Greenham, SV., Ferranti, EJS., Cork, NA., Jones, SA., Zhong, J., Haskins, B., Higgins, W., Grayson, N., Needle, S., Acton, WJF., MacKenzie, AR., Bloss, WJ., 2024. Mapping climate risk and vulnerability in the West Midlands. A guidance document produced by the WM-Air project, University of Birmingham. Funding provided by NERC innovation grant NE/S003487/1. Ferranti acknowledges EPSRC Fellowship EP/R007365/1.
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MAPPING CLIMATE RISK AND VULNERABILITY IN THE WEST MIDLANDS

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A guidance document from the WM-Air project

Version 1.0 November 2024

The climate is changing. As mean global surface temperatures rise, it brings changes to the climate and weather patterns. In the West Midlands, the likely changes are warmer, wetter winters; hotter, drier summers; and more extreme weather events.

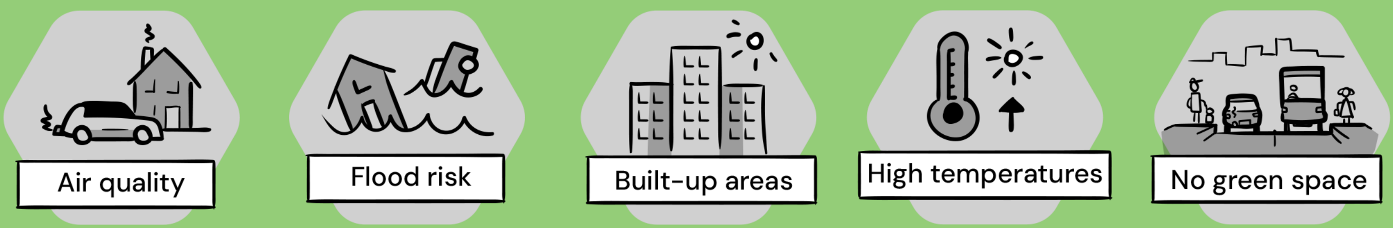
We need to adapt to a changing climate. Some of the weather events we are currently experiencing is unprecedented. Without adaptation, people, infrastructure and the natural environment are more at risk to the impacts of climate change.

The impacts of climate change are felt differently across the West Midlands, as climate hazards and socio-economic factors affecting people's ability to cope are unevenly spread across the region. It is therefore important to understand the spatial patterns.

Modern society faces several challenges. These include more people living in cities[1], income and wealth inequality[2], increases in the cost of living[3], as well as the changing climate[4]. Below are examples of five hazards connected to these challenges, which are all interlinked.

These challenges do not affect all people and places equally. Those of disadvantaged socio-economic backgrounds may have less ability to cope with hazards and are therefore more likely to be more negatively affected by climate change[5].

Hazards



Climate change brings about many different impacts on people. On the right are eight examples of these, which citizens must be protected from as much as possible. To achieve this, local and regional authorities that make decisions for its citizens need to know where climate risk is greatest so appropriate actions can be taken.

This guidance document describes the methodology used to develop a Climate Risk and Vulnerability Assessment map for the West Midlands; co-created by the WM-Air project group and the West Midlands Combined Authority (WMCA).

Climate impacts on people include:

- Respiratory diseases
- Poorer mental health
- Cardiovascular diseases
- Vector-borne diseases
- Loss of income
- Damage or loss of homes and possessions
- Overheating risk
- Bacterial and viral infections

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HOW IS THE CRVA MAP BUILT FOR THE WEST MIDLANDS?

A CRVA map requires several layers of data that would contribute to climate risk. The data parameters build a picture of climate risk as a function of data representative of **Hazards**, e.g. flood zones, temperature; **Vulnerability**, e.g. social, economic and demographic variables; and **Exposure**, e.g. population density. Each data layer is standardised in terms of both spatial scale and values. Then, they can be easily combined into one single layer that represents the total climate risk across the map. Therefore, it is important to note that this CRVA map is not an absolute assessment of climate risk and vulnerability, but only relative within the boundary of the area being assessed, which in this case, is the West Midlands regional boundary. This means that it is not directly comparable with other areas.

What tools and functions are required for a CRVA map?

A Geographic Information System (GIS) application is required to build a CRVA map. Throughout this guidance document, the Quantum GIS (QGIS)[6] free, open-source application was used; the approach is also compatible with ArcGIS. Several functions are used, but the main CRVA build uses raster (or matrix) algebra. Data layers are divided into small grids (cells) of equal dimension (in this case, 100m x 100m), with each cell comprising a single value.

Data used for this CRVA map of the West Midlands

This CRVA map comprises several datasets to produce 24 underlying layers that form the final CRVA map, shown in Table 1. Most data are open source or publicly available, so it is a replicable process for other regions or local authorities to produce a similar CRVA map. Developing a CRVA map is a cycle, shown in Figure 1. It works through four stages: (i) data collection, (ii) the scoring and layering of the data, (iii) the publication of the maps and (iv) adaptation engagement. This process is then repeated when new data are available and the map can then be updated.

Why is a CRVA map important for the West Midlands?

