Plymouth performing best, closely followed by Manchester City. One of the potential reasons for this was the time of APGB data acquisition – Plymouth was collected in June to July, which is ideal for vegetation mapping as it coincides with peak greening, while Manchester City was collected in April to May and Cambridge in early April during the leaf flushing period.

For the first trial (Greater Manchester, Tyneside and Birmingham, Black Country and Solihul) accuracies achieved ranged from 81 to 91% for Broad Habitats and 59 to 87% for

Detailed Habitats. Again, rates were affected by imagery capture dates (with early and later season dates generating lower accuracy rates) but in addition, accuracy rates Detailed Grassland classes proved to be lower than most other classes due to inherent difficulties in grassland differentiation using Earth Observation data. These difficulties are compound where data capture dates were early or late season.

The overall accuracy levels for the pilot and Phase 1 trial mapping are summarised in tables 9 and 10.

Table 9. Overall accuracy levels for Broad and Detailed Urban Habitats for the Pilot and Phase 1 Trial of the Urban Habitat Mapping. Note: some cells have been left deliberately blank

Location	Tile Date	Broad	Detailed
City of Cambridge	05/04/20	73	60
City of Plymouth	22/06/19 and 04/07/19 combined	87	75
City of Manchester	22/04/19 and 22/05/19 combined	82	60
West Midlands	30/04/2022	81	61
Tyneside	26/08/2019	91	87
	21/09/2019	85	66
	25/06/2020	91	72
	19/04/2021	84	66
Greater Manchester	22/04/2019	80	64
	22/05/2019	81	61
	23/05/2019	81	59
	30/05/2019	88	80

Location	Tile Date	Broad	Detailed
Range		73 to 91	59 to 87
Mean		84	68

Table 10. Range and mean values for accuracy levels for Broad Urban Habitat Classes and usual confusions in identification. See table 11 for full Urban Habitat Classification system used.

Urban Habitat	Range	Mean	Confusion
A – Grasslands	60 to 88	73	C, E, F, H sometimes B, D and J and K.
B – Woodlands	63 to 98	82	A, C, E and sometimes F, G, H, J
C – Rough, Abandoned and Derelict Land	10 to 84	56	A, B, E sometimes D, H, J
D – Wetlands	80 to 100	96	A, B, E, H sometimes C, F
E – Impervious and non-vegetated	55 to 88	75	A, B, C, D sometimes F, H, I
F – Private Gardens	83 to 100	86	A, B, C sometimes E,G, H
G – Formal Planting	64 to 100	90	A, B, C sometimes E, F, H
H – Parklands	85 to 95	92	B, D, E sometimes A, C, G, J
I - Coastal	84 to 85 (Small sample)	84	H

Urban Habitat	Range	Mean	Confusion
J - Agricultural	80 to 97	88	A, E sometimes C, F, H
K – Upland Habitats	80 to 85 (Small sample)	82	A, D, E, H

Classification systems.

Following development during the pilot phase and further testing during the first phase of trialling, an Urban Habitat Classification System was adopted as set out in table 11.

Table 11. The system of Broad and Detailed Habitat Classes relating the 30 Detailed Urban Habitat Classes to the 11 Broad classes.

Broad Key	Broad Class Name	Detailed Key	Detailed Class Name
A	Grasslands	A1	Amenity Grasslands
A	Grasslands	A2	Undifferentiated Grassland
B	Woodlands	B1	Broadleaved, Mixed and Yew Woodland
B	Woodlands	B2	Conifer-Dominated woodland
B	Woodlands	B3	Isolated and Scattered Trees.
C	Rough, Abandoned and Derelict Land	C1	Habitat Mosaics (Not currently mapped)
C	Rough, Abandoned and Derelict Land	C2	Scrubs
D	Wetlands	D1	Open Water

Broad Key	Broad Class Name	Detailed Key	Detailed Class Name
D	Wetlands	D2	Vegetated Wetlands
E	Impervious and Non-vegetated	E1	Sealed Surfaces and Buildings
E	Impervious and Non-vegetated	E2	Vegetated Building Structures and Green Roofs
E	Impervious and Non-vegetated	E3	Bareground
F	Private Gardens	F1	Non-vegetated Gardens
F	Private Gardens	F2	Vegetated Gardens
F	Private Gardens	F3	Garden Trees
F	Private Gardens	F4	Garden Scrubs
G	Formal Planting	G2	Allotments
H	Parklands	H1	Parkland Amenity Grassland
H	Parklands	H2	Parkland Undifferentiated Grassland
H	Parklands	H3	Parkland Wood Pasture
H	Parklands	H4	Parkland Scrubs
I	Coastal	I1	Coastal Sand
I	Coastal	I2	Coastal Dunes

Broad Key	Broad Class Name	Detailed Key	Detailed Class Name
I	Coastal	I3	Coastal Shingle, Loose and Bare Rocks
I	Coastal	I4	Coastal Mud
I	Coastal	I5	Coastal Saltmarsh
I	Coastal	I6	Coastal Cliffs and Slopes
J	Agricultural Land	J1	Vegetated Fields
J	Agricultural Land	J2	Ploughed Fields
K	Upland Habitats	K1	Upland Habitats

Use of Green Infrastructure Contexts.

Urban Habitat Maps are generated with a minimum mappable unit of 5 square metres. All the urban area is mapped (including buildings and manmade surfaces) and the mapping specifically separates and highlights habitat classes that occur within two key contexts of specific interest – Private Gardens Space and Parklands (predominantly Accessible Green Infrastructure spaces). For both Gardens and Parklands, habitats involving grassland, scrubs and trees are mapped as specific Detailed Habitats.

Urban Habitat Classification detailed overall process.

The urban habitat classification was carried out using "Trimble eCognition 10.2". This is a commercial software which provides advanced image segmentation tools to perform Object-Based Image Analysis (OBIA), as opposed to pixel-based analysis. OBIA relies on grouping pixels of similar spectral responses together into objects and allows the user to extract object features that could not be acquired using pixel-based techniques alone. These object features include spectral statistics, geometry, texture and context (relations to neighbouring, sub or super-objects in a hierarchical classification system). "eCognition" also allows pre-defined workflows (also called rulesets) to be applied to "scenes" in a batch process, making it an ideal candidate for large scale analysis. The datasets prepared were ingested into "eCognition" using a pre-defined XML file to automatically create a project containing all relevant layers for each city of interest.

The main stages of the ruleset are as follows:

1. Land feature extraction from existing third-party vector datasets.

2. Band calculation to generate a Digital Surface Model (DSM), a Canopy Height Model (CHM), a greyscale image and spectral indices.

3. Area of Interest (AOI) delineation and image segmentation to create spectrally distinct objects.

4. Initial object classification based on landscape features rather than land use.

5. Detailed classification to combine features and their context within the GI.

6. Clean-up of the detailed classification.

7. Broad classification derived from the detailed classes.

8. Export of final maps.

9. Accuracy assessment.

Land Feature Extraction from Third-Party Vector Datasets.

Land features were extracted from existing third-party vector datasets and stored in their own temporary layers within the “eCognition” project. Such features include;

Building footprints, private gardens, paths and natural spaces from the OSMM. Parklands, waterbodies, woodlands and allotments from the GI database These are crucial in supporting the analysis, particularly to provide context (e.g. within vs outside of parks or private gardens). Building footprints also aid in the detection of green roofs, which may otherwise be confused with trees (elevated vegetation), whilst waterbodies help in picking up vegetated wetlands, which may be confused with other low-lying vegetated areas.

Band Calculation.

Digital Surface Model (DSM) and Canopy Height Model (CHM). A Digital Surface Model (DSM) was created by rasterising the EA LiDAR point cloud with a kernel size of 3. The original point cloud density (before rasterisation) was 1 point density per sqm (1ppsqm) on average. This means that the actual “spatial resolution” of the LIDAR DSM could be assumed to be about 1m.

This number is not exact as point cloud density varies across the scan. During rasterisation, some pixels may contain higher point density than 1, and other pixels may have no data values. Linear interpolation was used in these instances.

This ensured sufficient detail was retained, whilst reducing the size of gaps. Linear interpolation was then carried out to fill the gaps in the DSM, but a waterbody mask was used to prevent artefacts over water surfaces. During analysis, all input datasets were resampled to 50 cm pixel size, which corresponds to the APGB CIR spatial resolution. As a result, the LiDAR point cloud was also rasterised to 50 cm pixel size.

Once the DSM was finalised, a Canopy Height Model (CHM) was calculated by subtracting the Digital Terrain Model (DTM) from the DSM. The spatial resolution of the DTM was 1m per pixel, but it was resampled to 50 cm pixel size during analysis. Similarly, the pixel size of the resulting CHM was 50cm, but the actual spatial resolution is closer to 1m per pixel.

Greyscale Image. The RGB imagery was used to calculate a greyscale image using varying band weights: Greyscale = 0.299 Red + 0.592 Green + 0.114 Blue.

Spectral Indices. The RGB and Colour Infrared (CIR) aerial datasets provided 6 bands from which to generate a series of spectral indices. However, two of these bands were duplicates (Red and Green). Table 12 shows the spectral indices calculated.

When choosing bands to calculate an index, bands from the same source dataset were used. E.g., for NDVI, only bands from the CIR dataset were used. For GRVI, only bands from the RGB dataset were used. This was to reduce potential artefacts from combining data sources with different spatial resolution together when creating these indices.

Spectral ranges for the APGB RGB were not available but ranges for the CIR were as follows.

NIRF18A (Near Infrared – NIR) Spectral range 690 to 1000 nm.

REDF14A (Red) Spectral range 580 to 700 nm.

GRNF16A (Green) Spectral range 480 to 630 nm.

Table 12. Table setting out the Spectral Indices used in Urban Habitat Mapping.

Spectral Index.	Acronym.	Calculation.
Green-Red Vegetation Index.	GRVI	(RGB Green – RGB Red) / (RGB Green + RGB Red)
Normalised Difference Soil Index.	NDSI	(Blue – RGB Red) / (Blue + RGB Red)
Normalised Difference Vegetation Index.	NDVI	(NIR – CIR Red) / (NIR + CIR Red)

Spectral Index.	Acronym.	Calculation.
Normalised Difference Water Index.	NDWI	(NIR – CIR Green) / (NIR + CIR Green)
Soil-Adjusted Vegetation Index.	SAVI	1.5 * (NIR – CIR Red) / (NIR + CIR Red + 0.5)

Area of Interest (AOI) Delineation & Image Segmentation.

The target areas Area of Interest (AOI) boundary was first used to delineate the analysis. Multi-resolution segmentation was then applied to the AOI using the CIR Red, CIR Green, NIR and CHM layers and a scale of 10. A higher weight was given to the NIR band. The segmentation was constrained to allotments, parks, waterbodies, building footprints, private gardens and paths to avoid objects overlapping two different contextual features.

Initial Object Classification.

The initial classification was focused on features of the landscapes, regardless of land use, such as; water, buildings, other impervious surfaces, bare ground, trees, scrubs and low-lying vegetation. All objects were classified using a threshold-based approach and a combination of spectral features, relational features, height, geometry and third-party data information. Shadows were quite extensive in the imagery and were also separated at this stage using brightness values. Brightness is automatically calculated in eCognition using all available input layers. However, these values are not normalised and can drastically change from scene to scene.

The thresholds were obtained through trial and error and thoroughly tested during the trial.

Table 13 shows the different features of the landscape in order of classification, as well as the data source and conditions used to separate them for Cambridge specifically. A summary of differing threshold values for both Cambridge and Plymouth is given in Table 13. This approach was essentially adopted for all further Urban Habitat Mapping.

Table 13. Summary of initial object classification focusing on features of the landscape rather than land use (where source information is not required, cells in the table are left blank).

Feature	Source	Condition
Shadow	Spectral	All objects with mean brightness values less than 60.
Water	GI	All objects (including shadows) that overlap GI waterbodies.
Buildings	OSMM	Remaining objects (including shadows) that overlap building footprints.
Impervious	OSMM, GI, Spectral	Remaining objects that either (1) overlap paths and parks, (2) overlap natural spaces by less than 15% and have mean NDVI and NDSI values smaller than 0.3 and 0.1 respectively, (3) overlap natural spaces by smaller than 15% and have a mean NDVI value smaller than 0.1, (4) overlap natural spaces by more than 15% and have mean NDVI and NDSI values smaller than 0.2 and 0 respectively.
Bareground	GI, Spectral	Remaining objects with mean SAVI value smaller than 0.2. Impervious objects that overlap allotments and have a mean SAVI value smaller than 0.3.

Feature	Source	Condition
Trees	Height, Spectral, Relational, OSMM	Remaining objects (including shadows) with a mean CHM value more than 2m. Water objects with a mean CHM value greater than 2m and neighbouring another tree object (allows some tree growth over water areas). Impervious objects that overlap paths and have mean CHM and NDVI values greater than 2m and 0.3 respectively (Allows tree growth over paths). Building objects with mean brightness and NDVI values greater than 70 and 0.2 respectively and a mean CHM difference with other building objects greater than 0 and neighbouring another tree object (Allows tree growth over buildings). Tree objects with a mean NDVI value smaller than 0.2 and a mean CHM difference with other building objects smaller than 0 and neighbouring another building object (Removes false positives along building edges). Remaining building objects that share 100% of their

Feature	Source	Condition
		border with trees and have a mean NDVI value greater than 0.25 (Fills holes in trees overhanging buildings).
Scrubs	Height, Relational, Geometry	Remaining objects with a mean CHM value between 1m and 2m. Water objects with a mean CHM value between 1m and 2m and neighbouring another scrub object (Allows scrubs over water). Remaining objects (including water) with a mean CHM value greater than 0.5 and neighbouring another scrub object. Remaining objects with a mean CHM value greater than 0.5 and a roundness smaller than 0.3 (Helps to locate isolated scrubs).
Coastal	Spectral, relational	Remaining objects (including bareground) that are within 20 of tidal waters and have mean values for SAVI, NDVI and greyscale of -0.1, -0.1 and 100 respectively.
Low Vegetation	-	All remaining objects.

Detailed Classification.

The detailed classification built on the initial object classification but added context, most often by looking for the presence of certain GI or OSMM features and adjusting the classes accordingly. For example, a tree object found within a private garden would be labelled as a garden tree (F3), but one found in a park would be labelled as park wood pasture (H3) and one found on a street would be labelled as an isolated/scattered tree (B3). Thresholds in combination with spectral features, relational features, geometry and third-party data were used, with the exception of grassland classification, which relied on training a machine learning model.

Table 14 summarises the detailed classes in order of classification, as well as the data source and conditions used to separate them. This stage is mostly contextual, and so requires very little adjustments for other cities as long as the initial classification is refined and accurate.

Table 14. Summary of detailed classification in order of classification in the Urban Habitat Mapping assessment process (where source information is not required, cells in the table are left blank).

Class	Source	Condition
Conifer Woodland (B2)	Geometry, NFI	Merged tree objects larger than 0.5 ha and that overlap NFI conifers.
Mixed Broadleaved Woodland (B1)	Geometry	Remaining merged tree objects larger than 0.5 ha
Isolated and Scattered Trees (B3)	Geometry	Remaining merged tree objects.
Garden Trees (F3)	OSMM	Isolated/Scattered Trees (B3) that overlap private gardens.
Parklands Wood Pasture (H3)	OSMM	Remaining isolated/Scattered Trees (B3) that overlap parks.

