Climate change, justice and vulnerability

Sarah Lindley, John O'Neill, Joseph Kandeh, Nigel Lawson, Richard Christian and Martin O'Neill

November 2011

This report is concerned with justice in the distribution of the effects of flooding and heatwaves on people's well-being.

Climate change will increase the intensity and frequency of extreme weather-related events such as flooding and heatwaves in the UK. While considerable effort has been made to understand patterns of current and future hazard-exposure, much less effort has been spent on addressing social, personal and environmental factors that render people more or less vulnerable to losses in well-being. This report provides a guide for analysing social vulnerability to the impacts of climate change. It shows how we can learn from past UK flooding and heatwave events to measure socio-spatial vulnerabilities and map geographical distributions of climate disadvantage. In doing so it supports the integration of the demands of justice into climate adaptation planning.

The report shows that:

- many aspects of well-being that are endangered by climate change are not adequately captured by existing approaches to adaptation policy;
- the social dimensions of vulnerability to climate change have not been sufficiently recognised in adaptation policy;
- there are uneven geographical distributions in climate-related social vulnerability and climate disadvantage in the UK; and
- the existence of distinct socially vulnerable groups helps to explain uneven geographical patterns.

JOSEPH ROWNTREE FOUNDATION

www.jrf.org.uk

Contents

List of figures and tables

Figures

Tables

Executive summary

Introduction

Climate change will increase the intensity and frequency of extreme weather events such as floods and heatwaves in the UK. This project is concerned with justice in the distribution of the effects of these events on well-being. The effects of extreme weather events will not be distributed evenly. How badly a person or group will be affected will depend not just on their exposure to the event, but on their vulnerability – that is, how well they are able to cope with and respond to floods and heatwaves. Vulnerability is a matter of how events convert into losses in well-being. Key terms used in the summary are listed in Box 1.

Box 1: Well-being, vulnerability and climate disadvantage – key terms

Resource-metric: Losses and gains in well-being measured in terms of losses and gains of resources such as income or property values.

Subjective welfare: Well-being conceived in terms of psychological states, such as feelings of happiness.

Capabilities and functionings: Well-being characterised in terms of capabilities to achieve central human functionings:

- functionings: the valuable states and activities a person can be in or do, e.g. being healthy, being housed, having close personal relationships;
- capabilities: freedoms or opportunities to achieve particular functionings;
- achieved functionings: the valuable states and activities that a person actually realises.

Vulnerability: Vulnerability of an individual or group is characterised by the degree to which an external event converts into losses in their well-being.

Conversion factors: The personal, environmental and social factors that determine how positive or negative events are converted into gains and losses in well-being:

- personal: features of the individual such as disability, age and health that affect the way in which resources and hazards produce different effects on well-being;
- environmental: features of the physical environment such as the availability of green space, quality of housing stock, elevation of buildings and access to public space that affect the way in which resources and hazards produce different welfare effects on well-being;

- social: features of the social and institutional context and situation, such as the strength of social networks, the cohesion of neighbourhoods, the institutional regimes in nursing homes, and levels of inequality and income, which affect the way in which resources and hazards produce different welfare effects on well-being.

Socio-spatial vulnerability: Socio-spatial vulnerability brings in aspects of place and time with personal, social and environmental factors resulting in the geographical expression of the degree to which an external event has the potential to convert into well-being losses. This is done from the perspective of social and socially related factors in five dimensions: sensitivity; enhanced exposure; ability to prepare; ability to respond and ability to recover.

Climate disadvantage: Climate disadvantage is a function of (a) the likelihood and degree of exposure to a hazard and (b) individual or group vulnerability with regards to such hazards. It can be estimated and mapped through the combination of representations of hazard-exposure and representations of socio-spatial vulnerability.

Climate justice and vulnerability

Understanding and measuring vulnerability to climate change requires an account of the different dimensions of well-being that are made insecure by floods and heatwaves and also the factors that are involved in converting the weather events into losses in well-being. One common way of measuring losses in well-being used by economists is to measure losses and gains of resources such as income or property values. However, these are not sufficient to capture either the full range or degree of the losses in quality of life that individuals and groups experience. A second popular measure is to use changes in psychological states of happiness. Losses in well-being are about changes in how good or bad people feel. Yet these happiness measures are ill-suited to measuring inequalities, since individuals' psychological states can adapt to states of deprivation. The measures that are better able to capture the range of losses in well-being are ones that consider directly what valuable things a person is able to be or do. In the most influential version of this account, well-being is defined in terms of opportunities (capabilities) to achieve the valuable things a person can do or be (functionings). Capabilities are the opportunities an individual has to realise these valuable states and activities. While opportunities are important, much of the focus of adaptation policy needs to be on the functionings a person actually achieves. Opportunities are more difficult to measure than achievements. Some central functionings such as achieved literacy, social networks and secure housing are conditions for exercising further opportunities.

Extreme weather events make a variety of dimensions of well-being insecure. Measures of the impacts of climate events such as flooding and heatwaves on well-being tend to focus on loss of life, damage to physical health and the loss of income and property. While these are important, a focus on these alone seriously underestimates the losses in well-being involved. Impacts of floods include, for example, living in temporary accommodation, the disruption of children's education, the irreplaceable loss of memorabilia and the loss of control of daily routines. These do not just matter for their impacts on health and livelihood. They are important losses in central dimensions of well-being in themselves.

The social dimensions of vulnerability

The social dimensions of vulnerability to climate change have not been sufficiently recognised in adaptation policy. A variety of personal, environmental and social factors are involved in the conversion of external stresses into losses in well-being. Adaptation policy often focuses on personal and environmental factors. With respect to both heat and flood, personal conversion factors include biophysical sensitivities associated with age and health. Environmental factors include the physical attributes of the neighbourhood, such as the amount of green space, and characteristics of the housing such as the elevations of residential buildings. However, while these are important, adaptation policy needs also to address more clearly social factors, which are less often invoked in discussion of climate policy. Specifically, social conversion factors will include income inequalities, the existence of social networks and the social characteristics of neighbourhoods.

In the case of heatwaves, social factors include: social isolation; the loss of public spaces in declining neighbourhoods; fear of crime, which leaves elderly people and others unwilling to leave their homes or open their windows; inflexible institutional regimes and the lack of personal independence in nursing homes. A variety of social factors affects the capacity of households to prepare for, respond to and recover from flooding. Low-income households are less able to take measures to make their property resilient to flooding and to respond to and recover from the impacts of floods. The ability to relocate is affected by wealth, as is the ability to take out insurance against flood damage. Social networks affect the ability of residents to respond to flooding: for example, through providing social supports and a response network, and by improving local knowledge bases.

Once the social dimensions of vulnerability are recognised, climate adaptation policy needs to address a broader range of concerns than is often supposed. It will include many areas of social policy that are neither specifically concerned with climate change nor traditionally included in adaptation responses. For example, policies concerning the care of the elderly, the quality of neighbourhoods and levels of income inequality are all important to climate adaptation. Indeed, events such as heatwaves and floods often reveal wider inequalities in the distribution of vulnerability. It is also particularly important to foster functionings such as being in effective social networks and being able to participate in public decision making, since these are not only important dimensions of well-being in themselves but are also important in supporting other dimensions of well-being.

An increased likelihood of flood exposure in itself increases the potential for losses in functionings over and above the direct consequences of the particular event itself. It makes individual functionings significantly insecure, and this insecurity can undermine well-being in a variety of ways. Insecure functionings are a cause of stress and anxiety. They lead to a loss of the ability to plan for and take control of future significant life events. In the context of the risk-differentiated insurance regime in the UK, the loss of insurance and prohibitively high insurance premiums and excesses are a particularly important source of insecurity for those threatened by floods.

Mapping vulnerability

Social vulnerability and climate disadvantage are linked to place. Measures of the various factors can be translated into indicators and used to construct an evidence base to assist decision makers. A synthesis of factors developed from a review of the literature is summarised in Chapter 3. Indicators were developed in relation to Middle Super Output Areas (MSOAs) in England and Wales, Data Zones (DZs) for Scotland and Super Output Areas (SOAs) for Northern Ireland. All of these units are subsequently referred to as neighbourhoods and these provided the basis for all of the mapping and analysis work. MSOAs are relatively large units so a finer-scale case-study assessment was carried out for Greater Manchester at Lower Super Output Area (LSOA) level.

Socio-spatial vulnerability brings in aspects of place and time with personal, social and environmental factors resulting in the geographical expression of the degree to which an external event has the potential to convert into well-being losses. A socio-spatial vulnerability index therefore provides insights into the uneven geographies of social vulnerabilities. When superimposed on to expressions of potential hazard-exposure it is possible to assess which UK neighbourhoods currently experience greatest climate disadvantage. Aggregation of indicators into socio-spatial vulnerability scores allows the extent of vulnerability to be assessed across national, regional and local scales relative to average (mean) values. Neighbourhood-specific 'signatures' help to explain which factors drive social vulnerability in particular localities and allow a picture to be constructed of the complex landscape of factors adding to and detracting from the potential for harm.

The five dimensions of socio-spatial vulnerability considered in this study are:

1 **sensitivity** – personal biophysical characteristics such as age and health which affect the likelihood that a heatwave or flood event will have negative welfare impacts;

2 **enhanced exposure** – the aspects of the physical environment, such as the availability of green space or housing characteristics, which tend to accentuate or mitigate the severity of heatwave or flood events;

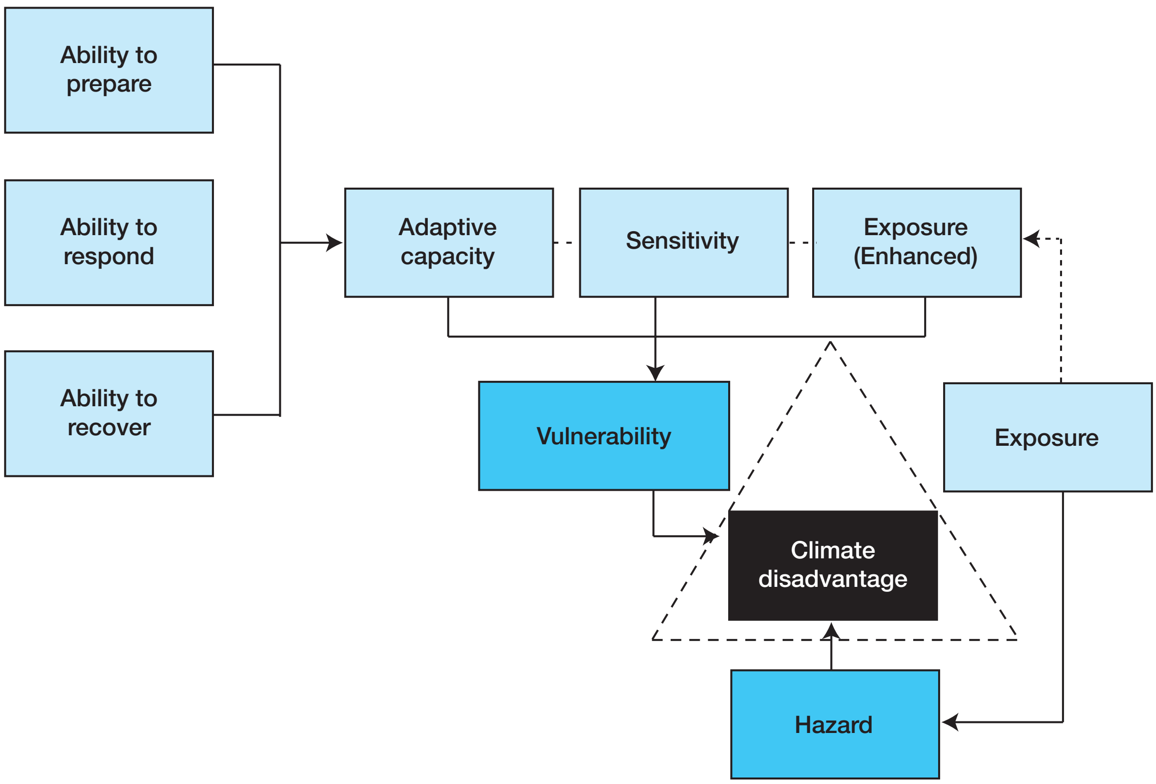
3 **ability to prepare** – the personal and social factors that enable an individual or community to prepare for heatwaves or floods, such as insurance, income and knowledge;

4 **ability to respond** – the personal, environmental and social factors that enable individuals and communities to immediately respond to heatwaves and flood events, such as income, insurance, personal mobility, fear of crime, community networks, availability of public spaces, local knowledge and personal autonomy;

5 **ability to recover** – the personal, environmental and social factors that enable individuals and communities to recover from heatwaves and flood events, such as income, insurance, housing mobility, social networks, knowledge, availability of hospital and GP services.

The final three dimensions are all directly associated with specifically social conversion factors and with facets of what one might call *social adaptive capacity*. The components of climate disadvantage as a whole are shown in Figure 1.

Figure 1: Conceptual framework for assessing socio-spatial vulnerability and climate disadvantage



Socio-spatial climate vulnerability and disadvantage

The results of the socio-spatial index highlight where there are extremes in climate-related social vulnerability in the UK. Addressing these inequalities is a useful policy aim in its own right. However, the full potential of a climate-related social vulnerability assessment can only be realised through considering the results alongside measures of hazard-exposure. It is only where neighbourhoods with high socially derived vulnerability have the potential to come into contact with hazards of a sufficiently large magnitude that climate disadvantage will occur. It is in climate-disadvantaged areas where adaptation efforts must be prioritised. Measures of potential hazard-exposure in relation to floods and high temperatures in the UK have been combined in order to make a first assessment of UK climate disadvantage.

Most, but not all, extremely socially vulnerable neighbourhoods are in the UK's large urban centres and there is a notable coastal component. Many neighbourhoods have joint climate-related social vulnerability in relation to heat and flood. For the UK this is true for about two thirds of the most extremely socially vulnerable neighbourhoods. There are also some joint patterns in neighbourhoods with extremely low climate-related social vulnerability too. In Wales, for example, 80% of extremely low-scoring neighbourhoods do so in the contexts of both flood and heat.

London neighbourhoods have the highest average (mean) socio-spatial heat vulnerability scores in England. Relative to the rest of England, almost 25% of all London neighbourhoods are highly socially vulnerable with respect to heat. A similar picture emerges in Northern Ireland and Wales with Belfast and Cardiff ranking at the top for mean socio-spatial heat vulnerability scores. Again, this is before the number of neighbourhoods is considered. In Scotland, Glasgow is markedly more socially vulnerable with respect to heat than any other part of Scotland.

The picture for the most socially flood-vulnerable locations is more complex. While many of the same areas exhibit extreme socially derived flood and heat vulnerability, this is not true everywhere. In England, for example, while London has the highest mean socio-spatial flood vulnerability score, it sees fewer of its neighbourhoods with extremely high or low scores compared to a number of other regions in England. The North West and Yorkshire and The Humber regions have the highest proportions of extremely socially flood-vulnerable neighbourhoods. They also have the highest proportions of the English national total. The lowest social vulnerability with respect to flood is seen in the South East and the East of England. Thus there is a distinct North–South divide in terms of social vulnerability in the context of flooding. For heat, if London is discounted this North–South divide also exists. However, in the case of heat, climate itself acts to redress some of the balance.

The North–South divide in English socio-spatial flood vulnerability is also seen to some extent with patterns of flood disadvantage. The Yorkshire and The Humber region is estimated to have the highest average flood disadvantage of all English regions and also the largest proportion of its neighbourhoods classed as being extremely flood disadvantaged. The East Midlands shows a similar pattern. The North West, North East and London all have average flood disadvantage scores which are above the English average (mean). However, considering average regional values alone overlooks the inequalities within regions. For example, although neighbourhoods in the South East are generally advantaged, 10% of all neighbourhoods in the region are classed as extremely flood disadvantaged.

In Wales, a number of local authorities score highly for social flood vulnerability and for flood exposure. As can also be the case elsewhere, high scores for hazard-exposure do not always combine with high scores for social vulnerability. A blanket response on the basis of hazard-exposure alone will therefore benefit some people and communities more than others, i.e. those who already have more resources and opportunities for adaptation. Responses can be fair only if they recognise that there are some who face the multiple disadvantages of being poor, old or ill and living in homes which might be uninsurable, mal-adapted and impossible to sell.

The study also analysed which indicators appear to be the strongest determinants of spatial patterns. This was carried out through the use of principal components analysis. Groups of indicators have been interpreted as representing key socially vulnerable groups. Although the nature of the groups varies in the UK as a whole, the following socially vulnerable groups appear to have a major role:

- **poverty and deprivation:** this was strongly associated with existing social deprivation;
- **new residents:** this category is associated with new arrivals more generally (as in Scotland and Northern Ireland) or with a component of new overseas arrivals (as in England and Wales);
- **mobility and access:** the ability to respond to and recover from events is a function of personal mobility and the general accessibility of services;
- **sensitivity:** a number of the determinants of climate sensitivity were grouped, allowing for the identification of enclaves of older people or areas with high proportions of young children. In Wales and Scotland, age and ill-heath were linked, and in Scotland and Northern Ireland, age and household composition were linked;
- **enhanced exposure:** some neighbourhood groups were identified through environmental indicators. In Northern Ireland, the proportion of residents in high rises was identified as a distinct measure of socio-spatial vulnerability in its own right. However, environmental and social indicators were often grouped, underlining the need for multiple adaptation responses in some areas.

Limitations

This study is a first look at developing a socio-spatial index of climate-related vulnerability for England, Wales, Northern Ireland and Scotland. The social vulnerability assessment at the heart of this study is made without an explicit consideration of the actual likelihood of an event itself or the climate drivers behind changing probabilities of events. Therefore the maps of social vulnerability are not relevant to assessing climate disadvantage everywhere. They suggest where community characteristics could lead to increased impacts, but they say nothing about whether those impacts are likely to occur. The realisation of the differential impact suggested by social vulnerability maps can occur only if the community in question is exposed to a hazard with the capacity to cause harm. Not all critical socially vulnerable locations are equally likely to be affected by flood or heatwave events; indeed some may never be. Neither is it true that every individual within a community has the same characteristics as the community as a whole and is therefore equally socially vulnerable. The results of this study shed light on which communities as a whole have the potential for higher impacts due to social and socially related drivers only, including those aspects of the physical environment of neighbourhoods which have a socially derived component.

The report text is supported by technical notes provided in the Notes. These provide important contextual information on several aspects of the work. They also expand on some of the key limitations. Some of the key limitations of the work are identified below; others are identified in Table 1 with associated recommendations:

- There are uncertainties about indicators due to a lack of consensus about the specific roles of factors in the literature. Selecting and interpreting indicators is inevitably contestable.
- Some factors may be difficult to represent as indicators. There is a general lack of suitable indicators at a fine geographical scale for some factors, such as social networks. There are other examples of factors which were difficult to represent, such as the availability of insurance.

- Social vulnerability is associated with multiple conversion factors and not all are of equal importance. They should not really be treated as being of equal weight – equal weighting of different factors is not the same as having no weights. However, evidence from weightings tests for Scotland suggests that the results of the socio-spatial index are reasonably insensitive to a weighting scheme.

- The analysis of socially vulnerable groups is based on implied associations between indicators; alternative interpretations might be equally valid.

- The geographical units used to represent neighbourhoods vary in size (and population) across the UK. The selection of unit geographies was a balance of data availability and practicality. They can provide a broad picture of socio-spatial vulnerability but their size and internal heterogeneity will mean not all socially vulnerable places will be identified. Local knowledge and fine-scale assessments using quantitative and qualitative methods are therefore a vital complement to national-scale analyses.

- The measures of hazard-exposure used in this study are illustrative. Measures of future heatwave probability are not included due to a lack of readily available data. Flood hazard-exposure data was available only for England and Wales and was estimated as a percentage proportion of the total land area of the neighbourhood. Even if neighbourhoods are identified as flood disadvantaged, it is possible that socially vulnerable populations are not located in flood-zone areas within those neighbourhoods.

- The process of combining spatial data on hazard-exposure and socio-spatial vulnerability introduces uncertainty due to the different spatial units used to represent each.

Key messages and recommendations

This research project has developed an integrated framework for understanding and assessing the ways in which climate-related social vulnerability is distributed across different groups and individuals in the UK. The new structure helps to underpin the process of developing just adaptation responses through its use of a more sophisticated understanding of climate-related social vulnerability and its distribution. Key messages and associated recommendations are summarised in Table 1.

Table 1: Summary of key messages and recommendations

Chapter/section	Key message	Associated recommendations
Chapter 4 'Climate vulnerability and climate disadvantage'	Many of the dimensions of well-being that are made insecure by climate-related hazards are not adequately captured by existing approaches to climate change adaptation policy.	Adaptation policy at both the national and local level needs to address the full range of losses in well-being that are consequent on flooding and heat events.
		Adaptation policy needs to address not only the direct impacts of flood and heat, but also losses in well-being that are a consequence of the insecurity that results from the increased likelihood of future flood and heat events.
		In terms of social justice, there is a strong case for a shift to a more solidaristic scheme of insurance that protects those who are disadvantaged.
	The social dimensions of vulnerability to climate change have not been sufficiently recognised in adaptation policy.	Climate adaptation policy needs to be understood much more broadly than is often supposed.
		Many social policies that are neither specifically concerned with climate change nor traditionally included in adaptation responses are of real importance in addressing the social factors converting climate-related events into welfare outcomes.

Chapter 4 'Addressing current socio-spatial vulnerability in the UK: evidence from empirical assessment'	There are uneven geographical distributions in climate-related social vulnerability and climate disadvantage in the UK.	Adaptation strategies and measures need to target specific places.
		Socio-spatial vulnerability needs to be considered alongside measures of hazard exposure.
	Uneven geographical distributions of socio-spatial vulnerability are driven by variations in the five dimensions of socio-spatial vulnerability.	Adaptation strategies and measures need to be informed by multi-dimensional assessments of social vulnerability.
	The existence of distinct socially vulnerable groups explains uneven geographical patterns (see sub-sections).	
	i) Poverty and deprivation	Benefits can be gained from mainstreaming climate adaptation measures and messages into the activities of agencies working to reduce social deprivation.
		Some adaptations can be facilitated by adaptations to social housing.
		Social deprivation indices are useful indicators for some aspects of socio-spatial vulnerability.
	ii) New residents	Information provision and the process of raising community awareness needs to be sensitive to the migration characteristics of neighbourhoods.
		Information provision needs to be tailored to communities.
		Information provision needs to be delivered in a range of different ways.
	iii) Mobility and access	Improving mobility and service accessibility can be targeted to selected communities.
	iv) Sensitivity	Sensitive groups, particularly where associated with other drivers of socio-spatial vulnerability, merit tailored policy responses.
	v) Enhanced exposure	Building adaptations should be prioritised for highly sensitive residents.
		There is a need to increase public and private green space in urban areas, particularly where communities have low mobility.
	There is evidence of joint climate-related social vulnerabilities in the UK.	There is a need for coordination in some areas so that activities are not duplicated or messages mixed.
	Quantitative assessments of socio-spatial vulnerability can support evidence-based policy making.	Socio-spatial vulnerability assessment needs to be applied at a range of spatial scales.
		The limitations of quantitative measures must be considered, particularly where there are incomplete data and missing indicators.
		Time series of existing datasets provide a means of tracking progress in building adaptive capacity.
		The analysis in this study should be carried out with new data from the 2011 Census and the most recent versions of other key socio-spatial vulnerability indicators.
Chapter 4 'Further developing the research base'	There is a current lack of indicators for mapping some facets of socio-spatial vulnerability.	New indicator sets should be developed at fine geographical resolution to better represent social conversion factors.
		Indicator datasets should be collated to act as a more direct indication of insurance costs or cover availability.
		There is a need to maintain and extend existing datasets on past flood events.
	There is insufficient understanding of the relative importance of dimensions of social vulnerability for determining uneven outcomes.	Future research needs to address the question of how different conversion factors, and the dimensions of socio-spatial vulnerability which they inform, should be weighted.

Introduction

This report is the product of an interdisciplinary assessment of how climate change has the capacity to impact on the health and well-being of people across the UK. The first stage of work focused on mapping out a conceptual framework for understanding the different dimensions of justice and vulnerability as they relate to climate change. A second stage built on this framework through developing a socio-spatial index of current vulnerability in the UK in the context of heat and flood. The index is used to identify critical socially vulnerable locations and socially vulnerable groups. The index results are mapped against various indicators of climate hazard-exposure to identify areas which are at most disadvantage, taking account of the differential levels of likely exposure to floods and heatwaves alongside the socio-spatial vulnerability assessment.

The research had the following aims:

- to develop a conceptual framework for understanding the different dimensions of justice as they relate to climate change and to map out the terrain and characterise the diversity of ethical issues salient to the topic;
- to employ this framework to define and to identify normative criteria to assess the differential vulnerabilities of individuals and groups to the impacts of climate change and to appraise policy responses;
- to develop a socio-spatial index of vulnerability for UK heat-related and flood hazards;
- to apply that index to identify critical socially heat- and flood-vulnerable locations;
- to identify areas in the UK which are at most disadvantage, taking account of likely exposures to floods in the present day (from fluvial and coastal sources) and from current and future high temperatures;
- to explore the implications of the findings for preparing for climate change in the UK.

Chapter 1 provides the foundation and principles for the study as a whole before exploring UK evidence in more detail in Chapter 2. Chapter 3 develops and applies the empirical mapping methodology. Chapter 4 concludes with key messages and recommendations.

1 Climate justice and vulnerability

The dimensions of climate justice

Climate change will have major impacts on human well-being. These are various in kind. There are those that are the direct consequence of climate change and those that result from policy responses to it. The first kind includes the harms to people that climate change will cause, for example through sea-level rise and the increased frequency and intensity of extreme weather events. Floods and heatwaves bring in their wake an increase in death, hunger, and ill-health, in displacement and social dislocation. The second kind includes the burdens associated with policies of climate change management; mitigation, designed to slow and diminish the warming of the earth; and the burdens associated with adaptation and economic change. One central question in environmental justice is how best to distribute these burdens. A few may benefit both from climate change and policy responses to climate change. However, many will be harmed and face new burdens.

There are different distributional dimensions of climate justice: justice in the distribution of the impacts of climate change on the well-being of different individuals and groups; justice in the distribution of costs and burdens of mitigation; justice in the distribution of the costs and burdens of adaptation. In addition to these distributional questions there are also questions of procedural justice concerning who has a voice in the formation of responses to climate change. For example, the talks at the Climate Conference in Copenhagen 2009 floundered on procedural questions. A feature of climate justice both globally and nationally is that these different dimensions of climate injustice are often interlinked or compounded, both with each other and with other injustices. Those who contribute least to the problem, whose responsibility for greenhouse gas (GHG) emissions is relatively low, are often those who face the most serious negative impacts, on whom the burdens of both mitigation and adaptation fall most heavily, and who have the least voice in the development of policy responses.

This is a problem internationally: although GHGs which cause climate change have been emitted overwhelmingly by the rich nations, climate change will overwhelmingly harm the poor. Poor nations will generally be more exposed to drought, flooding and heatwaves. Being poor, they will also be less able to adapt. However, it is also a problem internal to nations: it is the poor and disadvantaged who will be worst harmed by economic decline and by flooding and heatwaves: ‘the impacts of climate change will fall disproportionately upon developing countries and poor persons within all countries and thereby exacerbate inequalities in health status and access to adequate food, clean water and other resources’ (IPCC, 2001, p. 12). It is an intergenerational problem: the harms associated with climate change are likely to fall most heavily on future generations. It is also an intragenerational problem: some of the damaging effects of climate change are already being felt by current generations, as are many of the burdens associated with mitigation and adaptation policies.

Different dimensions of climate change become more or less salient at different scales. For example, a central question in the global debates concerns whether and how far the historical responsibilities of different nations towards GHG emissions should be taken into account in distributing the costs of mitigation and adaptation. At the national level this issue is less salient, in part since it is less easy to identify differential historical responsibilities between different actors at the domestic scale. Other issues that are less salient at the global level are more salient in the domestic case. For example, a central question in the UK context concerns the fairness and distributional consequences of reliance on a market-based insurance regime that differentiates according to risk and which leaves those who are poor as more likely to be uninsured.

This report focuses on a particular dimension of climate justice in the UK. It is concerned with the differential vulnerabilities of individuals and groups to the impacts of climate change. It will focus in particular on flooding and heatwaves. It needs to be stated clearly at the outset that no particular flooding event or heatwave can be straightforwardly causally attributed to climate change. Disasters associated with flooding and excessive heat have a long history independent of recent climate change. So also do the questions of justice about the uneven distribution of the effects of such events (Blaikie, *et al.*, 1994; Klinenberg, 2002). However, climate change will increase the frequency and intensity of extreme weather events in the UK (Pall, *et al.*, 2011). Therefore questions of justice associated with such events have become correspondingly more urgent.

Vulnerability and climate disadvantage

This report is about justice in the distribution of the impacts of climate change on the well-being of different individuals and groups in the UK. What metrics should be employed to capture the differential impacts of flood and heatwave on well-being? One obvious answer to that question might be the probability and degree of exposure to hazards such as floods and heatwaves. However, there are good reasons to think that the metrics of probability and severity of exposure are inadequate on their own. What matters is not only the likelihood and severity of exposure to the hazard but also the differential impacts of the event on well-being. How exposure converts into well-being will depend on a variety of personal, environmental and social factors – heatwaves, for example, disproportionately affect old people who live in poor neighbourhoods and who are socially isolated. Age, poverty, social isolation, and physical and social features of the neighbourhood make that population more vulnerable to the external stress of a heatwave.

Vulnerability is a matter of how the external event converts into a welfare outcome. Measuring climate disadvantage is correspondingly a matter of measuring how two sets of factors come together: (a) the likelihood and degree of exposure to a hazard and (b) individual or group vulnerability with regards to such hazards. How disadvantaged an individual or group will be to a climate event will be a function of their degree of exposure to the event and the extent of their vulnerability.

Vulnerability

In the long-standing risk and disaster management literature, a distinction is drawn between hazard, exposure and vulnerability:

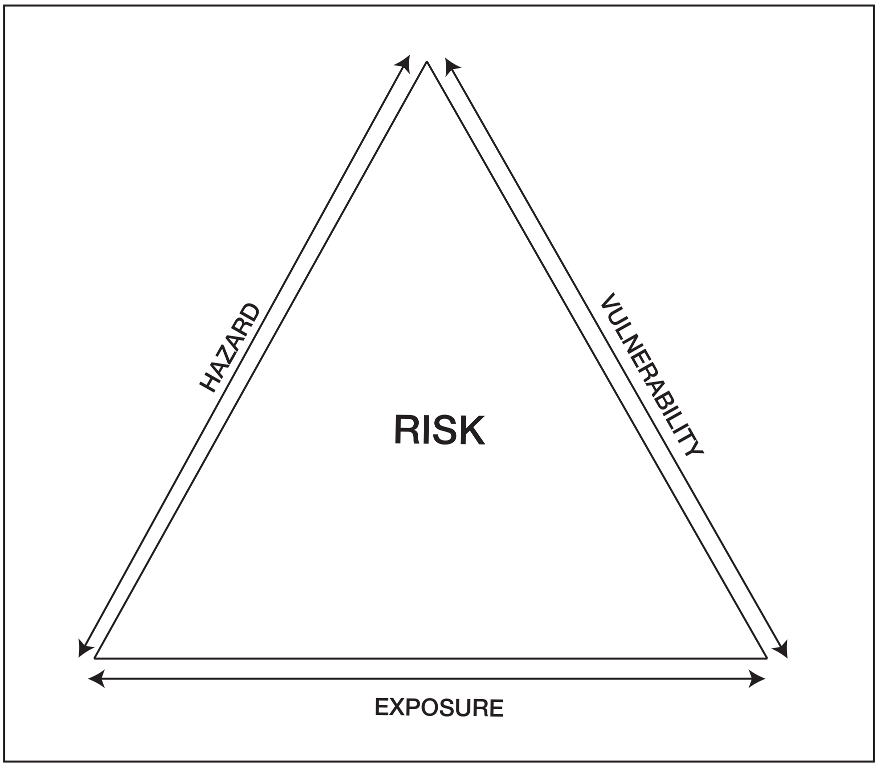
- hazard – the extent, severity and probability of the phenomenon which has the capacity to cause harm (in this case, climate and weather-related events);

- exposure – the degree to which elements at risk (e.g. people or places) may come into contact with the hazard of interest; and

- vulnerability – the susceptibility to damage of elements at risk of a particular hazard at a particular intensity (as determined by the degree of exposure which could occur).

Risk in this literature is taken to be a function of hazard, exposure and vulnerability. The relationships between each have been usefully illustrated through the risk ‘triangle’ (see Figure 2).

Figure 2: Illustration of the relationship between risk and its component elements



Source: Crichton and Salt, 2001

The concept of vulnerability in this context is used to describe the capacities of individuals and social groups to respond to the impacts of adverse events. A useful characterisation of vulnerability is offered by Kelly and Adger: 'we define vulnerability in terms of the ability or inability of individuals and social groupings to respond to, in the sense of cope with, recover from or adapt to, any external stress placed on their livelihoods and well-being' (Kelly and Adger, 2000, p. 328).

Vulnerability is a matter of how external stresses impact on well-being. An individual or group is more vulnerable if they are less able to respond to stresses placed on well-being. So understood, the concept of vulnerability raises a number of different questions. The central question we will address in this report is: how is vulnerability distributed across different individuals and groups?

However, the characterisation of vulnerability raises a number of prior questions:

1 How should well-being be conceptualised and measured?

2 What factors are relevant to understanding how external stresses convert into changes in well-being?

3 To what degree is the vulnerability specific to a particular hazard?

There has been a wide debate in the literature between 'end-point' or 'outcome' based approaches to vulnerability and 'starting-point' or 'contextual' approaches to vulnerability (Kelly and Adger, 2000; O'Brien, *et al.*, 2007; Füsell, 2009). The former is said to typically focus on biophysical impacts and adaptive capacities, the latter on social, economic and personal features of the persons and groups that influence their capacity to respond to stresses.

While the distinction does capture a contrast between approaches to vulnerability, the terms used to describe the contrast are liable to be misleading. Vulnerability is a matter of those features of a person or group that are relevant to the conversion of external events into welfare outcomes. As such, vulnerability is both about outcomes, specifically welfare outcomes, and about the characteristics of a person or group, specifically the personal, environmental and social characteristics that convert external events into welfare outcomes. The significant debate between the different approaches is not about the definition of vulnerability, but rather the richness of the accounts offered of welfare outcomes and conversion factors and of the degree to which vulnerability is hazard specific. They offer different answers to the three questions we have just outlined:

1 Many studies of the welfare impacts of climate events such as flooding and heatwaves have tended to focus on loss of life, damage to physical health and the loss of income. There are good reasons for this focus. They capture important dimensions of the ways in which such events impact on welfare. Moreover, they are relatively easy to measure. Yet a focus on these alone would seriously underestimate the welfare losses involved. These will include, for example, the disruption of social relationships, psychological stress, the loss of daily routines and the capacities to plan and control life, and the loss of significant memorabilia. A central question to be addressed in this chapter is how the nature and extent of these losses should be understood and measured.

2 Accounts of vulnerability need also to be rich in the variety of personal, social, economic and environmental factors involved in the conversion of external stresses into welfare impacts. Again, while biophysical properties of individuals and their environments such as age and health status are important, they are far from exhaustive. Social networks, institutional frameworks, the distribution of power, voice and income, the fear of crime, the possibility of insurance will all matter in consideration of how weather events such as flood and heatwaves differentially impact on different individuals and groups.

3 Some dimensions of vulnerability are hazard specific. For example, households with floodgates are better prepared than those without. However, many dimensions of vulnerability are not hazard specific. Social isolation, low income, the absence of voice and lack of insurance will render individuals vulnerable not just to climate events such as heatwaves and floods, but also to a variety of other external stresses. Correspondingly, events such as heatwaves and floods are often revelatory of wider patterns of distribution of vulnerability.

In this chapter we develop the answer to these questions in more detail.

Understanding well-being

How should well-being be conceptualised and measured? Events such as heatwaves and floods have a variety of impacts on the well-being of those affected. They have impacts on the income and the physical resources available to people. They affect life and health, and have major impacts on psychological well-being. Heatwaves and floods have effects on social relations and networks, and on the capacity of people to control their daily routines and to plan for the future. Any account of the welfare effects of climate events will need to incorporate the wide variety of different welfare impacts. How should such different dimensions of well-being be understood and measured? There are three common answers that are offered to that question: resources; subjective well-being; and capabilities (O'Neill, 2006; 2008; Robeyns and van der Veen, 2007; Stiglitz, *et al.*, 2009).

Resources

One possible answer is that we should use the amount of resources an individual has as an index of her well-being. Losses in well-being should be measured in terms of the loss of resources. Losses in income and financial losses in property values are, for example, typically used by economists to measure welfare impacts of events such as floods. There are, however, good reasons for rejecting a resource metric alone.

Resources matter. However, they matter since they are a means to well-being. They are not ends in themselves. The conversion of resources into well-being will not be uniform across different individuals and groups. A central difficulty with a resource-based view is the differential conversion of resources into welfare gains (Sen, 2009, ch. 12). The same resources can result in very different welfare outcomes.

A distinction can be drawn between three kinds of conversion factors of resources into opportunities and welfare outcomes: personal, social and environmental (Sen, 2009, ch. 12). For example, the resources a disabled person will require to realise the same opportunities for mobility will be greater than those of an able-bodied person. Personal physical disabilities, social and institutional prejudices and the physical layout of the built environment will all limit in different ways the conversion of resources into mobility. Hence, equality in resources need not result in equality in quality of life or opportunities to realise welfare outcomes.

The point has important implications for how disadvantage and inequality are to be addressed (Wolff, 2002). The potential disadvantage could be addressed in a number of different ways. First, the resources given to a disabled person could simply be increased – for example, by giving them a greater income. However, the conversion factors might also be targeted. The physical disability could be targeted through medical interventions. As social models of disability have stressed, the social sources of disadvantage might also be addressed through policies that aim to change institutional norms and prejudices against the disabled. The environmental conversion factors could be addressed through standards that improve the built environment to enable access. For reasons we outline below, the existence of different conversion factors is particularly significant in tackling climate disadvantage.

Subjective welfare

According to subjective state approaches, well-being is a matter of being in the right psychological state. Well-being is conceived in terms of happiness understood as a psychological state. 'By happiness I mean feeling good – enjoying life and wanting the feeling to be maintained' (Layard, 2005, p. 12). The approach is associated with the classical utilitarianism of Bentham. Well-being consists in pleasure and the absence of pain. The approach has undergone something of a revival. Proponents claim that developments in psychology and brain science now allow the realisation of the classical utilitarian aspiration of robust measurements of subjective well-being, for example, through global life-satisfaction surveys and a variety of experience sampling methods. Resources according to this approach matter only as a means to achieving subjective well-being. A growth in some resources for consumption need not lead to an improvement in well-being. Beyond a certain point, the absolute growth in consumer goods has not been correlated with an improvement in subjective well-being (Easterlin, 1995; Frey and Stutzer, 2002; O'Neill, 2006; 2008).

One standard problem with the subjective well-being approach is that some things make a difference to how well a person's life can be said to go independently of their subjective states. As Kahneman, one of the main figures in the development of hedonic psychology, notes in a paper with Sugden:

> *[H]uman well-being may be thought to depend, not only on the sum of moment-by-moment affective experiences … but also on other aspects of life, such as autonomy, freedom, achievement, and the development of deep interpersonal relationships, which cannot be decomposed into momentary affective experiences.*
>
> Kahneman and Sugden, 2005, p. 176

There are more specific problems in using subjective welfare as a measure of disadvantage and inequality. A central difficulty with subjective well-being and preference-satisfaction approaches to well-being is that mental states and preferences adapt to adverse situations. One response to deprivation is to shift one's aspirations in accordance with what is possible. 'The utilitarian calculus based on happiness or desirefulfilment can be deeply unfair to those who are persistently deprived, since our mental make-up and desires tend to adjust to circumstances, particularly to make life bearable in adverse situations.' (Sen, 2009, p. 282.) The result is that a metric of well-being based on subjective well-being or fulfilling preferences is liable to underestimate the welfare losses of those who are most deprived. Other more objective measures of well-being are required to capture social inequality and deprivation.

Capabilities and functionings

On this account well-being is defined in terms of capabilities to achieve central human functionings. Functionings are understood as 'the various things a person may value doing or being'. Typical functionings might include being housed, being healthy, being in control of one's own life, having close personal relationships, having good friends and neighbours, being mobile, having self-respect. Capabilities are defined as those 'substantive freedoms to achieve alternative functioning combinations' (Sen, 1999, p. 75). For Sen, capabilities – the opportunities to achieve central human functionings – rather than the achieved functionings themselves, are understood to matter for two reasons. First, they matter to a person's well-being as such. A person who is fasting for religious reasons differs from a person who is starving. The former has the freedom to eat that the other lacks. Second, they are taken to make the account consistent with the liberal claim that people should be free to make their own choices about their lives. Policy should aim to give individuals the options to achieve valuable functionings. It should not impose the achievement of those functionings on people.

However, there are reasons for thinking that sometimes the focus should be on achieved functionings rather than capabilities when it comes to measuring well-being. First, capabilities are much more difficult to measure than achieved functionings. It is much easier to measure how many people are actually housed than how many people have the opportunity to be housed. Second, some achieved functionings are a condition for people to be able to exercise an effective choice between different options. For example, an absence of achieved literacy, social networks and secure housing will all impact on the opportunities people have to achieve other important functionings and their ability to exercise choices between different options they have.

A capabilities approach is more able than others to include the different dimensions of well-being at stake in heatwaves and flooding. Resources do matter. While resources are not all that matter for welfare – resources can be differentially converted into welfare outcomes – resources clearly do matter instrumentally for the realisation of functionings. The possession of key resources is itself an important factor in how external climate events are converted into welfare outcomes. A lack of income puts a series of central functionings at jeopardy. Preparation, response and recovery from external stresses such as floods are all income dependent.

Similarly, while psychological well-being is not all that matters, it is an important constituent of well-being. Being able to be happy and to live a life without sorrow, anxiety and stress is an important capability in itself. It is also important as evidence of what other functionings matter to people (Sen, 2009, ch. 12). The loss of cherished family memorabilia in a flood is a source of sorrow. The loss of control over daily routines from displacement by flood is a source of stress. An inability to plan for the future for the same reason is a source of anxiety. The sorrow, anxiety and stress are all indicative of the functionings that matter to people, such as being in close social relationships and being in control of significant aspects of their life.

In the rest of the chapter, with some qualifications outlined below, we will assume a capabilities approach to well-being and consider its implications for understanding climate disadvantage.

Climate disadvantage: what functionings are at risk?

One virtue of the capabilities approach is that it potentially leads to a wider account of the impact of climate-related events on well-being. Some of these are well explored, for example, loss of life, damage to health and the loss of income. We outline these in more detail in the next chapter. They are important dimensions of well-being. However, consideration of only these would seriously underestimate losses in well-being. There is a much wider set of capabilities at stake.

Consider for example the impacts of flooding. Samwinga, *et al.* (2004) undertook a series of interviews to evaluate the different dimensions of homeowners' experience in flooding events which are useful to better understand the various aspects of vulnerability (see Table 2). In Heywood, Rochdale, living in temporary accommodation in remote neighbourhoods with young children as a result of residential displacement was often cited as particularly stressful (Lawson, *et al.*, 2008). Whittle, *et al.* (2010) note of the Hull floods:

> *The process of recovery is one that carries with it the challenge of adjusting to displacement (caravans, living upstairs, rented accommodation, living with family), managing the process of physical recovery (loss adjustors, insurance companies, builders, retailers), trying to maintain 'normality' in everyday life (work, school, child care, illness, deaths, births, celebrations) and trying to rebuild social life (adjust to a new home, new community relations, build trust in the future).*
>
> Whittle, *et al.*, 2010, p. 3

These reported impacts, such as living in temporary accommodation in remote neighbourhoods, the disruption of children's education, the irreplaceable loss of memorabilia and the loss of control of one's daily routines do not just matter for their impacts on health and livelihood. These losses matter in themselves since they involve important capabilities and functionings. It is for that reason that they are a source of stress and sorrow. For example, the loss of irreplaceable memorabilia is a loss of something that embodies important social ties and it matters for that reason.

Functionings such as being able to sustain close ties of social affiliation, and being in control of one's own life, are important dimensions of well-being in themselves. Moreover, their loss not only has impacts on actual functionings but also on the security of functionings (Wolff and de Shalit, 2007, ch. 3). The loss of security in functionings matters in itself and, as a result, exposure to even an increased likelihood of certain events can have negative consequences in a number of ways.

The increased likelihood of exposure carries with it the potential for losses in functionings and therefore in well-being over and above the direct consequences of the particular event itself. The pervasive threat of exposure makes individual functionings significantly insecure, and this insecurity can undermine well-being in a variety of ways. It can lead to stress and anxiety. Typical is the following statement, from an individual who suffered from a flood in Hull:

> *If it's raining you could drive down the street at one o'clock in the morning and you would be sure to spot a resident going out to check the drain because they haven't been able to sleep … When I go home, the first thing I do if it's been raining or is raining, is stop and check the level of the drain. The last thing I do before I leave is check the level of the drain just to make sure that I'm aware of its current state … There is a lot of anxiety if the weather is going to be bad.*
>
> Whittle, *et al.*, 2010, p. 42

Insecure functionings can also lead to a loss of the ability to plan for and take control of future significant life events, insofar as long-term planning presupposes stable expectations about what the future is likely to bring. As Wolff and de Shalit note, it can lead to a personal 'planning blight' that affects people's ability to shape and control their lives.

This sort of phenomenon means that the increased likelihood of exposure to a climate event can in itself have a deeply corrosive impact on one's capacity to sustain a variety of other functionings over time. Increased likelihood of exposure paradoxically can increase vulnerability to that exposure because it reduces adaptive capacity. It also leads to an increased vulnerability to future hazards. In particular, in a

Table 2: Homeowners' experiences of flood events

Dimensions of impacts	Factors which affected experience
Physical aspects	Flood characteristics, e.g. depth, quantity, contamination, duration
	Extent of damage: the extent of property damage and insurance cover
	Flood warning: how much warning homeowners had before the flood
	Flood timing or season: holiday time can be particularly distressing
Economic aspects	Financial expenses associated with living in temporary accommodation
	Insurance cover fear of potential premium rises and/or refusal by insurers to extend cover
	Fear of potential reduction in property value and/or demand
	Loss of property, some of which may not be replaceable
	Loss of earnings associated with staying off work to oversee repair work
Emotional issues	Fear of flooding in the aftermath of a flood event
	Leaving home and upheaval associated with living in alternative accommodation
	Loss of irreplaceable memorabilia of sentimental value
	Fatigue associated with cleaning up and repair work
	Reactions to flooding included disbelief, shock, surprise, devastation, stress, worry, 'get on with life'
Service-related issues	Service experience: how service providers dealt with them and the extent to which needs were met
	Communication: consistent, timely and information and/or advice
	Loss of control while the repairs are being carried out
	Temporary accommodation: proximity to home, comparability
	Speed of return to property
	Confidence in service providers: make it easy for homeowners to get on with other aspects of life while repairs are ongoing
	Fairness: how fair the homeowner perceives the settlement to have been
Social aspects	Family support network: helps to cushion the impact of the catastrophe
	Children: families with children experienced more difficulties in day-to-day running of household
	Friends support network: another source of help for flood victims
	Community spirit: may be fostered when a neighbourhood empathises
	Situational issues: other personal circumstances such as family tragedies can compound the stress felt by flood victims
	Homeowners' characteristics: individual characteristics may have a bearing on coping with the flood and its aftermath
	Experience of flooding: previously flooded homeowners find it easier to cope next time
	Personality: each homeowner is different and will cope differently in crisis
	Vulnerable groups such as infirm or elderly people had unique requirements and some found it difficult to cope with the resulting upheaval

Source: Samwinga, *et al.*, 2004

risk-differentiated insurance regime of the kind that exists in the UK, increased likelihood of flooding itself can become corrosive. A household at great likelihood of flooding has more difficulty in access to insurance either through increased premiums and excesses or insurance refusal:

> *Already flood excesses up to £20,000 or higher are becoming common and premiums are increasing in flood risk areas. After the floods of 2000, 45 per cent of respondents to a survey of residents and businesses in Lewes [East Sussex], reported substantial changes in their insurance premium and a further 18 per cent, mainly residents, reported that flood insurance had been refused. In a survey of the insurance industry published in* Insurance Times *in November 2006, 70 per cent of insurers said they intended taking a much firmer line in the future.*
>
> Dlugolecki, *et al.*, 2009, ch. 7, p. 21

Any account of vulnerability needs to include not just vulnerability at some particular point in time but also the impact over time, and needs to understand how current vulnerabilities can act to undermine or destabilise current and future functionings.

Conversion and vulnerability: from climate-related events to climate disadvantage

As noted above, a central argument against simply using a resource metric for well-being is that resources are differentially converted into capabilities. Personal, environmental and social conversion factors will mean that identical resources can have different welfare outcomes. The obverse of the differential conversion of resources into welfare gains is the differential conversion of negative external events into welfare losses. Vulnerabilities are a particular example of this obverse form of conversion. Negative environmental events such as floods and heatwaves convert differentially into welfare losses. The same event can have very different welfare outcomes.

The point is central to understanding climate justice. It would be a mistake to assume that the probability and degree of exposure to a hazard can be used alone as a metric to conceptualise the distribution of impacts. What also matters is the ways in which the exposure to a hazard is converted into well-being.

Heatwaves

Consider heatwave events. In one sense, high temperatures affect everyone in a particular area. All suffer an increased chance of heat-related illness. However, the conversion of the external event into losses of important functionings, in particular into illness and death, will depend on a number of personal, environmental and social conversion factors. These will be discussed in more detail in the next chapter. They include the following:

Personal conversion factors: Personal conversion factors are well rehearsed. A variety of biological sensitivities will affect the likelihood of harm. The young and the old, and those with previous health problems, will all be particularly sensitive to the effects of heat.

Environmental conversion factors: Environmental factors will include the physical attributes of the neighbourhood, such as the amount of green space, and characteristics of the housing such as the elevations of residential buildings.

Social conversion factors: Social networks and the social characteristics of neighbourhoods matter to the conversion of heatwaves into mortality and the loss of important functionings.The potential for adverse health effects from heatwaves exists for everyone. However, there is evidence that a range of social factors increases the likelihood of dying during a heatwave, including living alone, social isolation, and the social characteristics of neighbourhoods (Kovats and Ebi, 2006, p. 592). The vulnerability of the elderly in particular is increased by physical and social isolation. Consider, for example, the social dimension of deaths in the Chicago heatwave of 1995 (Klinenberg, 2002). Social isolation and the fear of crime were major factors in determining uneven patterns of harm. Old people died alone. Some died in rooms with windows and doors locked from fear of crime. Old people were often unwilling to leave the home to keep cool. The decline of neighbourhoods led to the loss of public spaces with air conditioning in which vulnerable people could gather.

Research in Europe in 2003 highlights additional issues for older people in retirement and nursing homes (Kovats, *et al.*, 2006). This is also evident in the UK. The largest percentage increase in deaths of the over-75s by place of residence was in nursing homes. The infrastructure of nursing homes was a factor, including not just the physical infrastructure of the building, but also the social infrastructure: the way nursing homes are organised, who controls the heating systems and who controls the mobility of the patients. The rules that govern life in nursing homes are significant, for example, that there are fixed routines, which are not adjusted for the weather. There are impacts of habitual practices for dealing with old people, for example the custom to always keep them very warm and give them only tea to drink. Many practices render the elderly dependent on others. Important through all of this is the capacity of old people to sustain some independence and control over their own environment (Brown and Walker, 2008).

Flooding

Similar points about the conversion of events into welfare losses apply to flooding. Flooding events reveal in a clear way why the likelihood and degree of an exposure to a hazard is on its own an inadequate metric for understanding questions of climate justice. Flooding can be of different kinds: tidal, fluvial and pluvial flooding. There is some link between social deprivation and the likelihood of exposure to coastal flooding. Studies have shown that there are eight times more people living in tidal floodplains who are in the most deprived 10% of the population than those from the least deprived 10% (Walker, *et al.*, 2003).

However, relationships are not always straightforward. Indeed, according to one report for fluvial flooding, there may be an inverse relationship between deprivation and the potential for exposure to fluvial flooding, with a slightly higher proportion of the more affluent deciles in the floodplain (Walker, *et al.*, 2003 cf. Lucas, *et al.*, 2004, p. 81). This may change in the future. In particular, if insurance regulation after 2013 leads to more risk-sensitive differentiation in insurance coverage, housing in floodplains will become less insurable, leading to the loss of property values and the concentration of the poor in areas of higher flood probability (Crichton, 2004, p. iv). However, the likelihood of exposure to flood is not all that matters in measuring climate disadvantage. Again, what is important is the way personal, environmental and social factors convert a flooding event into welfare losses. These will be explored in more detail in the following chapter. They include the following:

Personal conversion factors: As with heat-related impacts, the impacts of floods on health are more likely to be felt by the old, the young and those with prior health problems.

Environmental conversion factors: Environmental factors will include the physical characteristics of housing – for example, people in basement accommodation and street-level accommodation will suffer worse than others – and of the neighbourhood, such as drainage and green space.

Social conversion factors: A variety of social factors differentially affect the capacity of households to prepare for, respond to and recover from flooding:

- **Low-income households** are less able to take measures to make property resilient to flooding: for example, permanent dry-proofing is expensive. The uptake of floodgates, even when they are offered free of charge, is affected by social factors such as the fear of crime and the anxiety that they could indicate that the residents are away.

- **Social networks** affect the ability of residents to respond to flooding: for example, through providing social support and a response network, and by improving knowledge bases. Thus the impact of past flooding can strengthen networks required for future events. For example, in Cumbria, the experience of past events meant that communities were also more resilient (with 18 compared to a previous 12 flood action groups). Where such groups existed, a quicker and more effective response was possible ('Cumbria flood recovery – six months on', Cumbria County Council, 19 May 2010). The sort of fostering of community spirit implied by the establishment of flood action groups has also been reported elsewhere. Along with other support networks provided by friends and family, community empathy helps in the process of recovery (Samwinga, *et al.*, 2004; Whittle, *et al.*, 2010).

