OVERHEATING RISK MAPPING

EVIDENCE REVIEW

ZERO CARBON HUB

The Zero Carbon Hub was established in 2008, as a non-profit organisation, to take day-to-day operational responsibility for achieving the government's target of delivering zero carbon homes in England from 2016. The Hub reports directly to the 2016 Taskforce.

To find out more, or if you would like to contribute to the work of the Zero Carbon Hub, please contact: info@zerocarbonhub.org.

Zero Carbon Hub
Layden House
76-86 Turnmill Street
London
EC1M 5LG

This report is available as a PDF download from:
www.zerocarbonhub.org

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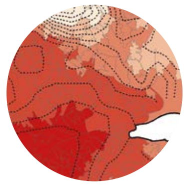

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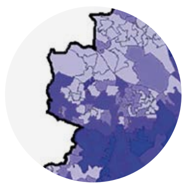

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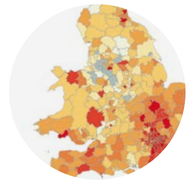

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01 INTRODUCTION

This Evidence Review forms part of a wider evidence gathering exercise being undertaken by the Zero Carbon Hub to assist industry and government decision makers in managing current and future overheating risk in England and Wales. It considers evidence relating to overheating in residential buildings, including homes, care homes and student accommodation, and some of the adverse impacts on people. The Review therefore links closely with the Impacts of Overheating Evidence Review. Gaps in the evidence are identified and recommendations are put forward regarding where additional research is needed.

Heat-related risk maps for areas of the UK have been produced by a number of studies, referenced in this Review. These include locations such as London and Birmingham. The studies use data to create maps that pictorially display the relative level of risk by location.

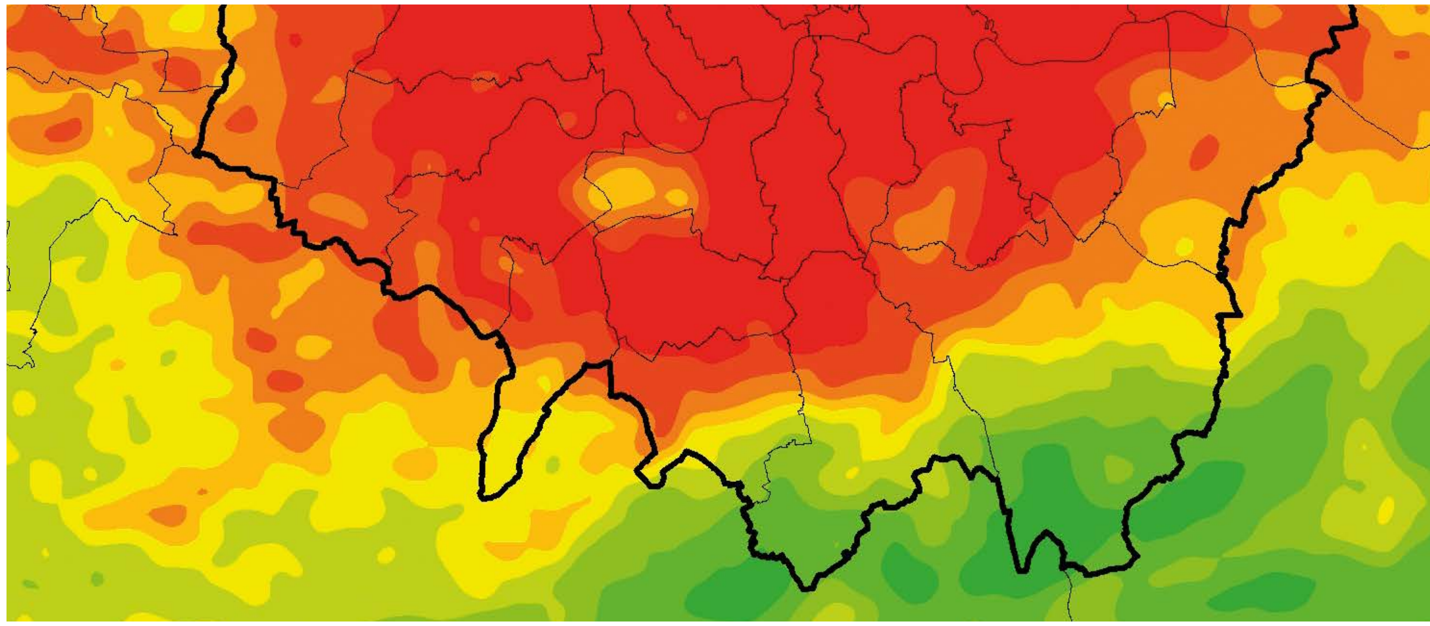
A number of researchers have also developed a methodology for identifying and processing data related to overheating risk. The data used in the studies are based on current and/or historic data. It is reasonable to assume that the methods described could be repeated to create maps for other locations in the UK given sufficient location specific data. Maps based on projected changes to the climate and demographics in decades to come may also be possible and should be considered, helping to optimise resilience strategies.

Overheating in homes is more prevalent in certain parts of the country and certain types of buildings. This Review does not attempt to 'map' impacts, but does present examples of where risk mapping has been used to highlight particular risk 'hot spots'. This kind of approach can help decision-makers, such as local authorities and housing providers understand where to target mitigation strategies.

This Review details the current research and risk mapping methods, including the outcomes presented for a regional level such as Greater London and at a national level for England and Wales.

This Evidence Review forms part of a wider evidence gathering exercise being conducted by the Zero Carbon Hub for our *Tackling Overheating in Homes* project. It provides a summary of relevant evidence and concepts relevant to the theme: overheating risk mapping.

Risk mapping can help decision-makers, such as local authorities, to understand where to target resources.



Key points

- Overheating risk maps can be an extremely useful resource for policy makers when planning for heat waves and developing climate change adaptation strategies. The maps display the relative risk of overheating by location.
- This kind of approach is perhaps particularly relevant to local authorities, helping them to target limited resources towards areas of greatest need.
- In addition to local authorities, there is the potential for developers and those with housing management responsibilities to make use of risk maps to help them understand whether they are building in a high risk area, and/or whether residents are more likely to experience overheating. Again, this approach allows businesses to target their overheating mitigation efforts.

02 CATEGORISING RISK FACTORS

Identifying and categorising overheating risk factors has been shown to be particularly useful in risk mapping projects such as the ARUP study: Reducing Urban Heat Risk (ARUP 2014). The study is a collaborative research project between ARUP and partners: The Greater London Authority (GLA), The London Climate Change Partnership (LCCP), University College London (UCL) and the London Borough of Islington. The project ran from November 2012 to July 2014. The report identifies the importance of understanding where people live as well as the individual's circumstances. Location specific factors are considered as well as building types and designs.

ARUP's research drew on the Community Resilience to Extreme Weather (CREW) study (The CREW Project: Final Report 2013, 52) which separated out four typical dwelling types into two tiers: higher and lower risk. Knowing this type of information allowed ARUP to build a narrative on high, medium and low risk scenarios. The scenarios are illustrated in an infographic (Figure 1) summarising the main overheating risks and potential solutions.