Class	Source	Condition
Non-vegetated Gardens (F1)	OSMM	Bareground and Impervious objects that overlap private gardens.
Vegetated Gardens (F2)	OSMM	Low Vegetation objects that overlap private gardens.
Garden Scrubs (F4)	OSMM	Scrub objects that overlap private gardens.
Parkland Scrubs (H4)	GI	Remaining scrub objects that overlap parks.
Scrubs (C2)	-	Remaining scrub objects.
Green Roofs (E2)	Spectral	Building objects that have mean NDVI and NDSI and brightness values greater than 0.2 and 0.05 and 70 respectively.
Sealed Surfaces and Buildings (E1)	-	Remaining building and impervious objects.
Bareground (E3)	-	All bareground objects.
Coastal Sand (I1)	Spectral	Coastal objects that have a mean GRVI value of - 0.03.
Coastal Shingle, Loose and Bare Rocks (I3)	Spectral	Remaining coastal objects that have a mean GRVI value between -0.3 and 0.
Vegetated Wetlands (D2)	Spectral	Water objects that have mean NDVI and NDSI values greater than 0.2 and 0.05 respectively.

Class	Source	Condition
Open Water (D1)	-	Remaining water objects.
Allotments (G2)	GI	All objects (including shadows but excluding woodlands) that overlap allotments.

Agricultural Land and Upland Habitats were added as contextual classes outside of the Built-Up Areas during the first trial project.

Machine Learning for Grassland Classification.

Amenity grasslands are heavily maintained – they are kept relatively short and tend to be species poor, resulting in a homogeneous landscape. In contrast, undifferentiated grasslands often contain a mix of species of different heights and spectral signatures. In an attempt to separate the two habitat classes based on their homogeneity, Grey Level Co-occurrence Matrix (GLCM) texture layers were generated using the greyscale image and the CHM for low-lying vegetated areas derived from the initial object classification:

- Greyscale and CHM contrast layers – higher values indicate higher contrast between neighbouring pixels in the object.
- Greyscale and CHM entropy layers – higher values indicate lower orderliness and a higher level of randomness in the object.
- Greyscale correlation layer – higher values indicate that neighbouring pixels in the object have predictable and linear relationships between them.

Amenity and undifferentiated grasslands have proved difficult to separate using thresholds alone. As a results, a Random Forest machine learning model was trained using the samples collected during the desk-based survey. The samples were first simplified to combine all grasslands of the same type together, whether outside or within parks (H1 combined with A1 and H2 combined with A2), thus increasing the pool of data. The samples for each grassland type were then split in half in a random manner, with 50% used in training the model, and the remaining 50% reserved to generate a confusion matrix and assess the accuracy of the model.

The mean object features fed into the model were as follows:

- Spectral bands: RGB Red, RGB Green, Blue, CIR Red, CIR Green, NIR
- Spectral indices: GRVI, NDSI, NDVI, NDWI, SAVI
- LiDAR: CHM

- GLCM textures: CHM contrast, CHM entropy, greyscale contrast, greyscale correlation, greyscale entropy

RGB and CIR spectral bands were used because spectral information about the APGB RGB dataset was lacking. Because of this, it couldn't be assumed that the bands were exactly the same. In addition, the original datasets have different spatial resolutions, yielding different average pixel values when resampling. As a result, all bands were retained for mapping grasslands using Machine Learning (Random Forest). This allowed for testing of the usefulness of each.

The features of greatest importance in the model related to the CHM which provides height and structural information. The overall accuracy for grassland classification in Cambridge consistently exceeded 75%. Amenity and undifferentiated grasslands within parks (as defined in section 2.2) were then converted to the correct detailed class (H1 or H2).

Clean-Up.

This stage aims to clean-up and simplify the outputs before the final broad classification. All neighbouring objects of the same detailed class are first merged together. Shadows and objects smaller than 5 sqm are then combined with neighbouring objects based on spectral similarity.

Broad Classification.

The broad classification is performed on a hierarchical level above the detailed classification, allowing broad classes to be inherited directly from the detailed level below. For example, if an object is classified as a garden tree (F3) on the detailed level, it automatically inherits the private garden (F) class at the broad level. All neighbouring objects of the same broad class are then merged together to create larger parcels.

Accuracy assessments.

For the pilot project, accuracy checks included some field verification. However, one of the objectives of the first phase of trialling was to amend the process so that it can be run for large scale whole city regions. Accuracy assessment was restricted to desk-based assessment performed directly on the final maps, rather than through digitisation prior to classification. "eCognition" objects for each urban habitat class at both detailed and broad levels were assessed using stratified sampling. If the assessor disagreed with the assigned class, a corrective class was suggested. This process was done on a selected sample of map output tiles. Confusion matrices were then generated to assess the Producer Accuracy (PA) and User Accuracy (UA) of each class, as well as the Overall Accuracy (OA) for each tile.

As a result of the inherent identification confusions resulting in variable accuracy levels, the resultant Urban Habitat Maps must be considered as “probability maps”.

An example Confusion Matrix is given below. Actual accuracy rates vary by habitat class and date tile for the aerial imagery so that a confusion matrix has to be generated for each date tile. Accuracy can also be affected by date mismatches between the Aerial tiles and the LiDAR data. This matrix in table 15 is purely illustrative of the approach for the Broad Habitat Class system.

The table shows where classification samples agree between initial output (producer) and accuracy check (user) and where they do not, and which habitat class confusions have occurred.

An overall accuracy is also calculated.

Table 15. Accuracy Assessment Confusion Matrix detailing accuracy rates for each habitat class, incidence, and type of confusion with other classes and an overall Aerial data tile accuracy. For example, in this illustrative case, Habitat Class A (Grasslands) had 28 samples with 3 having confusions with Scrubs and agricultural land. This gave producer accuracy of 89% and User Accuracy of 63%. The overall tile accuracy (calculated across all classes) was 91%.

Classification	A	B	C	D	E	F	G	H	J
A	25	0	1	0	11	1	0	0	2
B	0	42	1	0	1	0	0	0	0
C	2	0	15	0	2	0	0	1	0
D	0	0	0	26	0	0	0	0	0
E	0	0	0	0	52	0	0	1	4
F	0	0	0	0	0	78	0	0	0
G	0	0	0	0	0	0	20	0	0
H	0	0	0	0	6	1	0	71	0
J	1	0	0	0	0	0	0	0	30
Total samples	**28**	**42**	**17**	**26**	**72**	**80**	**20**	**73**	**36**
Producer accuracy	**89**	**100**	**88**	**100**	**90**	**100**	**100**	**90**	**97**
User accuracy	**63**	**95**	**75**	**100**	**90**	**100**	**100**	**90**	**96**
Overall accuracy.	**91**								

Summary tables for definitions and thresholds.

Table 16. Summary table setting out the definitions and any thresholds used to identify Broad Class Urban Habitats.

Broad Urban Habitat Class	Identification and thresholds
Grassland	Spectral thresholds, vegetation below 1M.
Woodlands	Spectral thresholds, brightness and CHM <2M.
Rough, Abandoned and Derelict Land	Currently limited to "Scrubs". CHM 1 to 2 m. Roundness < 0.5 m.
Wetlands	Green Infrastructure Database – Blue Infrastructure Network.
Impervious and non-vegetated surfaces.	OSMM Buildings and sealed surfaces and spectral thresholds.
Private Gardens	OSMM
Formal Planting	OSMM Allotments.
Parklands	OSMM / Green Infrastructure data - the following GI assets were considered as Parklands. Access Land (CRoW), Activity Spaces Provision, Cemeteries and Religious Grounds, Golf Courses, Other Sports Facilities, Play Space Provision, Playing Fields, Country Parks, General Public Parks, Millennium or Doorstep Greens.
Coastal	OSMM and PHI.
Agricultural Land	Agricultural land outside Built Up Areas.
Upland Habitats	All areas above the Moorland Line – undifferentiated.

Table 17. Summary table setting out the definitions and any thresholds used to identify Detailed Urban Habitat Classes.

Detailed Urban Habitat Classes.	Identification and thresholds.
Amenity Grassland.	Grasslands detected via machine learning (random samples 50:50 split) as Amenity.
Undifferentiated Grassland.	Grasslands detected via machine learning (random samples 50:50 split) as Undifferentiated.
Broadleaved, mixed and Yew Woodlands.	NFI broadleaved woodland <2M and greater than 0.5 ha not overlapping Parklands or Gardens.
Conifer Dominated Woodlands.	NFI conifer dominated <2M and greater than 0.5 ha not overlapping Parklands or Gardens.
Isolated and Scattered Trees.	Greater than 2M not overlapping Parklands or Gardens.
Habitat Mosaics.	Not identified in current method.
Scrubs.	All vegetation between 1 and 2M outside Parklands and Gardens.
Open Water.	Green Infrastructure BI Network data.
Vegetated Wetlands.	Open water with spectral signature for vegetation and PHI data.
Sealed surfaces and buildings.	OSMM and spectral thresholds.
Vegetated building surfaces and Green Roofs.	Buildings above required spectral threshold for vegetation.
Bareground.	Spectral thresholds outside Allotments.

Detailed Urban Habitat Classes.	Identification and thresholds.
Non-vegetated Gardens.	Sealed surface and bare ground within gardens.
Vegetated Gardens.	Vegetation below 1M in Gardens.
Garden Trees.	Greater than 2M and overlapping Gardens.
Garden Scrubs.	Vegetation between 1 and 2 M in a garden (Cannot differentiate Scrub, from Shrub from Hedge from scattered bush).
Allotments.	Vegetation below 1M and Bareground within Allotments (derived from GI Mapping and OSMM).
Parkland Amenity Grasslands.	Grasslands detected via machine learning (random samples 50:50 split) as Amenity and in Parklands.
Parkland Undifferentiated Grassland.	Grasslands detected via machine learning (random samples 50:50 split) as Undifferentiated and within Parklands.
Parkland Wood Pasture.	Greater than 2M, Smaller than 0.5 Ha and overlapping parklands.
Parkland Scrubs.	Vegetation between 1 and 2M within Parklands.
Coastal Habitats.	OSMM and PHI data.
Vegetated Fields.	Areas of low vegetation (below 1 m) outside Built Up Areas that overlap “Agricultural land” class in OSMM.
Ploughed Fields.	Bareground outside of Built Up Areas that overlap “Agricultural land” class in OSMM.

Detailed Urban Habitat Classes.	Identification and thresholds.
Upland Habitats.	All areas above the Moorland Land – undifferentiated.

Overall lessons to date.

The Urban Habitat and Naturalness Mapping project has demonstrated that city-wide habitat mapping at a 5 sqm scale using airborne true-colour and colour infra-red imagery is achievable for a selection of classes at the broad and detailed level.

Most of the methodology described in this report relied on thresholds rather than machine learning, which reduced the need for training samples. It was noted, however, that those thresholds should be adjusted for different environmental and seasonal conditions. Whilst most habitat classes could be spectrally separated in a reliable manner, some proved more challenging, such as amenity and undifferentiated grasslands, as well as coastal habitats. Some other classes, particularly at the detailed level, required additional contextual information obtained from other datasets (e.g. private garden boundaries or green roofs or PHI).

Habitat Mosaics (land parcels with an intricate mix of habitats and often complex biodiversity that can sometimes be associated with land that has been left alone after previous development) are significant elements of the urban ecosystem and their identification was part of the original effort to create a method for Urban Habitat Mapping. They have proved difficult to map and it was decided to suspend their incorporation into the habitat schema with their constituent habitats being mapped separately. However, with further definitional development and refined method, it is hoped they can be incorporated into future iterations of the mapping.

Naturalness Mapping.

Naturalness Factor Classification System.

The approach to mapping Naturalness is still in development and maps for V 2.1 have not been developed. The approach as it currently stands (with some sample outputs) is included here for information.

A new approach to Naturalness mapping is being developed to compliment the Urban Habitat Maps with spatial information on the degree and level of management intensity that individual Urban Habitats are likely to be subject to.

Naturalness is intended to provide a basic measure of “quality” and is based on a 6-factor system with Factor 1 representing “least apparent level of management intensity (most “natural”) and 6 representing the “highest apparent level of management intensity (least “natural”).

Naturalness in this content is not intended to infer anything about “natural ecosystem function” and is purely an attempt to understand “naturalness” from an aesthetic perspective.

The “Naturalness Factors” from 1 to 6 have been assigned to each of the Urban Habitat Detailed Classes. This system is still developmental and may change based on future feedback.

The naturalness data can be used to understand the distribution of “naturalness” character across an entire city area. The naturalness data may also be used on a land parcel basis through the calculation of a “Combined Naturalness Score” based on the mix of Urban Habitat Classes within a given polygon and the proportion of the polygon area covered by each respective class.

The current attribution of Naturalness Factor to Urban Habitat Class is set out in Table 18.

Table 18. Assignment of Naturalness Factor to Detailed Urban Habitat classes.

Broad Class	Detailed Class	Naturalness Factor
Coastal	Sand, dunes, shingle, loose and bare rock and Saltmarsh	1
Woodlands	Broadleaved, Mixed and Yew Woodlands	1
Wetlands	Vegetated Wetlands	1
Woodlands	Conifer-dominated Woodlands	2
Coastal	Mud	2
Rough, Abandoned and Derelict Land	Habitat Mosaics	2
Private Gardens	Garden Scrubs	3

Broad Class	Detailed Class	Naturalness Factor
Private Gardens	Garden Trees	3
Wetlands	Open Water	3
Parklands	Parkland Scrubs	3
Woodlands	Isolated and Scattered Trees	3
Rough, Abandoned and Derelict Land	Scrubs	3
Formal Planting	Allotments	4
Impervious and non-vegetated	Vegetated Building Surfaces and Green Roofs	4
Parklands	Parland Undifferentiated Grassland	4
Parklands	Parkland Wood Pasture	4
Grasslands	Undifferentiated Grassland	4
Private Gardens	Vegetated Gardens	4
Grasslands	Amenity Grassland	5
Impervious and non-vegetated	Bareground	5
Parklands	Parklands Amenity Grassland	5
Private Gardens	Non-vegetated Gardens	6

Broad Class	Detailed Class	Naturalness Factor
Impervious and non-vegetated	Sealed Surfaces and Buildings	6

Combined Naturalness Factors.

Combined Naturalness Factors are designed to permit the identification of the measure of Naturalness an individual Green Infrastructure polygon has and to allow comparison of Naturalness between polygons, especially those of common typology.

This would for example permit the comparison of Naturalness as a criteria of quality assessment (aesthetic quality) between two parks or other spaces. Combined Naturalness might also be used to examine potential to improve the Naturalness of an asset as part of management planning.

The Combined Naturalness Factor is derived from a simple calculation based on the Detailed Urban Habitats within a polygon, the amount of that polygon covered by each habitat type multiplied by their respective Naturalness Factors.

For example, a parkland parcel from the Green Infrastructure database containing 30% deciduous woodlands, 50% undifferentiated grasslands and 20% sealed surfaces will have an N factor of:

N Factor = (0.30 x 1) + (0.50 x 2) + (0.20 x 6) = 2.5

A different parkland parcel containing 70% amenity grasslands and 30% sealed surfaces will have a much higher combined naturalness factor of 5.3 (Higher values mean lower Naturalness).

N Factor = (0.7 x 5) + (0.3 x 6) = 5.3

Higher Combined Naturalness Factors equate to lower Naturalness quality.

Example outputs.

Urban Habitat Maps.

The product is derived from the Aerial Photography for Great Britain (APGB) colour-infrared imagery to provide spectral information, and from the Environment Agency (EA) National

LiDAR Programme dataset to provide height and structural information. Object-Based Image Analysis techniques (OBIA) are used to segment the datasets into meaningful objects which are spectrally distinct. The minimum mapping unit for objects is 5 sqm. A threshold-based approach developed using spectral science is applied to each object in a hierarchical classification system. More complex classes such as grassland types are classified using Random Forest Machine Learning models, which are locally trained. The analysis is supplemented by other existing datasets (e.g., Ordnance Survey Master Map, Green Infrastructure and Blue Infrastructure database, National Forest Inventory, OS Open Built-Up Areas, Priority Habitat Inventory and Moorland Line), to provide contextual information. For example, this enables individual tree objects to be differentiated by context (e.g., street trees, private garden trees and park trees), which would not be achievable using Earth Observation alone. The product is validated using a desk-based survey methodology, where a certain number of objects in each detailed class are selected for review.