- **Social inequalities** are also clearly important in the ability of different groups to respond to and recover from the impacts of floods. The ability to relocate is affected by wealth. So also is the ability to take out insurance against flood damage. We noted above that both insurance premiums and excesses are increasing in floodplains; the increases affect those on low incomes in a disproportionate way. They take place against a background where those on lower incomes are already disproportionately uninsured. Thus the Pitt review notes:

  Low-income households are least able to recover from the financial impact of flooding and are statistically the least likely to be insured. The lack of home contents insurance in low-income households is widespread. Of people in low and very low-income households, one-third of all UK households, 69 per cent are in social housing. Of this 29 per cent have no insurance at all and 50 per cent do not have home contents insurance as opposed to 1 in 5 of those on average income.

  Pitt, 2008, 9.28 p.148

  The impact of flood for low-income uninsured households is evident in qualitative research on flooding in the UK (see Box 2). Income inequalities have major impacts on the ability not just to respond to and recover from a flooding event but also to prepare for future flooding events.

Box 2: Low-income and insurance

Helen, a council tenant, had no contents insurance and had to re-furnish her home on a very limited income (she was disabled and couldn't work). Having had this experience, Helen was determined to purchase insurance to protect her home in future. However, none of the companies she contacted would insure her. Even those whose cover was intact sometimes found the terms of their new policies very unfavourable, as Leanne described:

> *We went on the web looking for insurances and … other insurance companies don't particularly want to take you on and the premiums were that high it was unbelievable. So we stuck with the same insurance company and they took us back on and the premium only went up £50 and that wasn't a problem. But the excess has gone up £5,000 we have to pay on contents and £5,000 on buildings. So if the same thing happened again we've £10,000 to find before we start. And where do we pluck that from? … We haven't got £10,000. Or do we save anything at all or do we literally just let the whole lot go and say it's all gone and claim what we can and just have everything lesser?*
>
> Whittle, *et al.*, 2010, p.111

Fertile functionings and corrosive disadvantages

Some functionings such as health, social ties and the ability to control important aspects of one's environment also appear in lists of conversion factors from external events to welfare losses. These functionings matter in themselves – loss of health, social isolation, loss of autonomy are all losses in human well-being. However, they also matter because they support the realisation of other functionings. These functionings are what Wolff and de Shalit call 'fertile functionings' (Wolff and de Shalit, 2007, pp. 121–5). For example, the development of social networks around flood events improves the capacity of communities to prepare for and respond to future events. Threats to future welfare losses are lowered. Conversely some losses of functionings are corrosive. They threaten other aspects of welfare. To lose those functionings is a 'corrosive disadvantage' (*ibid.*). In heatwaves an old person who is isolated and lacks networks or who is in an institutional setting that renders her unable to control her own environment is in a situation where other functionings are threatened by future events. Supporting fertile functionings and addressing corrosive disadvantages will be of particular significance for public policy.

Participation, voice and just procedures

One important fertile functioning is participation in decisions that will affect one's life. The ability matters in three ways: it is an important functioning in itself; a requirement of justice; and a fertile functioning that fosters the realisation of other important functionings.

A significant capability is the ability to have a voice in decision making itself: 'being able to participate effectively in political choices that govern one's life' (Nussbaum, 2000, p. 80). Participation is in itself an important functioning, an important part of what makes for a good life in modern conditions.

The distribution of voice in decision making is central to procedural justice. Procedures matter to justice in two different ways. First, procedures matter insofar as they produce just outcomes. However, those outcomes might be judged just or unjust according to some criterion that is independent of the procedures themselves. Second, the procedures matter since outcomes can only be fully just if they are the outcome of fair procedures. An absence of fairness in the decision-making process taints the justice of the outcome even if it is just according to other criteria.

In addition to being an important functioning in itself and a requirement of justice, being able to participate matters instrumentally. Having a voice is a fertile functioning. It fosters the realisation of other important functionings. Likewise, its absence weakens the ability to protect other functionings. For that reason it is important not just for the legitimacy of policy, but also for its effectiveness. Policy that is developed without the voice of those involved can be less effective. Consider, for example, the provision of floodgates in poor neighbourhoods. As we noted above, even where they are offered free of charge there can be a low take-up in socially deprived neighbourhoods. Members of the community may be reluctant to use them through fear of crime – they can indicate when a householder is absent. The development of an effective flood-defence policy for households would be best fostered with the participation of those involved, where individuals are able to develop solutions to the problems of vulnerability that they face, in a way that is sensitive to their environment and to their needs, fears and aspirations.

Hazard-independent vulnerabilities and patterns of inequality

Many patterns of inequality in vulnerability exist independently of the specific event that reveals them. Not all the vulnerabilities involved are hazard specific. Old people die alone in locked rooms irrespective of heatwaves. The loss of independence and autonomy within institutional settings exists independently of the effects in heatwaves. The external hazard is revelatory of independently existing patterns of inequality and vulnerability. As Klinenberg notes of the 1995 Chicago heatwave:

> *[E]xtreme exogenous factors such as the climate have become disastrous partly because the emerging isolation and privatization, the extreme social and economic inequalities, and the concentrated zones of affluence and poverty pervasive in contemporary cities create hazards for vulnerable residents in all seasons … [T]he event expressed and exposed conditions that are always present but difficult to perceive.*
>
> Klinenberg, 2002, p. 230

Similarly, floods are revelatory of pre-existing inequalities and deprivations and are not hazard specific. For example, the impacts of low insurance penetration for those on low incomes exist independently of flood events. The external event reveals and worsens existing forms of deprivation. For this reason, there are good grounds for mapping those vulnerabilities independently of hazards.

Climate justice and climate disadvantage

Climate justice is not then simply a matter of the differential likelihood of exposure to events such as heatwaves and floods. It is a matter of differential vulnerabilities to these events – about how those events are converted into welfare losses. Climate disadvantage occurs where differential exposure coincides with vulnerability. These points matter to how climate disadvantage should be addressed. It can be addressed by a reduction in the likelihood of exposure to hazards through mitigation. Mitigation policy is a matter of justice both at the global and national level, given the differential impacts of climate events on welfare. Flood-defence policies will reduce exposure from flooding. However, adaptation policy is a matter of addressing how climate events are converted into the full range of welfare losses. In particular, both environmental and social conversion factors matter. Policy on climate disadvantage needs to address factors such as the physical and social characteristics of neighbourhoods, social networks, the habitual practices of institutions, the distribution of income and insurance regimes. All are factors in the way that climate events translate into welfare losses and gains and all are associated with different potential policy responses.

Measuring vulnerability

Climate disadvantage is a function not just of the likelihood and degree of exposure to climate hazards but also of the personal, environmental and social factors that convert exposure to hazards into welfare outcomes: that is, of the different vulnerabilities of individuals and communities with respect to that hazard. Vulnerability concerns the ways in which adverse events convert into welfare outcomes. Climate change threatens a wide variety of functionings. How exposure converts into well-being will depend on the ways in which personal, environmental and social factors adversely affect those functionings. An individual or group is of greater vulnerability if for a variety of personal, environmental and social factors, they are less able to respond to stresses placed on well-being (see Table 3).

How should vulnerability be measured? Much of the work on vulnerability has centred on the Intergovernmental Panel on Climate Change (IPCC)'s account of vulnerability. According to the IPCC, vulnerability to climate change is:

> *[T]he degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.*
>
> IPCC, 2007, p. 883

Table 3: Illustrative examples of conversion factors

Factor	Flooding	Heat
Environment	Physical characteristics of housing Drainage Green space	Green space Building elevation Neighbourhood characteristics
Social	Income Social networks Insurance	Social networks Institutional routines Independence and control of environment
Personal	Age Health	Age Health

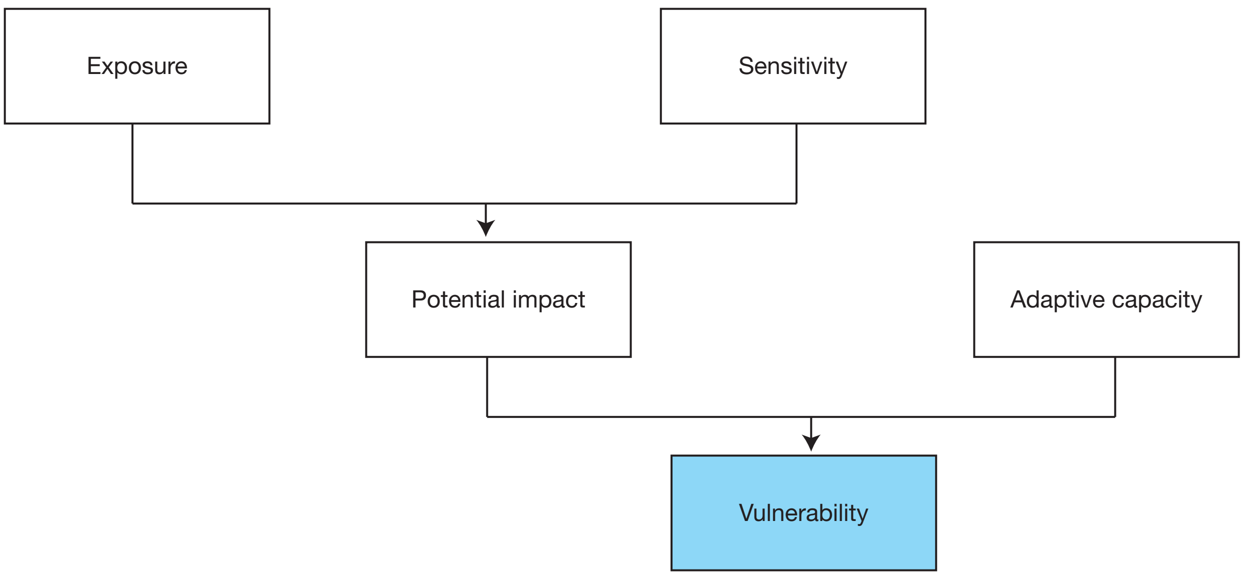
Vulnerability is contrasted with resilience, characterised as 'the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change' (IPCC, 2007, p. 880). According to this account, people's vulnerability to climate change depends on their exposure to climate changes; their sensitivity to its impact; and their capacity to adapt (SNIFFER, 2009) (see Figure 3):

- **exposure** – the degree to which an exposure unit (e.g. a person or place) comes into contact with a hazard such as a heatwave event, a fluvial flooding event or other significant climate-related variations;

- **sensitivity** – the degree to which an exposure unit has the propensity to be affected (adversely or beneficially) by this exposure;

- **adaptive capacity** – the ability of an exposure unit to adjust and therefore to avoid negative impacts (and conversely to benefit from positive impacts).

Figure 3: Components of vulnerability



Source: Spickett, *et al.*, 2008

For example in the context of heat, the IPCC explains that vulnerability is:

> *[A] function of: the degree of exposure to the heat hazard, sensitivity to changes in weather/ climate (the degree to which a person or system will respond to a given change in climate, including beneficial and harmful effects), and adaptive capacity (the degree to which adjustments in practices, processes, or structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change in climate).*
>
> IPCC, 2001, in McGregor, *et al.*, 2007, p. 9

The IPCC definition is sometimes cited as an exemplar of an 'outcome-oriented' view of vulnerability that focuses on biophysical aspects of vulnerability and excludes at least some of the social and economic aspects of vulnerability. For others it provides a basis for incorporating the variety of social, personal and environmental factors affecting differential impacts. These factors can be associated with individuals, communities, institutions or the physical characteristics of the neighbourhoods within which people live. Taking a more inclusive view of vulnerability is in keeping with the key concepts behind place-based models, such as hazards-of-place (Cutter, *et al.*, 2002; Cutter, *et al.*, 2008). This group of models emphasises the important role of geographic context for understanding expressions of vulnerability, which is also at the centre of the accompanying empirical work presented later in this report.

The empirical work in this study considers five dimensions of vulnerability which bring together aspects of place and time with personal, social and environmental factors, further elaborated in Chapter 2, as the basis for assessing *socio-spatial vulnerability*:

1. **Sensitivity** – personal biophysical characteristics, such as age and health, which affect the likelihood that a heatwave or flood event will have negative welfare impacts.

2. **Enhanced exposure** – the aspects of the physical environment, such as the availability of green space or housing characteristics, which tend to accentuate or mitigate the severity of heatwave or flood events. This recognises that hazard-exposure is not independent of socially related drivers. These are not fully accounted for in all hazard-exposure assessments.

3. **Ability to prepare** – the personal and social factors that enable an individual or community to prepare for heatwaves or floods, such as insurance, income and knowledge.

4. **Ability to respond** – the personal, environmental and social factors that enable individuals and communities to immediately respond to heatwaves and flood events such as income, insurance, personal mobility, fear of crime, community networks, availability of public spaces, local knowledge and personal autonomy.

5. **Ability to recover** – the personal, environmental and social factors that enable individuals and communities to recover from heatwaves and flood events, such as income, insurance, housing mobility, social networks, knowledge, and availability of hospital and GP services.

Some limitations and challenges

There are difficulties and limitations associated with measuring socio-spatial vulnerability that need to be noted at the outset. First, many of the personal, physical and social factors involved in the conversion of climate-related events into welfare outcomes cannot be measured directly – and even where measures could exist, none in fact does. The research has used a variety of proxy quantitative measures that are associated with the geographical distribution of vulnerabilities. Proxies are imperfect: for example, levels of crime that can be measured at neighbourhood levels need not correlate with levels of fear of crime. The coverage of different factors will be incomplete. Indeed, some factors, such as levels of personal autonomy and independence, can be difficult to capture in any proxy measure. Therefore, even with improved databases it will always be necessary to carry out qualitative research into particular events to complement quantitative research activities.

Second, there are multiple conversion factors and not all are of equal importance. One should not really treat them all as being of equal weight – equal weighting of different factors is not the same as having no weights. However, judgements about the relative importance of different factors can be difficult to make. Yet in practice, for the purpose of identifying the most climate disadvantaged, the problem is made less pressing due to the unfortunate social fact that many of these factors cluster. For example, low income, lack of insurance, low housing mobility, living in inner cities with little green space and high crime may all come together for a large portion of the most vulnerable populations. Robust measurements of the most and least vulnerable neighbourhoods are therefore often possible despite the difficulty of assessing the relative importance of one factor against another. As we show in Chapter 3, 'Impacts of weighting schemes on the results of the socio-spatial index', identification of the most socially vulnerable populations is relatively insensitive to the weighting schemes tested in this study.

Third, the capabilities and functionings are themselves plural, so there may be no plausible single measure for the welfare outcomes of climate-related events such as heatwaves and floods. As we noted above, people suffer in different ways – from physical health problems, psychological impacts, social dislocation, a loss of control over daily and long-term life events and so on. Moreover, the loss of some functionings may matter more than others and they matter in different ways: their gravity – how seriously a person will be harmed; their urgency – how rapidly action must be taken to avoid harm; their corrosiveness – how much their loss threatens other functionings (Wiggins, 1998; Wolff and De Shalit, 2007). Again, however, the unfortunate fact of clustering of different dimensions of deprivation means in practice it may not be difficult to identify the most vulnerable and climate-disadvantaged persons and neighbourhoods.

Fourth, while we have made a distinction between the likelihood and severity of exposure to a hazard, on the one hand, and vulnerabilities to the hazard, on the other, in practice the difference is more blurred than the initial distinction might suggest. The reason is that, as noted above, increased threats of exposure can themselves be corrosive of functionings. The very fact of an increased threat makes a person more vulnerable to that threat. For example, in a risk-differentiated insurance regime, those with the greatest likelihood of flooding are also those who have greater problems in access to institutional protection against the consequences of flooding. Hence, vulnerability measures will not in practice be independent of likelihoods of exposure.

Fifth, there are inherent uncertainties associated with representing vulnerabilities using geospatial data and combining this information with representations of hazard. Unit geographies tend not to adhere to natural environmental units and so cut across floodplains and urban areas. Similarly, they can cut across social units and can fail to identify clusters which would emerge using alternative representations. The area-based data used in this analysis is only an indication of general neighbourhood characteristics and should not be used to make inferences about individuals within neighbourhoods. Further, the use of average data for relatively large units inevitably masks the true heterogeneity of people and communities within zones. Although hazard data has been represented on the same geographies as those used for vulnerability indicators, this does not mean that communities within zones are necessarily living in affected areas, particularly in the case of highly geographically constrained hazards, such as fluvial flooding.

This report is presented as an initial exercise in assessing a number of important dimensions in the geographic distribution of climate-related social vulnerability that will form part of a more complete account of climate disadvantage. In the next chapter we will examine the different dimensions of vulnerability in more detail. Chapter 3 develops and applies the empirical mapping methodology.

2 Measuring and mapping vulnerability

The introduction provided a framework for understanding climate-related justice. This chapter builds on that foundation by summarising the UK evidence base of factors which explain how, where and why people are differentially impacted when exposed to the same events or conditions. Its aim is to inform a methodology through which these factors can be translated into indicators which can be used to represent socio-spatial vulnerability within quantitative assessments. In doing so it develops in more detail the conceptual framework for the empirical component of this study.

Dimensions of vulnerability

A wide range and number of factors contributing to vulnerability in the UK are cited in the literature (see Tapsell, *et al.*, 2002; 2005; Thrush, *et al.*, 2005; SNIFFER, 2009; Fielding, *et al.*, 2005; Walker, *et al.*, 2006). These have both personal biophysical, environmental and social dimensions. The following sections explore which factors have been highlighted as important to understanding vulnerability. Since the evidence draws on the analysis of past events, there is also a review of some of the past UK events themselves.

Flooding

Exposure

The overall number of people likely to be exposed to flooding is growing. At present it is estimated that 'there are over 2.6 million properties in England and Wales which are exposed to flooding from rivers and the sea, and over 3.9 million properties exposed to flooding from surface water' (Smith, 2010, p. 1). One in six properties is likely to be exposed to some form of flooding. The Environment Agency (EA) is now attaching great importance to community involvement in local flood-risk management and in collaborating with the flood information charity, the National Flood Forum (Smith, 2010).

Understanding patterns of exposure and its change is an important area of work. National-scale quantifications of how fluvial and coastal flood potential compares with patterns of population have already been developed (e.g. Hall, *et al.*, 2003; Hall, *et al.*, 2005). However, there are conflicts in the estimated numbers of people who could be affected in the UK and figures range from 1.5 million to 5 million (Watkiss, 2009; Walker, *et al.*, 2003; 2006). This alone makes questionable the prudence of relying solely on measures of exposure in order to best prepare UK communities for the future. However, as argued in Chapter 1, even in a world where there is perfect knowledge about hazards and potential exposure, developing just responses to climate impacts necessitates a social vulnerability-oriented assessment and one which is framed by potential future well-being. Understanding the dimensions of vulnerability and their impacts on well-being requires a discussion of the evidence coming from analyses of past events, in terms of both the impacts associated with the events themselves and also the characteristics of those most affected.

Welfare impacts – health and income

Compared to other parts of the world, the UK is not associated with a high degree of flood mortality. Although past UK flood events have resulted in direct fatalities – e.g. 13 in the 2007 UK floods (Pitt, 2008); two in the 2005 Carlisle floods (Wheater, 2006) and five in the January 2005 storm which hit the Outer Hebrides (Werritty, *et al.*, 2007) – and any loss of life is a source of sorrow, mortality is not a good measure of their overall impacts and certainly not the only facet to be explored for understanding vulnerability.

It has been recognised for many years that floods can have indirect as well as direct health effects. For example, Bennet (1970) analysed the longer-term effects of floods on mortality after the 1968 floods in Bristol. During the twelve months after the floods, he found a 50% increase in population mortality in the flooded part of the city but no appreciable change in mortality in the non-flooded part. Other literature suggests that indirect mortality may be caused by the shock of an event and the stress of recovery, which 'exacerbates pre-existing health conditions, such as heart disease and strokes, particularly among the elderly' (Werritty, *et al.*, 2007, 2.6). This evidence suggests that there are some biophysical aspects of populations which may result in impacts on future well-being, i.e. there is a sensitivity element to flood vulnerability. However, evidence from Scotland suggests that even within the same sensitive groups there are different impacts associated with income: 'households with an annual income of less than £20,000 … reported higher levels of stress and anxiety and more adverse health impacts after flooding' (Werritty, *et al.*, 2007, p. iii). Income is therefore one of the factors which helps to explain differential impacts on well-being.

Although some of the health impacts are important and have differential effects, this does not allow for the investigation of all factors and processes affecting vulnerability or the full range of functionings threatened. For example, the 2007 summer flooding severely affected many areas in England, particularly South Yorkshire, Hull, Gloucestershire, Worcestershire and the Thames Valley (Pitt, 2008). The flooding of 55,000 properties resulted in 'tens of thousands of people' being made homeless, and many businesses being 'put out of action for months on end' (Pitt, 2008, ES. 5). The floods ranked as 'the most expensive in the world in 2007' (Pitt, 2008, ES. 3). The January 2005 Carlisle floods covered 2,000 properties and caused significant disruption to residents, businesses and visitors (Wheater, 2006).

Information, adaptation and resilience

According to research reported by Norfolk County Council, 'only one in ten households understand that they have a responsibility to protect their homes against flooding, incorrectly believing it is the remit of local government, the Environment Agency, or water companies' (Aviva, 2005). Flood protection measures were estimated by the Association of British Insurers to cost between £2,000 and £6,000 to deal with flash-floods using dry proofing measures, and from £20,000 up to £40,000 to make buildings resilient for long duration floods. However, flood resilient repair can save between 50% and 80% of the cost of a future flood (ABI, 2006). Flood protection measures can bring multiple benefits. Not only are financial costs of restoring homes greatly reduced (e.g. reductions from £48,564 to £8,560 per household have been reported) but there are the benefits in well-being from the speedier return of householders to affected properties (Aviva, 2005; Association of British Insurers and National Flood Forum, 2007). Preparing for flood events therefore requires access to appropriate information about the benefits of flood protection measures as well as the resources to carry out preventative measures.

Some 60 approximately 100-year-old small terraced houses in two distinct areas of Heywood, Rochdale were flooded for the first time in recorded memory in 2004, and again in 2006. The damage to the homes in Heywood, which experienced internal flooding, was typically to all downstairs flooring, plaster, furniture, fixtures and fittings. In most cases, water entered the homes through doors, air vents and from under suspended floors. It has been noted that people generally are ill-informed about how best to protect their properties. Only 20% of Heywood homes flooded internally in 2004 and 2006 have taken some form of precaution against future flooding, such as acquiring floodgates, retaining sand bags, improving doors and changing air vents. However, an additional 25% of those flooded would have liked to take preventative measures but did not know how to do so, or felt that there was nothing they could do to avoid being flooded (Lawson, *et al.*, 2008).

This suggests that local knowledge of past flood events can help some to build resilience to future events. Nevertheless, there are people with past experience who still feel unable to prepare for future events. This may be as a result of a lack of material resources. Indeed, some measures, such as permanent dry-proofing, can be very expensive at around £6,000–£8,000 per house (Lawson, *et al.*, 2008). On the other hand, temporary dry-proofing (at around £3,000 per house) or wet-proofing measures (such as waterproofing of the building fabric at £300–£3,000) can be much more accessible. Part of the problem then may be due to a lack of understanding of technical or other possible preventative solutions, some of which may be low/no cost. However, there is also increasing evidence that some of the reasons behind a lack of preparation in areas previously affected include more subtle issues such as risk perception and personal outlook, factors which are very difficult to quantify (Adger, 2006). In fact, even where properties have some protection against flood events, the tendency for some within these communities to assume that they are immune from impact causes its own set of vulnerability issues (Thrush, *et al.*, 2005).

Flood-resilient buildings are generally encouraged by the insurance industry, and flood-resilient repair is a potential opportunity to reduce potential damage to the building stock. However, the responsibility and cost for flood resilience generally has to be borne by the homeowner, and this therefore disenfranchises those who are unable to take proactive measures because of their status as tenants or a lack of access to the necessary funds. Mortgage lenders are typically supportive of homeowners undertaking flood-resilient repairs. Indeed, the insurance industry has promoted the idea of mortgage lenders extending loans for flood-resilience measures by allowing homeowners to add to their existing mortgage in order to fund the difference between a like-for-like repair and a flood-resilient repair. However, such lines of credit are of course not available to tenants (Lawson, *et al.*, 2008) or to those without stable work, with poor credit or who otherwise may be refused loans. Flood preparation therefore depends on tenancy arrangements, employment characteristics and income levels.

Some of the factors demonstrated in these examples echo those found in other published work. The following specific social indicators explaining differential potential for flood awareness and preparedness have also been previously identified: people who have no experience of past flooding; people in lower socio-economic groups (C, D and E); tenants; people who are new to an area, especially those arriving within the last year; and people who are unemployed (Fielding, *et al.*, 2005). New arrivals may have less knowledge of the potential for exposure in an area.

Social limits to adaptation

Even where the costs of adaptation measures could be borne by a householder, there is reluctance by some living in low-cost housing with frontal access to a street to install flood-mitigation measures. One reason given by householders was that it would make it obvious that the house was liable to flooding, and thus more difficult to sell. With regards to some measures that would need to be in place when the resident was out of the home, such as floodgates, some residents expressed a concern that these measures could make the houses more prone to burglary, as they would make it obvious that the householder was away (Douglas, *et al.*, 2010). Therefore, crime, or the fear of crime, restricts adaptive capacity and this is likely to have a differential impact depending on the characteristics of a particular neighbourhood.

Applying some of these adaptive measures may require some advance warning that an event may occur. There may be little time – two hours or less – in which to respond. For individuals, an actual warning of a flood is usually obtained by signing up to, or by calling, the EA's Floodline. Floodline only covers areas recognised by the EA to be at risk (i.e. likely to be exposed) to flooding. This relies on the accuracy of maps, which would in any case exclude nearly all pluvial flooding (although the EA has recently published a set of pluvial exposure maps). Other warning devices are flood risk and severe weather reports on national and local radio and by local authority loudspeaker vans when advance knowledge and government plans and resources exist (Lawson, *et al.*, 2008).

The EA is moving towards 'a flood warning system in which people who have landlines are automatically registered to receive warnings' unless they request otherwise (Smith, 2010). However, people living in rented accommodation, for example, may not have access to a landline. Although there is some overlap with the ability to prepare, there are also factors which therefore help to determine a differential capacity to respond to events, even when there is advance warning. For example, there may be groups who are less able to understand and interpret warnings owing to language or other barriers to understanding. There are also groups who may not be able to act as quickly or efficiently as others because they are away from home or have reduced mobility.

Stress and disruption

The impacts of flood events are not just directly associated with householders in terms of their immediate losses of property. One of the reasons that floods are so stressful is that the day-to-day activities of whole communities are disrupted, sometimes for years. Disruption can occur through work, community services, transport and other infrastructure. The awareness and preparedness of local authorities can help to mitigate against some of these impacts but there are roles for other community groups in terms of preparing for, responding to and recovering from events. The extent to which formal and informal measures are adopted will depend on the characteristics of particular communities and the resources that they have available (both financial and non-financial). A variety of social networks, from flood action groups through to support networks provided by friends, family and local community, are significant in the process of recovery (Samwinga, *et al.*, 2004).

Recovery

Even with the best precautionary measures, it may be impossible to avoid some exposure to floods. After a flood event, further inequalities may result through differential capacities to recover. For some this could be relatively quick. For example, the very wealthy may be able to relocate to equivalent housing independently and replace lost items from existing savings, in lieu of insurance claims, as suggested in Chapter 1. Those who are less wealthy may have restricted options for satisfactory relocation. For example, 50% of flood-affected Heywood residents had to evacuate their homes for varying periods up to eight months while cleaning and renovation was taking place. Living in temporary accommodation in remote neighbourhoods with young children was cited as being particularly stressful. Homes in the areas of Heywood which experienced flooding are blighted and unsaleable (Lawson, *et al.*, 2008). For some, including the under-insured or uninsured, full recovery may be impossible.

Insurance

Most people in the UK have to rely on insurance claims for financial assistance in reinstatement and remediation of damage and losses caused by flooding. The financial impact of floods on households will therefore depend on the degree to which people are adequately insured. As we noted in Chapter 1, people on low income and in social housing have much lower rates of insurance take-up. The inability to take up insurance is also exacerbated by other factors. Living in areas of high crime can make insurance premiums still more unaffordable (Ketteridge and Fordham, 1998). Problems in meeting previous losses can render the position worse. According to one report around a third of uninsured people on low incomes are forced to increase their debt levels in order to replace household goods that have been stolen or damaged (ABI, 2007). The insurance system itself can also sometimes be difficult to negotiate and may result in additional problems for some ethnic minority communities. For example, members of Banbury's Asian community were found to be less likely to understand the insurance system than their white neighbours as well as tending to have lower incomes (Tapsell, *et al.*, 1999; Walker, *et al.*, 2006).

The UK is unusual in not passing all or part of the burden of floods to government schemes (Clark, 1998). The continuing availability of flood insurance for businesses and householders depends on a voluntary agreement between members of the ABI and the government, known as the 'Statement of Principles'. The agreement says that ABI members will continue to offer insurance cover to existing customers where the probability of their properties being flooded in any single year is 1 in 75 or less, or where flood defences planned in the next five years will bring flood probability down to that level. While financial costs of flood events are in part shared, not everybody benefits. According to the ABI, around 78% of households nationwide have contents insurance, but less than 25% of people in some areas affected by the summer 2007 floods in England had such cover (Pitt, 2008). The ending of the current agreement between government and the insurance industry in 2013 has large implications for the insurability of those with a high probability of flooding. Without government action and stricter enforcement of planning controls to prevent new homes being built on floodplains, the ABI has reported that some properties could become 'uninsurable, un-saleable and uninhabitable' (ABI, 2008). Insurance is an important facet of the ability to recover and its uneven availability is a cause of differential patterns of vulnerability.

Mobility and social networks

Some of the other factors affecting the ability to recover are the same as those associated with the ability to prepare for and respond to events. In particular, income, housing mobility, general mobility, social networks and the availability and use of information are all determinants of the degree to which future well-being may be affected.

Summary

The repercussions of flood events have also been summarised in other studies (see Table 4). From this review it is clear that factors affecting vulnerability are related to individual, household, community and institutional contexts. Thrush, *et al.* (2005) also identified a wide range of factors explaining vulnerability to flooding, covering biophysical determinants (such as the elderly, particularly the unsupported elderly and the frail and confused) and social elements (single parents; minority ethnic populations; people without

Table 4: Differential experiences of the social impacts of floods

Social impacts	Evidence of differential effect for individual, household or neighbourhood characteristics
Economic impacts	Ethnicity, age, income and property type all have a bearing on the experience of economic impacts.
Non-economic losses	Age and property type inform the perception of, and extent of, this impact.
Physical health	Pre-existing health status, age and gender all have a bearing on the experience of health impacts.
Psychological health	Gender, age, social class and household composition all have a bearing on the experience of psychological health impacts.
Evacuation and temporary accommodation	Age, gender and income are relevant to understanding how this phase affects people. Levels of social capital are likely to be important in understanding community response and resilience.
Household disruption	Gender, ethnicity, age, property type and tenure type all influence how individuals and households are affected.
Community and neighbourhood changes	No research evidence, but suggestion that deprived neighbourhoods and those with low levels of social capital will be particularly hard hit.

Source: Walker, *et al.*, 2006, p. 45

resources; people new to an area and without previous flood experience). While it may not be possible to quantify all of these factors as indicators in a socio-spatial index, it is nevertheless important to recognise all of the possible determinants since this provides a means of appreciating the limitations of the results of the current study.

Heat

Heat and health

Heat-related events have very different characteristics from those associated with floods. One of the key differences is in terms of the impacts which can be expected. Empirical evidence suggests that heatwaves result in a rapid rise in mortality (Ellis, *et al.*, 1980; Semenza, *et al.*, 1999; Johnson, *et al.*, 2005; Kovats, *et al.*, 2006; McGregor, *et al.*, 2007; Robine, *et al.*, 2008; Hertel, *et al.*, 2009). The greatest number of deaths is normally reported on days with the hottest temperature (Ellis, *et al.*, 1980; Kovats, *et al.*, 2006).

The UK has experienced a number of heatwave events, for example in 1976, 1995 and 2003. The greatest effects of the 2003 heatwave were felt in mainland Europe where there was excess mortality in many countries (Johnson, *et al.*, 2005; Robine, *et al.*, 2008). It is estimated that more than 70,000 excess deaths occurred in 16 European countries during summer 2003 (Robine, *et al.*, 2008). Compared to other European countries, the impact on mortality of the August 2003 heatwave in England and Wales was less severe (Johnson, *et al.*, 2005; Robine, *et al.*, 2008). Nevertheless, it was by far the most extreme of the heatwaves in England and Wales (Johnson, *et al.*, 2005; Kovats, *et al.*, 2006; McGregor, *et al.*, 2007). It was characterised by temperatures topping 30 °C for ten days in a row and in some places it peaked at a new record of 38.5 °C on 6, 9 and 10 August 2003 (Stedman, 2004; Kovats, *et al.*, 2006). During the period of 4–13 August 2003 there were an estimated 2,091 (17%) excess deaths in England and Wales compared to the same period between 1998 and 2002 (Johnson, *et al.*, 2005). The high mortality rates associated with the 2003 heatwave are partly explained by the nature of the event, i.e. the fact it was unusually prolonged and was associated with poor air quality (Stedman, 2004), but the influence of social factors must also be seen as part of the explanation (McGregor, *et al.*, 2007).

Epidemiological studies have shown that there are various characteristics of communities and populations which explain heatwave vulnerability (Johnson, *et al.*, 2005; Kovats, *et al.*, 2006; Hajat, *et al.*, 2007; McGregor, *et al.*, 2007; Reid, *et al.*, 2009; SNIFFER, 2009). The heatwaves of 1976, 1995 and 2003 in England and Wales were characterised by high excess deaths of which the population most affected was the elderly (Ellis, *et al.*, 1980; McGregor, *et al.*, 2007). Those over 75 years old are known to be highly sensitive to the impacts of heat as are babies and the very young (SNIFFER, 2009; Department of Health (DoH) Heat Health Watch, 2010). Since most heatwave impacts are health-related it is necessary to have a good understanding of the causal factors associated with heat-related mortality in order to understand the processes through which vulnerability is heightened or reduced. In addition to age, it is also well known that those with existing chronic and severe illness are more susceptible. Patterns of impacts are not solely related to biophysical implications but also to how age and health can affect adaptive capacity (SNIFFER, 2009; DoH Heat Health Watch, 2010).

Social and institutional factors

Although potential impacts may be strongly influenced by physiological characteristics, these characteristics do not provide a full explanation of vulnerability. Some of the susceptibility of elderly groups is associated with people living on their own or in a care home (SNIFFER, 2009; DoH Heat Health Watch), which implies that vulnerability is also affected by other social and institutional factors. As we noted in the last chapter, social networks and links are particularly important functionings. They are also significant in the conversion of heatwaves into other welfare outcomes. So, while an elderly older person is more susceptible to heat stress, the extent to which this matters in real events will depend on the contact that they have with others. Analyses of heat events generally imply that stronger social networks mean that people are less vulnerable to heat (Adger, *et al.*, 2004; Pelling and High, 2005). While some close social networks can lead to maladaptations, for example, through the transmission of inaccurate information (Wolf, *et al.,* 2010), wider social networks are important sources of information in preparing for heat events. They are even more important for responding to and recovering from heat events.

People in care homes are particularly vulnerable (Kovats, *et al.*, 2006). Much of this can be explained by the fact that people living in such environments are already among the more sensitive to events, given that they are more likely to be frail and/or have existing health problems. On the other hand, as we noted in the previous chapter, there is also evidence of institutional procedures being insufficiently responsive to heat impacts and leading to a loss of a capacity of those cared for to exercise some independence and control (Brown and Walker, 2008).

Enhanced exposure

Analysis of the 2003 heatwave in Europe revealed that excess mortality occurred in inhabitants of cities and suburban areas, again with the elderly severely affected (Grize, *et al.*, 2005). The issue of overexposure due to living accommodation (e.g. city dwellers or those living in top-floor flats), as well as working environments (e.g. outdoor or heated indoor environments) is highlighted within the Heat Health Watch and can be a critical determinant of differential impacts. In other words, there is an element of enhanced exposure which explains differential impacts, something which is not specifically determined by the nature of the hazard event itself (i.e. experienced temperature depends on neighbourhood and housing characteristics).

In the UK the building stock is generally not well adapted to heat-related hazards (Smith and Levermore, 2008). The ability to reduce exposure is therefore very important. Air conditioning strongly affects patterns of impact in a US context (Browning, *et al.*, 2006) but prevalence of air conditioning in the UK is comparatively small. Access to air conditioning may be limited for tenants and those on low income, and in any case is not ideal as an adaptation solution due to its implications for energy use. Given the importance of being able to find cool locations, whether inside or outside the home, it is important to appreciate the range of factors which differentiate between those more likely to be able to respond in a heatwave event and those less able to respond. Uneven availability of opportunities to reduce exposure is another driver of adaptive capacity and therefore vulnerability.

The availability of cool areas outside the home is related to social deprivation; people living in deprived areas in England and Scotland are less likely than others to live near parks and green spaces, making it hard for them to retreat from high temperatures (SNIFFER, 2009). People in socially deprived areas are also less likely to access environmental information (SNIFFER, 2009). In view of the potential for overexposure in the UK housing stock, and the fact that many heat-related deaths occur at night, it is recommended that windows are left open through the night during heatwave events. Those living alone or living in fear of crime may not feel able to follow this advice, even where they are aware of the potential benefits.

Community resources

There is a compelling case for the influence of wider neighbourhood factors in helping to provide adaptation opportunities (Browning, *et al.*, 2006). Neighbourhood decline was a core determinant explaining the differences in mortality in 80 Chicago neighbourhoods during a 1995 heatwave event. Klinenberg (2002) reports cases in which the response to the rapidly rising temperatures was to increase visits to the local grocery store where chatting to store owners and use of air conditioning could be combined. Where community and commercial facilities are fewer and/or there are barriers to accessing them, such as a fear of neighbourhood crime, then adaptive capacity is lower. Again, this holds even where an understanding of what should be done exists. In some cases access to environmental information can be associated with barriers, e.g. where large proportions of the population are new to an area, have limited resources or have a first language which is not English.

The vulnerable have less access than others to transport facilities, thereby having less capacity to relocate and to access essential services in times of need. Lack of mobility or physical isolation from medical help could mean the difference between life and death during a heatwave and it is therefore important to recognise this element of differential impact. As with flooding, the factors which affect vulnerability and future well-being may be different depending on whether they are explaining inequalities in ability to prepare, ability to respond or ability to recover.

Summary

Many believe that heat-related deaths are preventable (Reid, *et al.*, 2009). Facilitating the process of prevention, however, is not just about understanding biophysical processes and health outcomes. It is about appreciating the wider contexts through which people come into contact with heat, what they do about it and who can help them. Much of that context can come from analysing the characteristics of the neighbourhoods in which people live; appreciating how they live and understanding what resources they have available to them, whether personal, community or institutional. While there is value in doing this on a case-by-case basis, it is also important to see how these cases fit into the wider picture and for that wider picture to be as sensitive as possible to all of the evidence about what makes one person or community suffer more than another.

Framework for the development of a socio-spatial vulnerability index

This short review of evidence highlights a range of factors which explain differential impacts to flooding and heat events. Table 5 summarises factors in terms of their influence on sensitivity, enhanced exposure and adaptive capacity. Here the concept of enhanced exposure is used to extend the meaning of exposure (degree of contact with a hazard) in order to reflect the potential for some factors to actually enhance the expression of the hazard itself. A heatwave event that affects Birmingham would be associated with a range of temperatures across the city and a home on a tree-lined avenue would have different internal temperatures from top-floor flats in a high-rise apartment block a few streets away.

Table 5 lists many factors affecting adaptive capacity but they do not impact equally throughout all of the phases of a hazard event. Some factors, such as tenure, may be primarily an influence on preparation, while others, such as income, may affect preparing for, responding to and recovering from an event. Even the ‘double counting’ of factors in relation to these dimensions of adaptive capacity can be argued to represent a true reflection of the compound effects which are associated with some of the factors influencing vulnerability. Therefore the socio-spatial index adds an explicit representation of the stages through which adaptive capacity can act to influence vulnerability.

The socio-spatial index developed in Chapter 4 constructs an indicator-based dataset which attempts to assign factors identified in the literature to the dimension(s) of vulnerability with which they are most strongly associated. Factors in the index have to be measurable and have a spatial component.

- **Sensitivity:** What are the mainly non-socially determined aspects of differential impacts? Primarily these relate to age and pre-existing health factors which shape the potential for different biological susceptibilities to health and health-related outcomes of events, whether these are directly associated with events or represent longer-term indirect effects.

- **Enhanced exposure:** What are the largely physical neighbourhood characteristics which have the capacity to enhance or mitigate residential exposure in the event of a hazard? For example, how far are areas affected by a lack of green space and do they have housing characteristics which may enhance the impact of hazard exposure? For heat, this is affected by the number of high-rise residences, a lack of private gardens and a lack of public green space. For flooding, it is affected by the number of residences with ground or sub-ground level accommodation and a relative lack of pervious cover to facilitate drainage.

- **Ability to prepare:** What are the factors which affect ability to prepare? For example, which particular factors prevent people being able to adapt their personal environments in advance? In terms of flooding, for example, do they have the resources to flood proof and insure their homes?

- **Ability to respond:** What are the factors which affect ability to respond? What prevents people being able to take action during an event? Do they know what to do? Do they feel that they are able to act on the knowledge they have? If they feel unwell during hot weather, for example, is there somewhere that they can go or someone they can contact?

- **Ability to recover:** What are the factors which affect ability to recover? If someone succumbs to heat stress, how likely are they to be helped and how quickly can they get medical attention? If someone's home is damaged by flood waters, what help can they get and how quickly can life get back to normal?

While not all factors can be fully represented using readily available quantitative neighbourhood-based data, this study attempts to incorporate as many as possible, and to explore which other datasets might be needed. Factors are grouped into domains within each of the five vulnerability dimensions for flood and heat contexts (see Tables 6 and 7). The final datasets can then be used to explore the geographies of social and socially derived vulnerability across the UK. Finally, the results from the socio-spatial index can be combined with measures of hazard-exposure to see how this translates into patterns of climate disadvantage (see Figure 4).

Figure 4: Conceptual framework for assessing socio-spatial vulnerability and climate disadvantage

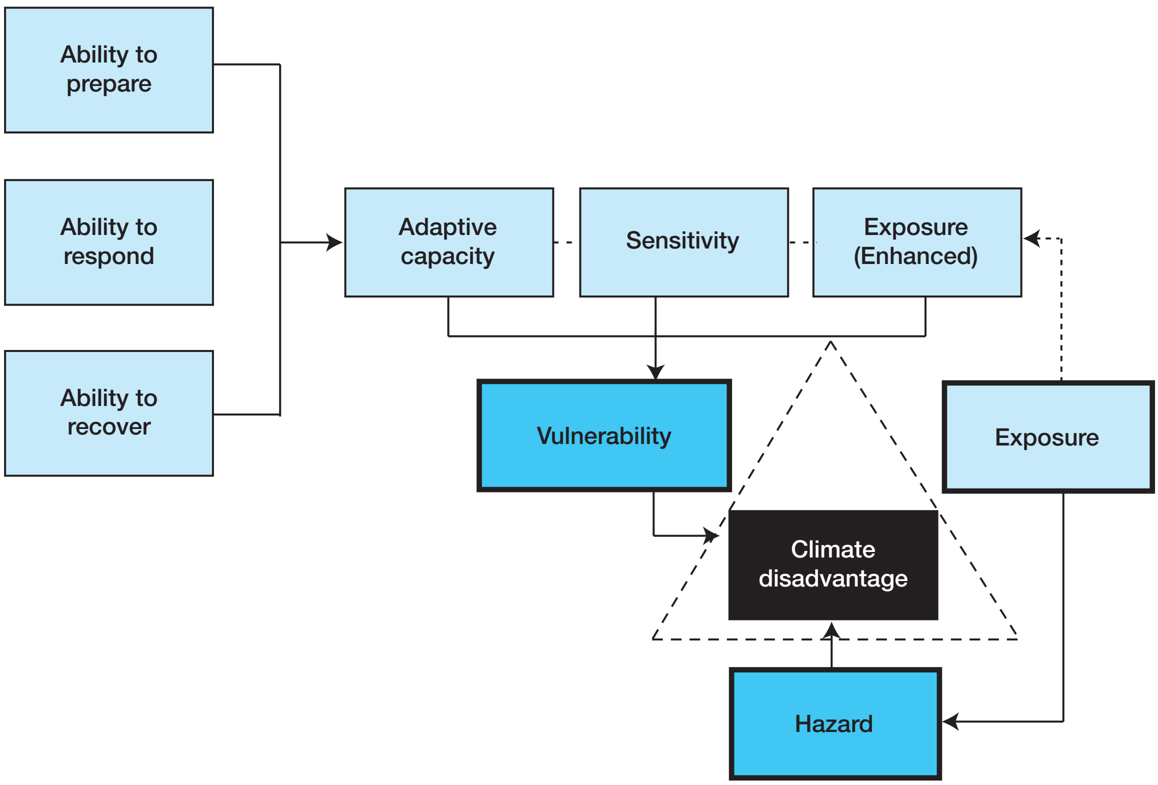


Table 5: Summary of factors associated with differential impacts of climate-related drivers

Influence	Factor	Heat/Flood
Sensitivity: (+) increasing susceptibility; (–) reducing susceptibility	Age: very young and elderly (+)	Both
	Health status: illness (+)	Both
	Residential care homes (+)	Both
	Gender: women may be more likely to have caring responsibilities (+), men (esp. young) associated with risk-taking behaviour (+)	Both
	Physical and mental health problems (+)	Both
	Homeless, tourists, transients (+)	Both
Exposure: (+) enhancing; (–) offsetting	Neighbourhood characteristics (+/–)	Both
	Thermo-insulate housing: air conditioning (–)	Heat
	Unventilated buildings (+)	Heat
	Urban heat island (+), urban dwellers (+), living in city centre (+), land cover (+/–), green space (–), access to parks and green spaces (–)	Heat
	Overcrowding (+)	Both
	High housing density (+)	Both
	Location (+/–)	Both
	Top-floor flats (+)	Heat
	Basement, single storey and mobile housing (+)	Flood
Adaptive capacity: (+) reducing ability to adapt; (–) increasing ability to adapt	Low income (+)	Both
	High social deprivation (+)	Both
	Resources available to local authorities (+/–)	Both
	Lack of skills and access to technology, e.g. access to environmental information (+)	Both
	Mobility: lack of transportation (+)	Both
	Social isolation (+)	Both
	Socio-economic status (+/–)	Both
	Disability, e.g. lack of mobility (+)	Both
	Unemployment (+)	Both
	Occupation: skilled (–) or unskilled (+), also linked to income and financial status	Both
	Poor educational attainment (+)	Both
	Family/household composition: large families (+), single parents (+), single-person households (+)	Both
	Length of residence, linked to prior experience: short residence (+)	Both
	High proportion of minority ethnic groups and new migrants/visitors, e.g. due to potential language issues (+), high population turnover (+)	Both
	Access to decision making: increased access (–)	Both
	Level of awareness and preparedness: high awareness (–)	Both
	Serviced by flood warning system: yes (–), no (+)	Flood
	Previous flood experience: no experience (+)	Flood
	Trust in authorities: no (+), yes (–)	Both
	Renters (+), homeowners (–)	Both
	Higher density of medical establishments and services (–)	Heat
	Access to medical establishments (–)	Heat
	Density and access to air-conditioned environments outside the home (–)	Heat
	Good insurance accessibility (–)	Flood

Source: main sources McGregor, *et al.*, 2007; Tapsall, *et al.*, 2005; Cutter, *et al.*, 2009

Table 6: Domains associated with socio-spatial flood vulnerability

Dimension	Domain	Example explanation
Sensitivity *Biophysical characteristics*	Age	Old and young are more physically susceptible to harm
	Health	Those with pre-existing illnesses are more susceptible
	Special care	Those in care environments already require additional support
Exposure *Physical neighbourhood attributes*	Physical environment	Amount of green or blue space; availability of gardens
	Housing characteristics	Type of building (basement and street-level dwellings)
Preparation *Taking precautions*	Income	Ability to obtain technical solutions (e.g. floodgates)
	Tenure	Ability to modify living environments
	Information use	Ability to use/access information
	Local knowledge	Availability of personal or community experience from past events in the local area
	Insurance	Likelihood of insurance being available
Response *Avoiding losses*	Income	Ability to use technical and other solutions
	Information use	Language and education affecting the ability to respond to warnings
	Local knowledge	Availability of personal or community experience from past events in the local area
	Insurance	Likelihood of insurance being available
	Social networks	Availability of personal or community networks
	Mobility	Availability of personal/household mobility
	Crime	Ability to deploy adaptive measure, e.g. floodgates
	General accessibility	General neighbourhood accessibility
Recovery *Recovering from a flood event*	Income	Ability to replace lost goods, find temporary accommodation
	Information use	Ability to understand what help is available and what to do (language and education)
	Insurance	Ability to claim for damages and re-insure
	Social networks	Availability of personal/community networks (if isolated, less likely to obtain assistance)
	Mobility	General mobility/disability
	Housing mobility	Ability to move away from an area

Table 7: Domains associated with socio-spatial heat vulnerability

Dimension	Domain	Example explanation
Sensitivity *Biophysical characteristics*	Age	Old and young are more physically susceptible to harm
	Health	Those with pre-existing illnesses are more susceptible
	Special care	Those in care environments already require additional support
Exposure *Physical neighbourhood attributes*	Physical environment	Amount of green or blue space; availability of gardens
	Physical geography	Physical location (e.g. elevation)
	Housing characteristics	Type of building (e.g. high-rise dwellings)
Preparation *Taking precautions*	Income	Ability to obtain technical solutions (e.g. air conditioning)
	Tenure	Ability to modify living environments
	Information use	Ability to use/access information
Response *Avoiding heat stress during an event*	Income	Ability to use technical and other solutions
	Information use	Language and education affecting the ability to respond to warnings
	Social networks	Availability of personal or community networks
	Mobility	Availability of personal/household mobility
	Crime	Ability to deploy adaptive measure (e.g. open windows)
	General accessibility	General neighbourhood accessibility
	General infrastructure	Availability of cool built environments (e.g. local shops)
Recovery *Recovering from heat stress if it occurs*	Information use	Ability to understand what help is available and what to do (language and education)
	Social networks	Availability of personal/community networks
	Mobility	General mobility/disability
	Service access	Availability of GPs and hospitals

3 Socio-spatial climate vulnerability and disadvantage

This chapter summarises the methodology for the empirical analysis and the result of its UK application. It is supported by technical notes listed in the Notes section. The empirical analysis investigates UK socio-spatial vulnerability in the context of climate-related hazards and associated patterns in climate disadvantage. It centres on the identification of critical socially vulnerable locations and vulnerable groups and it does this in relation to the five dimensions of socio-spatial vulnerability already identified and explained in the previous chapters. The reasons for specific communities emerging as being socially vulnerable can vary, for example, according to their members' age and health; with their living environments, which would act to accentuate the impacts of an event; and/or with the degree to which events can be prepared for, responded to or recovered from. Similarly, the measures which need to be taken to address social vulnerabilities and improve resilience in communities will vary too.

The social vulnerability assessment at the heart of this study is made without an explicit consideration of the actual likelihood of an event itself and the climate drivers behind changing probabilities of events. Therefore the maps of social vulnerability are not relevant to assessing climate disadvantage everywhere. They suggest where community characteristics could lead to increased impacts, but they say nothing about whether those impacts are likely to occur. The realisation of the differential impact suggested by social vulnerability maps can occur only if the community in question is exposed to a hazard with the capacity to cause harm. We do not claim that all critical socially vulnerable locations are equally likely to be affected by flood or heatwave events; indeed some may never be. We also do not claim that every individual within a community has the same characteristics as the community as a whole. The results of this study shed light on which communities as a whole have the potential for higher impacts due to social and socially related drivers only, including those aspects of the physical environment of neighbourhoods which have a socially derived component.

On the other hand, the maps have a clear relevance where supplementary information shows that there is the potential for a socially vulnerable community to come into contact with a significant hazard. Such communities are climate disadvantaged. Decision makers should therefore use maps of social vulnerability alongside maps and other sources of information which can provide an indication of whether communities may come into contact with a climate-related hazard and to what degree. All other things being equal, a socially just response to climate hazards would favour the most disadvantaged, i.e. those with the least capability to deal with floods and heatwaves yet likely to be exposed to one or both climate-related hazards.

In order to illustrate the need to consider the social vulnerability results in tandem with other information sources, this study also provides some hazard-exposure contextualisation. This is achieved through combining the social vulnerability maps with a number of measures of floods and high temperatures. Through this process an assessment can be made of the extent to which exposure to the climate-related hazard drivers of flood and heat are likely to add to or detract from the associated socio-spatial climate vulnerability which already exists in UK neighbourhoods. Decision makers should use additional data to help provide further perspectives on the hazard-exposure characteristics necessary to contextualise the associated social vulnerability results. Indeed, flood-related social vulnerability can also be usefully contextualised against pluvial flood maps, although this was outside the scope of the current study.

Approaches and methods for assessing socio-spatial vulnerability

The main objective of this study is to develop a socio-spatial index of vulnerability in the UK. There are various approaches and methods for achieving this objective. Central to many quantitative methods is the use of indicators.[1] Some vulnerability measures emphasise biophysical aspects of vulnerability (e.g. based on damage or cost functions) and others emphasise social aspects of vulnerability. They can be analysed and assessed in different ways, for example:

- **Regression** involves establishing statistical relationships between indicators and proxies of climate change outcomes (Adger, *et al.*, 2004; Peduzzi, 2006). The findings of regression analyses can be used to construct damage functions or to understand the key drivers and relative importance of indicators.[2] While it is possible to carry out retrospective analyses of past heatwave events using this sort of approach, it is more difficult for other hazards, such as flooding. Further, there are problems with the extent to which these metrics can represent impacts on well-being, i.e. impacts which do not have a measurable outcome.

