

# London Climate Risk

## A Spatial Analysis of Climate Risk Across Greater London: Methodology Report

Update 2022

This report was prepared for the Greater London Authority by

**Bloomberg Associates**

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# I. Introduction

## Background

The data produced for this project is the result of an ongoing partnership between the GLA and Bloomberg Associates to support sustainability initiatives across the city of London. To help the GLA target its resources to communities with the highest climate risks, Bloomberg Associates produced a series of citywide maps in March 2021 overlaying key metrics to identify areas within London that are most exposed to climate impacts with high concentrations of vulnerable populations. Metrics were identified through research and collaboration between the GLA and Bloomberg Associates in consultation with external stakeholders, leveraging past studies and projects about climate risk.

Bloomberg Associates (BA) is the philanthropic consulting arm of Bloomberg Philanthropies that works side by side with client cities to improve the quality of life for residents. The organization takes a strategic, collaborative and results-oriented approach to make cities strong, safer, more equitable and efficient.

Climate-related impacts will not affect all communities equally. As the COVID-19 pandemic has exposed the health inequalities that place a heavier burden on marginalized groups, climate impacts such as heatwaves and floods will disproportionately harm exposed and vulnerable communities. Assessing the spatial distribution of risk factors across cities can help support informed decisions to help vulnerable populations through the allocation of resources.

In 2022, Bloomberg Associate updated London's climate risk maps to include additional data layers at a finer geographic scale (LSOA boundaries). These maps were built upon earlier maps using the Transport for London (TfL) hexagonal grid (often referred to in this report as the "Hex Grid").

In addition, the map interface was updated to allow users to compare individual data layers to the Overall, Heat and Flooding Climate Risk maps. Users can now also see the specific metrics for each individual LSOA to understand which factors are driving risk throughout the city.

The Climate Risk maps were produced to show these three primary risks:

- Overall Risk using 13 metrics (Ages Under 5, Ages Over 75, English Proficiency, Income Deprivation, Social Renters, BAME, Average Land Surface Temperature, Surface Water Flood Risk, PM2.5, NO2, Green/Blue Land Cover, Areas of Deficiency In Access To Public Open Space)
- Flood Risk Using 9 Metrics (Ages Under 5, Ages Over 75, English Proficiency, Income Deprivation, Social Renters, BAME, Surface Water Flood Risk, Green/Blue Land Cover, Areas of Deficiency In Access To Public Open Space)
- Heat Risk Using 11 Metrics (Ages Under 5, Ages Over 75, English Proficiency, Income Deprivation, Social Renters, BAME, Average Land Surface Temperature, PM2.5, NO2, Tree Canopy Cover, Areas of Deficiency in Access to Public Open Space)

## II. Data and Technology

These maps were produced using datasets available in tabular, vector, and raster format. 13 metrics were analyzed in this study, including six Climate Vulnerability Metrics and seven Climate Exposure Metrics. To visualize the Climate Vulnerability metrics, population data from the 2011 Census and 2019 mid-year population estimates were used. Population data tables were downloaded, cleaned, and joined to corresponding vector geographies using GIS software. To visualize the Exposure metrics, both raster and vector datasets were used. All metrics were converted to the LSOA census tracts before use as input layers to produce the final Risk maps for the 2.0 version.

Details on the data sources' geographies, data formats, and temporal years are listed below (additional information and citations can be found in the Appendix of this document). All spatial analysis for this project was conducted using ArcMap 10.8.

Vulnerability Metrics	Data Source	Geography	Data Type	Temporal Year
Young children (% under 5 years)	ONS (NOMIS website)	Output Area	Tabular	2019
Elderly people (% over 75 years)	ONS (NOMIS website)	Output Area	Tabular	2019
Not English Proficient (% unable to speak English well or at all)	ONS (NOMIS website)	Output Area	Tabular	2011
Black, Asian, and Minority Ethnic (% of BAME population)	ONS (NOMIS website)	Output Area	Tabular	2011
Social Renters (% of households categorized as social renters)	ONS (NOMIS website)	Output Area	Tabular	2011
Income Deprivation (% income deprived)	English Indices of Multiple Deprivation (MHCLG)	LSOA	Tabular	2015

Exposure Metrics	Data Source	Geography	Data Type	Temporal Year
Average Land Surface Temperature	ARTi Analytics BV	-	Raster	2016 - 2020
Tree Canopy	Breadboard Labs / GLA	LSOA	Vector	2013
Areas of Deficiency in Access to Public Open Space	Green Infrastructure Focus Map (GiGL data)	LSOA	Vector	2016
Air Pollution Concentrations: PM2.5	GLA and TFL Air Quality	-	Raster	2016
Air Pollution Concentrations: NO2	GLA and TFL Air Quality	-	Raster	2016
Flood Risk from Surface Water	Environment Agency	-	Vector	2013
London Green / Blue Land Cover	GLA	-	Vector	2016

# III. Methodology

The methodology used to produce this series of maps can be understood in three phases:

1. Gathering data
2. Preparing input layers
3. Producing decision maps

## 1. Gathering data

Both publicly available and privately licensed data were used for this project. Bloomberg Associates aimed to secure the smallest-scale, most up-to-date datasets available for each of the 13 metrics, all of which needed to span the whole of Greater London. The GLA aided in securing these datasets, and metrics were finalized based on the data that was available.

## 2. Preparing input layers

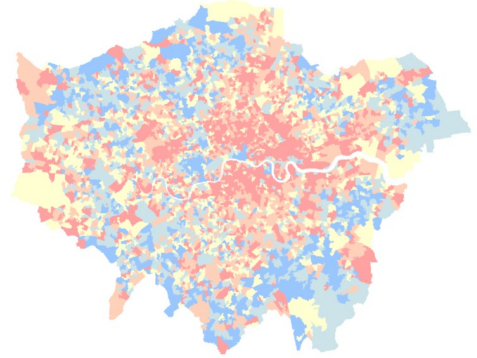
Upon obtaining all 13 datasets, each metric was prepared to be used as an input layer to create three final “decision maps”: the Overall Climate Risk Map, the Flood Risk Map, and the Heat Risk Map. Using ArcMap, metrics were mapped to their respective small-scale geographies or visualized in their original vector or raster format before re-aggregating them to the hex grid. The diagrams on the following pages outline the steps taken to convert data to the hex.

## 3. Producing decision maps

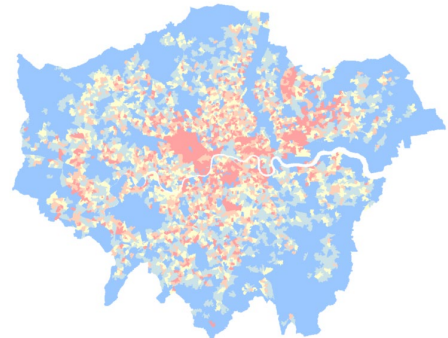
Map Algebra was used to combine the input metric layers to produce the final series of pan-London Climate Risk Maps. After rasterizing each metric vector layer, the values of rasters were reclassified into five quintiles, each of which was reassigned with a value of 1 - 5 (1 indicating the lowest exposure or vulnerability grouping of values, 5 indicating the highest exposure or vulnerability grouping of values). In the final maps, each hex within has a resultant “risk score” created by the addition of these reclassified input layers.

Different combinations of the 13 metrics were used to create the three final decision maps (see pages 21 - 23 for details). The final maps display Overall Climate Risk, Flood Risk, and Heat Risk across London’s LSOAs. The maps available on the London Datastore utilize a gradient symbology, stretching a gradient of color across the risk score values.

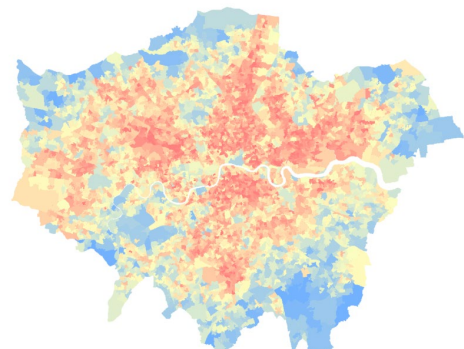
Vulnerability Metrics



Exposure Metrics



Decision Maps



Data downloaded and cleaned. Data tables, shapefiles and rasters added to ArcMap.

2011 Census + 2019 mid-year population estimate  
+ Income Deprivation data tables

2011 Census Boundaries (LSOA)

Table Join 2011 Census data (Social Renter, Not English Proficient), 2019 mid-year population estimate data (Under 5, Over 75), and Income Deprivation data to respective LSOA boundaries.

**Vulnerability Metrics are aggregated to Census Boundaries**

Calculate estimated metric population percentage (%) for each metric data in respective LSOA's

- % Under 5
- % Over 75
- % Social Renters
- % Not English Proficient
- % BAME
- % Income Deprived

Data downloaded. Shapefiles and rasters added to ArcMap.