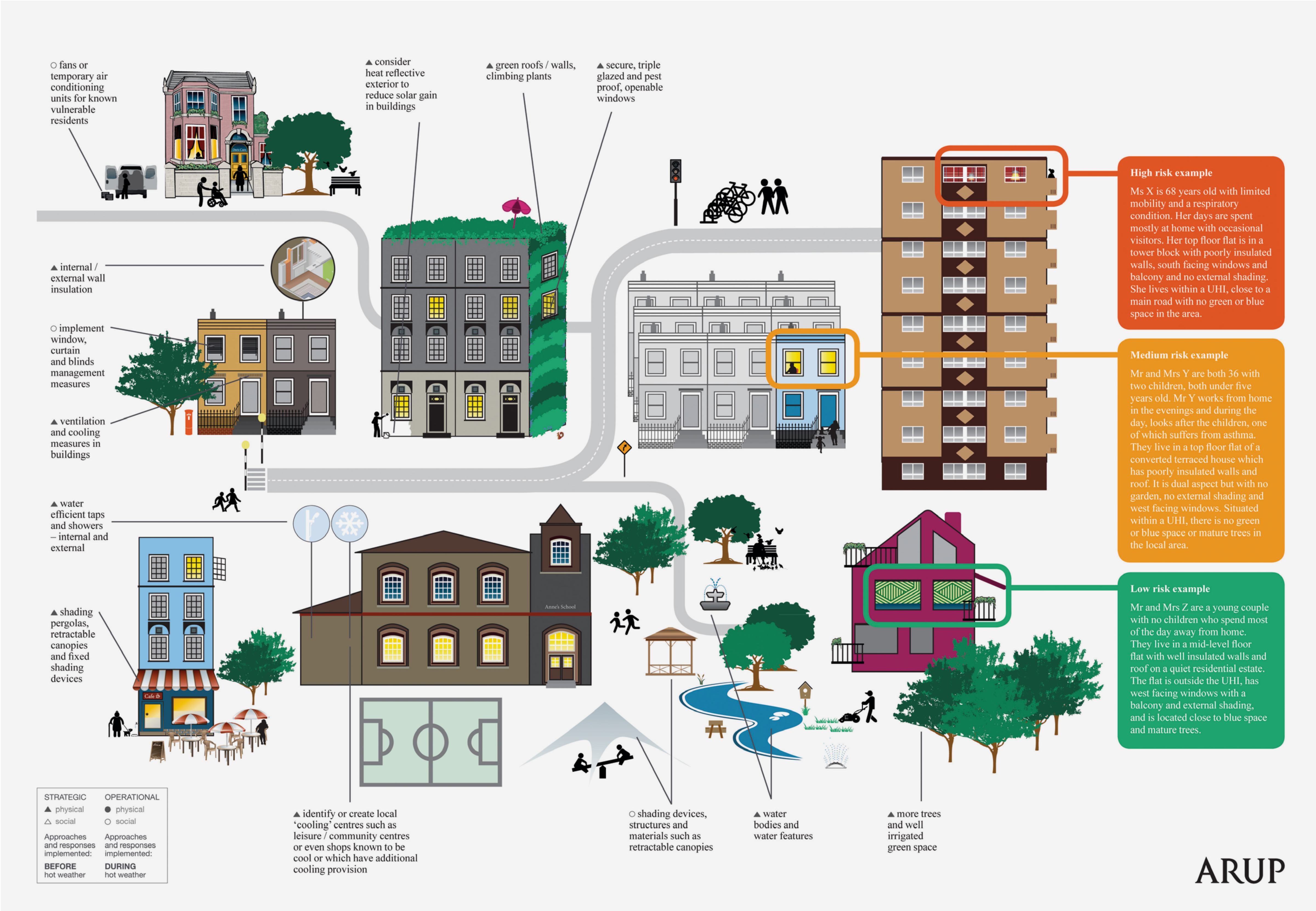


Figure 1. ARUP infographic depicting approaches and responses to reducing urban heat risk (ARUP 2014, 36)

03 SPATIAL MAPPING

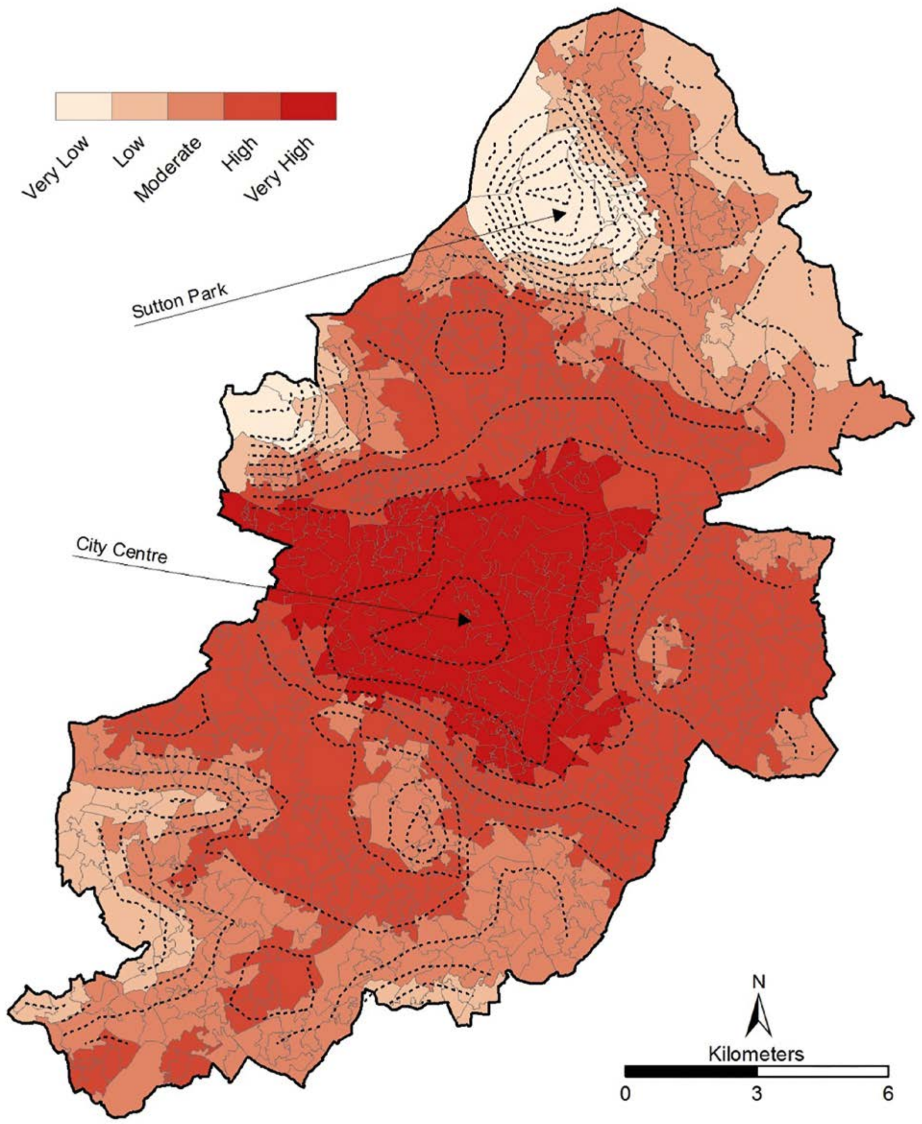


Figure 2. **Level of the Urban Heat Island in Birmingham under heatwave conditions and categorised by Lower Super Output Area – night time 18th July 2006 (Tomlinson et al. 2011, 7)**

Air and surface temperatures of surrounding buildings are identified as drivers of overheating in homes (ARUP 2014; Wolf and McGregor 2013; Tomlinson et al. 2011). These temperatures can be mapped across regions of the United Kingdom. Tomlinson's study of Birmingham's heat health risk, adopted the night-time recorded Land Surface Temperature (LST) for 18th July 2006 to represent the spatial variation in the Urban Heat Island (UHI) identified as the "Hazard Layer" (Figure 2) (Tomlinson et al. 2011, 4). The range displayed is from the lowest to highest recorded mean average LST for each Lower Super Output Area (LSOA). No actual temperatures were quoted.