The West Midlands conurbation is the second most populous metropolitan county in the United Kingdom. While it has undergone substantial redevelopment in recent decades, challenges remain, such as climate impacts, socio-economic deprivation, public health issues, and poor housing quality[7]. The CRVA map provides a means of understanding where challenges may be concentrated. This may help the WMCA, with supporting evidence for climate change adaptation reporting to the Government under the Climate Change Act 2008[8], and monitoring progress against the West Midlands Climate Change Adaptation Plan[9].

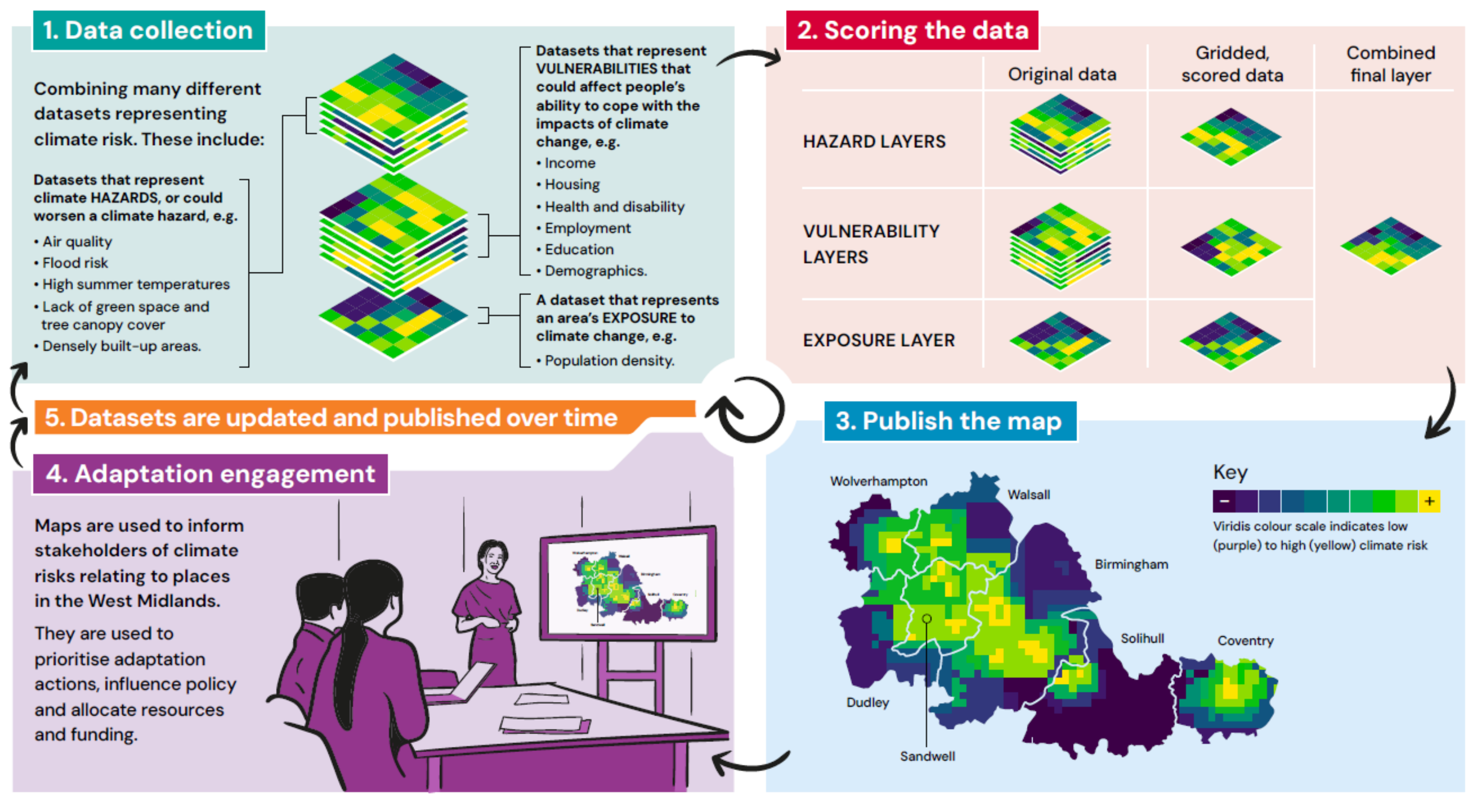

Figure 1. The cyclical process of developing a CRVA map

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Table 1. Key information on each layer used to build the CRVA map