- **Composite index methods** involve summation of direct and proxy indicators into an aggregate total. This is the general approach taken for generating the UK's Indices of Multiple Deprivation and there are examples of the use of this method for social vulnerability assessment.[3] Standardised scores are given for indicators representing factors of interest, these scores are combined into domain subtotals, and the domain subtotals are combined into a final score. Domains, such as income and education, can be combined based on equal weighting, but are more often combined using an estimate of the perceived relative importance of each domain in the index. Composite indices are relative rather than absolute measures and are useful for comparative purposes. They are not flawless; they can oversimplify and it is difficult to reduce a phenomenon such as vulnerability to a single value or figure (Downing, *et al.*, 2001; Adger, *et al.*, 2004). There is also the potential for indices to be overly sensitive to specific indicators and to provide different results depending on the aggregation technique (Füssel, 2009). However, the value of composite indices is amply illustrated by the extensive use of multiple deprivation indices.

- **Data reduction methods:** principal components analysis (PCA) is one of the most widely used methods in developing composite indicators (Nardo, *et al.*, 2005).[4] Despite this, the number of examples of the use of PCA in assessing social vulnerability in a UK climate change context is limited. PCA is both a data reduction tool and a tool for identifying underlying dimensions/components that are uncorrelated in a set of data. The basic assumption made by PCA is that a few underlying components or factors within the data can be used to explain complex relationships between the whole dataset. Factor analysis, which is related to PCA, is used to generate weights for the UK's Indices of Multiple Deprivation.

Research methodology

The specific methodology was developed in order to provide a set of results which would allow the following questions to be answered:

- What is the relative geography of neighbourhood social vulnerability in the context of flood and heat?

- Which combinations of indicators emerge as the best representations of socio-spatial vulnerability?

- How do patterns of socio-spatial vulnerability compare with patterns of hazard and what does this mean for climate disadvantage?

The research itself was undertaken in the following six steps:

Step 1 was all about understanding current knowledge about vulnerability in the UK. Past quantitative and qualitative studies were reviewed in order to establish the evidence base. Existing conceptual frameworks were also reviewed in order to construct the conceptual model underpinning this analysis. It resulted in the conceptualisations reported in Chapter 1 and Chapter 2.

Step 2 was about understanding how social and socially related vulnerability factors can be quantified and mapped. Data sources were reviewed and evaluated to establish which measures could be quantified spatially using direct and proxy measures. The selection of unit geographies was a balance of data availability and practicality. Middle Super Output Areas (MSOAs) were used for England and Wales, Data Zones (DZs) for Scotland and Super Output Areas (SOAs) for Northern Ireland.[5] MSOAs are relatively large units so a finer-scale case-study assessment was carried out for Greater Manchester at Lower Super Output Area (LSOA) level. Geographical units for the main analysis are subsequently referred to as 'neighbourhoods'. Many of the selected indicators are derived from the UK Census but others are derived from statistical or environmental service data, and the results of geospatial analysis. The number of indicators in each domain within the five dimensions of socio-spatial vulnerability is given in Appendix I, Table 1. Appendix I also contains the lists of specific indicators used along with their associated data sources. Other data sources are acknowledged in the Notes. Since identical indicators and unit geographies were not used across the UK, the results between countries are not directly comparable.

Step 3 involved constructing the database of indicators to use as the basis of the critical socially vulnerable locations and the socially vulnerable groups work. For consistency, each indicator was converted to a form whereby high positive values represented high socio-spatial vulnerability. In most cases this was done for the original indicator. Each indicator was standardised to produce a set of scores relative to the study area mean.[6] The database was firstly used to identify critical socially vulnerable locations using a composite index method (see Chapter 3, 'Approaches and methods for assessing socio-spatial vulnerability'). Individual indicators were selected to represent important aspects of each of the domains of interest while attempting to minimise overt unintended double-counting.

Deciding on an appropriate weighting scheme through which scores associated with components of an additive model are combined is difficult and contentious.[7] Here, scores were aggregated on an equal weighting basis. This means that all indicators within each domain, all domains within each of the five dimensions of socio-spatial vulnerability and all five dimensions themselves were given the same relative importance. An equal weighting scheme is not necessarily an accurate reflection of the relative importance of the factors of interest (see Chapter 1, 'Some limitations and challenges'). In order to be able to consider the potential impact of weighting schemes on the final results, alternative weights have been tested for Scotland (see Chapter 3, 'Impacts of weighting schemes on the results of the socio-spatial index'). Application of the method allowed maps to be produced which show the relative social vulnerabilities of neighbourhoods, including where there are extremes at either end of the spectrum. This allows assessment of the current geographical inequalities in climate-related social vulnerability. Any method which uses quantitative indicators to represent the differences between people and places is associated with some inherent limitations (see Chapter 1, 'Some limitations and challenges' and Chapter 3, 'Limitations of the empirical analysis and associated recommendations').

Step 4 was to verify the results for selected locations. This was done through the production of summaries for selected areas, followed by semi-structured interviews with local authority representatives.

The verification process was also used as a means of establishing the extent to which methods and data can add to the current evidence base used for adaptation planning.

Step 5 used the database constructed at Step 3 for an analysis of socially vulnerable groups. It used PCA as a data-reduction technique to identify groups of indicators which are dominant in explaining the variance within the entire set of indicators for each study area.[8] As well as identifying groups, the geographies of groups can also be explored. The approach and interpretation of the results is in keeping with published examples, e.g. Schmidtlein, *et al.*, 2008; Wood, *et al.*, 2010. The identified groups can be thought of as representing the characteristics of key indicator subsets which have been extracted from the full set of neighbourhood social vulnerability indicators. They do not represent the characteristics of all individuals within all neighbourhoods, rather the broad characteristics of the neighbourhoods as a whole. Similarly, there is variability between neighbourhoods within the same group, so that the mix of influencing factors on a case-by-case basis will differ. Groups are presented in the order of their strength in explaining patterns. Where possible, groups have been given names to capture their essential characteristics. Any naming attempts to broadly characterise the most socially vulnerable neighbourhoods within the identified group or the overall theme that the group represents. It should be noted that this process is open to different interpretations. Results tables and further supporting evidence are provided in Appendix II.

Step 6 moved on to considering the socio-spatial vulnerability results within the context of the particular climate-related hazards framing the rest of the study. It recognises that some locations are more likely than others to be affected by an event with the capacity to cause harm. Unfortunately, estimating the spatial patterns of these events for the future is still difficult. Even in cases where supporting data could in theory be generated, the associated analysis is complex and data intensive, and the results would still have limitations.[9] Instead, comparison of the socio-spatial heat vulnerability results has been made with reference to two heat hazard-exposure measures sourced from the UK Climate Projections (UKCP09). The two simple (and limited) 25km resolution measures are: the geography of projected mean summer maximum temperatures in the 2050s and the geography of the projected changes in temperature associated with the warmest summer day in the 2050s compared with the 1961–90 baseline. The former are presented in the main report and selected examples of the latter are given in Appendix III. Social vulnerability data is not projected and only represents the current day.

The probabilistic nature of UKCP09 data means that it is strongly recommended that analysts use a range of probabilities and emission scenarios.[10] The 50th percentile results for the low, medium and high emissions scenarios are given in the main body of the report and examples of results for the 10th and 90th percentile values are shown in Appendix III. In terms of flooding, there is no specific modelled data of future flood events available in the public domain. Here we use available EA data on current probabilities of flooding[11] to provide a measure of flood hazard-exposure against which the socio-spatial flood vulnerability results can be compared. This data is available only for England and Wales. The flood hazard-exposure assessment is limited to estimating the percentage cover of current significant and moderate flood zones (i.e. the areas which are likely to flood most frequently).

These analyses are not exhaustive and are intended only to provide a first look at potential climate disadvantage. We recognise that these simple measures provide just part of the picture of what may turn socio-spatial climate-related vulnerability into climate disadvantage. These and some of the other key limitations of the study, together with a set of associated recommendations, are given in Chapter 3, 'Limitations of the empirical analysis and associated recommendations'. The imperfections of the assessment of the climate and hazard contexts for the disadvantage assessments should not detract from the value of the socio-spatial vulnerability assessments themselves, given that decision makers can combine them with a range of other measures of hazard-exposure.

Socio-spatial vulnerability and climate disadvantage in England

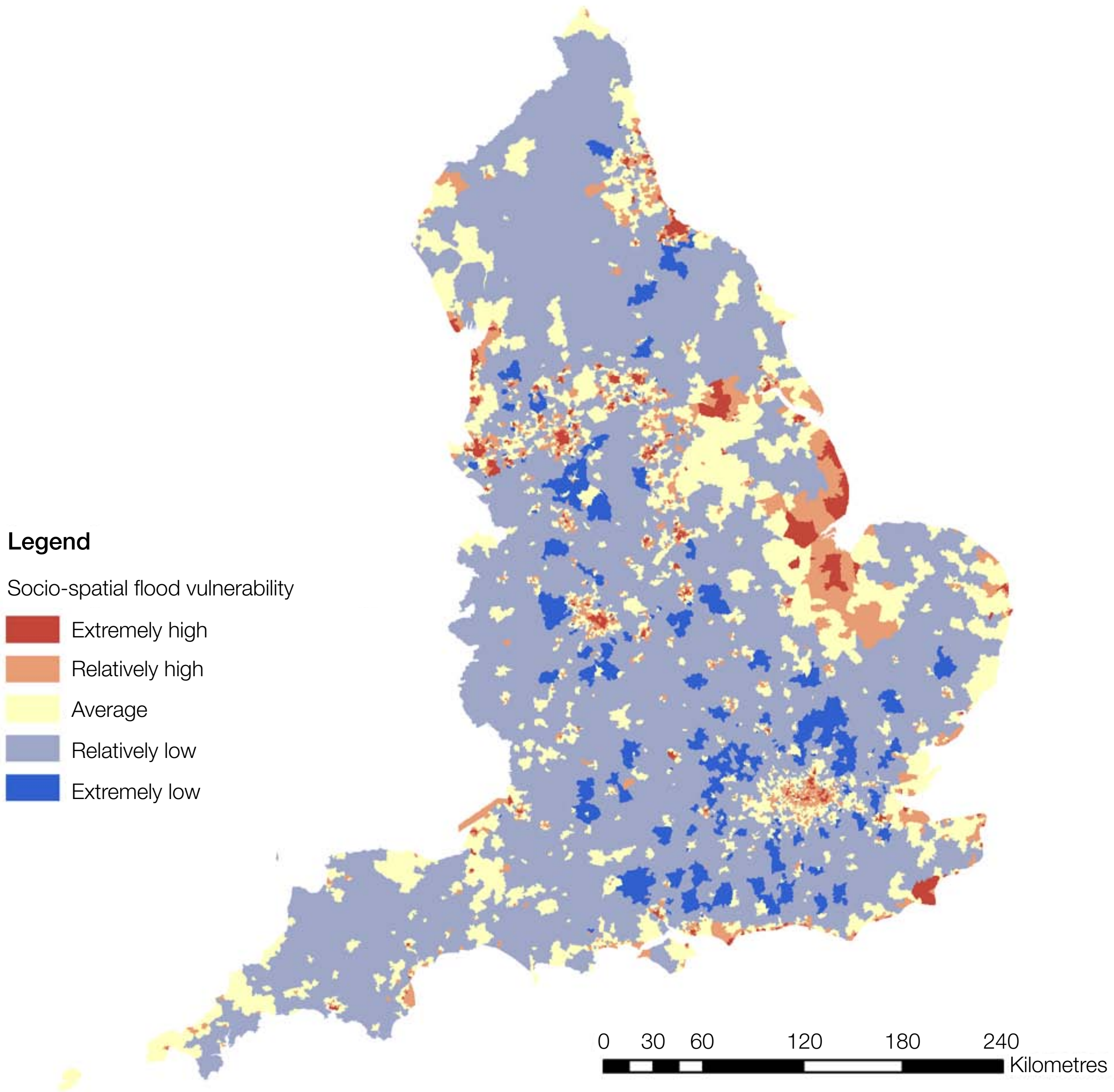
Critical socially vulnerable locations in England

Socio-spatial flood vulnerability

Figure 5 shows the spatial distribution of aggregate flood-related social vulnerability in England. Around 8% of English neighbourhoods are estimated to have extremely high flood-related social vulnerability compared to only around 3% with extremely low flood-related social vulnerability.[12] The extremely high cases have a strong urban and coastal dimension; all have their population centres in urban areas[13] and 28% are within 1km of the coast (38% within 2km).

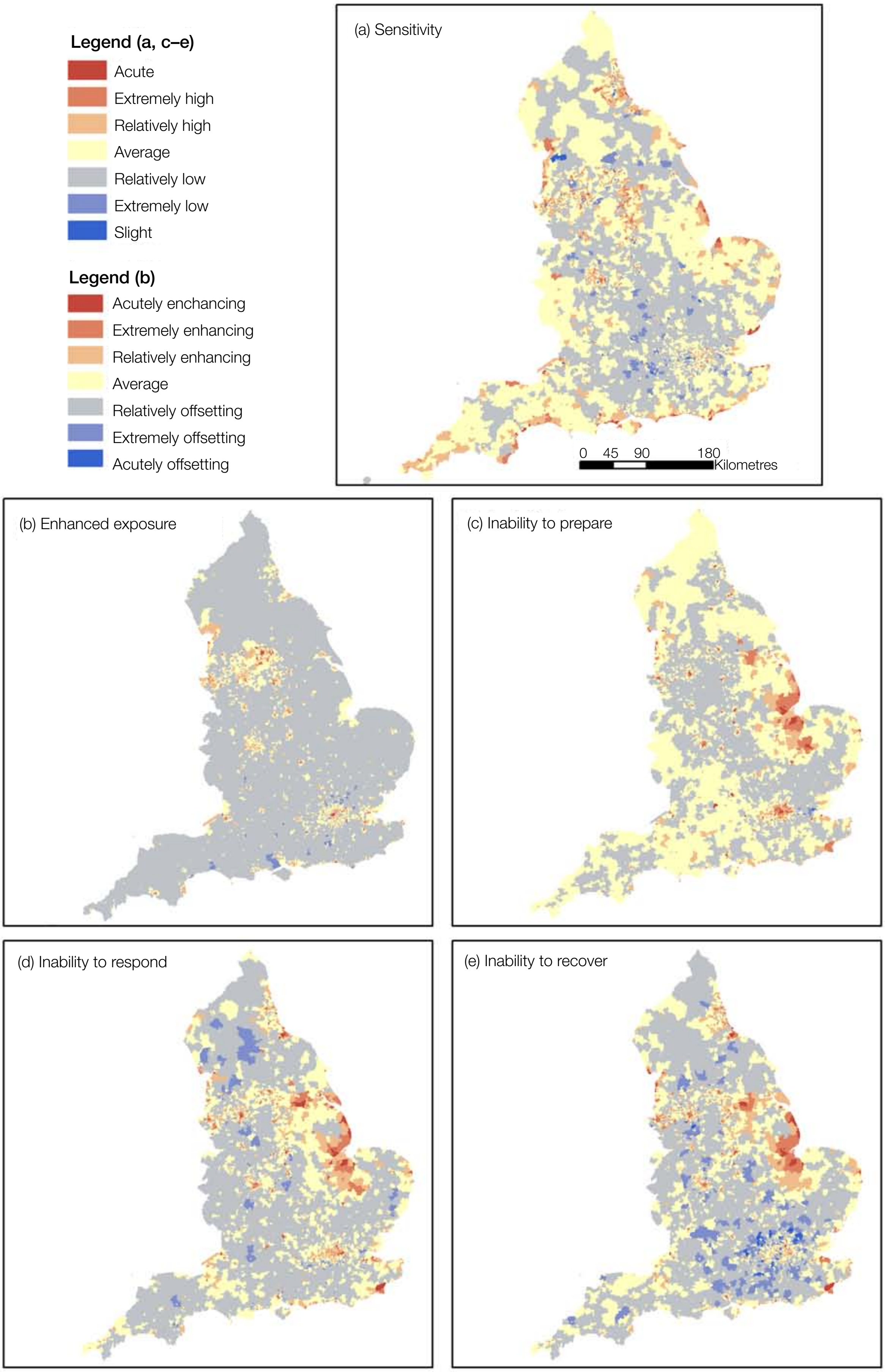
Sensitivity, enhanced exposure and adaptive capacity all show different geographical distributions (see Figure 6). The geographical distribution of the old and ill (see Figure 6a) has a particularly marked coastal component. Enhanced exposure shows a very different pattern (see Figure 6b). Given the nature

Figure 5: Socio-spatial flood vulnerability in England



Source: Boundary data: EDINA UKBORDERS, Crown copyright

Figure 6: Geographical distributions in the five dimensions of socio-spatial flood vulnerability in England



Source: Boundary data: EDINA UKBORDERS, Crown copyright

of the selected indicators, which include lack of gardens and other green spaces (as a measure of reduced drainage capacity), it is not surprising that major conurbations are highlighted as being strongly exposure enhancing. Also interesting is the concentration of these factors with proportions of housing with basements or semi-basements in the North of England. Patterns of adaptive capacity show some similarities for the three dimensions: inability to prepare, respond and recover (see Figure 6c–e respectively). Urban and coastal locations are again highlighted as among the most socially flood vulnerable in terms of their low ability to adapt. The measures include a proxy measure of insurance availability, which is linked to current flood probabilities (see Appendix I) since there are areas where insurers are not required to provide cover.

Where locations of possible low insurance cover also coincide with other measures which are suggestive of people's reduced capacity to deal with floods, such as through low average incomes, a general lack of local knowledge or low mobility, we can expect that well-being is particularly threatened. The difference in the geographies of the different dimensions of social vulnerability across the country implies there is a need for a different balance of strategies within adaptation plans from place to place. The results of this study provide an evidence base for assisting in the process of deciding what that balance should be.

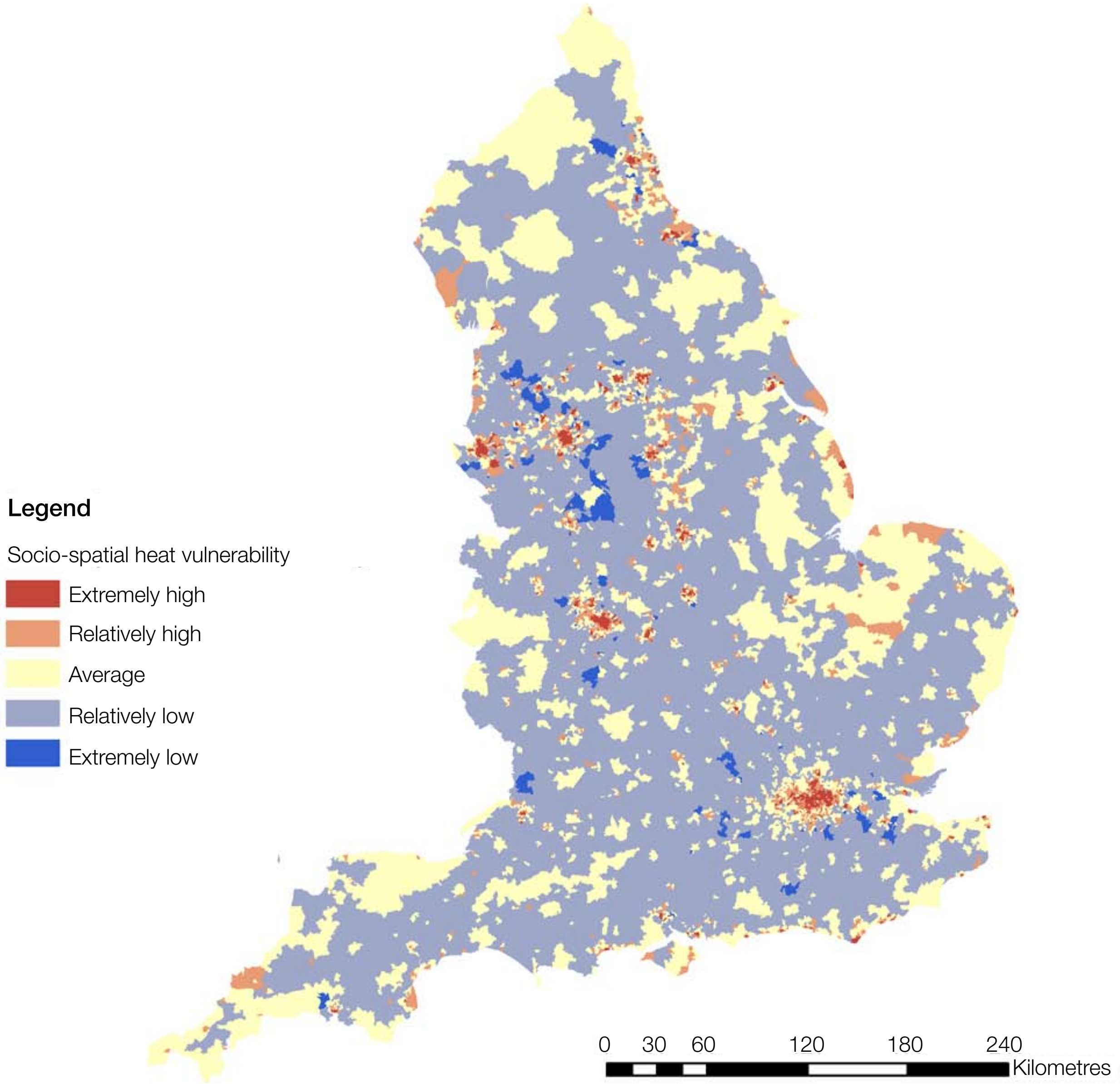
Socio-spatial heat vulnerability

The proportion of English neighbourhoods estimated to have extremely high social vulnerability with respect to heat is around 9% compared to only 1% with extremely low heat-related social vulnerability.[12] Taken as a whole, extreme heat-related social vulnerability is an urban phenomenon[13] (see Figure 7) although the inability to recover from heatwaves has a rural dimension given that people living in more remote neighbourhoods have lower accessibility to medical services through GPs and hospitals (see Figure 8d). There is also a coastal component to the distribution of very socially vulnerable neighbourhoods with respect to heat, e.g. along the south coast of England. This partly reflects the pattern of sensitive populations (see Figure 6a), which is the same in the contexts of both flooding and heat, and is despite many of these areas benefiting from relatively low enhanced exposure to heat compared to the English mean (see Figure 8a). Overall, 20% of the extremely high cases have an average distance from the coast of less than 1km and 36% are within 2km. There is evidence of joint social vulnerability to multiple climate-related hazards in England since 64% of the extremely socially vulnerable neighbourhoods in the context of flood are also classed as being extremely socially vulnerable with respect to heat.

Regional patterns in socio-spatial vulnerability in England

Patterns of social vulnerability in the context of flood show a strong North–South divide with the North faring the worst. At least 10% of all neighbourhoods in the North West, East Midlands, Yorkshire and The Humber and the North East regions are estimated to be extremely socially flood vulnerable. The South East has the largest proportions of its neighbourhoods estimated to have extremely low socially derived vulnerability for flood compared to other English regions (see Figure 9). Only the South East and East of England regions have a higher proportion of extremely low socially flood-vulnerable compared to extremely high socially flood-vulnerable neighbourhoods. The South East region has nearly 40% of the total number of extremely low socially flood-vulnerable neighbourhoods and the North West nearly 25% of the total number of extremely high socially flood-vulnerable neighbourhoods in the whole of England. Although London does not show the same marked extremes as in the other English regions, it does have the largest mean socially derived flood vulnerability by region. Therefore, on average, London neighbourhoods are the most socially flood vulnerable in England. The North West, North East and Yorkshire and The Humber all have neighbourhood social flood vulnerabilities which are on average above the English mean.

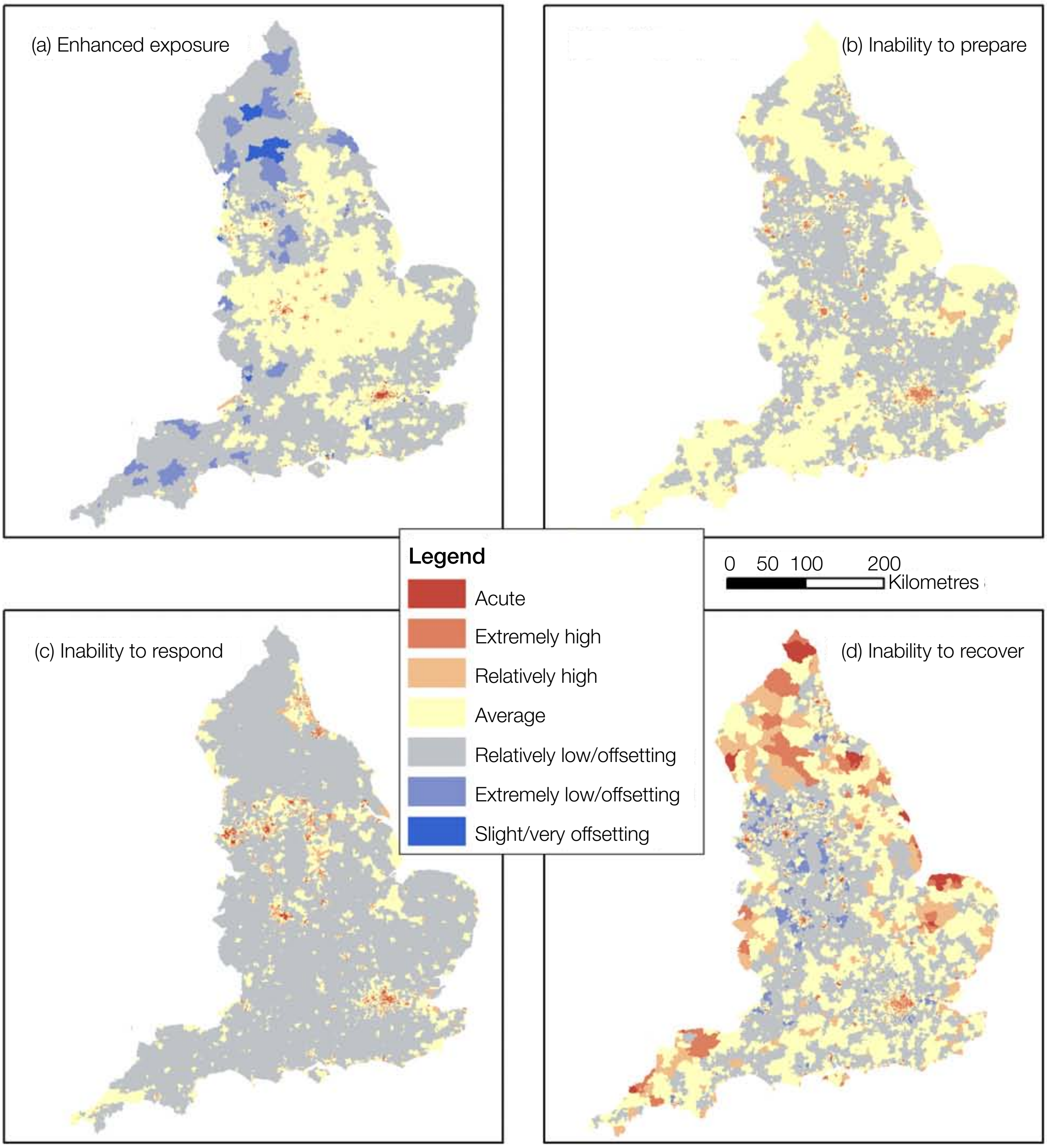
Figure 7: Socio-spatial heat vulnerability in England



Source: Boundary data: EDINA UKBORDERS, Crown copyright

For socially derived heat vulnerability there is also a strong regional characterisation. A regional breakdown of the results shows that almost a quarter of London neighbourhoods are extremely socially vulnerable with respect to heat (see Figure 10). London also contains 40% of the total number of extremely high socially heat-vulnerable neighbourhoods and has by far the largest mean values. Mean social vulnerability to heat in London is three times higher than in any other region. The North West, West Midlands and Yorkshire and The Humber all have around 10% of their neighbourhoods classed as extremely socially heat vulnerable. The South East, East of England, South West and East Midlands all have mean scores which are below the overall English mean.

Figure 8: Geographical distributions in the dimensions of socio-spatial heat vulnerability in England



Note: Sensitivity shown in Figure 6

Source: Boundary data: EDINA UKBORDERS, Crown copyright

Figure 9: Proportions of all neighbourhoods in each region estimated to have extremely high or low socio-spatial vulnerability with respect to flood

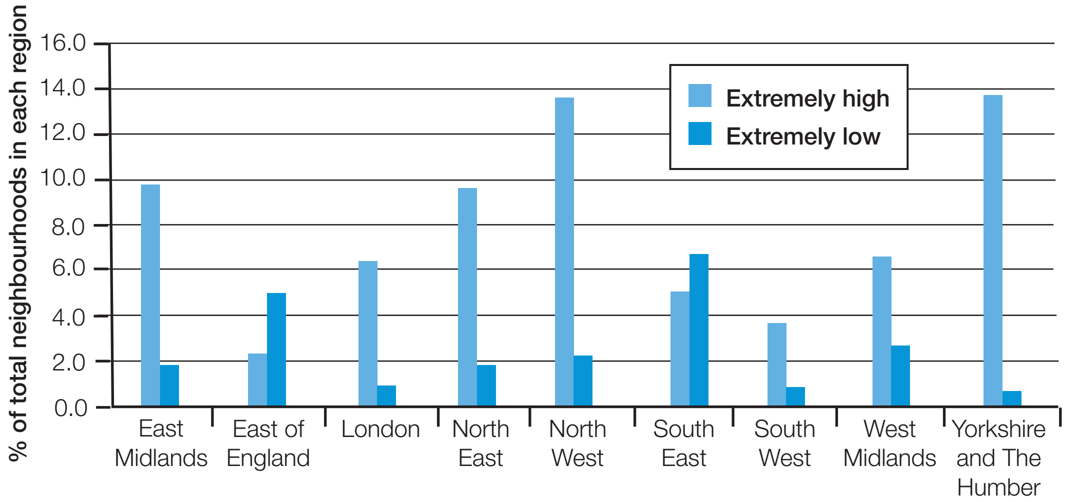
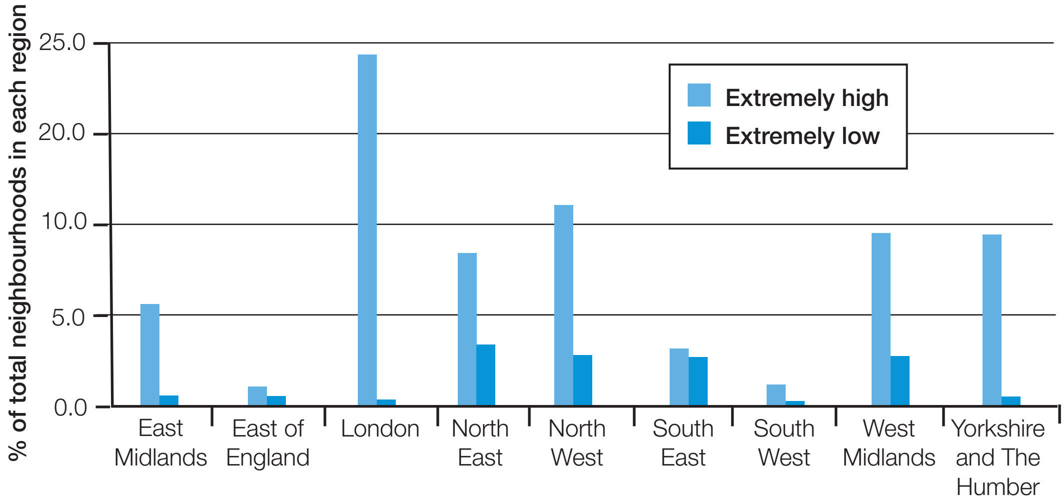


Figure 10: Proportions of all neighbourhoods in each region estimated to have extremely high or low socially derived vulnerability with respect to heat



Socially vulnerable groups in England

The analysis now considers which indicator groups emerge as the most influential on socio-spatial vulnerability (see Appendix II for further information).

Socially flood-vulnerable groups

There are five key groups within the socio-spatial flood indicator dataset for England. They are taken as representative of England's socially vulnerable groups in the context of flood.

Group 1 links seven indicators, the most influential of which are income, house ownership and household composition. The socially flood-vulnerable neighbourhoods associated with this group can be broadly interpreted as being associated with relatively *low incomes and young families* as well as relatively low rates of home ownership. Lack of resources may affect the affordability of technical and other measures to adapt to potential flood events and recovering from such events may also be more difficult. Identified socially flood-vulnerable neighbourhoods in the group also tend to have a higher proportion of people with caring responsibilities for some of the most sensitive to the direct and indirect health effects of floods. Other indicators point to higher proportions with relatively low educational attainment compared to other neighbourhoods. For some this may translate into a lower likelihood to research what to do before, during and after a flood event. There are two factors which offset socio-spatial vulnerability in this group: the first is an association with above-street accommodation, which means that enhanced exposure is less likely, and the second is that there are generally lower percentages of disabled people, on average.

Group 2 links five indicators. The most influential in this case are: car ownership; long-term illness; in-migration; and distance travelled to work, and so represent health and mobility. The socially flood vulnerable within the group might be characterised as being associated with relatively *poor health and low mobility*. Where neighbourhoods are associated with relatively high proportions of households with no personal transport, there may be a lack of ability to respond to events. A high proportion of people with limiting long-term illness suggests a heightened susceptibility to direct and indirect health impacts. There may also be a lack of local knowledge within the more socially vulnerable neighbourhoods in this group since they also tend to be associated with higher proportions of new arrivals. Lower rates of provision of unpaid care may mean that there are fewer carers, or that the carers within these communities simply are not paid. Many of these indicators increase social vulnerability through increased sensitivity and lower adaptive capacity. This is offset by associations with lower distances travelled to work but this may not equate to lower travel times, given a lack of personal transport. Of all socially flood-vulnerable groups identified for England, Group 2 is the most strongly correlated to the English Indices of Multiple Deprivation 2004.

Group 3 has a mix of indicators, some of which enhance and some of which offset socially derived vulnerability. They broadly represent social vulnerabilities associated with *work and insurance*. Neighbourhoods with higher proportions of people working long hours are linked with the potential for lower availability of insurance. Working long hours may reduce the capacity for people to act rapidly in the event of a flood warning, even if they have equipment such as floodgates. However, vulnerability tends to be offset by lower crime rates so people may be more likely to deploy floodgates or other flood defence measures even if they will be away from home. Higher rates of home working offset social vulnerability for these neighbourhoods so community-wide response times could also generally be quicker compared with others. While some people in this group may live within flood zones, finer-scale analysis is needed to establish the extent of relationships. There are other neighbourhoods in Group 3 where the inverse applies so that higher crime rates are associated with lower proportions of home working but these neighbourhoods are not generally associated with insurance availability issues with respect to flooding (but they could be for other reasons, such as crime).

Groups 4 and 5 are less influential on the pattern of social flood vulnerability overall. Group 4 makes links between neighbourhoods which tend, on the one hand, to have higher proportions of young children and people born overseas but tend, on the other, to have lower proportions of older and disabled people. Conversely those neighbourhoods with higher proportions of people over 65 and higher proportions of disabled people tend to have lower proportions of young children and people born overseas. Consequently, neighbourhoods at either extreme have an element of socially derived vulnerability, one in relation to populations sensitive due to being young and the possibility for language difficulties, and the other in relation to populations sensitive due to old age and with lower adaptive capacity due to disability-related factors. Group 5, *unemployment*, suggests a socially vulnerable group associated with neighbourhoods where there are higher rates of unemployment, indicating fewer resources, but this is offset by lower rates of long-term unemployment. The social vulnerability characteristics of this group are open to some interpretation but the group has only a small influence on overall patterns (see Appendix II).

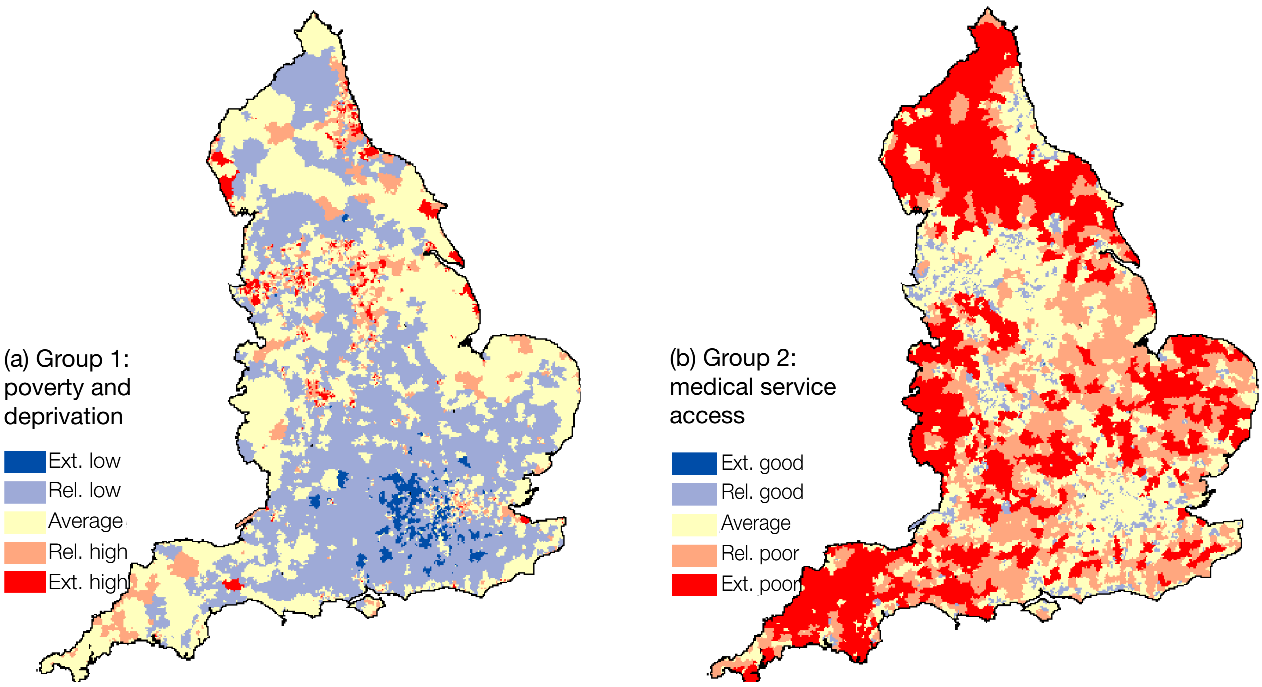
Socially heat-vulnerable groups

There are five key groups within the socio-spatial heat indicator dataset for England. They are taken as representative of England's socially vulnerable groups in the context of heat.

Group 1 contains nine indicators, most of which represent *poverty and deprivation*, and which together strongly correlate with the English Indices of Multiple Deprivation 2004. This group is the most influential on overall patterns of social vulnerability with respect to heat. The socially vulnerable neighbourhoods associated with this group tend to be characterised by associations between higher percentages of disability, unemployment, people with a basic education, limiting long-term illness, and lone parents with dependent children. Associated neighbourhoods also tend to have higher crime rates and lower mean weekly incomes. Those who work tend to do so away from home. The only element to reduce socially derived heat vulnerability is a tendency for a lower mean number of hours to be worked but this does not do much to offset the other factors; indeed, in these areas this characteristic might be related to low incomes and under-employment. This group is considered socially vulnerable for reasons of their higher sensitivity (they are more likely to be ill) and their lower adaptive capacity (due to disability or lack of resources). Crime rates in these neighbourhoods may mean that those who really need to be able to apply adaptation measures in their homes, for example, through leaving windows open in the evenings and at night, may feel unable to do so. It may be particularly difficult for those who are frail or alone with young children to act on Heat Health Watch advice, even where they are aware of this advice and know what they should do to cool their homes during heatwave events.

Geographically, neighbourhoods scoring highly in this group are associated with urban zones in London, the Midlands and the North (see Figure 11a). The group is strongly associated with social indicators which explain heatwave response (see Appendix II), i.e. those social factors which help to explain why people in one community succumb to heat stress while people in another do not. As would be expected, these areas also appear in the socially vulnerable locations results for heat response (see Figure 8c) but additional locations are also highlighted, such as a number of coastal fringe areas, which may also merit directed adaptation measures, even though hazard-exposure may be lower.

Figure 11: (a) Group 1: poverty and deprivation and (b) Group 2: low medical service access



The most socially vulnerable neighbourhoods in **Group 2** can be broadly summarised as those with relatively *low medical service accessibility*. Neighbourhoods are characterised by longer travel times to medical facilities by public transport and lower public transport availability with respect to GP and hospital access. There is a higher potential for people in these neighbourhoods to struggle to find medical help quickly if they were to suffer heat stress. While access to personal transportation might be assumed to be generally higher, this is not always so. One indicator in the group suggests a tendency towards higher proportions of people with no car to live outside of 15 minutes travel time to medical help (by walking or public transport). Some of these indicators are linked to heatwave recovery and the geographical patterns (see Figure 11b) are even more strongly associated with rural areas than in the 'ability to recover' dimension of the socio-spatial index results (see Figure 8d).

In general, the more socially vulnerable in **Group 3** are associated with higher public transport reliance, the possibility for English to be a second language and a lack of green space, which enhances exposure. However, this is offset by relatively good accessibility to GPs. **Group 4** sees neighbourhoods with lower percentages of people over 65 coupled with lower proportions of unemployment among adults with no children. While these indicators suggest lower social vulnerability in affected neighbourhoods, this is offset by a number of other indicators such as a tendency for higher proportions of young children. The final **Group 5** makes associations between neighbourhoods with higher rates of new overseas arrivals, higher proportions of long-term unemployment, higher proportions of renting from private landlords and lower proportions of people providing unpaid care. Socially derived vulnerability here can be linked to information access, resource availability, control over living environments and the potential for poorer social networks, each of which has an associated potential policy response.

Relationships between socio-spatial vulnerability and climate disadvantage in England

The social vulnerability maps presented in the previous section do not explicitly account for the likelihood of neighbourhoods to come into contact with a hazard event, i.e. a flood or heatwave. Climate disadvantage is a function of a neighbourhood's socially derived vulnerability, its likelihood of being affected by a hazard and the extent of any contact. Neighbourhoods which are both highly socially vulnerable with respect to a particular climate-related hazard and which are also highly likely to be exposed to it can be said to be associated with a climate disadvantage relative to other areas.

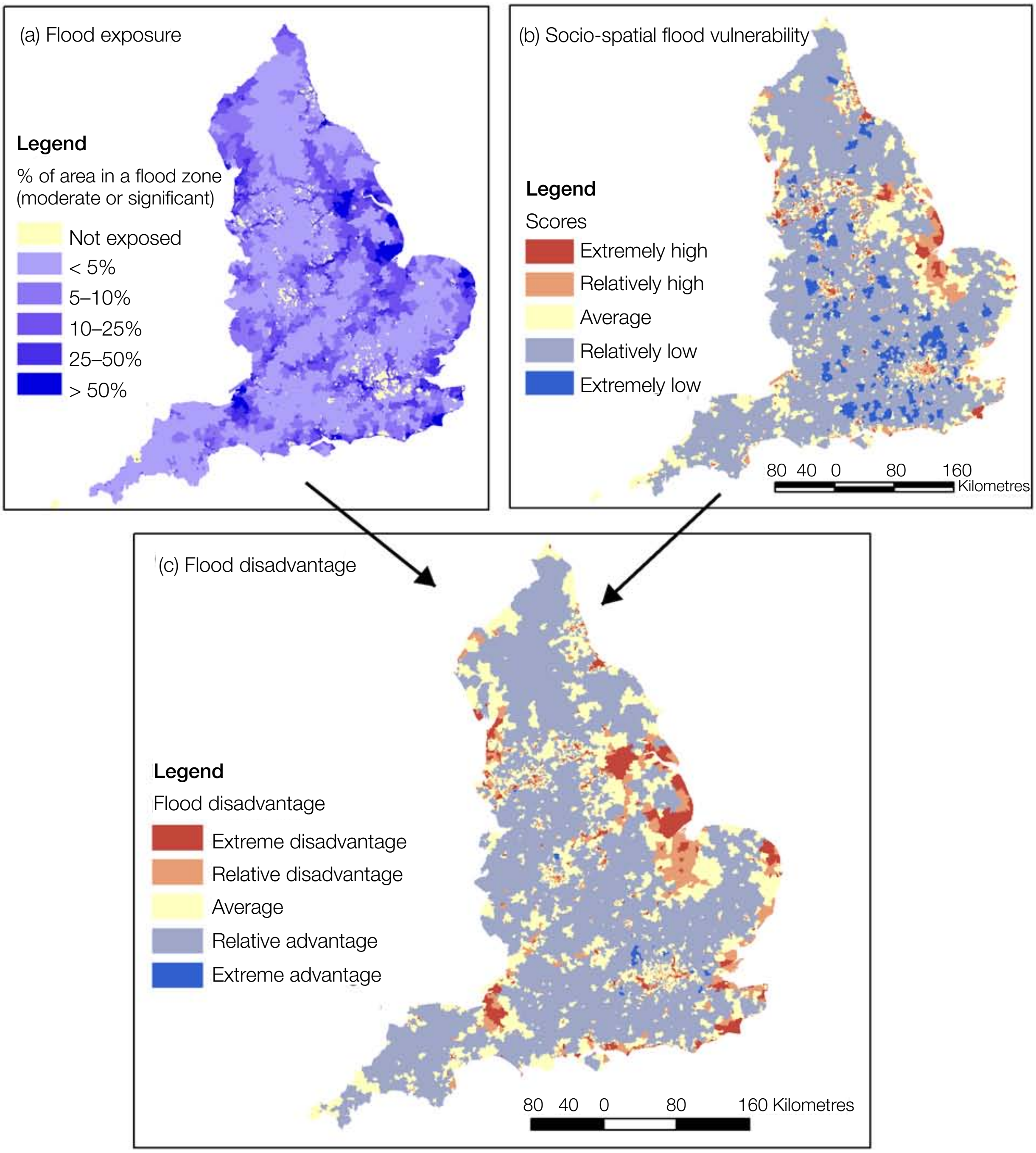
Flood disadvantage

To estimate flood disadvantage, a measure of flood hazard-exposure[11] has been overlaid on to the map of socially derived flood vulnerability presented in Chapter 3 'Socio-spatial flood vulnerability'. From this, it is estimated that extreme flood disadvantage affects some 7.5% of English neighbourhoods, with a handful (less than half of 1%) having extreme flood advantage from fluvial and coastal flooding.[12] The measure of flood hazard-exposure in Figure 12 is based on the proportion of each neighbourhood area estimated to be covered by flood during relatively high likelihood events (termed 'moderate' and 'significant' by the EA). It excludes low probability events and pluvial sources and therefore underplays the full picture of possible flood hazard-exposure. One important reason for mapping social vulnerability with respect to flooding independently of existing flood exposure maps is that the latter are not sensitive to pluvial flooding. Those at flood disadvantage are likely to be greater than many estimates suppose.

On average, English neighbourhoods have 8.4% of their land area classified as being associated with significant or moderate flood likelihoods. However, only 1.7% of neighbourhoods have more than 50% of their land area covered and there is a large variability of values geographically (see Figure 12). There are 22.2% of English neighbourhoods which are estimated to have no exposure[14] to moderate or significant flood likelihoods. Taking low, moderate and significant flood likelihoods together, the mean area coverage for an English neighbourhood is 12.8%; 6.5% have >50% cover and 16.4% have no exposure.

The neighbourhoods with extremely low socially derived flood vulnerability have an average of 4.4% land cover by zones with significant or moderate flood likelihoods. This is only around a quarter of the estimated figure (18.5%) for neighbourhoods associated with extremely high socially derived flood vulnerability. Considering low, moderate or significant zones together, these figures are 6.8% and 27.5% respectively.[15] A higher level of flood hazard-exposure for the more socially vulnerable neighbourhoods is to be expected given that the availability of insurance within a neighbourhood, one of the social vulnerability indicators considered in this study, is linked to significant flood likelihood (1-in-75-year events). This explains some of the similarities between the top two maps in Figure 12. This 'double counting' is considered to be a legitimate reflection of the double issue of difficulties obtaining insurance

Figure 12: Relative flood disadvantage in England as a composite of (a) flood exposure and (b) socio-spatial flood vulnerability



Source: Boundary data: EDINA UKBORDERS, Flood-exposure data Environment Agency, Crown copyright (see Notes) cover and a high chance of being affected. As we noted in Chapter 1, one perverse effect of increased likelihood of flooding is that the very fact of increased likelihood of exposure can in itself have a deeply corrosive impact on individuals' capacity to sustain a variety of other functionings over time.

By English region, the Yorkshire and The Humber region has the highest average flood disadvantage. It also has the largest proportion of its neighbourhoods (15%) classed as being extremely flood disadvantaged (see Figure 13). This is indicative of both general flood disadvantage across the region and also of extreme flood disadvantage in a sizeable proportion of neighbourhoods. The East Midlands, North West, North East and London all have average flood disadvantage scores which are above the English average. The South East does not generally have flood disadvantage given that its regional average is below that for England as a whole. However, there are marked inequalities within the South East region which need to be considered. The results of this study suggest that more than 10% of all neighbourhoods in the South East are extremely disadvantaged with respect to flood. The East of England is the only other English region with more than 10% of neighbourhoods classed as extremely flood disadvantaged.

Heat disadvantage

To estimate heat disadvantage, two measures of heat hazard-exposure[10] have been generated and overlaid on to the map of socially derived heat vulnerability presented in Chapter 3 'Socio-spatial heat vulnerability'. In order to make the results of the social vulnerability assessment comparable with the climate data, mean socio-spatial vulnerability scores and neighbourhood weighted estimates have been calculated for each of the 25km grid cells in the UKCP09 database.[16] Figure 14 shows heat disadvantage as a function of neighbourhood-weighted socio-spatial vulnerability against the geography of mean summer maximum temperatures in the 2050s. Other results are given in Appendix III, such as the geography of absolute temperature changes associated with the warmest summer day between the 1961–90 baseline and the 2050s. Caveats associated with these hazard-exposure measures are discussed elsewhere (see Chapter 1, 'Some limitations and challenges' and Chapter 3, 'Limitations of the empirical analysis and associated recommendations').

The results show that neighbourhoods in London will be among the most heat disadvantaged in England in terms of all of the heat-related measures used in this study. Although Londoners are already the most adapted to hotter temperatures in the present day, their climate disadvantage is driven by very high average socially driven vulnerabilities and disproportionate numbers of some (but not all) of the high

Figure 13: Proportions of all neighbourhoods in each English region estimated to have extremely high or extremely low flood disadvantage

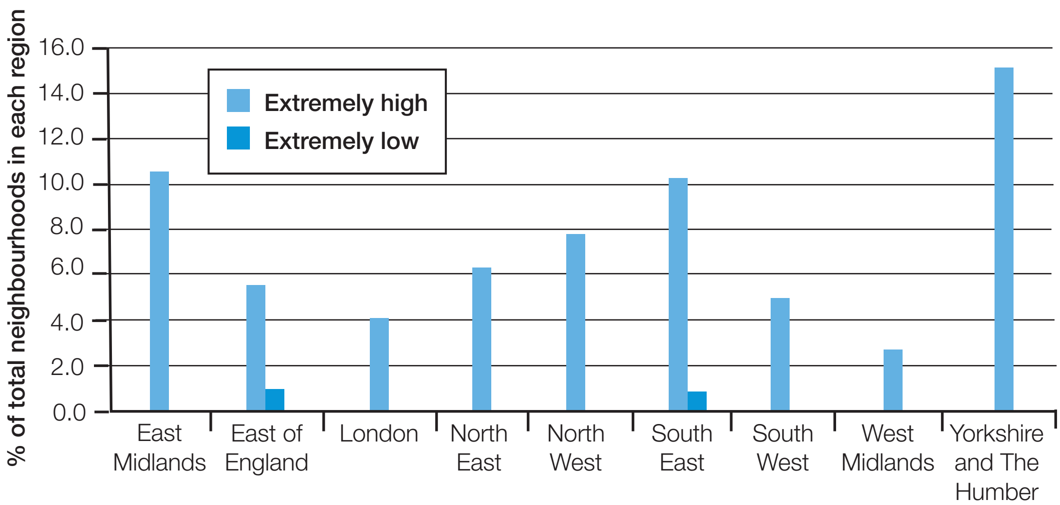
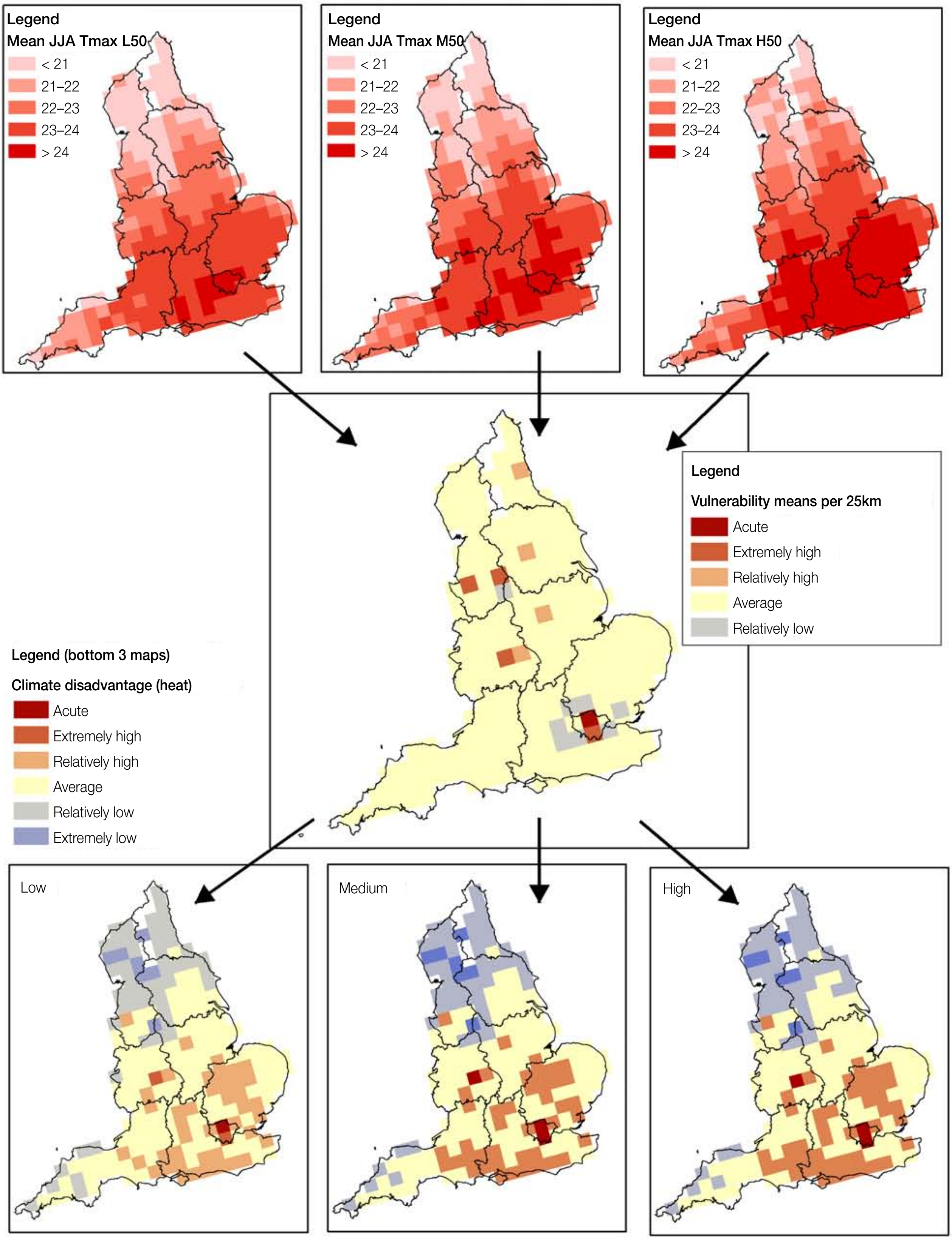


Figure 14: Heat disadvantage in England in the 2050s as a combination of neighbourhood-weighted socio-spatial heat vulnerability[16] and the geography of mean summer day maximum temperatures (°C)



Note: JJA refers to June, July, August. Tmax refers to maximum temperature.