Exposure Metric Shapefiles  
(**Surface Temperature, Surface Water Flood Risk, Green/Blue Land Cover**)

Exposure Metric Rasters (**Air Pollution Concentrations: PM2.5 and NO2**)

Exposure Metric Rasters aggregated to the Hex (**Average Land Surface Temperature, Tree Canopy Cover, Access to Open Green Space**)

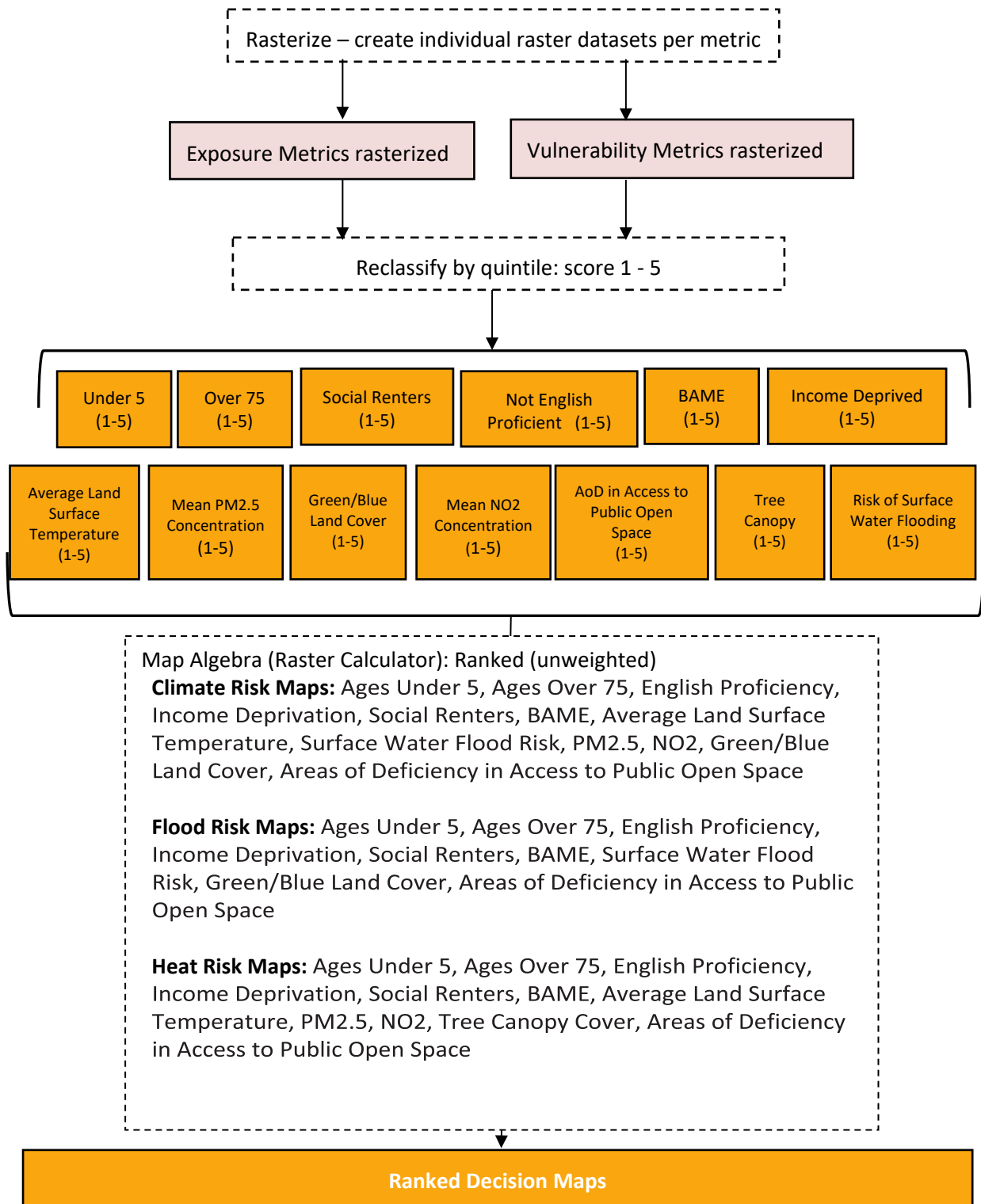
Spatial Joined the intersected shapefiles with LSOA boundary census tracts. Calculated the proportion of SWFR and Green/Blue Land Cover area within the LSOA area (divide SWFR area by LSOA area, multiplied by 100 to calculate percentage)

Used Raster to Point to extract raster values to points.  
Spatial Joined points to the LSOA census tracts, summarizing the MEAN point values falling within the LSOA area.

**Exposure Metrics are aggregated to Census Boundaries**

- Average Land Surface Temperature
- Mean PM2.5 Concentration
- % Of Area covered by Green/Blue Land Cover
- Mean NO2 Concentration
- % Of households within LSOA's in an AoD in Access to Public Open Space
- % Of Area covered by Tree Canopy
- % Of Area at Risk of Surface Water Flooding

## Creating Decision Maps





## Metric Overview + Metadata

METRIC CREATION: Population Under Age 5	
Metric Category	Vulnerability Metric
What is measured	The percentage of the population under the age of 5
Unit of measurement	Count (percentage calculated by summarizing population counts under age 5 and dividing by total population count)
Method for Aggregation	<ul style="list-style-type: none"> <li>Population data provided in table format at the Output Area (OA) level</li> <li>Population data joined to 2011 OA boundaries; Exported to individual shapefile</li> <li>Created new field to calculating area of OAs in square meters (<i>SqM_OA</i>)</li> <li>New data fields calculated:               <ul style="list-style-type: none"> <li><i>SqM_Clip</i>: calculated area of individual intersected polygons</li> <li><i>Clip_AProp</i>: calculated proportion of clipped OA boundary (dividing <i>SqM_Clip</i> by <i>SqM_OA</i>)</li> <li><i>Est_All Ages</i>: calculated the estimated total number of people living in a given OA (multiplied <i>Clip_AProp</i> by the sum of all ages from 2019 mid-year estimates living in the OA; rounded to nearest whole number)</li> <li><i>Est_Und5</i>: calculated the estimated number of people living in the clipped OA under the Age of 5 (multiplied <i>Clip_AProp</i> by the total number of people under 5 living in the OA; rounded to nearest whole number)</li> </ul> </li> <li>Turn Features to Point to use for spatial Join</li> <li>Spatial Joined the intersected OA shapefile with LSOA shapefile, summarizing the estimated under 5 counts of any clipped OA geometries based on LSOA</li> <li>Added new field under the new Spatial Joined shapefile:               <ul style="list-style-type: none"> <li><i>Und5_per</i>: divided <i>Est_Und5/Est_AllAges</i> to calculate the decimal estimated percentage; multiplied by 100 to calculate the <b>estimated percentage of individuals under the age of 5 living within the estimated total population</b></li> </ul> </li> </ul>
DATA SOURCES	
Source	ONS 2019 mid-year Estimates of population for the UK, England and Wales, Scotland and Northern Ireland
Citation	Office for National Statistics (2020). 2019 Estimates of the population for the UK, England and Wales, Scotland and Northern Ireland. Office for National Statistics. Dataset. Available from: <a href="https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland">https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland</a>
Data type	Tabular
Geographic resolution	Output Area - Greater London
Year of publication	2020
Temporal resolution	2019

METRIC CREATION: Population Over Age 75	
Metric Category	Vulnerability Metric
What is measured	The percentage of the population over the age of 75
Unit of measurement	Count (percentage calculated by summarizing population counts over age 75 and dividing by total population count)
Method for Aggregation	<ul style="list-style-type: none"> <li>• Population data provided in table format at the Output Area (OA) level</li> <li>• Population data joined to 2011 OA boundaries; Exported to individual shapefile</li> <li>• Created new field calculating area of OAs in square meters (<i>SqM_OA</i>)</li> <li>• New data fields calculated:               <ul style="list-style-type: none"> <li>• <i>SqM_Clip</i>: calculated area of individual intersected polygons</li> <li>• <i>Clip_AProp</i>: calculated proportion of clipped OA boundary (dividing <i>SqM_Clip</i> by <i>SqM_OA</i>)</li> <li>• <i>Est_AllAges</i>: calculated the estimated total number of people living in a given OA (multiplied <i>Clip_AProp</i> by the sum of all ages from 2019 mid-year estimates living in the OA; rounded to nearest whole number)</li> <li>• <i>Est_Over75</i>: calculated the estimated number of people living in the clipped OA over the age of 75 (multiplied <i>Clip_AProp</i> by the total number of people over 75 living in the OA; rounded to nearest whole number)</li> </ul> </li> <li>• Turn Features to Point to use for spatial Join</li> <li>• Spatial Joined intersected OA shapefile with LSOA shapefile, summarizing the estimated Over 75 counts of any clipped OA geometries based on the LSOA</li> <li>• Added new field under the new Spatial Joined shapefile:               <ul style="list-style-type: none"> <li>• <i>Over75_per</i>: divided <i>Est_Over75/Est_AllAges</i> to calculate the decimal estimated percentage; multiplied by 100 to calculate the <b>estimated percentage of individuals over the age of 75 living within the estimated total population</b></li> </ul> </li> </ul>
DATA SOURCES	
Source	ONS 2019 mid-year Estimates of population for the UK, England and Wales, Scotland and Northern Ireland
Citation	Office for National Statistics (2020). 2019 Estimates of the population for the UK, England and Wales, Scotland and Northern Ireland. Office for National Statistics. Dataset. Available from: <a href="https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalescotlandandnorthernireland">https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalescotlandandnorthernireland</a>
Data type	Tabular
Geographic resolution	Output Area - Greater London
Year of publication	2020
Temporal resolution	2019

METRIC CREATION: English Proficiency	
Metric Category	Vulnerability Metric
What is measured	The percentage of the population unable to speak English well or at all.
Unit of measurement	Count (percentage calculated by summarizing population counts of those unable to speak English well or at all and dividing by total population count)
Method for Aggregation	<ul style="list-style-type: none"> <li>• Population data provided in table format at the Output Area (OA) level</li> <li>• Population data joined to 2011 OA boundaries; Exported to individual shapefile</li> <li>• Created new field calculating area of OAs in square meters (<i>SqM_OA</i>)</li> <li>• New data fields calculated:               <ul style="list-style-type: none"> <li>• <i>SqM_Clip</i>: calculated area of all intersected polygons</li> <li>• <i>Clip_AProp</i>: calculated proportion of clipped OA boundary (dividing <i>SqM_Clip</i> by <i>SqM_OA</i>)</li> <li>• <i>EST_EngTOT</i>: calculated the estimated total number of people with varying levels of English proficiency living in a given OA (multiplied <i>Clip_AProp</i> by the sum of all ages from 2019 mid-year estimates living in the OA; rounded to nearest whole number)</li> <li>• <i>EST_EngNP</i>: calculated the estimated number of people living in the clipped OA that do not speak English well or do not speak English at all (multiplied <i>Clip_AProp</i> by the total number of people that do not speak English well or at all living in the OA; rounded to nearest whole number)</li> </ul> </li> <li>• Turn Features to Point to use for spatial Join</li> <li>• Spatial Joined intersected OA shapefile with LSOA shapefile, summarizing the estimated Non-Proficient English Speaker count of any clipped OA geometries based on the LSOA's</li> <li>• Added new field under the new Spatial Joined shapefile:               <ul style="list-style-type: none"> <li>• <i>EST_EngPer</i>: divided <i>EST_EngNP/EST_EngTOT</i> to calculate the decimal estimated percentage; multiplied by 100 to calculate the <b>estimated percentage of individuals that do not speak English well or do not speak English at all living within the estimated total population within a LSOA</b></li> </ul> </li> </ul>
DATA SOURCES	
Source	2011 Census
Citation	Office for National Statistics (2011). 2011 Census - Proficiency in English. Office for National Statistics. Dataset. Available from: <a href="https://www.nomisweb.co.uk/census/2011/qs205ew">https://www.nomisweb.co.uk/census/2011/qs205ew</a>
Data type	Tabular
Geographic resolution	Output Area - Greater London
Year of publication	2011