Layer	Data type	Layer score parameters
Nitrogen dioxide (NO_2) concentration[10]	**Hazard**	Mean annual concentration per grid square; binned into 20 quantiles
Annual fine particulate ($PM_{2.5}$) concentration[10]	**Hazard**	Mean annual concentration per grid square; binned into 20 quantiles
Fluvial flood risk[11-13]	**Hazard**	% coverage per grid square by flood risk; binned into 20 quantiles
Pluvial flood risk[14-16]	**Hazard**	% coverage per grid square by flood risk; binned into 20 quantiles
Open green space deficit[17]	**Hazard**	% coverage per grid square by green space; binned into 20 quantiles
Other green space deficit[18,19]	**Hazard**	% coverage per grid square by green space; binned into 20 quantiles
Tree canopy cover deficit[20]	**Hazard**	% coverage per grid square by tree canopy; binned into 20 quantiles
Local climate zones[21]**	**Hazard**	0 = completely open space, 1 = most densely built-up, high-rise**
Surface temperature (summer daily max)[22]	**Hazard**	Temperature per grid square; binned into 20 quantiles
Households deprived regarding education[23]	**Vulnerability**	% of households in category per grid square, binned into 20 quantiles
Households deprived regarding employment[23]	**Vulnerability**	% of households in category per grid square, binned into 20 quantiles
Households deprived regarding health & disability[23]	**Vulnerability**	% of households in category per grid square, binned into 20 quantiles
Households deprived regarding housing[23]	**Vulnerability**	% of households in category per grid square, binned into 20 quantiles
Households with dependent children under 15 years[23]	**Vulnerability**	% of households in category per grid square, binned into 20 quantiles
Households of single occupancy over 65 years[23]	**Vulnerability**	% of households in category per grid square, binned into 20 quantiles
Population of ethnic minority[23]	**Vulnerability**	% of population in category per grid square, binned into 20 quantiles
Population whose main language is not English[23]	**Vulnerability**	% of population in category per grid square, binned into 20 quantiles
Households with no access to a car or van[23]	**Vulnerability**	% of households in category per grid square, binned into 20 quantiles
Households who do not own their property outright[23]	**Vulnerability**	% of households in category per grid square, binned into 20 quantiles
Average annual household income[24]	**Vulnerability**	Mean income per grid square, binned into 20 quantiles
Average net disposable household income[24]	**Vulnerability**	Mean income per grid square, binned into 20 quantiles
% of household income that is disposable[24]	**Vulnerability**	Mean % of income per grid square, binned into 20 quantiles
% of household income spent on travel to work[24]	**Vulnerability**	Mean % of income per grid square, binned into 20 quantiles
Population density[22]	**Exposure**	Mean population density per grid square, binned into 20 quantiles

* Lower resolution open data is available from DEFRA[25]
** See Greenham et al.[26] for the local climate zone breakdown and assigned CRVA scores

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PRODUCING THE CRVA MAP

The step-by step processes in QGIS to produce each underlying layer at the standardised 100m resolution in raster format are outlined in Table 2. Once the layers for each variable are created, those comprising hazard features and vulnerability features are each are summed and rescaled to a score range of 0-1, resulting in two new layers that summarise the combination of hazard and vulnerability data respectively. Only one layer reflects exposure (population density) so no further steps are undertaken.

As shown in box 2 of Figure 1, the combined hazard, combined vulnerability and the exposure layers are combined further to produce the final risk map. This is done via raster algebra in QGIS, using the raster calculator to multiply the three layers together. It produces a final 100m raster layer that can then be rescaled again to create a total risk score range of 0-1 across the West Midlands region. The step-by-step process to create the combined hazard and vulnerability layers, and using these with the exposure data layer to create the final CRVA map for the West Midlands is outlined in Table 3.

Using zonal statistics in QGIS, the 100m raster layer can be aggregated to different area scales. It produces risk scores based on the average of all 100m raster cell scores within each area. Figure 2 shows the average total risk score map for the West Midlands region at Output Area (OA) these are areas of between 40 and 250 households and a resident population typically between 100 and 625 persons[27]. It shows that climate risk and vulnerability are unevenly distributed across the West Midlands. Many areas most at risk are within Birmingham, Sandwell, Coventry, and Walsall.