Source: UKCP09 50th percentile estimates for the low (L50), medium (M50) and high (H50) emissions scenarios.

UK Climate Projections 2009, Crown copyright

socially vulnerable groups with respect to heat, identified in Chapter 3, ‘Socially heat-vulnerable groups’. Even when mean socio-spatial vulnerabilities are considered, this pattern remains (see Appendix III). Climate disadvantage is also marked in the urban Midlands but climate offsets vulnerability in the cities of the North. People in the North benefit from generally cooler temperatures, but peak temperatures are expected to rise more here and in the South West (Appendix III) and people are less well adapted. High climate disadvantage also has a coastal component with a consistent pattern associated with the southern and East Midlands coasts, despite the benefits of some of these locations for reducing temperatures.

Temperature changes between the 1961–90 baseline and the 2050s for neighbourhoods with extremely low socially derived vulnerability compared with extremely high socially derived vulnerability have been compared in order to investigate the extent to which any climate disadvantage may emerge by the 2050s. If there were no changes in social vulnerability between the current day and the 2050s, the results might suggest that there is not likely to be a major difference between these groups either for the warmest summer night or the warmest summer day. This might suggest that climate change will not increase inequalities between the highest and lowest extremely socially derived heat-vulnerable neighbourhoods, all other things being equal. However, as we have shown elsewhere in the report, changes in social vulnerability are likely to be increasingly exacerbated by the effects of the climate-related events themselves during this period, and in fact inequalities might be expected to increase.

Socio-spatial vulnerability and climate disadvantage in Wales

Critical socially vulnerable locations in Wales

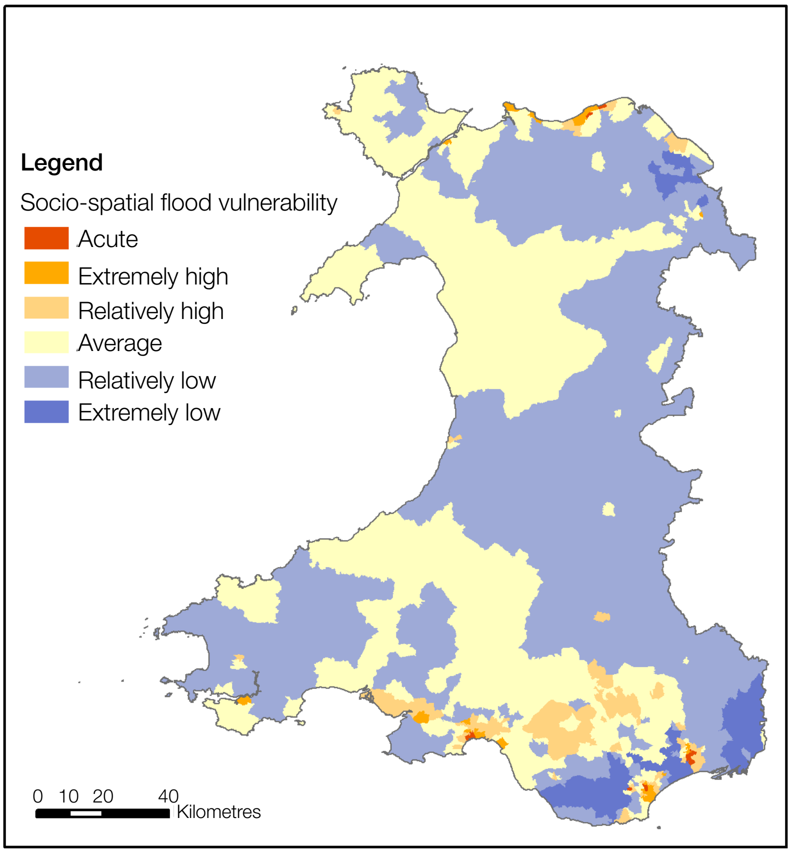
As with England, socially vulnerable locations have been found through assessing the relative contributions of a range of indicators which measure positive and negative drivers of individual and community sensitivity, enhanced exposure and ability to adapt (see Appendix I).

Socio-spatial flood vulnerability

The spatial distribution of aggregate socio-spatial flood vulnerability in Wales is shown in Figure 15. Around 8% of Welsh neighbourhoods are estimated to have extremely high flood-related social vulnerability compared to around 5% with extremely low flood-related social vulnerability.[12] Over two-thirds of socially flood-vulnerable neighbourhoods have their centres in urban areas[13] and 85% within 0.5km of urban areas. There is also a strong coastal dimension to the geography of socially derived flood-vulnerable neighbourhoods since over half of the top 10% most vulnerable neighbourhoods are within 1km of the coastline. This is partly because of the locations of the major cities in Wales.

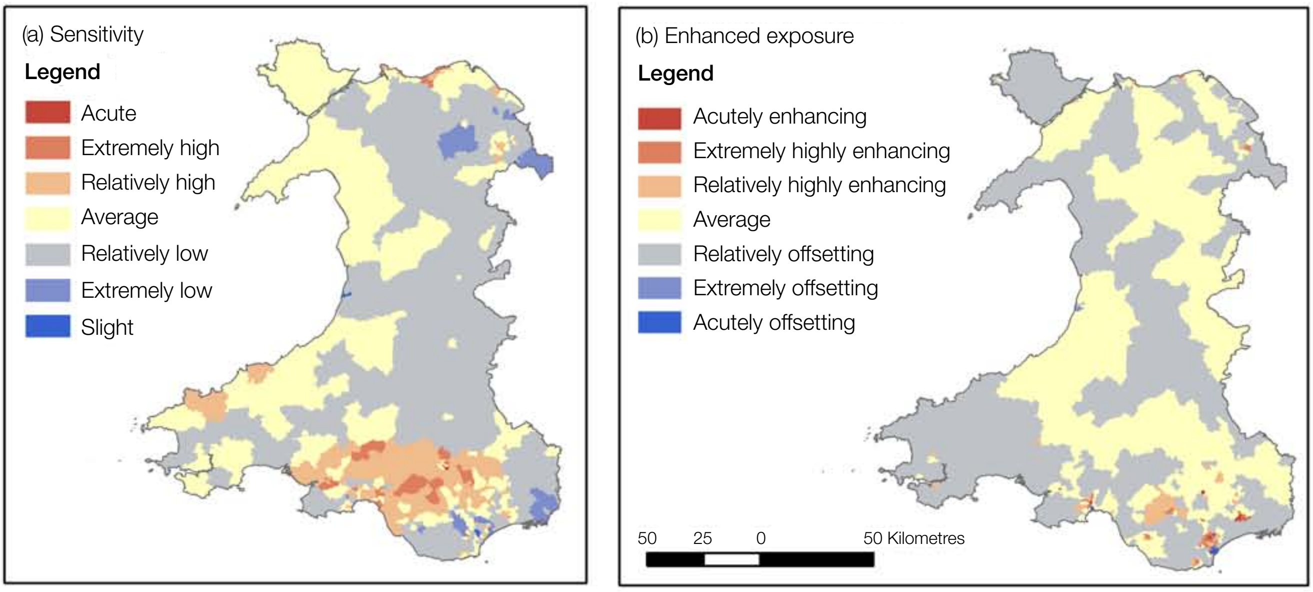
There is a clear concentration of sensitive groups in Wales, with many being located in South Wales and coastal fringes in North and West Wales (see Figure 16a). Figure 16b shows that many of the neighbourhoods with high proportions of sensitive populations benefit from neighbourhood characteristics which are more likely to offset exposure during floods. The three dimensions of adaptive capacity show similar geographies with high vulnerability associated with more densely populated areas (see Appendix IV, Figure 17a–c). The pattern of relative inability to recover suggests that there may be associations between sensitive groups and some of the factors which have a negative influence on how far people are able to get back to normal following a flood. Some of the factors here include low incomes and the potential for members of communities to be isolated because they are single parents or lone pensioners, but these are not the only factors affecting the distributions (see Appendix I).

Figure 15: Socio-spatial flood vulnerability in Wales



Source: Boundary data: EDINA UKBORDERS, Crown copyright

Figure 16: Geography of (a) sensitivity and (b) enhanced exposure dimensions of socio-spatial flood vulnerability in Wales

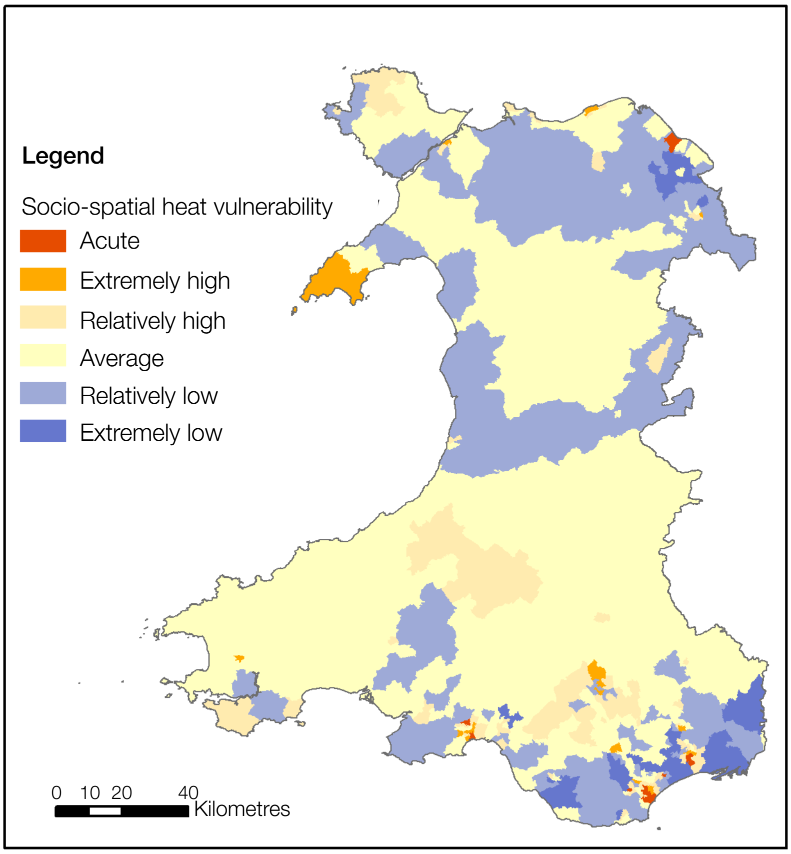


Source: Boundary data: EDINA UKBORDERS, Crown copyright

Socio-spatial heat vulnerability

The proportion of Welsh neighbourhoods estimated to have extremely high heat-related social vulnerability is around 7% compared to 6% with extremely low heat-related social vulnerability.[12] Over half of the 10% most socially heat-vulnerable neighbourhoods have their centres in urban areas[13] and nearly 80% are within 0.5km of urban areas.

Figure 17: Socio-spatial heat vulnerability in Wales



Source: Boundary data: EDINA UKBORDERS, Crown copyright

The geography of socially derived heat-vulnerable neighbourhoods in Wales (see Figure 17), like England, shows large differences depending on the dimension (see Appendix IV) and this implies that there are different adaptation requirements in different communities, all other things being equal. As with flood vulnerable neighbourhoods, many of the factors offset one another, only here the inverse relationships are even more marked. Enhanced heat exposure is likely to occur in urban areas with high-rise living and in lowland zones away from coasts. Therefore, despite poor general accessibility and access to services in many upland and coastal areas, there does tend to be a benefit from the heat offsetting characteristics of associated neighbourhoods. The coastal settings of Wales' major cities are also beneficial, but there is a range of other socio-economic factors which still makes the levels of socially derived heat vulnerability in some neighbourhoods within these cities extremely high.

Socio-spatial flood and heat vulnerability in Welsh local authority areas

Patterns of socio-spatial flood vulnerability show some distinct variations across Wales. Nearly a quarter of neighbourhoods in Cardiff rank in the top 10% most socially flood vulnerable (see Table 8). This is also true for socially derived heat vulnerability (see Table 9). Cardiff contains 30% of the Welsh total of both socially derived flood and socially derived heat-vulnerable neighbourhoods. While these may not be the same neighbourhoods, there is some evidence for joint socially derived vulnerability in Wales as a whole since around 60% of the top 10% most socially flood-vulnerable neighbourhoods also appear in the top 10% most socially heat vulnerable. Despite this evidence of joint socio-spatial vulnerability, context-specific socio-spatial vulnerability assessments are still valuable given that around 40% of the most highly socially vulnerable neighbourhoods are not held in common. In terms of the least socially vulnerable neighbourhoods, there is evidence for joint benefits. A large proportion of neighbourhoods appear in both the flood and heat top 10% least socially vulnerable categories (80%). It may suggest that some very low socially vulnerable neighbourhoods will be resilient to a whole range of other external threats to well-being.

Although Cardiff contains a large proportion of the most socially flood-vulnerable neighbourhoods in Wales as a whole, different patterns emerge when considering the proportions of highly socially vulnerable neighbourhoods as a proportion of the total number of neighbourhoods within specific local authority areas (see Table 8). Over a quarter of all neighbourhoods in Newport and Conwy are estimated to be highly socially flood vulnerable. Conwy in the North has the largest proportion of its neighbourhoods in this group (27%). Cardiff, Newport, Swansea and Conwy together contain 63% of all of the most socially flood-vulnerable neighbourhoods. In terms of the 10% least socially flood vulnerable, Flintshire fares best with 45% of its neighbourhoods in this class. Monmouthshire and the Vale of Glamorgan also have high proportions of their neighbourhoods classed in this group. Four council areas have no neighbourhoods in either group. The widest inequalities between neighbourhoods within individual local authority areas occur in Newport, Denbighshire, Neath Port Talbot, and Cardiff, which all have at least 10% of their total neighbourhoods in each class.

Table 8: Distribution of the top 10% and bottom 10% scoring neighbourhoods for socially derived flood vulnerability by Welsh local authority

		Scores in top 10% (flood)			Scores in bottom 10% (flood)		
Local authority (LA)	**Count of neighbour-hoods**	**Count of neighbour-hoods**	**% of LA neighbour-hoods**	**% of all Welsh neighbour-hoods**	**Count of neighbour-hoods**	**% of LA neighbour-hoods**	**% of all Welsh neighbour-hoods**
Blaenau Gwent	9	0	0	0	0	0	0
Bridgend	19	0	0	0	2	11	5
Caerphilly	24	1	4	3	1	4	2
Cardiff	47	11	23	28	5	11	12
Carmarthenshire	26	0	0	0	0	0	0
Ceredigion	10	0	0	0	0	0	0
Conwy	15	4	27	10	0	0	0
Denbighshire	16	3	19	8	2	13	5
Flintshire	20	1	5	3	9	45	22
Gwynedd	17	1	6	3	0	0	0
Isle of Anglesey	9	0	0	0	0	0	0
Merthyr Tydfil	7	1	14	3	0	0	0
Monmouthshire	11	0	0	0	4	36	10
Neath Port Talbot	19	3	16	8	2	11	5
Newport	20	5	25	13	4	20	10
Pembrokeshire	16	2	13	5	0	0	0
Powys	19	0	0	0	1	5	2
Rhondda, Cynon, Taff	31	2	6	5	3	10	7
Swansea	31	5	16	13	1	3	2
The Vale of Glamorgan	15	0	0	0	4	27	10
Torfaen	13	0	0	0	1	8	2
Wrexham	19	1	5	3	2	11	5
Total / *Mean*	413	40	*10*	100	41	*10*	100

Table 9: Distribution of the top 10% and bottom 10% scoring neighbourhoods for socially derived heat vulnerability by Welsh local authority

		Scores in top 10% (heat)			Scores in bottom 10% (heat)		
Local authority (LA)	**Count of neighbour-hoods**	**Count of neighbour-hoods**	**% of LA neighbour-hoods**	**% of all Welsh neighbour-hoods**	**Count of neighbour-hoods**	**% of LA neighbour-hoods**	**% of all Welsh neighbour-hoods**
Blaenau Gwent	9	0	0	0	0	0	0
Bridgend	19	0	0	0	3	16	7
Caerphilly	24	0	0	0	1	4	2
Cardiff	47	12	26	29	5	11	12
Carmarthenshire	26	0	0	0	1	4	2
Ceredigion	10	0	0	0	0	0	0
Conwy	15	1	7	2	0	0	0
Denbighshire	16	2	13	5	0	0	0
Flintshire	20	1	5	2	8	40	20
Gwynedd	17	2	12	5	0	0	0
Isle of Anglesey	9	0	0	0	0	0	0
Merthyr Tydfil	7	2	29	5	0	0	0
Monmouthshire	11	0	0	0	3	27	7
Neath Port Talbot	19	1	5	2	2	11	5
Newport	20	5	25	12	3	15	7
Pembrokeshire	16	1	6	2	0	0	0
Powys	19	1	5	2	0	0	0
Rhondda, Cynon, Taff	31	4	13	10	2	6	5
Swansea	31	7	23	17	3	10	7
The Vale of Glamorgan	15	0	0	0	5	33	12
Torfaen	13	1	8	2	3	23	7
Wrexham	19	1	5	2	2	11	5
Total / *Mean*	413	41	*10*	100	41	*10*	100

For socio-spatial heat vulnerability (see Table 9), the largest proportions of Wales' top 10% most socially vulnerable neighbourhoods are in Cardiff, Swansea and Newport and the largest local authority proportions are found in Merthyr Tydfil, Newport, Cardiff and Swansea. The larger urban areas have the greatest inequalities in socially derived heat vulnerability, the most marked being Newport. There is a strong geographical concentration of the top 10% most heat vulnerable and eight (27%) of Welsh councils have no neighbourhoods classed in this group (which is similar to the flood context).

Socially vulnerable groups in Wales

Socially flood-vulnerable groups

Welsh socio-spatial flood vulnerability is explained through the characteristics of six groups, presented in order of their overall influence (see Appendix II). There are ten indicators that make up **Group 1**, which together can be termed *poverty and deprivation*. The socially derived flood-vulnerable neighbourhoods in this group tend to be particularly associated with lower incomes, higher proportions of households which are not owner occupied and higher rates of unemployment. Social vulnerability in Group 1 is therefore partly driven by lack of financial resources to modify living environments but also by tenure characteristics. Other factors in Group 1 include car ownership, crime, social isolation, education and ill-health. Lower mobility may reduce capacities for effectively responding to flood events and any subsequent relocation following flooding may lead some to become isolated from friends and family, work and work opportunities.[17] Other notable characteristics of the more socially vulnerable neighbourhoods are higher proportions of lone parents, higher likelihood of only basic educational attainment and higher proportions of social renters. Fear of crime may also be high, given associations with higher rates of violent crime within the neighbourhoods and this, along with several other factors (such as high proportions with a limiting long-term illness), may mean that some flood prevention measures are either unpopular or impractical.

Group 2 contrasts three indicators which increase adaptive capacity and therefore lower social flood vulnerability (lower distances travelled to work; lower travel times to transport hubs; and lower average hours worked) with five which are positively associated with social flood vulnerability (a higher reliance on public transport for work commuting; a lack of personal transport, higher rates of recorded theft and burglary; higher proportions of neighbourhoods classified as urban; and higher proportions of female lone parents). The more generally socially vulnerable here might benefit from the increased accessibility of urban areas but aspects of mobility, isolation and crime lower adaptive capacity and there is a tendency for enhanced exposure due to a positive association with higher proportions of urban land cover.

Group 3 links neighbourhoods with higher proportions of migrants from overseas with higher proportions of people not born in the UK, suggestive of the possibility for language difficulties and a lack of local knowledge. These *overseas enclaves* are also associated with higher rates of private renting, which limits the ability of residents to carry out their own home adaptations. People in this group could live in flood-zone areas and not be aware of the fact. Private landlords may be difficult to engage in residential flood protection planning and information drives may not be frequent enough to ensure that people living in rented accommodation with higher turnover rates receive the relevant guidance (Salford City Council, 2011). The relatively large proportion of single-person households may make information provision a still greater challenge.

Groups 4 and 5 are associated with aspects of *age and health* and *housing and population change* respectively (see Appendix II). **Group 6** relates old age and residential care through identifying *elderly enclaves* where there is a link between neighbourhoods with higher influxes of people over 65 and higher proportions of people in residential care. Groups 4 and 6 are therefore important for identifying sensitive groups who will need additional support during any flood event.

Socially heat-vulnerable groups

There are seven socially related heat-vulnerable groups identified in Wales. **Group 1** comprises eight indicators, many of which are associated with *poverty and deprivation* (see Appendix II). Similar groups are identified within the socially derived heat vulnerability groups in England and socially derived flood vulnerability groups in Wales. The indicators suggest that the main driver of socially derived heat vulnerability in this group is a lack of adaptive capacity, particularly associated with existing poverty and material disadvantage. However, there is also a positive association with higher levels of ill-health and therefore sensitive populations. People in these neighbourhoods are more likely to lack the ability to modify their homes and to respond in the event of a heatwave. The lack of mobility suggested by lower car ownership will impact on individuals within areas but also on other people that they care about; for example, it will affect the individuals' ability to check on elderly relatives or those with young children. The tendency for neighbourhoods in the more socially vulnerable neighbourhoods in Group 1 to have higher violent crime rates means that there is the potential for more isolated members of communities to feel unsafe leaving their homes even when they are aware of the ways in which they can avoid heat stress. Lack of an above-basic education may, on the other hand, suggest that some people within these neighbourhoods may be unlikely to seek or engage with advice about what to do, or indeed what not to do, in periods of very hot weather.

Group 2 has very different characteristics. The seven indicators include aspects of tenure, migrants from overseas and percentage of people born overseas. The socially vulnerable within this group can be characterised as living within *overseas enclaves* and the group is similar to that identified for flood-related social vulnerability. On average, neighbourhoods have higher proportions of single-person households, which may suggest the potential for social isolation, especially since this is coupled with lower rates of unpaid care provision. However, neighbourhoods with relatively high existing proportions of people born overseas, coupled with the tendency for higher overseas migrant influx rates, may be suggestive of thriving single- or multi-ethnicity areas which could have social and other networks which are not picked up in the indicators used in this study. Other factors in this group acting to offset social vulnerability include: tendencies for relatively high densities of retail infrastructure, which is taken as an indicator of service availability and community adaptation potential, and lower proportions of people with only a basic education. Socially derived vulnerability in this group is therefore primarily driven by: possible language barriers; lack of ability to adapt living environments; and the possibility for some social isolation given the likelihood for single-person households. On the other hand, given that the context for the social vulnerability is heat in this case, it is possible that people in at least some of the neighbourhoods identified may actually be more highly adapted to heat and have better knowledge of effective adaptation strategies compared with the wider Welsh population.

There are five other smaller groups which are identified in the analysis for Wales and each of these has less than 10% influence overall (see Appendix II). Three of these represent distinct groups with different implications for enhancing national preparedness for heatwave events in the future.

The socially vulnerable in **Group 3** have similarities with Group 2 associated with social flood vulnerability, but with fewer indicators to offset vulnerability (see Appendix II). Just the fact of community members being out at work may reduce the ability of communities within a neighbourhood to adapt. While individuals themselves may not be in danger of heat stress, they may be affected through their concerns for others and their ability to assist others in their family or social networks (since they are more likely to be lone female carers than elsewhere in Wales). This is, however, offset in this particular group by the likelihood of living closer to work, providing that public transport networks are not affected (since there are also high dependencies on public transport). Two indicators suggest property and personal crime rates tend to be relatively high in these areas, on average, which may limit how safe people feel to seek cooler urban outdoor environments during the day and to leave windows open during the night.

The next two groups are associated with particular sensitive groups, each associated with different areas of Wales. Again, there are similarities with groups identified in the context of flood so there are joint socially driven vulnerabilities. The first (**Group 4** *age and housing*) relates neighbourhoods with higher proportions of young children and with lower proportions of the over 65s and lower chances of homes being owned outright. **Group 5** is similar to **Group 6** identified in the context of flood and allows the identification of *elderly enclaves*. Group 6 and **Group 7** are explained further in Appendix II.

Relationships between socio-spatial vulnerability and climate disadvantage in Wales

This section combines the socio-spatial vulnerability results with measures of hazard-exposure in order to estimate climate disadvantage in Wales.

Flood disadvantage

To estimate flood disadvantage from fluvial and coastal flooding, the same method has been used as for England. Extreme flood disadvantage affects around 7.5% of Welsh neighbourhoods with three (0.72%) having extreme flood advantage.[12] The most disadvantaged show strong clustering and a clear coastal component; on average they are within 1km of the coast (see Figure 18). These percentages do not capture the full extent of flood disadvantage since they do not include pluvial flooding.

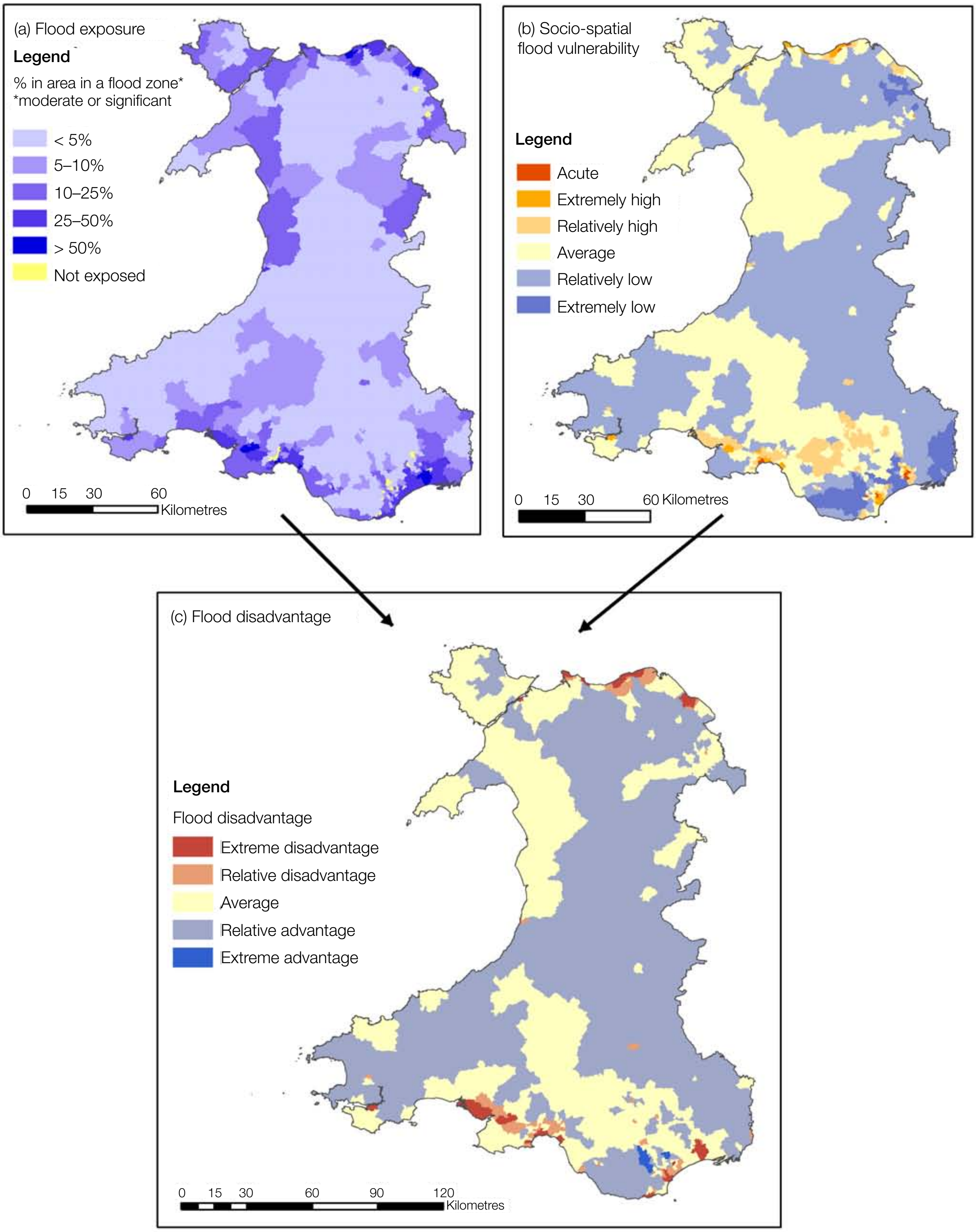
Relatively few Welsh neighbourhoods have no exposure to floods.[14] For moderate and significant flood zones,[11] this is only 7.7% in Wales compared to 22.2% in England. On average, neighbourhoods in Wales have 10.7% of their land area classified as associated with moderate or significant flood likelihood compared to 8.4% in England and there are 3.1% of neighbourhoods which have more than 50% coverage compared to just 1.7% in England.

Local authorities have been grouped into three classes according to their average estimated flood disadvantage, flood-exposure and socio-spatial vulnerability scores (see Appendix V, Table 15). Some local authorities, such as Newport, score very highly for socio-spatial vulnerability and percentage cover of land area by moderate or significant floodplain (hazard-exposure) and therefore also for flood disadvantage. Average values mask internal variations between neighbourhoods with Newport, Conwy and Denbighshire having the highest variability in flood disadvantage scores compared to other Welsh local authorities. However, they also contain six out of the top ten socially flood-vulnerable neighbourhoods. Neath Port Talbot and Carmarthenshire both appear in the high flood disadvantage group although mean scores are driven more by estimated flood-exposure than by socially derived vulnerability. On the other hand some local authorities, such as Merthyr Tydfil, have high socio-spatial vulnerability scores which are offset by flood-exposure, according to the metrics used in this study.

According to Appendix V, Table 15, Monmouthshire and Flintshire both have flood-exposure scores which are above the average for all Welsh local authorities but socially related flood vulnerability scores that are classed as 'low'. Consequently, people in these locations tend to have better chances of being able to experience a flood event without a long-term impact on their health and well-being. This is due to a multitude of inter-playing factors associated with relatively low overall sensitivity due to age and health, the advantages of housing and physical environment attributes and/or the social, material and community resources which characterise the neighbourhoods that they are in. Again, the use of average scores masks inevitable variations between neighbourhoods in these two authorities, particularly in Flintshire, underlining that mean values can mask high inequalities between some neighbourhoods. Indeed, two neighbourhoods in Flintshire rank in the top 20 most flood disadvantaged in the whole of Wales.

The Environment Agency Wales' flood risk assessment for Wales (Environment Agency Wales, 2009) uses the number of properties exposed in each local authority area as a measure of flood-exposure. Although not directly comparable with the % area metric used in the current study,[11] the relative rankings of local authorities which result from the two studies appear broadly similar. Appendix V, Table 15 suggests that high flood exposure does not necessarily result in high flood disadvantage. For example, Flintshire and Swansea have a similar number of properties with a moderate or significant chance of being affected by flood (Environment Agency Wales, 2009) and a similar mean percentage area covered as estimated in this study. However, when Swansea's very high mean social flood vulnerability is taken into account relative to Flintshire's very low one, it is Swansea which has higher overall flood disadvantage. Finer-scale assessment is important since it is possible that a large proportion of the 6,000 or so exposed properties identified by the Environment Agency Wales are within Flintshire's high-ranking socially flood-vulnerable neighbourhoods. This example underlines the need to consider socially derived flood vulnerability as well as hazard-exposure in formulating socially just adaptation responses.

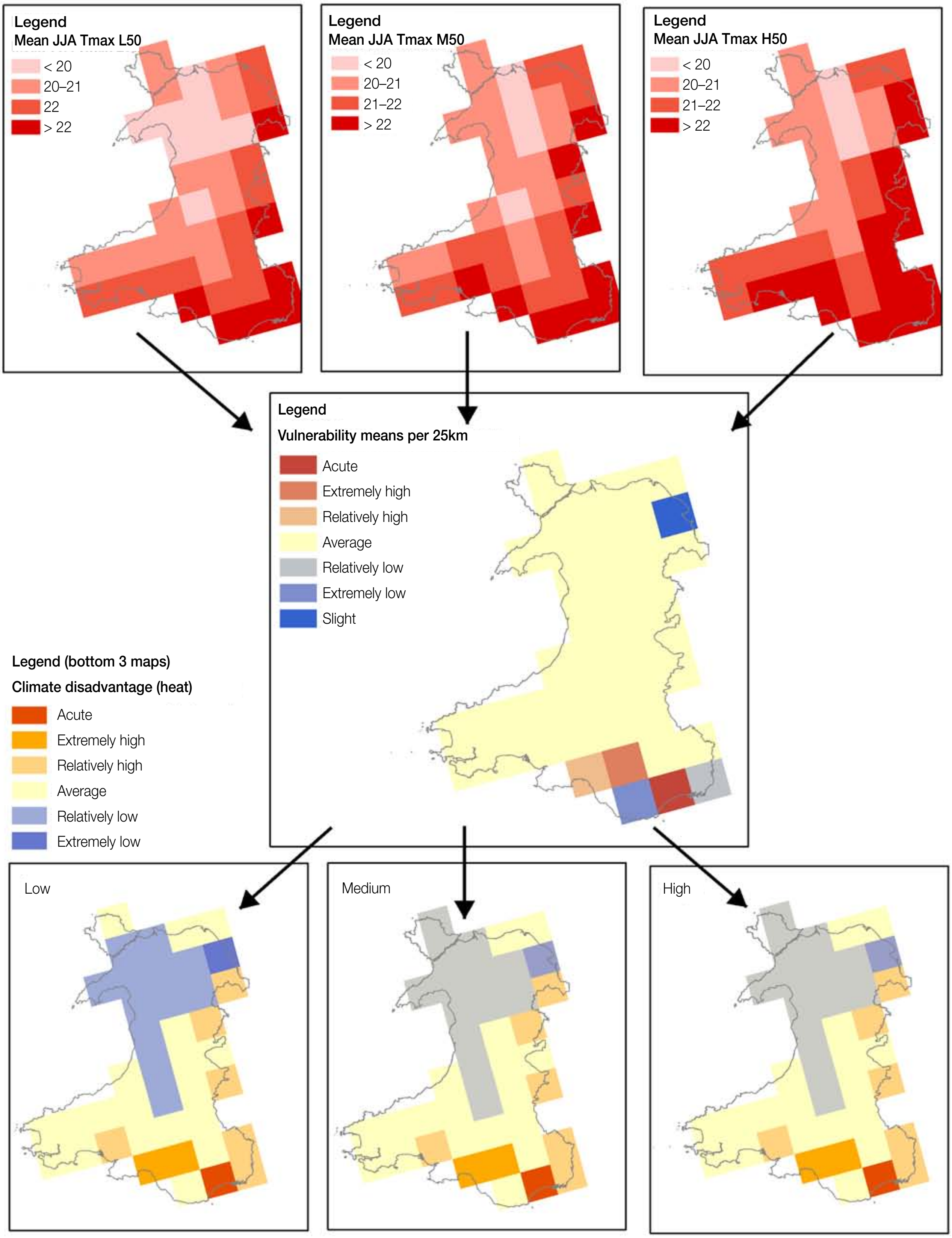
Figure 18: Relative flood disadvantage in Wales as a composite of (a) flood exposure and (b) socio-spatial flood vulnerability



Source: Boundary data: EDINA UKBORDERS, Flood-exposure data Environment Agency, Crown copyright (see Notes)

Heat disadvantage

Figure 19: Heat disadvantage in Wales in the 2050s as a combination of neighbourhood-weighted socio-spatial heat vulnerability[16] and the geography of mean summer day maximum temperatures (°C)



Note: JJA refers to June, July, August. Tmax refers to maximum temperature.

Source: UKCP09 50th percentile estimates for the low (L50), medium (M50) and high (H50) emissions scenarios.

UK Climate Projections 2009, Crown copyright

Heat disadvantage has been estimated using the same methodology as for England. Figure 19 shows climate disadvantage through considering the relative geography of mean summer maximum day temperatures in the 2050s against neighbourhood-weighted socio-spatial heat vulnerability scores. Future mean summer maximum temperatures tend to be lower in the North and West and higher in the South and East, as would be expected. Based on this metric and all other things being equal, higher temperatures are more likely to impact the relatively socially heat vulnerable in Wales. This is also true using average socio-spatial vulnerability scores and the alternative heat-exposure measure of change in the temperature of the warmest summer day (see Appendix III). For reference, relative socio-spatial vulnerability scores for Welsh local authorities are categorised into high, medium and low groups (see Appendix V, Table 15).

Socio-spatial vulnerability and climate disadvantage in Northern Ireland

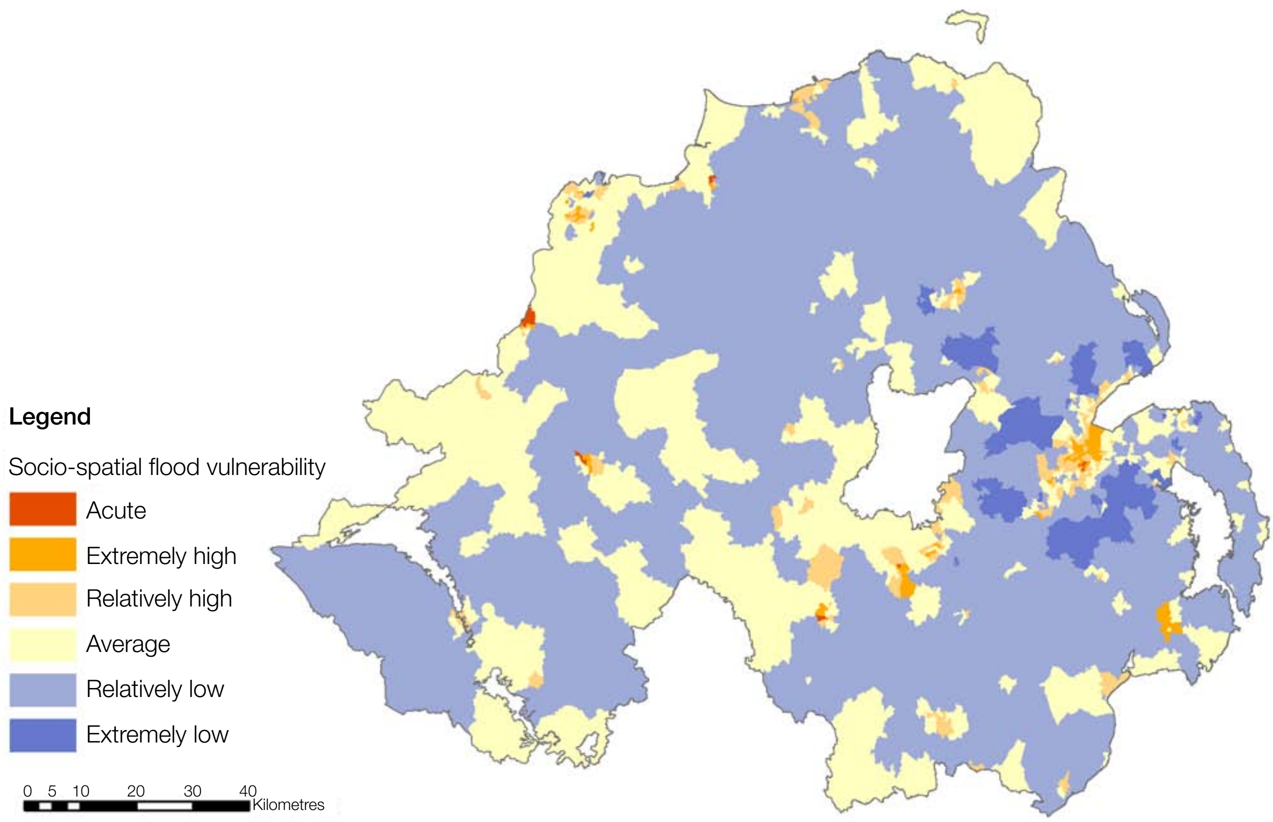
Critical socially vulnerable locations in Northern Ireland

The specific indicators used for Northern Ireland differ a little from those for England and Wales but are considered broadly compatible (Appendix I). Another difference is that the neighbourhood definitions are for geographical areas with smaller populations, which make them similar in size to English sub-neighbourhoods[5] (see Chapter 3, 'Greater Manchester case study').

Socio-spatial flood vulnerability

Around 9% of Northern Ireland neighbourhoods are estimated to have extremely high flood-related social vulnerability compared to around 3% with extremely low flood-related social vulnerability (see Figure 20).[12]

Figure 20: Socio-spatial flood vulnerability in Northern Ireland



Source: Boundary data: EDINA UKBORDERS, Crown copyright

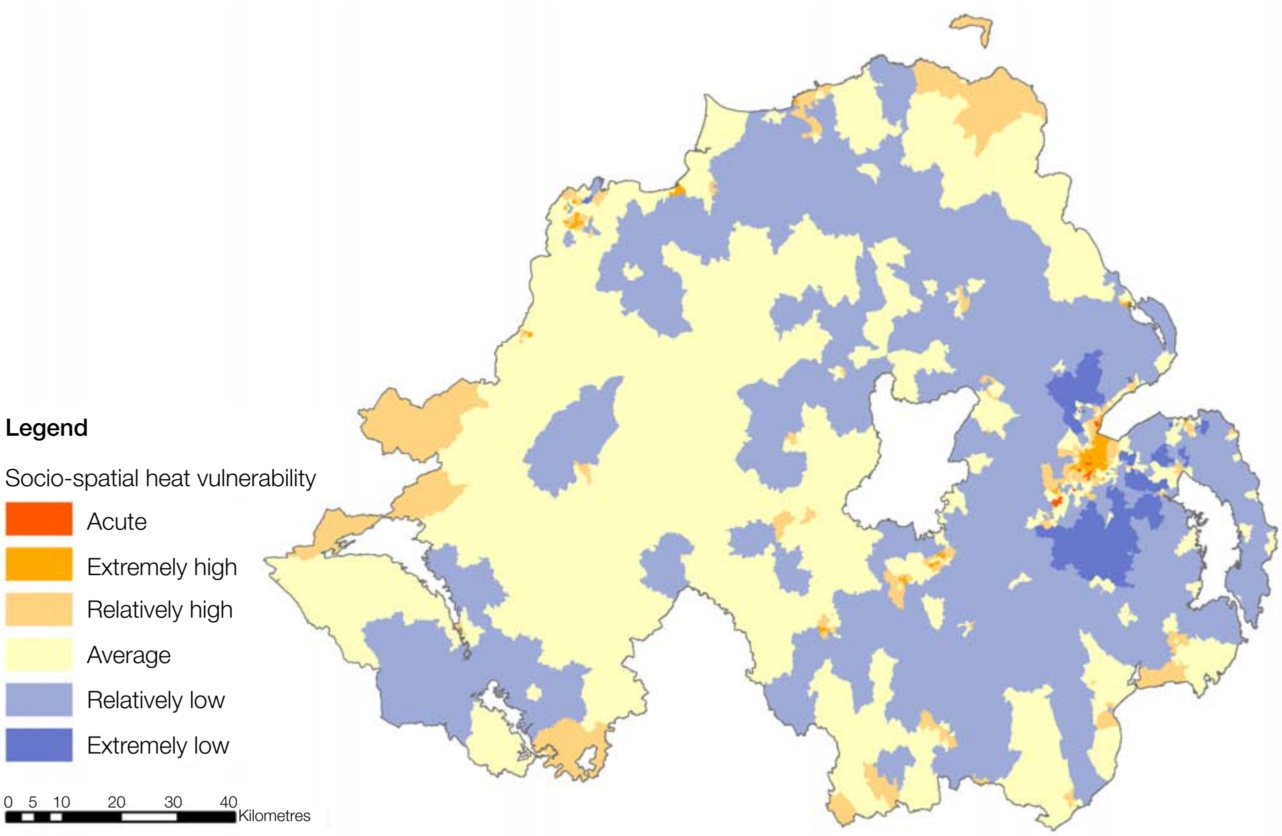
Almost all of Northern Ireland's top 10% most socially flood-vulnerable neighbourhoods are within urban areas, whereas the top 10% least socially vulnerable have relatively low proportions of urban cover (16% on average). The most socially vulnerable (taking all factors into account) are more likely to be associated with above-ground living accommodation. Thus the housing and physical environment factors in these groups offset one another. The least socially vulnerable neighbourhoods are generally located on urban fringes and therefore are likely to experience some enhanced exposure compared to the neighbourhoods which are classified as entirely non-urban (some quarter of all Northern Ireland neighbourhoods). Maps showing the spatial distributions of scores associated with each of the five dimensions of socio-spatial flood vulnerability can be found in Appendix IV, Figure 19a–d.

The clearest aspect of the geography of socially derived flood vulnerability in Northern Ireland is the contrast between urban areas and their rural hinterlands. There is not such a strong coastal dimension to socio-spatial flood vulnerability since fewer than 10% of all neighbourhoods in the top 10% most socially flood vulnerable are within 1km of the coast. In the absence of available flood-zone data equivalent to that used for England and Wales, historical flood zones have been used as an alternative measure of potential issues with access to insurance. The use of a different insurance indicator for Northern Ireland could be part of the explanation for this different geography of socially derived flood vulnerability. Even so, the distribution of neighbourhoods which are highly heat vulnerable show a similar tendency to be located a little further from coasts than is the case in Wales, for example (see below, 'Socio-spatial heat vulnerability').

Socio-spatial heat vulnerability

The proportion of Northern Ireland neighbourhoods estimated to have extremely high heat-related social vulnerability relative to extremely low heat-related social vulnerability is similar to that for flooding at around 8% and 4% respectively.[12] As was seen in the context of flood socio-spatial vulnerability, virtually all of the top 10% most socially heat-vulnerable neighbourhoods are in urban areas and again fewer than 10% are

Figure 21: Socio-spatial heat vulnerability in Northern Ireland



Source: Boundary data: EDINA UKBORDERS, Crown copyright

within a kilometre of the coast (see Figure 21). Two-thirds of the neighbourhoods in the top 10% are identified for both socially derived heat and socially derived flood vulnerability. Further, two-thirds of the top 10% least socially heat-vulnerable neighbourhoods also appear in the top 10% least socially flood vulnerable. Although there is some evidence for hazard-independent social vulnerability, this is not true for all of the most socially vulnerable people and places.

The geography of aggregate socially derived heat vulnerability also has some commonalities with that for flood. The most notable difference is the tendency for peripheral locations to have relatively high socially derived heat vulnerabilities. This geographical pattern is influenced by the distributions of scores in the sensitivity dimension (see Figure 22a) but also aspects of adaptive capacity, such as ability to recover (see Figure 22c). Although ability to recover is estimated from a number of indicators, accessibility measures are an influential component. However, it should be noted that the measure used in this study has limitations: for example, it may be unrepresentative of true accessibility near to the Eire border. Aggregate socio-spatial heat vulnerability scores in some peripheral locations remain relatively high despite a low enhanced exposure (see Figure 22b). Very high enhanced exposures for some urban locations (see Figure 22b) are associated with particular concentrations of high-rise housing in some neighbourhoods. Maps showing the other two dimensions of socio-spatial heat vulnerability can be found in Appendix IV, Figure 20a–b.

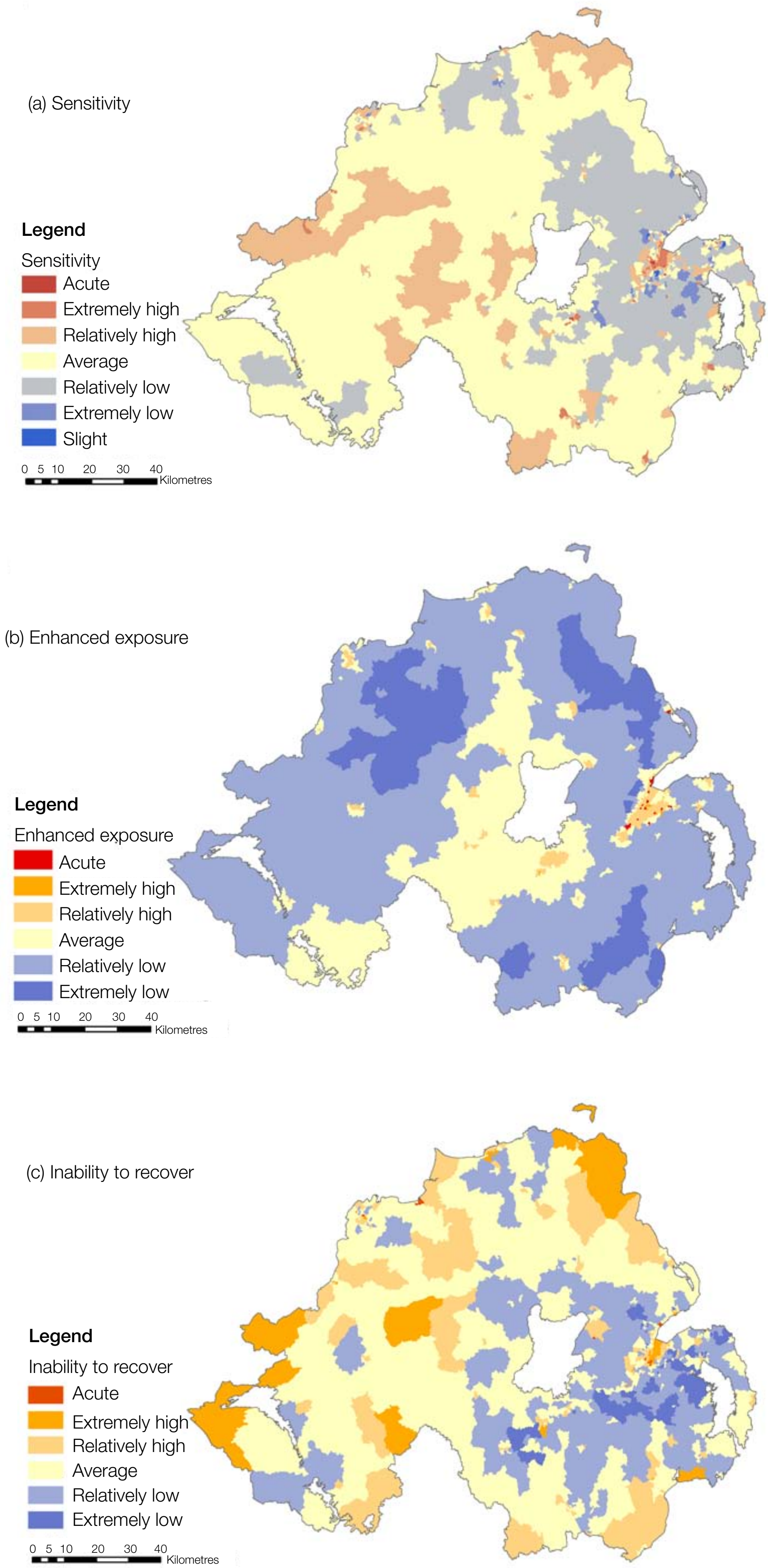
Socio-spatial flood and heat vulnerability in Northern Ireland authority areas

Belfast has the highest mean and neighbourhood-weighted mean scores for both flood and heat-related social vulnerability, remembering that this is independent of the spatial pattern of the hazards themselves. For heat, scores for Belfast are three times higher than the next ranked authority.

Besides Belfast, Strabane, Derry, Craigavon and Omagh are all in the highest-scoring group for socio-spatial flood vulnerability (see Appendix V, Table 17). These are the only five authorities with mean flood vulnerability scores above the Northern Ireland mean. Since Strabane has a history of past flooding, it is possible that insurance could be difficult and/or expensive to obtain, affecting the ability of residents to prepare for, respond to and recover from future events. Strabane is also estimated to have wider social vulnerabilities too, i.e. there are other factors which also contribute to its score. At the other end of the spectrum, Ards ranks as the least socially vulnerable, especially when neighbourhood-weighted scores are considered. Other low-scoring authorities are also shown in Appendix V, Table 17.

A similar picture emerges when considering the breakdown of the top and bottom 10% scoring neighbourhoods for socio-spatial flood vulnerability within local authority areas (see Table 10). Belfast has the highest proportion of its neighbourhoods in the top 10% most socially flood vulnerable and half of all of the neighbourhoods in this group in the whole of Northern Ireland. Other areas with high (>10%) proportions of their neighbourhoods scoring in the top 10% most socially flood vulnerable are Strabane, Craigavon, Derry, Omagh and Limavady. Ten districts have high proportions (>10%) of their neighbourhoods which are classed as being in the bottom 10% of neighbourhood socio-spatial flood vulnerability scores. A fifth of authorities have neighbourhoods represented in both categories, which is indicative of high inequalities with respect to socio-spatial flood vulnerability. For heat (see Table 11), Belfast again dominates the results, with 60% of Northern Ireland's most socially heat-vulnerable neighbourhoods and only 2% of its least. Derry is the next biggest contributor to the Northern Ireland total and is also high in terms of the proportion of neighbourhoods within the authority itself. Chapter 3, 'Relationships between socio-spatial vulnerability and climate disadvantage in Northern Ireland' considers these results against relative temperature patterns.