The recorded surface temperature data in Tomlinson's et al. paper (2011) is available from NASA satellites and the Moderate Resolution Imaging Spectroradiometer (MODIS) offers a resolution of 1 sq km . Similar sources of data were obtained from the UK Space Agency and The University of Leicester for the ARUP study (2014). Importantly the data is linked to a Geographic Information System (GIS) database thereby matching the hazard to a location. The studies define the spatial analysis area by boundaries. Fixed physical size LSOAs are useful measures as they are not influenced by other boundary shifts making statistical data linked to them ideal for ongoing studies (Tomlinson et al. 2011, 3). For areas that do not have the highest resolution of statistical data, it is possible to utilise Medium Super Output Area (MSOA) data covering a combination of LSOAs.

ARUP's commentary and further analysis go on to highlight the importance of identifying "green" (parks and trees) and "blue" (rivers and reservoirs) spaces when determining the overheating risk level. The report compares the All London Green Grid (ALGG) (Figure 3) with a recorded image of the Greater London Land Surface Temperature (LST) in June 2011 (Figure 4). The conclusion is that there is a close correlation between cooler LST spots and green/blue spaces.

Information

The ARUP report cites an example that on the 26th June 2011 there was a 4°C temperature difference between the open green spaces of Richmond Park and the heavily urbanised West End. Richmond Park was measured as having an Land Surface Temperature (LST) of 27°C and the West End an LST of 31°C.

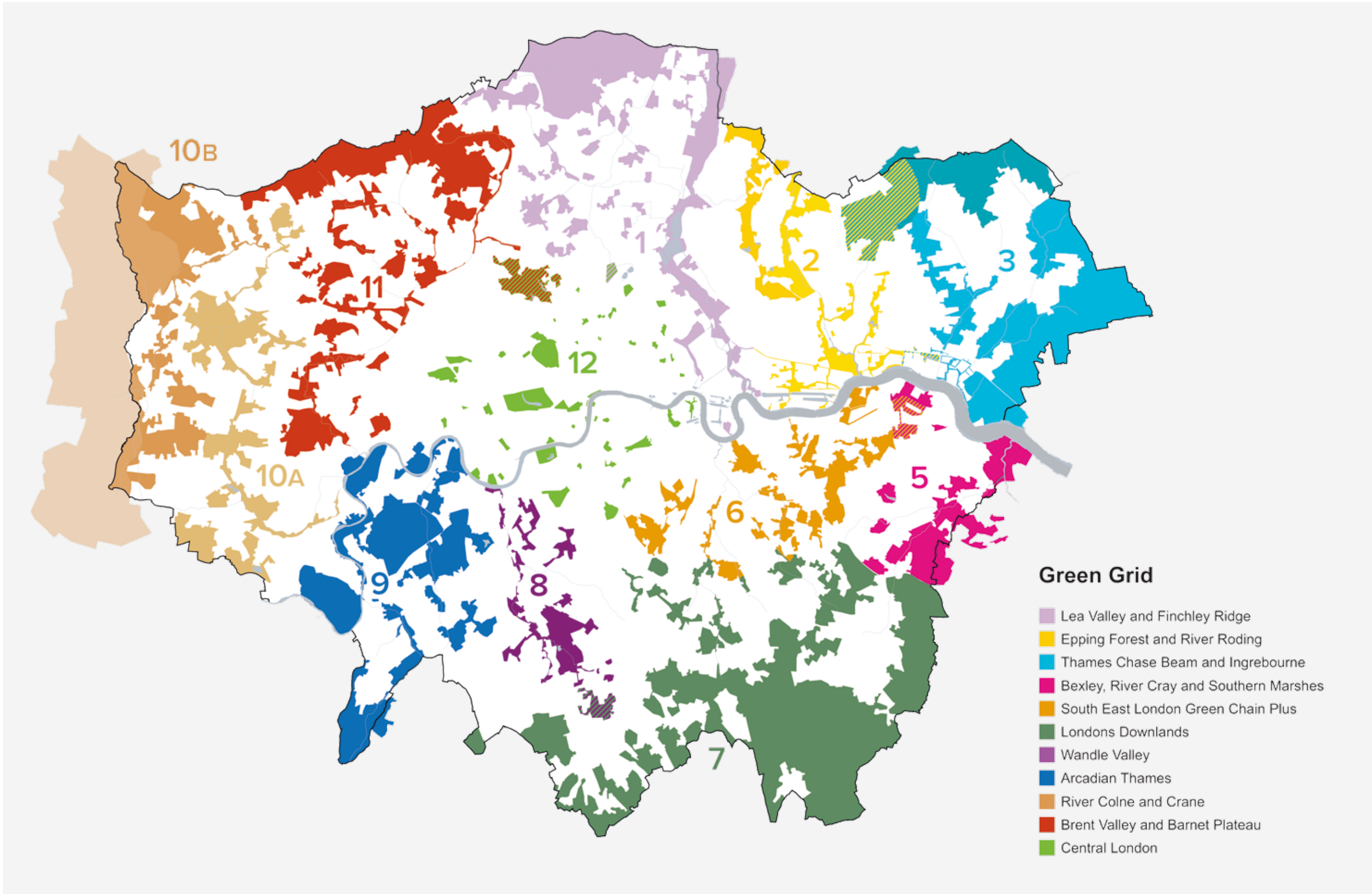


Figure 3. **All London Green Grid (ALGG) showing Greater London green spaces (Greater London Authority 2014)**