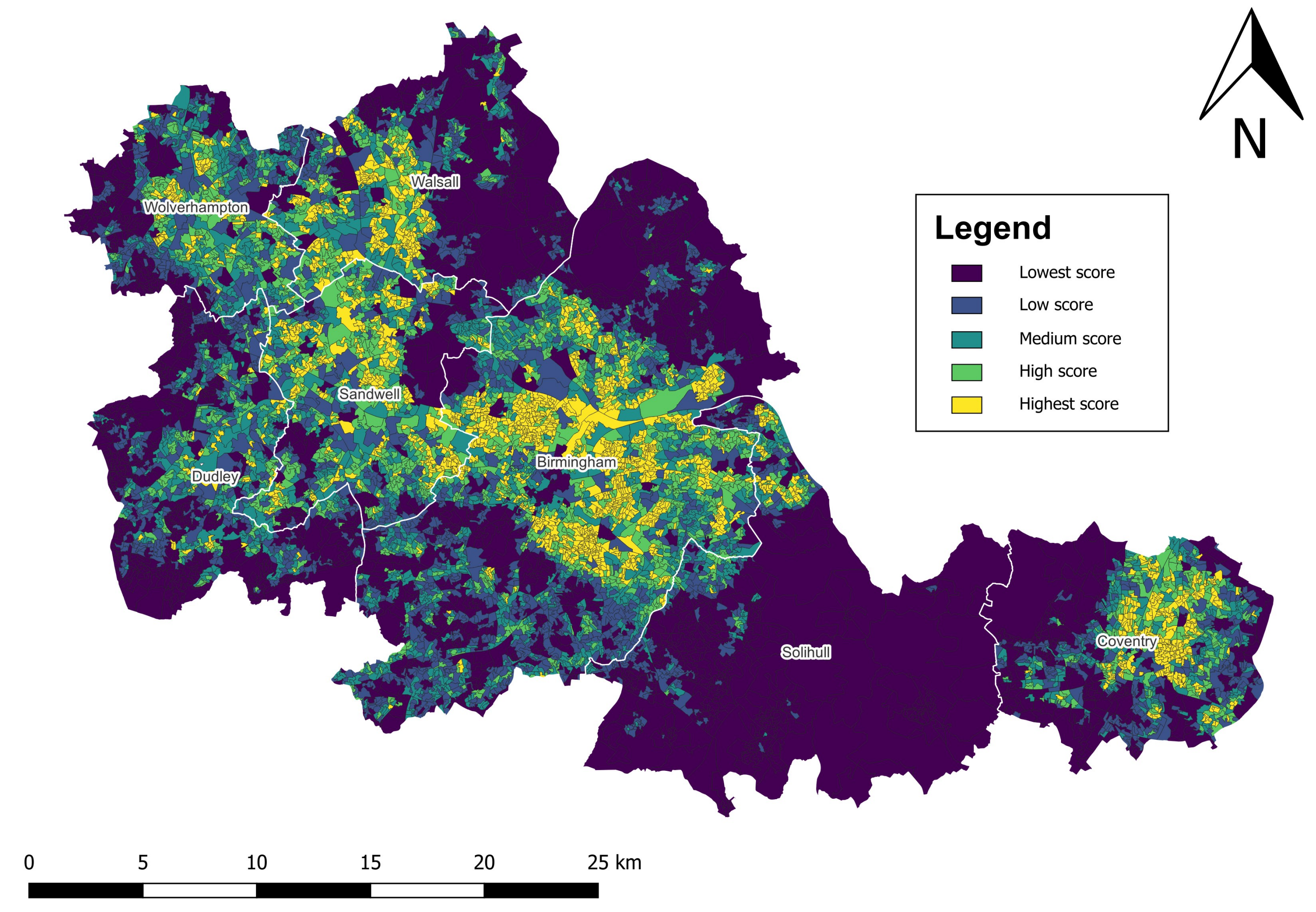

Figure 2. Total CRVA risk map for the West Midlands at OA level. White boundaries and labels denote the 7 constituent Local Authorities.

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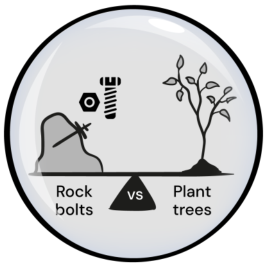
UTILISING THE CRVA MAP: HOW CAN IT HELP?

Monitor and evaluate adaptation progress

An important feature of the climate change adaptation process is that plans are monitored and evaluated[28]. Adaptation works effectively when handled as an iterative process. In a CRVA context, monitoring and evaluation is achievable as data are updated that are fed into the map. As adaptation plans are carried out, these may affect the data that are updated. Consequently, overall CRVA scores may change, and potentially see climate risk reduce over time.

Prioritise adaptation actions

A benefit of the CRVA is that the data layers can be reviewed to better understand what may be primarily influencing the overall scores in different areas. This is particularly useful where areas have similar scores. By reviewing the drivers beneath the scores, decision-makers have greater insight into what might be a more suitable adaptation solution e.g. different tree options or design focused on limiting flood risk in one area compared with air quality/health in another.

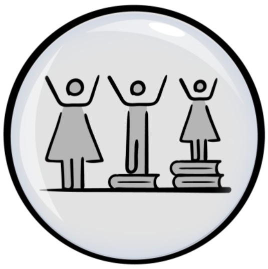


Inform and engage with the community on climate change

Engaging with stakeholders is essential as part of the adaptation process, particularly those directly affected by the impacts of climate change[29]. The CRVA map works as a method of communication to stakeholders to raise awareness in the community regarding climate change. Outcomes could include improving preparedness and response by citizens in the event of an extreme weather event, and may even improve relationships with decision-makers.

Review development proposals

More emphasis is needed in addressing climate risk and vulnerability as part of new development proposals. The CRVA map is a useful tool to review these, particularly for decision-makers in planning. If a new development proposal were located where a CRVA score is high, the underlying layers can be reviewed to ensure that developers design to standards that address specific climate change challenges, so the development helps reduce overall risk.

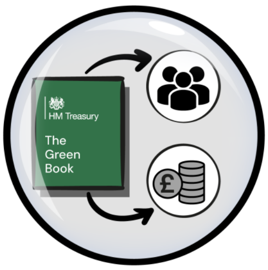


Support inclusive growth

Areas of greater socio-economic deprivation are often disproportionately affected by climate change [30,31]. Although the causes of this are extremely complex, focusing on adaptation in these areas (i.e. those with high overall CRVA scores) helps prevent climate change from further exacerbating existing inequalities. As the most climate vulnerable communities are more disproportionately affected, prioritising them addresses inclusive growth and reducing poverty.