METRIC CREATION: Black, Asia, and Minority Ethnic (BAME)	
Metric Category	Vulnerability Metric
What is measured	The percentage of BAME population in the neighborhood
Unit of measurement	Count (percentage calculated by summarizing population counts of BAME and dividing by total population count)
Method for Aggregation	<ul style="list-style-type: none"> <li>• Population data provided in table format at the Output Area (OA) level</li> <li>• Population data joined to 2011 OA boundaries; Exported to individual shapefile</li> <li>• Created new field calculating area of OAs in square meters (<i>SqM_OA</i>)</li> <li>• New data fields calculated:               <ul style="list-style-type: none"> <li>• <i>SqM_Clip</i>: calculated area of all intersected polygons</li> <li>• <i>Clip_AProp</i>: calculated proportion of clipped OA boundary (dividing <i>SqM_Clip</i> by <i>SqM_OA</i>)</li> <li>• <i>EST_EthTOT</i>: calculated the estimated total number of people with varying levels of English proficiency living in a given OA (multiplied <i>Clip_AProp</i> by the sum of all ages from 2019 mid-year estimates living in the OA; rounded to nearest whole number)</li> <li>• <i>EST_BAME</i>: calculated the estimated number of people living in the clipped OA that belong to Black, Asian and Mixed ethnicities (multiplied <i>Clip_AProp</i> by the total number of people BAME in the OA; rounded to nearest whole number)</li> </ul> </li> <li>• Turn Features to Point to use for spatial Join</li> <li>• Spatial Joined intersected OA shapefile with LSOA shapefile, summarizing the estimated Non-Proficient English Speaker count of any clipped OA geometries based on the LSOA's</li> <li>• Added new field under the new Spatial Joined shapefile:               <ul style="list-style-type: none"> <li>• <i>EST_BAMEPer</i>: divided <i>EST_BAME/EST_EthTOT</i> to calculate the decimal estimated percentage; multiplied by 100 to calculate the <b>estimated percentage of individuals that belong to the Black, Asian and Mixed ethnicities.</b></li> </ul> </li> </ul>
DATA SOURCES	
Source	2011 Census
Citation	Office for National Statistics (2011). 2011 Census - Tenure. Office for National Statistics. Dataset. Available from: <a href="https://www.nomisweb.co.uk/census/2011/ks402ew">https://www.nomisweb.co.uk/census/2011/ks402ew</a>
Data type	Tabular
Geographic resolution	Output Area - Greater London
Year of publication	2011

METRIC CREATION: Social Renters	
Metric Category What is measured Unit of measurement	Vulnerability Metric  The percentage of households categorized as social renters  Household Count (percentage calculated by summarizing household categorized as social renters and dividing by total household count)
Method for Aggregation	<ul style="list-style-type: none"> <li>• Household data provided in table format at the Output Area (OA) level</li> <li>• Household data joined to 2011 OA boundaries; Exported to individual shapefile</li> <li>• Created new field calculating area of OAs in square meters (<i>SqM_OA</i>)</li> <li>• New data fields calculated:               <ul style="list-style-type: none"> <li>• <i>SqM_Clip</i>: calculated area of all intersected polygons</li> <li>• <i>Clip_AProp</i>: calculated proportion of clipped OA boundary (dividing <i>SqM_Clip</i> by <i>SqM_OA</i>)</li> <li>• <i>EST_AllHH</i>: calculated the estimated total number of households in a given OA (multiplied <i>Clip_AProp</i> by all households included in the census table)</li> <li>• <i>EST_SocRen</i>: calculated the estimated number of households categorized as social rented in the clipped OA (multiplied <i>Clip_AProp</i> by the total number of households social rented in the OA; rounded to nearest whole number)</li> </ul> </li> <li>• Turn Features to Point to use for spatial Join</li> <li>• Spatial Joined intersected OA shapefile with LSOA shapefile, summarizing the estimated number of social rented households within any clipped OA geometries based on the LSOA's</li> <li>• Added new field under the new Hex OA Social Rented Spatial Joined shapefile:               <ul style="list-style-type: none"> <li>• <i>EST_SocRen</i>: divided <math>EST\_SocRen/EST\_AllHH</math> to calculate the decimal estimated percentage; multiplied by 100 to calculate the <b>estimated percentage of households categorized as social rented within the estimated total households in a LSOA</b></li> </ul> </li> </ul>
DATA SOURCES	
Source	2011 Census
Citation	Office for National Statistics (2011). 2011 Census - Tenure. Office for National Statistics. Dataset. Available from: <a href="https://www.nomisweb.co.uk/census/2011/ks402ew">https://www.nomisweb.co.uk/census/2011/ks402ew</a>
Data type	Tabular
Geographic resolution	Output Area - Greater London
Year of publication	2011

METRIC CREATION: Income Deprivation	
Metric Category	Vulnerability Metric
What is measured	The percentage of the population identified as Income Deprived.
Unit of measurement	Person Count (percentage calculated by dividing income deprivation count by total population count)
Method for Aggregation	<ul style="list-style-type: none"> <li>• Population data provided in table format at the LSOA level</li> <li>• Population data joined to 2011 LSOA boundaries; Exported to individual shapefile</li> <li>• Created new field calculating area of LSOAs in square meters (<i>SqM_LSOA</i>)               <ul style="list-style-type: none"> <li>• <i>SqM_Clip</i>: calculated area of all intersected polygons</li> <li>• <i>Clip_AProp</i>: calculated proportion of clipped LSOA boundary (dividing <i>SqM_Clip</i> by <i>SqM_LSOA</i>)</li> <li>• <i>EST_AllPop</i>: calculated the estimated total number of people living in a given OA (multiplied <i>Clip_AProp</i> by the total population living in the LSOA; rounded to nearest whole number)</li> <li>• <i>Est_IncDep</i>: calculated the estimated number of income deprived people living in the clipped LSOA (multiplied <i>Clip_AProp</i> by the total number of estimated income deprived people in the LSOA; rounded to nearest whole number)</li> </ul> </li> <li>• Added new field under the SOA Income Deprived SpatialJoined shapefile:               <ul style="list-style-type: none"> <li>• <i>IncDep_per</i>: divided <i>EST_IncDep/EST_AllPop</i> to calculate the decimal estimated percentage; multiplied by 100 to calculate the <b>estimated percentage of income deprived individuals living within the estimated total population in a LSOA</b></li> </ul> </li> </ul>
DATA SOURCES	
Source	English Indices of Multiple Deprivation (MHCLG)
Citation	Ministry of Housing, Communities & Local Government (2019). Indices of Deprivation. Greater London Authority. Dataset. Available from: <a href="https://data.london.gov.uk/dataset/indices-of-deprivation">https://data.london.gov.uk/dataset/indices-of-deprivation</a>
Data type	Tabular
Geographic resolution	LSOA - Greater London
Year of publication	2019
Temporal Resolution	2015

METRIC CREATION: Surface Temperature	
Metric Category	Exposure Metric
What is measured	The average land surface temperature within the LSOA area.
Unit of measurement	Degree Celsius
Dataset Aggregated to LSOA	Dataset is aggregated to the Hex Grid; resultant feature class visualizes the <b>2016-2020 average Land Surface Temperature (summertime, daytime LST)</b>
DATA SOURCES	
Source	National Observatory of Athens
Citation	The High Resolution Intra-Urban Temperature Variability information layer for Greater London Area was produced by ARTi Analytics BV as part of EXTREMA Global portfolio of services.
Data Type	Vector
Year of publication	2021
Temporal Resolution	2016 - 2020 (summer months)

METRIC CREATION: Tree Canopy	
Metric Category	Exposure Metric
What is measured	Tree canopy cover for the Greater London area
Unit of measurement	Percent of households in an AoD in Access to Local and District Public Open Space
Dataset Aggregated	Dataset is aggregated to the LSOA through turning the raster to points feature and using spatial join to calculate counts within the LSOA ; resultant feature class visualizes the <b>proportion of a LSOA covered by tree canopy</b>
DATA SOURCES	
Sources	Curio (Breadboard Labs Limited) / GLA
Citation	Breadboard Labs (2018). Curio Canopy - London Tree Canopy Cover. London DataStore. Dataset. Available from: <a href="https://data.london.gov.uk/dataset/curio-canopy">https://data.london.gov.uk/dataset/curio-canopy</a>
Data type	Vector
Year of publication	2015
Temporal Resolution	2013

<b>METRIC CREATION: Areas of Deficiency in Access to Public Open Space</b>	
Metric Category	Exposure Metric
What is measured	Percent of households in an Area of Deficiency (AoD) in Access to Public Open Space
Unit of measurement	Percent of households
Dataset Aggregated to the Hex Grid	Dataset is aggregated to the LSOA through turning the raster to points feature and using spatial join to calculate counts within the LSOA ; resultant feature class visualizes the resultant feature class visualizes the <b>proportion of households in a LSOA within an Area of Deficiency (AoD) in Access to Local and District Public Open Space</b>
<b>DATA SOURCES</b>	
Sources	GIGL CIC Area of Deficiency (AoD) in Access to Local and District Public Open Space and Ordnance Survey AddressBase Plus
URLs	GIGL CIC AoD data: <a href="https://www.gigl.org.uk/open-spaces/areas-of-deficiency-in-access-to-public-open-space/">https://www.gigl.org.uk/open-spaces/areas-of-deficiency-in-access-to-public-open-space/</a> OS AddressBase Plus data: <a href="https://www.ordnancesurvey.co.uk/business-and-government/products/addressbase-plus.html">https://www.ordnancesurvey.co.uk/business-and-government/products/addressbase-plus.html</a>
License	https://data.london.gov.uk/dataset/green-infrastructure-focus-map © Environment Agency copyright and/or database right 2015 Licensed by Greenspace Information for Greater London CIC and Ordnance Survey
Citation	Greenspace Information for Greater London CIC Crown Copyright and database right 2018. Ordnance Survey 100032216 GLA.
Data type	Vector
Year of publication	GiGL CIC Area of Deficiency (AoD) in Access to Local and District Public Open Space: 2016 OS AddressBase Plus: 2018
Temporal Resolution	2016
<b>DATA NOTES</b>	
A hex containing no address points is allocated no value and treated as 'no data', or -999. Within the Climate Risk Map series, these hexes do not return risk values and are visualized with a grey color.	