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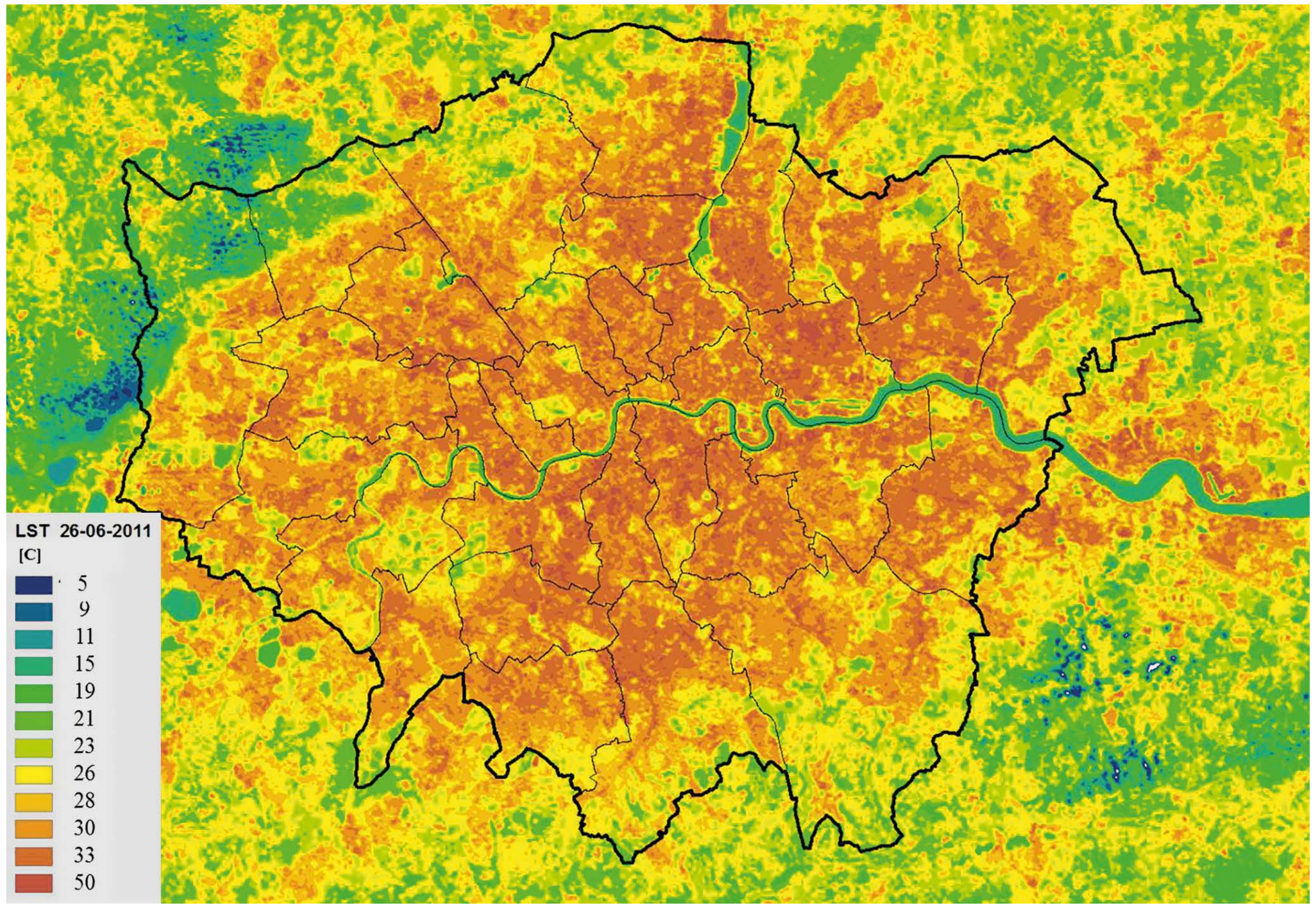


Figure 4. **Greater London measured Land Surface Temperatures (°C) – day time 26th June 2011 (ARUP 2014, 21)**

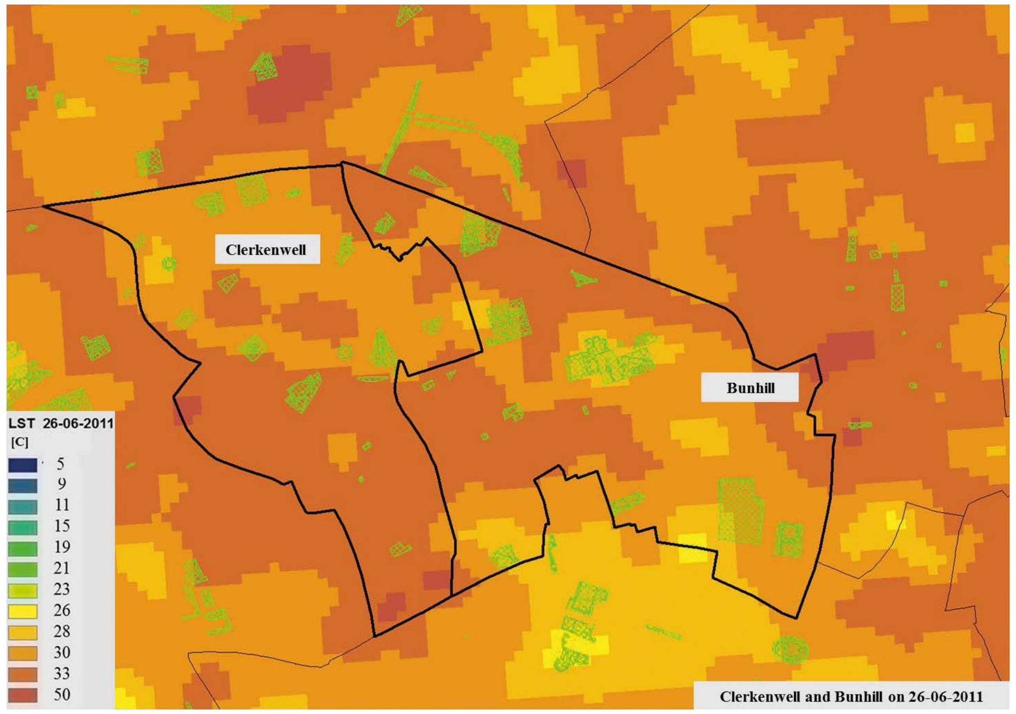


Figure 5. **Clerkenwell and Bunhill measured Land Surface Temperatures – day time 26th June 2011 and green spaces map overlay (ARUP 2014, 24)**