Influence local and regional policy

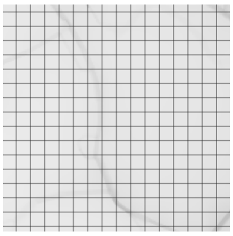
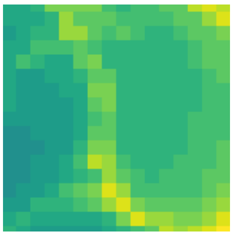
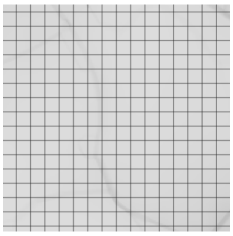
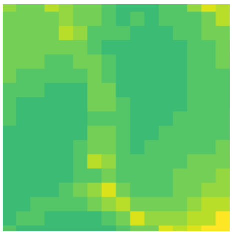
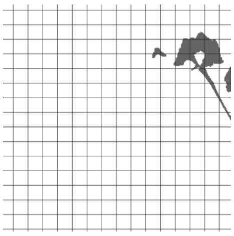
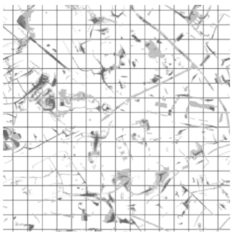
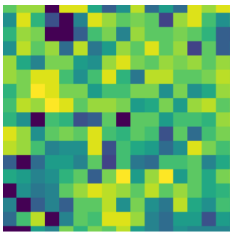
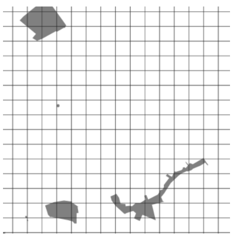
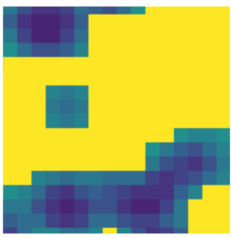
The CRVA map is a clear and simple communication tool. It can help decision-makers both in and outside of climate teams mainstream climate risk and adaptation considerations within their local and regional place-based policies. The CRVA map can encourage a “call to action” to senior representatives on climate-related issues by demonstrating the links across multiple factors of political importance to ensure that climate change issues are addressed.



Allocate resources and funding

Where budgets are fixed or limited, the CRVA map provides a quick-glance overview of the areas most in need of adaptation, in accordance with areas where CRVA scores are overall the highest. Linked to prioritising adaptation actions, decision-makers are then able to review the area and the factors driving the CRVA scores to ensure the appropriate or proportionate levels of funding and resources are allocated, enabling adaptation plans to be delivered.

Table 2. Conversion processes of each layer underpinning the CRVA process

	Data layer	Converted layer	GIS processing
Annual NO_2 concentration			• Reproject using average resampling from current scale using 100m fishnet grid resolution and extent • Clip raster to fishnet grid extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Annual $PM_{2.5}$ concentration			• Reproject using average resampling from current scale using 100m fishnet grid resolution and extent • Clip raster to fishnet grid extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Fluvial flood risk			• Merge EA Flood zone layers then dissolve to "layer" field • Merge BGS and EA flood risk layers so that there are 4 features representing EA Zone 2, EA Zone 3, BGS High potential and BGS low potential • Create "Weight" field and assign a value of 0.25 to EA features and 0.5 for BGS features (as EA Zones 2 and 3 features can overlap). The maximum value will be 1 • Use "union" tool to create duplicate shapes where overlaps occur • Use "aggregate" tool to sum the weightings with grouping expression "geom_to_wkt($geometry)" • Rasterise to a 5m grid with layer extents set to 100m fishnet grid to align grids and use "maximum" function • Use Zonal Statistics to read mean values into the 100m fishnet grid then rasterise • Clip raster to fishnet grid extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Pluvial flood risk			• Merge all downloaded shapefiles for region (repeat for each risk level: 1 in 30, 100 and 1000) • Dissolve (to "layer" and "hazard" fields) • Use field calculator to create a numerical hazard field from 1 (Low) to 4 (High) • Create "likelihood" field using "layer" field as guide (1in30, 1in100 or 1in1000) • Use extract by attribute for each likelihood, then rasterize to a 5m grid, using 100m fishnet grid extents • Sum all three layers using raster calculator (maximum value will be 12) • Use Zonal Statistics to read mean values into the 100m fishnet grid then rasterize • Clip raster to fishnet grid extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Open green space deficit			• Rasterise using 100m fishnet grid resolution and extent • Replace null values with 0 • Use raster calculator to inverse values (1 - raster) • Clip raster to fishnet grid extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)