<b>METRIC CREATION: Air Pollution Concentrations: PM2.5</b>	
Metric Category	Exposure Metric
What is measured	The ground level concentrations of PM2.5 across Greater London
Unit of measurement	Micro gramme per cubic metre
Method for Hex Aggregation	<ul style="list-style-type: none"> <li>Data provided in raster format at 20m grid resolution</li> <li>Used Raster to Point tool to convert PM2.5 raster values to points</li> <li>Spatial Joined points to the LSOA, summarizing the mean point values, resulting in the mean PM2.5 values aggregated to the LSOA</li> </ul>
<b>DATA SOURCES</b>	
Source	GLA and TFL Air Quality
Citation	GLA and TFL Air Quality (2019). London Atmospheric Emission (LAEI) 2016. London DataStore. Dataset. Available from: <a href="https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory--laei--2016">https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory--laei--2016</a>
Data type	Raster
Resolution	20m grid resolution
Year of publication	2020
Temporal Resolution	2016

<b>METRIC CREATION: Air Pollution Concentrations: NO2</b>	
Metric Category	Exposure Metric
What is measured	The ground level concentrations of NO2 across Greater London
Unit of measurement	Micro gramme per cubic metre
Method for Hex Aggregation	<ul style="list-style-type: none"> <li>Data provided in raster format at 20m grid resolution</li> <li>Used Raster to Point tool to convert PM2.5 raster values to points</li> <li>Spatial Joined points to the Hex Grid, summarizing the mean point values, resulting in the mean NO2 values aggregated to the Hex Grid</li> </ul>
<b>DATA SOURCES</b>	
Source	GLA and TFL Air Quality
Citation	GLA and TFL Air Quality (2019). London Atmospheric Emission (LAEI) 2016. London DataStore. Dataset. Available from: <a href="https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory--laei--2016">https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory--laei--2016</a>
Data type	Raster
Resolution	20m grid resolution
Year of publication	2020
Temporal Resolution	2016

METRIC CREATION: Flood Risk from Surface Water	
Metric Category	Exposure Metric
What is measured	Percentage of LSOA Area (square metres) at risk of flooding from Surface Water
Unit of measurement	Percentage of Area
Method for Hex Aggregation	<ul style="list-style-type: none"> <li>Data provided in vector format, displaying Risk of Flooding from Surface Water Extent (RFSWE) (3.3 percent annual chance)</li> <li>Merged and Dissolved vector layer to create a contiguous multi-part vector</li> <li>Intersected RFSWE dataset with LSOA; Calculated areas of resultant polygons intersected with each LSOA</li> <li>Spatial Joined intersected RFSWE feature class to LSOA               <ul style="list-style-type: none"> <li>Replaced LSOA rows with “null” values in RFSWE area field with zero (values read as “null” when no RFSWE polygon area is present within a LSOA)</li> </ul> </li> <li>Calculated proportion of RFSWE area within LSOA Area (dividing RFSWE area by LSOA area, multiplied by 100 to calculate percentage)</li> <li>Resultant feature class visualized the <b>percentage of the LSOA area that is 3.3 percent annual chance of Risk of Flooding from Surface Water</b></li> </ul>
DATA SOURCES	
Source	Environment Agency
Citation	Department for Environment, Food & Rural Affairs (2011). Risk of Flooding from Surface Water Extent: 3.3 percent annual chance. Data.gov.uk. Dataset. Available from: <a href="https://environment.data.gov.uk/dataset/90d2ff8f-d465-11e4-8cb5-f0def148f590">https://environment.data.gov.uk/dataset/90d2ff8f-d465-11e4-8cb5-f0def148f590</a>
License	© Environment Agency copyright and/or database right 2015
Data type	Vector
Resolution	20m grid resolution
Year of publication	2015
Temporal Resolution	2013

METRIC CREATION: Green / Blue Land Cover	
Metric Category	Exposure Metric
What is measured	Percentage of LSOA Area (square metres) covered by green/blue land
Unit of measurement	cover Percentage of Area
Method for Hex Aggregation	<ul style="list-style-type: none"> <li>• Data provided in vector format, displaying Green/Blue land cover across London</li> <li>• Merged and Dissolved vector layer to create a contiguous multi-part vector</li> <li>• Intersected Green/Blue land cover dataset with LSOA's, maintaining land cover type; Calculated areas of resultant polygons intersected with each LSOA</li> <li>• Spatial Joined intersected Green/Blue land cover feature class to LSOA               <ul style="list-style-type: none"> <li>• Replaced LSOA rows with "null" values in RFSWE area field with zero (values read as "null" when no RFSWE polygon area is present within a LSOA)</li> </ul> </li> <li>• Calculated proportion of Green/Blue land cover area within LSOA Area (dividing Green/Blue land cover area by LSOA area, multiplied by 100 to calculate percentage)</li> <li>• Resultant feature class visualizes the <b>percentage of the LSOA area that consists of Green/Blue land cover</b></li> </ul>
DATA SOURCES	
Source	GLA
Citation	Greater London Authority (2019). London Green and Blue Cover. Greater London Authority. Dataset. Available from: <a href="https://data.london.gov.uk/dataset/green-and-blue-cover">https://data.london.gov.uk/dataset/green-and-blue-cover</a>
License	© Environment Agency copyright and/or database right 2015
Data type	Vector
Year of publication	2019
Temporal Resolution	2016

## IV. Outputs

The primary output for this project is a series of three pan-London Climate Risk Maps, provided in raster format, with risk scores assigned to Hexes across London. Each of the three maps (the Overall Climate Risk Map, the Flood Risk Map, and the Heat Risk Map) were created using a unique set of exposure and vulnerability metrics to produce a final decision map, which highlights areas of higher and lower risk, relative to the values mapped across London’s hex grid.

In addition to this metadata guide, a package of the original data tables used to create individual metric layers is available for download on the London Datastore (.xlsx or .csv tables are available for any population data used, while raster images or shapefiles were used for others). The available tables display data collected from their original geographies (i.e., Output Area, LSOA, or MSOA).

### Symbology + Risk Scores

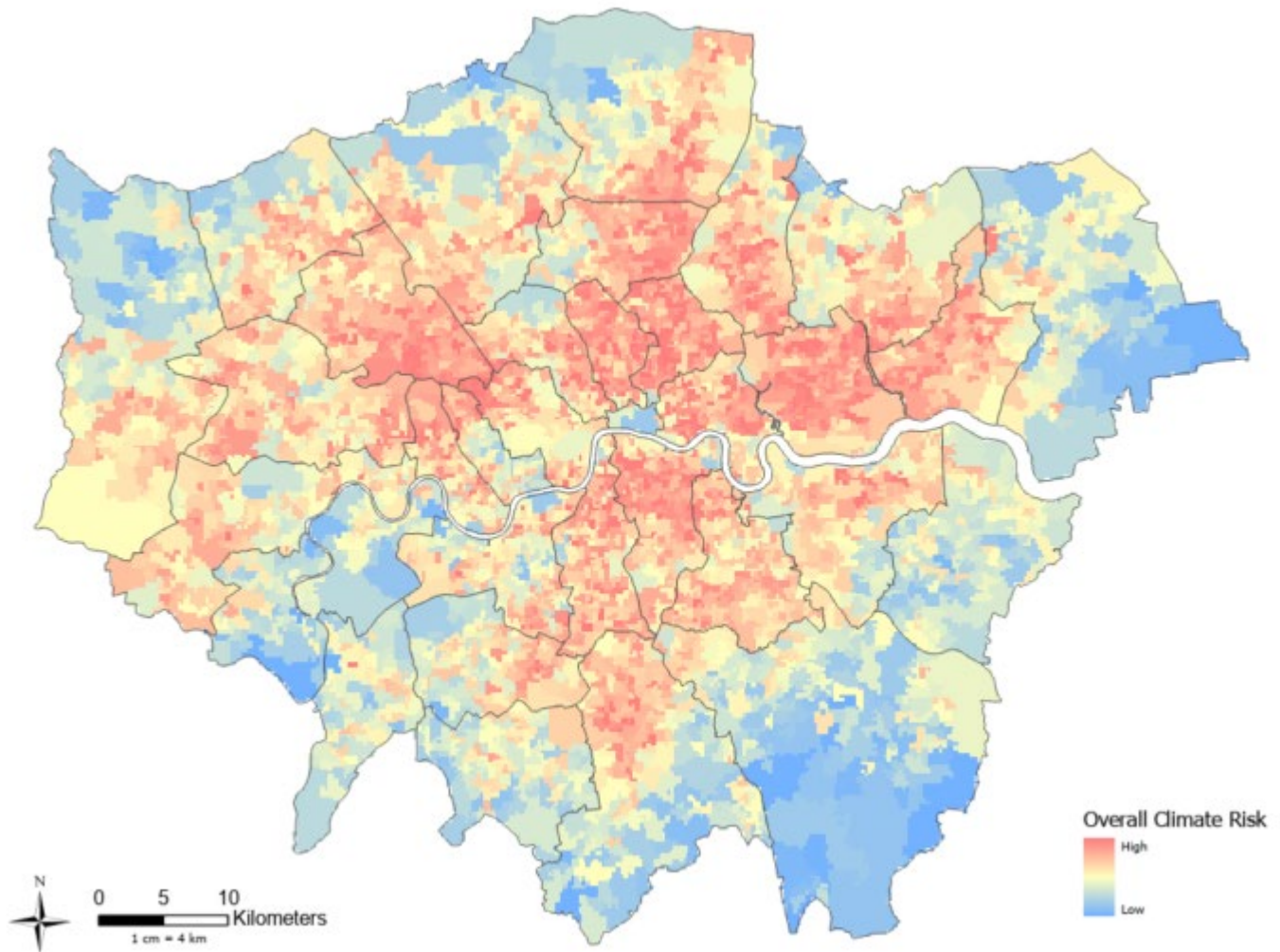
The symbology used for the Climate Risk maps highlights areas with “low” to “high” risk scores across London using a sliding color scale. All scores are relative to each other; blue hexes indicate areas with lower risk scores, and red hexes indicate areas with higher risk scores. The minimum and maximum scores vary for each map, as the set of metric input layers vary for each map.