The Urban Habitat Map provides a complete urban picture, enabling gaps between known Green Infrastructure parcels to be filled. The detailed map in particular can provide information about green roofs, street trees, and private gardens for a more holistic view. This product is delivered as 5km OS grid tiles in a geodatabase (GDB) file format.

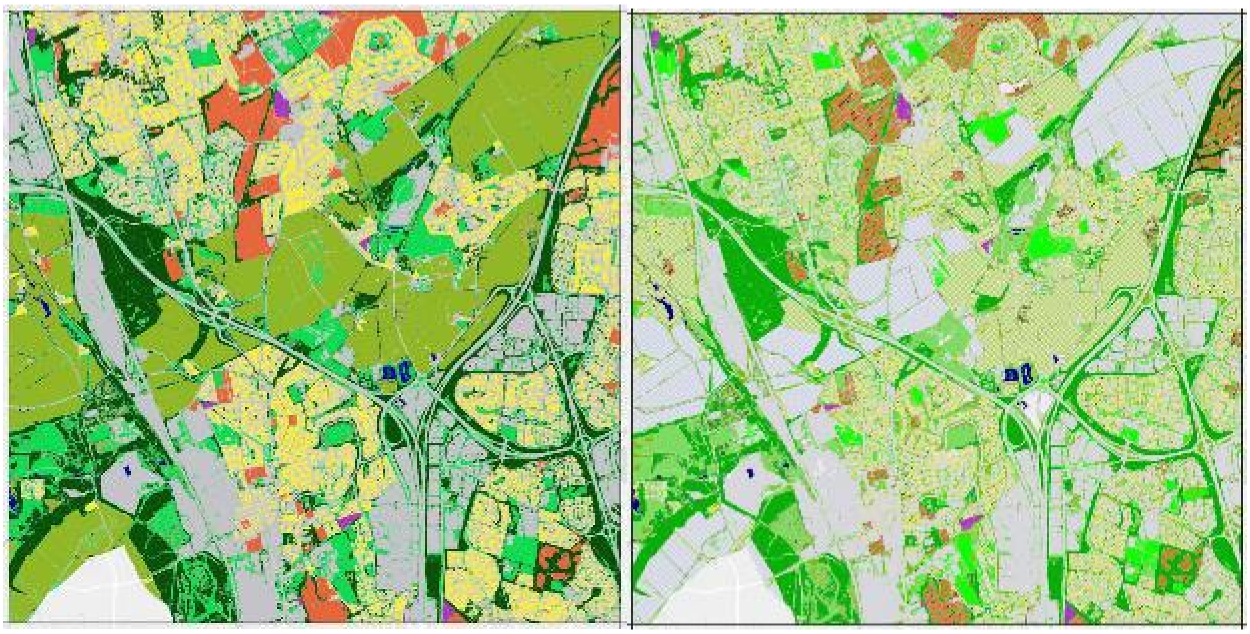

Figure 9. Sample Broad (left) and Detailed (right) Urban Habitat Maps. © Natural England 2024, reproduced with the permission of Natural England.

Sample Naturalness Map.

Aggregated Naturalness Map

The Aggregated Naturalness Map product is derived from the detailed Urban Habitat Map and provides a city-wide overview of naturalness. Each object in the Urban Habitat Map is assigned a naturalness score from 1 to 6 based on its detailed class, where 1 is the highest level of naturalness (e.g., deciduous woodlands) and 6 is the lowest (e.g., non-vegetated private gardens). All objects with the same naturalness scores (regardless of detailed class) are then aggregated over an entire city. The output can be interpreted as a heatmap of naturalness, enabling further statistical and connectivity analysis to be carried out.

Figure 10. Example Aggregated Naturalness Map showing the distribution of Naturalness Factors across the urban area. Factor 1 (darkest) has highest Naturalness and Factor 6 (lightest) has lowest Naturalness. © Natural England 2024, reproduced with the permission of Natural England.

Sample “Combined Factor Naturalness Map”.

Green Infrastructure Parcels Combined Naturalness.

The Green Infrastructure Parcels Combined Naturalness product is derived from the Aggregated Naturalness Map and the Green Infrastructure database. Each parcel in the existing database is assigned a combined naturalness factor (N factor), which is calculated from the proportion of each naturalness scores making up the parcel.

This product enables direct comparison between Green Infrastructure parcels of the same typology.

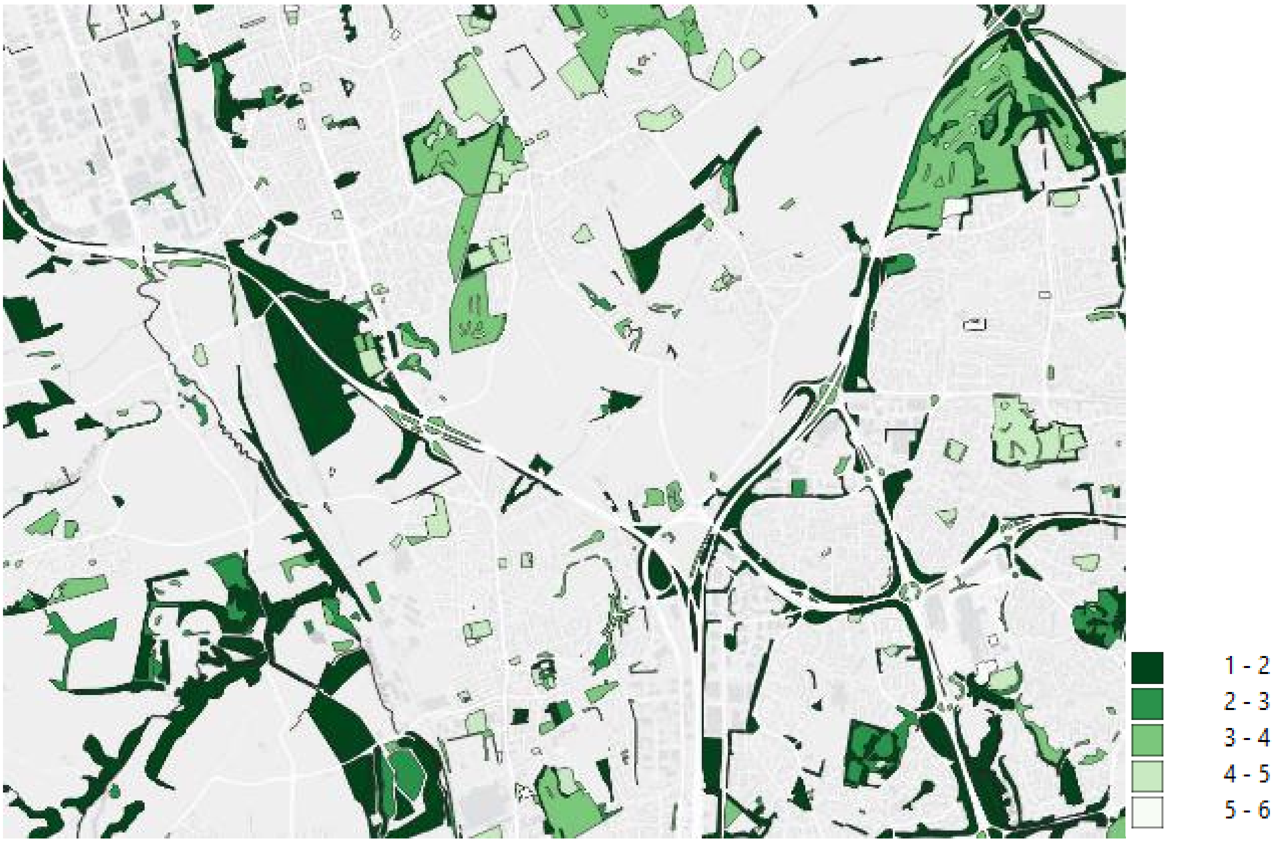

Figure 11. Combined Naturalness Factor Map showing different scores for different Green Infrastructure Typology polygons. Combined Naturalness allows the comparison of Naturalness between different polygons, especially polygons of the same typology. © Natural England 2024, reproduced with the permission of Natural England.

Section 13. Heat Management – Experimental module.

Work to develop the Heat Management module was undertaken by the University of Manchester (Lindley, S.J. and Figueroa Alfaro, R) between 2021 and 2024.

References provided are listed at the end of this section.

Whilst outputs for the module cover all England, the method is considered to be most relevant to urban areas.

Overview of the module.

July 2022 saw England's most intense heatwave ever recorded to that time with evidence of a growing trend towards more frequent high temperature events (Yule et al., 2023). Given impacts on health and wellbeing and expected future trends, increased heat exposure is considered a high magnitude risk for the UK (Arbuthnott and Hajat, 2017; HM Government, 2022).

Urban green infrastructure can help mediate temperatures to reduce the Urban Heat Island (UHI) effect due to shading and evapotranspiration and therefore green infrastructure features as a key adaptation strategy in urban areas (Bowler et al., 2010). The various components of green infrastructure each provide a different amount of cooling and there is a varying need for this cooling across England depending on geographical location and social characteristics. Social characteristics are an important consideration given their influence on the potential for harm from high temperatures. For instance, age and health can result in different heat sensitivities and factors like income and mobility affect adaptive capacity (Lindley et al., 2010).

Aim and outputs from the Urban Heat Management mapping.

The aim of this work is to develop an initial assessment of (a) the likelihood of cooling from urban green infrastructure (b) community need for cooling taking account of climate gradients and social characteristics and (c) the degree of geographical alignment between cooling provision and social need. The latter is used to make a provisional assessment of priority areas for cooling. Four datasets have been developed:

- 250m aggregation of 10m spatial resolution heat mitigation index results (HMi) – Cooling Provision
- Lower Super Output Area (LSOA) average HMi – Cooling Provision
- Lower Super Output Area (LSOA) Need for Cooling
- Priority areas as the combination of Provision and Need (LSOA)

This document sets out the methodology for creating preliminary versions of each of these datasets as a proof-of-concept exercise. The subsequent sections identify inputs, assumptions made and key limitations for onward use of the resources. It is anticipated that further improvements will be made in future iterations as higher resolution and more localised data become available.

Cooling provision by Green Infrastructure, creating the Heat Mitigation Index (HMi).

Estimates of the cooling effect of urban green infrastructure have been made using the InVEST tool (Natural Capital Project, 2023, v3.10). InVEST's urban cooling model estimates the degree of cooling provided by green infrastructure. Here, model runs were set up to represent average characteristics expected in towns and cities within an English context.

The model calculates a Cooling Capacity index for each data unit based on assumptions about the shading, evapotranspiration and albedo characteristics of different land covers. A further consideration is made of the size of vegetated areas (i.e. > 2 hectares) and their influence on surrounding areas to calculate a Heat Mitigation index (HMi). This helps to take account of the 'cool islands' associated with discrete green space parcels such as public parks and gardens. The data inputs are set out in Figure 12 and the following sections.

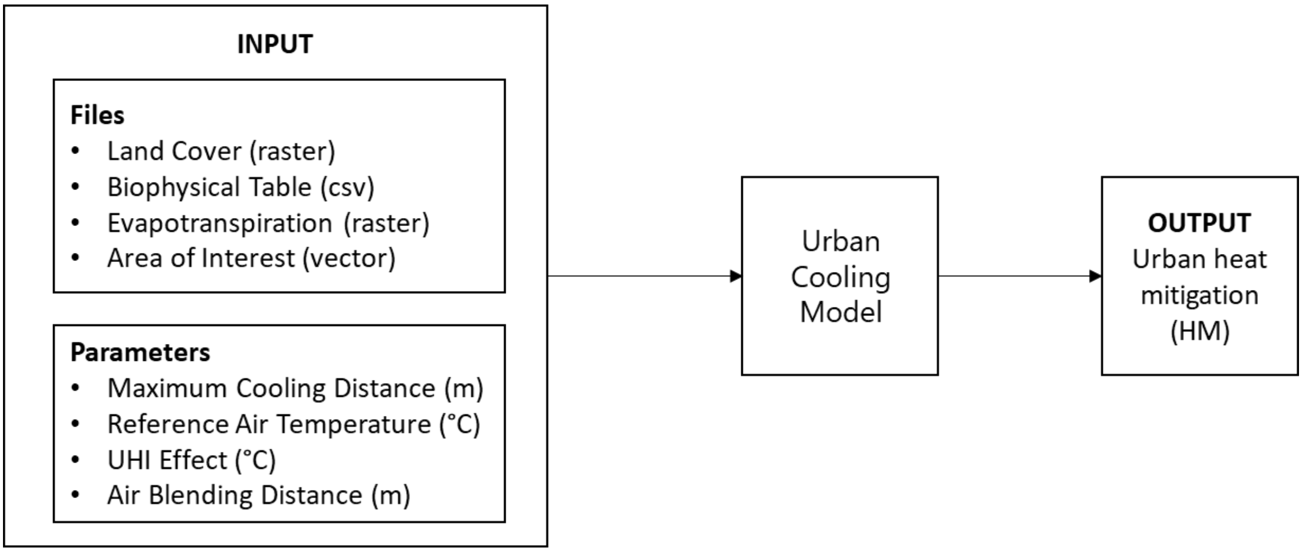

Figure 12. Data inputs required for the InVEST cooling model.

Input datasets.

Land Cover (raster).

The Centre for Ecology and Hydrology (CEH) 10m UK Land Cover Map (LCM) 2020 was used as the source of land cover data (Morton et al., 2021). A 5km buffer of the coastline was used to include coastal waters. A look-up table was developed to map the classes from LCM to the inputs required by the InVEST model (see Table 19). Of the 25 land covers covered in InVEST, 12 were used in the England case with landcovers matched according to descriptions provided in the LCM and InVEST Product documentation.

Table 19. Look up table to match LCM land cover classes with the InVEST landcover schema.

UKCEH Landcover Class	LCM Identifier	InVEST Code	InVEST Landcover Description
Broadleaved woodland	1	9	**Deciduous Forest**
Coniferous woodland	2	10	**Evergreen Forest**
Arable	3	6	**Cultivated Land**
Improved grassland	4	8	**Grassland**
Neutral grassland	5	8	**Grassland**
Calcareous grassland	6	8	**Grassland**
Acid grassland	7	8	**Grassland**
Fen	8	15	**Palustrine Emergent Wetland**
Heather	9	12	**Scrub/Shrub**
Heather grassland	10	12	**Scrub/Shrub**

UKCEH Landcover Class	LCM Identifier	InVEST Code	InVEST Landcover Description
Bog	11	15	**Palustrine Emergent Wetland**
Inland rock	12	20	**Bare Land**
Saltwater	13	21	**Water**
Freshwater	14	21	**Water**
Supralittoral rock	15	20	**Bare Land**
Supralittoral sediment	16	19	**Unconsolidated Shore**
Littoral rock	17	20	**Bare Land**
Littoral sediment	18	19	**Unconsolidated Shore**
Saltmarsh	19	18	**Estuarine Emergent Wetland**
Urban	20	2	**High intensity built-up (>80% impervious area)**
Suburban	21	3	**Medium intensity built-up (50-80%)**

Biophysical Table (csv).

The default biophysical input dataset was adapted for England (see table 20), derived from evidence in UK and European literature. Water was considered to be greenspace in order for it to be included in the model, following experimentation in Zawadzka et al., (2021). Assumptions are made according to the expected average values of 10m cells in urban areas drawing on Bosch et al., 2021, Zawadzka et al., 2021; Taha, 1997 and various sources of detailed land cover data for urban areas across England.

Values for the biophysical UHI Input table.

The biophysical data includes crop coefficient kc; green_area (true/false, 1 and 0 respectively; shade (ratio) as area covered by tree canopy >2 m high; albedo (ratio) as the solar radiation directly reflected; and building_intensity (ratio) as the ratio of building floor area to footprint area (0-1).

Table 20. Table of values used for biophysical input data for Urban Heat Island inputs.