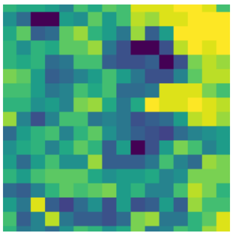
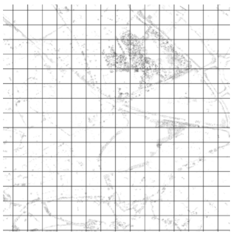
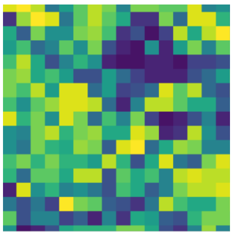
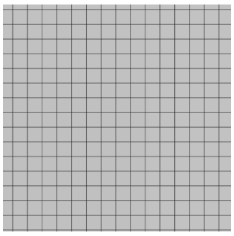
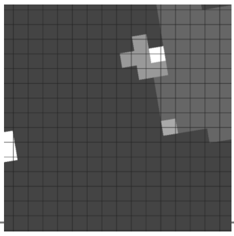
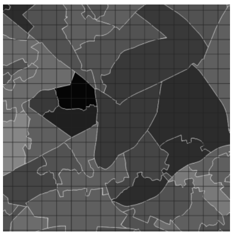
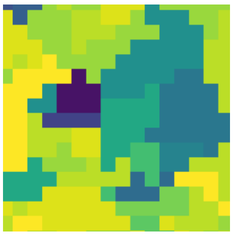
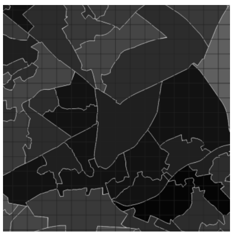
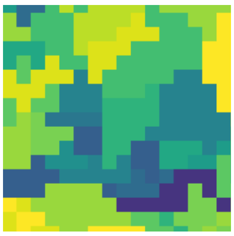
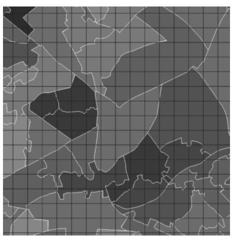
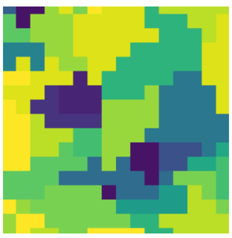
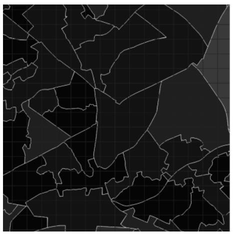
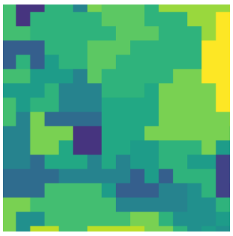
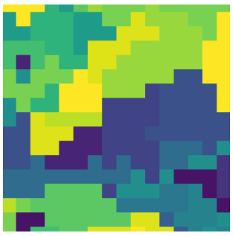
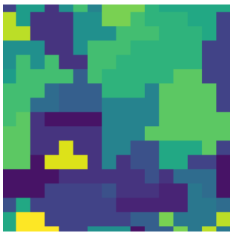
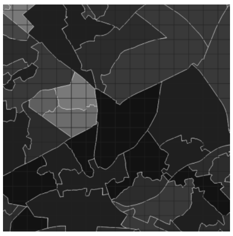
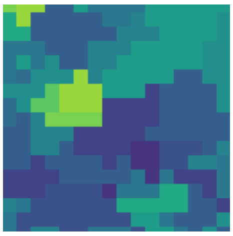
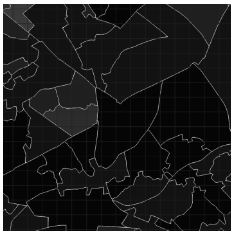
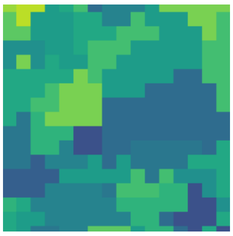
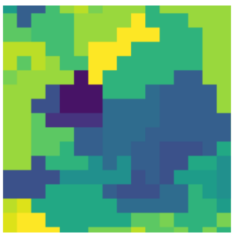
	Data layer	Converted layer	GIS processing
Other green space deficit			• Filter UKCEH data by green space, vectorise and dissolve • Clip raster to fishnet grid extent • Merge vectorised UKCEH data with OS Mastermap data • Rasterise using 100m fishnet grid resolution and extent • Replace null values with 0 • Use raster calculator to inverse values (1 - raster) • Clip raster to fishnet grid extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Tree canopy cover deficit			• Use raster calculator to convert to binary form ((((raster > 0) = 1) + ((raster = 0) = 0) / 2) • Reproject using average resampling from current scale using 100m fishnet grid resolution and extent • Clip raster to fishnet grid extent • Use raster calculator to inverse values (1 - raster) • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Surface temperature			• Reproject using bilinear interpolation resampling from current scale using 100m fishnet grid resolution and extent • Clip raster to fishnet grid extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Local climate zone			• Reproject to the GB coordinate reference system (EPSG:27700/OSGB 1936) to 100m cell resolution using fishnet grid extent • Reproject using nearest neighbour resampling using 100m fishnet grid resolution and extent • Clip raster to fishnet grid extent • Reclassify by table (see Table 3 of Greenham et al., 2023[26])
Households deprived regarding education			• In the .csv file, calculate the % of each OA that falls into the criteria • Join .csv file to OA boundary vector file by OA name • Join to grid - 100m fishnet grid by majority score according to OA area intersecting the fishnet grid • Rasterise using 100m fishnet grid resolution and extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Households deprived regarding employment			• In the .csv file, calculate the % of each OA that falls into the criteria • Join .csv file to OA boundary vector file by OA name • Join to grid - 100m fishnet grid by majority score according to OA area intersecting the fishnet grid • Rasterise using 100m fishnet grid resolution and extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Households deprived regarding health and disability			• In the .csv file, calculate the % of each OA that falls into the criteria • Join .csv file to OA boundary vector file by OA name • Join to grid - 100m fishnet grid by majority score according to OA area intersecting the fishnet grid • Rasterise using 100m fishnet grid resolution and extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)