It is important to note that these scores have not been normalized or manipulated to hold significant meaning on their own. It is not recommended that raw scores be displayed to the general public; when taken out of context, the scores hold little meaning.

### Climate Risk Map Rasters

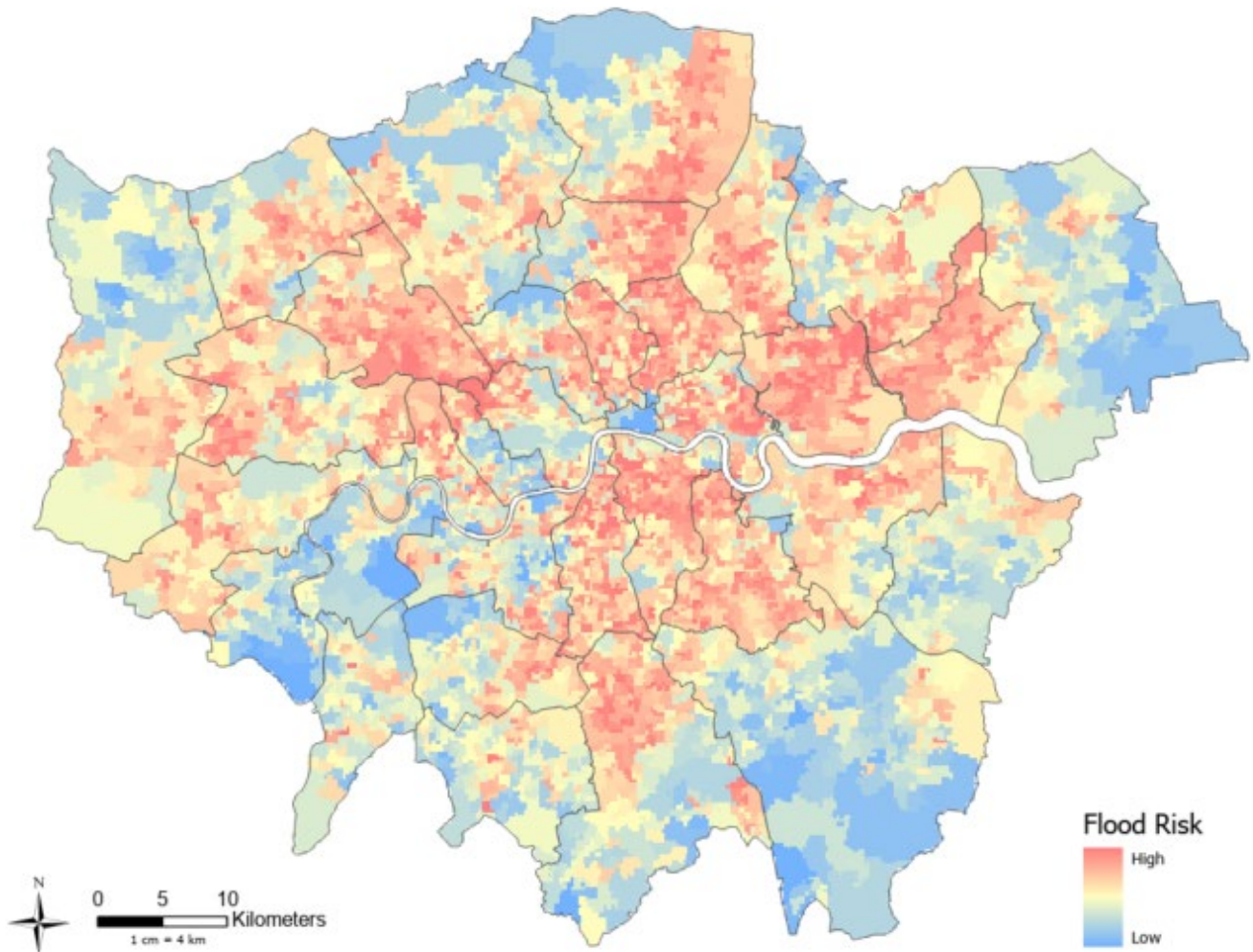
The following Climate Risk Maps are available for download in raster format on the London Datastore.

## Overall Climate Risk Map



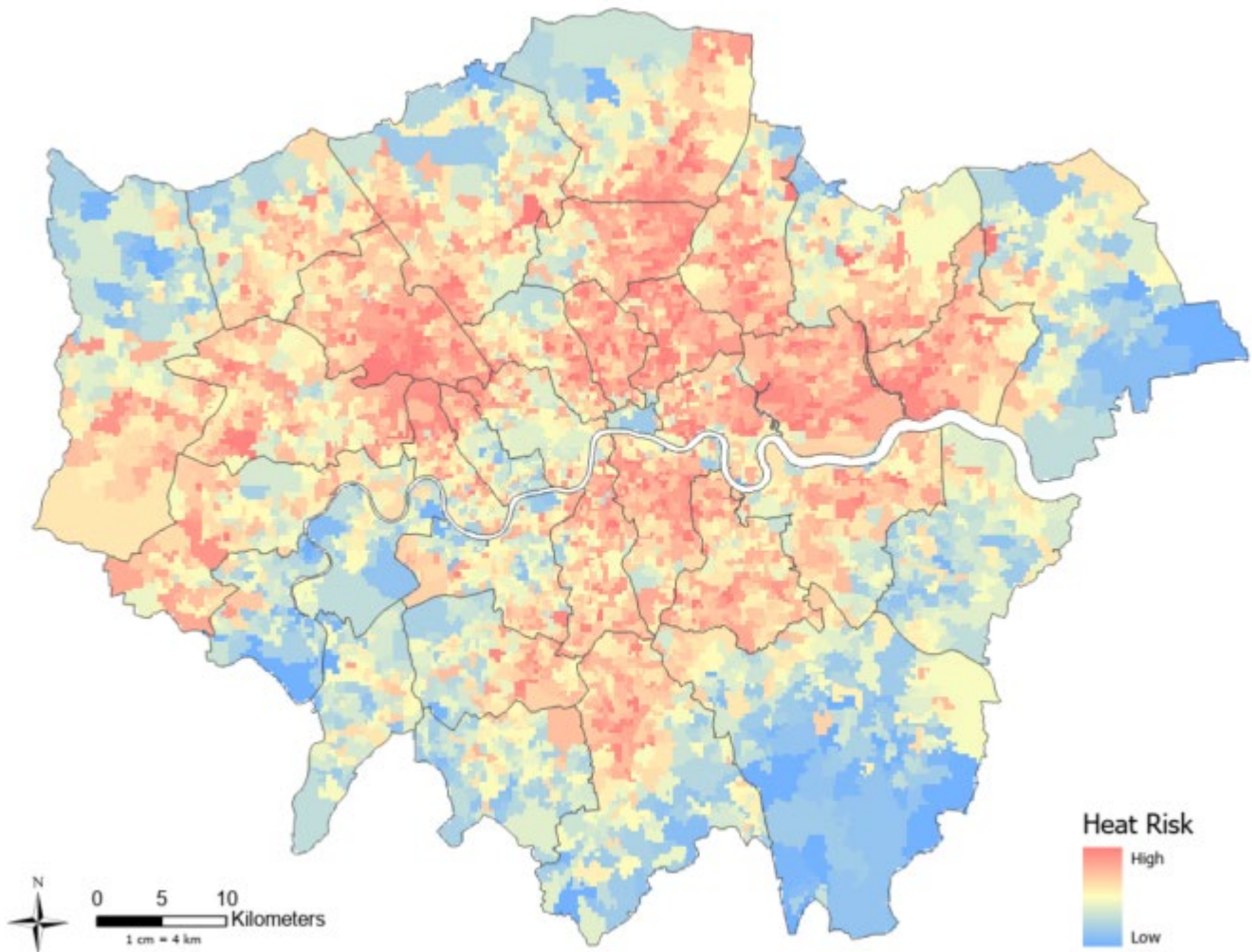
The **Overall Climate Risk map** was created using 12 of the 13 metrics:  
Ages Under 5, Ages Over 75, English Proficiency, Income Deprivation, Social Renters, BAME, Average Land Surface Temperature, Surface Water Flood Risk, PM2.5, NO2, Green/Blue Land Cover, Areas of Deficiency in Access to Public Open Space

## Flood Risk Map



The **Flood Risk map** was created using 9 of the 13 metrics:  
Ages Under 5, Ages Over 75, English Proficiency, Income Deprivation, Social Renters, BAME, Surface Water Flood Risk, Green/Blue Land Cover, Areas of Deficiency in Access to Public Open Space

## Heat Risk Map



The **Heat Risk map** was created using 11 of the 13 metrics:  
Ages Under 5, Ages Over 75, English Proficiency, Income Deprivation, Social Renters, BAME, Average Land Surface Temperature, PM2.5, NO2, Tree Canopy Cover, Areas of Deficiency in Access to Public Open Space

## V. Conclusion

### Limitations of the Methodology

The methodology used for this study allows for the analysis of multiple metrics in combination with each other across London. However, it is not recommended that these London-wide maps be used for neighbourhood-level decision making, given the geospatial manipulation of datasets to assess climate risk at the citywide-scale.