Figure 22: Geography of (a) sensitivity, (b) enhanced exposure and (c) ability to recover dimensions of socio-spatial heat vulnerability in Northern Ireland



Note: (a) is the same for heat and flood sensitivity

Source: Boundary data: EDINA UKBORDERS, Crown copyright

Table 10: Distribution of the top 10% and bottom 10% scoring neighbourhoods for socially derived flood vulnerability by Northern Ireland local authority

		Scores in top 10% (flood)			Scores in bottom 10% (flood)		
Local authority (LA)	**Count of neighbour-hoods**	**Count of neighbour-hoods**	**% of LA neighbour-hoods**	**% of all N. Irish neighbour-hoods**	**Count of neighbour-hoods**	**% of LA neighbour-hoods**	**% of all N. Irish neighbour-hoods**
Antrim	25	0	0	0	4	16	4
Ards	46	0	0	0	12	26	13
Armagh	25	2	8	2	2	8	2
Ballymena	29	2	7	2	7	24	8
Ballymoney	16	0	0	0	1	6	1
Banbridge	19	0	0	0	3	16	3
Belfast	150	44	29	49	1	1	1
Carrickfergus	20	0	0	0	4	20	4
Castlereagh	33	0	0	0	10	30	11
Coleraine	29	2	7	2	2	7	2
Cookstown	16	0	0	0	0	0	0
Craigavon	44	9	20	10	3	7	3
Derry	57	11	19	12	1	2	1
Down	36	3	8	3	5	14	6
Dungannon	22	0	0	0	2	9	2
Fermanagh	25	0	0	0	0	0	0
Larne	16	0	0	0	3	19	3
Limavady	18	2	11	2	0	0	0
Lisburn	58	5	9	6	12	21	13
Magherafelt	21	0	0	0	1	5	1
Moyle	9	0	0	0	0	0	0
Newry and Mourne	47	0	0	0	0	0	0
Newtownabbey	47	0	0	0	11	23	12
North Down	40	1	3	1	5	13	6
Omagh	24	4	17	4	0	0	0
Strabane	18	4	22	4	0	0	0
Total / *Mean*	890	89	*10*	100	89	*10*	100

Socially vulnerable groups in Northern Ireland

Socially flood-vulnerable groups

Socio-spatial flood vulnerability in Northern Ireland is explained through the characteristics of six groups (see Appendix II). Some of the groups are in keeping with those identified in England and Wales, despite the use of quite different scales for neighbourhood units and some differences in indicators in the case of Northern Ireland (Appendix I).

Group 1 is related to the *overseas enclave* group identified previously and comprises five indicators (see Appendix II). The more socially flood-vulnerable neighbourhoods are characterised by an association between greater rates of new arrivals from outside the UK and Ireland, higher percentages of people born outside of the UK and Ireland and higher percentages born in the EU. In the Northern Ireland context,

Table 11: Distribution of the top 10% and bottom 10% scoring neighbourhoods for socially derived heat vulnerability by Northern Ireland local authority

		Scores in top 10% (heat)			Scores in bottom 10% (heat)		
Local authority (LA)	**Count of neighbour-hoods**	**Count of neighbour-hoods**	**% of LA neighbour-hoods**	**% of all N.Irish neighbour-hoods**	**Count of neighbour-hoods**	**% of LA neighbour-hoods**	**% of all N. Irish neighbour-hoods**
Antrim	25	0	0	0	3	12	3
Ards	46	0	0	0	17	37	19
Armagh	25	1	4	1	2	8	2
Ballymena	29	0	0	0	1	3	1
Ballymoney	16	0	0	0	0	0	0
Banbridge	19	0	0	0	3	16	3
Belfast	150	53	35	60	2	1	2
Carrickfergus	20	0	0	0	4	20	4
Castlereagh	33	2	6	2	12	36	13
Coleraine	29	2	7	2	0	0	0
Cookstown	16	0	0	0	0	0	0
Craigavon	44	7	16	8	4	9	4
Derry	57	11	19	12	2	4	2
Down	36	0	0	0	3	8	3
Dungannon	22	0	0	0	0	0	0
Fermanagh	25	0	0	0	0	0	0
Larne	16	1	6	1	2	13	2
Limavady	18	2	11	2	0	0	0
Lisburn	58	5	9	6	12	21	13
Magherafelt	21	0	0	0	0	0	0
Moyle	9	0	0	0	0	0	0
Newry and Mourne	47	0	0	0	0	0	0
Newtownabbey	47	3	6	3	15	32	17
North Down	40	1	3	1	7	18	8
Omagh	24	0	0	0	0	0	0
Strabane	18	1	6	1	0	0	0
Total / *Mean*	890	89	*10*	100	89	*10*	100

though, this group is also associated with high rates of *new arrivals* more generally. The characteristics of this group suggest that language could be an issue but perhaps the most significant message is that this group may lack local knowledge and may not be well informed of any potential for flood exposure in the areas within which they live. This group is associated with higher rates of private rented accommodation, which presents a challenge in terms of the opportunities that people have to adapt their homes and also the fact that authorities involved in adaptation planning find private landlords difficult to engage with (Salford City Council, 2011).

Group 2 is similar to Group 2 identified for Wales. Here there are associations between six indicators, the most influential of which link higher proportions of people working away from home, lower proportions of homes which are owned outright, lower relative numbers of hours worked and higher usage of public transport. Lower personal mobility is also suggested through lower car/van ownership rates. Finally, the more socially flood-vulnerable neighbourhoods in Group 2 tend, as a whole, to have higher crime rates. The importance of these factors for socially derived flood vulnerability has been previously explained.

Group 3 represents *age and household composition*. Here neighbourhoods with higher proportions of children and families are connected with lower proportions of older people and all-pensioner households (and vice versa). Neighbourhoods at either extreme of the Group 3 distributions are therefore likely to have higher sensitivity to health-related impacts from flood events and there are also implications for adaptive capacity too.

Group 4 represents *poverty and deprivation*. The group represents socially vulnerable neighbourhoods which are on average associated with higher unemployment and therefore the potential for resource-related lack of adaptive capacity. There are also associations with limiting long-term illness and higher proportions of people with few qualifications. The results also indicate that there is likely to be lower personal mobility within this group. Group 4 is strongly correlated to the Northern Ireland Multiple Deprivation Measure 2005. There are low or no correlations with other groups except for a moderate correlation with Group 2.

Group 5 links areas of high rates of change, both generally and of the over 65s. The final **Group 6** recognises the role of past flood events and makes a link between possible insurance access problems and higher proportions of homes with basements, and therefore the possibility for enhanced exposure.

Socially heat-vulnerable groups

There are six groups which represent socio-spatial heat vulnerability in Northern Ireland. **Group 1** highlights ten indicators, some of which increase and some of which decrease socially derived heat vulnerability. This, in addition to a relatively large number of indicators, makes the group difficult to interpret and to name. Six indicators in Group 1 are related to access and mobility, but they tend to cancel one another out so that on average neighbourhoods in Group 1 tend to have three access and mobility indicators which contribute to socially derived vulnerability and three which offset it. For example, neighbourhoods with higher percentages of people working away from home, higher reliance on public transport to travel to work, and higher proportions with no access to a car or van tend to be associated with lower average distances to GP surgeries and to emergency hospitals and low mean numbers of hours worked. This can be partly explained by the additional positive association of these neighbourhoods with urban areas and in turn relatively high crime and relatively high proportions of non-pensioner single-person households. Overall, the balance of indicators tends to suggest that the more socially vulnerable neighbourhoods in Group 1 are urban despite the accessibility benefits which come with these locations.

Group 2 brings together a set of factors already explained in the context of socio-spatial flood vulnerability as being associated with *poverty and deprivation*. All indicators in this group are positively associated with socially derived heat vulnerability so that the more socially vulnerable neighbourhoods tend to have higher unemployment rates, more limiting long-term illness, a more basic education and a lack of private transport. Group 2 is strongly correlated with the Northern Ireland Multiple Deprivation Measure.

Groups very similar to Groups 3 and 4 have already been discussed in relation to either the flood vulnerability groups or the wider UK analysis. **Group 3** is largely associated with *age and household composition*. **Group 4** is largely associated with identifying *overseas enclaves*. **Group 5** links neighbourhoods that have a higher influx of younger populations with higher proportions of single-person households, both of which could be interpreted as increasing socially derived vulnerability, but also with lower influx of people over 65, which offsets it. **Group 6** is actually a single indicator which represents housing associated with increased heat exposure, namely the percentages of people living in accommodation on the fifth floor or above.

Relationships between socio-spatial vulnerability and climate disadvantage in Northern Ireland

Unfortunately, equivalent flood exposure data like that accessed for England and Wales could not be made available for this study for Northern Ireland. Therefore the climate disadvantage results are only available for heat.

Heat disadvantage

Mean summer maximum temperatures in the 2050s (see Figure 23) are expected to be cooler along the northern coasts with inland areas particularly to the South East seeing the higher temperatures. While the temperature range across Northern Ireland is not tremendously high, there is the potential for some differentiation and this may impact on the distribution of peak temperatures in the event of any heatwaves. Superimposing the distributions of temperature over the distributions of socio-spatial vulnerability demonstrates that the lower temperatures in the North are somewhat offset by the higher socio-spatial vulnerabilities seen in some northern neighbourhoods. The areas which have only average vulnerability towards the south of Northern Ireland emerge as having higher climate disadvantage relative to the rest of the country. Belfast has the double impact of high socio-spatial vulnerability and relatively high temperatures and this is consistent through all of the analyses undertaken in this study. These findings are not unexpected but do add a further richness and depth to understanding how and why this is the case. Cooler zones in the higher elevation areas combine with lower vulnerabilities to result in relative climate advantage. Additional results for other metrics are shown in Appendix III.

Socio-spatial vulnerability and climate disadvantage in Scotland

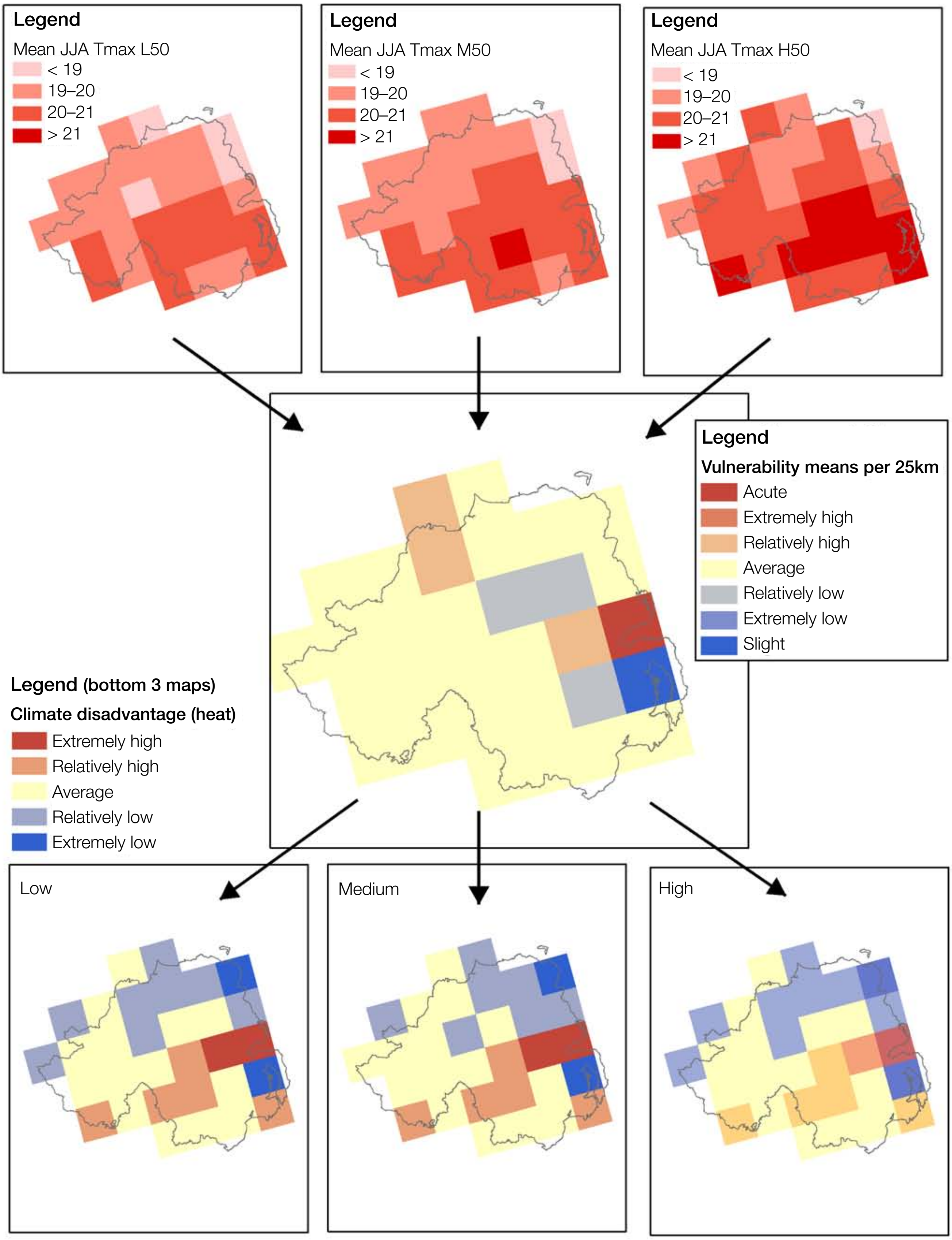
Critical socially vulnerable locations in Scotland

The socio-spatial vulnerability index for Scotland uses a set of indicators mapped to the Data Zone level (see Appendix I). Although Data Zones represent neighbourhoods for the purposes of this study, it should be noted that their population sizes make them equivalent in size to English sub-neighbourhoods,[5] i.e. those used in the analysis in Chapter 3, ‘Greater Manchester case study’. The set of indicators is slightly different from that used for the other devolved administrations but is considered broadly compatible.

Socio-spatial flood vulnerability

Around 7% of Scottish neighbourhoods have extremely high flood-related social vulnerability compared to less than 5% with extremely low flood-related social vulnerability.[12] The extremely socially flood-vulnerable neighbourhoods are concentrated in urban areas (Figure 24, bottom left inset) since around 90% have their centres in urban zones.[13] There is also a discernible coastal component to social vulnerability with respect to flood. Around 30% of all extremely socially flood-vulnerable neighbourhoods are within 1km of the coast (40% within 2km). Both enhanced exposure and ability to recover have strong urban–rural contrasts compared to the geography of sensitive populations and those of the ability to prepare and respond dimensions (Appendix IV, Figure 21a–e).

Figure 23: Heat disadvantage in Northern Ireland in the 2050s as a combination of neighbourhood-weighted socio-spatial heat vulnerability[16] and the geography of mean summer day maximum temperatures (°C)

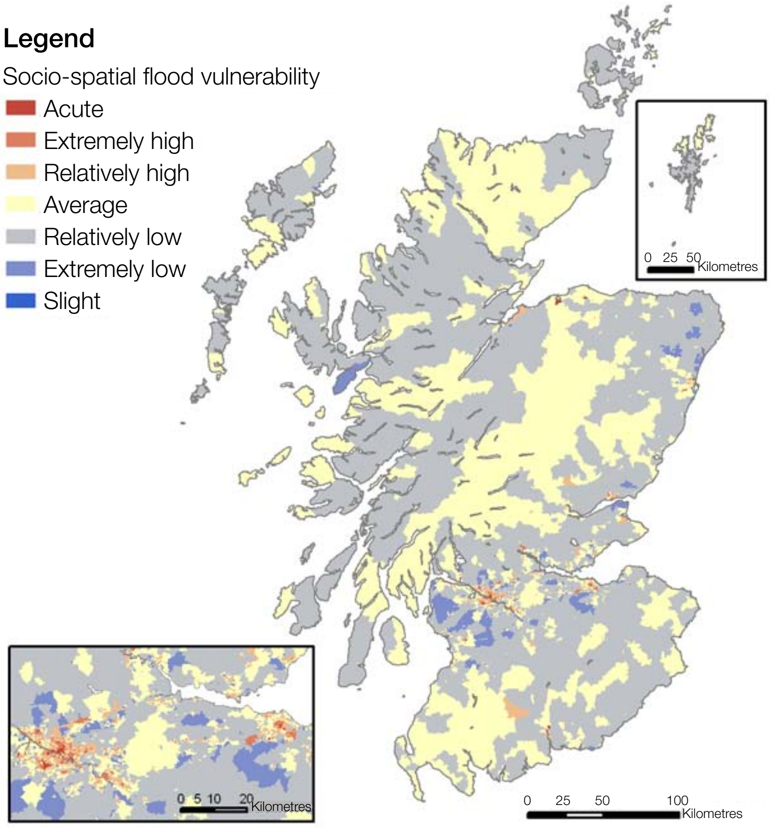


Notes: JJA refers to June, July, August. Tmax refers to maximum temperature.

Source: UKCP09 50th percentile estimates for the low (L50), medium (M50) and high (H50) emissions scenarios.

UK Climate Projections 2009, Crown copyright

Figure 24: Socio-spatial flood vulnerability in Scotland



Source: Boundary data: EDINA UKBORDERS, Crown copyright

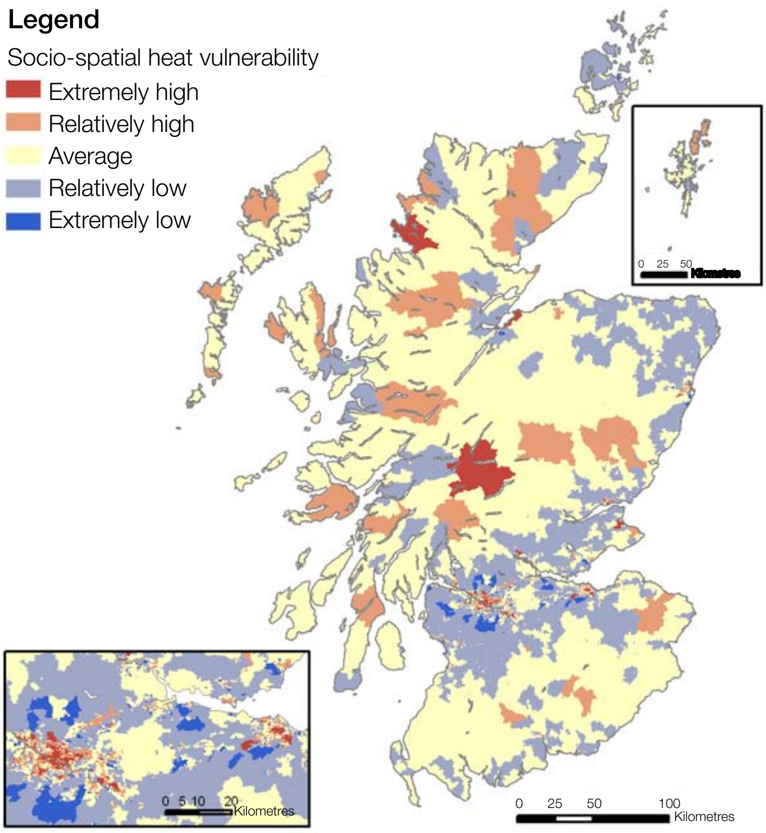
Socio-spatial heat vulnerability

Similar proportions of Scottish neighbourhoods have extremely high (7%) and extremely low (4%) socio-spatial heat vulnerability as was found in the context of flood.[12] The geographies of the highest- compared to lowest-scoring neighbourhoods are shown in Figure 25. Extremely socially heat-vulnerable neighbourhoods have a very strong urban dimension and a tendency to be located near the coast; 27% have their centres within 1km (44% within 2km). This is despite proximity to the coast being used as an indicator acting to reduce enhanced exposure. Therefore the most critical socially vulnerable locations tend to be low-elevation urban areas with large proportions of tower block and high-rise tenement housing. Further, the selection of an indicator relating to proportions of households on the fifth floor or higher will mean that there are some tenement buildings which have not been included in the analysis. In some locations, tenement buildings lower than five floors in height may be associated with high internal temperatures in upper-floor apartments during any heat event.

Given the similarities in the geographical locations of extremely flood and heat-vulnerable neighbourhoods, it is to be expected that many that have been highlighted may have joint socially derived vulnerabilities. In fact, around two-thirds of extremely high-scoring neighbourhoods do so for both socially derived flood and socially derived heat vulnerabilities.

The geography of socio-spatial heat vulnerability in Figure 25 shows an interesting pattern which requires further investigation to be fully understood. A small number of large, very sparsely populated neighbourhoods emerge as having high socially derived heat vulnerability. To some extent, the large size of these neighbourhoods masks the fact that the vast majority of extremely socially derived heat-vulnerable neighbourhoods are urban. Nevertheless, there are components of socially derived heat vulnerability which clearly have a rural component according to the methodology and indicators used in this study.

Figure 25: Socio-spatial heat vulnerability in Scotland

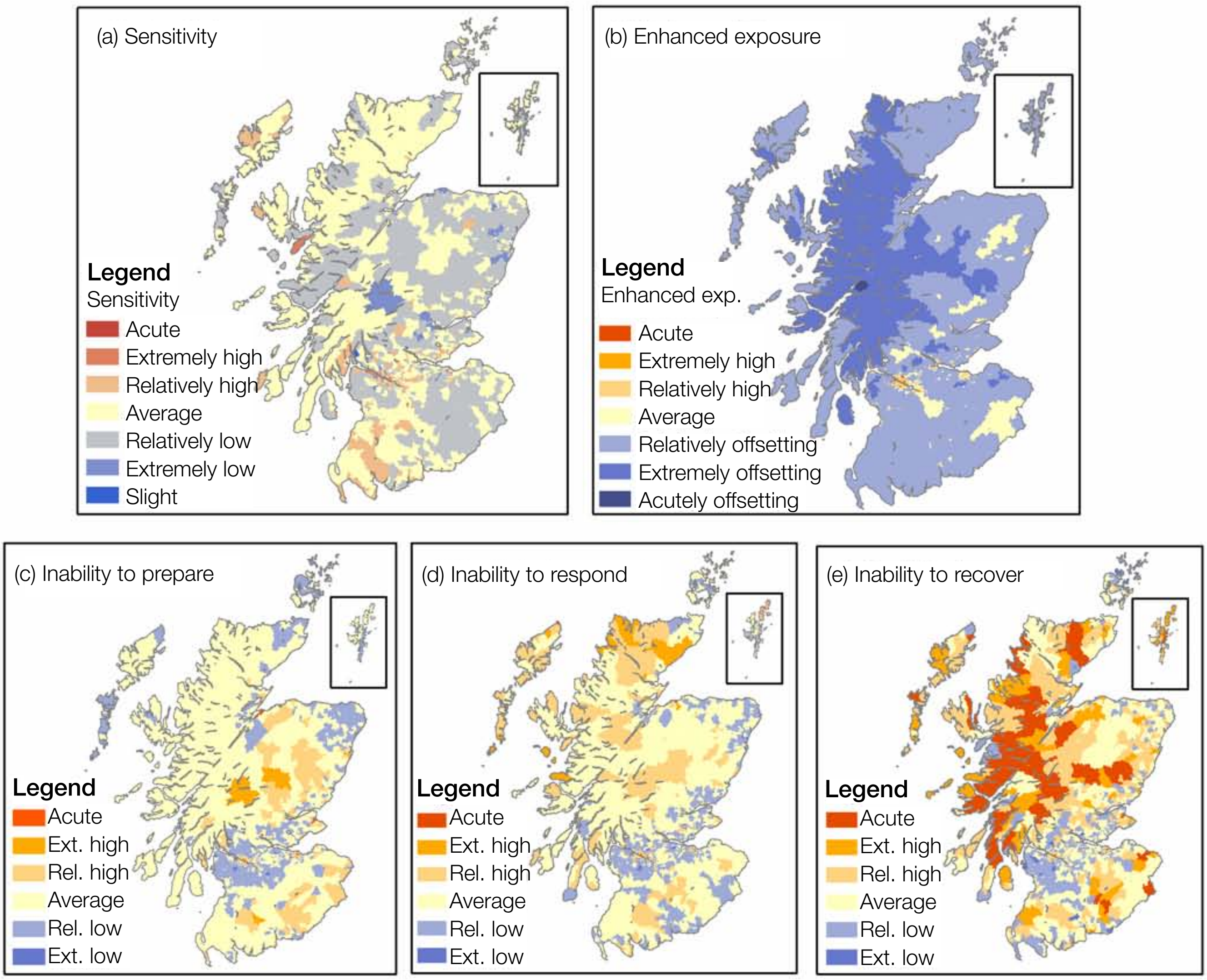


Source: Boundary data: EDINA UKBORDERS, Crown copyright

Figure 26 illustrates the different geographies of the five dimensions behind the aggregate map. A number of neighbourhoods score relatively highly in relation to sensitivity (related to age and health) with a rural component to all of the adaptive capacity dimensions, particularly ability to recover (see Figure 26e). Within ability to recover, it is principally access to GP surgeries which dominates the rural contribution and this is affected by a large range in the GP access indicator. Some of the highest-scoring socially derived heat-vulnerable neighbourhoods in rural areas are so categorised because, as well as having low GP access, they are also associated with other social vulnerability-enhancing indicators, such as above-average proportions of people from overseas compared to other neighbourhoods in Scotland. The combination of indicators is interpreted as being associated with high socio-spatial vulnerability because of the potential for language restrictions and the lack of ready availability of medical support. However, in some locations, both here and in the rest of the UK, there may be other local social characteristics (not included in this study) which tend to counter this interpretation. Local ground-truthing and contextualisation is therefore important.

It should also be remembered that these socio-spatial index results do not include an estimate of the relative likelihood of neighbourhoods experiencing a heatwave with the capacity to cause harm. Indeed, the geographical settings of some of the highly scoring zones would tend to suggest that extremely elevated temperatures would be unlikely, something which is also supported by the low enhanced exposure scores (see Figure 26b). This discussion underlines the points made at the beginning of Chapter 3 that it is strongly recommended that measures of hazard-exposure are also taken into account (see Chapter 3, 'Relationships between socio-spatial vulnerability and climate disadvantage in Scotland'). The discussion also raises questions about the influence of weighting schemes within the index, therefore Scotland is used as a case study for exploring the implications of a limited number of alternative weighting schemes relative to the equal weighting principle used throughout the study (see Chapter 3, 'Impacts of weighting schemes on the results of the socio-spatial index').

Figure 26: Geography of the five dimensions of socio-spatial heat vulnerability in Scotland



Source: Boundary data: EDINA UKBORDERS, Crown copyright

Flood and heat-related social vulnerability in Scottish local authority areas

Breakdowns of the socio-spatial vulnerability results have been produced for the 32 Scottish unitary authorities (UAs). This allows an assessment to be made of patterns in mean socio-spatial vulnerability scores (see Appendix V, Table 18) and the relative proportions of the most and least socially vulnerable within each administration area.

Glasgow City is the most highly socially vulnerable of any Scottish UA, and by a wide margin. It is nearly twice as socially flood vulnerable, on average, than the next highest in the high group and more than twice as socially vulnerable with respect to heat. While Edinburgh is in the highest-ranking group in terms of its mean socio-spatial vulnerability, its average scores only place it towards the lower end of the group in the context of both flood and heat, although it is second when accounting for population size. Na H-Eileanan an Iar (Outer Hebrides) appears quite far up the list for heat vulnerability, which may appear a curious result (see Appendix V, Table 18). Again, the socio-spatial vulnerability index takes no explicit account of current or future temperatures and so it is necessary to view this information alongside the results before determining the extent of any climate disadvantage relative to the rest of Scotland. High socially derived vulnerability in Na H-Eileanan an Iar is the combination of many factors but is in part linked to relatively high levels of social deprivation (Scottish Index of Multiple Deprivation).

Table 12: Distribution of extremely high- compared to extremely low-scoring neighbourhoods for socially derived flood vulnerability by Scottish unitary authority

		Extremely high or above (flood)			Extremely low or below (flood)		
Unitary authority	**Count of neighbour-hoods**	**Count of neighbour-hoods**	**% of UA neighbour-hoods**	**% of all Scottish neighbour-hoods**	**Count of neighbour-hoods**	**% of UA neighbour-hoods**	**% of all Scottish neighbour-hoods**
Aberdeen City	268	19	7	4	16	6	5
Aberdeenshire	302	5	2	1	23	8	7
Angus	142	2	1	0	2	1	1
Argyll and Bute	147	7	5	2	0	0	0
City of Edinburgh	550	58	11	13	19	3	6
Clackmannanshire	65	1	2	0	3	5	1
Dumfries and Galloway	194	9	5	2	4	2	1
Dundee City	179	31	17	7	3	2	1
East Ayrshire	154	5	3	1	14	9	4
East Dunbartonshire	127	2	2	0	16	13	5
East Lothian	120	3	3	1	7	6	2
East Renfrewshire	119	1	1	0	10	8	3
Falkirk	197	1	1	0	13	7	4
Fife	454	13	3	3	20	4	6
Glasgow City	694	191	28	42	2	0	1
Highland	317	9	3	2	4	1	1
Inverclyde	110	15	14	3	3	3	1
Midlothian	112	0	0	0	6	5	2
Moray	116	16	14	4	0	0	0
Na H-Eileanan an Iar	53	0	0	0	1	2	0
North Ayrshire	179	10	6	2	6	3	2
North Lanarkshire	418	15	4	3	35	8	11
Orkney Islands	42	0	0	0	1	2	0
Perth and Kinross	176	14	8	3	0	0	0
Renfrewshire	214	9	4	2	31	14	10
Scottish Borders	131	2	2	0	0	0	0
Shetland Islands	41	0	0	0	0	0	0
South Ayrshire	148	2	1	0	10	7	3
South Lanarkshire	399	7	2	2	38	10	12
Stirling	112	4	4	1	3	3	1
West Dunbartonshire	119	4	3	1	5	4	2
West Lothian	211	2	1	0	22	10	7
Total / *Mean*	6610	457	*7*	100	317	*5*	100

Turning to the analysis of extremes in socio-spatial vulnerability in Scotland (see Tables 12 and 13), Glasgow City contributes over 40% of Scotland's total of extremely socially flood-vulnerable neighbourhoods and nearly half of its total in relation to heat. These make up almost a third of all neighbourhoods within the city. Glasgow has only a handful of neighbourhoods classified as having extremely low socio-spatial vulnerability. Therefore, even in the unlikely event of a heatwave of equal severity across Scotland, the physical and socio-economic characteristics of Glasgow mean that its residents are the ones who are very likely to suffer disproportionate harm.

Table 13: Distribution of extremely high- compared to extremely low-scoring neighbourhoods for socially derived heat vulnerability by Scottish unitary authority

		Extremely high or above (heat)			Extremely low or below (heat)		
Unitary authority	**Count of neighbourhoods**	**Count of neighbourhoods**	**% of UA neighbourhoods**	**% of all Scottish neighbourhoods**	**Count of neighbourhoods**	**% of UA neighbourhoods**	**% of all Scottish neighbourhoods**
Aberdeen City	268	24	9	5	20	7	8
Aberdeenshire	302	1	0	0	17	6	7
Angus	142	0	0	0	2	1	1
Argyll and Bute	147	2	1	0	1	1	0
City of Edinburgh	550	61	11	14	15	3	6
Clackmannanshire	65	0	0	0	2	3	1
Dumfries and Galloway	194	5	3	1	1	1	0
Dundee City	179	26	15	6	2	1	1
East Ayrshire	154	3	2	1	7	5	3
East Dunbartonshire	127	0	0	0	10	8	4
East Lothian	120	1	1	0	4	3	2
East Renfrewshire	119	0	0	0	19	16	8
Falkirk	197	4	2	1	14	7	6
Fife	454	9	2	2	11	2	5
Glasgow City	694	215	31	48	1	0	0
Highland	317	10	3	2	5	2	2
Inverclyde	110	17	15	4	1	1	0
Midlothian	112	2	2	0	5	4	2
Moray	116	0	0	0	0	0	0
Na H-Eileanan an Iar	53	0	0	0	0	0	0
North Ayrshire	179	7	4	2	2	1	1
North Lanarkshire	418	21	5	5	22	5	9
Orkney Islands	42	0	0	0	1	2	0
Perth and Kinross	176	3	2	1	0	0	0
Renfrewshire	214	8	4	2	20	9	8
Scottish Borders	131	0	0	0	0	0	0
Shetland Islands	41	1	2	0	1	2	0
South Ayrshire	148	2	1	0	3	2	1
South Lanarkshire	399	9	2	2	33	8	14
Stirling	112	6	5	1	3	3	1
West Dunbartonshire	119	12	10	3	3	3	1
West Lothian	211	1	0	0	18	9	7
Total / *Mean*	6610	450	*7*	100	243	*4*	100

Other UAs which have over 10% of their total number of neighbourhoods classed as extremely socially flood vulnerable include East Ayrshire, Inverclyde, Moray and Edinburgh, although it is only Edinburgh which has more than 10% of the overall count of Scotland's extremely socially flood-vulnerable neighbourhoods (after Glasgow's 42% contribution). At the other end of the spectrum, over 10% of the neighbourhoods in Renfrewshire and East Dunbartonshire are classed as having extremely low vulnerability with respect to floods even though it is North and South Lanarkshire which have the largest shares of these neighbourhoods in Scotland overall (see Table 12). Despite its relatively small overall mean socio-spatial vulnerability scores, Aberdeen City has the largest contrasts in its neighbourhoods: 7.1% are classed as having extremely high social flood vulnerability and 6.0% extremely low social flood vulnerability; the figures for heat are 9.0% and 7.5% respectively. North Lanarkshire also shows a reasonably large inequality in terms of its neighbourhoods (see Table 13).

After Glasgow the highest proportion of Scotland's most socially heat-vulnerable neighbourhoods is found in Edinburgh (13.6%) and no other UA has a contribution of more than 6%. Within UAs, Inverclyde, Dundee City, Edinburgh and West Dunbartonshire all have more than 10% of their neighbourhoods classed as extremely socially heat vulnerable. Only four UAs have no extremely socially flood-vulnerable neighbourhoods. Twice as many have no extremely socially vulnerable neighbourhoods in terms of heat. Moray has no extremely socially heat-vulnerable neighbourhoods despite there being nearly 14% with respect to floods, suggesting that this may be driven by insurance availability and local knowledge (which are not included in the socio-spatial heat index). This also underlines the importance of this layer for understanding what drives social vulnerability in one place compared to another. It should be noted that the insurance layer for Scotland is based on an imperfect historical flood event layer which does not record past events to an equal extent for all of Scotland. It is known that other areas have experienced past flood events and therefore are likely to have subsequent insurance access problems. However, the relevant data is not currently available in a suitable form in order for this to be adequately captured in the current analysis. Finally, it is useful to note that the Scottish Borders, Na H-Eileanan an Iar and Moray all have no neighbourhoods with very extreme socio-spatial heat vulnerability, despite Na H-Eileanan an Iar's score being slightly over the Scottish mean taken as a whole.

Socially vulnerable groups in Scotland

Socially flood vulnerable groups

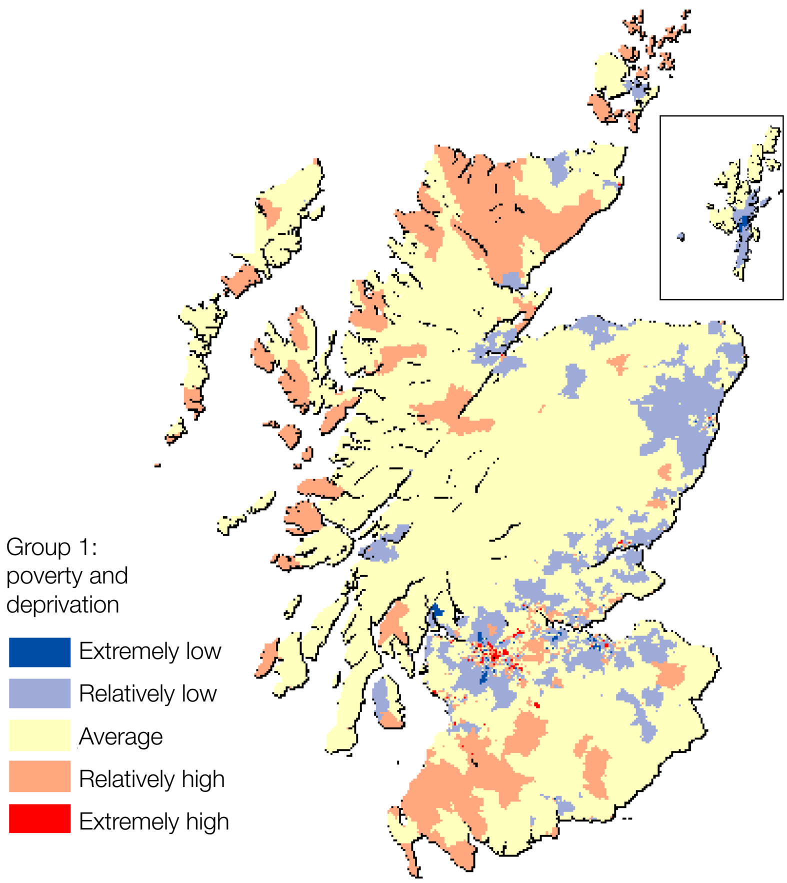
Scottish socially derived flood vulnerability is explained through the characteristics of five groups. **Group 1** is the most influential and there are very similar groups identified in the rest of the UK. It relates to existing *poverty and deprivation* and is very strongly correlated to the Scottish Index of Multiple Deprivation. The group brings together a number of sensitivity measures and makes a connection between neighbourhoods where proxy indicators suggest lower incomes, the potential for relatively poor social networks, relatively high burdens of caring responsibilities and difficulties accessing or using information about flood likelihood. The neighbourhoods scoring highly on socio-spatial flood vulnerability for all of these factors tend also to have reduced personal mobility through a relatively low rate of car/van ownership. The geography of the neighbourhoods associated with this group (see Figure 27) has both urban and rural characteristics, although the greatest extremes are associated with Scotland's urban zones. There are also obvious areas of relative wealth and advantage, which are predominantly associated with the rural hinterlands around Scotland's main cities.

Group 2 is very similar to *overseas enclaves* identified elsewhere, except in Scotland there is also an association with higher social vulnerability associated with *new arrivals* from within the UK too. On average the neighbourhoods identified as socially flood vulnerable in this group are linked to high proportions of: non-UK born (overseas and EU) people; some ethnic minority groups new to the immediate neighbourhood; and other households new to the immediate area. Neighbourhoods also tend to be characterised by higher tenure rates. Social vulnerability centres on the potential for a lack of local knowledge, possible language problems, a lack of ability to modify living environments and possible higher transience within affected communities. These factors and their implications are discussed in more detail earlier in the chapter.

Group 3 has similarities with Group 2 in Wales except for a stronger emphasis on *work and work-related transport*. In the case of Scotland there is no crime association. The composition of the indicators suggests that it is the more isolated rural communities in this group which have greater socially derived vulnerability. These are the neighbourhoods in the group where there is an association between larger proportions of people working away from home, higher distances to travel to work and higher mean working hours but also lower urban land cover and lower reliance on public transport for work-related travel. Workers within these communities may be slow to respond to flood events due to the chance of being a long way from home but on the other hand they are not so likely to be restricted to travelling by the public transport network.

Group 4 picks up the *age and household composition* association between higher proportions of older people and lower proportions of young children as seen elsewhere in the UK. The *elderly enclaves* identified through this group tend also to be connected with higher proportions of people with limiting long-term illnesses. The final group, **Group 5**, associates two indicators with the capacity to increase social flood vulnerability (through the likelihood of higher rates of single-person households and higher proportions of private renting). Although there is the potential for poorer social networks and a lack of control over personal environments, the group is also linked to higher proportions of above street-level accommodation. In the case of flooding, this offsets social vulnerability because of the likelihood of lower enhanced exposure.

Figure 27: Geography of the poverty and deprivation socially flood-vulnerable group in Scotland



Source: Boundary data: EDINA UKBORDERS, Crown copyright

Socially heat vulnerable groups

There are only four groups explaining socio-spatial heat vulnerability in Scotland and they have strong similarities to some of those identified elsewhere in the UK, despite the use of slightly different indicators.

Group 1 is primarily the same *poverty and deprivation* group which has been discussed previously. Since this group cross-cuts many areas of the UK and often both flood and heat contexts, it is highly likely that it represents a group at risk of harm from a whole range of external shocks including climate and non-climate related impacts. Climate-related socio-spatial vulnerability is therefore another form of deprivation facing this group.

Group 2 is the *overseas enclave* group, which in this case is also linked to relatively high educational attainment rates. Since local knowledge is not so important for heatwave preparedness, response and recovery as it is for flood, the identification of this group is linked more strongly to information use as a result of possible language issues. Further, links to tenure characteristics and the potential for relatively high proportions of single-person households suggests a lack of ability to adapt personal living spaces and the potential for members within the associated communities to be relatively isolated compared to the members of other communities in Scotland.

Group 3 is the *age and household composition* group, again linked to ill-health as was the case in the context of flood.

Group 4, *accessibility and enhanced exposure*, is the least influential of the four but is interesting to discuss since this specifically relates to the connection between rural isolation (which reduces adaptive capacity) and reduced exposure, on the one hand, and urban accessibility and increased exposure, on the other. Neighbourhoods with lower maximum elevations are associated with higher proximity to GP surgeries, lower distances to work and higher urban percentage cover. The fact that these groups of indicators act in opposition to one another may explain why the socio-spatial heat vulnerability map tends to highlight outliers in the other dimensions of social vulnerability, i.e. because the exposure dimension and ability to recover dimension tend to cancel one another out. Nevertheless, this will not happen everywhere.

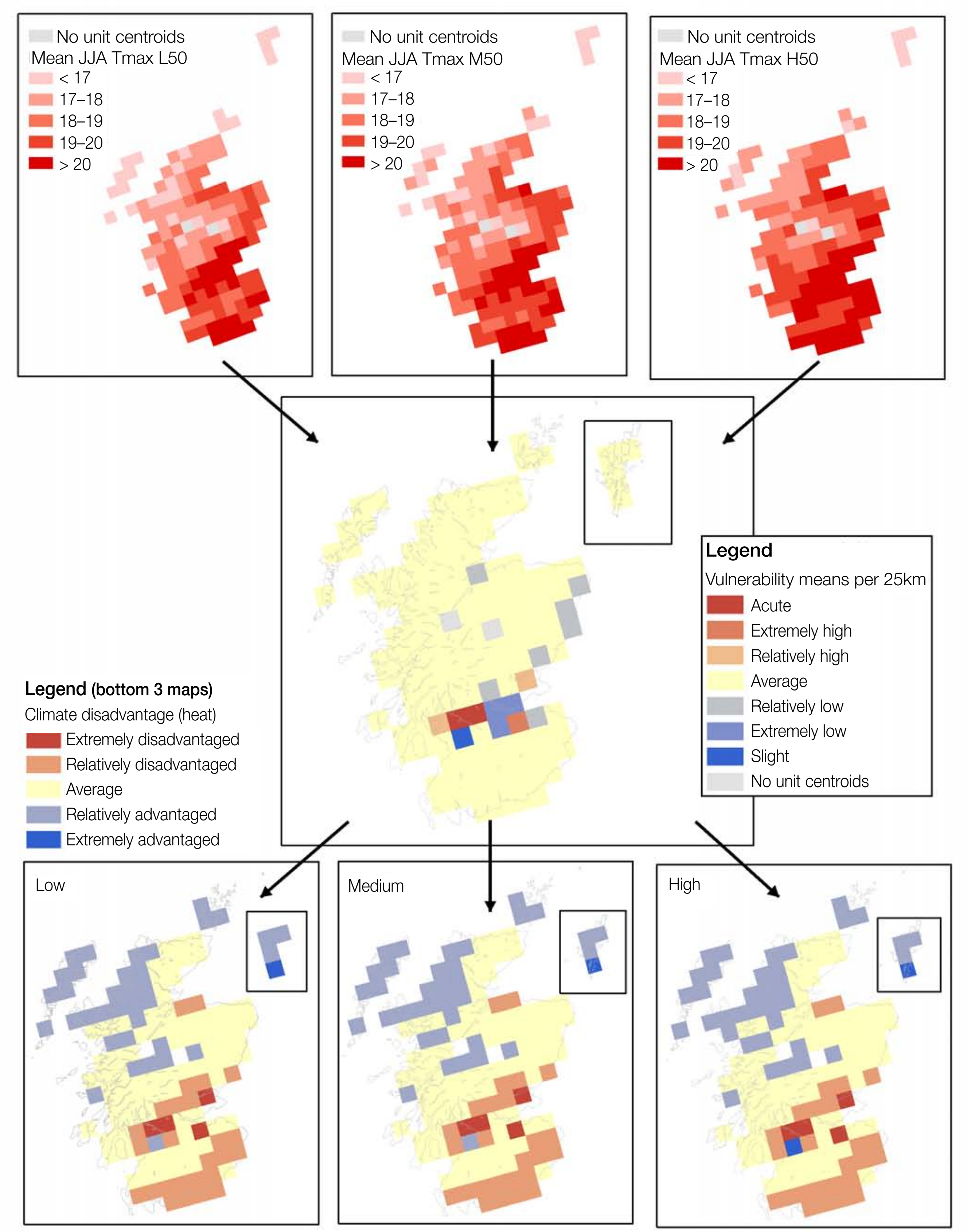
Relationships between socio-spatial vulnerability and climate disadvantage in Scotland

The sections below relate the largely hazard-independent socio-spatial vulnerability assessment results to the potential for hazard exposure in neighbourhoods in Scotland. Since no flood-zone data was available for Scotland, the analysis concentrates on disadvantage with respect to heat.

Heat disadvantage

Climate disadvantage in relation to heat has been assessed through the simple metrics of temperature patterns in mean summer maximum temperatures in the 2050s (see Figure 28). In Scotland, like in much of the rest of the UK, many of the most socially heat-vulnerable areas coincide with areas of relatively high temperatures. Areas to the north west tend to see climate offsetting heat vulnerability. Again, this is not necessarily indicative of future patterns of heatwaves, and differential patterns of existing biophysical adaptation should also be considered too, i.e. where those currently residing in warmer zones already have enhanced adaptation relative to those living in cooler environments.

Figure 28: Heat disadvantage in Scotland in the 2050s as a combination of neighbourhood-weighted socio-spatial heat vulnerability[16] and the geography of mean summer day maximum temperatures (°C)



Note: 'No unit centroids' refers to 25km cells which do not contain the centre points of any neighbourhoods. Also see Note 13. JJA refers to June, July, August. Tmax refers refers to maximum temperature.

Source: UKCP09 50th percentile estimates for the low (L50), medium (M50) and high (H50) emissions scenarios. UK Climate Projections 2009, Crown copyright

Case-study analyses and verification

Greater Manchester case study

A case-study analysis was carried out for Greater Manchester. Taken as a whole, Greater Manchester has a slightly higher than average socio-spatial vulnerability and a higher variability between neighbourhoods with respect to heat than is the case in the rest of England. Although Greater Manchester is fortunate in that it is less likely to see the extremes of temperature that may be expected in London, for example, it should be noted that people in the city are also less used to heat compared to those in the capital.

The aims of the case study work were:

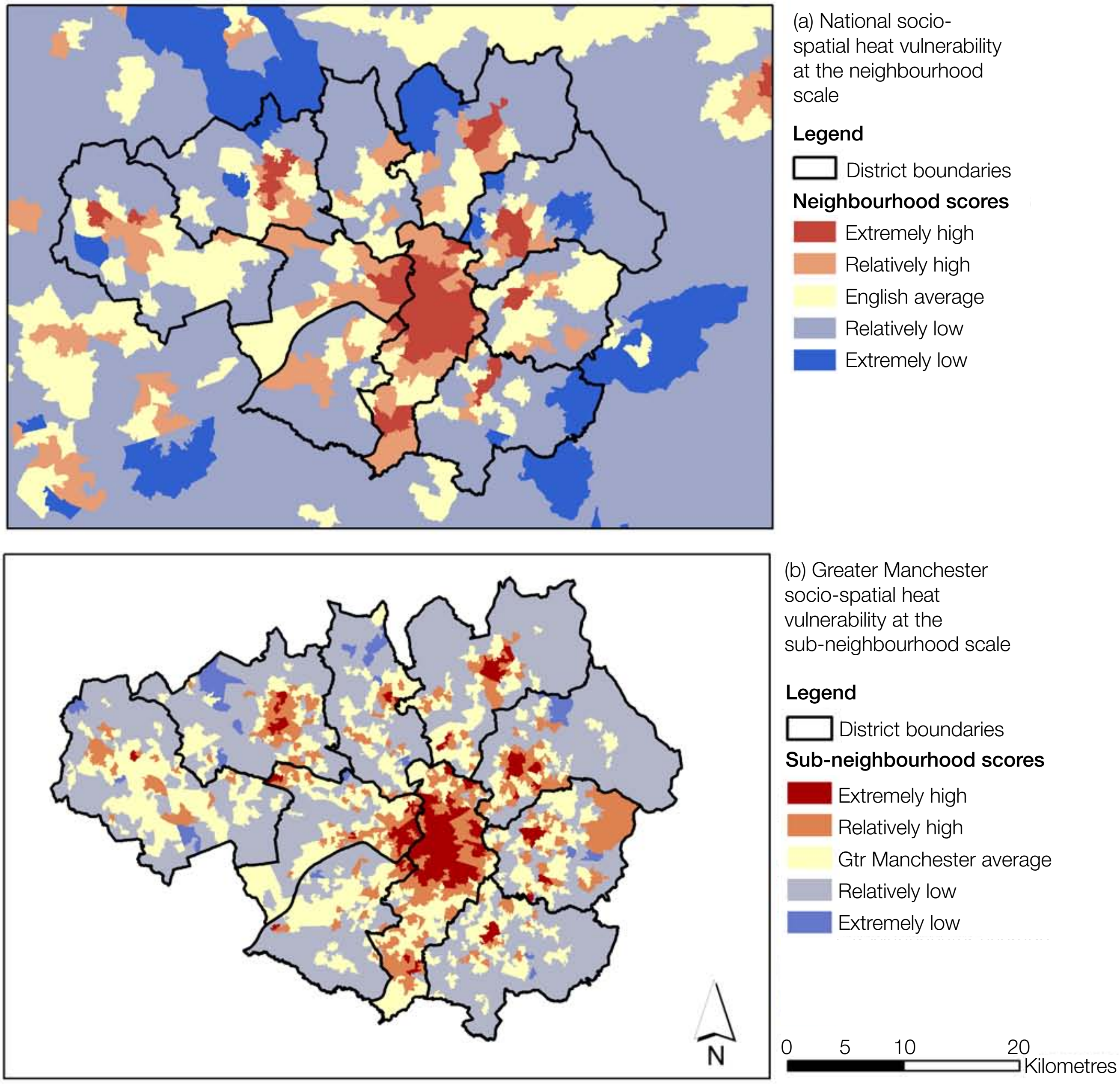
- to allow some exploration of potential effects of scale on the socio-spatial index results;
- to provide a means of ground-truthing the critical socially vulnerable locations results as recommended in the literature (e.g. Schmidtlein, *et al.*, 2008); and
- to demonstrate how the aggregate socio-spatial vulnerability scores for specific neighbourhoods might be linked to a locally relevant social vulnerability narrative which can support directed policy-making.

Some of this verification work was carried out independently while part was carried out through stakeholder interviews with representatives from two Greater Manchester local authorities (Wigan Metropolitan Borough Council and Salford City Council). Indicative results are presented for heat-related social vulnerability although the verification work itself covered both flood and heat.

To address the first aim, a set of indicators was developed at sub-neighbourhood[5] level and applied to Greater Manchester. Although efforts were made to fully represent all indicators used in the England index, not all were available at a finer spatial scale. Another problem in conducting a full comparison is that the generated results are produced relative to the Greater Manchester mean rather than the English mean. Thus the results are not perfectly comparable. Nevertheless, they do allow a broad cross-reference to be made between the two scales (see Figure 29). Visual comparison suggests that the patterns of socio-spatial vulnerability at both scales are very similar. Nevertheless, as expected, there are sub-neighbourhoods where the coarser English neighbourhood scale masks within-neighbourhood variability. Some good examples of this can be seen in Figure 29 in the southern part of Wigan (the westernmost district). This underlines the importance of multiple scales of investigation and the use of local knowledge. Nevertheless, the local stakeholders interviewed felt that even at the coarser neighbourhood scale the results of the work provided a good additional evidence base to support their adaptation activities (the interviews were conducted prior to the availability of the sub-neighbourhood results). It was also confirmed that the index provided additional information which was not otherwise readily available.

Interviews suggested that the Indices of Multiple Deprivation tend to be used as a measure of neighbourhood social vulnerability. While this captures important elements of what governs the potential for unequal impacts in terms of climate-related hazards, it does not provide a complete picture. The additional metrics to understand social vulnerability that were used in this study were felt to provide a richer picture, which would be helpful for supporting adaptation planning. Results have also been reviewed for elsewhere in England. For example, the results for Hampshire have been provisionally verified by a representative of Hampshire County Council and considered to be a useful addition to their climate change risk-assessment work.

Figure 29: Comparison of (a) neighbourhood and (b) sub-neighbourhood scale socially derived heat vulnerability in Greater Manchester



Source: Boundary data: EDINA UKBORDERS, Crown copyright

To demonstrate how this additional information can assist with understanding social vulnerabilities and possible responses, it is helpful to discuss the characteristics of a single neighbourhood in more detail. One of Salford's neighbourhoods is ranked within the top 1% of the most socially vulnerable in England with respect to heat and so it is useful to examine it for this purpose. There are several neighbourhoods in Salford which are also classed as extremely socially heat vulnerable, based on their scores relative to the English mean. While it is obvious that the selected case-study neighbourhood is within this group, it is not considered appropriate or necessary to name the specific area itself.

The case-study neighbourhood has above average scores in all of the dimensions of socio-spatial heat vulnerability considered in this work. It has a particularly high enhanced exposure score which contributes to the high overall score. This is because this neighbourhood has a disproportionate amount of high-rise accommodation compared to other neighbourhoods in England as a whole. The neighbourhood has 28% of households with a lowest floor level at fifth floor or higher, compared to just

1% for England as a whole. The wider implications are that many of the top-ranking socially heat-vulnerable neighbourhoods may similarly be associated with high-rise living. This is a fair reflection of an extremely important driver of differential impacts between communities, particularly where those communities are subject to barriers to adaptation. Another notable, and related, indicator in this group is the low proportion of garden space available. In the case-study neighbourhood there is 56% less private garden space than in an average English neighbourhood.