Table 2. Conversion processes of each layer underpinning the CRVA process

	Data layer	Converted layer	GIS processing
Households deprived regarding housing			• In the .csv file, calculate the % of each OA that falls into the criteria • Join .csv file to OA boundary vector file by OA name • Join to grid - 100m fishnet grid by majority score according to OA area intersecting the fishnet grid • Rasterise using 100m fishnet grid resolution and extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Households with dependents under 15 years			• In the .csv file, calculate the % of each OA that falls into the criteria • Join .csv file to OA boundary vector file by OA name • Join to grid - 100m fishnet grid by majority score according to OA area intersecting the fishnet grid • Rasterise using 100m fishnet grid resolution and extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Households of single occupancy over 65 years			• In the .csv file, calculate the % of each OA that falls into the criteria • Join .csv file to OA boundary vector file by OA name • Join to grid - 100m fishnet grid by majority score according to OA area intersecting the fishnet grid • Rasterise using 100m fishnet grid resolution and extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Population of ethnic minority			• In the .csv file, calculate the % of each OA that falls into the criteria • Join .csv file to OA boundary vector file by OA name • Join to grid - 100m fishnet grid by majority score according to OA area intersecting the fishnet grid • Rasterise using 100m fishnet grid resolution and extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Population whose main language is not english			• In the .csv file, calculate the % of each OA that falls into the criteria • Join .csv file to OA boundary vector file by OA name • Join to grid - 100m fishnet grid by majority score according to OA area intersecting the fishnet grid • Rasterise using 100m fishnet grid resolution and extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Households with no access to a car or van			• In the .csv file, calculate the % of each OA that falls into the criteria • Join .csv file to OA boundary vector file by OA name • Join to grid - 100m fishnet grid by majority score according to OA area intersecting the fishnet grid • Rasterise using 100m fishnet grid resolution and extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)

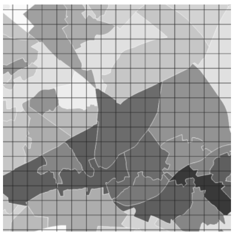
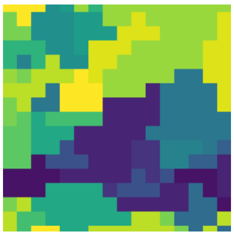
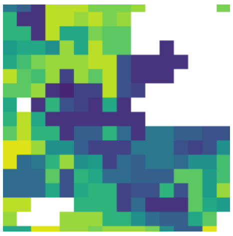
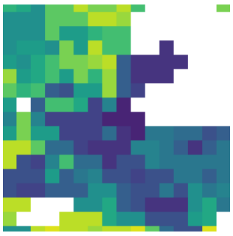
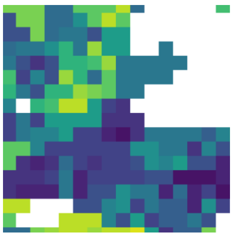
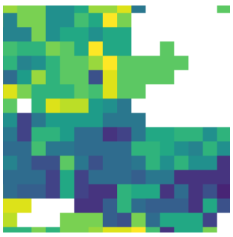
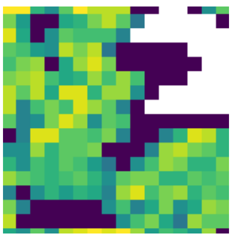
	Data layer	Converted layer	GIS processing
Households who do not own their property outright			• In the .csv file, calculate the % of each OA that falls into the criteria • Join .csv file to OA boundary vector file by OA name • Join to grid - 100m fishnet grid by majority score according to OA area intersecting the fishnet grid • Rasterise using 100m fishnet grid resolution and extent • Use quantile function to determine 20 quantile bins (5%iles) • Reclassify by table according to bin values (0-1, 0.05 intervals)
Average annual household income	Provided directly in tabular format by WMCA		• WMCA produced percentile ranking of all data in a .csv file, using a list of fishnet ID codes aligning with postcode majority area • Quantiles set in attribute table by adding a column to reclassify percentiles via field calculator (e.g. "WHEN @percentile < 0.05 THEN '0.05'", etc.) • Join .csv file to postcode boundary vector file by postcode name • Rasterise using 100m fishnet grid resolution and extent
Average net disposable household income	Provided directly in tabular format by WMCA		• WMCA produced percentile ranking of all data in a .csv file, using a list of fishnet ID codes aligning with postcode majority area • Quantiles set in attribute table by adding a column to reclassify percentiles via field calculator (e.g. "WHEN @percentile < 0.05 THEN '0.05'", etc.) • Join .csv file to postcode boundary vector file by postcode name • Rasterise using 100m fishnet grid resolution and extent
% of household income that is disposable	Provided directly in tabular format by WMCA		• WMCA produced percentile ranking of all data in a .csv file, using a list of fishnet ID codes aligning with postcode majority area • Quantiles set in attribute table by adding a column to reclassify percentiles via field calculator (e.g. "WHEN @percentile < 0.05 THEN '0.05'", etc.) • Join .csv file to postcode boundary vector file by postcode name • Rasterise using 100m fishnet grid resolution and extent
% of household income spent on travel to work	Provided directly in tabular format by WMCA		• WMCA produced percentile ranking of all data in a .csv file, using a list of fishnet ID codes aligning with postcode majority area • Quantiles set in attribute table by adding a column to reclassify percentiles via field calculator (e.g. "WHEN @percentile < 0.05 THEN '0.05'", etc.) • Join .csv file to postcode boundary vector file by postcode name • Rasterise using 100m fishnet grid resolution and extent
Population density	Not possible to show due to multiple datasets used		• Sum all population per postcode in Census .csv file • Join Census data to postcode boundary vector file by postcode • Convert AddressBase.csv residential data into vector points* • Sum the number of properties per postcode • Average the number of people per property per postcode • Intersect AddressBase points with 100m fishnet grid to find the properties per 100m grid • Multiply the average population with properties per 100m grid • Rasterise, quantile bin and reclassify per other census layers