Some degree of accuracy is always lost when manipulating spatial data from one geography to another. All datasets used in this study were converted to LSOA geographies from different statistical boundaries or other data types. The uniform LSOA geography is larger than some geographic scales available for use, and re-aggregating datasets to this uniform geography inevitably reduces the small-scale accuracy of the analysis.

However, the methodology does not require all inputs to be aggregated to the same geography. The same study could be conducted using datasets aggregated to their original geographies. While this would increase the geospatial accuracy of the outputs, it would be more difficult to highlight and analyze trends at a citywide scale.

### Future Uses of Data

The Climate Risk maps produced for this project are actively being used to inform new and ongoing initiatives by the GLA aimed at addressing climate change and supporting climate resilience. While it is not recommended that these maps be used as sole determinants for project direction and implementation, they can serve as a supplementary reference when identifying priority areas for targeting resources. These maps are meant to serve as a first iteration of an evolving methodology for Climate Risk analysis for London.

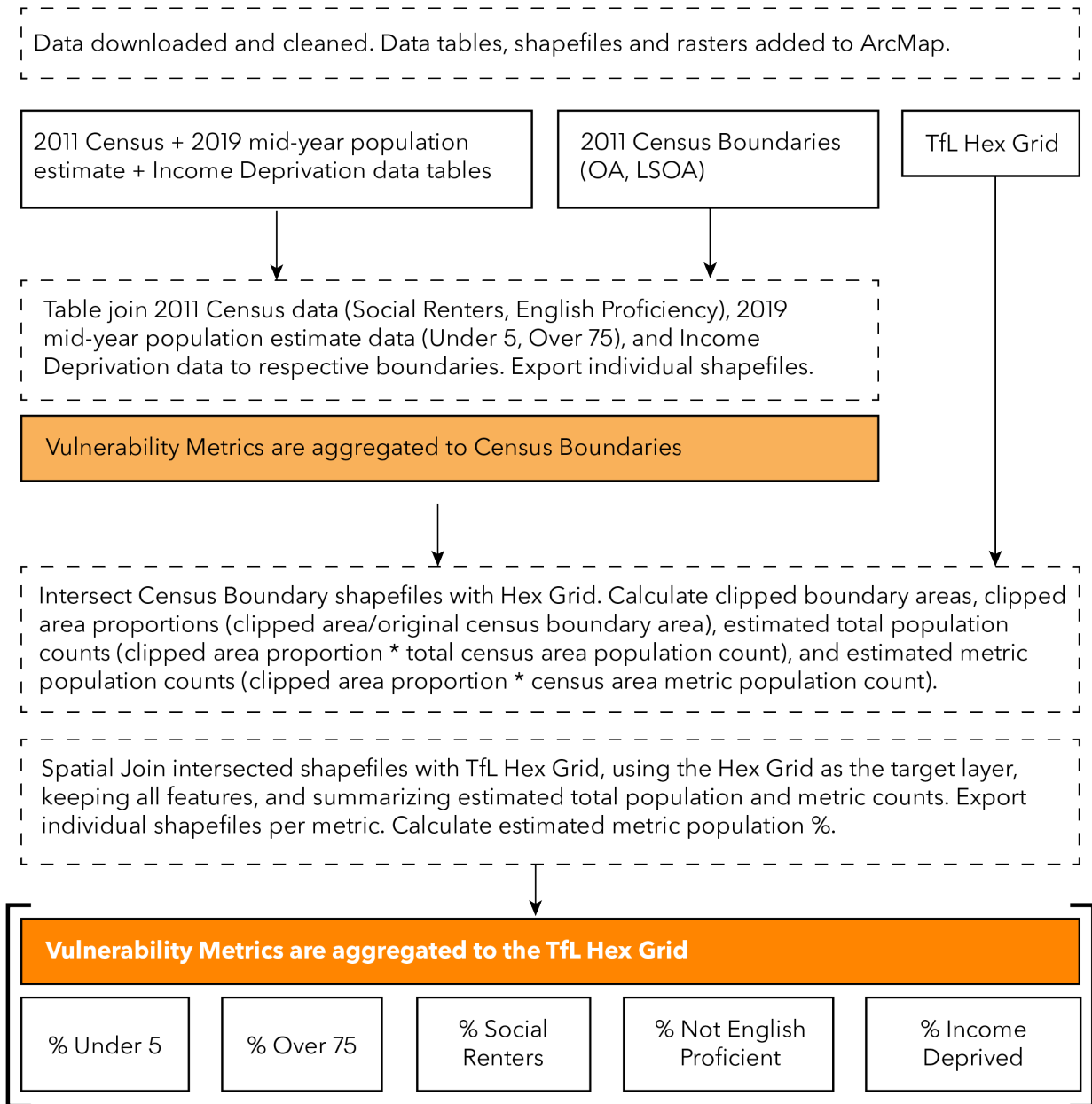


## VI. Appendix

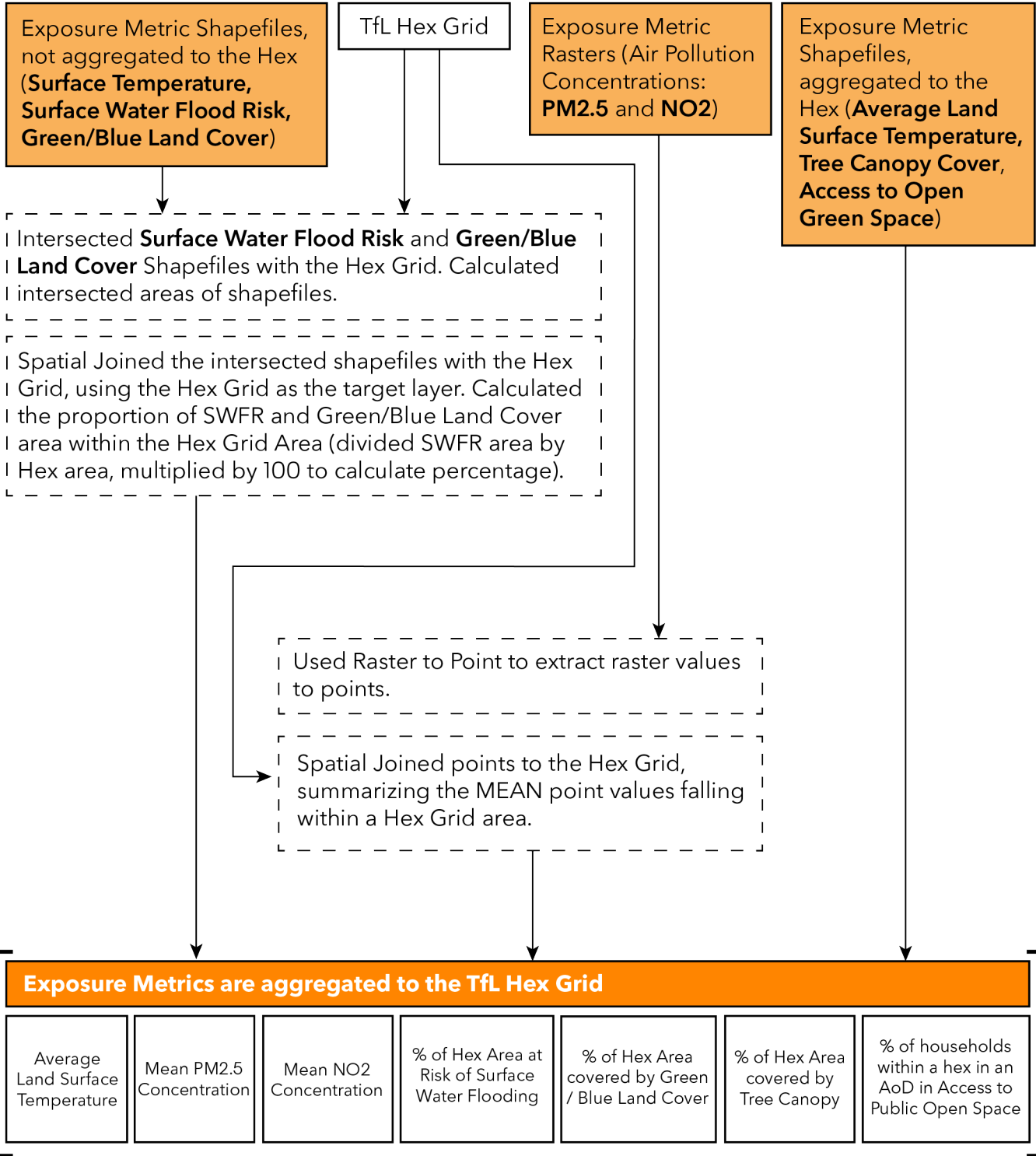
METRIC	EVIDENCE SUPPORTING USE OF THIS VARIABLE
Young children (% under 5 years)	Research has shown that young children and babies face disproportionate health effects from climate-related impacts relative to many adults, as they are more biophysically susceptible to hazards (Vardoulakis & Heaviside, 2012). Young children are more likely to be affected by hot weather because their bodies create more heat energy, they sweat less, and dehydration affects them more quickly compared to healthy adults (Public Health England, 2014).
Elderly people (% over 75 years)	Conclusive evidence reveals that older people, particularly those over 75, consistently face more severe impacts because of heatwaves (Vardoulakis & Heaviside, 2012) (Hames et al., 2012). A range of characteristics increase their vulnerability, such as being socially isolated, being in ill-health, having lower personal mobility, living in certain types of housing, or having low income (Haq et al., 2008).
Not English Proficient (% unable to speak English well or at all)	People who cannot read, write, and/or speak English or who are less proficient in English are more likely to have difficulty obtaining and using information and guidance provided to the public (Lindley et al., 2011).
Black, Asian and Mixed Ethnicities (% of BAME population)	Population of non-white race or ethnicities according to research have been known to live in areas with vulnerable areas that are easily affected by climate change, mobility, ability to afford proper housing or infrastructure.
Social Renters (% of households categorized as social renters)	Social housing tenants may encounter difficulties in preparing for and responding to flooding due to their living arrangements and because they are likely to have a low income. Tenants are often not allowed to make physical alterations to their properties, and leaseholders may be disinclined to make these alterations as they may not feel the additional expense is not worthwhile given that they do not own the property (Combined 'Info Sheets', 2018).
Income Deprivation (% income deprived)	Poverty is an important determinant of how well people can prepare for, respond to, and recover from climate-related events. People on low incomes are more likely to have a lower adaptive capacity to heatwaves because they lack both the resources to act and the power to make changes. Additionally, low-income households are less likely to have the capacity to fully prepare for floods (through insurance and property level measures). They are also more likely to be displaced as a result of flooding (Combined 'Info Sheets', 2018).