There are proportionally fewer children under four than the national mean and also fewer older people so the area does not have a highly sensitive population in terms of age. However, those in the area do tend to have a much higher likelihood of reporting a limiting long-term illness. Around 30% of all residents report a limiting long-term illness compared to 18% in the average English neighbourhood. This tendency for having poor health is therefore coupled with a lack of private outdoor space and high-rise living in this particular neighbourhood.

To understand further the extent of socio-spatial vulnerability, it is important to consider what adaptation resources, both tangible and more intangible, may be associated with the neighbourhood. The area has an above-average proportion of social tenants (11% compared to 6%) but a proportion of private renters which is just below the English mean. So although many residents may have some restrictions in adapting their personal environments, the local council could have a role to assist if appropriate resources were made available to them for this purpose. Indeed, this could be a very effective and efficient way of reaching the most highly sensitive within communities like this one.

Otherwise, another factor which would tend to restrict autonomous adaptation would also come into play – that of low income. In this particular community, people are not likely to have a large amount of disposable income once the basic necessities of their day-to-day lives have been covered. They live on very low average incomes compared to English neighbourhoods as a whole; after housing this is just £240 per week compared to £390 for the average English neighbourhood. These factors all suggest that there is potential for a lack of preparedness in this particular area and this therefore explains and justifies why it ranks so highly relative to English neighbourhoods as a whole.

The people in this neighbourhood are also challenged in terms of response. We have already seen the physical environment of their neighbourhood has the potential to enhance the effect of any heatwave event, but there are also social factors which inhibit adaptive capacity with respect to responding to heatwaves. To avoid heat stress it is important that people within a community with these characteristics know how to keep cool, that they are able to act on this knowledge and that they watch their old, young and ill neighbours, who are the most susceptible to being harmed by very high temperatures.

Looking at the evidence for this particular neighbourhood, there is the suggestion that wider community resilience has several challenges. A number of indicators suggest that social networks may not be as strong as elsewhere in the country. For example, there is a higher proportion of single-pensioner households (20% compared to 14%). Other potentially isolated groups are at higher than expected proportions too. The percentage of lone parents with dependent children is 9% (compared to 6% across the country as a whole). The area is also associated with general population loss on the one hand but a relatively high rate of overseas arrivals on the other. While the latter may have come from areas where they are personally used to high temperatures, the fact of their recent arrival may mean that they are less likely to be well integrated. The two factors together therefore suggest a level of community transience which could be an indicator of rather poor social networks.

While the area has a higher than average loss of business units (see Appendix I), it has a retail density which is around the English norm. It is therefore possible that agreements could be made with local businesses, which may offer a cool environment for some sensitive community members to use during a heatwave. Indeed, this could be achieved through using other public spaces for this purpose, such as libraries. This sort of strategy is used in cities across Europe where heatwave planning is particularly advanced, such as in Greece. Here there are agreements with hotels and other places with air conditioning to provide cool refuges for people within the community.

However, to make use of this sort of strategy, people need to feel secure in their communities in the first place. For this particular neighbourhood, the much higher crime rates compared to the rest of the country may make some feel more inclined to stay in the home. Given that many heatwave deaths are associated with night-time temperatures, this may also impact on people's capacity to act on advice to leave open windows. High-rise living may actually be a benefit in this context, although it does depend on the specific characteristics of the individual flats themselves how practical and effective cooling would be, or in fact whether this is as secure as would be expected. For those living in housing at street level, the crime context of this particular neighbourhood may very well be a restriction on the use of passive ventilation solutions during hot weather. Although this section has used only one example neighbourhood, it is important to note that similar stories could be told for other UK neighbourhoods based on the results of this study.

Impacts of weighting schemes on the results of the socio-spatial index

In order to explore the extent of potential sensitivity of the critical socially vulnerable location results to the weighting schemes used, two additional schemes were tested. The analysis was carried out for Scotland for the reasons outlined in Chapter 3, 'Socio-spatial heat vulnerability'. The first alternative scheme was based on equally weighting sensitivity, enhanced exposure and adaptive capacity and the second was developed from the weighting used in the 2009 Scottish Index of Multiple Deprivation (see Appendix VI). All of the broad domains could be mapped on to some component of social vulnerability considered in this work, although two additional categories were also created to include social networks and insurance availability. The additional categories were weighted to be equal to the mean weighting. The weightings of individual domains generated through this process were generally quite similar. However, given that domains have been combined in different ways, this is still considered a reasonable test of general sensitivity.

The results of applying these two alternative weighting schemes are presented in Appendix VI. Although the mapped outputs show some visual differences, the level of agreement between the identification of the top 10% most vulnerable and top 10% most resilient neighbourhoods was reasonably good (70–80%). This suggests that the socio-spatial index results are fairly insensitive to weighting in terms of identifying the inequalities in climate-related socio-spatial vulnerability. However, it is also true that all of the results are driven by a subset of the indicators used within the work.

Limitations of the empirical analysis and associated recommendations

This study is a first look at developing a socio-spatial index of climate-related vulnerability for England, Wales, Northern Ireland and Scotland. The introduction to Chapter 3 discussed the value of assessing socio-spatial vulnerability and made some important points about what can and cannot be drawn from an assessment like this one. At the end of Chapter 1 we noted a series of limitations and challenges raised by this study. Other caveats have also been emphasised at appropriate points in the text and these must be considered in any onward use of the results. Some further key issues are listed below.

In relation to the socio-spatial vulnerability index:

1 Indicators have been selected on the basis of an interpretation of the factors affecting social vulnerability, which have been identified in the existing literature. In some cases there is disagreement about whether factors act to enhance or reduce the potential for harm.

2 Factors may be difficult to represent as indicators. There is a general lack of suitable indicators at a fine geographical scale for some factors, such as social networks. There are other examples of factors which were difficult to represent, such as the availability of insurance. Here a proxy indicator has been

used; either historical flood events or significant (1-in-75-year) flood zones (see Appendix I). These provide only an impression of the factor which they are intending to represent. Further, a percentage cover analysis has been used here and this is limited as a means of representing relationships.[18] For example, a neighbourhood may have a large proportion of its land area regularly flooded, but this could be in an entirely unpopulated area. Results should therefore be locally verified and treated with caution.

Recommendation: A wider range of social indicators, explicitly geographical in nature, needs to be developed.

Recommendation: There is a need for a formal measure of insurance availability and affordability to be developed.

3 Selecting and interpreting indicators is inevitably contestable. For instance, where both flood zone and historical flood data were made available, the former has been used to represent local knowledge and the latter insurance availability. It could equally be argued that both represent a lack of insurance opportunity and that this is more important than the local knowledge associated with previous flooding in a locality. Indeed, this local knowledge, rather than acting to improve resilience, could be more indicative of people living in fear of the 'next' event (even though it may not occur in their lifetimes) and also those who may not have fully recovered from previous events.

4 In selecting indicators for the assessment of critical socially vulnerable locations, efforts have been made to try to avoid unintentional double-counting while also being sensitive to some of the subtleties of the factors identified from the literature. Inevitably this is an imperfect process. The socially vulnerable group analysis reduces some of the potential problems with indicator selection for future studies since it helps to highlight those which best explain the characteristics of all of the 80 or so indicators considered, as well as their internal associations. However, an indicator can only be extracted if it is already in the database and the analysis process itself is reliant on some assumptions that are themselves open to debate.

5 Evidence from the Scotland weightings tests suggests that the results of the socio-spatial index are reasonably insensitive to the weighting schemes used. However, it is still recognised that the weights used for the main analysis may not capture the true importance of different factors and each of the dimensions that the work considers.

Recommendation: Further work is required to better understand the relative importance of different factors, domains and dimensions in terms of heat and flood socio-spatial vulnerability. One central question is how the relative weighting should be determined. One possibility is to use expert groups. However, another is to combine expert weightings with citizen participation (Burgess, *et al.*, 2007; Davies, *et al.*, 2003; De Marchi, *et al.*, 2000; Stirling, 2008). Given the importance of voice and participation as a fertile functioning in addressing climate disadvantage, there is a strong case to be made for citizen engagement in the assessment of the different weights that should be placed on different factors.

6 The analysis of socially vulnerable groups is based on an analysis of variability within the indicator dataset. Implied associations between indicators have been interpreted according to what they may mean for social vulnerability and are in keeping with examples in the academic literature. However, it is important to appreciate that this is only an interpretation. It does not prove associations between facets of socio-spatial vulnerability, and alternative interpretations might be equally valid.

The size of units used in this study provides a broad picture of socio-spatial vulnerability. However, the size of units and their internal heterogeneity will mean not all socially vulnerable places will be identified. Although some units, such as Scotland's Data Zones, are constructed to be sensitive to 'natural' physical and social boundaries and are relatively small compared to those selected for England and Wales, it is still not possible to infer the broad characteristics of neighbourhoods to all individuals within them. This same point is therefore also true for the socially vulnerable group analysis. Local knowledge and very fine-scale assessments using quantitative and qualitative methods are therefore a vital complement to national-scale analyses (Schmidtlein, *et al.*, 2008).

Recommendation: There is a need for multiple-scale and multiple method analysis to link national studies to local contexts.

7 Much of the socio-economic data used in this study is drawn from the UK Census of Population 2001. Hence, it is 10 years old. It is inevitable that some places have changed their characteristics over this period. Where possible, indicators have been taken from a similar period to the UK Census and they may not necessarily represent the latest available data. Socially vulnerable places and groups may have changed over the intervening period.

Recommendation: This study should be updated with new indicator data developed from the UK Census of Population 2011.

In relation to assessing climate disadvantage:

8 Socio-spatial vulnerability results have been manipulated to a 25km grid in order to combine the results with climate metrics.[16] This introduces uncertainties since it involves modifying the geographies associated with the index data sources and results. Different geographies can be found in spatial data just through the effects of different zoning schemes and the use of different scales.[19]

9 The assessment of flood disadvantage has the same limitations identified under point 2 above. We cannot be sure that there is a match between the people in the vulnerable communities described and the flood-zone areas identified by the flood exposure indicators.

10 This study has not used a measure of future heatwave probability. This data can be created using the tools provided alongside the UKCP09 scenarios but is not made available in an easily accessible format for use in nationwide studies of this type. As an alternative, simple metrics of future heat hazard are used. It is recognised that they may not be representative of the geography of future heatwave probabilities across the UK. They are merely illustrative of the different pictures of relative climate disadvantage which may emerge and which are only a very small part of the full picture of climate change impacts in the country. Furthermore, temperatures are not the only climate determinant of heat stress.[20] The use of temperatures here is guided by the use of temperature thresholds for heatwave warning systems in the UK.

Recommendation: Pre-processed datasets of key 5km resolution UKCP09 (Weather Generator) outputs are made available.

Conclusions from the socio-spatial and climate disadvantage assessment work

Understanding the socio-spatial vulnerability of UK communities to climate-related hazards requires an understanding of their geography: the social, economic, environmental, physical and location characteristics which together define the extent to which they are likely to suffer disproportionate harm. To a greater or lesser extent, all of these elements are affected by socially related drivers.

The results of the socio-spatial index highlight where there are extremes in climate-related social vulnerability in the UK. Addressing these inequalities is a useful policy aim in its own right. However, the full potential of a climate-related social vulnerability assessment can only be realised through considering the results alongside measures of hazard-exposure. It is only where neighbourhoods with high socially derived vulnerability have the potential to come into contact with hazards of a sufficiently large magnitude that climate disadvantage will occur. It is in climate-disadvantaged areas where adaptation efforts must be prioritised. Therefore the socio-spatial vulnerability index findings have been compared to some measures of potential hazard-exposure in relation to floods and high temperatures in the UK. The results for each country are not directly comparable due to differences in scales and indicator availability but there are commonalities that can still be seen.

In terms of critical socially vulnerable locations, our results confirm that most, but not all, extremely socially vulnerable neighbourhoods are in the UK's large urban centres. In Northern Ireland, for example, almost all of the top 10% most extremely socially vulnerable neighbourhoods with respect to heat and floods have their centres in urban zones. The same is true for England. For Wales there is also a strong urban component to socially derived vulnerability with two-thirds of neighbourhoods being urban (and 85% close to urban areas). In addition to this association with urban areas, there is also a notable coastal component to the geography of UK socio-spatial vulnerability. The social vulnerability of coastal neighbourhoods is most marked in Wales, where over half of the most socially vulnerable top 10% of neighbourhoods are within 1km of the coast. This coastal effect is less marked in Northern Ireland.

Many neighbourhoods have joint climate-related social vulnerability in relation to heat and flood. For the UK this is about two-thirds of the most extremely socially vulnerable neighbourhoods. There are also some joint patterns in neighbourhoods with extremely low climate-related social vulnerability. In Wales, for example, 80% of extremely low-scoring neighbourhoods do so in the contexts of both flood and heat.

London neighbourhoods have the highest mean socio-spatial heat vulnerability scores in England. Relative to the rest of England, almost 25% of all London neighbourhoods are highly socially vulnerable with respect to heat. Although Londoners are generally more used to high temperatures than inhabitants of other UK urban areas, heatwave events are likely to be more extreme given the position of the capital at the warmer end of the UK climate gradient. A similar picture emerges in Northern Ireland and Wales, with Belfast and Cardiff ranking at the top for mean socio-spatial heat vulnerability scores. Again, this is before the number of neighbourhoods is considered. Once numbers of neighbourhoods are included as a means of weighting the results by population, then the findings become unequivocal. In Scotland, Glasgow is markedly more socially vulnerable with respect to heat compared to any other part of Scotland.

The picture for the most socially flood-vulnerable locations is more complex. While many of the same areas exhibit extreme socially derived flood and heat vulnerability, this is not true everywhere. In England, for example, while London has the highest mean socio-spatial flood vulnerability score, London sees fewer of its neighbourhoods in the top and bottom 10% of English scores compared to other regions in England. The North West and Yorkshire and The Humber regions have the highest proportions of extremely socially flood-vulnerable neighbourhoods. They also have the highest proportions of the English national total. The lowest social vulnerability with respect to flood is seen in the South East and the East of England. Thus there is a distinct North–South divide in terms of social vulnerability in the context of flooding. For heat, if London is discounted this North–South divide also exists. However, in the case of heat, climate itself acts to redress some of the balance.

The North–South divide in English socio-spatial flood vulnerability is also seen to some extent with patterns of flood disadvantage. The Yorkshire and The Humber region is estimated to have the highest average flood disadvantage of all English regions and also the largest proportion of its neighbourhoods classed as being extremely flood disadvantaged. The East Midlands shows a similar pattern. The North West, North East and London all have average flood disadvantage scores which are above the English mean. However, considering average regional values alone overlooks the inequalities within regions. For example, although neighbourhoods in the South East are generally advantaged, 10% of all neighbourhoods in the region are classed as extremely flood disadvantaged.

For Wales, a number of local authorities score highly for social flood vulnerability and for flood exposure. On the other hand a number of local authorities rank highly for flood exposure but not for flood vulnerability and therefore they have a lower overall flood disadvantage. The results for Wales demonstrate how and why national and local adaptation planning on the basis of analysing flood exposure alone will miss some important aspects of climate disadvantage.

The results of the study do not suggest a radically different geography from those produced by other organisations (such as by the Environment Agency Wales). However, there are subtle but important differences which need to be taken into account in order to ensure that limited flood protection and adaptation resources are fairly allocated. This allocation can only be fair if it recognises that there are some who face the multiple disadvantages of being poor, old or ill and living in homes which might be uninsurable, mal-adapted and impossible to sell. While this message is important, it does not mean that there are no critical socially vulnerable locations or people within local authorities with low mean socio-spatial vulnerability scores. Indeed, it is recommended that this work be seen as a starting point through which some of the more subtle determinants of climate disadvantage can be assessed. Ultimately, this assessment will need to bring in both local knowledge and finer-scale analyses.

To assist with this process, we have also analysed which indicators appear to be the strongest determinants of spatial patterns and have interpreted the findings in terms of key socially vulnerable groups. Understanding the characteristics of these groups helps to inform the process of adaptation planning and is an important complement to the critical socially vulnerable locations analysis. Although the nature of the groups varies, there are a number of socially vulnerable groups which emerge as key determinants of spatial patterns. Many of these are held in common across England, Wales, Scotland and Northern Ireland. In the UK as a whole, the following socially vulnerable groups appear to have a major role:

- **Poverty and deprivation:** this varies from a full range of indicators associated with multiple deprivation in some places (e.g. Scotland), where the correlation can be >90% with the Index of Multiple Deprivation, to subsets in others (e.g. Northern Ireland) where the correlation is slightly lower.

- **New residents:** a distinct group was found relating to people new to neighbourhoods. In England and Wales this tended to be mainly associated with people from overseas but in Scotland and Northern Ireland this tended to include all new arrivals. Lack of local knowledge, the potential for language difficulties and community transience all add to social vulnerability.

- **Mobility and access:** across the UK there is evidence for distinct groupings associated with relative accessibility. Sometimes this was related to other factors such as enhanced exposure as in Scotland and/or employment, as in Scotland and Wales. In England, low medical service accessibility emerged as a group for heat-related social vulnerability, strongly linked to the ability to respond to heatwaves.

- **Sensitivity:** a number of the determinants of sensitivity were grouped, allowing for the identification of elderly enclaves or areas with high proportions of young children. In Wales, age and ill-heath were linked as were areas associated with increasing elderly populations and care establishments. Age and health was also a dimension of vulnerability highlighted for Scotland. In Scotland and Northern Ireland, age and household composition were linked. Aspects of sensitivity were also linked with mobility in some cases, e.g. in England in the context of flood.

- **Enhanced exposure:** although exposure indicators were sometimes linked with social indicators, there were some examples where one or more specific exposure indicators were grouped. In Northern Ireland, the proportion of residents in high-rises was identified as a factor in its own right.

Interview evidence from three authorities suggests that the findings have a role to play in helping to develop climate adaptation plans in the UK. It also suggests that the study works well as a proof of concept; it provides evidence to back up plans and policy development and it also adds new information about facets of social vulnerability which link people to places.

4 Key messages and recommendations

This research has developed an integrated framework for understanding and assessing the ways in which climate-related social vulnerability is distributed across different groups and individuals in the UK. The new structure helps to underpin the process of developing just adaptation responses through its use of a more sophisticated understanding of climate-related social vulnerability and its distribution. The results themselves have been summarised in Chapter 3, 'Conclusions from the socio-spatial and climate disadvantage assessment work'. The main focus of Chapter 4 is on distilling key messages and recommending associated policy responses. The chapter also includes a set of recommendations for future research.

Climate vulnerability and climate disadvantage

Key message: Many dimensions of well-being are not adequately captured by existing approaches to climate change adaptation policy

Measuring climate disadvantage is a question of measuring how two sets of factors come together: (a) the likelihood and degree of exposure to a hazard and (b) individual or group vulnerability with regards to such hazards. How disadvantaged an individual or group will be to a climate event will be a function of their degree of exposure to the event and the extent of their vulnerability. Vulnerability is a matter of how the external event converts into losses in well-being. An individual or group is of greater vulnerability if they are less able to respond to stresses placed on well-being. Adaptation policy needs to address all the significant dimensions of well-being that are made insecure by climate-related hazards.

Conceptualising and measuring vulnerability requires a full account of the dimensions of well-being that are made insecure by climate change and of the personal, environmental and social factors that are involved in the conversion of climate-related events into losses in well-being. Traditional resource-based measures of well-being used by economists, for example, in terms of loss of income or property values, are not sufficient to capture the losses involved. Resources are a means to an end, and they convert differentially into changes in well-being. Subjective welfare approaches to well-being conceive of well-being in terms of happiness understood as a psychological state (see Box 3). However these are not well-suited to measuring inequalities. Since psychological states tend to adapt to adverse situations, subjective welfare measures are liable to underestimate the welfare-losses of those who are most deprived. A capabilities approach (see Box 3) to well-being is better able than others to include the different dimensions of well-being at stake in heatwaves and flooding and to capture the inequalities and injustices in climate impacts.

According to this approach, well-being is defined in terms of opportunities (capabilities) to achieve the valuable things a person can do or be (functionings). Typical functionings might include being housed, being healthy, being in control of one's own life, having close personal relationships, having good friends and neighbours, being mobile and having self-respect. Capabilities are the opportunities an individual has to achieve such functionings. However, while such opportunities are important, much adaptation policy needs to focus on the functionings a person actually achieves rather than opportunities. Capabilities are more difficult to measure than functionings – it is harder to measure opportunities than achievements. Moreover, some central functionings such as achieved literacy, social networks and secure housing are a condition of exercising further opportunities.

Box 3: Well-being, vulnerability and climate disadvantage – key terms

Resource-metric: Losses and gains in well-being measured in terms of losses and gains of resources such as income or property values.

Subjective welfare: Well-being conceived in terms of psychological states, such as feelings of happiness.

Capabilities and functionings: Well-being characterised in terms of capabilities to achieve central human functionings:

- functionings: the valuable states and activities a person can be in or do, e.g. being healthy, being housed, having close personal relationships;
- capabilities: freedoms or opportunities to achieve particular functionings;
- achieved functionings: the valuable states and activities that a person actually realises.

Vulnerability: Vulnerability of an individual or group is characterised by the degree to which an external event converts into losses in their well-being.

Conversion factors: The personal, environmental and social factors that determine how positive or negative events are converted into gains and losses in well-being:

- personal: features of the individual such as disability, age and health that affect the way in which resources and hazards produce different effects on well-being;
- environmental: features of the physical environment such as the availability of green space, quality of housing stock, elevation of buildings and access to public space that affect the way in which resources and hazards produce different welfare effects on well-being;
- social: features of the social and institutional context and situation such as the strength of social networks, the cohesion of neighbourhoods, the institutional regimes in nursing homes, and levels of inequality and income, which affect the way in which resources and hazards produce different welfare effects on well-being.

Socio-spatial vulnerability: Socio-spatial vulnerability brings in aspects of place and time with personal, social and environmental factors resulting in the geographical expression of the degree to which an external event has the potential to convert into well-being losses. This is considered from the perspective of social and socially related factors in five dimensions: sensitivity; enhanced exposure; ability to prepare; ability to respond and ability to recover.

Climate disadvantage: Climate disadvantage is a function of (a) the likelihood and degree of exposure to a hazard and (b) individual or group vulnerability with regards to such hazards. It can be estimated and mapped through the combination of representations of hazard-exposure and representations of socio-spatial vulnerability.

One virtue of the capabilities approach is that it is more inclusive of the full range of losses in well-being incurred by climate-related events. Measures of the welfare impacts of climate events such as flooding and heatwaves tend to focus on loss of life, damage to physical health and the loss of income and property. While these are important, a focus on these alone seriously underestimates the losses in well-being involved. Impacts of floods include, for example, living in temporary accommodation, the disruption of children's education, the irreplaceable loss of memorabilia and the loss of control of daily routines. These do not just matter for their impacts on health and livelihood. They involve important losses in central functionings.

An increased likelihood of flood exposure in itself carries with it the potential for losses in well-being over and above the direct consequences of the particular event itself. It makes individual functionings significantly insecure, and this insecurity can undermine well-being in a variety of ways. It can lead to a loss of the ability to plan for and take control of future significant life events. In a risk-differentiated insurance regime of the kind that exists in the UK, a household which has already been affected by a flood, or which is estimated to be at high likelihood of flooding in the future, has more difficulty in accessing insurance either through increased premiums and excesses or insurance refusal.

Recommendations:

- **Adaptation policy at both the national and local level needs to address the full range of losses in well-being that are consequent on flooding and heatwave events.** While health effects, income losses and the loss of property values are all important, policy needs to address wider losses in functionings. One considerable source of stress from floods lies in the length of time people are placed in temporary accommodation and the stress and loss of daily routines that this entails. Policy needs to address the more timely restoration of homes after flooding and better provision of social networks of support while individuals are displaced.

- **Adaptation policy needs to address not only the direct impacts of flood and heat, but also losses in well-being that are a consequence of the insecurity which results from the increased likelihood of future flood and heat events.**

- **In the context of the risk-differentiated insurance regime in the UK, the loss of insurance and prohibitively high insurance premiums and excesses are a particularly important source of insecurity for those threatened by floods.** Policy on insurance has particular urgency given the expiry of the current agreement between the government and insurance industry in 2013. The possible future agreements are currently under discussion. There are two broad models for insurance: a market-based risk-differentiated model that is advocated by many in the insurance industry (ABI, 2011); or a more solidaristic pooled insurance model advocated by some flood action groups (Morpeth Group, 2010). In terms of social justice, there is a strong case for a shift to a more solidaristic scheme of insurance that protects those who are more disadvantaged (O'Neill and O'Neill, forthcoming).

Key message: The social dimensions of vulnerability to climate change have not been sufficiently recognised in adaptation policy

A wide range of personal, environmental and social factors is involved in the conversion of climate events into losses in well-being. Many social policies that are neither specifically concerned with climate change nor traditionally included in adaptation responses are of real importance in addressing the social factors converting climate-related events into welfare outcomes.

Vulnerability is a matter of how the external weather event converts into welfare outcomes. An individual or group has greater vulnerability if they are less able to respond to stresses placed on well-being. Adaptation policy needs to address the full range of personal, environmental and social factors involved in the conversion of hazards into welfare losses.

Accounts of vulnerability need to be rich in the variety of personal, environmental and social factors involved in the conversion of external stresses into welfare impacts. With respect to both heat and flood, personal conversion factors will include biophysical sensitivities associated with age and health. Environmental factors include the physical attributes of the neighbourhood, such as the amount of green space, and characteristics of the housing, such as the elevations of residential buildings. Specifically social conversion factors will include the income inequalities, the existence of social networks and the social characteristics of neighbourhoods. In the case of heatwaves, typical social factors include: social isolation; the loss of public spaces in declining neighbourhoods; fear of crime which leaves the old and others with personal vulnerabilities unwilling to leave their homes or open their windows; inflexible institutional regimes and the loss of independence in nursing homes. A variety of social factors differentially affects the capacity of households to prepare for, respond to and recover from flooding. Low-income households are less able to take measures to make their property resilient to flooding and take out insurance against flood damage. Social networks affect the ability of residents to respond to flooding: for example, through providing social supports and a response network, and by improving local knowledge bases.

Some functionings, such as health, social ties and the ability to control important aspects of one's environment, also appear in lists of conversion factors from external events to welfare losses. They matter not only in themselves but also because they support the realisation of other significant dimensions of well-being. They are fertile functionings and their loss is a corrosive disadvantage (Wolff and De Shalit, 2007). One important fertile functioning is participation in decisions that will affect one's life.

Some vulnerabilities are hazard specific. However, many are not. Social isolation, low income, the absence of voice and lack of insurance will render individuals vulnerable not just to climate events such as heatwave and floods, but also to a variety of other external stresses. Events such as heatwaves and floods often reveal wider uneven patterns of distribution of vulnerability that are pervasive disadvantages.

Recommendations:

- **Climate adaptation policy needs to be understood much more broadly than is often supposed.** Adaptation policy has often focused on features of the physical environment. It tends to include measures associated with physical infrastructure and, more recently, a range of so-called 'soft engineering' responses, which together address patterns of drainage, halting the increase in pavement and asphalt in the urban environment, the development of green space, improving the design and resilience of housing and the provision of floodgates. These are all important measures, particularly for reducing hazard likelihood and enhanced exposure. Personal factors have also been important in planning adaptation responses: the identification of those parts of the population that are particularly sensitive to heatwaves and flooding – the old, the young and those with health problems – is of particular importance in planning responses to such events. However, adaptation policy should also more clearly address social factors which are less often invoked in discussion of climate policy although they are invoked in other areas of social policy.

- **Many social policies that are neither specifically concerned with climate change nor traditionally included in adaptation responses are of real importance in addressing the social factors converting climate-related events into welfare outcomes.** Examples of policies that address the social dimension of climate-related vulnerabilities could include the following:

– addressing institutional routines and habits of places such as nursing homes that care for those with personal vulnerabilities;
– maintaining and improving social care for the elderly in their homes;
– the provision of more solidaristic pooled insurance for flood that protects those who are more disadvantaged;
– reversing the decline of neighbourhoods and the rise of the fear of crime;
– the sustenance of public spaces such as post offices and libraries in which members of the local community can meet and which might act as safe and cool spaces during a heatwave;
– making other spaces, such as schools and local businesses, available to the public;
– fostering of community support groups;
– fostering greater engagement of local communities in decision making about responses to flooding;
– reversing increasing income inequalities.

Adaptation policy should particularly foster fertile functionings such as being in effective social networks and being able to participate in public decision making, since these are not only important dimensions of well-being in themselves but are also important in supporting other dimensions of well-being.

Addressing current socio-spatial vulnerability in the UK: evidence from empirical assessment

Key message: There are uneven geographical distributions in climate-related social vulnerability and climate disadvantage in the UK

The research has shown that there are distinct geographies to the distributions of the most and least socially vulnerable to climate-related hazards. These are summarised in Chapter 3, 'Conclusions from the socio-spatial and climate disadvantage assessment work' and must be considered alongside the list of limitations in Chapter 3, 'Limitations of the empirical analysis and associated recommendations'. Most critically socially vulnerable locations are associated with urban areas and many with large urban areas. Thus London, Cardiff, Belfast and Glasgow all score very highly for average socially derived climate vulnerability. In many cases there is also a notable coastal component to extreme socio-spatial vulnerability; for example, this is quite marked in Wales.

There can be considerable inequalities in socio-spatial vulnerability within UK administrative areas and this is seen nationally, regionally and locally. An urban-rural contrast occurs in many parts of the UK, with the rural hinterlands of larger urban areas tending to show the least social vulnerability. There is a distinct North–South divide in terms of socio-spatial flood vulnerability in England. If London is discounted, this North–South divide also exists with respect to heat. However, in the case of heat, climate itself tends to redress some of the balance.

Comparing maps of socio-spatial flood vulnerability with maps of potential flood exposure allows an assessment of how far social flood vulnerability translates into flood disadvantage. In Wales, for example, the results show that although local authorities such as Merthyr Tydfil score very highly for social flood vulnerability this is offset by a lower potential for moderate and significant flood exposure compared to elsewhere in Wales. Other local authorities, such as Newport, score highly for social flood vulnerability and flood exposure. The North–South divide in English socio-spatial flood vulnerability is also seen to some extent with patterns of flood disadvantage. The Yorkshire and The Humber region is estimated to have the highest average flood disadvantage of all English regions and also the largest proportion of its neighbourhoods classed as being extremely flood disadvantaged. The East Midlands shows a similar pattern. The North West, North East and London all have general flood disadvantage since neighbourhoods tend to have scores which are above the English mean. Elsewhere there may be no general regional flood disadvantage but this masks some important extremes. For example, the South East has more than 10% of its neighbourhoods classed as extremely flood disadvantaged.

Recommendations:

- **Adaptation strategies and measures need to target specific places.** Adaptation planning needs to have a strong spatial component in order to help to build resilience in the neighbourhoods and communities where it is currently lacking. National policy can help to frame responses in urban and coastal areas but local authorities will have an important role in targeting neighbourhoods within these zones. In targeting responses, it is important not to miss zones of extreme socio-spatial vulnerability and climate disadvantage associated with inland and rural areas.

- **Socio-spatial vulnerability needs to be considered alongside measures of hazard exposure.** In the specific context of preparing for climate change, the socio-spatial vulnerability results in this research need to be combined with measures of hazard-exposure in order to effectively target resources to the most needy. Much of the research effort in this project has been centred on constructing the socio-spatial index but this is only part of the picture. Although illustrative data of hazard (flood and heat exposure) has been used, decision makers using the evidence in this report should refer to additional sources of data concerning flood and heatwave likelihood. It is particularly important that decision makers in Scotland and Northern Ireland access appropriate flood exposure data in further interpreting the reported results, given the lack of any flood exposure data being made available for this study.

Key message: Uneven geographical distributions of socio-spatial vulnerability are driven by variations in its five dimensions of socio-spatial vulnerability

Inequalities in social vulnerability between neighbourhoods have multiple causality. The uneven geographical distributions found in the socio-spatial index results are driven by diverse combinations of indicators which represent five different dimensions of socio-spatial vulnerability. The relative significance of individual indicators varies from place to place and community to community. Assessing the five dimensions of socio-spatial vulnerability is important for understanding and targeting all of the sets of personal, environmental and social conversion factors which are associated with turning exposure to a hazard into health and well-being outcomes. Therefore policy must also deal with: sensitivity (age and health); enhanced exposure (home and neighbourhood environments) and adaptive capacity (specifically tackling differences in abilities to prepare; abilities to respond and abilities to recover).

Recommendation:

- **Adaptation strategies and measures need to be informed by multi-dimensional assessments of social vulnerability.** The importance of appreciating the full landscape of socio-spatial vulnerability factors can be seen through the example of preparing for heatwave events. To some extent sensitive people are already well targeted, e.g. through health-based measures such as the DoH's Heat Health Watch in England and Wales. Sensitivity maps help to show where there are higher concentrations of sensitive people and therefore where emergency planning and information provisions might be particularly directed. However, it is only through superimposing the remaining dimensions on to the distribution of sensitive populations that the additional challenges facing some can be fully appreciated and tackled by appropriate agencies. For example, enhanced exposure maps show where the built fabric of areas amplifies hazard-drivers or where this is less of an issue. Aspects of adaptive capacity also have different implications for policy response; these must be explored in order to capture all of the elements of the process through which hazards can lead to long-term impacts. For example, adaptation policy needs to address issues associated with the lack of social networks, poor mobility or remoteness from medical services.

Key message: The existence of distinct socially vulnerable groups explains uneven geographical patterns

Indices are important in order to assess the full picture of relative socio-spatial vulnerability in its five dimensions. Nevertheless, the geography of social vulnerability in England, Wales, Scotland and Northern Ireland can in part be explained through a smaller number of indicator subsets. These can be related to discrete socially vulnerable groups with their own distinct geographical patterns. Each group is open to interpretation in a social vulnerability context but they can still help to identify which particular characteristics tend to be associated with one another and the neighbourhoods in which these connections occur. It provides a basis to navigate the complexities of addressing vulnerabilities and a further means to target action.

The exact composition of indicator subsets often varies but a number of cross-cutting themes are held in common across the UK. Themes associated with key socially vulnerable groups are given below together with recommendations for possible responses.

Poverty and deprivation

Existing poverty and deprivation was a recurrent group associated with heightened socially derived climate vulnerability. This group was found to be well represented by existing social deprivation indices. Policies which are already in place for tacking social deprivation will also improve social vulnerability but there may be further opportunities for mainstreaming climate adaptation activities through existing frameworks.

Recommendations:

- **Benefits can be gained from mainstreaming climate adaptation measures and messages into the activities of agencies working to reduce social deprivation.** Some of the most extremely socially vulnerable people and places are already subject to forms of support through care systems, social services and local authority housing, which should facilitate the dissemination of appropriate additional advice and resources. The use of familiar or trusted support mechanisms to deliver new messages may help with the acceptability of adaptation measures and the willingness to engage. However, additional resources will need to be available so that this does not become a burden for existing service-providers.

- **Some adaptations can be facilitated by adaptations to social housing.** Although social renting may reduce autonomous adaptation by individuals, it means that local authorities may be able to offset some of the harm for the most vulnerable in the communities by assisting in the process of adapting homes in order to lower the impacts of future flood events. Flood proofing of social housing may be a good long-term option for some vulnerable groups but there is evidence that measures such as raising plug sockets can also be unpopular (Salford County Council, 2011). Another concern is that wide-scale retrofitting is difficult and expensive although flood resilience measures could be considered as part of regular maintenance activities (SCC, 2011). While wide-scale retrofitting of technical solutions may be impractical, even simple messages about the safe storage of personal memorabilia would mean that the impacts of floods could be far less devastating.

- **Social deprivation indices are useful indicators for some aspects of socio-spatial vulnerability.** However, reliance on social deprivation indices alone will miss other important groups who require particular support. Further, they do not always include measures which pick up on some of the themes identified in this report. For example, the measures in the living environments domain of the English indices of social deprivation could be extended to include measures of private and public green space.

New residents

A set of neighbourhoods was identified where communities are characterised as having relatively high levels of new arrivals. It is important to identify this group from the perspective of climate adaptation as they may potentially lack local knowledge: for example, about past flooding and the likelihood for future flooding. In some areas of the UK there was a link with private renting and single-person households in this group. Therefore, where information is only periodically provided to householders it is possible for some to be excluded and for community networks to be relatively poor. Where new arrivals are from overseas, there is also the potential for language barriers to affect the dissemination of information. Levels of transience and associated neighbourhood characteristics are likely to be most important in the context of flood.

Recommendations:

- **Information provision and the process of raising community awareness needs to be sensitive to the migration characteristics of neighbourhoods.** Information provision can be less frequent in areas with low population turnovers and good community links but it needs to be more frequent in areas with poor social networks and high turnovers.

- **Information provision needs to be tailored to communities.** This might include provision in other languages. Where flood likelihood is high but where there has been no recent event, ways of remembering and recording past events could help foster intergenerational flood adaptation.

- **Information provision needs to be delivered in a range of different ways.** For example, renters in the private sector could have information provided as part of the process of completing tenancy agreements.

Mobility and access

Ability to respond to and recover from events is a function of personal mobility (such as access to private transport) and the general accessibility of services (such as distances to the nearest GP or hospital in terms of heat stress recovery). Indicators in this group are sometimes combined with other characteristics, such as employment, giving some variations in group compositions across the UK and sometimes rather complex messages about patterns of associated social vulnerability. The use of some common accessibility indicators means that there will be some representation of these groups through social deprivation indices, e.g. the barriers to service access domain in the English deprivation index.

Recommendation:

- **Improving mobility and service accessibility can be targeted to selected communities.** Transport and accessibility are important aspects of emergency planning and these might usefully involve existing community groups. Further they could also help with the development of social networking during periods of crisis. Transport planners and deliverers could also usefully prioritise infrastructure protection in areas with poor access and mobility characteristics. Measures which assist those with care responsibilities as well as sensitive groups directly have the greatest potential for improving response and recovery.

Sensitivity

Elderly enclaves and areas with high proportions of young children tend to be identified as having a distinct geography. Again, there can be links to other indicators, For example, in Wales and Scotland old age and ill-heath are linked, as are age and household composition in Scotland and Northern Ireland. In England young families on low incomes are highlighted as a discrete group. Issues and measures associated with sensitive groups have already been touched on in previous recommendations. Knowledge about the locations of concentrations of sensitive groups, particularly where these are associated with other social vulnerability enhancing factors, helps in targeting community-specific measures.

Recommendation:

- **Sensitive groups, particularly where associated with other drivers of socio-spatial vulnerability, merit tailored policy responses.** For example, the elderly may benefit from measures aimed at securing and enhancing social networks, establishing cool refuges in public places (such as libraries, schools and post offices) and negotiated agreements for public use of air-conditioned environments with local businesses (such as hotels and shops, as is already done in some southern European countries). Measures which improve security and the sense of security in local communities during the day and in homes during the night will also help in some cases. Measures centred on improving neighbourhood security will also help wider populations in the context of flood, since householders may feel more able to employ floodgates when away from home. Poorer households with young families require additional resources in order to assist in preparing for potential future events and in the event of exposure will also need additional support for response and recovery compared with other households.

Enhanced exposure

Groups of indicators associated with environmental conversion factors emerged for some areas and were sometimes linked to social indicators. In Northern Ireland the proportion of 5th floor or above households was shown as a distinct measure of socio-spatial heat vulnerability in its own right. Some of the issues associated with enhanced exposure were touched on in previous recommendations. There is a range of measures which can be targeted at improving neighbourhood environments from the perspective of climate adaptation.

Recommendations:

- **Building adaptations should be prioritised for highly sensitive residents.** For example, the provision of low-cost artificial cooling could be justified for the most sensitive groups living in high-rise accommodation, even though this is an adaptation measure not to be encouraged for the wider population, given its negative role for climate mitigation.

- **There is a need to increase public and private green space in urban areas, particularly where communities have low mobility.** Green space has benefits for mitigating high temperatures and reducing run-off as well as a range of other benefits for well-being.

Key message: There is evidence of joint climate-related social vulnerabilities in the UK

Many neighbourhoods have joint social vulnerabilities in relation to heat and flood and this is seen in terms of the highest- and lowest-scoring neighbourhoods. For the UK this ranges from about 60% to two-thirds of the most extremely socially vulnerable neighbourhoods. There are also some joint patterns in neighbourhoods with extremely low climate-related social vulnerability too. In Wales, for example, 80% of extremely low-scoring neighbourhoods do so in the contexts of both flood and heat. This may be more widely indicative of the potential for uneven patterns of harm in the event of other climate and non-climate related external shocks.

Recommendation:

- **There is a need for coordination in some areas so that activities are not duplicated or messages mixed.** For example, those coordinating adaptation planning within an authority need to liaise with other departments within the authority and agencies outside of it.

Key message: Quantitative assessments of socio-spatial vulnerability can support evidence-based policy making

The recommendations above demonstrate the value of quantitative and geospatial assessments of social and socially related drivers of differential impacts. Quantitative databases can be used to construct basic pen portraits of individual neighbourhood socio-spatial signatures that help to explain which factors tend to enhance and offset vulnerability in particular locations (see Chapter 3, ‘Greater Manchester case study’). It has been shown that this also helps to target action and determine which actors and agencies are best able to deliver actions on the ground. Recommendations can be made for the wider use of quantitative indicators.

Recommendations:

- **Socio-spatial vulnerability assessment needs to be applied at a range of spatial scales.** Socio-spatial assessments carried out at local authority level alone will help to establish patterns of needs within small areas. However, they will not identify the extent of the problem in the authority in a wider context, such as the regional and national setting. The need for national pictures of climate risk is being addressed via initiatives such as the Climate Change Risk Assessment. However, unless this adequately addresses the social dimensions of vulnerability, it will not provide a sufficiently robust framework for understanding how some communities are disproportionately affected. Further, it will not provide the necessary empirical evidence base for ensuring adaptation measures are applied in a just and fair manner. Exposure alone is not an adequate measure and cost-benefit analysis fails to capture non-monetary dimensions of loss of well-being in affected communities. The Welsh Index of Multiple Deprivation already contains a measure of flood likelihood; this idea could be more widely adopted and extended to include a wider range of vulnerability factors such as those considered in the illustrative empirical analysis in this report.

- **The limitations of quantitative measures must be considered, particularly where there are incomplete data and missing indicators.** Chapter 3, ‘Limitations of the empirical analysis and associated recommendations’, identifies limitations with this particular study.

- **Time series of existing datasets provide a means of tracking progress in building adaptive capacity.** Examples are the extent of private gardens and public green space, and house prices (e.g.

within flood zones). Single indicators or indicator subsets may be flagged as metrics and used as the basis of identifying targets within adaptation plans. These can be used alongside information gained from social deprivation indices (or selected domains within deprivation indices). Additional indicators can also be recommended (see below, 'Further developing the research base').

- **The analysis in this study should be carried out with new data from the 2011 Census and the most recent versions of other key socio-spatial vulnerability indicators.** Some data is based on the 2001 Census, therefore the characteristics of some neighbourhoods can be expected to have undergone a lot of change which is not recognised in this study.

Further developing the research base

Key message: There is a current lack of data for mapping some facets of socio-spatial vulnerability

Additional data resources are required to fully represent all factors which have been identified in the literature as having a role in determining uneven outcomes from climate-related hazards. While no quantitative metrics can ever be perfect representations of all of the nuances of the processes and characteristics they aim to represent, they nevertheless are an important means of targeting action and tracking progress towards policy goals. It was beyond the scope of the research to construct new UK datasets of social indicators although possible sources of data were identified for some measures. Existing social indicator datasets tend to be aggregated to coarse spatial scales which are unsuitable for a project of this nature. Other datasets have restricted access and/or are deemed commercially sensitive, e.g. insurance costs and associated cover, owing to the market-based insurance regime prevalent in the UK.

Recommendations:

- **Develop new indicator sets at fine geographical resolution to better represent social conversion factors.** Most pressing is the need for fine-scale geospatial measures which can act as proxies for social networks and community engagement. Organisations such as Volunteer England and its counterparts in the devolved administrations may hold appropriate datasets which could act as a useful proxy measure.

- **Collate indicator datasets which can act as a more direct indication of insurance costs or cover availability.** Insurance cover is also a factor which is currently difficult to measure, and national-scale datasets are required to better understand the accessibility of insurance, where homes are under-insured or have no insurance and where alternative insurance models could therefore be targeted to improve distributional justice.

- **Maintain and extend existing datasets on past flood events.** In the absence of data derived from commercial sources, data on past flood events from the UK's environmental agencies is a very important data source which can provide information about past flood experience and possible future insurance access issues. Further resources need to be channelled into helping to maintain and extend the existing geospatial data, recording both the occurrence and the extent of past flood events in the UK.

Key message: There is insufficient understanding of the relative importance of dimensions of social vulnerability for determining uneven outcomes

There are multiple conversion factors and not all are of equal importance. This report has used an equal weighting assumption that is clearly contestable. A number of basic alternative weighting schemes were tested for Scotland. While they suggested a relative lack of sensitivity to scheme weights for identifying the most extremely socially vulnerable, this requires more in-depth analysis with other case-study examples to be conclusive. Possible weighting schemes were explored through a stakeholder workshop session; the lack of any consensus also points to the need for more research in this area and for the involvement of affected communities themselves.

Recommendation:

- **Future research needs to address the question of how different conversion factors, and the dimensions of socio-spatial vulnerability which they inform, should be weighted.** Regression analyses of the health outcomes of heatwave events provide some clues for possible weighting of some factors. However, the limited scope of indicator datasets in most existing studies and the inability to analyse more subtle well-being outcomes means that they are of limited use in a study such as this one. Well-being outcomes are particularly important in the context of flood, where alternative research approaches would be required. Consideration should be given to the deliberative participation of affected communities in the weighting of different factors.

Notes

Chapter 3

1 Indicators are ‘quantitative measures intended to represent a characteristic or a parameter of a system of interest’, often reduced to a single figure (Cutter, *et al.*, 2009, p. 13).

2 An example of a regression-based analysis is the Predictive Indicators of Vulnerability (PIV) project (Brooks, *et al.*, 2005).

3 A useful example of a climate-related composite vulnerability index is the Social Flood Vulnerability Index (SFVI) (Tapsell, *et al.*, 2002, 2005). The SFVI is a composite additive index based on three social-group characteristics and four financial-deprivation indicators (Tapsell, *et al.*, 2002, 2005). It has also been compared to the distribution of hazard-exposure (e.g. Hall, *et al.*, 2005).

4 An example of a PCA-based vulnerability index is the US Social Vulnerability Index (SoVI) (Cutter, *et al.*, 2003). This study initially identified over 250 variables from the 1990 US Census covering 3,141 US counties. These 250 variables were reduced to 42 independent variables, which eventually derived 11 composite factors that differentiated vulnerabilities across US counties. It is possible to then use these factors in a composite model. The SoVI approach has been applied extensively (e.g. Azar and Rain, 2007, Boruff and Cutter, 2007, Vescovi, *et al.*, 2005, Wood, *et al.*, 2010 and Rinner, *et al.*, 2010).

5 Middle Super Output Areas (MSOAs) for England and Wales have a mean of 7,200 residents and a minimum of 5,000; Data Zones (DZs) for Scotland have between 500 and 1,000 residents; and Super Output Areas (SOAs) for Northern Ireland have a minimum of 1,300 residents and a mean of 1,900. These are termed neighbourhoods for the purposes of reporting. Lower Super Output Area (LSOA) level units have a mean of 1,500 residents and a minimum of 1,000. They are termed subneighbourhoods for the purposes of reporting but it should be noted that these are actually the equivalent size to the data-zone units used for Scotland and Northern Ireland. The number of LSOAs in England and Wales as a whole (around 84,000) made analysis at LSOA level prohibitive. Further, the selection of MSOAs allowed the additional of several indicators which would not otherwise be available, such as house prices. The number of neighbourhoods analysed totals around 7,000 for England and Wales, 4,500 for Scotland and 900 for Northern Ireland. (Source: 2001 Census, Output Area Boundaries. Crown copyright 2003. Crown copyright material is reproduced with the permission of the Controller of HMSO.)

6 Standardisation was done using z-scores. This provided a consistent basis for the composite index and the PCA work.

7 A workshop session was carried out as part of this study in order to collect expert judgements on possible weights. However, the lack of any broad consensus in the results meant that the weights generated through this process were not considered sufficiently robust to apply. This, and the absence of any widely agreed weighting scheme(s) for climate-related social vulnerability assessments, resulted in the decision to use equal weights. Although PCA might also be used to generate weights for combining indicators and domains, the literature is equivocal about the value of weights generated from PCA; therefore this is not attempted in this study. Further discussion about the limitations associated with this decision are given in Chapter 3, ‘Limitations of the empirical

analysis and associated recommendations', in the main report and the sensitivity of the index result to alternative weighting schemes is discussed in Chapter 3, 'Impacts of weighting schemes on the results of the socio-spatial index', in relation to the results for Scotland.

8 The PCA approach allows a means of identifying key indicators and removing ones which simply duplicate. Future work may therefore consider fewer indicators than those analysed in the course of this study. The term 'groups' is used to represent the factors or components derived from PCA. Factors and factor loadings are interpreted in line with the examples given in the text. Although Schmidtlein, *et al.* (2008) note that transforming the direction of indicators before PCA does not necessarily remove the need to manipulate the signs reported on factor loadings, it was carried out before analysis in this case so that the composite index and the PCA used the same database. It was also considered helpful for subsequent interpretation of the results. Readers are directed to the examples given in the text for more information about this technique and associated caveats.

9 Estimating patterns of future heatwave probability, for example, would need to recognise that what would be termed a heat-hazard event in north east England (exceeding a threshold of 28 °C in the day and 15 °C in the night for at least two consecutive days and the intervening night) is different from that for London (where the respective temperatures are 31 °C and 16 °C). A set of UK maps of possible future occurrences of these events under high, medium and low emissions scenarios would therefore have step changes at the regional boundaries associated with these different thresholds. While it would be a useful addition to this study to carry out this analysis, it has not been attempted here.

10 All analyses are based on UKCP09 data for the 2050s time horizon. It must be noted that the socio-spatial vulnerability results are not projections and only relate to the current period. The study has used low, medium and high emission scenarios and a range of probabilities. The recommended probability thresholds are used:

- 10th percentile: values are 90% likely to be above this threshold;
- 50th percentile: the central estimate;
- 90th percentile: values are 90% likely to be below this threshold.

The metrics which have been used are: projected mean summer maximum temperatures in the 2050s and projected changes in temperature associated with the warmest summer day in the 2050s compared to the 1961–90 baseline (in °C). The former is limited because we know people are already differentially adapted, hence the different heat warning thresholds mentioned above.[9] The latter is limited because geographical changes in warmest summer day temperature changes can be very small. The greatest difference is observed between scenarios and not within them.

11 A hazard-exposure assessment for neighbourhoods in England and Wales has been carried out using data on significant and moderate flood likelihood ('risk') from the Environment Agency's National Flood Risk Assessment (NaFRA) published in summer 2010. The NaFRA data provides an assessment of the likelihood of flooding in 50m cells both as a result of the location of the cell and the potential for flood defences to be breached. The categories of flood risk (i.e. what is termed likelihood in Chapter 3) are:

- low – the annual chance of flooding is 0.5% (equivalent to 1 event in 200 years) or less;

- moderate – the annual chance of flooding is less than 1.3% (equivalent to 1 event in 75 years) but more than 0.5% (equivalent to 1 event in 200 years);

- significant – the annual chance of flooding is greater than 1.3% (1 event in 75 years).

The above information was derived from the NaFRA Spatial Flood Likelihood Category Grid Data Description (June 2010). Terminology has been slightly modified in order to fit with the terms being used in this study. Neighbourhood-scale flood-hazard exposure for England and Wales has been calculated as the percentage land area estimated to be associated with a significant or moderate flood zone in each individual neighbourhood, proportional to its total land area. Caveats associated with the use of the data in this way are explained in Chapter 3, 'Limitations of the empirical analysis and associated recommendations'. Alternative datasets are available from the Environment Agency, which could provide the basis for alternative estimates of flood-hazard exposure.[18]

12 Neighbourhoods are defined as having extremely high or extremely low socio-spatial vulnerability if they have scores which are >= 1.5 or <= –1.5 respectively. Being classed as having extremely high socio-spatial vulnerability is equivalent to neighbourhood scores being greater than or equal to 1.5 standard deviations above the relevant national or local average (a score of zero). This group therefore also includes neighbourhoods classed as 'acute' in the mapped outputs (see below). Being classed as having extremely low socio-spatial vulnerability is equivalent to neighbourhood scores being greater than or equal to 1.5 standard deviations below the relevant national or local average (a score of zero). This group therefore also includes neighbourhoods classed as 'slight' in the mapped outputs (see below). It should be noted that the regional and local breakdowns use classes which are determined on the above basis in England and Scotland. However, due to very low numbers of neighbourhoods for subsequent analysis in Northern Ireland and Wales, regional/local breakdowns have been analysed based on an assessment of the top 10% scoring neighbourhoods compared to the bottom 10% scoring neighbourhoods for these two study areas. All scores are based on standardised values (z-scores) following examples in the literature (e.g. Wood, *et al.*, 2010). The same principles are used for the assessment of climate disadvantage. The following summarises the technical details of the classes used in the map legends:

- Acute: >= a score of 2.5 or 2.5 standard deviations above the relevant national or local average (a score of zero).

- Extremely high: >= a score of 1.5 or 1.5 standard deviations above the relevant national or local average (a score of zero) but less than 2.5.

- Relatively high: >= a score of 0.5 or 0.5 standard deviations above the relevant national or local average (a score of zero) but less than 1.5.

- Average: a score between 0.5 and –0.5, or within 0.5 standard deviations of the relevant national or local average (a score of zero).

- Relatively low: <= a score of –0.5 or 0.5 standard deviations below the relevant national or local average (a score of zero) but greater than –1.5.

- Extremely low: <= a score of –1.5 or 1.5 standard deviations below the relevant national or local average (a score of zero) but greater than –2.5.

- Slight: <= a score of –2.5 or 2.5 standard deviations below the relevant national or local average (a score of zero).

Equivalent principles are used for the dimensions of socio-spatial vulnerability and the examples of the spatial distributions associated with socially vulnerable groups. Not all categories appear in all maps because of the different nature of the distributions from case to case.