Table 3. Final conversion processes to produce the combined risk CRVA map

	Hazards	Vulnerabilities	Exposure	Combined risk
Layers	NO2 concentration PM2.5 concentration Fluvial flood risk Pluvial flood risk Open green space deficit Other green space deficit Tree canopy cover deficit Local climate zones Surface temperature	Households deprived regarding education Households deprived regarding employment Households deprived regarding health & disability Households deprived regarding housing Households with dependent children under 15 years Households of single occupancy over 65 years Population of ethnic minority Population whose main language is not English Households with no access to a car or van Households who do not own their property outright Average annual household income Average net disposable household income % of household income that is disposable % of household income spent on travel to work	Population density	Hazard layer Vulnerabilities layer Exposure layer
GIS processing	• Ensure all layers are loaded in and processing has been completed per Table 2 • Use Raster calculator to sum all nine layers • Save layer down, do not save an “on-the-fly” temporary raster • Rescale raster to 0-1 range	• Ensure all layers are loaded in and processing has been completed per Table 2 • Use Raster calculator to sum all 14 layers • Save layer down, do not save an “on-the-fly” temporary raster • Rescale raster to 0-1 range	• No action required, use processed Population density layer produced per Table 2	• Use Raster calculator to multiply the three layers together • Save layer down, do not save an “on-the-fly” temporary raster • Rescale raster to 0-1 range (optional)

ADDITIONAL INFORMATION ON GIS TECHNIQUES

This CRVA map used tools within the QGIS application (version 3.28.11 Firenze long-term release).

Creating a fishnet grid
Vector > Research Tools > Create Grid
A fishnet grid is a vector layer, which is a conversion of another vector file into gridded squares. It is used for the CRVA map as the reference layer to align all raster conversions.

Resampling: Bilinear interpolation
Raster > Projections > Warp (Reproject)
Resampling creates a new raster layer based on sampling from another raster layer. The reasons for doing this include reprojecting or aligning raster cells to a new grid size or position. Bilinear interpolation is a resampling method using the weighted four nearest cell centres[32].

Resampling: Nearest neighbour
Raster > Projections > Warp (Reproject)
Using the same process as bilinear interpolation, nearest neighbour resampling is determined by the nearest cell centre on the input grid.

Joining attributes by location (summary)
Processing toolbox > Vector general > Join attributes by location (summary)
This process takes vector attributes and assigns them to each grid square. It is therefore a step before converting vector data into a raster layer.

Identifying percentile values of continuous layer data
Processing toolbox > GRASS > Raster > r.quantile
This produces a table with the percentile boundaries of continuous raster data. To establish 5%ile bins, the number of quantiles is set to 20.
Processing Toolbox > Raster Analysis > Reclassify by table
After identifying the boundary ranges, the percentile break ranges can be set using reclassify by table.

Rescaling raster layer 0-1
Processing Toolbox > Raster Analysis > Rescale raster
This process quickly normalises a raster layer, where the highest value is scaled to 1 and the lowest scaled to 0. This is used when rasterising a layer creates cell values between 0 and 255, reflective of colour band values, or after the summing of other layers to normalise the value range.

Local climate zone scoring
Processing Toolbox > Raster Analysis > Reclassify by table
See Table 3 in Greenham et al. (2023)[26].

Converting total CRVA scores to other geographic boundaries
Processing toolbox > Raster Analysis > Zonal statistics
CRVA score can be averaged in accordance with vector files that include smaller boundaries, such as wards or hex grids.

References

32. ESRI (2023) FAQ: What is the difference between Nearest Neighbor, Bilinear Interpolation and Cubic Convolution? Available at: https://support.esri.com/en/technical-article/000005606 (last accessed 20/03/2023)

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