Lucode	Description	Shade	Kc	Albedo	Green area	Building intensity
0	Background	0	0	0	0	0
1	Unclassified (Cloud, Shadow, etc)	0	0	0	0	0
2	High intensity (>80% IA)	0.05	0.37	0.25	0	0.95
3	Med intensity (50-80%)	0.2	0.75	0.19	0	0.3
4	Low intensity (20-50%)	0.33	0.75	0.19	0	0.1
5	Open space (<20%)	0.45	0.75	0.2	0	0.1
6	Cultivated Land	0.01	0.75	0.2	1	0
7	Pasture/Hay	0.02	0.75	0.2	1	0
8	Grassland	0.05	0.95	0.2	1	0
9	Deciduous Forest	0.95	0.95	0.18	1	0
10	Evergreen Forest	1	1	0.15	1	0
11	Mixed Forest	1	1	0.18	1	0
12	Scrub/Shrub	0	0.95	0.18	1	0
13	Palustrine Forested Wetland	1	1	0.1	1	0

Lucode	Description	Shade	Kc	Albedo	Green area	Building intensity
14	Palustrine Scrub/Shrub Wetland	0.05	0.68	0.1	1	0
15	Palustrine Emergent Wetland	0	0.68	0.1	1	0
16	Estuarine Forested Wetland	1	1	0.1	1	0
17	Estuarine Scrub/Shrub Wetland	0.05	0.68	0.1	1	0
18	Estuarine Emergent Wetland	0	0.68	0.1	1	0
19	Unconsolidated Shore	0	0.75	0.25	0	0
20	Bare Land	0	0.75	0.2	0	0
21	Water	0	1	0.09	1	0
22	Palustrine Aquatic Bed	0	0.75	0.06	1	0
23	Estuarine Aquatic Bed	0	0.75	0.06	1	0
24	Tundra	0	0.68	0.2	1	0
25	Snow/Ice	0	0.68	0.75	0	0

Evapotranspiration (raster).

Daily total potential evapotranspiration has been used for July at 12 km resolution derived from the UK Climate Projections 2018 Regional Climate Model ensemble 1980-2080.

Area of Interest (vector).

The area of interest is used as the basis for aggregating and summarizing the final results. Here, 14 individual zones were used based on UK Met Office climate districts (Figure 13). The zones account for climate zones across England for which average rural background values and Urban Heat Island intensities can be assessed. The original Met Office zones were further differentiated to account for topographical barriers, built up area extents (i.e. to minimise urban areas being split over different zones) and differences observed in 1km Met Office datasets (see next section). Each zone was modelled separately with a 5km buffer except the zone containing London which used a 25km buffer. The results were clipped to the original zone extent after processing. This was necessary to account for the influence of surrounding land covers on urban zones towards the edges of each area of interest. Modelled air temperature outputs were only used as a validation dataset. For this reason, they are not included in the data package.

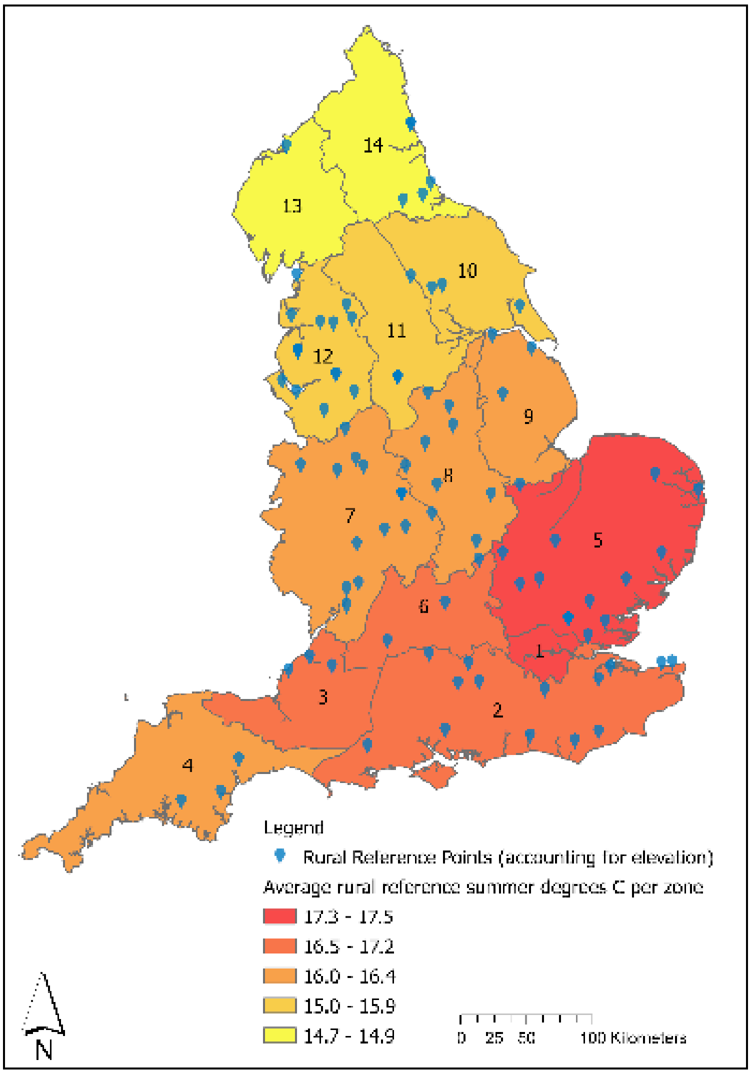

Figure 13. Fourteen climate zones for processing based on Met Office Climate Districts (inset) and with estimated Rural reference values (from 1km grids) and Urban Heat Island Intensities (based on empirical data and literature).

Zone Number	Zone Name	Average Rural Reference Temperature (ºC)	Average estimated Urban Heat Island Intensity
1	London	17.5	1.8
2	South and East	17.2	1.9
3	North South West	17.1	1.3
4	South West	16.2	1.5
5	East Anglia	17.3	1.8
6	South Midlands	17.1	1.4
7	West Midlands	16.4	2.3
8	East Midlands	16.3	1.9
9	East	16.2	1.9
10	Yorkshire and Humber	15.9	2.1
11	Mid Pennines	15.4	1.9
12	North West	15.9	1.7
13	North North West	14.9	1.

Input parameters.

Maximum Cooling Distance (m) (dcool).

This value accounts for the ‘park cooling effect’ (Bowler et al., 2010) and represents the distance over which green areas larger than 2 hectares have a cooling effect. In this case, 150m was used. The literature for cases in England suggests that validation statistics are strongest at dcool values of <=100m for air and surface temperatures (Zawadzka et al., 2021). Similar conclusions were made by Bosch et al., 2021 (referencing 89m). A slightly higher value was selected to account for higher mean parcel size across England than in the study acting as a primary reference for this work. It also takes account of the considerably larger recommended value in the InVEST product documentation guidelines (450m). The assumption of 150m was also broadly supported by evidence published for nocturnal cooling distances of typical greenspaces in London (Vaz Monterio et al., 2016).

Reference Air Temperature (°C).

Rural reference values are required to identify background temperatures where no Urban Heat Island effect is observed for the Areas of Interest. In this case the reference value was taken from the seasonal mean temperature at 1 km resolution as the average of June, July, and August (JJA) of 2021 using Met office gridded data. Given that temperatures are strongly influenced by elevation, a median value was taken from a range of rural reference points at similar elevations to larger urban areas in each Area of Interest zone (Figure 13).

Urban Heat Island (UHI) Effect (°C).

The difference between urban and rural temperatures were estimated using a combination of published sources and empirical data, including Global Surface UHI Explorer as recommended in the InVEST product guidance (Manoli et al., 2019, Chakraborty and Lee, 2019). The maximum UHI intensity for each area of interest was used, though discounting anomalously large values relative to values reported for London. This and the reference rural air temperature input was required for running the model, but not for the main HMi outputs.

Air Blending Distance (m).

A value of 500m radius was used as the area over which to average air temperatures to account for air mixing. This is within the recommended range in the InVEST product guidelines and was only required for the interim air temperature outputs.

Results and validation.

Figure 14 shows the output HMi data for the gridded datasets of 10m and 250m grid squares. The latter was standardised using z-scores to represent values relative to the English mean.

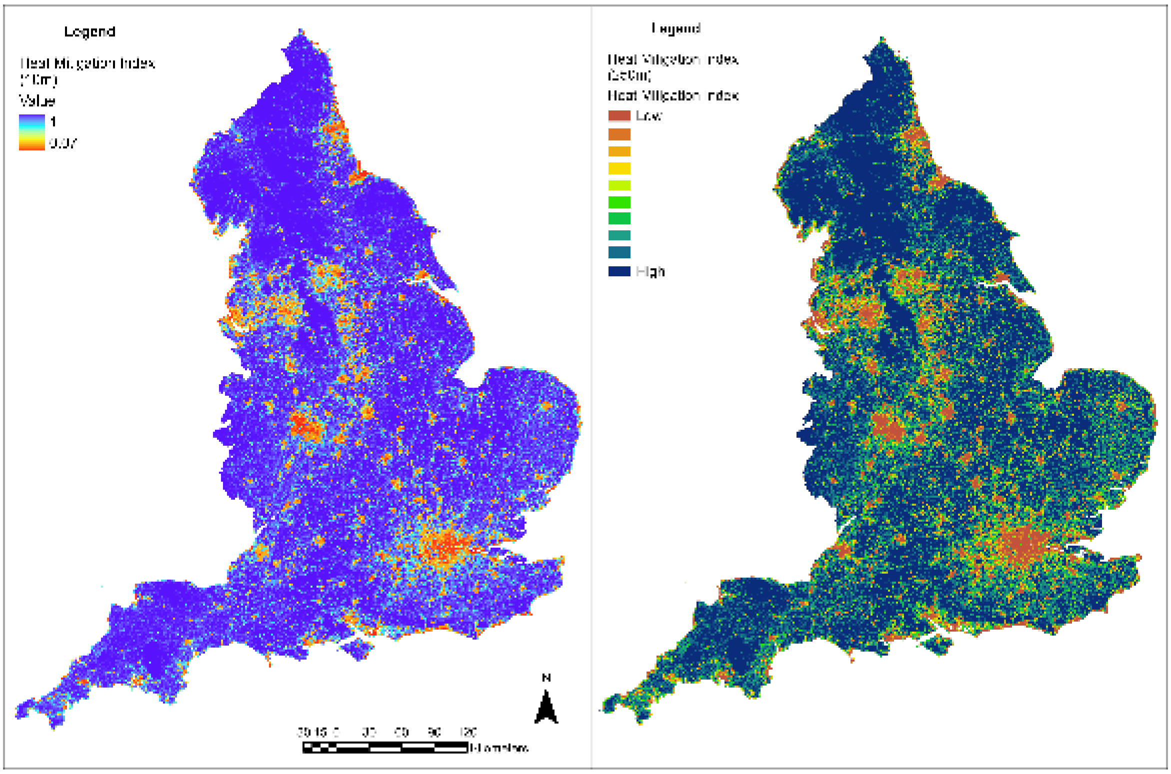

Figure 14. Provision of cooling (HMi) results for 10m grid (left) 250m grid (right) and LSOA (bottom).

Air temperature outputs were used to validate the HMi and assumptions. The model outputs at 1km were compared to the 1km Met Office average data for June, July, and August (JJA) of 2021. This comparison was considered valid as the validation data were only used as an input for the rural reference locations and not urban increments. The degree of agreement was reasonable for the Built-Up Area (BUA) extent of London (Figure 15). Although the model outputs tended to overestimate temperatures relative to the Met office data, the Met Office data may themselves underestimate the UHI effect.

Spatially, there is a trend towards InVEST modelled temperatures being overestimated compared to 1km Met office data within Built Up Areas (BUAs) in northern England compared to BUAs in the south. Conversely BUAs located towards the southern fringes of the 14 areas of interest, as well as some locations in central London tended to have modelled temperatures underestimated.

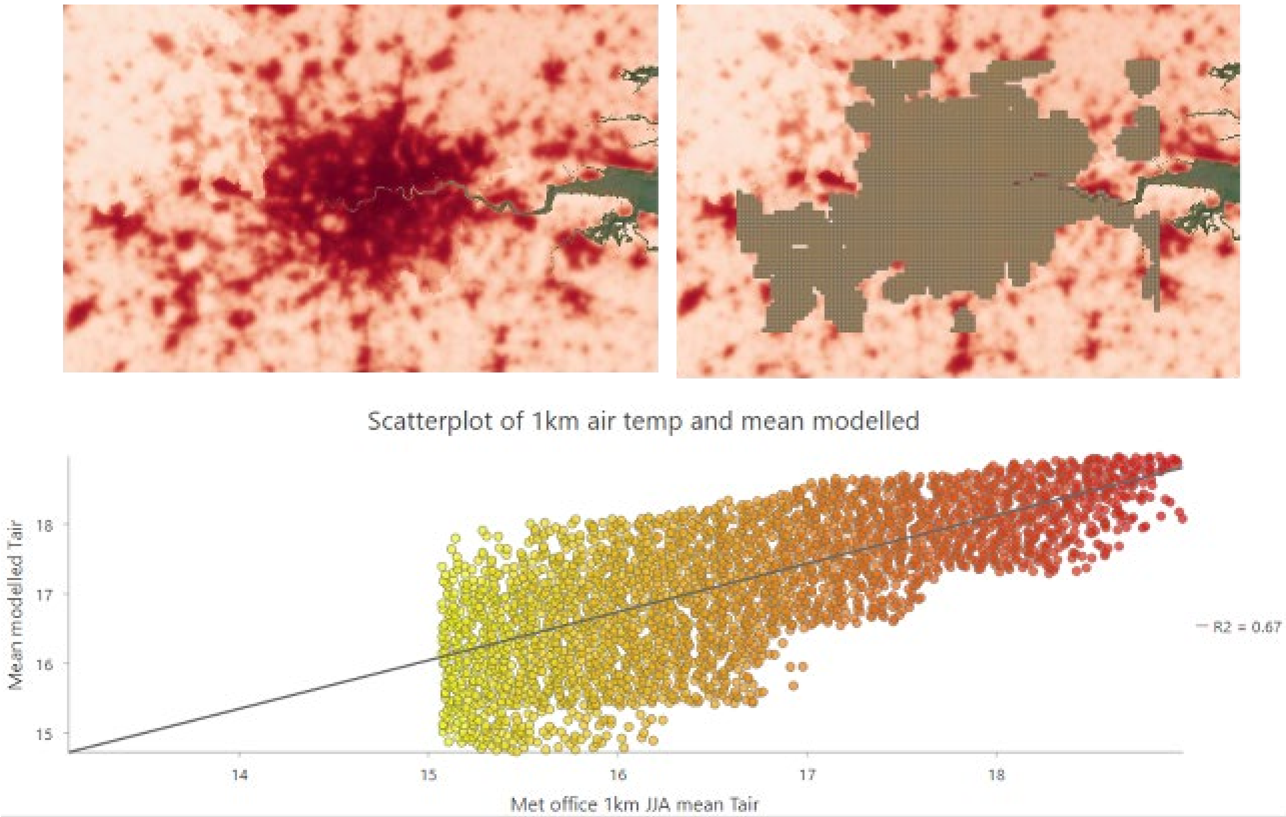

Figure 15. Basic validation of the output data for London.

Limitations.

This assessment has used average estimated values of land cover characteristics (e.g. proportions of tree cover in urban residential areas) across urban England. These will not be a reliable indicator of actual tree cover locally and considerable geographical variability in biophysical properties is expected. Given that grassland areas are estimated to have low tree cover, cooling values may be artificially low compared to the surrounding urban fabric.

The Land Cover Map 2020 data have only two intensities of built cover in urban areas, urban and sub-urban. As a result, there is less differentiation of vegetation cover within largely built-up zones than is supported by the InVEST model.

The cooling distance (dcool) parameter is interpreted very differently in the sources consulted making it uncertain. Further experimentation would be ideal to establish the impact of different dcool values on output data. These values are expected to differ according to the size of areas, the time of year and time of day.