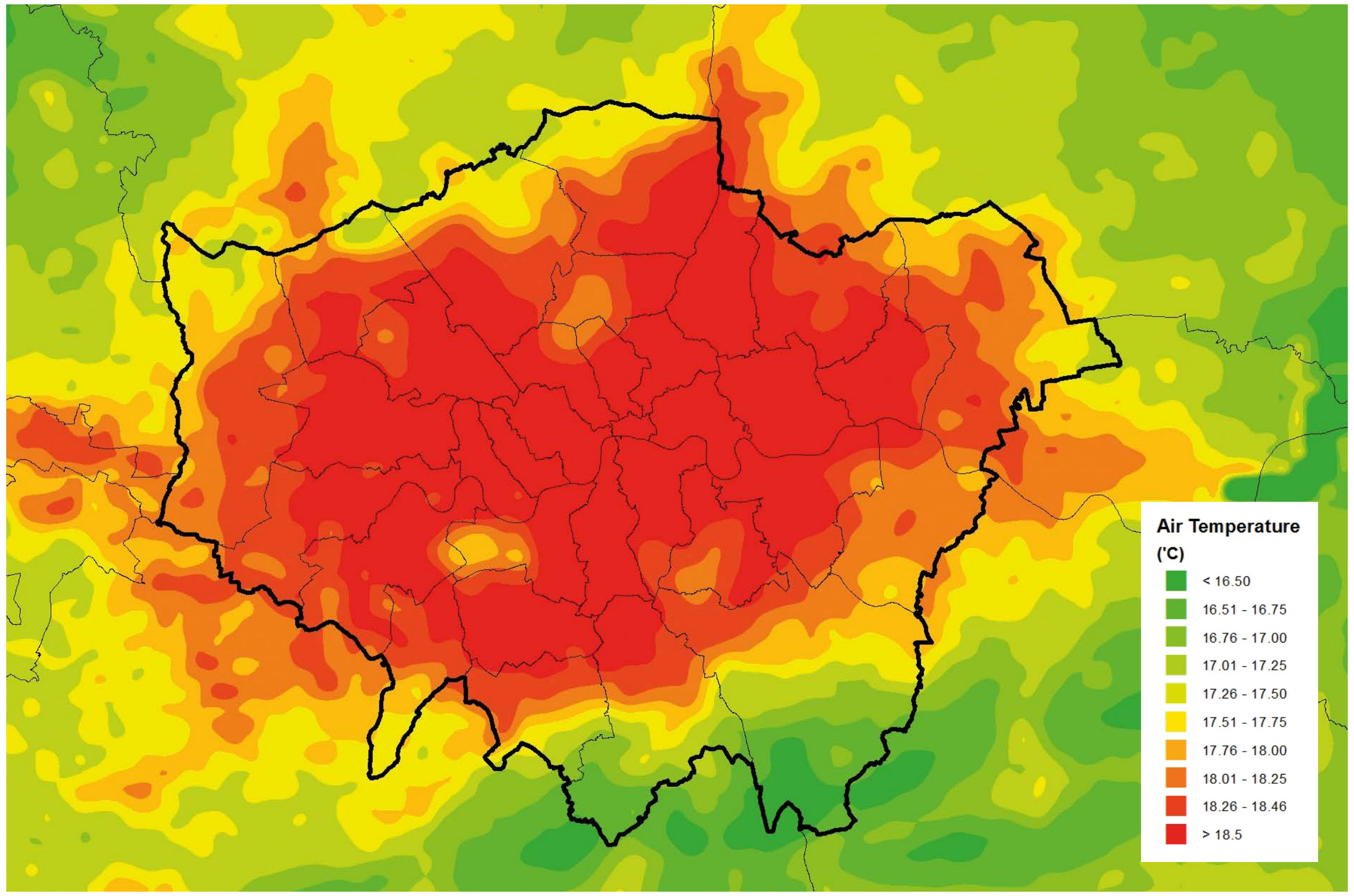


Figure 6. **Greater London modelled average air temperature for May-July 2006 (ARUP 2014, 21)**

Specifically, ARUP considered two pilot areas within the London Borough of Islington: Bunhill and Clerkenwell (see Figure 5). Both locations are in central London and have low green space density and high LST. The co-occurrence is an indicator of greater heat risk (ARUP 2014, 22–23). An image of the two areas comparing LST and green spaces by overlaying each separate map on a fine spatial scale shows that whilst larger green spaces can influence the LST, smaller spaces have a limited effect.

Combining the different maps of London including the air temperature map shown in ARUP's report (Figure 6) will allow 'hot spot' areas to be identified and flagged as an area of increased overheating risk (ARUP 2014, 2). From the temperature maps shown, the difference between rural and urban areas is noticeable. The recorded rural LST and average air temperatures are lower. This trend fits the findings of Doick and Hutchings (2013) who have undertaken a literature review from a number of sources reporting the effects of the UHI. The paper highlights that during the August 2003 heatwave, the difference between the night time air temperature of London, and the surrounding areas, was observed as 9°C (Doick and Hutchings 2013, 2).

04 CO-OCCURRENCE OF HAZARDS AND VULNERABILITIES

Wolf and McGregor's paper (2013) states that by categorising or indexing different hazards and vulnerabilities to overheating risk, it is possible to observe co-occurrence by location. The study identified risk factors from a number of different sources and adapted census data to a "Principal Component Analysis" to integrate the various indicators to a heat vulnerabiltiy index. Cities such as London or Birmingham have high levels of information based on census data and other records that can be spatially separated and GIS tagged. The two London studies referenced in this Review (Wolf and McGregor 2013; ARUP 2014) make use of 2001 census data and GIS to locate the demographic, lifestyle and economic status of populations. Future work may be updated with 2011 census data (ARUP 2014, 17). The integration of the risk factors with maps is described more fully in section 5.

Three categories of risk are set out in ARUP's report: location within London, building characteristics, and people characteristics. The characteristic categories sort high from low risk by the factors listed in Table 1. A combination of the three categories can be used to create an overall risk profile and, using a qualitative approach, to define high, medium and low risk scenarios. Combining the demographics that are most vulnerable with the buildings at greatest risk of overheating and located in the 'hot spots' of London gives a high-level overheating risk rating. A quantifiable metric was not used in this analysis.

Table 1. **Two of the three ARUP (2014, 27) triple risk index categories**

Building Characteristics	People Characteristics
Age of construction	Age
Materials	Health
Orientation	Mobility
Layout	Sex
Height	Socio-economic status
Storeys	Culture
Deep plan	Languages spoken
Single or dual aspect	Awareness and experience of hot weather
Balcony	Perception of heat risk
Garden	Level of social connection
Glazed areas	Adaptive capacity issues
Insulation	
Thermal mass	
Shading level	
Ventilation	

05 HEAT VULNERABILITY INDEX

Tomlinson et al (2011) applied a method for quantifying overheating risk to people in their homes, resulting in a rating that was applied to each LSOA across Birmingham. The results – scored by a combination of rated risk factors shown in Figure 7 – are then plotted on a combined regional map as a range of five ratings, from very low to very high (Figure 8). The risk factors in Figure 7 relate to, for example, the age of the population (labelled 'Old'), and the health of the population (labelled 'Ill').