METRIC	EVIDENCE SUPPORTING USE OF THIS VARIABLE
Surface Temperature	Understanding land surface temperature (LST), a measurement of the temperature of the Earth’s surface, can help to inform how hot or cold a specific location is relative to its surroundings. Elevated urban temperatures can have a direct impact on people’s health and wellbeing. Research funded by the Department of Health in the UK indicates that over 7,000 people could die from the effects of urban heat waves per year by the 2050s (House of Commons, 2018). Elevated urban temperatures can also impact air and water quality, and demands for energy, with implications for carbon neutral targets, public health, strategic planning and city resilience (Nation-wide heat hazard, 2020).
Flood Risk from Surface Water	‘Pluvial’ (rain-related) floods, which occur following short intense downpours, cannot be quickly enough evacuated by the drainage system or infiltrated to the ground, particularly in built-up urban areas. Pluvial floods often occur with little warning in areas not obviously prone to flooding, and they have recently been identified as the type most likely to increase in severity as a result of climate change. They are also the most difficult to manage because they are difficult to predict and it is challenging to provide adequate warning times (Houston et al., 2011).
Air Pollution Concentrations: PM2.5	A City Hall commissioned report estimated over 9,000 Londoners died prematurely from long-term exposure to air pollution in 2010. Two pollutants are of specific concern: particulate matter (PM10, PM2.5, and black carbon) and nitrogen dioxide (NO2). Particulate matter is damaging to health at any level and must be reduced (London Environment Strategy, 2018). Further, elevated air pollution levels and high temperatures have been associated with the increase in urban heat islands and air pollution in London, England (McMichael et al., 2003; Rooney, McMichael, Kovats, & Coleman, 1998).
Air Pollution Concentrations: NO2	In London, road transport and heating systems are the main sources of nitrous oxide (NOx) emissions. NOx is primarily made up of two pollutants: nitric oxide (NO) and nitrogen dioxide (NO2). NO2 is of most concern due to its impact on health. However, NO easily converts to NO2 in the air, so to reduce concentrations of NO2, it is essential to control emissions of NOx. London is failing to meet the legal limit for NO2 (London Environment Strategy, 2018).
Green/Blue Land Cover + Tree Canopy Cover	London’s green and blue land cover - its parks, green spaces, trees, rivers, wetlands and green roofs – can reduce the impacts of climate change and help to store carbon. It can improve air quality and water quality. It can promote healthier lives, reduce car dependency and encourage more walking and cycling. It can improve biodiversity and ecological resilience (London Environment Strategy, 2018).
Areas of Deficiency in Access to Public Space	Some parts of London have more green spaces than others, but almost half of Londoners have poor access to parks. Councils now have less money to spend on maintaining parks, so their quality has declined in some places. Access to good quality green space and living in greener neighborhoods can have a big impact on people’s health and quality of life, and on how attractive a place London is in which to live, visit and do business (London Environment Strategy, 2018).

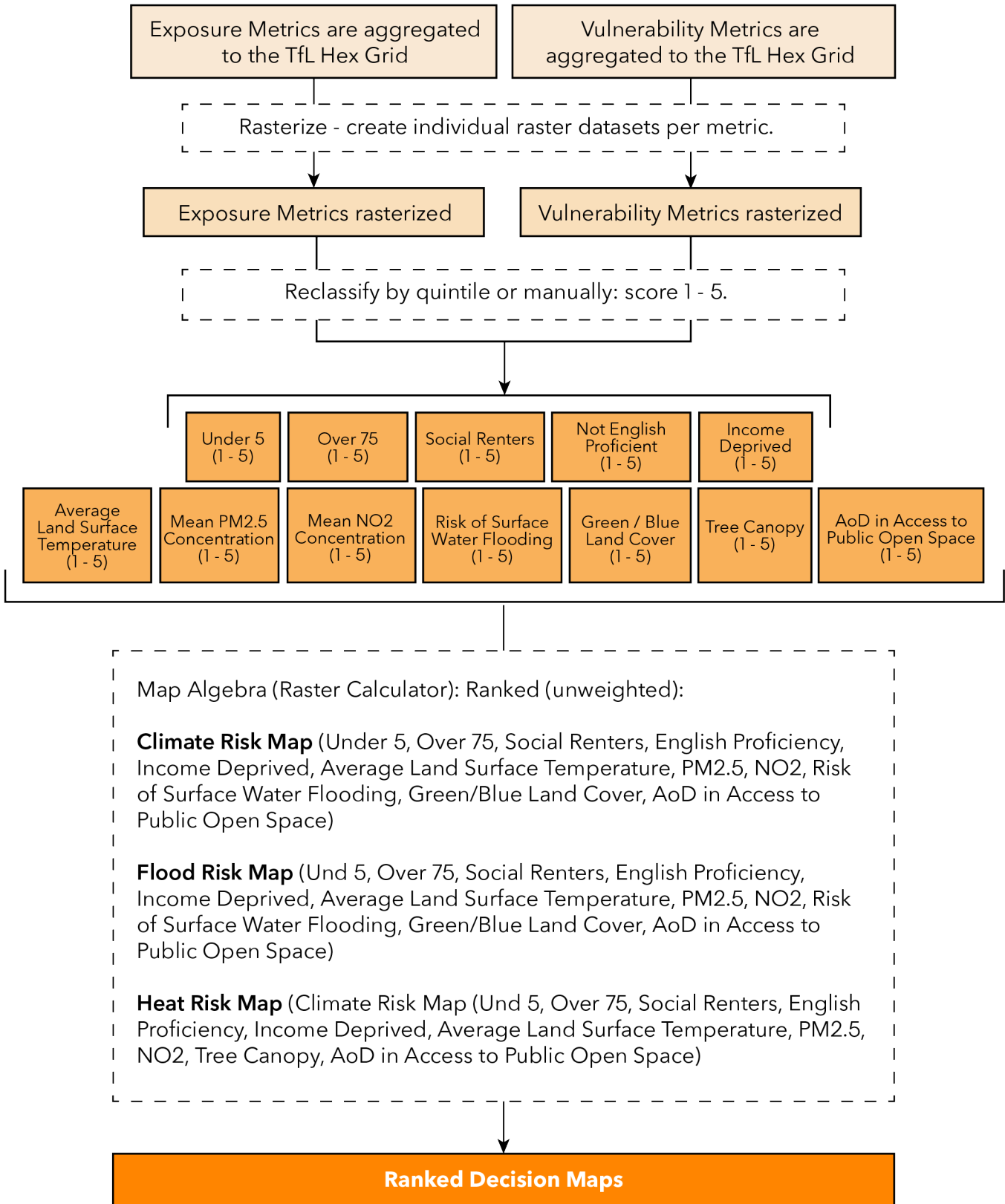
# Original Hex Grid Maps & Methodology

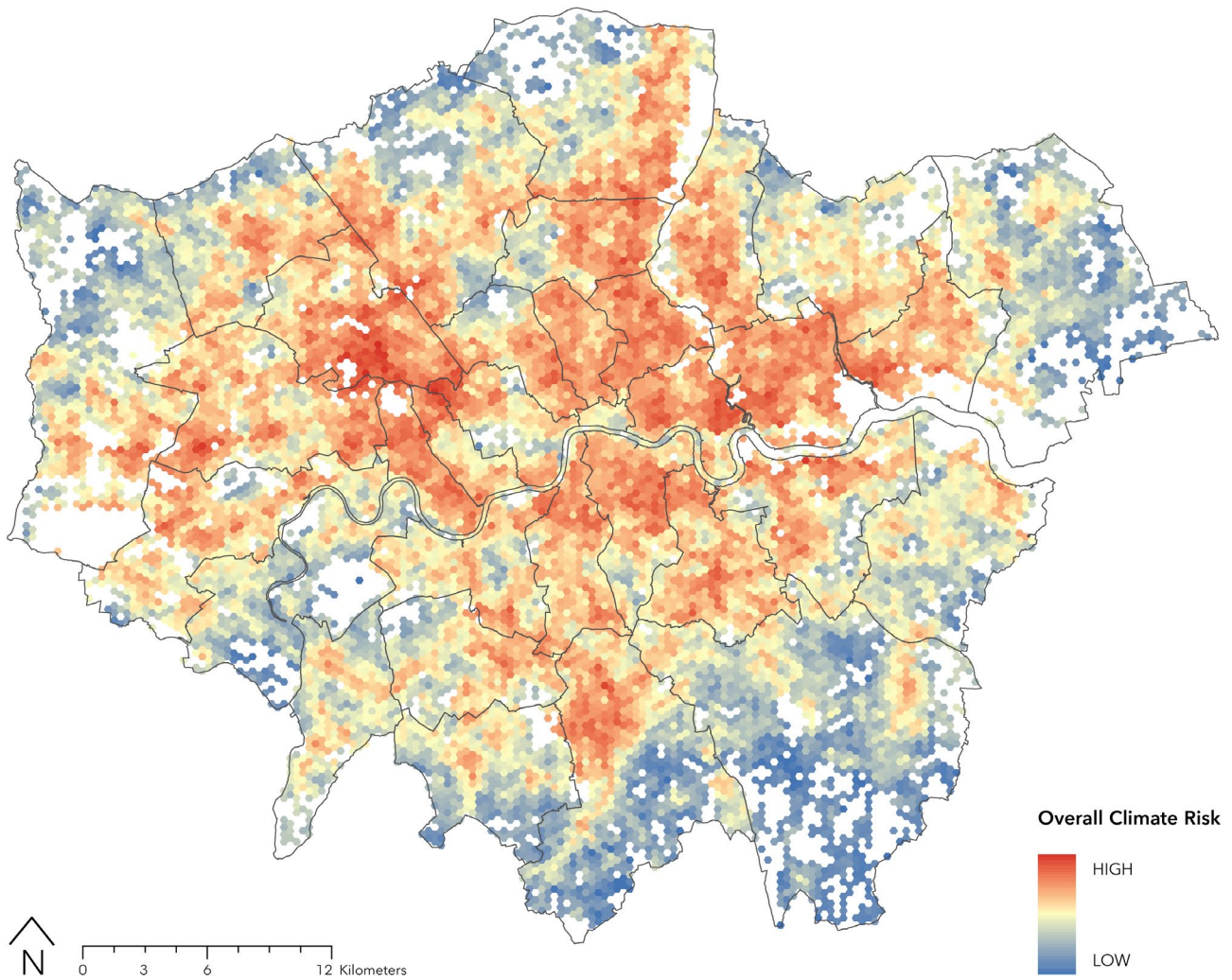


Data downloaded. Shapefiles and rasters added to ArcMap.