Published values of UHI intensity are variable according to the time frames of assessment and source of input data. This remains an uncertainty in the model outputs, though it should be noted that the outputs used in the HMi do not directly use these data as they are required to run the model and for air temperature estimates only.

The InVEST model is empirically based and does not take account of feedbacks which may render the cooling from vegetation lower in reality, for instance as a result of water availability. The values pertain to summer periods but will not always represent relative cooling values during actual extreme events.

The InVEST model is primarily focussed on vegetation cooling and is less well suited for estimating the effect of cooling from water bodies.

Due to the uncertainties data are only available at 250m and LSOA level and uses of these data must take account of the caveats reported here. Aggregation to other spatial units also causes uncertainty.

There has been only a basic validation of model outputs with further data runs and validation work recommended for future versions of the data.

Need for cooling – heat disadvantage.

Existing heat disadvantage data for England were used as a measure for the need for cooling. These data take account of both social vulnerability and the temperature gradient across England and are reported at LSOA level.

The social vulnerability data were developed using a previously published methodology with updated data and minor modifications to underpinning domains to reflect emerging data and evidence in the literature (Lindley et al., 2011) (see www.climatejust.org.uk) (Note: Data were produced with funding by Friends of the Earth, following previous iterations funded by the Joseph Rowntree Foundation and Environment Agency).

Data for 16 themes (domains) (Table 21) and over 40 separate indicators were used in an additive index to show the distribution of aggregate vulnerability to heat according to population sensitivity, enhanced exposure, ability to prepare for, respond to and recover from heat-related events. Data are reported as z-scores to standardize values relative to the English mean (Figure 16).

Table 21: Domains used in the social vulnerability to heat dataset.

Domains	Description
Age	Age composition indicator (physical sensitivity to heat impacts) % older adults, % younger children.
Health	Health composite indicator (ill health increases physical sensitivity to heat impacts).
Income	Income composite indicator (reduced adaptive capacity).

Domains	Description
Tenure	Property tenure composite indicator (reduced adaptive capacity).
Language	Information use composite indicator (reduced adaptive capacity).
Internet	Access to information composite indicator (reduced adaptive capacity).
Local Knowledge	Local knowledge composite indicator (reduced adaptive capacity).
Social Networks	Social networks composite indicator (reduced adaptive capacity).
Mobility	Mobility composite indicator (reduced adaptive capacity).
Crime	Crime composite indicator (reduced adaptive capacity).
General infrastructure	Infrastructural condition indicator (reduced adaptive capacity).
GP Access	Access to GP indicator (reduced adaptive capacity – ability to recover).
Hospital Access	Access to hospital indicator (reduced adaptive capacity – ability to recover).
Pharmacy Access	Access to pharmacy indicator (reduced adaptive capacity – ability to recover).
Physical Environment	Physical environment composite indicator (How much the local environment increase / decreases temperatures).
Housing Characteristics	Housing characteristics composite indicator (how much housing increases / decreases heat).

Heat disadvantage was estimated by combining social vulnerability data with a measure of heat hazard-exposure. In this case, the estimate of hazard-exposure used UKCP18 model outputs for the top 5% hottest summer day (standardised using z-scores) under a 3 degree C warming scenario relative to means in the recent past (the 30 year mean 1990-2019) (Kennedy-Asser et al., 2022) (Figure 16).

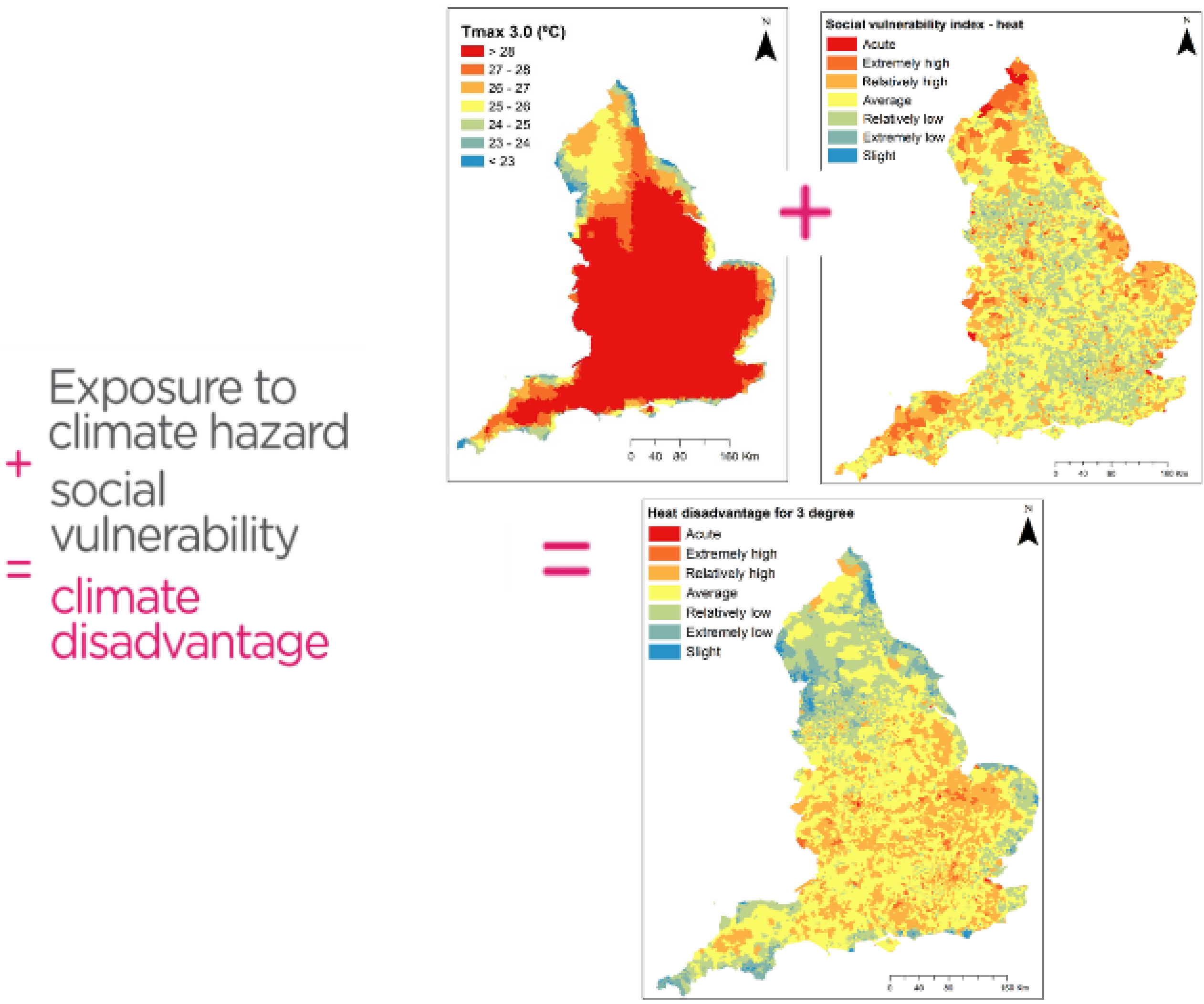

Figure 16. Heat disadvantage data for England (bottom centre) created using a measure of high temperatures (top left) and social vulnerability to heat (top right).

Indicative identification of areas of "Need for cooling".

An indicative first draft England-wide assessment of areas potentially most in need for cooling was created by combining standardised z-scores for cooling provision and the need for cooling.

Users of the data should be aware of the limitations associated with inputs as outlined above. It should also be noted that areas which have undergone considerable development or development since 2020, will not be shown accurately. Furthermore, the aggregation of HMi values to Census units sometimes averages the cooling influence of green spaces over multiple LSOAs reducing the apparent impact of individual spaces.

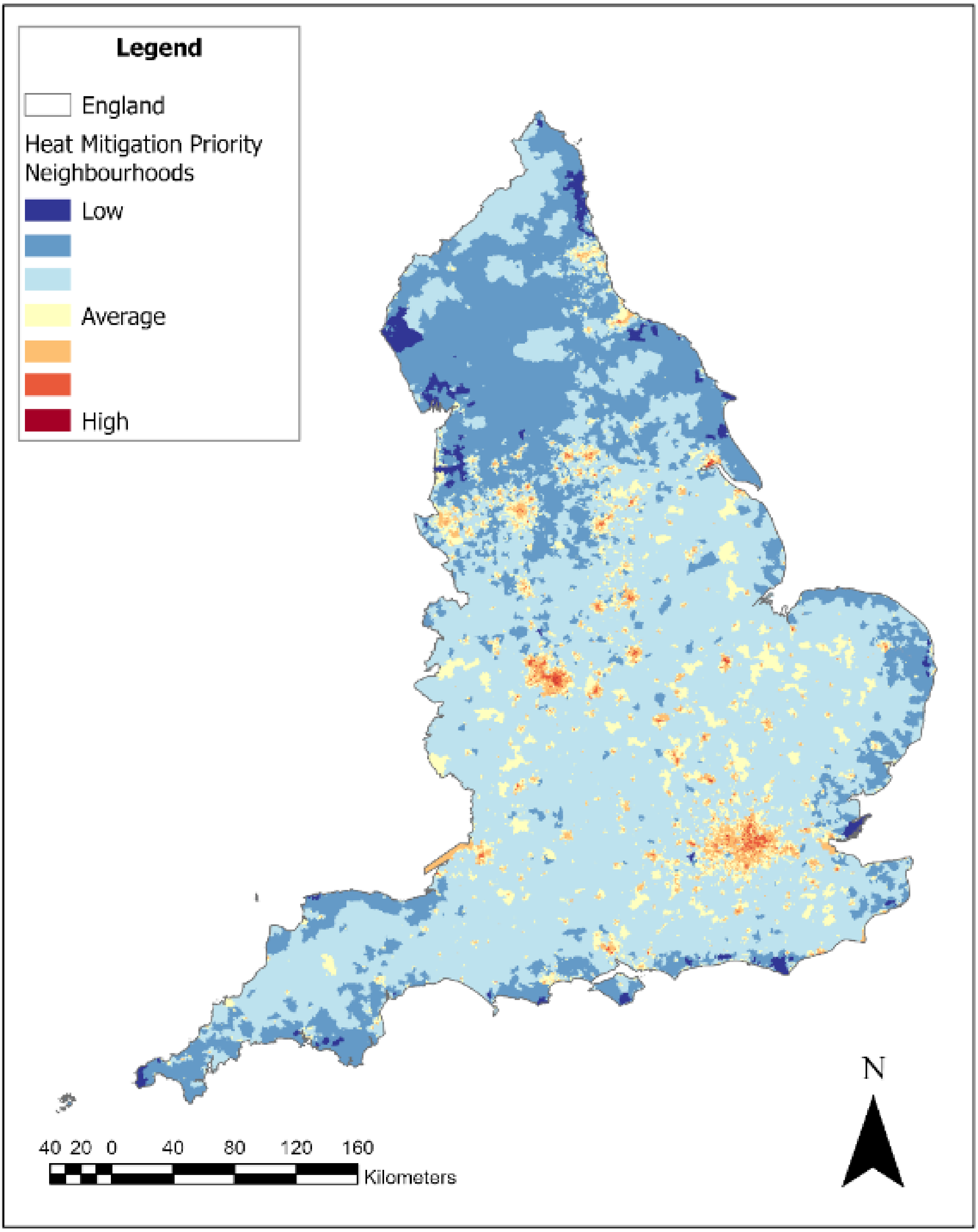

Figure 17. Indicative Heat mitigation priority neighbourhoods. A first iteration and indicative map of LSOA which on the basis of this assessment may be assigned lower to higher need for cooling.

Reference sources for the Heat Management Module.

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Section 14. Urban Air Quality and Green Infrastructure – Experimental module.

Provision of and need for PM2.5 removal: Greater Manchester Test Case.

The work to develop this module was undertaken by the University of Manchester Dr Lindley, S.J.

References provided for this module are listed at the end of the section.

Introduction.

Despite falling emissions of primary pollutants, poor air quality remains a significant health challenge across England, and especially in its urban areas. There are multiple air pollutants which cause health impacts, but fine particulate matter is considered a key pollutant of concern. For example, England's NHS and social care costs attributable to $PM_{2.5}$ alone is estimated to have been at least £41.2 million in 2017 (Public Health England, 2018).

Emission controls remain the primary lever for improving air quality. Nevertheless, the role of vegetation for pollution removal is not insignificant. $PM_{2.5}$ removal by vegetation, especially trees, across the UK is estimated to have led to 26,000 fewer life years lost in 2015 and a saving of around £910 million (2012 prices) in avoided health damage costs (Jones et al, 2017). In urban areas, vegetation-air quality relationships are complex, for example depending on species and positioning relative to emissions sources. Even so, the aggregate effect is an overwhelmingly positive one, not least considering the range of other environmental and social benefits attributed to vegetation.

Aim and Outputs.

The aim of this work was to develop an initial assessment of (a) the likelihood of $PM_{2.5}$ from urban green infrastructure (b) community need for $PM_{2.5}$ removal taking account of $PM_{2.5}$ concentration gradients and health characteristics (Years of Life Lost) and (c) the degree of geographical alignment between pollutant removal provision and social need.

The latter is used to make a provisional assessment of priority areas for potential further consideration.

Three datasets have been developed:

- Lower Super Output Area (LSOA) average provision of $PM_{2.5}$ removal.
- Lower Super Output Area (LSOA) Need for $PM_{2.5}$ removal.

- Potential areas of need that compare the alignment between need for air quality improvement versus extant Green Infrastructure potentially making a contribution to air quality management (LSOA).

The methodology used for this module has created prototype versions of each of these datasets as a proof-of-concept exercise using Greater Manchester as a test case.

Method, Results and Limitations.

PM2.5 removal provision.

Annual estimates of the pollution removal from green infrastructure are made regularly via the UK's Natural Capital Accounts process (Office of National Statistics, 2023). Underpinning data products are released with the accounts, including estimates of total pollutant removal per pollutant per 1km (all habitats combined) and habitat-specific removal per pollutant by local authority. To make estimates of the average provision of $PM_{2.5}$ removal at Lower Super Output Area (LSOA), Local Authority level habitat-specific estimates of the total mass of $PM_{2.5}$ removed for 2022 have been spatially disaggregated to create a set of habitat-specific factors per local authority. Factors were then applied to Natural England's Urban Habitat Map (Broad Classes) and re-aggregated to LSOA level. This process was necessary due to the lack of availability of habitat-specific results at finer resolutions.

Since the Natural Capital Accounts habitat classes differ from those contained in Natural England's Broad Urban Habitat classification scheme, it was necessary to use additional data and assumptions. To differentiate urban from rural habitats an urban extents layer was generated using the variable buffer methodology used in the Natural Capital Accounts (eftec, 2017). Matching habitat classes used a look-up scheme (Table 22) with habitat totals cross-checked by local authority. For some habitat classes, e.g. 'Freshwater, wetlands, and floodplains' compared to 'Wetland', there were very significant differences in land area totals between the Natural Capital Accounts and Natural England's data. Where possible, pollution removal totals were reassigned between classes to avoid creating very unrepresentative factors.

Table 22. Look-up table aligning Urban Habitat Classes with Natural Capital Accounts habitat classes used for disaggregation.

Classes for pollution removal factors	Natural England Broad Urban Habitat Class	Natural Capital Accounts Class	Disaggregation rules
Urban Woodland	Woodland	Urban trees	Only in urban extent
Urban Grassland	Parkland; Grassland; Rough, Abandoned and Derelict Land; Formal Planting; Upland Habitats; Agricultural Land	Urban grassland	Only in urban extent
Rural Woodland	Woodland	Broadleaf woodland or Coniferous woodland	Only in rural extent
Rural Grassland	Parkland; Grassland; Rough, Abandoned and Derelict Land; Formal planting	Semi-natural grassland	Only in rural extent
Upland	Upland Habitats	Mountains, moorland, and heath	Only in rural extent
Wetland	Wetland	Freshwater, wetlands, and floodplains	Anywhere
Agriculture	Agricultural Land	Enclosed farmland	Only in rural extent

In the test case, the rules in Table 22 created 7 spatially-averaged individual factors for each Local Authority, two specifically for urban areas and four specifically for rural areas (Table 21). To assess the impact of spatial averaging, totals for 1km areas were compared using the Centre for Ecology and Hydrology’s 1km pollutant removal grid (Jones et al., 2017). Given that data are not available for comparable years, a mean of available data has been used.