13 Calculated using population-weighed centroids compared to UKBORDERS urban outlines data (acknowledged elsewhere). Where population centroids were not included in the relevant Census download file, geometric centroids have been used instead. The geometric centroid is the geographical centre point of the neighbourhood unit rather than the centre determined by maximum population. It is therefore not such a good representation of the environment of the neighbourhood for its residents. However, it is still considered an appropriate measure of residential characteristics. In England, for example, for extremely high-scoring neighbourhoods with respect to heat, over 95% of neighbourhood centres are in urban areas regardless of whether population-weighted or geometric centroids are used.

14 No exposure according to the Environment Agency dataset described in 11. However, some areas estimated as having no exposure are still associated with the Environment Agency's extreme floodplain extent, which covers an annual 0.1% or 1 in 1,000 chance of flooding in any year.

15 The socio-spatial index only used data relating to past flood events and significant flood zones. Therefore there is no double-counting in terms of this additional exposure to moderate and low flood zones in the most highly socially vulnerable areas.

16 25km versions of the socio-spatial heat index results were calculated based on the means of the population-weighted centroids of each of the neighbourhood zones (e.g. MSOAs in the case of England and Wales). Where no population-weighted centroids were available, geometric centroids were used in their place (see Note 13). Blank cells denote cells with no centroids. A neighbourhood-weighted measure of socio-spatial vulnerability is also constructed based on the mean 25km resolution index score value multiplied by the number of neighbourhoods in the 25km cell. The full results of the analysis are shown in Appendix III.

17 Although it was included as a response indicator, car ownership was not included as a factor associated with flood recovery in the composite index work and its significance for socio-spatial flood vulnerability may have been underestimated.

18 While the authors are aware that data exists which determines numbers of properties in flood-exposed areas, the data and methods used in this study would still not be able to identify the specific characteristics of the individuals within those properties. It should also be noted that some of the historical flood-zone data is not fully representative of past events. For instance, for Scotland, some data was not in a suitable form to convert to a percentage cover metric, so the data does not have a consistent geographic coverage. Therefore it is highly likely that some areas with past flood problems and the associated availability of insurance have not been identified.

19 Scale and zone aggregation effects are related elements associated with the Modifiable Area Unit Problem. Some possible scale effects have been discussed in the main report in relation to the case study. However, it should also be noted that aggregation is associated with problems too. The effects of some of these issues are explored in Schmidtlein, *et al.*, 2008 but are not explored in detail in this

study although some of the same problems apply. The 25km version of the socio-spatial vulnerability index masks a lot of internal variation in some parts of the UK. Further, the UKCP09 grid does not take account of the distributions of large urban areas. In effect, this means that some places tend to see variations masked more than others, e.g. where a climate cell boundary passes through the middle of a major conurbation. Using a 5 x 5km geography from the UKCP09 Weather Generator would be a better solution although it was too time consuming for the time and resources available for this study. Nevertheless, the same issues would still apply and, indeed, new issues emerge.

20 It is also important to point out that heat stress is not just a function of temperatures but also levels of humidity. Heatwave warning systems in other countries use additional measures as well as temperature. Other caveats are that thermal comfort between individuals is also subject to more subtle variations and related to activity levels and personal adaptation such as clothing. Finally, it should be noted that the differences between temperatures in urban and rural areas are only maximised if high temperatures coincide with low wind speeds and clear skies.

References

ABI (2006) Flood resilience and resistance factsheet for insurers and loss adjusters. Association of British Insurers and the Chartered Institute of Loss Adjusters. Available at: http://www.abi.org.uk/content/contentfilemanager.aspx?contentid=24922 [Accessed November 2011]

Adger, W. N. (2006) 'Vulnerability'. *Global Environmental Change*, 16(3), pp. 268–81

Adger, W. N., Brooks, N., Kelly, M., Bentham, G., Agnew, M. and Eriksen, S. (2004) 'New indicators of vulnerability and adaptive capacity: Final project report', Tyndall Centre for Climate Change Research, University of East Anglia, Norwich. Available at:
http://www.tyndall.ac.uk/content/new-indicators-vulnerability-and-adaptive-capacity

Association of British Insurers (2007) 'Access for all: Extending the reach of insurance'. London: ABI

Association of British Insurers (2008) 'Unsaleable, uninsurable, uninhabitable', news release. Available at: http://www.abi.org.uk/Media/Releases/2008/02/Unsaleable_Uninsurable_Uninhabitable__Tougher__planning_controls_needed_for_new_homes_says_the_ABI.aspx [Accessed 2 October 2011]

Association of British Insurers (2011) Summary of the ABI position on Insurance for Flooding: The Northern Flood Conference, 2011. Available at: http://www.morpethfloodaction.org.uk/html/abi_statement.html [Accessed 02 October, 2011]

Association of British Insurers and National Flood Forum (2007) 'Repairing your home or business after a flood: how to limit damage and disruption in the future'. London: ABI and Worcestershire: National Flood Forum

Aviva (2005) 'UK householders fear flood risk is increasing' (11 February 2005). Available at: www.aviva.co.uk [Accessed 23 July 2010]

Azar, D. and Rain, D. (2007) 'Identifying population vulnerable to hydrological hazards in San Juan, Puerto Rico'. *GeoJournal*, 69(1), pp. 23–43

Bennet, G. (1970) 'Bristol floods 1968: Controlled survey of effects on health of local community disaster'. *British Medical Journal*, 3(5720), pp. 454–58

Blaikie, P. M., Cannon, T., Davis, I. and Wisner, B. (1994) *At Risk: Natural Hazards, People's Vulnerability, and Disasters*. London: Routledge

Boruff, B. J., Emrich, C. and Cutter, S. L. (2005) 'Erosion hazard vulnerability of US coastal counties'. *Journal of Coastal Research*, 21(5), pp. 932–42

Boruff, B. J. and Cutter, S. L. (2007) 'The environmental vulnerability of Caribbean Island nations'. *Geographical Review*, 97(1), pp. 24–45

Brooks, N., Adger, W. N. and Kelly, P. M. (2005) 'The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation'. *Global Environmental Change Part A*, 15(2), pp. 151–63

Brown, S. and Walker, G. (2008) 'Understanding heatwave vulnerability in nursing and residential homes'. *Building Research & Information* 36(4), pp. 363–72

Browning, C., Feinberg, S. L., Wallace, D. and Cagney, K. A. (2006) 'Neighborhood social processes, physical conditions, and disaster-related mortality: The case of the 1995 Chicago heatwave'. *American Sociological Review*, 71(4), pp. 661–78

Burgess, J., Stirling, A., Clark, J., Davies, G., Eames, M., Staley, K. and Williamson, S. (2007) 'Deliberative mapping: Developing an analytic-deliberative methodology to support contested science-policy decisions'. *Public Understanding of Science*, 16, pp. 299–322

Clark, M. J. (1998) 'Flood insurance as a management strategy for UK coastal resilience'. *The Geographic Journal*, 164, pp. 333–43

Crichton, D. (2004) 'The future of flood management in the UK'. *Insurance Research and Practice*, No 1, December 2007. Journal of the Chartered Insurance Institute. London. Available at www.cii.co.uk/knowledge/irp

Crichton, D. and Salt, J. E. (eds) (2001) *The Implications of Climate Change for the Insurance Industry: An Update and Outlook to 2020*. Watford: Building Research Establishment

Cumbria County Council, 2010. 'Cumbria flood recovery: six months on'. Available at: www.cumbria.gov.uk/news/2010

Cutter, S. L., Mitchell, J. T. and Scott, M. S. (2000) 'Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina'. *Annals of the Association of American Geographers*, 90(4) 713–37

Cutter, S. L., Boruff, B. J. and Shirley, W. L. (2003) 'Social vulnerability to environmental hazards'. *Social Science Quarterly*, 84(2), pp. 242–61

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E. and Webb, J. (2008) 'A place-based model for understanding community resilience to natural disasters'. *Global Environmental Change*, 18(4), pp. 598–606

Cutter, S. L., Emrich, C. T., Webb, J. J. and Morath, D. (2009) *Social Vulnerability to Climate Variability Hazards: A Review of the Literature*. Hazards and Vulnerability Research Institute, University of South Carolina, Columbia. Available at http://adapt.oxfamamerica.org/resources/Literature_Review.pdf [Accessed 20 November 2009]

Davies, G., Burgess, J., Eames, M., Mayer, S., Staley, K., Stirling, A. and Williamson, S. (2003) *Deliberative Mapping: Appraising Options for Addressing 'the Kidney Gap'*. London: Wellcome Trust

Department of Health (DoH) Heat Health Watch (2010) 'What to do in case of a heatwave'. Available at: www.dh.gov.uk/en/Aboutus/MinistersandDepartmentLeaders/ChiefMedicalOfficer/CMOtopics/DH_4135398 [Accessed 25 October 2011]

De Marchi, B., Funtowicz, S., Casio, S. and Munda, G. (2000) 'Combining participative and institutional approaches with multicriteria evaluation'. *Ecological Economics*, 34, pp. 267–82

Dlugolecki, A., *et al.* (2009) *Coping with Climate Change*. London/ CII_3112: Chartered Insurance Institute, London

Douglas, I., Garvin, S., Lawson, N., Richards, J., Tippett, J. and White, I. (2010) 'Urban pluvial flooding: A qualitative case study of cause, effect and nonstructural mitigation'. *Journal of Flood Risk Management*, 3(2), pp. 112–25

Downing, T. E., Butterfield, R., Cohen, S., Huq, S., Moss, R., Rahman, A., Sokona, Y. and Stephen, L. (2001) *Vulnerability Indices: Climate Change Impacts and Adaptation*. Nairobi: UNEP

Downing, T. E., Patwardhan, A., Klein, R. J. T., Mukhala, E., Stephen, L., Winograd, M. and Ziervogel, G. (2002) *Assessing Vulnerability for Climate Adaptation*. Available at: http://content.undp.org/go/cms-service/stream/asset/?asset_id=2200850

Easterlin, R. (1995) 'Will raising the incomes of all increase the happiness of all?' *Journal of Economic Behavior and Organization*, 27, pp. 35–47

EDINA UKBORDERS. Available at http://edina.ac.uk/ukborders

Ellis, F. P., Prince, H. P., Lovatt, G. and Whittington, R. M. (1980) 'Mortality and morbidity in Birmingham during the 1976 heatwave'. *Quarterly Journal of Medicine*, 49, pp. 1–8

Environment Agency Wales (2009) 'Flooding in Wales: A national assessment of flood risk'. Cardiff: Environment Agency Wales. Available at: http://www.environment-agency.gov.uk/static/documents/Research/ENV0005_Flooding_in_Wales_ENGLISH_AW_LR(1).pdf [Accessed 29 September 2011]

Fielding, J., Gray, K., Burningham, K. and Thrush, D. (2005) 'Flood warning for vulnerable groups: Secondary analysis of flood data'. R&D Report W5C-018/2. Bristol: Environment Agency. Available at: http://library.coastweb.info/340/1/lit_review_flood_risk.pdf [Accessed September 2011]

Frey, B. and Stutzer, A. (2002) *Happiness and Economics: How the Economy and Institutions Affect Human Well-Being*. Princeton: Princeton University Press

Füssel, H. M. (2009) 'Review and quantitative analysis of indices of climate change exposure, adaptive capacity, sensitivity, and impacts'. Background Note to the World Development Report 2010. Available at: http://siteresources.worldbank.org/INTWDR2010/Resources/5287678-1255547194560/WDR2010_BG_Note_Fussel.pdf [Accessed 29 September 2011]

Grize, L., Huss, A., Thommena, O., Schindlera, C. and Braun-Fahrländera, C. (2005) 'Heatwave 2003 and mortality in Switzerland'. *Swiss Medical Weekly*, 135, pp. 200–05

Hall, J. W., Evans, E. P., Penning-Rowsell, E. C., Sayers, P. B., Thorne, C. R. and Saul, A. J. (2003) 'Quantified scenarios analysis of drivers and impacts of changing flood risk in England and Wales: 2030–2100'. *Environmental Hazards*, 5(3–4), pp. 51–65

Hall, J. W., Sayers, P. B. and Dawson, R. J. (2005) 'National-scale assessment of current and future flood risk in England and Wales'. *Natural Hazards*, 36(1), pp. 147–64

Hajat, S., Kovats, R. S. and Lachowycz, K. (2007) 'Heat-related and cold-related deaths in England and Wales: Who is at risk?' *Occupational and Environmental Medicine*, 64(2), pp. 93–100

Hertel, S., Le Tertre, A., Jöckel, K.-H. and Hoffmann, B. (2009) 'Quantification of the heatwave effect on cause-specific mortality in Essen, Germany'. *European Journal of Epidemiology*, 24(8), pp. 407–14

IPCC (2001) *Climate Change 2001*. New York: Cambridge University Press

IPCC (2007) *Climate Change 2007: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J. and Hanson, C. E. (eds). Cambridge: Cambridge University Press

Johnson, H., Kovats, R. S., McGregor, G., Stedman, J., Gibbs, M., Walton, H., Cook, L. and Black, E. (2005) 'The impact of the 2003 heatwave on mortality and hospital admissions in England'. *Health Statistics Quarterly*, (25), pp. 6-11 (Spring)

Kahneman D. and Sugden, R. (2005) 'Experienced utility as a standard of policy evaluation'. *Environmental and Resource Economics*, 32, pp. 161–81

Kelly, P. M. and Adger, W. N. (2000) 'Theory and practice in assessing vulnerability to climate change and facilitating adaptation'. *Climatic Change*, 47(4), pp. 325–52

Ketteridge, A. and Fordham, M. (1998) 'Flood evacuation in two communities in Scotland: Lessons from European research'. *International Journal of Mass Emergencies and Disasters*, 1998, 16(2), pp. 119–43

Klinenberg, E. (2002) *Heatwave: A Social Autopsy of Disaster in Chicago*. Chicago, IL: University of Chicago Press

Kovats, R. S. and Ebi, K. L. (2006) 'Heatwaves and public health in Europe'. *European Journal of Public Health*, Vol. 16, No. 6, pp. 592–599

Kovats, R. S., Johnson, H. and Griffiths, C. (2006) 'Mortality in southern England during the 2003 heatwave by place of death'. *Health Statistics Quarterly*, 29, pp. 6–8

Lawson, N., Douglas, I., Garvin, S., Richards, J., Tippett, J. and White, I. (2008) *Risk Assessment and Risk Management for Small Urban Catchments*. Final Report. London: Defra

Layard, R. (2005) *Happiness: Lessons for a New Science*. London: Allen Lane

Lucas, K., Walker, G., Eames, M., Fay, H. and Poustie, M. (2004) *Environment and Social Justice: Rapid Research and Evidence Review*. London: Policy Studies Institute

McGregor, G. R., Pelling, M., Wolf, T. and Gosling, S. (2007) *The Social Impacts of Heatwaves*, Science Report – SC20061/SR6. Environment Agency. Available at: http://publications.environment-agency.gov.uk/PDF/SCHO0807BNCW-E-E.pdf [Accessed 29 September 2011]

Morpeth Group (2010) Flood Insurance in the UK: Our Proposal for the Way Forward. Available at: http://www.morpethfloodaction.org.uk/html/proposal.html [Accessed 23 October 2011]

Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Hoffman, A. and Giovannini, E. (2005) 'Handbook on constructing composite indicators: Methodology and user guide', OECD Statistics Working Papers, 2005/3

Nussbaum, M. (2000) *Women and Human Development*. Cambridge: Cambridge University Press

O'Brien K., Eriksen, S., Nygaard, I. and Schjolden, A. (2007) 'Why different interpretations of vulnerability matter in climate change discourses'. *Climate Policy*, 7, pp. 73–88

O'Neill. J. (2006) 'Citizenship, well-being and sustainability: Epicurus or Aristotle?' *Analyse & Kritik*, 28, pp.158–72

O'Neill, J. (2008) *Living Well Within Limits: Well-Being, Time and Sustainability*. Sustainable Development Commission. Available at: http://www.sd-commission.org.uk/publications/downloads/John_ONeil_thinkpiecel.pdf [Accessed 2 October 2011]

O'Neill, J. and O'Neill, M. (forthcoming) *Climate Change, Social Justice and the Future of Flood Insurance*. Joseph Rowntree Foundation

Osbourne, H. (2008) 'Home insurance: Flood-risk properties could be "uninsurable"' (Updated 18 June 2008) Available at www.guardian.co.uk [Accessed 21 July 2010]

Pall, P., Aina, T., Stone, D., Stott, P., Nozawa. T., Hilberts, A., Lohmann, D. and Allen, M. (2011) 'Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000'. *Nature*, 470, pp. 382–5

Peduzzi, P. (2006) 'The disaster risk index: Overview of a quantitative approach'. In Birkmann, J. (ed) (2006) *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies*. Tokyo, New York, Paris: UNU-Press

Pelling, M. and High, C. (2005) 'Understanding adaptation: What can social capital offer assessments of adaptive capacity?' *Global Environmental Change Part A*, 15(4), pp. 308–19. Elsevier

Pitt, M. (2008) 'Learning lessons from the 2007 floods'. London: Cabinet Office

Reid, C. E., O'Neill, M. S., Gronlund, C. J., Brines, S. J., Brown, D. G., Diez-Roux, A. V. and Schwartz, J. (2009) 'Mapping community determinants of heat vulnerability'. *Environmental Health Perspectives*, 117(11), pp. 1730–6

Rinner, C., Patychuk, D., Bassil, K., Nasr, S., Gower, S. and Campbell, M. (2010) 'The role of maps in neighborhood-level heat vulnerability assessment for the City of Toronto'. *Cartography and Geographic Information Science* 37(1), pp. 31–44

Robeyns, I. and van der Veen, R. J. (2007) *Sustainable Quality of life: Conceptual Analysis for a Policy-relevant Empirical Specification*. Netherlands Environmental Assessment Agency. Available at http://www.rivm.nl/bibliotheek/rapporten/550031006.pdf [Accessed: 2 October 2011]

Robine, J. M., Cheung, S. L. K., Le Roy, S., Van Oyen, H., Griffiths, C., Michel, J.-P. and Herrmann, F. R. (2008) 'Death toll exceeded 70,000 in Europe during the summer of 2003'. *Comptes Rendus Biologies*, 331(2), pp. 171–8

Salford City Council (2011) Report of climate adaptation workshop held at Salford City Council, February 2011 (unpublished)

Samwinga, V., Proverbs, D. G. and Homan, J. (2004) *Exploring the Experience of UK Homeowners in Flood Disaster*. Royal Institution of Chartered Surveyors. Available at http://www.rics.org/site/download_feed.aspx?fileID=2488&fileExtension=PDF [Accessed 2 October 2011]

Schmidtlein, M. C., Deutsch, R. C., Piegorsch, W. W. and Cutter, S. L. (2008) 'A sensitivity analysis of the Social Vulnerability Index'. *Risk Analysis*, 28(4), pp. 1099–114

Scottish Index of Multiple Deprivation. Available at http://simd.scotland.gov.uk/map

Semenza, J. C., McCullough, J. E., Flanders, W. D., McGeehin, M. A. and Lumpkin, J. R. (1999) 'Excess hospital admissions during the July 1995 heatwave in Chicago: Do hospital records contain adequate documentation?' *American Journal of Preventive Medicine*, 16(4), pp. 269–77

Sen, A. (1999) *Development as Freedom*. Oxford: Oxford University Press

Sen, A. (2009) *The Idea of Justice*. Harmondsworth: Penguin

Smith, C. (2010) Chairman's speech to the National Flood Forum Annual Conference, Lord Chris Smith. Environment Agency. Available at www.environment-agency.gov.uk/static/media/National_Flood_Forum_speech_Feb_2010.final.pdf [Accessed 22 July 2010]

Smith, C. L. and Levermore, G. J. (2008) Foresight Report B11: 'Designing urban spaces and buildings to improve sustainability and quality of life in a warmer world'. *Energy Policy*, 36(12), 4558–62

SNIFFER (2009) 'Differential social impacts of climate change in the UK'. SNIFFER Project UKCC22. Available at http://www.sniffer.org.uk/Resources/UKCC22/Layout_Default/0.aspx [Accessed 29 September 2011]

Spickett, J., Brown, H. and Katscherian, D. (2008) *Health Impacts of Climate Change: Adaptation Strategies for Western Australia*. Department of Health, Australian Government. Available at http://www.public.health.wa.gov.au/cproot/1510/2/Health_Impacts_of_Climate_Change.pdf [Accessed 29 September 2011]

Stedman, J. R. (2004) 'The predicted number of air pollution related deaths in the UK during the August 2003 heatwave'. *Atmospheric Environment*, 38(8), pp. 1087–90

Stiglitz, J., Sen, A. and Fitoussi, J.-P. (2009) Report by the Commission on the Measurement of Economic Performance and Social Progress. Available at: http://www.stiglitz-sen-fitoussi.fr/documents/rapport_anglais.pdf [Accessed 2 October 2011]

Stirling, A. (2008) ' "Opening up" and "closing down": Power, participation and pluralism in the social appraisal of technology'. *Science, Technology, & Human Values*, 33, pp. 262–94

Tapsell, S. M., Penning-Rowsell, E. C., Tunstall, S. M. and Wilson, T. L. (2002) 'Vulnerability to flooding: health and social dimensions'. *Philosophical Transactions: Mathematical, Physical and Engineering Sciences*, 360(1796), pp. 1511–25

Tapsell, S. M., Tunstall, S. M., Green, C. and Fernandez, A. (2005) Indicator set. Report T11-07-01 of FLOODsite Integrated Project, Flood Hazard Research Centre, Enfield. Available at http://www.floodsite.net/html/publications3.asp?taskID=11 [Accessed 29 September 2011]

Tapsell, S. M., Tunstall, S. M., Penning-Rowsell, E. C. and Handmer, J. W. (1999) 'The health effects of the 1998 Easter flooding in Banbury and Kidlington'. Report to the Environment Agency, Thames Region. Enfield, Middlesex: Flood Hazard Research Centre, Middlesex University

Thrush, D., Burningham, K. and Fielding, J. (2005) *Flood Warning for Vulnerable Groups: Measuring and Mapping Vulnerability*. Bristol: Environment Agency

UKCP09, UK Climate Projections, Defra. Available at http://ukclimateprojections.defra.gov.uk

Vescovi L., Rebetez M. and Rong F. (2005) 'Assessing public health risk due to extremely high temperature events: Climate and social parameters'. *Climate Research*, 30, pp. 71–8

Walker, G., Burningham, K., Fielding, J., Smith, G., Thrush, D. and Fay, H. (2006) *Addressing Environmental Inequalities: Flood Risk*. Bristol: Environment Agency

Walker, G. P., Mitchell, G., Fairburn, J. and Smith, G. (2003) *Environmental Quality and Social Deprivation. Phase II: National Analysis of Flood Hazard, IPC Industries and Air Quality*. Bristol: The Environment Agency

Watkiss, P. (2009) Literature review: 'Scoping study for a national climate change risk assessment and cost-benefit analysis', Version 3, Paul Watkiss Associates

Werritty, A., Houston, D., Ball, T., Tavendale, A. and Black, A. (2007) *Exploring the Social Impacts of Flood Risk and Flooding in Scotland*. Scottish Executive Social Research, p. 157. Available at: http://www.scotland.gov.uk/Resource/Doc/174676/0048938.pdf

Wheater, H. S. (2006) 'Flood hazard and management: A UK perspective'. *Philosophical Transactions of the Royal Society A*, 364(1845), pp. 2135–45

Whittle, *et al.* (2010) 'After the rain: Learning the lessons from flood recovery in Hull', final project report for *Flood, Vulnerability and Urban Resilience: A real-time study of local recovery following the floods of June 2007 in Hull*. Lancaster: Lancaster University

Wiggins, D. (1998) 'The claims of need' in *Needs, Values, Truth*, 3rd edition. Oxford: Clarendon Press

Wolf, J., Adger, W. N., Lorenzoni, I., Abrahamson, V. and Raine, R. (2010) 'Social capital, individual responses to heatwaves and climate change adaptation: An empirical study of two UK cities'. *Global Environmental Change*, 20, pp. 44–52

Wolff, J. (2002) *The Message of Redistribution: Disadvantage, Public Policy and the Human Good*. London: Catalyst Trust

Wolff, J. and de Shalit, A. (2007) *Disadvantage*. Oxford: Oxford University Press

Wood, N., Burton, C. and Cutter, S. (2010) 'Community variations in social vulnerability to Cascadia-related tsunamis in the U. S. Pacific Northwest'. *Natural Hazards*, 52(2), pp. 369–89

Appendix I

Indicators used in the socio-spatial vulnerability index

Table 1 summarises the number of indicators used and these are listed in more detail in Tables 2–4. A subset of indicators was selected to input into the socio-spatial index (i.e. to identify vulnerable locations) with the entire dataset used for PCA (i.e. to identify indicators which together identify key vulnerable groups).

Table 1: Summary of the number of indicators and domains associated with the different elements of this study

Country	Vulnerability dimension	Locations				Groups	
		Domains		Indicators		Indicators	
		Heat	Flood	Heat	Flood	Heat	Flood
England	Sensitivity	2	2	4	4	11	11
	Enhanced exposure	3	2	6	4	8	4
	Preparedness	3	5	10	13	19	23
	Response	7	8	17	20	29	34
	Recovery	4	6	17	14	35	26
Wales	Sensitivity	2	2	4	4	11	11
	Enhanced exposure	3	2	4	3	6	3
	Preparedness	3	5	10	13	19	23
	Response	7	8	19	20	31	36
	Recovery	4	5	11	13	20	23
N. Ireland	Sensitivity	2	2	4	4	11	11
	Enhanced exposure	3	2	4	3	6	3
	Preparedness	3	5	10	12	18	21
	Response	6	8	15	18	27	33
	Recovery	4	5	10	13	20	22
Scotland	Sensitivity	2	2	4	4	9	9
	Enhanced exposure	3	2	4	3	6	3
	Preparedness	3	5	10	12	18	21
	Response	6	8	16	19	27	33
	Recovery	4	5	10	14	19	23

Table 2: List of indicators and domains used for England

Dimension	Domain	Indicator	Locations		Groups	
			Heat	Flood	Heat	Flood
Sensitivity	Age	% very young (<5)	Y	Y	Y	Y
Sensitivity	Age	% old (>65)			Y	Y
Sensitivity	Age	% very old (>75)	Y	Y	Y	Y
Sensitivity	Age	Net change in population of children (2001–02)			Y	Y
Sensitivity	Age	Net change in population of older people (2001–02)			Y	Y
Sensitivity	Health	% with limiting long-term Illness (LLTI)	Y	Y	Y	Y
Sensitivity	Health	% with LLTI but working			Y	Y
Sensitivity	Health	% in poor health			Y	Y
Sensitivity	Health	% households with at least one person with LLTI	Y	Y	Y	Y
Sensitivity	Care	% in nursing care			Y	Y
Sensitivity	Care	% in residential care			Y	Y
Enhanced exposure	Physical environment	% zone not green space 2001[a]	Y	Y	Y	Y
Enhanced exposure	Physical environment	Area of domestic buildings per unit area of domestic gardens 2001[a]	Y	Y	Y	Y
Enhanced exposure	Physical environment	% zone not blue space 2001[a]	Y		Y	
Enhanced exposure	Physical geography	Distance from coast for the zone population weighted centroid[b]	Y		Y	
Enhanced exposure	Physical geography	Average distance to coast of zone[b]			Y	
Enhanced exposure	Physical geography	Average elevation for the zone population weighted centroid (low = high exposure)[c]	Y		Y	
Enhanced exposure	Physical geography	Average elevation for the zone (low = high exposure)[c]			Y	
Enhanced exposure	Housing	% households lowest floor level: basement or semi-basement		Y		Y
Enhanced exposure	Housing	% households lowest floor level: ground floor (street level)		Y		Y
Enhanced exposure	Housing	% households lowest floor level: fifth floor or higher	Y		Y	
Preparedness	Income	% unemployed	Y	Y	Y	Y
Preparedness	Income	% in low-income work (routine/manual)	Y	Y	Y	Y
Preparedness	Income	% never worked	Y	Y	Y	Y
Preparedness	Income	% households with no adults working and with dependent children	Y	Y	Y	Y
Preparedness	Income	% households with no adults working with no dependent children			Y	Y
Preparedness	Income	Average weekly household total income estimate (low = high vulnerability)[d]			Y	Y
Preparedness	Income	Average weekly household net income estimate (low = high vulnerability)[d]			Y	Y

Preparedness	Income	Average weekly household net income estimate (equivalised before housing costs) (low = high vulnerability)[d]			Y	Y
Preparedness	Income	Average weekly household net income estimate (equivalised after housing costs) (low = high vulnerability)[d]	Y	Y	Y	Y
Preparedness	Income	% all-pensioner households	Y	Y	Y	Y
Preparedness	Tenure	% renting from social landlords	Y	Y	Y	Y
Preparedness	Tenure	% renting from private landlords	Y	Y	Y	Y
Preparedness	Tenure	% households not owner occupied (reverse of formal variable)			Y	Y
Preparedness	Tenure	% households not owned outright (reverse of formal variable)			Y	Y
Preparedness	Info use	% born outside UK	Y	Y	Y	Y
Preparedness	Info use	% born in other EU countries			Y	Y
Preparedness	Info use	% born outside Europe			Y	Y
Preparedness	Info use	New migrants from overseas (people with <1 yr residency coming from outside UK)	Y	Y	Y	Y
Preparedness	Info use	% with basic education			Y	Y
Preparedness	Local knowledge	New migrants from outside the local area		Y		Y
Preparedness	Local knowledge	Net change in population (community knowledge loss)				Y
Preparedness	Local knowledge	Flood experience (% area associated with past events)[e]		Y		Y
Preparedness	Insurance	Insurance availability proxy (high values = high % area classed as 1-in-75-year flood zone)[f]		Y		Y
Response	Income	% economically active unemployed 16–74	Y	Y	Y	Y
Response	Income	% people routine/manual	Y	Y	Y	Y
Response	Income	% people never worked/long-term unemployed	Y	Y	Y	Y
Response	Income	% households with no adults in employment and dependent children	Y	Y	Y	Y
Response	Income	% households with no adults in employment (no children)			Y	Y
Response	Income	Average weekly household total income estimate (low = high vulnerability)[d]			Y	Y
Response	Income	Average weekly household net income estimate (low = high vulnerability)[d]			Y	Y
Response	Income	Average weekly household net income estimate (eq. before housing costs) (low = high vulnerability)[d]			Y	Y
Response	Income	Average weekly household net income estimate (eq. after housing costs) (low = high vulnerability)[d]	Y	Y	Y	Y
Response	Income	% all pensioner households	Y	Y	Y	Y
Response	Info use	% born outside UK	Y	Y	Y	Y

Response	Info use	% born in other EU countries			Y	Y
Response	Info use	% born elsewhere (outside Europe)			Y	Y
Response	Info use	% people with no or level 1 qualification			Y	Y
Response	Info use	People with <1 yr residency coming from outside UK	Y	Y	Y	Y
Response	Local knowledge	People with <1 yr residency in immediate area		Y		Y
Response	Local knowledge	Net change; all ages rate per 1,000 persons				Y
Response	Local knowledge	Flood experience (% area associated with past events)[e]		Y		Y
Response	Insurance	Insurance availability proxy (high values = high % area classed as 1-in-75-year flood zone)[f]		Y		Y
Response	Social networks	% single-pensioner households	Y	Y	Y	Y
Response	Social networks	% female lone-parent households			Y	Y
Response	Social networks	% single-person households (non-pensioner)			Y	Y
Response	Social networks	% lone-parent households with dependent children	Y	Y	Y	Y
Response	Social networks	% households with dependent children aged <4			Y	Y
Response	Social networks	% people who do not provide unpaid care (reverse of formal variable)	Y	Y	Y	Y
Response	Mobility	% disabled	Y	Y	Y	Y
Response	Mobility	% households with no car	Y	Y	Y	Y
Response	Mobility	% households without more than one car (reverse of formal variable)			Y	Y
Response	Mobility	Distance travelled to work		Y		Y
Response	Mobility	% not home workers (resident population)		Y		Y
Response	Mobility	% travel to work by public transport (resident population)				Y
Response	Mobility	Mean hours worked				Y
Response	Crime	MDI crime score (no disaggregated burglary)[g]	Y	Y	Y	Y
Response	General access	% area not road[a]	Y	Y	Y	Y
Response	General infrastructure	Density of VAT-registered retail units 2005 (low = higher vulnerability)[h]	Y		Y	
Response	General infrastructure	% change in number of enterprises (all) between 2005 and 2007 (high negative = high vulnerability)[h]	Y		Y	
Response	General infrastructure	% change in number of enterprises (retail) between 2005 and 2007 (high negative = high vulnerability)[h]			Y	
Recovery	Income	% EA unemployed aged 16–74		Y		Y
Recovery	Income	% people routine/manual		Y		Y
Recovery	Income	% people never worked/long-term unemployed		Y		Y
Recovery	Income	% households with no adults in employment and dependent children		Y		Y
Recovery	Income	% people never worked/long-term unemployed				Y

Recovery	Income	% households with no adults in employment and dependent children				Y
Recovery	Income	% households with no adults in employment (no children)				Y
Recovery	Income	Average weekly household total income estimate (low = high vulnerability)[d]				Y
Recovery	Income	Average weekly household net income estimate (low = high vulnerability)[d]				Y
Recovery	Income	Average weekly household net income estimate (low = high vulnerability) (eq. before housing costs)[d]				Y
Recovery	Income	Average weekly household net income estimate (low = high vulnerability) (eq. after housing costs)[d]		Y		Y
Recovery	Income	% all pensioner households		Y		Y
Recovery	Info use	% born outside UK	Y	Y	Y	Y
Recovery	Info use	% born in other EU countries			Y	Y
Recovery	Info use	% born outside Europe			Y	Y
Recovery	Info use	% people with no or level 1 qualification			Y	Y
Recovery	Info use	People with <1 yr residency coming from outside UK	Y	Y	Y	Y
Recovery	Insurance	Insurance availability proxy (high values = high % area classed as 1-in-75-year flood zone)[f]		Y		Y
Recovery	Social networks	% single-pensioner households	Y	Y	Y	Y
Recovery	Social networks	% female lone-parent households			Y	Y
Recovery	Social networks	% single-person households (non-pensioner)			Y	Y
Recovery	Social networks	% lone-parent households with dependent children	Y	Y	Y	Y
Recovery	Social networks	% households with dependent children <4			Y	Y
Recovery	Social networks	% people who do not provide unpaid care (reverse of formal variable)	Y	Y	Y	Y
Recovery	Mobility	% disabled	Y	Y	Y	Y
Recovery	Mobility	% households with no car	Y		Y	
Recovery	Mobility	% households without more than one car (reverse of formal variable)			Y	
Recovery	Mobility	Distance travelled to work	Y		Y	
Recovery	Mobility	% not home workers (resident population) (reverse of formal variable)	Y		Y	
Recovery	Mobility	% travel to work by public transport (resident population)			Y	
Recovery	Mobility	Mean hours worked			Y	
Recovery	Service access	Travel time to nearest GP by walk/PT[i]	Y		Y	
Recovery	Service access	Frequency score reflecting the availability[i] of bus services providing this travel time (low = high vulnerability)			Y	
Recovery	Service access	Travel time to nearest GP centre by car[i]			Y	

Recovery	Service access	% of risk population (no car) outside of 15 minutes by walk/PT reverse of formal variable)[i]	Y		Y	
Recovery	Service access	% of risk population (no car) outside of 30 minutes by walk/PT (reverse of formal variable)[i]			Y	
Recovery	Service access	Number of GPs within 15 minutes by walk/PT (low = high vulnerability)[i]	Y		Y	
Recovery	Service access	Number of GPs within 15 minutes by car (low = high vulnerability)[i]	Y		Y	
Recovery	Service access	Number of GPs within 30 minutes by walk/PT (low = high vulnerability)[i]			Y	
Recovery	Service access	Number of GPs within 30 minutes by car (low = high vulnerability)[i]			Y	
Recovery	Service access	Travel time to nearest hospital by walk/PT[i]	Y		Y	
Recovery	Service access	Frequency score reflecting the availability of bus services providing this travel time (low = high vulnerability)[i]			Y	
Recovery	Service access	Travel time to nearest hospital centre by car[i]	Y		Y	
Recovery	Service access	% of risk population outside of 30 minutes by walk/PT (reverse of formal variable)[i]	Y		Y	
Recovery	Service access	% of risk population outside of 60 minutes by walk/PT (reverse of formal variable)[i]			Y	
Recovery	Service access	Number of hospitals within 30 minutes by walk/PT (low = high vulnerability)[i]	Y		Y	
Recovery	Service access	Number of hospitals within 30 minutes by car (low = high vulnerability)[i]			Y	
Recovery	Service access	Number of hospitals within 60 minutes by walk/PT (low = high vulnerability)[i]			Y	
Recovery	House price	Price indicators for all dwellings; median (2003–08 % change)[j]		Y		Y
Recovery	House price	Price indicators for all dwellings; mean (2003–08 % change)[j]				Y
Recovery	House price	Price indicators for all dwellings; ninety-eight percentile (2003–08 % change)[j]				Y

Notes:

All data is from or derived from the UK Census 2001, except for:

a Land Use Statistics (Generalised Land Use Database), 2005, Office of National Statistics

b Calculated from EDINA UKBORDERS coastline data; estimates are based on as-the-crow-flies (Euclidean) distances

c Calculated from US Geological Survey Digital Elevation Model (1km)

d Income: Model-based Estimates at MSOA Level, 2004/05, Office of National Statistics

e Environment Agency historical flood zones

f Environment Agency NaFRA Spatial 0910

g English Indices of Multiple Deprivation 2004, Office of National Statistics

h VAT-based Enterprises by Broad Industry Group, 2005 and 2007, Office of National Statistics

i Accessibility statistics, 2008, Office of National Statistics

j Changes of Ownership by Dwelling Price, 2008, Office of National Statistics

Table 3: List of indicators and domains used for Wales

Differences in indicators compared with England are shown in bold.

Dimension	Domain	Indicator	Locations		Groups	
			Heat	Flood	Heat	Flood
Sensitivity	Age	% very young (<5)	Y	Y	Y	Y
Sensitivity	Age	% old (>65)			Y	Y
Sensitivity	Age	% very old (>75)	Y	Y	Y	Y
Sensitivity	Age	Net change in population of children (2001–02)			Y	Y
Sensitivity	Age	Net change in population of older people (2001–02)			Y	Y
Sensitivity	Health	% with limiting long-term illness (LLTI)	Y	Y	Y	Y
Sensitivity	Health	% with LLTI but working			Y	Y
Sensitivity	Health	% in poor health			Y	Y
Sensitivity	Health	% households with at least one person with LLTI	Y	Y	Y	Y
Sensitivity	Care	% in nursing care			Y	Y
Sensitivity	Care	% in residential care			Y	Y
Enhanced exposure	Physical environment	**% urban[a]**	Y	Y	Y	Y
Enhanced exposure	Physical geography	**Average distance to coast of zone[b]**	Y		Y	
Enhanced exposure	Physical geography	**Minimum distance from coast in the zone[b]**			Y	
Enhanced exposure	Physical geography	**Average elevation for the zone (low = high exposure)[c]**	Y		Y	
Enhanced exposure	Physical geography	**Maximum elevation for the zone (low = high exposure)[c]**			Y	
Enhanced exposure	Housing	% households lowest floor level: basement or semi-basement		Y		Y
Enhanced exposure	Housing	% households lowest floor level: ground floor (street level)		Y		Y
Enhanced exposure	Housing	% households lowest floor level: fifth floor or higher	Y		Y	
Preparedness	Income	% unemployed	Y	Y	Y	Y
Preparedness	Income	% in low-income work (routine/manual)	Y	Y	Y	Y
Preparedness	Income	% never worked	Y	Y	Y	Y
Preparedness	Income	% households with no adults working and with dependent children	Y	Y	Y	Y
Preparedness	Income	% households with no adults working with no dependent children			Y	Y
Preparedness	Income	Average weekly household total income estimate (low = high vulnerability)[d]			Y	Y
Preparedness	Income	Average weekly household net income estimate (low = high vulnerability)[d]			Y	Y
Preparedness	Income	Average weekly household net income estimate (eq. before housing costs) (low = high vulnerability)[d]			Y	Y
Preparedness	Income	Average weekly household net income estimate (eq. after housing costs) (low = high vulnerability)[d]	Y	Y	Y	Y

Preparedness	Income	% all-pensioner households	Y	Y	Y	Y
Preparedness	Tenure	% renting from social landlords	Y	Y	Y	Y
Preparedness	Tenure	% renting from private landlords	Y	Y	Y	Y
Preparedness	Tenure	% households not owner occupied (reverse of formal variable)			Y	Y
Preparedness	Tenure	% households not owned outright (reverse of formal variable)			Y	Y
Preparedness	Info use	% born outside UK	Y	Y	Y	Y
Preparedness	Info use	% born in other EU countries			Y	Y
Preparedness	Info use	% born outside Europe			Y	Y
Preparedness	Info use	New migrants from overseas (people with <1 yr residency coming from outside UK)	Y	Y	Y	Y
Preparedness	Info use	% with basic education			Y	Y
Preparedness	Local knowledge	New migrants from outside the local area		Y		Y
Preparedness	Local knowledge	Net change in population (community knowledge loss)				Y
Preparedness	Local knowledge	Flood experience (% area associated with past events)[e]		Y		Y
Preparedness	Insurance	Insurance availability proxy (high values = high % area classed as 1-in-75-year flood zone)[f]		Y		Y
Response	Income	% EA unemployed aged 16–74	Y	Y	Y	Y
Response	Income	% people routine/manual	Y	Y	Y	Y
Response	Income	% people never worked/long-term unemployed	Y	Y	Y	Y
Response	Income	% households with no adults in employment and dependent children	Y	Y	Y	Y
Response	Income	% households with no adults in employment (no children)			Y	Y
Response	Income	Average weekly household total income estimate (low = high vulnerability)[d]			Y	Y
Response	Income	Average weekly household net income estimate (low = high vulnerability)[d]			Y	Y
Response	Income	Average weekly household net income estimate (eq. before housing costs) (low = high vulnerability)[d]			Y	Y
Response	Income	Average weekly household net income estimate (eq. after housing costs) (low = high vulnerability)[d]	Y	Y	Y	Y
Response	Income	% all-pensioner households	Y	Y	Y	Y
Response	Info use	% born outside UK	Y	Y	Y	Y
Response	Info use	% born in other EU countries			Y	Y
Response	Info use	% born elsewhere (outside Europe)			Y	Y
Response	Info use	% people with no or level 1 qualification			Y	Y
Response	Info use	People with <1 yr residency coming from outside UK	Y	Y	Y	Y
Response	Local knowledge	People with <1 yr residency in immediate area		Y		Y
Response	Local knowledge	Net change; all ages rate per 1,000 persons				Y

Response	Local knowledge	Flood experience (% area associated with past events)[e]		Y		Y
Response	Insurance	Insurance availability proxy (high values = high % area classed as 1 in 75 flood zone)[f]		Y		Y
Response	Social networks	% single-pensioner household	Y	Y	Y	Y
Response	Social networks	% female lone-parent households			Y	Y
Response	Social networks	% single-person households (non-pensioner)			Y	Y
Response	Social networks	% lone-parent households with dependent children	Y	Y	Y	Y
Response	Social networks	% households with dependent children aged <4			Y	Y
Response	Social networks	% people who do not provide unpaid care (reverse of formal variable)	Y	Y	Y	Y
Response	Mobility	% disabled	Y	Y	Y	Y
Response	Mobility	% households with no car	Y	Y	Y	Y
Response	Mobility	% households without more than one car (reverse of formal variable)			Y	Y
Response	Mobility	Distance travelled to work		Y		Y
Response	Mobility	% not home workers (resident population)		Y		Y
Response	Mobility	% travel to work by public transport (resident population)				Y
Response	Mobility	Mean hours worked				Y
Response	Crime	**Rate of recorded violent crime per 100 people (FY 2006–07)[g]**	Y		Y	Y
Response	Crime	**Rate of recorded burglary per 100 buildings (FY 2006–07)[g]**	Y	Y	Y	Y
Response	Crime	**Rate of recorded theft per 100 people (FY 2006–07)[g]**	Y		Y	Y
Response	General access	**Travel time to the nearest transport hub[h]**	Y	Y	Y	Y
Response	General infrastructure	Density of VAT-registered retail units 2005 (low = higher vulnerability)[i]	Y		Y	
Response	General infrastructure	% change in number of enterprises (all) between 2005 and 2007 (high negative = high vulnerability)[i]	Y		Y	
Response	General infrastructure	% change in number of enterprises (retail) between 2005 and 2007 (high negative = high vulnerability)[i]			Y	
Recovery	Income	% EA unemployed aged 16–74		Y		Y
Recovery	Income	% people routine/manual		Y		Y
Recovery	Income	% people never worked/long-term unemployed		Y		Y
Recovery	Income	% households with no adults in employment and dependent children		Y		Y
Recovery	Income	% households with no adults in employment (no children)				Y
Recovery	Income	Average weekly household total income estimate (low = high vulnerability)[d]				Y

Recovery	Income	Average weekly household net income estimate (low = high vulnerability)[d]				Y
Recovery	Income	Average weekly household net income estimate (low = high vulnerability) (eq. before housing)[d]				Y
Recovery	Income	Average weekly household net income estimate (low = high vulnerability) (eq. after housing costs)[d]		Y		Y
Recovery	Income	% all-pensioner households		Y		Y
Recovery	Info use	% born outside UK	Y	Y	Y	Y
Recovery	Info use	% born in other EU countries			Y	Y
Recovery	Info use	% born outside Europe			Y	Y
Recovery	Info use	% people with no or level 1 qualification			Y	Y
Recovery	Info use	People with <1 yr residency coming from outside UK	Y	Y	Y	Y
Recovery	Insurance	Insurance availability proxy (high values = high % area classed as 1-in-75-year flood zone)[f]		Y		Y
Recovery	Social networks	% single-pensioner households	Y	Y	Y	Y
Recovery	Social networks	% female lone-parent households			Y	Y
Recovery	Social networks	% single-person households (non-pensioner)			Y	Y
Recovery	Social networks	% lone-parent households with dependent children	Y	Y	Y	Y
Recovery	Social networks	% households with dependent children <4			Y	Y
Recovery	Social networks	% people who do not provide unpaid care (reverse of formal variable)	Y	Y	Y	Y
Recovery	Mobility	% disabled	Y	Y	Y	Y
Recovery	Mobility	% households with no car	Y		Y	
Recovery	Mobility	% households without more than one car (reverse of formal variable)			Y	
Recovery	Mobility	Distance travelled to work	Y		Y	
Recovery	Mobility	% not home workers (resident pop.) (reverse of formal variable)	Y		Y	
Recovery	Mobility	% travel to work by public transport (resident population)			Y	
Recovery	Mobility	Mean hours worked			Y	
Recovery	Service Access	**Average travel time to nearest GP**[h]	Y		Y	
Recovery	Service Access	**Average travel time to transport nodes**[h]	Y		Y	

Notes:

All data is from or derived from the UK Census 2001, except for:

a Calculated from urban footprint boundaries EDINA UKBORDERS

b Calculated from EDINA UKBORDERS coastline data. Estimates are based on as-the-crow-flies (Euclidean) distances

c Calculated from US Geological Survey Digital Elevation Model (1km)

d Income: Model-based Estimates at MSOA Level, 2004/05, Office of National Statistics

e Environment Agency historical flood zones

f Environment Agency NaFRA Spatial 0910

g Welsh Index of Multiple Deprivation, www.dataunitwales.gov.uk

h Accessibility indicators, www.dataunitwales.gov.uk

i VAT-based Enterprises by Broad Industry Group, 2005 and 2007, Office of National Statistics

Table 4: List of indicators and domains used for Northern Ireland

Differences in indicators compared with England are shown in bold.

Dimension	Domain	Indicator	Locations		Groups	
			Heat	Flood	Heat	Flood
Sensitivity	Age	% very young (<5)	Y	Y	Y	Y
Sensitivity	Age	% old (>65)			Y	Y
Sensitivity	Age	% very old (>75)	Y	Y	Y	Y
Sensitivity	Age	Net change in population of children (2001–02)			Y	Y
Sensitivity	Age	Net change in population of older people (2001–02)			Y	Y
Sensitivity	Health	% with limiting long-term illness (LLTI)	Y	Y	Y	Y
Sensitivity	Health	% with LLTI but working			Y	Y
Sensitivity	Health	% in poor health			Y	Y
Sensitivity	Health	% households with at least one person with LLTI	Y	Y	Y	Y
Sensitivity	Care	% in nursing care			Y	Y
Sensitivity	Care	% in residential care			Y	Y
Enhanced exposure	Physical environment	**% urban[a]**	Y	Y	Y	Y
Enhanced exposure	Physical geography	**Average distance to coast of zone[b]**	Y		Y	
Enhanced exposure	Physical geography	**Minimum distance from coast in the zone[b]**			Y	
Enhanced exposure	Physical geography	**Average elevation for the zone (low = high exposure)[c]**	Y		Y	
Enhanced exposure	Physical geography	**Maximum elevation for the zone (low = high exposure)[c]**			Y	
Enhanced exposure	Housing	% households lowest floor level: basement or semi-basement		Y		Y
Enhanced exposure	Housing	% households lowest floor level: ground floor (street level)		Y		Y
Enhanced exposure	Housing	% households lowest floor level: fifth floor or higher	Y		Y	
Preparedness	Income	% unemployed	Y	Y	Y	Y
Preparedness	Income	% in low-income work (elementary occupations)	Y	Y	Y	Y
Preparedness	Income	% never worked	Y	Y	Y	Y
Preparedness	Income	**% unemployed never worked/long-term unemployed**			Y	Y
Preparedness	Income	% households with no adults working and with dependent children	Y	Y	Y	Y
Preparedness	Income	% households with no adults working with no dependent children			Y	Y
Preparedness	Income	**% households in relative poverty, unequivalised, 2004–05[d]**			Y	Y

Preparedness	Income	**% households in relative poverty, equivalised, 2004–05[d]**	Y	Y	Y	Y
Preparedness	Income	% all-pensioner households	Y	Y	Y	Y
Preparedness	Tenure	% renting from social landlords	Y	Y	Y	Y
Preparedness	Tenure	% renting from private landlords	Y	Y	Y	Y
Preparedness	Tenure	% households not owner occupied (reverse of formal variable)			Y	Y
Preparedness	Tenure	% households not owned outright (reverse of formal variable)			Y	Y
Preparedness	Info use	% born outside UK and Ireland	Y	Y	Y	Y
Preparedness	Info use	% born in other EU countries (excluding Ireland)			Y	Y
Preparedness	Info use	% born elsewhere (outside Europe)			Y	Y
Preparedness	Info use	New migrants from overseas (people with <1 yr residency coming from outside UK)	Y	Y	Y	Y
Preparedness	Info use	% with basic education (no or level 1)			Y	Y
Preparedness	Local knowledge	New migrants from outside the local area		Y		Y
Preparedness	Local knowledge	Net change in population (community knowledge loss)				Y
Preparedness	Insurance	**Past flood events (% area associated with past events)[e]**		Y		Y
Response	Income	% EA unemployed aged 16–74	Y	Y	Y	Y
Response	Income	% people elementary occupations	Y	Y	Y	Y
Response	Income	% people never worked/long-term unemployed	Y	Y	Y	Y
Response	Income	**% unemployed never worked/long-term unemployed**			Y	Y
Response	Income	% households with no adults in employment and dependent children	Y	Y	Y	Y
Response	Income	% households with no adults in employment (no children)			Y	Y
Response	Income	**% households in relative poverty, unequivalised, 2004–05[d]**			Y	Y
Response	Income	**% households in relative poverty, equivalised, 2004–05[d]**	Y	Y	Y	Y
Response	Income	% all-pensioner households	Y	Y	Y	Y
Response	Info use	% born outside UK and Ireland	Y	Y	Y	Y
Response	Info use	% born in other EU countries (excluding Ireland)			Y	Y
Response	Info use	% born elsewhere (outside Europe)			Y	Y
Response	Info use	% people with no or level 1 qualification			Y	Y
Response	Info use	People with <1 yr residency coming from outside UK	Y	Y	Y	Y
Response	Local knowledge	People with <1 yr residency in immediate area		Y		Y
Response	Local knowledge	Net change; all ages rate per 1,000 persons				Y

Response	Insurance	**Past flood events (% area associated with past events)**[e]		Y		Y
Response	Social networks	% single-pensioner households	Y	Y	Y	Y
Response	Social networks	% female lone-parent households			Y	Y
Response	Social networks	% single-person households (non-pensioner)			Y	Y
Response	Social networks	% lone-parent households with dependent children	Y	Y	Y	Y
Response	Social networks	% households with dependent children			Y	Y
Response	Social networks	% people who do not provide unpaid care (reverse of formal variable)	Y	Y	Y	Y
Response	Mobility	% disabled	Y	Y	Y	Y
Response	Mobility	% households with no car/van	Y	Y	Y	Y
Response	Mobility	% households without more than one car/van (reverse of formal variable)			Y	Y
Response	Mobility	% not home workers (resident pop.)		Y		Y
Response	Mobility	% travel to work by public transport (resident population)				Y
Response	Mobility	Mean hours worked				Y
Response	Crime	**Crime and Disorder Score**[d]	Y	Y	Y	Y
Response	Crime	**Crime Score**[d]			Y	Y
Response	Crime	**Disorder Score**[d]			Y	Y
Response	General access	**Proximity to Services Score**[d]	Y	Y	Y	Y
Recovery	Income	% EA unemployed aged 16–74		Y		Y
Recovery	Income	% people elementary occupations		Y		Y
Recovery	Income	% people never worked/long-term unemployed		Y		Y
Recovery	Income	**% unemployed never worked/long-term unemployed**				Y
Recovery	Income	% households with no adults in employment and dependent children		Y		Y
Recovery	Income	% households with no adults in employment (no children)				Y
Recovery	Income	**% households in relative poverty, unequivalised, 2004–05**[d]				Y
Recovery	Income	**% households in relative poverty, equivalised, 2004–05**[d]		Y		Y
Recovery	Income	% all-pensioner households		Y		Y
Recovery	Info use	% born outside UK and Ireland	Y	Y	Y	Y
Recovery	Info use	% born in other EU countries (excluding Ireland)			Y	Y
Recovery	Info use	% born elsewhere (outside Europe)			Y	Y
Recovery	Info use	% people with no or level 1 qualification			Y	Y
Recovery	Info use	People with <1 yr residency coming from outside UK	Y	Y	Y	Y
Recovery	Insurance	**Past flood events (% area associated with past events)**[e]		Y		Y

Recovery	Social networks	% single-pensioner households	Y	Y	Y	Y
Recovery	Social networks	% female lone-parent households			Y	Y
Recovery	Social networks	% single-person households (non-pensioner)			Y	Y
Recovery	Social networks	% lone-parent households with dependent children	Y	Y	Y	Y
Recovery	Social networks	% households with dependent children <4			Y	Y
Recovery	Social networks	% people who do not provide unpaid care (reverse of formal variable)	Y	Y	Y	Y
Recovery	Mobility	% disabled	Y	Y	Y	Y
Recovery	Mobility	% households with no car	Y		Y	
Recovery	Mobility	% households without more than one car (reverse of formal variable)			Y	
Recovery	Mobility	% not home workers (resident population) (reverse of formal variable)	Y		Y	
Recovery	Mobility	% travel to work by public transport (resident population)			Y	
Recovery	Mobility	Mean hours worked			Y	
Recovery	Service access	**Proximity to Services Score**[d]			Y	
Recovery	Service access	**Mean distance to nearest GP**[f]	Y		Y	
Recovery	Service access	**Average travel time to nearest hospital with emergency services**[f]	Y		Y	

Notes:

All data is from or derived from the UK Census 2001 (accessed from Northern Ireland Neighbourhood Information Service (NINIS), www.ninis.nisra.gov.uk), except for:

a Calculated from urban footprint boundaries EDINA UKBORDERS

b Calculated from EDINA UKBORDERS coastline data. Estimates are based on as-the-crow-flies (Euclidean) distances

c Mean elevation, Northern Ireland Neighbourhood Information Service (NINIS), www.ninis.nisra.gov.uk

d Northern Ireland Multiple Deprivation Measure 2005, Northern Ireland Neighbourhood Information Service (NINIS), www.ninis.nisra.gov.uk

e Northern Ireland historical flood zones, Rivers Agency, Department of Agriculture, Rural Development Northern Ireland (DARDNI)

f Calculated from locations of GPs and emergency hospitals from geospatial data provided by Northern Ireland Neighbourhood Information Service (NINIS), www.ninis.nisra.gov.uk. Estimates are based on as-the-crow-flies (Euclidean) distances

Table 5: List of indicators and domains used for Scotland

Differences in indicators compared with England are shown in bold.