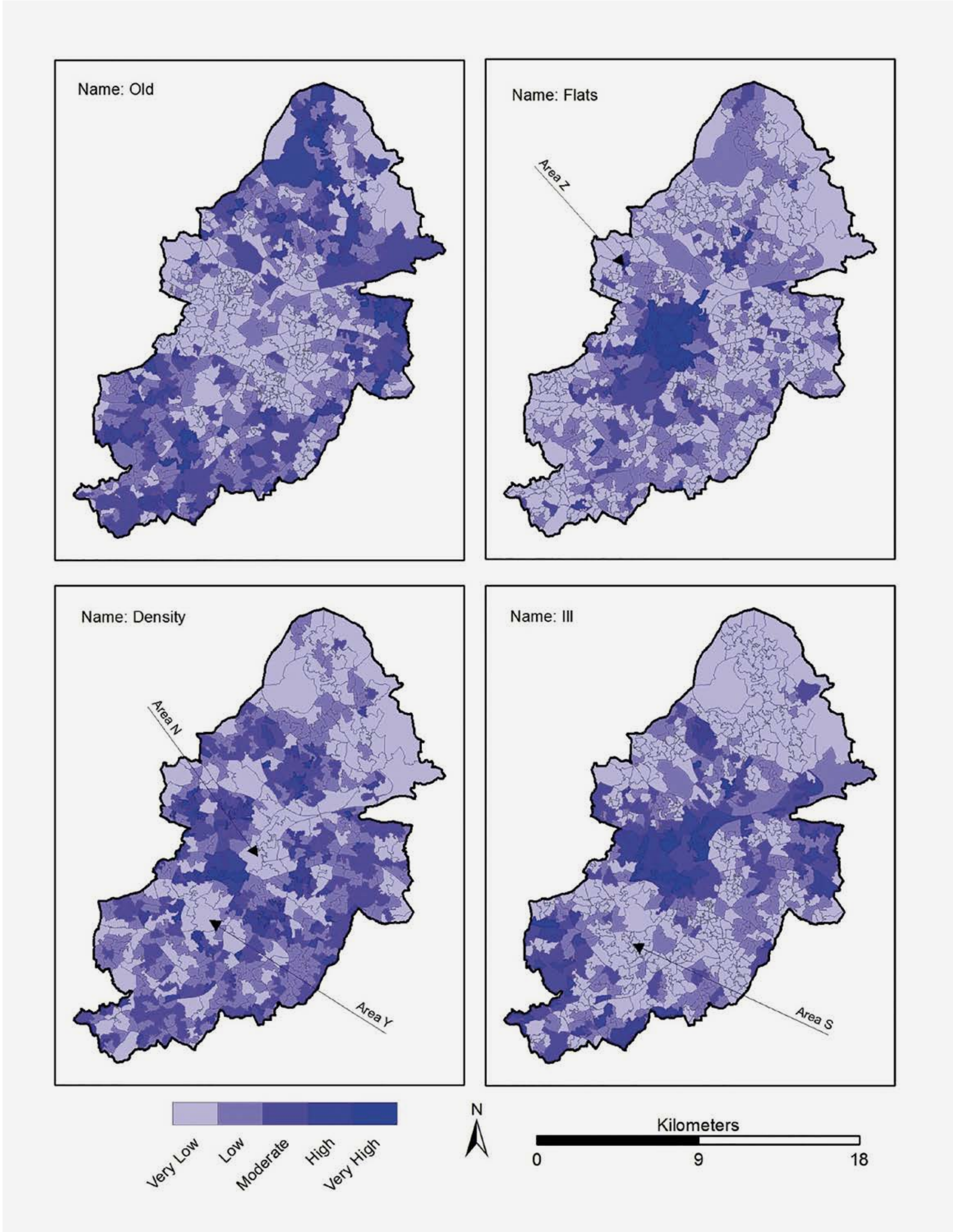


Figure 7. **Birmingham risk factor layers at LSOA level**

The full set of risk factors were characterised as:

People factors

- Population age; and
- Health.

Environmental factors

- Household density;
- Dwelling type; plus
- The Urban Heat Island.

The map labelled 'Old' in Figure 7 refers to the relative increased concentration of elderly people in the LSOA and is based on data for Birmingham households updated bi-annually (dataset year: 2009). The same dataset is used to calculate the household density and concentration of those that fall into the 'ill' vulnerability category. In this study the density range is taken to be an indicator of increased number of high rise buildings. Area Z in Figure 7 is cited as an area containing clusters of student housing including high rise blocks. The research considers each of the component ratings to be equally weighted. It was recognised, however, that a justifiable weighting could be applied, but that this would need careful consideration.