Table 23. Estimated disaggregation factors (PM2.5 removal g per 5m cell).

Local Authority	Urban Woodland	Urban Grassland	Rural Woodland	Rural Grassland	Upland	Wetland	Agriculture
Bolton	12.482	1.238	10.019	0.885	0.788	1.155	0.922
Bury	12.859	1.682	7.491	0.538	1.273	0.069	0.968
Oldham	8.098	1.792	10.070	0.959	1.865	1.836	0.828
Rochdale	4.795	1.271	14.110	0.944	1.667	1.721	1.066
Salford	8.412	1.275	5.598	1.017	0.000	0.000	0.000
Stockport	4.089	1.333	8.368	0.605	0.051	0.000	0.757
Tameside	10.667	2.293	6.774	0.427	0.876	1.519	0.800
Trafford	3.443	1.125	5.233	1.431	0.000	0.000	0.000
Wigan	6.098	1.336	11.369	0.900	0.000	0.000	0.340

Results and cross-checks

Figure 18 shows the output $PM_{2.5}$ removal data for the gridded dataset and LSOA level averages. The latter were standardised using z-scores to represent values relative to the test case (Greater Manchester) mean. High $PM_{2.5}$ removal rates are found in river corridors such as the Irwell and Tame and LSOAs with a high density of trees.

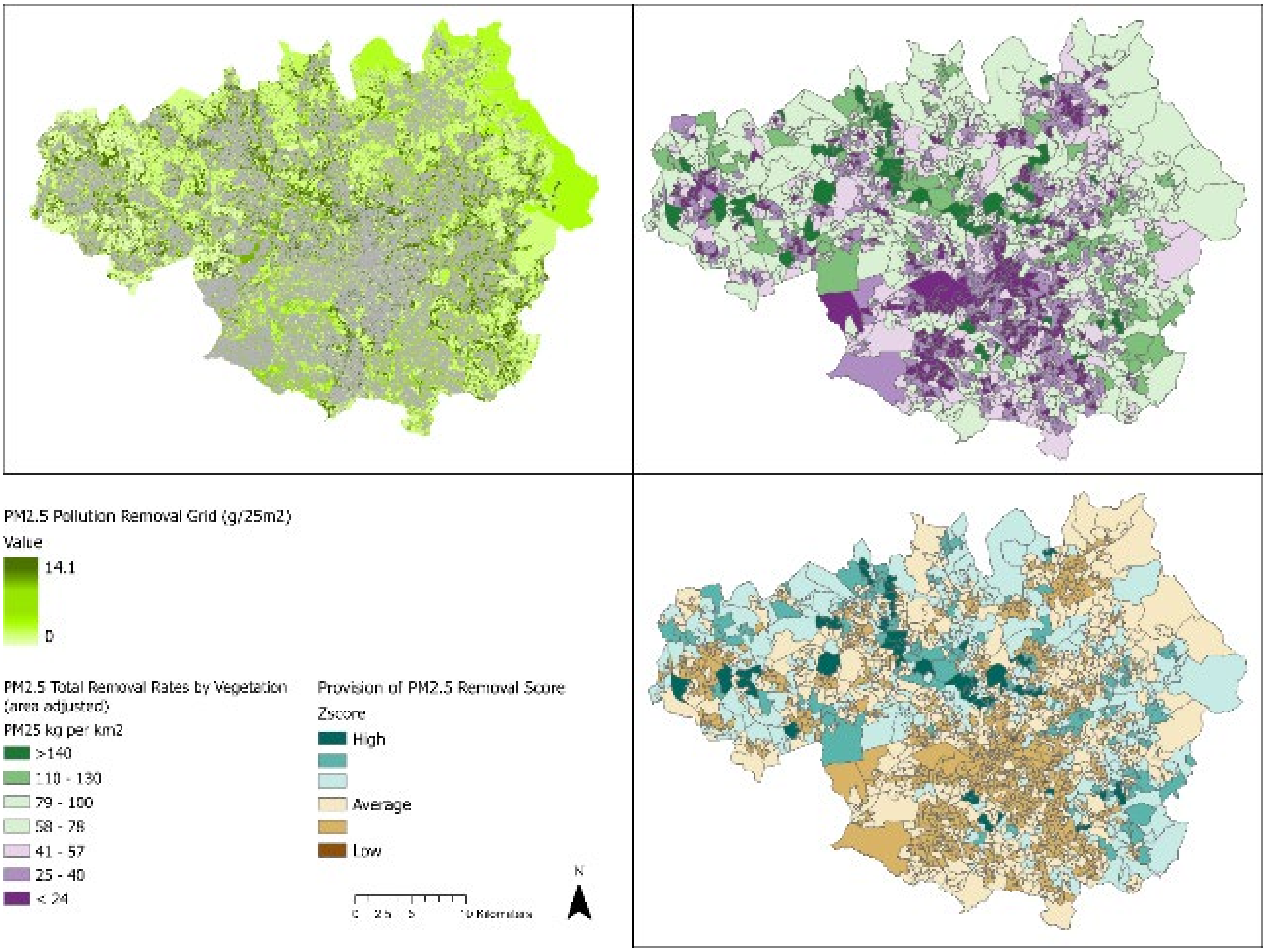

Figure 18. Provision of PM2.5 removal results: 5m grid (top left); LSOA PM2.5 removal aggregate by unit area (top right); and LSOA standardised (bottom right right).

All data are confirmed as internally consistent to Local Authority level. However, as expected, there are spatial differences in $PM_{2.5}$ pollution totals when comparing data reaggregated to 1km in this assessment with the data produced in the original pollution removal assessments (Jones et al, 2017).

Reasons for observed differences include:

Expected differences expected due to spatial averaging, for instance to even out the influence of concentrations and associated pollution removal rates into 20 spatial zones, i.e. urban/rural areas of each local authority.

Use of different habitat data, with the data from Natural England also including a greater proportion of urban vegetated areas.

Differences in time periods. An average of 2015 and 2030 annual data were used from Jones et al., (2017) which is not a precise match for the 2022 Natural Capital Account year of 2022.

Limitations and opportunities for further development.

This assessment has used spatially averaged estimates of PM2.5 pollution removal values which do not capture the full variation within Local Authorities. The use of spatially averaged PM2.5 pollution removal values leads to under- and over-estimates at the local level as an inevitable consequence of the methodology. Further spatially refined source data on habitat-specific PM2.5 pollution removal rates would improve accuracy. It should also be noted that considerable variability within habitat classes should be expected, for instance due to species, configuration and structure, and positioning relative to emissions sources.

Natural England Broad Habitat classes are not fully aligned with Natural Capital Accounts habitat classes. Differences in the classifications require assumptions to be made to attribute Natural Capital Account habitat-based $PM_{2.5}$ pollution removal totals to Natural England Broad Habitat classes. There is some uncertainty inherent in this process. Two particular limitations are highlighted:

There were instances of very different areal extents for similar habitat classes. For example, in Oldham, the Natural Capital Accounts 'Freshwater, wetlands, and floodplains' class covered 29 km^2 compared to <2 km^2 in Natural England's 'Wetland' class. Conversely, the area coverage for the Natural Capital Accounts 'Mountains, moorland, and heath' was 16 km^2 compared to 39 km^2 for Natural England's 'Upland Habitat' class. Visual inspection confirmed that much of the over/under estimation in this case was due to differences in classifications in upland areas. Here an equivalent amount of the pollution removal total for 'Wetland' could be reassigned to 'Upland Habitats' based on area differences. However, such reassignment was not always possible due to the need to maintain internal coherence of Local Authority totals, i.e. to ensure that the disaggregated 5m version of the dataset generated the same Local Authority level kg total as shown in the original Natural Capital Accounts.

The Private Garden broad habitat within Natural England's dataset was excluded as a pollution removal source. Instead, it was combined with the general 'urban' category and any vegetated categories assigned a zero $PM_{2.5}$ pollution removal value. Although private gardens will provide some $PM_{2.5}$ pollution removal, their contribution is not likely to be fully represented within the Natural Capital Accounts because the 10m spatial resolution Land Cover Map (i.e. the base data used to generate pollution removal estimates for the National Capital Accounts) tends to combine this class within the general urban and especially 'suburban' classes. Furthermore, land cover characteristics of gardens also tend not to be well represented in other datasets used to refine categorisations.

The latest Natural Capital Accounts shows that 'Enclosed Farmland' in Trafford and Salford had a marginal positive net contribution to $PM_{2.5}$ concentrations. In other words, they have been estimated to increase rather than offset $PM_{2.5}$ concentrations (values of -1 kg and -21kg for Trafford and Salford respectively for 2022). ONS reconfirmed 'Enclosed Farmland' as a pollution source, though for the purposes of this assessment they have been attributed a 0 $PM_{2.5}$ pollution removal value. This is expected to have little impact on the estimates for Salford, but with a larger impact on estimates for Trafford.

Although this proof-of-concept assessment used pollution removal rate factors, equivalent factors could be produced for the prevention of Years of Life Lost from vegetation as these are also reported as part of the National Capital Accounts process.

Need for PM2.5 pollution removal.

The need for $PM_{2.5}$ pollution removal has been divided into two components (Figure 19):

(a) Physical need – concentrations of $PM_{2.5}$ as an annual mean for 2022 expressed in $\mu g\ m^{-3}$ (Defra 2024). The 1km resolution data were re-apportioned to average concentrations across LSOAs.

(b) Social need – Years of Life Lost as a measure of poor health. These data were available at LSOA level and standardized to the Greater Manchester average.

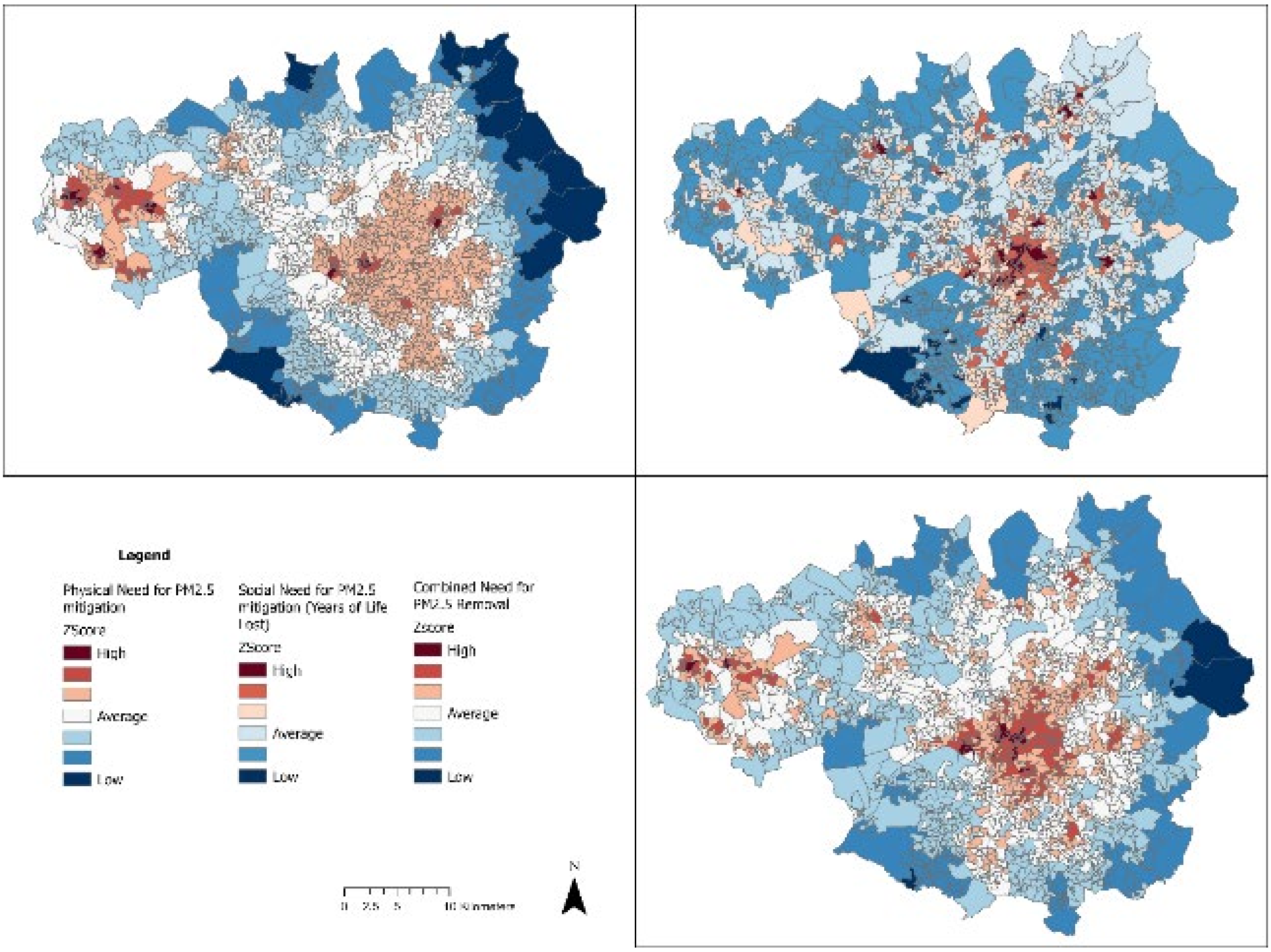

Figure 19. Need for PM2.5 pollution removal: Physical need based on concentrations of PM2.5 by LSOA (top left); Social Need based on Years of Life Lost by LSOA (top right); and a combined need for PM2.5 removal by LSOA (bottom right).

Limitations and opportunities for further development

Further (or alternative) measures of social need could be considered. For the purposes of this assessment a single dataset has been used as an exemplar.

It is acknowledged that $PM_{2.5}$ concentrations are included within the process used to estimate $PM_{2.5}$ removal rates for vegetation. Although this brings an element of circularity in the current assessment, it is nevertheless considered important to represent the $PM_{2.5}$ pollution gradient as part of the relative pattern of need. Users can opt to select one or both measures in their assessment of priority areas for green infrastructure interventions. It should be noted that the placement of interventions within neighbourhoods should take account of positioning relative to emission sources, see for example the recommendations guide produced by the Greater London Authority (2019).

Indicative areas of need for PM 2.5 removal.

Figure 20 provides an indicative first draft test case assessment of what could be priority needs for $PM_{2.5}$ pollution removal. The dataset was created by combining standardised z-scores for $PM_{2.5}$ pollution removal provision (i.e. lack of provision) with standardised z-scores for the need for $PM_{2.5}$ pollution removal as explained in previous sections. This map should be seen in the light of the limitations associated with inputs as outlined above.