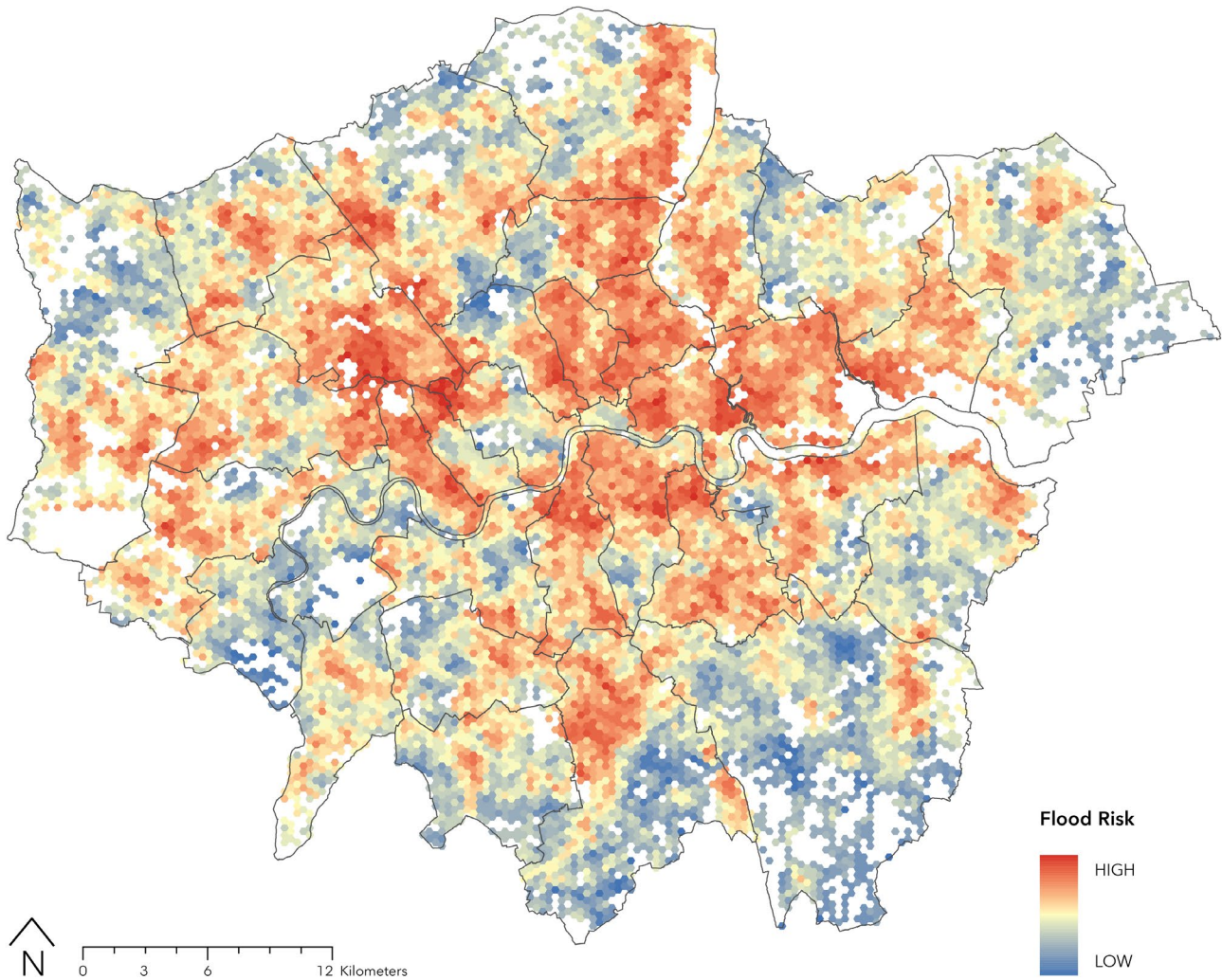
## Creating Decision Maps





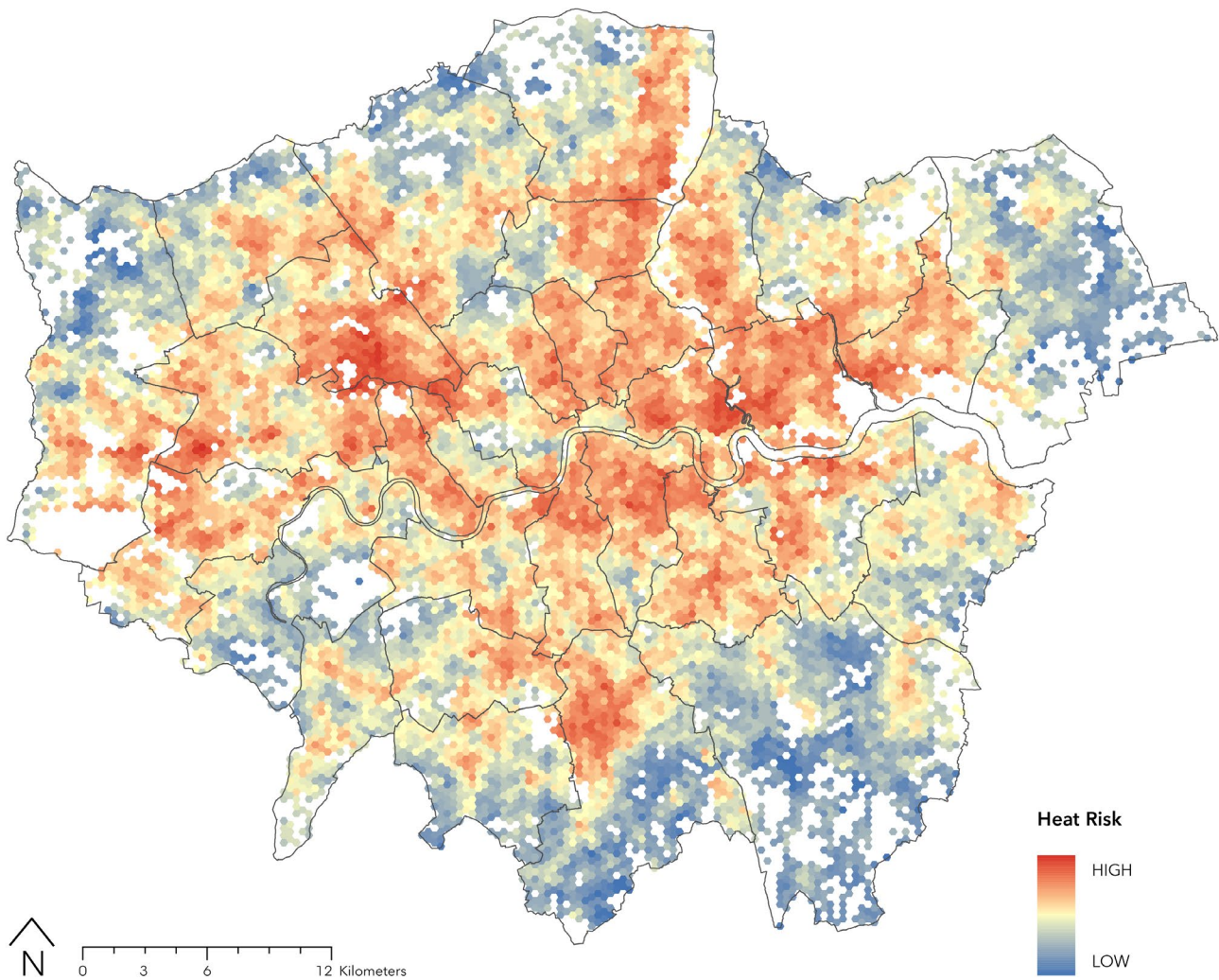
The **Overall Climate Risk map** was created using 11 of the 12 metrics:  
Ages Under 5, Ages Over 75, English Proficiency, Income Deprivation, Social Renters, Average Land Surface Temperature, Surface Water Flood Risk, PM2.5, NO2, Green/Blue Land Cover, Areas of Deficiency in Access to Public Open Space

## Flood Risk Map



The **Flood Risk map** was created using 6 of the 12 metrics: English Proficiency, Income Deprivation, Social Renters, Surface Water Flood Risk, Green/Blue Land Cover, Areas of Deficiency in Access to Public Open Space

## Heat Risk Map



The **Heat Risk map** was created using 10 of the 12 metrics:  
Ages Under 5, Ages Over 75, English Proficiency, Income Deprivation, Social Renters, Average Land Surface Temperature, PM2.5, NO2, Tree Canopy Cover, Areas of Deficiency in Access to Public Open Space



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The High Resolution Intra-Urban Temperature Variability information layer for Greater London Area was produced by ARTi Analytics BV as part of EXTREMA Global portfolio of services.