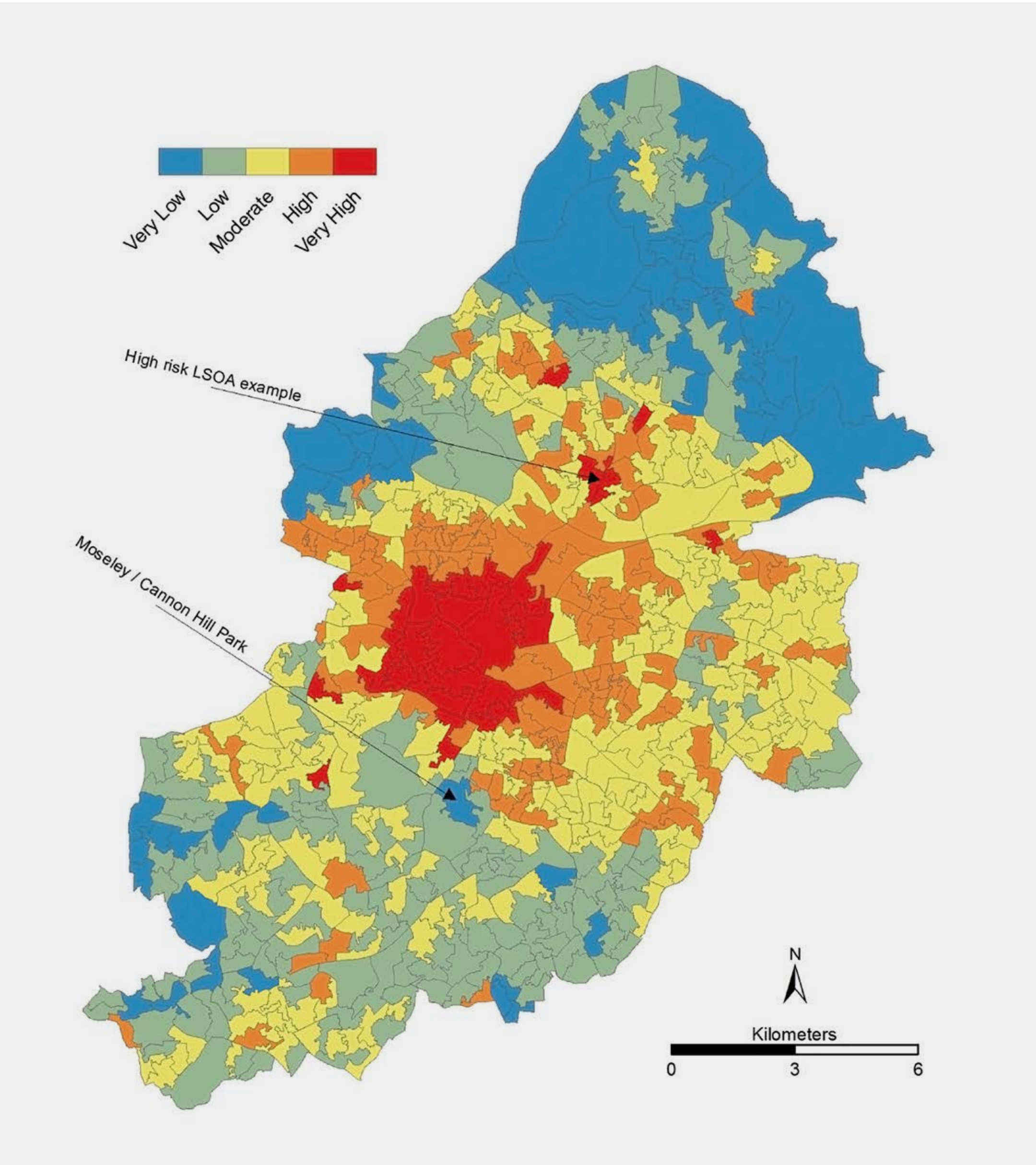
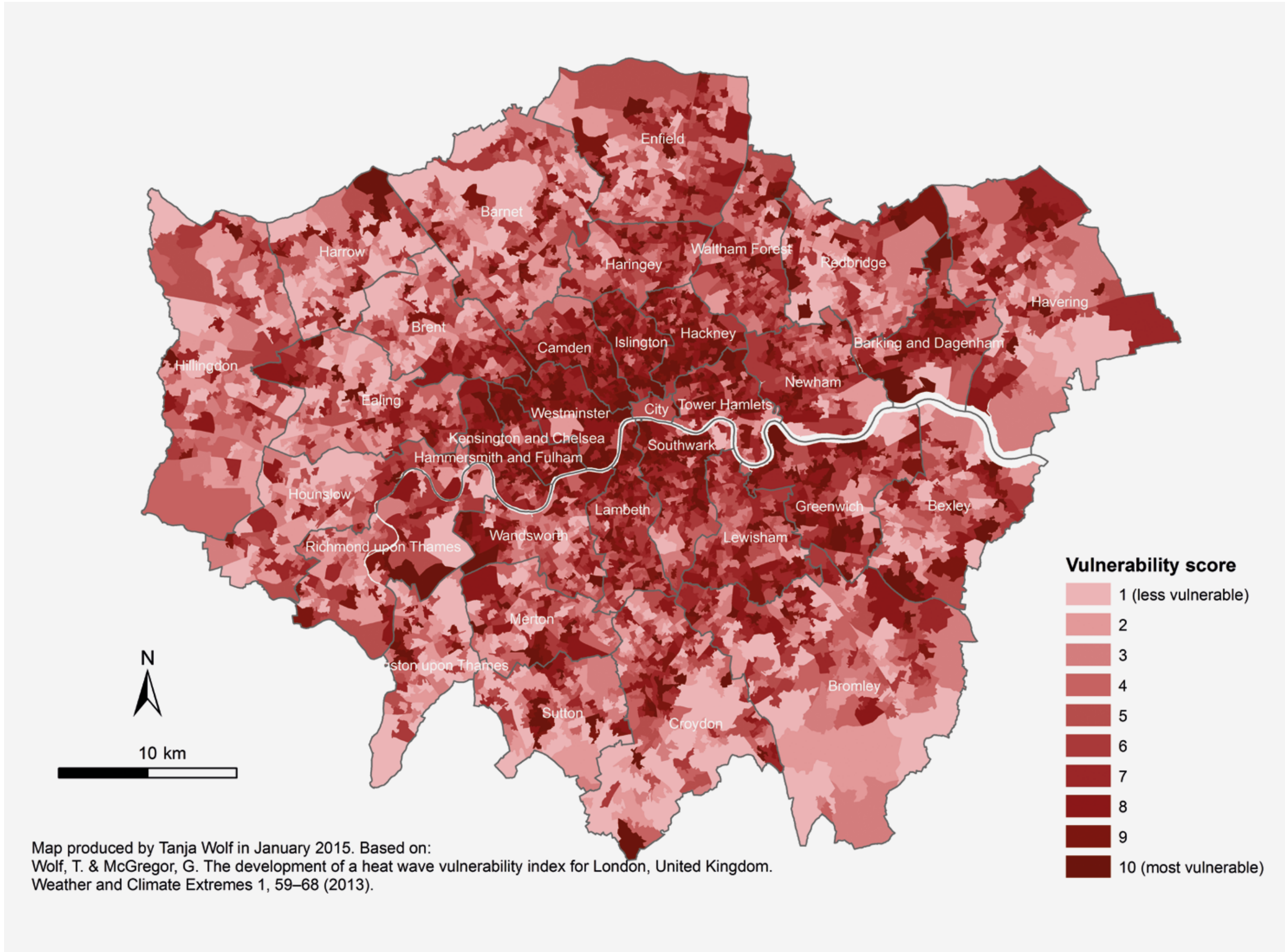
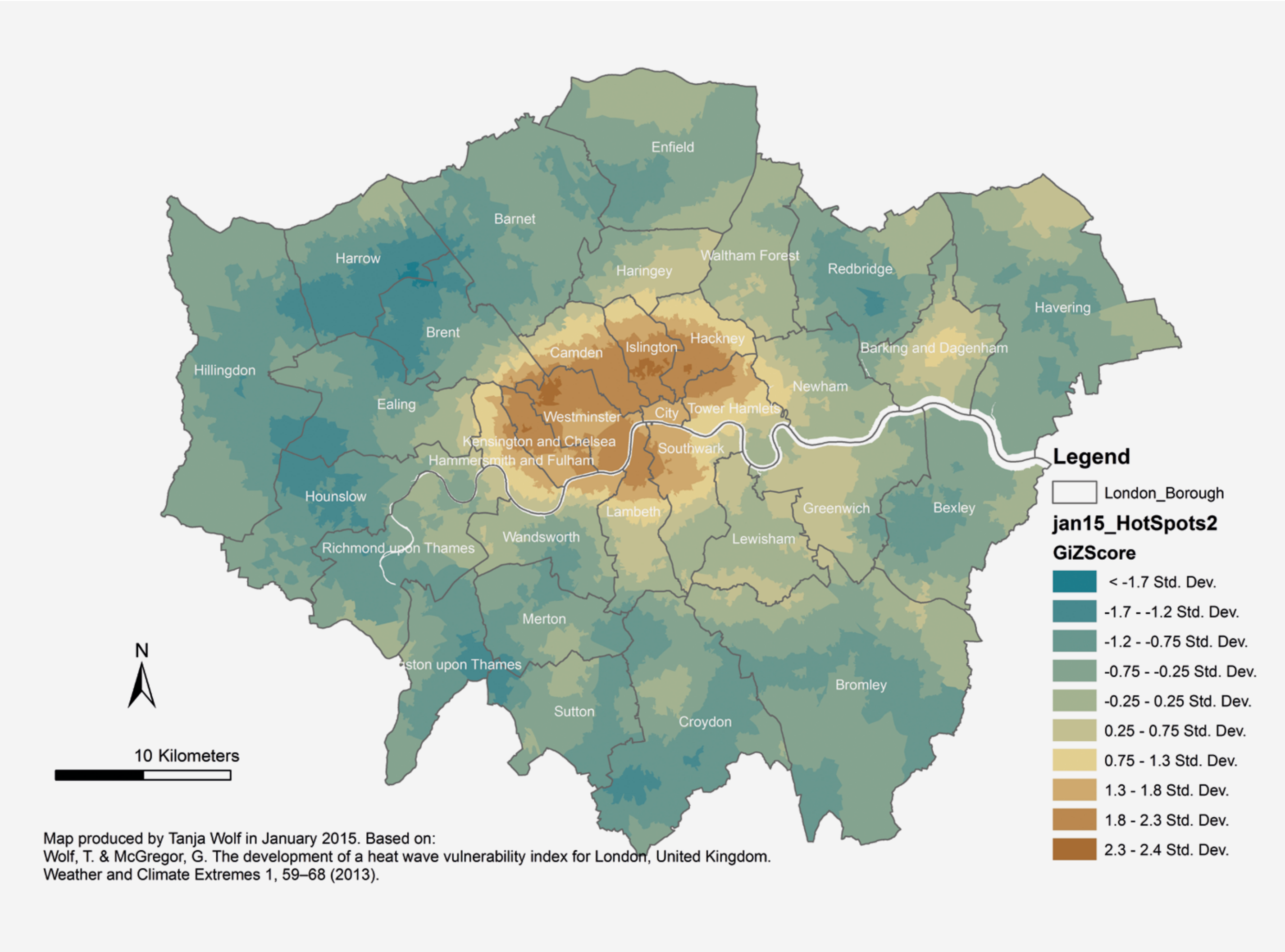


Figure 8. **Combines the heat risk factors based on household information and UHI temperature variations in Birmingham.**

The study for Greater London by Wolf and McGregor (2013) follows a similar approach to Tomlinson et al. but instead applies a weighting to the factors, or "Principal Components". The range of components is similar to the range of factors used to define each category in the Tomlinson et al (2011) study. The resultant 'Heat Vulnerability Index' (HVI) is a score between one and ten – ten indicating the most vulnerable – relating solely to the buildings and occupants. Each LSOA is scored and plotted on a map of Greater London as illustrated in Figure 9.

Figure 9. **Greater London Heat Vulnerability Index (HVI) (Wolf and McGregor 2013, 64)**





The study has mapped the HVI with a GIS and identified 'heat vulnerability hot spot clusters' through a cluster analyis. See Figure 10. The map identifies the following boroughs as being particularly sensitive to heat: Hammersmith and Fulham, Kensington and Chelsea, Westminster, Camden, Islington, Hackney, Southwark and Tower Hamlets.

Figure 10. **Greater London 'hot spot clusters' (Wolf and McGregor 2013, 65)**

06 APPLIED LOCAL KNOWLEDGE

Visual aids of geographic maps differentiating overheating risk levels throughout the country and in cities are a powerful way of communicating information. ARUP (2014, 26) point out that such illustrations have the greatest value when used in the context of the local built environment and the specific challenges an areas faces.