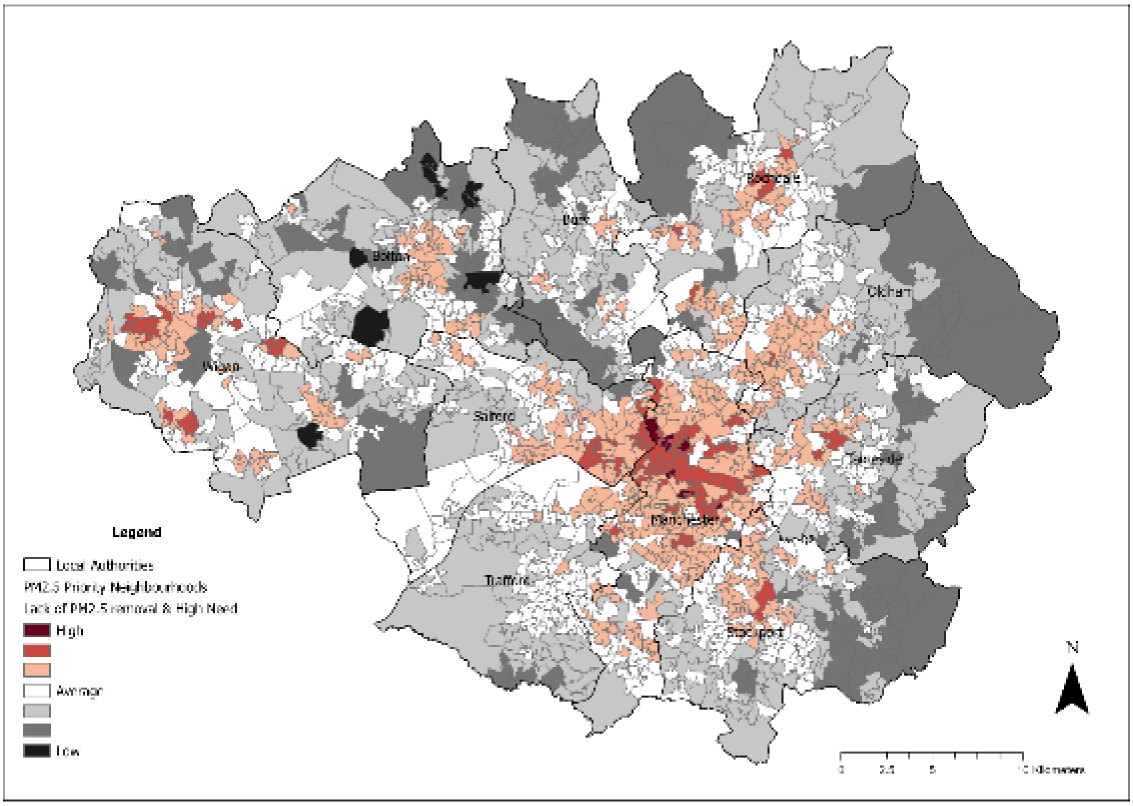

Figure 20. Indicative map of potential areas of need for PM 2.5 removal (LSOA).

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Section 15. Urban Food Production – Experimental module.

Work for this module was done by the University of Manchester (Dr Lindley, S.J.).

References provided for this module are listed at the end of the section.

Provision of and need for local food: Greater Manchester Test Case.

Introduction.

In England, urban food growing is practiced for a variety of reasons including food security, health and wellbeing due to exercise and improved diets, sustainability, and cultural reasons (Dobson et al., 2020). Despite considerable interest in food growing, there is no national dataset covering local food production in England and little systematic data collection on production rates in urban areas (Edmondson et al., 2019; Edmondson et al., 2020). Further, the need for local food growing is also poorly understood, though data recently published by the Consumer Data Research Centre (CDRC) does provide insights into neighbourhoods across England facing a range of food insecurities.

Aim and Outputs.

The aim of this work is to develop an initial assessment of: (a) the likelihood of local food production from urban green infrastructure; (b) community need for local food production taking account of social factors; (c) the opportunity to engage in local food production; and (d) the degree of geographical alignment between provision, need and opportunity. The latter is used to make a provisional assessment of priority areas for further interventions.

The following datasets have been developed:

- Lower Super Output Area (LSOA) provision of, and need for, local food growing.
- Provision of local food growing (estimated vegetable and fruit area in allotments and gardens).
- Need for local food growing (according to the CDRC Priority Places for Food Index).
- Opportunity for engaging in food production as a combination of (a) the proximity to allotments and community gardens and (b) the area of vegetated private gardens.
- Indicative potential priority areas as the combination of Provision, Need and Opportunity.
- A 250m gridded representation of estimated vegetable and fruit area likely to be associated with allotments and gardens.

This module presents a prototype version of each of these datasets as a proof-of-concept exercise using Greater Manchester as a test case. The subsequent sections identify inputs, assumptions made and key limitations for onward use of the resources. Suggestions for improvements to the methodology are also provided.

Method, Results and Limitations.

Local food provision.

Local food growing associated with allotments, community gardens and private gardens has been estimated using assumptions from field surveys published in the academic literature for Leicester, Cardiff and Oxford (Edmundson et al., 2020; Grafius et al., 2020).

Allotments and community gardens.

Field surveys in Leicester suggested that an average of 51.5% of allotment land area is associated with vegetable and fruit production (with proportions ranging 15% to 87%). These assumptions have been combined with estimates of vegetated garden cover and cultivated allotment area from Natural England's detailed urban habitat dataset at 5m resolution. Cultivated areas as a proportion of allotment area in the latter dataset are larger, estimated to be 78.2%, 81.7% and 83.9% for Plymouth, Greater Manchester and Tyneside respectively (Natural England, personal communication). Areas yielding vegetables and fruit is therefore expected to be lower than the areal extent of classified cultivated areas. It has been assumed that 51.5% of classified cultivated area produces vegetables and fruit with the remainder a mosaic of bare land, paths, sheds and equipment. This conservative estimate of productive area for vegetable and fruit production also takes account of lower estimates for Sheffield of 27% cultivation per plot on average (with a range of 6-67% from 38 allotment plots surveyed) (Clarke, 2014). The lower values for Sheffield have been attributed in part to topographic and climatological factors, some of which are held in common with parts of Greater Manchester.

Private Gardens.

The proportion of land area devoted to vegetable and food production in private gardens is estimated to be 1.9% drawing on data published for Leicester, Oxford and Cardiff (Grafius et al., 2020).

Results and cross-checks.

Figure 21 shows estimations of area devoted to local food production for each LSOA, both as a total for each category and as an area-weighted measure. The latter was standardised using z-scores to represent values relative to the test case (Greater Manchester) mean and used as the measure of Provision. As would be expected, the urban core of Greater

Manchester is estimated to have very little or no local food production. The distributions of total estimates are strongly driven by the locations of allotments and community gardens which are generally sited in suburban areas of the city-region, especially in the south.

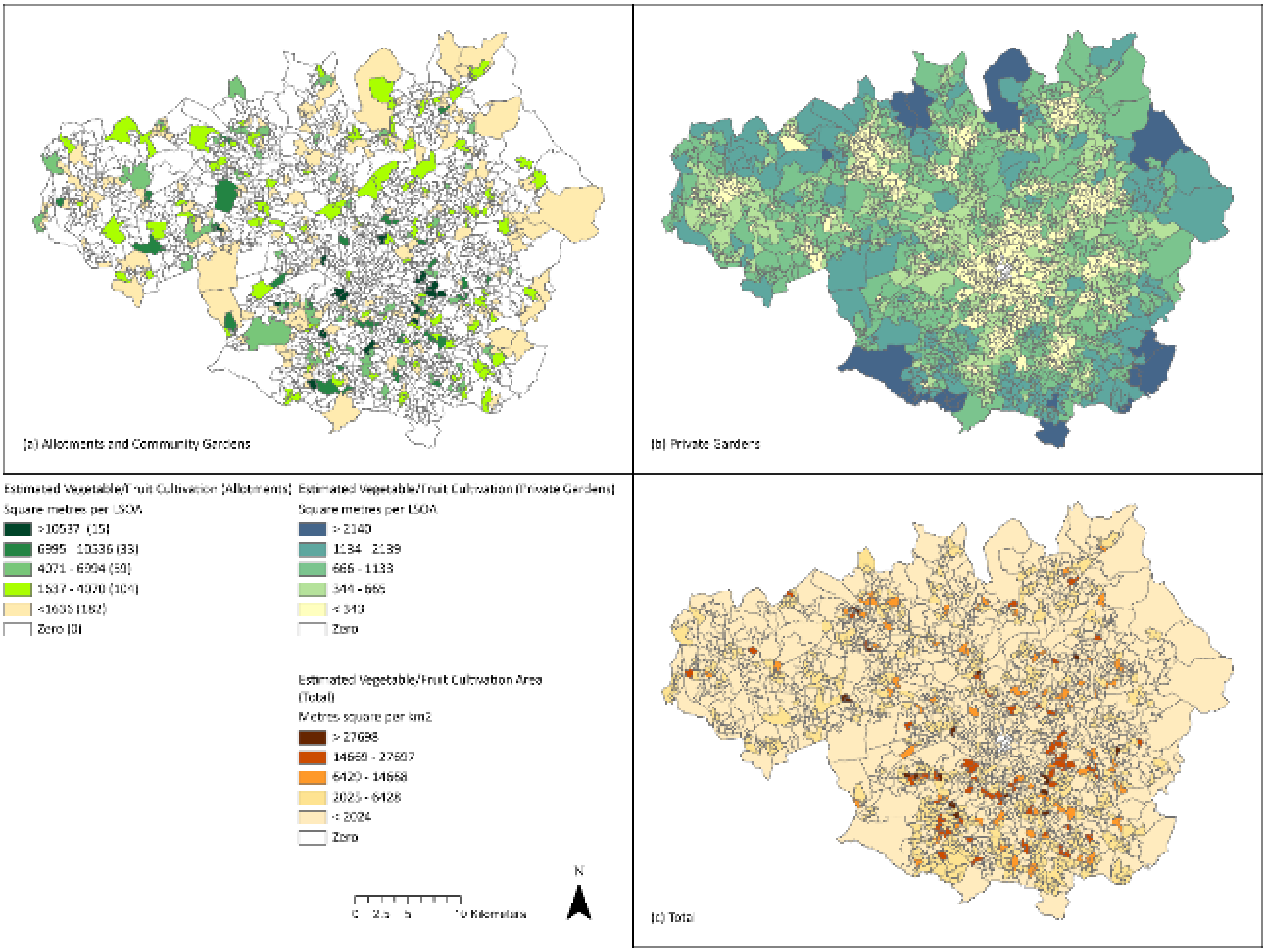

Figure 21. Provision of local vegetable and fruit: (a) Allotments and Community Gardens; (b) Private Gardens; and (c) Total (standardised by LSOA area).

There is a good agreement of area covered by allotments and community gardens between the core green infrastructure dataset used in this analysis and independent data available via Open Street Map (OSM) (Table 22). Some 2.54 km^2 of allotment and community garden area is identical between the two datasets, though combined they cover 3.3km^2. Visual inspection of aerial photography confirms the existence of additional allotments and community gardens in OSM, some of which are newly developed. There are also allotments and community gardens in both datasets which appear to be no longer in use and/or where the primary use is not for growing vegetable and fruit.

Limitations and opportunities for further development

This assessment has used spatially averaged assumptions about the proportion of private gardens and allotments and community gardens associated with vegetable and fruit growing. Just as the proportion of cultivated area varies across different sites, so the proportion of vegetable and fruit growing in the cultivated areas will vary due to environmental and socio-cultural factors. As an example, the area of cultivated gardens in Manchester City is very varied. Recent estimates have shown a cultivated proportion of 11.8%, with a standard deviation of 14.31% and cases up to 77.14% (Baker, 2018). However, it is not known what proportion of this cultivated area is associated with vegetable and fruit growing.

The methodology could be further developed through sampling surface cover properties within growing spaces and relating this to environmental properties such as elevation, slope and aspect using further case study cities in broad climate zones across England. This can take account of multiple sources of data about growing areas based on community generated and official sources and drawing on a wider variety of data sources such as community science records, community group data and grey-literature sources.

Some growing of vegetables, fruits and herbs takes place in very small spaces which are difficult to record and represent, including in other land use types, such as schools and amenity grassland areas. This assessment has not considered these additional small scale local production sources.

Need for local food production.

The need for local food production is taken directly from the CDRC (2022) Priority Places for Food Index (Figure 22) standardised to represent the Need for local food production data layer. It is a combination of the following domains:

- Proximity to supermarket retail services (distance to large grocery stores and count of stores within 1km).
- Accessibility to supermarket retail facilities (average distance travelled and journey time via public transport).
- Access to online grocery deliveries and propensity to shop online.
- Proximity to non-supermarket food provision (distance to markets, count of markets within 1km and count of non-supermarket retail food stores within 1km).
- Socio-economic barriers (lack of car access).
- Family food support (free school mean eligibility; Healthy start voucher usage; distance to the nearest foodbank).
- Fuel Poverty (Proportions of households in fuel poverty; prepayment meters).

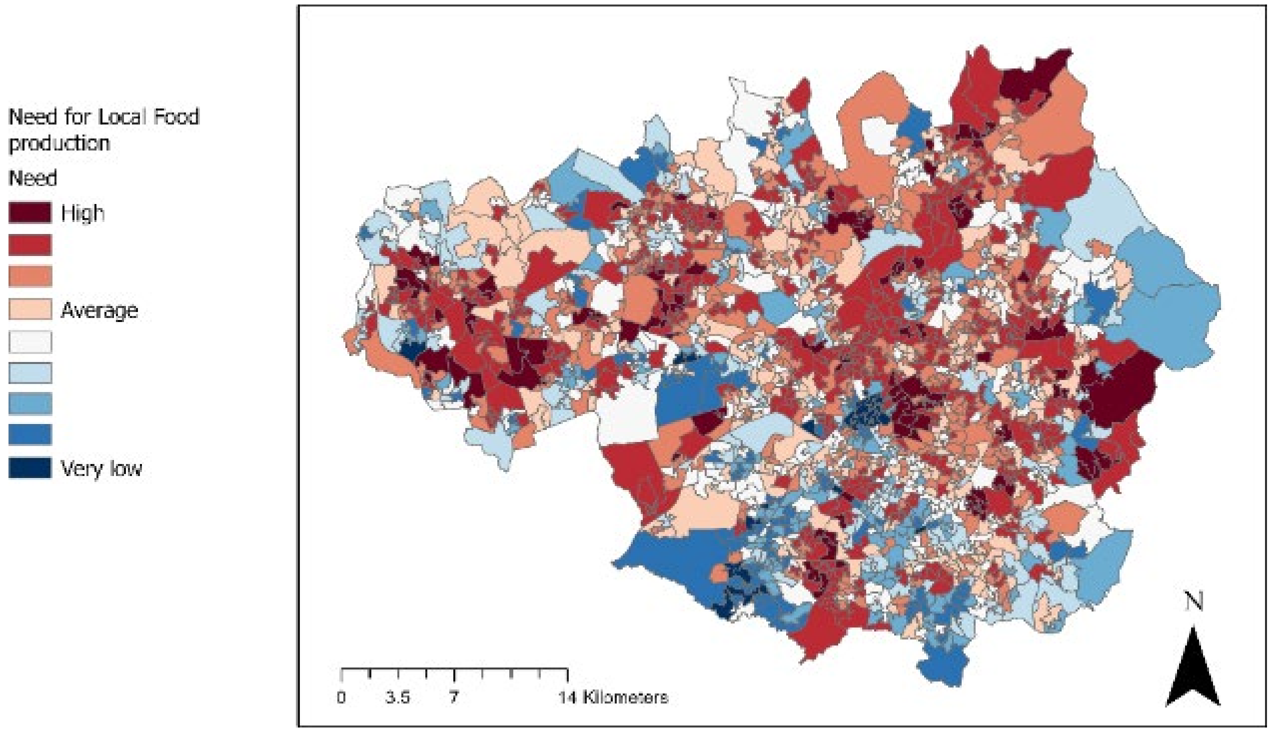

Figure 22. Need for local food production (see end for data acknowledgement).

Limitations and opportunities for further development

Further (or alternative) measures of social need could be considered. For the purposes of this assessment a single dataset has been used as an exemplar.

The CDRC (2022) Priority Places for Food Index is reported as ordinal data for England as a whole. It is acknowledged here that z-scores are technically inappropriate for use with ordinal data. However, given that Greater Manchester has been taken as a sample of ranks for England (ranging 4-32818 from a possible range 1-32844) these data have been taken as pseudo-continuous.

Future versions should consider alternative standardisations as well as perform suitable data transformations for all of the metrics being considered across the assessments.

Opportunity for local food production.