As an example of how risk mapping could be used practically, the Heatwave Plan (2014, 38) includes a recommendation that local authorities should review their heatwave plans and alert strategies. Understanding where to target resources can be assisted by mapping the level of relative risks across the local area.

The Local Borough of Islington is also putting risk mapping to use. The Borough's Seasonal Health Interventions Network (SHINE) programme uses heatwaves to trigger extra vigilance from their staff. SHINE advises staff to pay particular attention to their vulnerable clients. Risk maps will assist the borough in prioritising resources and targeting vulnerable individuals in their community.

In addition to local authorities, there is the potential for developers and those with housing management responsibilities to make use of risk maps to help them understand whether they are building in a high risk area, and/or whether residents are more likely to experience overheating. Again, this approach allows businesses to target their overheating mitigation efforts.

Information

Consideration of overheating risk at a regional or national level can help policy makers to plan infrastructure improvements along with targeting resources and advice.

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07 REGIONAL TEMPERATURE AND MORTALITY MAPPING

Supporting theoretical risk mapping, Bennett et al. (2014) produced a paper which uses mortality records for England and Wales between May and September of 2001-2010 to map heat vulnerability. Cardiorespiratory deaths, known to be linked with high temperatures, are quantified and compared at local authority district level across England and Wales. The study adjusts for other factors that may affect cardiorespiratory mortality such as air quality and whether the day was a national holiday where behaviour and health service availability might vary.

The results are illustrated in Figure 11 by plotting the percentage increase in the odds of cardiorespiratory death of elderly women (a vulnerable demographic) and the posterior probability (i.e. the probability after taking into account the recorded evidence following the heatwave) compared with the national average.

The national average percentage increase in the odds of cardiorespiratory death for women over the age of 85 for every 1°C increase in mean daily summer temperature is 3.9%. From the map in Figure 11 it can be seen that Greater London and regions in the South East shaded in red have a significantly higher (>6.2%) increase in odds when compared with the national average for every degree increase in temperature.

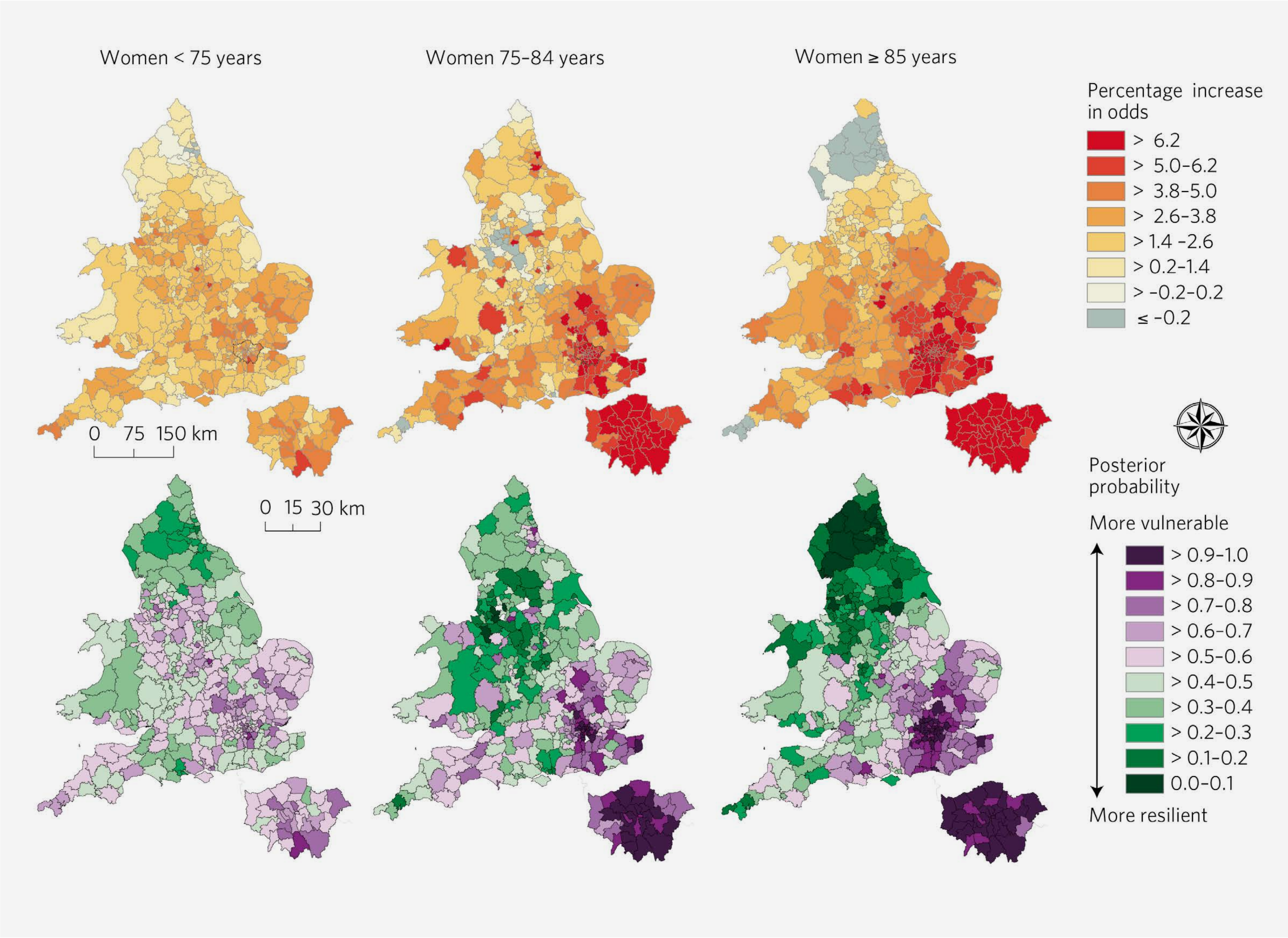

Figure 11. England and Wales percentage increase in the odds of cardiorespiratory death for 1°C increase in mean daily summer temperature above the threshold followed by probabilities that the estimated effect is different from the national average (Bennett et al. 2014, 270)

08 OBSERVATIONS

Overheating risk maps can be an extremely useful resource for policy makers when planning for heat waves and developing climate change adaptation strategies.

The maps display the relative risk of overheating by location. They each define a method to calculate the level of risk incorporating the identified factors. The data is suitably tagged to link the factor with location. It is the co-location or co-occurrence of each high risk factor that flags the area where homes or people could be at greatest risk of overheating. Such maps should be useful for decision-makers, local authorities and housing providers.

However, none of the maps referenced in this Review use future climate data or projected changes to our cities. There is therefore scope to use the methods to define future hot spots too. Also, the focus of studies to date has been mainly on large conurbations which logically, due to greater UHI effect, are considered to be at greatest risk.

To extend the knowledge of overheating risk areas it will be important to expand on the evidence base. The following steps are suggested to maximise the benefit of such mapping:

- Undertake a study to develop a suitable risk mapping methodology that can be adopted across the UK. The study should refer to the published literature to identify the methods already in use;
- Expand mapping techniques to include future climate and socioeconomic changes; and
- Encourage up-take of the new tools by national and local governments.

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Zero Carbon Hub
Layden House
76-86 Turnmill Street
London EC1M 5LG

T. 0845 888 7620
E. info@zerocarbonhub.org
www.zerocarbonhub.org