Allotments and community gardens are community resources which are not solely of benefit for residents within the LSOA in which they are located. Indeed, some allotment and community growing areas are located across LSOA boundaries. Given that users of allotments and community gardens can be expected to travel to sites, an assessment has been made of proximity to allotments and community gardens by LSOA. Distance has been calculated as the mean distance to an allotment or community garden within the built up area extent of Greater Manchester. This assessment was made using allotments and community gardens identified in the England Green Infrastructure mapping dataset with the urban extent defined using the Natural Capital Accounts urban boundary (Eftec, 2017). The proximity to allotments or community gardens measure represents one element of the opportunity for local growing.

A second measure of the opportunity for local growing is the availability of private gardens. Householders with access to private garden space have the option to grow vegetables and fruit if they so wish. This option will be much reduced where there are no private gardens, or where private gardens are relatively small. To account for this opportunity, a measure of the total area of vegetated private garden space has been used as a proxy for the opportunity for local food production in private gardens. This measure has not been area weighted and is produced as a LSOA total. Both measures of opportunity were converted to z-scores and combined to produce the final Opportunity measure (representing lack of opportunity).

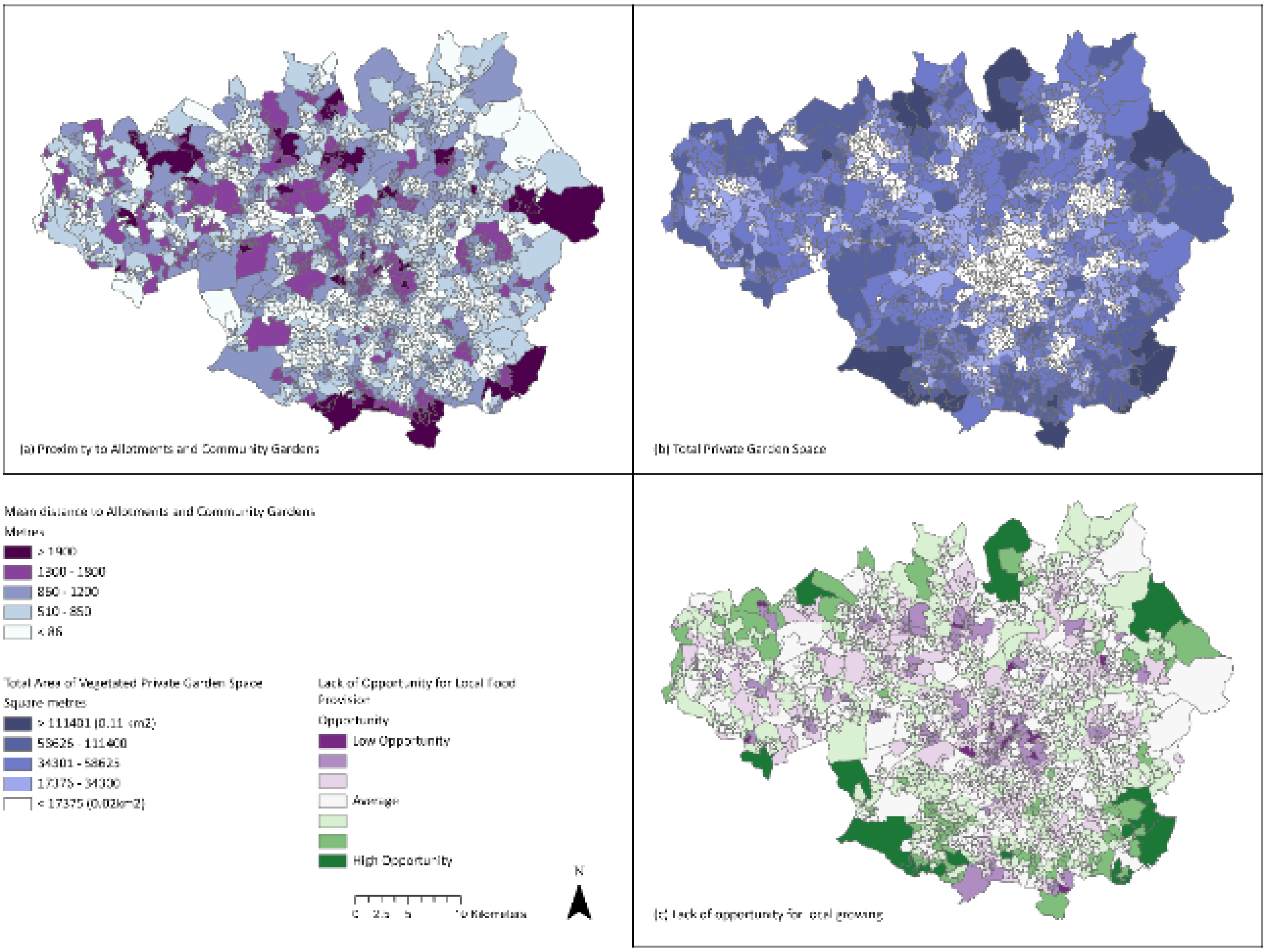

Figure 23. Opportunities for local vegetable and fruit: (a) Proximity to Allotments and Community Gardens; (b) Size of vegetated area of Private Gardens; and (c) Lack of opportunity for local food growing.

Limitations and opportunities for further development.

Proximity has been assessed using an as-the-crow-flies measure within the urban boundary. This is due to built-up areas having relatively dense networks of roads and paths. Some allotments and community gardens are located outside of the boundary and so are excluded. Network analysis-based assessment of proximity would give more reliable estimates of the accessibility of community growing spaces.

The use of vegetated garden areas as a proxy for local food growing opportunities does not take account of areas which may be unsuitable, for instance due to shading or other environmental factors. Equally, there may be opportunities for local food production in garden areas which are not classified as being vegetated.

Indicative identification of Priority areas.

The final output (Figure 24) provides an indicative first draft test case assessment of priority needs for local food growing. The dataset was created by combining standardised z-scores for:

- Low estimated vegetable and fruit cultivation (i.e. lack of provision of locally grown food)
- High food insecurity (i.e. high need for local food production)
- Low proximity to existing allotments and community garden spaces and low amounts of vegetated garden space (i.e. lack of opportunity for local food production)

Areas of high priority tend include areas directly north and east of Manchester city centre and are generally located more towards the north of the city-region. Some local authorities, such as Trafford and Stockport, have few priority areas according to the assessment methodology and metrics used in this test case.

This output indicates the sort of results that might be achieved using the described method.

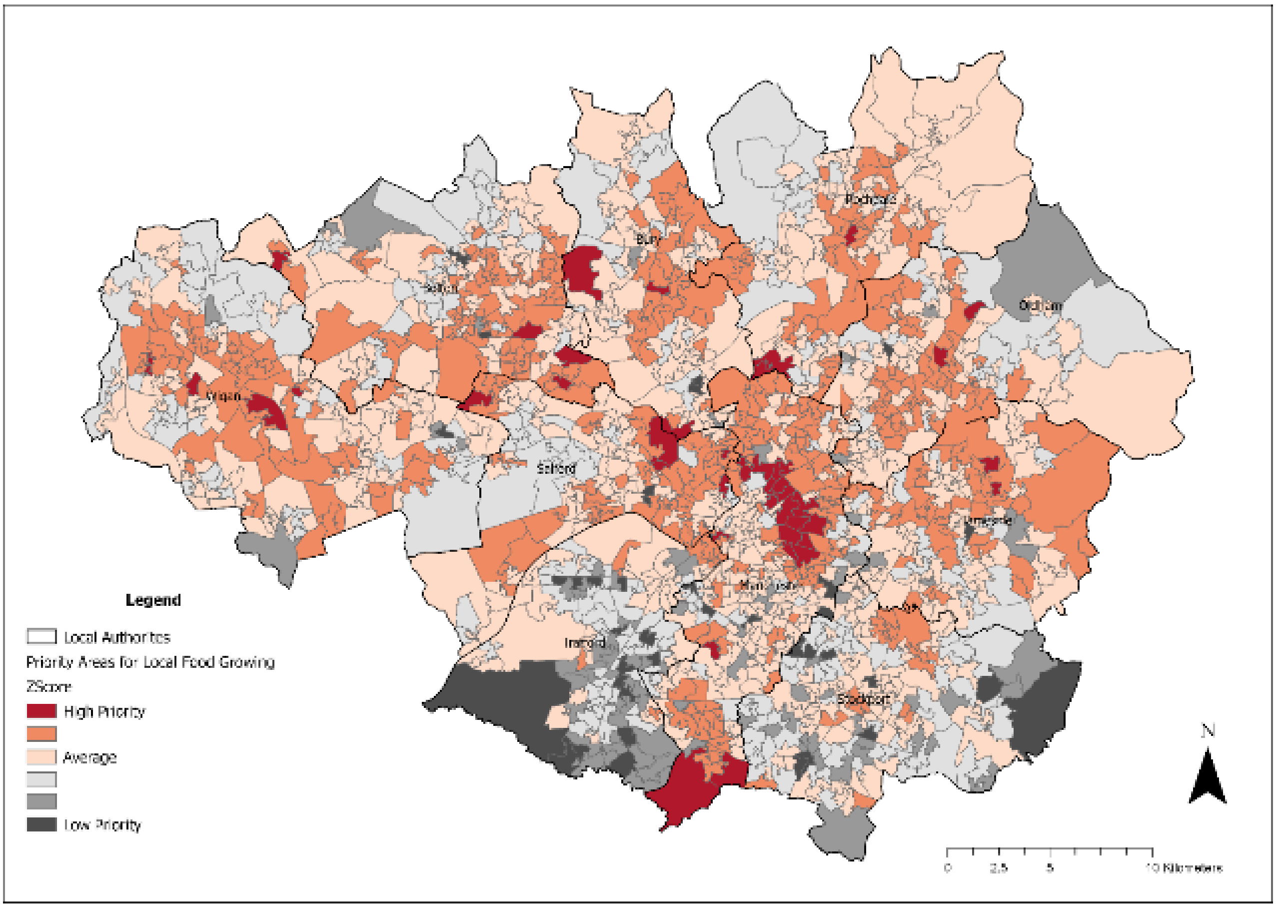

Figure 24. Indicative potential priority areas for local food growing. The method involves comparing LSOA are coded with respect to levels of food production, levels of food insecurity and proximity to opportunity to grow food. LSOA are colour coded to indicate how areas might be prioritised for interventions related to urban food production.

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Data Acknowledgements

Data provided by the Consumer Data Research Centre (CDRC), an ESRC Data Investment, refs ES/L011840/1; ES/L011891/1. The Priority Places for Food Index was developed by the CDRC at the University of Leeds in collaboration with Which? https://data.cdrc.ac.uk/dataset/priority-places-food-index

Some of the analysis has used map data from OpenStreetMap OpenStreetMap and Natural England's Green Infrastructure Database (which contains Ordnance Survey data).

List of abbreviations.

AGSt. Accessible Green Space Standards.

AGI. Accessible Green Infrastructure.

APGB. Aerial Photography Great Britain.

BI. Blue Infrastructure.

BUA. Built Up Area (ONS data).

CDRC. Consumer Data Research Centre.

CEH. Centre for Ecology and Hydrology.

CHM. Canopy Height Model.

CIR. Colour Infrared Imagery.

DSM. Digital Surface Model.

DTM. Digital Terrain Model.

EA. Environment Agency.

ESRI. American multinational geographic information system software company.

GB. Great Britain.

GI. Green Infrastructure.

GIS. Geographic Information System.

GLCM. Grey Level Co-Occurance Index.

GRVI. Green-Red Vegetation Index.

HMI. Heat Mitigation Index.

IMD. Index of Multiple Deprivation.

LAZ. EA Point Cloud data.

LDU. Landscape Description Unit.

LIDAR. Light Detection and Ranging data.

LSOA. Lower Super Output Area.

MSOA. Middle Super Output Area.

NDSI. Normalised Difference Snow Index.

NDVI. Normalised Difference Vegetation Index.

NDWI. Normalised Difference Water Index.

NFM. Natural Flood Management.

NIR. Near Infrared.

OBIA. Object Based Image Analysis.

OGL. Open Government License.

ONS. Office for National Statistics.

OS. Ordnance Survey.

OSM. Open Street Map.

OSMM. Ordnance Survey MasterMap.

PM2.5. Particulate Matter (size up to 2.5 micrometres)

PRoW. Public Right of Way.

RGB. Spectral bands Red, Green, Blue.

SAVI. Soil Adjusted Vegetation Index.

SuDS. Sustainable Drainage.

UHI. Urban Heat Island.

WWNP. Working With Natural Processes.

XML. Extensible Marup Language.

Glossary.

Access Land. The Countryside and Rights of Way Act 2000 (CROW Act) normally gives a public right of access to land mapped as ‘open country’ (mountain, moor, heath and down) or registered common land. These areas are known as ‘open access land’. You can find out if the public has a right of access to land under the CROW Act using the online maps.

Accessible Green Infrastructure. Green Infrastructure Typologies used in the England Green Infrastructure Mapping that are classed as “Publicly Accessible”.

Accessible Green Space Standards. The AGSt approach aims to address differences in access to the natural environment across the country through local green spaces by setting a range of accessibility benchmarks for sites of “higher level” naturalness and areas within easy reach of people’s homes.

Albedo effect. Albedo is an expression of the ability of surfaces to reflect sunlight (heat from the sun).

Artificial Intelligence. Broadly defined as a capacity of machines, especially computer systems, to exhibit “intelligence”.

Evapotranspiration. Loss of water from the soil both by evaporation from the soil surface and by transpiration from the leaves of the plants growing on it.

Green Infrastructure. There are many definitions of Green Infrastructure. The England Green Infrastructure Framework uses the definition in the National Planning Policy Framework: “A network of multi-functional green and blue spaces and other natural features, urban and rural, which is capable of delivering a wide range of environmental, economic, health and wellbeing benefits for nature, climate, local and wider communities and prosperity”.

Index of Multiple Deprivation. The English indices of deprivation measure relative deprivation in small areas in England called lower-layer super output areas.

Landscape Description Units. Areas of landscape that share broadly similar physical characteristics.

Output Areas are the lowest level of geographical area for census statistics. Output areas usually comprise between 40 and 200 households and between 100 and 625 usually resident persons.

Lower layer Super Output Areas (LSOAs) are made up of groups of Output Areas, usually four or five. They comprise between 400 and 1,200 households and have a usually resident population between 1,000 and 3,000 persons.

Middle layer Super Output Areas (MSOAs) are made up of groups of LSOAs, usually four or five. They comprise between 2,000 and 6,000 households and have a usually resident population between 5,000 and 15,000 persons. MSOAs fit within local authorities.

Machine Learning. Machine learning (ML) is a branch of Artificial Intelligence and computer science that focuses on the using data and algorithms to enable AI to imitate the way that humans learn, gradually improving its accuracy.

Naturalness. In the GI mapping this is taken to be a measure of the aesthetic of “level of management intervention” that a space is likely to display to people in it.

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Public Right of Way. A public right of way is a right by which the public can pass along linear routes over land at all times. Public rights of way are all highways in law, but the term ‘public rights of way’ is generally used to cover more minor highways. Actual mode of transport rights differ by class. PRoW are defined as Public Footpaths, Bridleways, Restricted Byways and Byways Open to All Traffic

Rural-Urban Classification. The Rural-Urban Classification is a typological system of administrative units based on physical settlement and related characteristics.

Random Forest. Random forest is a machine learning algorithm used for classification and regression tasks.

Sustainable Drainage. SUDS are drainage systems that are considered to be environmentally beneficial, causing minimal or no long-term detrimental damage. They are often regarded as a sequence of management practices, control structures and strategies designed to efficiently and sustainably drain surface water, while minimising pollution and managing the impact on water quality of local water bodies.

Z score. The z-score, also referred to as standard score, z-value, and normal score, is a dimensionless quantity that is used to indicate the signed, fractional, number of standard deviations by which an event is above or below the mean value being measured.

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