Dimension	Domain	Indicator	Locations		Groups	
			Heat	Flood	Heat	Flood
Sensitivity	Age	% very young (<5)	Y	Y	Y	Y
Sensitivity	Age	% old (>65)			Y	Y
Sensitivity	Age	% very old (>75)	Y	Y	Y	Y
Sensitivity	Health	% with limiting long-term illness (LLTI)	Y	Y	Y	Y
Sensitivity	Health	% with LLTI but working			Y	Y
Sensitivity	Health	% in poor health			Y	Y
Sensitivity	Health	% households with at least one person with LLTI	Y	Y	Y	Y
Sensitivity	Care	% in nursing care			Y	Y
Sensitivity	Care	% in residential care			Y	Y
Enhanced exposure	Physical environment	**% urban[a]**	Y	Y	Y	Y
Enhanced exposure	Physical geography	**Average distance to coast of zone[b]**	Y		Y	
Enhanced exposure	Physical geography	**Minimum distance from coast in the zone[b]**			Y	
Enhanced exposure	Physical geography	**Average elevation for the zone (low = high exposure)[c]**	Y		Y	
Enhanced exposure	Physical geography	**Maximum elevation for the zone (low = high exposure)[c]**			Y	
Enhanced exposure	Housing	% households lowest floor level: basement or semi-basement		Y		Y
Enhanced exposure	Housing	% households lowest floor level: ground floor (street level)		Y		Y
Enhanced exposure	Housing	% households lowest floor level: fifth floor or higher	Y		Y	
Preparedness	Income	% unemployed	Y	Y	Y	Y
Preparedness	Income	% in low-income work (routine/manual)	Y	Y	Y	Y
Preparedness	Income	**Workless client group: % of working age population[d]**			Y	Y
Preparedness	Income	**% unemployed never worked/long-term unemployed**	Y	Y	Y	Y
Preparedness	Income	% households with no adults working and with dependent children	Y	Y	Y	Y
Preparedness	Income	% households with no adults working with no dependent children			Y	Y
Preparedness	Income	**% households income deprived (decile, 2004–05)[e]**	Y	Y	Y	Y
Preparedness	Income	% all-pensioner households	Y	Y	Y	Y
Preparedness	Income	% pensioners	Y	Y	Y	Y
Preparedness	Tenure	% renting from social landlords	Y	Y	Y	Y
Preparedness	Tenure	% renting from private landlords	Y	Y	Y	Y

Preparedness	Tenure	% households not owner occupied (reverse of formal variable)			Y	Y
Preparedness	Tenure	% households not owned outright (reverse of formal variable)			Y	Y
Preparedness	Info use	% born outside UK	Y	Y	Y	Y
Preparedness	Info use	% born in other EU countries			Y	Y
Preparedness	Info use	% born elsewhere (outside Europe)			Y	Y
Preparedness	Info use	New migrants from overseas (people with <1 yr residency coming from outside UK)	Y	Y	Y	Y
Preparedness	Info use	% with basic education (no or level 1)			Y	Y
Preparedness	Local knowledge	New migrants from outside the local area		Y		Y
Preparedness	Local knowledge	**% non-white households with <1 yr residency in area**				Y
Preparedness	Insurance	**Past flood events (% area associated with past events)**[f]		Y		Y
Response	Income	% unemployed	Y	Y	Y	Y
Response	Income	% in low-income work (routine/manual)	Y	Y	Y	Y
Response	Income	**Workless client group: % of working age population**[d]			Y	Y
Response	Income	**% unemployed never worked/long-term unemployed**	Y	Y	Y	Y
Response	Income	% households with no adults working and with dependent children	Y	Y	Y	Y
Response	Income	% households with no adults working with no dependent children			Y	Y
Response	Income	**% households income deprived (decile, 2004–05)**[e]	Y	Y	Y	Y
Response	Income	% all-pensioner households	Y	Y	Y	Y
Response	Income	% pensioners	Y	Y	Y	Y
Response	Info use	% born outside UK	Y	Y	Y	Y
Response	Info use	% born in other EU countries			Y	Y
Response	Info use	% born elsewhere (outside Europe)			Y	Y
Response	Info use	New migrants from overseas (people with <1 yr residency coming from outside UK)	Y	Y	Y	Y
Response	Info use	% with basic education (no or level 1)			Y	Y
Response	Local knowledge	New migrants from outside the local area		Y		Y
Response	Local knowledge	**% non-white households with <1 yr residency in area**				Y
Response	Insurance	**Past flood events (% area associated with past events)**[f]		Y		Y
Response	Social networks	% single-pensioner households	Y	Y	Y	Y
Response	Social networks	% female lone-parent households			Y	Y
Response	Social networks	% single-person households (non-pensioner)			Y	Y

Response	Social networks	% lone-parent households with dependent children	Y	Y	Y	Y
Response	Social networks	% households with dependent children			Y	Y
Response	Social networks	% people who do not provide unpaid care (reverse of formal variable)	Y	Y	Y	Y
Response	Mobility	% disabled	Y	Y	Y	Y
Response	Mobility	**Average yearly incapacity benefit/ severe disablement allowance claimants**[d]	Y	Y	Y	Y
Response	Mobility	% households with no car/van	Y	Y	Y	Y
Response	Mobility	% households without more than one car/ van (reverse of formal variable)			Y	Y
Response	Mobility	% not home workers (resident pop.)		Y		Y
Response	Mobility	% travel to work by public transport (resident pop.)				Y
Response	Mobility	Mean hours worked				Y
Response	Crime	**Total no. of SIMD crimes**			Y	Y
Response	Crime	**No. SIMD crimes per 10,000**[e]	Y	Y	Y	Y
Response	General access	**Average distance (km) travelled to place of work or study**[d]	Y	Y	Y	Y
Recovery	Income	% unemployed		Y		Y
Recovery	Income	% in low-income work (routine/manual)		Y		Y
Recovery	Income	**Workless client group: % of working age population**[d]				Y
Recovery	Income	**% unemployed never worked/long-term unemployed**		Y		Y
Recovery	Income	% households with no adults working and with dependent children		Y		Y
Recovery	Income	% households with no adults working with no dependent children				Y
Recovery	Income	**% households income deprived (decile, 2004/05)**[e]		Y		Y
Recovery	Income	% all-pensioner households		Y		Y
Recovery	Income	% pensioners		Y		Y
Recovery	Info use	% born outside UK and Ireland	Y	Y	Y	Y
Recovery	Info use	% born in other EU countries (excluding Ireland)			Y	Y
Recovery	Info use	% born elsewhere (outside Europe)			Y	Y
Recovery	Info use	% people with no or level 1 qualification			Y	Y
Recovery	Info use	People with <1 yr residency coming from outside UK	Y	Y	Y	Y
Recovery	Insurance	**Past flood events (% area associated with past events)**[e]		Y		Y
Recovery	Social networks	% single-pensioner households	Y	Y	Y	Y
Recovery	Social networks	% female lone-parent households			Y	Y
Recovery	Social networks	% single-person households (non-pensioner)			Y	Y
Recovery	Social networks	% lone-parent households with dependent children	Y	Y	Y	Y

Recovery	Social networks	% households with dependent children <4			Y	Y
Recovery	Social networks	% people who do not provide unpaid care (reverse of formal variable)	Y	Y	Y	Y
Recovery	Mobility	% disabled	Y	Y	Y	Y
Recovery	Mobility	**Average yearly incapacity benefit/ severe disablement allowance claimants**[d]	Y	Y	Y	Y
Recovery	Mobility	% households with no car	Y		Y	
Recovery	Mobility	% households without more than one car (reverse of formal variable)			Y	
Recovery	Mobility	% not home workers (resident population) (reverse of formal variable)	Y		Y	
Recovery	Mobility	% travel to work by public transport (resident population)			Y	
Recovery	Mobility	Mean hours worked			Y	
Recovery	Service access	**Mean distance to GP surgery**[d]	Y		Y	

Notes:

All data is from or derived from the UK Census 2001 (OA area data aggregated to DZ level), except for:

a Calculated from urban footprint boundaries EDINA UKBORDERS

b Calculated from EDINA UKBORDERS coastline data. Estimates are based on as-the-crow-flies (Euclidean) distances

c Mean elevation, calculated from the same source as for the other devolved nations

d Scottish National Statistics

e Scottish Index of Multiple Deprivation 2004/5, Scottish National Statistics

f Scottish Environment Protection Agency historical flood zones

Table 6: Specific indicators used for the LSOA analysis (Greater Manchester)

Dimension	Domain	Indicator	Locations		Groups	
			Heat	Flood	Heat	Flood
Sensitivity	Age	% very young (<5)	Y	Y	Y	Y
Sensitivity	Age	% old (>65)			Y	Y
Sensitivity	Age	% very old (>75)	Y	Y	Y	Y
Sensitivity	Age	Net change in population of children (2001–02)			Y	Y
Sensitivity	Age	Net change in population of older people (2001–02)			Y	Y
Sensitivity	Health	% with limiting long-term illness (LLTI)	Y	Y	Y	Y
Sensitivity	Health	% with LLTI but working			Y	Y
Sensitivity	Health	% in poor health			Y	Y
Sensitivity	Health	% households with at least one person with LLTI	Y	Y	Y	Y
Sensitivity	Care	% in nursing care			Y	Y
Sensitivity	Care	% in residential care			Y	Y
Enhanced exposure	Physical environment	% zone not green space 2001[a]	Y	Y	Y	Y
Enhanced exposure	Physical environment	Area of domestic buildings per unit area of domestic gardens 2001[a]	Y	Y	Y	Y
Enhanced exposure	Physical environment	% zone not blue space 2001[a]	Y		Y	
Enhanced exposure	Physical geography	Distance from coast for the zone population weighted centroid[b]	Y		Y	
Enhanced exposure	Physical geography	Average distance to coast of zone[b]			Y	
Enhanced exposure	Physical geography	Average elevation for the zone population weighted centroid (low = high exposure)[c]	Y		Y	
Enhanced exposure	Physical geography	Average elevation for the zone (low = high exposure)[c]			Y	
Enhanced exposure	Housing	% households lowest floor level: basement or semi-basement		Y		Y
Enhanced exposure	Housing	% households lowest floor level: ground floor (street level)		Y		Y
Enhanced exposure	Housing	% households lowest floor level: fifth floor or higher	Y		Y	
Preparedness	Income	% unemployed	Y	Y	Y	Y
Preparedness	Income	% in low-income work (routine/manual)	Y	Y	Y	Y
Preparedness	Income	% never worked	Y	Y	Y	Y
Preparedness	Income	% households with no adults working and with dependent children	Y	Y	Y	Y
Preparedness	Income	% households with no adults working with no dependent children			Y	Y
Preparedness	Income	Income deprivation affecting children[d]	Y	Y	Y	Y
Preparedness	Income	Income deprivation affecting older people[d]	Y	Y	Y	Y
Preparedness	Income	Income score[d]			Y	Y
Preparedness	Income	% all-pensioner households			Y	Y

Preparedness	Tenure	% renting from social landlords	Y	Y	Y	Y
Preparedness	Tenure	% renting from private landlords	Y	Y	Y	Y
Preparedness	Tenure	% households not owner occupied (reverse of formal variable)			Y	Y
Preparedness	Tenure	% households not owned outright (reverse of formal variable)			Y	Y
Preparedness	Info use	% born outside UK	Y	Y	Y	Y
Preparedness	Info use	% born in other EU countries			Y	Y
Preparedness	Info use	% born outside Europe			Y	Y
Preparedness	Info use	New migrants from overseas (people with <1 yr residency coming from outside UK)	Y	Y	Y	Y
Preparedness	Info use	% with basic education			Y	Y
Preparedness	Local knowledge	New migrants from outside the local area		Y		Y
Preparedness	Local knowledge	Net change in population (community knowledge loss)				Y
Preparedness	Local knowledge	Flood experience (% area associated with past events)[e]		Y		Y
Preparedness	Insurance	Insurance availability proxy (high values = high % area classed as 1-in-75-year flood zone)[f]		Y		Y
Response	Income	% EA unemployed aged 16–74	Y	Y	Y	Y
Response	Income	% people routine/manual	Y	Y	Y	Y
Response	Income	% people never worked/long-term unemployed	Y	Y	Y	Y
Response	Income	% households with no adults in employment and dependent children	Y	Y	Y	Y
Response	Income	% households with no adults in employment (no children)			Y	Y
Response	Income	Income deprivation affecting children[d]	Y	Y	Y	Y
Response	Income	Income deprivation affecting older people[d]	Y	Y	Y	Y
Response	Income	Income score[d]			Y	Y
Response	Income	% all-pensioner households			Y	Y
Response	Info use	% born outside UK	Y	Y	Y	Y
Response	Info use	% born in other EU countries			Y	Y
Response	Info use	% born elsewhere (outside Europe)			Y	Y
Response	Info use	% people with no or level 1 qualification			Y	Y
Response	Info use	People with <1 yr residency coming from outside UK	Y	Y	Y	Y
Response	Local knowledge	People with <1 yr residency in immediate area		Y		Y
Response	Local knowledge	Net change; all ages rate per 1,000 persons				Y
Response	Local knowledge	Flood experience (% area associated with past events)[e]		Y		Y
Response	Insurance	Insurance availability proxy (high values = high % area classed as 1-in-75-year flood zone)[f]		Y		Y

Response	Social networks	% single-pensioner households	Y	Y	Y	Y
Response	Social networks	% female lone-parent households			Y	Y
Response	Social networks	% single-person households (non-pensioner)			Y	Y
Response	Social networks	% lone-parent households with dependent children	Y	Y	Y	Y
Response	Social networks	% households with dependent children aged <4			Y	Y
Response	Social networks	% people who do not provide unpaid care (reverse of formal variable)	Y	Y	Y	Y
Response	Mobility	% disabled	Y	Y	Y	Y
Response	Mobility	% households with no car	Y	Y	Y	Y
Response	Mobility	% households without more than one car (reverse of formal variable)			Y	Y
Response	Mobility	Distance travelled to work		Y		Y
Response	Mobility	% not home workers (resident population)		Y		Y
Response	Mobility	% travel to work by public transport (resident population)				Y
Response	Mobility	Mean hours worked				Y
Response	Crime	MDI crime score (no disaggregated burglary)[g]	Y	Y	Y	Y
Response	General access	% area not road[a]	Y	Y	Y	Y
Recovery	Income	% EA unemployed aged 16–74		Y		Y
Recovery	Income	% people routine/manual		Y		Y
Recovery	Income	% people never worked/long-term unemployed		Y		Y
Recovery	Income	% households with no adults in employment and dependent children		Y		Y
Recovery	Income	% households with no adults in employment (no children)				Y
Recovery	Income	Income deprivation affecting children[d]		Y		Y
Recovery	Income	Income deprivation affecting older people[d]		Y		Y
Recovery	Income	Income score[d]				Y
Recovery	Income	% all-pensioner households				Y
Recovery	Info use	% born outside UK	Y	Y	Y	Y
Recovery	Info use	% born in other EU countries			Y	Y
Recovery	Info use	% born outside Europe			Y	Y
Recovery	Info use	% people with no or level 1 qualification			Y	Y
Recovery	Info use	People with <1 yr residency coming from outside UK	Y	Y	Y	Y
Recovery	Insurance	Insurance availability proxy (high values = high % area classed as 1-in-75-year flood zone)[f]		Y		Y
Recovery	Social networks	% single-pensioner households	Y	Y	Y	Y
Recovery	Social networks	% female lone-parent households			Y	Y
Recovery	Social networks	% single-person households (non-pensioner)			Y	Y

Recovery	Social networks	% lone-parent households with dependent children	Y	Y	Y	Y
Recovery	Social networks	% households with dependent children aged <4			Y	Y
Recovery	Social networks	% people who do not provide unpaid care (reverse of formal variable)	Y	Y	Y	Y
Recovery	Mobility	% disabled	Y	Y	Y	Y
Recovery	Mobility	% households with no car	Y		Y	
Recovery	Mobility	% households without more than one car (reverse of formal variable)			Y	
Recovery	Mobility	Distance travelled to work	Y		Y	
Recovery	Mobility	% not home workers (resident population) (reverse of formal variable)	Y		Y	
Recovery	Mobility	% travel to work by public transport (resident population)			Y	
Recovery	Mobility	Mean hours worked			Y	
Recovery	Service access	Travel time to nearest GP by walk/PT[h]	Y		Y	
Recovery	Service access	Frequency score reflecting the availability[h] of bus services providing this travel time (low = high vulnerability)			Y	
Recovery	Service access	Travel time to nearest GP centre by car[h]			Y	
Recovery	Service access	% of risk population (no car) outside of 15 minutes by walk/PT (reverse of formal variable)[h]	Y		Y	
Recovery	Service access	% of risk population (no car) outside of 30 minutes by walk/PT (reverse of formal variable)[h]			Y	
Recovery	Service access	Number of GPs within 15 minutes by walk/PT (low = high vulnerability)[h]	Y		Y	
Recovery	Service access	Number of GPs within 15 minutes by car (low = high vulnerability)[h]	Y		Y	
Recovery	Service access	Number of GPs within 30 minutes by walk/PT (low = high vulnerability)[h]			Y	
Recovery	Service access	Number of GPs within 30 minutes by car (low = high vulnerability)[h]			Y	
Recovery	Service access	Travel time to nearest hospital by walk/PT[h]	Y		Y	
Recovery	Service access	Frequency score reflecting the availability of bus services providing this travel time (low = high vulnerability)[h]			Y	
Recovery	Service access	Travel time to nearest hospital centre by car[h]	Y		Y	
Recovery	Service access	% of risk population outside of 30 minutes by walk/PT (reverse of formal variable)[h]	Y		Y	
Recovery	Service access	% of risk population outside of 60 minutes by walk/PT (reverse of formal variable)[h]			Y	
Recovery	Service access	Number of hospitals within 30 minutes by walk/PT(low = high vulnerability)[h]	Y		Y	

Recovery	Service access	Number of hospitals within 30 minutes by car (low = high vulnerability)[h]	Y
Recovery	Service access	Number of hospitals within 60 minutes by walk/PT (low = high vulnerability)[h]	Y

Notes:

All data is from or derived from the UK Census 2001, except for:

a Land Use Statistics (Generalised Land Use Database), 2005, Office of National Statistics

b Calculated from EDINA UKBORDERS coastline data; estimates are based on as-the-crow-flies (Euclidean) distances

c Calculated from US Geological Survey Digital Elevation Model (1km)

d English Indices of Multiple Deprivation 2004, Office of National Statistics

e Environment Agency historical flood zones

f Environment Agency NaFRA Spatial 0910

g English Indices of Multiple Deprivation 2004, Office of National Statistics

h Accessibility statistics, 2008, Office of National Statistics

Appendix II

Detailed PCA results supporting the socially vulnerable groups analysis

Socially flood vulnerable groups in England

For total socio-spatial flood vulnerability, five factors accounted for 84% of the variance (Table 7).

Table 7: Underlying factors in the composite socio-spatial flood vulnerability dataset for England

All indicators show high positive values = high vulnerability	**Component**				
	1	**2**	**3**	**4**	**5**
Average weekly household net income estimate (reversed high values = low incomes)	.929				
% households of total not owner occupied	.860				
% households with dependent children aged <4	.768				
% households lowest floor level: ground floor (street level)	–.676				
% people with no or level 1 qualification	.617				
% households with no car		.928			
% with a limiting long-term illness (LLTI)		.918			
People with <1 yr residency in immediate area		.785			
Distance travelled to work		–.716			
% people not providing unpaid care		.661			
Mean hours worked			.792		
Potential for insurance access problems (high % area covered by 1:75 flood zone) (high area = high vulnerability)			.752		
% not home workers (resident population) (low home-working = high vulnerability)			–.679		
MDI crime score			–.670		
% aged 0–4				.839	
% aged >65				–.838	
% born outside UK				.726	
% disabled	–.611			–.618	
% EA unemployed aged 16–74					.788
% people never worked/long-term unemployed	.653				–.654
% variance explained	**37%**	**24%**	**11%**	**7%**	**5%**

Notes: Extraction method: Principal Component Analysis

Rotation method: Varimax with Kaiser Normalization

Rotation converged in 7 iterations

- Component 1 (see Figure 1a) has seven indicators and represents 37% of the variability in the total indicator dataset covering the five dimensions of socio-spatial flood vulnerability. High positive loadings on this component associate neighbourhoods with relatively low incomes, low home ownership and high proportions of young children. Housing may be particularly associated with non-street-level accommodation and further associations are made with relatively high proportions of people with only basic education rates. Proportions of disabled people are negatively loaded on this factor.

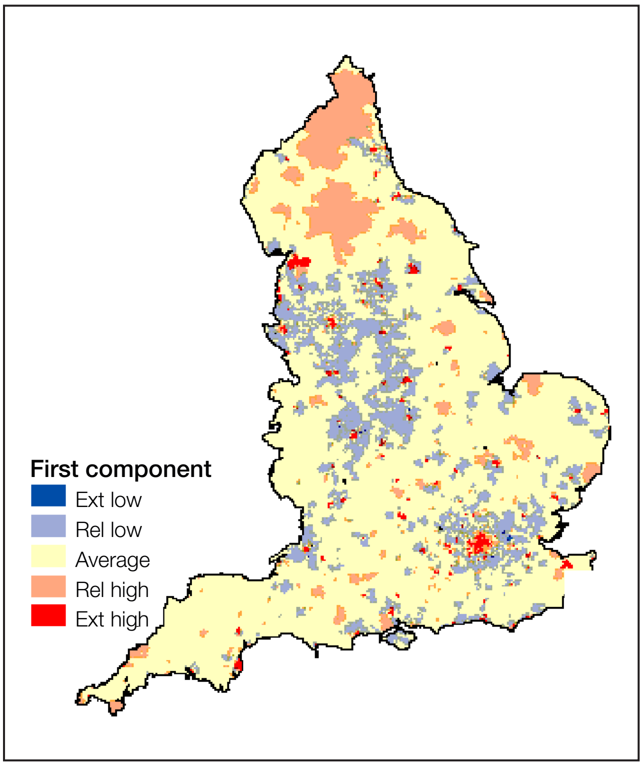
- Component 2 (see Figure 1b) (24%) links areas with lower proportions of private transport ownership and relatively high proportions of ill-health. Areas are also associated with a relatively high proportion of new migrants and low proportions of carers. People in these areas tend to work closer to home, which offsets some of their vulnerability.

- Component 3 (11%) associates long working hours which increases social vulnerability and higher likelihoods of a lack of insurance availability. The group is also associated with higher proportions of home working and lower crime, which offsets social vulnerability.

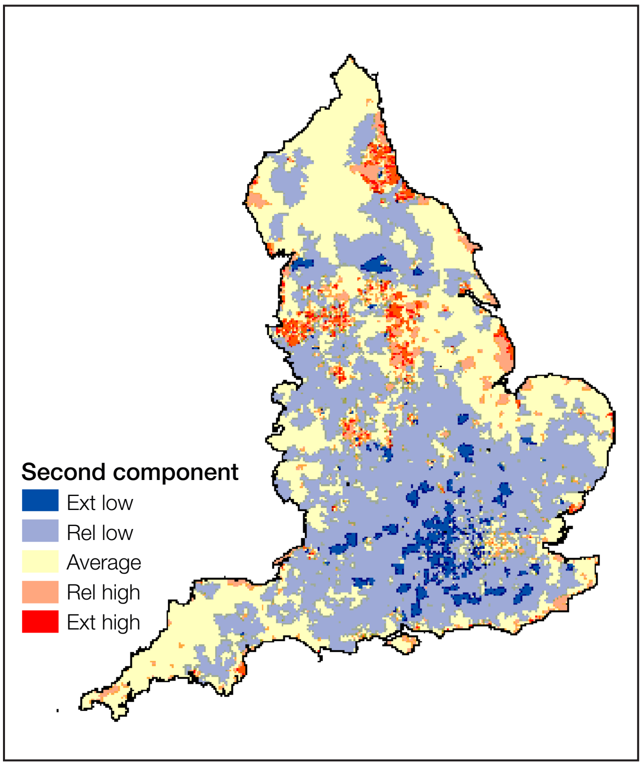
- Component 4 (7%) inversely associates higher proportions of young children and people born outside of the UK with lower proportions of people over 65 and proportions of disabled people.

- Component 5 (5%) finds areas with inversely related associations between unemployment rates and proportions of people who have never worked.

Figure 1a: First component – explains 37%



1b: Second component – explains 24%



Note: The most socially vulnerable neighbourhoods are shown in red and the least socially vulnerable neighbourhoods in blue. Yellow denotes study area means

Socially heat-vulnerable groups in England

The composite heatwave socially vulnerable group analysis, using PCA, extracted five factors as shown in Table 8. These components explain 75% of the overall variance in the socio-spatial heat vulnerability indicator database.

Table 8: Underlying factors in the composite socio-spatial heat vulnerability dataset for England

All indicators show high positive values = high vulnerability	Component				
	1	2	3	4	5
% disabled	.888				
Average weekly household net income estimate (reversed high values = low incomes)	.880				
% people with no or level 1 qualification	.816				
% with a limiting long-term illness (LLTI)	.786			–.532	
% EA unemployed aged 16–74	.785				
% lone-parent households with dependent children	.784				
MDI crime score (no disaggregated burglary)	.601				
Mean hours worked	–.535				
Frequency score reflecting the availability of bus services providing this travel time		.826			
Travel time to nearest hospital by walk/PT		.803			
Frequency score reflecting the availability of bus services providing this travel time		.776			
Travel time to nearest GP by walk/PT		.738			
% home workers (resident population) (reverse low = high vulnerability)	.592	–.665			
% of risk population (no car) outside of 15 minutes by walk/PT (reverse of formal variable)		.664			
% travel to work by public transport (resident population)			.803		
% born outside UK			.669		
% not green space			.606		
Number of GPs within 15 minutes by walk/PT		.533	–.580		
% population aged >65				–.865	
% households with no adults in employment (no children)				–.820	
% population aged <5				.780	
% people not providing unpaid care (reversed from original)				.597	.567
People with <1 yr residency coming from outside UK					.916
% people never worked/long-term unemployed					.845
% households rented from private landlords					.791
% variance explained	**31%**	**20%**	**10%**	**9%**	**5%**

Factor 1 (see Table 8) measures relative deprivation. The associations between all of the nine variables are positive except ‘mean hours worked’, which is not only negatively directed but also exhibiting the lowest loading. The factor explains 31% out of a total variance of 75%. Factor 1 enables MSOAs to be highlighted that are characterised by relatively high percentages of: disability, unemployment, low income, basic education, limiting long-term illness (LLTI), lone-parents with dependent children and high crime rates contrasted by mean hours worked. The geography of Factor 1 (see Figure 2) reveals high vulnerability in mostly urban areas of London, the North West, North East and Midlands. Examination of Factor 1 of the heatwave composite vulnerability reveals a great deal of similarity both in spatial pattern and underlying variables with Factor 1 of the heatwave response index. Figures 3–5 show the spatial distributions associated with the other components.

Figure 2: First component (31%)

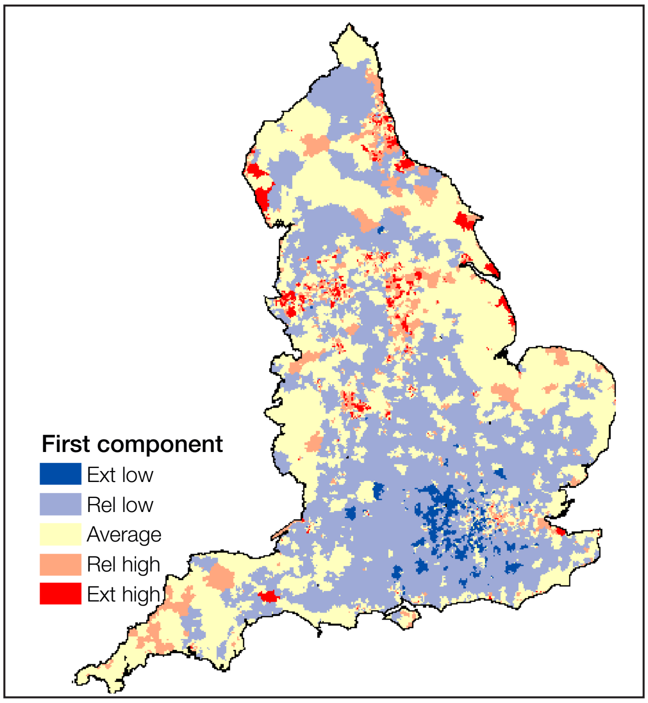


Figure 3: Second component (20%)

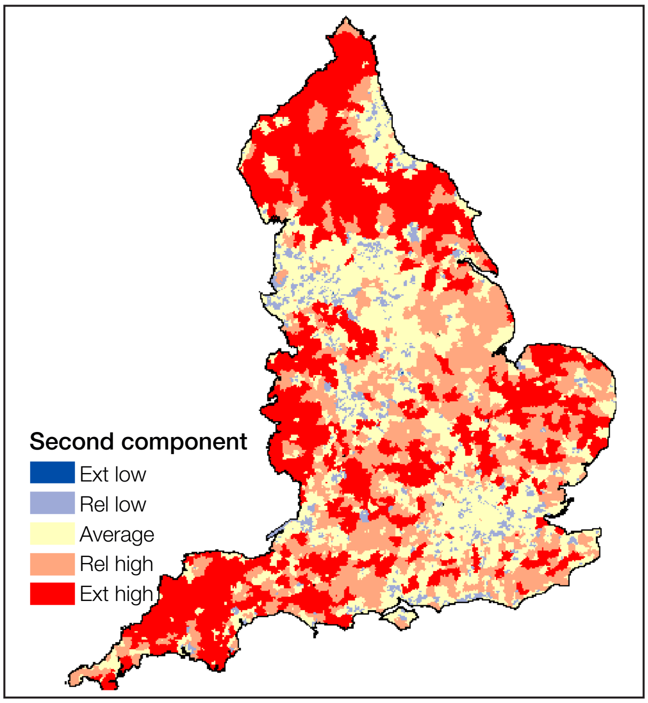


Figure 4: Third component (10%)

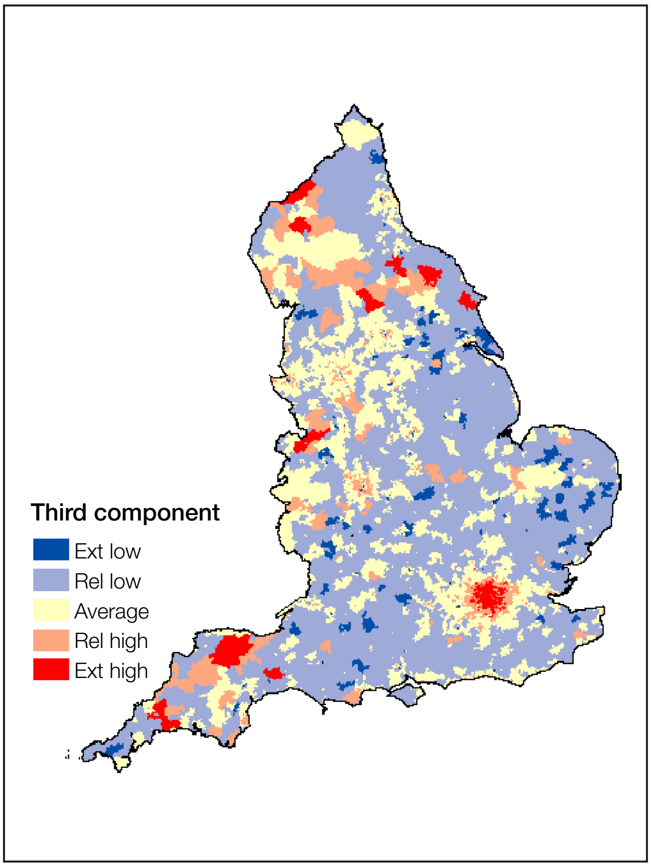
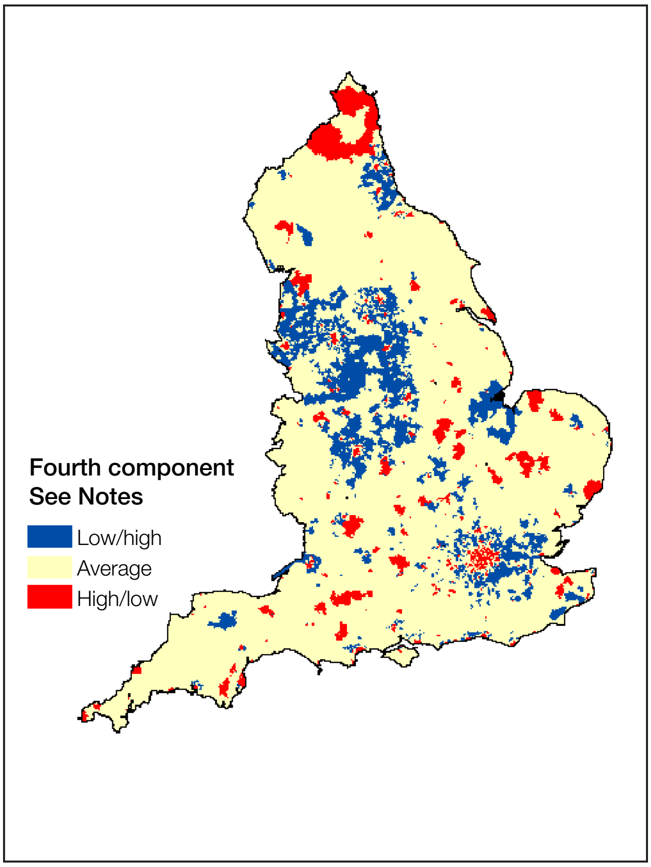


Figure 5: Fourth component (9%)



Note: The most highly socially vulnerable neighbourhoods are shown in red and the least socially vulnerable neighbourhoods in blue. Yellow denotes study area means. The fourth componenet can be interpreted as having socially vulnerable groups at either end of the spectrum of values.

Socially flood-vulnerable groups in Wales

Table 9: Underlying factors in the composite socio-spatial flood vulnerability dataset for Wales

All indicators show high positive values = high vulnerability	Component					
	1	2	3	4	5	6
Income (mean net after housing costs) (reversed high values = low incomes)	.882					
% households not owner occupied	.872					
% unemployed	.849					
% households with no car	.777	.521				
Rate of recorded violent crime per 100 people (2006–07)	.734					
% lone-parent households with dependent children	.717					
% with basic education	.699		–.597			

% renting from social landlords	.518					
Average distance (km) travelled to fixed place of work		–.803				
Travel time to the nearest transport hub		–.784				
% travel to work by public transport (resident population)		.741				
Mean hours worked		–.723				
Rate of recorded theft per 100 people (FY 2006–07)		.665				
% urban		.657				
% female lone-parent households		.605				
Rate of recorded burglary per 100 buildings (FY 2006–07)		.594				
New migrants from overseas			.887			
% born outside UK			.826			
% renting from private landlords			.820			
% people who do not provide unpaid care			.703			
% single-person households (non-pensioner)			.562			
% households with no adults working with no dependent children				–.917		
% aged >65				–.824		
% aged 0–4				.726		
% households not owned outright	.550			.565		
% with a limiting long-term illness (LLTI)	.524			–.550		
% households lowest floor level: basement or semi-basement					.756	
Net change in population (high values = high population and community knowledge loss)					.571	–.509
Net change; aged 1–14 (2001–02)					–.556	
% households lowest floor level: ground floor (street level)						
Net change; aged >65 (2001–02)						.768
% residents living in residential care						.673
% variance explained	**31%**	**15%**	**12%**	**8%**	**5%**	**3%**

Notes: Extraction method: Principal Component Analysis

Rotation method: Varimax with Kaiser Normalization

Rotation converged in 6 iterations

The first three components (groups) are explained in the main report. The three remaining components represent 16% from the 75% of the variance explained by the six factors as a whole. Group 4 shows associations between neighbourhoods with relatively low proportions of households with no members in work and no children, relatively low proportions of older people and relatively low proportions of people reporting limiting long-term health problems. These neighbourhoods are likely to be associated with higher proportions of children under 4 and higher percentages of homes which are not owned outright. Neighbourhoods at this end of the spectrum within Group 4 could therefore be considered to have some social vulnerability characteristics. However, the inverse relationships within Group 4 means that the group also contains neighbourhoods at the other end of the spectrum, i.e. neighbourhoods where relatively high proportions of people aged over 65 tend to be associated with relatively high proportions of people reporting LLTI, relatively high proportions of homes which are owned outright and relatively high proportions of households with no members in work. Clearly these neighbourhoods also have some vulnerability characteristics. Group 5 points to areas of relatively high proportions of basement housing being associated with population loss, both generally and in young people. The final group links population increases with high net change in people over 65 and higher proportions of people in residential care.

Socially heat-vulnerable groups in Wales

Table 10: Underlying factors in the composite socio-spatial heat vulnerability dataset in Wales

All indicators show high positive values = high vulnerability	Component						
	1	2	3	4	5	6	7
Income (mean net) (reversed high values = low incomes)	.880						
% unemployed	.872						
% households with no car	.807						
% households not owner occupied	.800						
Rate of recorded violent crime per 100 people (FY 2006–07)	.751						
% with basic education	.737	−.515					
% lone-parent households with dependent children	.666						
% with a limiting long-term illness (LLTI)	.657						
% renting from social landlords							
% renting from private landlords		.869					
New migrants from overseas		.843					
% born outside UK		.799					
% people who do not provide unpaid care		.714		.518			
Density of VAT-registered retail units (low density = high values)		−.712					
% single-person households (non-pensioner)		.644					
Net change; aged 1–14 (2001–02)							
Average distance (km) travelled to fixed place of work			−.817				
Rate of recorded theft per 100 people (FY 2006–07)			.729				
% not home workers			.726				
% travel to work by public transport (resident population)			.724				

Rate of recorded burglary per 100 buildings (FY 2006–07)			.631				
% urban			.621				
% female lone-parent households			.540				
% aged >65				–.805			
% aged 0–4				.780			
% households not owned outright				.653			
Net change; aged >65 (2001–02)					.790		
% residents living in residential care					.699		
People (count/1,000) with <1 yr residency coming from outside UK					–.543		
Mean proximity to coast for MSOA (metres)						–.871	
Maximum elevation (reversed so that high values = low elevation = higher enhanced exposure)						.748	
% change in number of enterprises (all) between 2005 and 2007 (reversed so that loss = positive values)							–.709
% households lowest floor level: fifth floor or higher							.679
% variance explained	**30%**	**16%**	**9%**	**7%**	**5%**	**4%**	**3%**

Notes: Extraction method: Principal Component Analysis

Rotation method: Varimax with Kaiser Normalization

Rotation converged in 8 iterations

The first five groups are explained in the main report. The final two groups are linked to enhanced exposure and community adaptation resource. They represent indicators which when taken together do not have a clear outcome in terms of overall social vulnerability; if anything, there is an aggregate social vulnerability reducing effect for the neighbourhoods associated with these groups. For example, in the penultimate group, the first indicator (which is the most influential), simply highlights that neighbourhoods with lower average distances to the coast (i.e. where temperatures are assumed to be generally offset compared to more inland locations) tend also to be associated with lower mean elevations (i.e. where temperatures are assumed to be generally enhanced compared with more upland locations). Therefore, for some neighbourhoods these two factors counteract one another. The final group associates areas with the potential for a relatively high enhanced exposure as a result of high-rise living with a tendency for relatively high amounts of commercial infrastructure and here the latter is the more dominant. Together, all of the groups explain 74% of the total variance in the indicator dataset for socio-spatial heat vulnerability in Wales.

Figure 6a is a seven-group aggregate showing socially derived heat vulnerability, which is generated using a methodology similar to the SoVI (see note 4). Figure 6b is an aggregate of the first three groups, which together explain 55% of the variance in the entire dataset. It shows the locations where there is spatial coincidence of the highly scoring neighbourhoods for each of the groups identified in the analysis.

Figure 6a: Seven-group aggregate

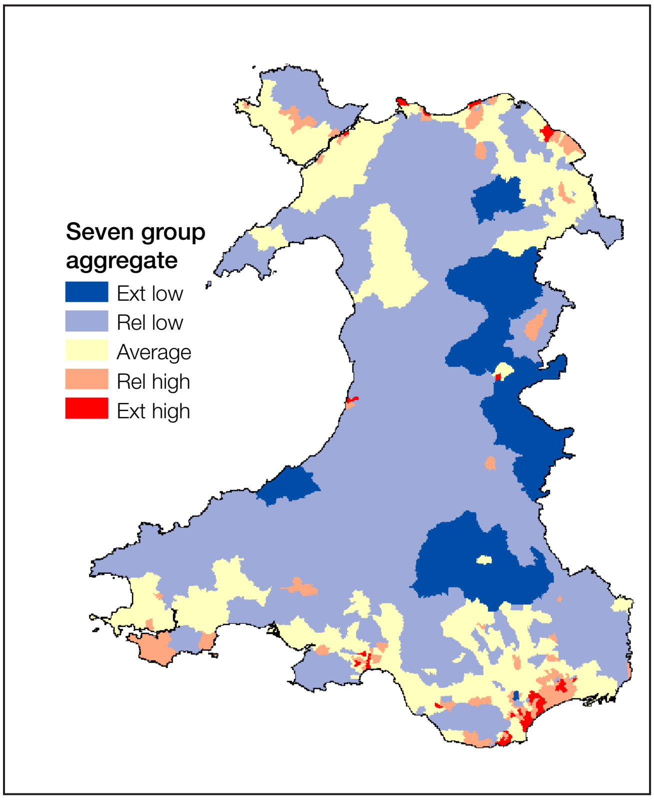
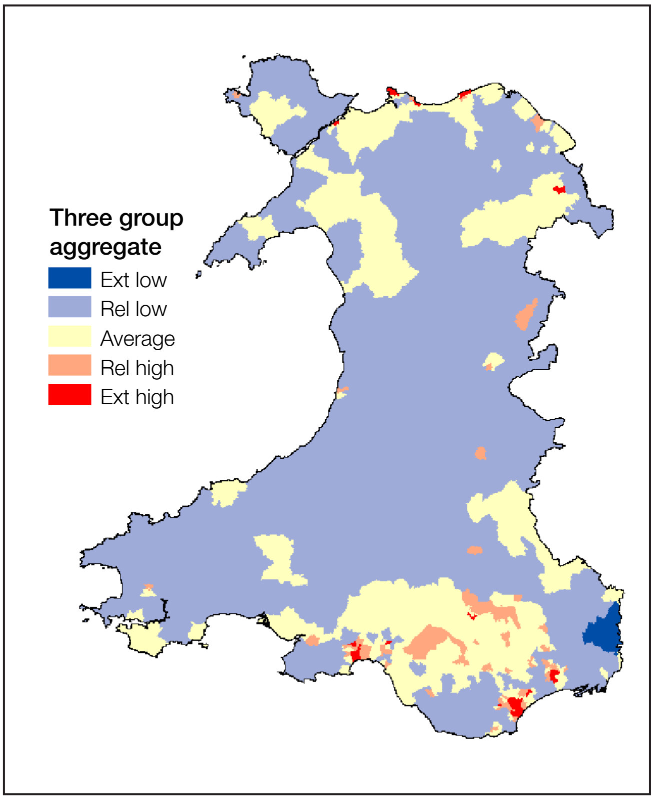


Figure 6b: Three-group aggregate



Note: The most highly socially vulnerable neighbourhoods are shown in red and the least socially vulnerable neighbourhoods in blue. Yellow denotes study area means

Socially flood-vulnerable groups in Northern Ireland

Table 11: Underlying factors in the composite socio-spatial flood vulnerability dataset in Northern Ireland (76% variance explained)

All indicators show high positive values = high vulnerability	Component					
	1	2	3	4	5	6
People with <1 yr residency coming from outside UK (2001)	.892					
% born outside UK and Ireland	.854					
People with <1 yr residency in immediate area	.837					
% households rented from private landlords	.768					
% born in other EU countries (excluding Ireland)	.732					
% households lowest floor level: ground floor (street level)						
% not home workers		.920				
% households owned outright (to be reversed)		.786				
Mean hours worked		–.764				
% travel to work by public transport (resident population)		.678				

Crime and disorder score from MDI (2005)		.586				
% aged <65			–.927			
% all households with dependent children (aged 0–15 or student <18)			.858			
% aged 0–4			.832			
% all-pensioner households			–.810			
% EA unemployed aged 16–74				.822		
% unemployed who never worked/long-term unemployed				.810		
% with LLTI				.748		
% households without access to a car or van		.593		.736		
% people with no or level 1 qualification				.734		
Net change; aged >65 (2001–02)					.767	
Net change; all ages rate per 1,000 persons					.677	
Possible insurance availability issues (% area previously flooded)						.715
% households lowest floor level: basement or semi-basement						.634
% variance explained	**26%**	**19%**	**14%**	**8%**	**5%**	**4%**

Notes: Extraction method: Principal Component Analysis

Rotation method: Varimax with Kaiser Normalization

Rotation converged in 7 iterations

Figure 7 is the six-component aggregate of the main socially vulnerable groups associated with flood in Northern Ireland. It should be noted that component three inversely relates two sensitive groups: the relatively old and the relatively young. Understanding the geography of the first-component new arrivals may be helpful for targeting regular information programmes in flood-prone areas.

Figure 7: Six-group aggregate

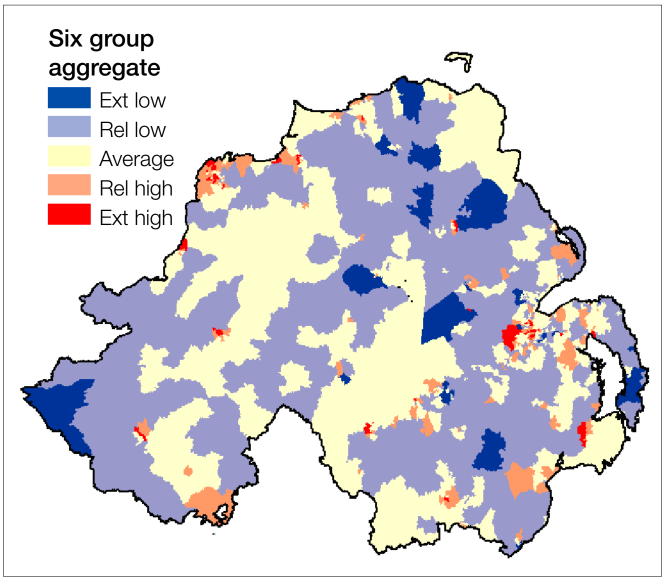
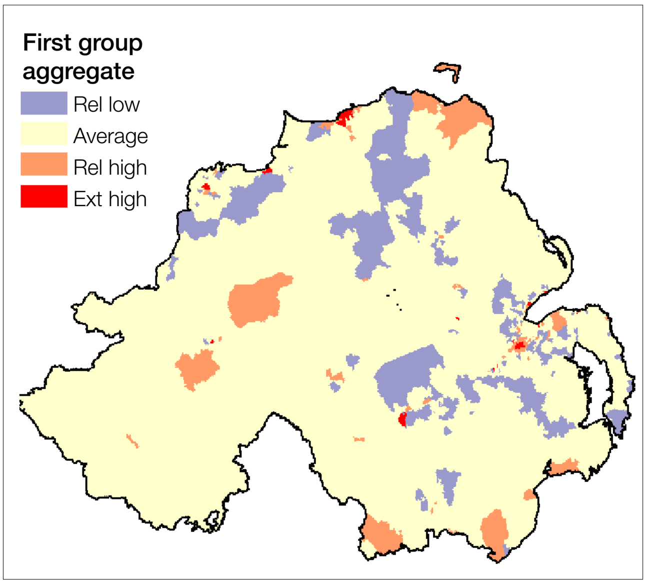


Figure 8: First component



Note: The most highly socially vulnerable neighbourhoods are shown in red and the least socially vulnerable neighbourhoods in blue. Yellow denotes study area means.

Table 12: Underlying factors in the composite socio-spatial heat vulnerability dataset in Northern Ireland (76% variance explained)

All indicators show high positive values = high vulnerability	Component					
	1	2	3	4	5	6
% not home workers	.916					
Mean distance to GP surgery	–.870					
% urban	.835					
% households not owned outright	.728		.510			
Mean hours worked	–.700					
Mean distance to emergency hospital	–.696					
% travel to work by public transport (resident population)	.651					
Crime and disorder score from MDI (2005)	.586					
% EA unemployed aged 16–74		.836				
% unemployed who never worked/long-term unemployed		.797				
% with a limiting long-term illness (LLTI)		.774				
% households without access to a car or van	.533	.772				
% people with no or level 1 qualification		.732				
% aged >65			–.859			
% aged 0–4			.854			
% all-pensioner households			–.840			
% all households with dependent children (aged 0–15 or student <18)			.766			
% people who do not provide unpaid care			.602			
Count of people with <1 yr residency coming from outside UK (2001)				.891		
% born outside UK and Ireland				.854		
% born in other EU countries (excluding Ireland)				.761		
% households rented from private landlords				.700		
Net change; aged 1–14 (2001–02)					.671	
Net change; aged >65 (2001–02)					–.651	
% single-person households (non-pensioner)	.506				.510	
% households lowest floor level: fifth floor or higher						.690
% variance explained	**28%**	**17%**	**13%**	**10%**	**4%**	**4%**

Notes: Extraction method: Principal Component Analysis

Rotation method: Varimax with Kaiser Normalization

Rotation converged in 6 iterations

Table 13: Underlying factors in the composite socio-spatial flood vulnerability dataset for Scotland (77% variance explained)

Rotated Component Matrix

All indicators show high positive values = high vulnerability	**Component**				
	1	**2**	**3**	**4**	**5**
% with limiting long-term illness (LLTI) but working	.872				
% EA unemployed aged 16–74	.841				
% households with no car	.815				
% people with no or level 1 qualification	.786				
% lone-parent households with dependent children	.765				
% with LLTI	.755			–.508	
% households not owned outright	.644				
% female lone-parent (of lone households)	.572				
% born outside UK and Ireland		.887			
People with <1 yr residency coming from outside UK		.887			
% born in other EU countries (excluding Ireland)		.848			
% non-white households with <1 yr residency in area		.806			
% households associated with <1 yr residency in area		.797			
% households rented from private landlords		.615			.526
% not home workers (resident population)			–.790		
Average distance (km) travelled to place of work or study			–.777		
Mean hours worked			–.705		
% urban			.654		
% travel to work by public transport (resident population)			.607		
% aged >65				–.902	
% all households with dependent children (aged 0–15 or student <18)				.781	
% aged 0–4				.763	
% all-pensioner households				–.704	
% single-person households (non-pensioner)					.770
% households lowest floor level: ground floor (street level)					–.562
% variance explained	**29%**	**23%**	**13%**	**8%**	**4%**

Notes: Extraction method: Principal Component Analysis

Rotation method: Varimax with Kaiser Normalization

Rotation converged in 6 iterations

Socially heat-vulnerable groups in Scotland

Table 14: Underlying factors in the composite socio-spatial heat vulnerability dataset for Scotland (76% variance explained)

Rotated Component Matrix

All indicators show high positive values = high vulnerability	**Component**			
	1	**2**	**3**	**4**
% with limiting long-term illness (LLTI) but working	.892			
% households with no car	.848			
% EA unemployed aged 16–74	.839			
% people with no or level 1 qualification	.754	–.523		
% lone-parent households with dependent children	.739			
% households not owned outright	.732			
% with LLTI	.724		.540	
% households rented from private landlords		.847		
% born outside UK and Ireland		.813		
% born in other EU countries (excluding Ireland)		.782		
% single-person households (non-pensioner)	.519	.655		
% aged >65			.900	
% all households with dependent children (aged 0–15 or student <18)			–.799	
% aged 0–4			–.764	
% all-pensioner households			.676	
Mean distance to GP surgery				–.821
Maximum elevation (reversed so that high values = low elevation = higher enhanced exposure)				.804
Average distance (km) travelled to place of work or study				–.722
% urban				.657
% variance explained	**30%**	**19%**	**17%**	**10%**

Notes: Extraction method: Principal Component Analysis

Rotation method: Varimax with Kaiser Normalization

Rotation converged in 5 iterations

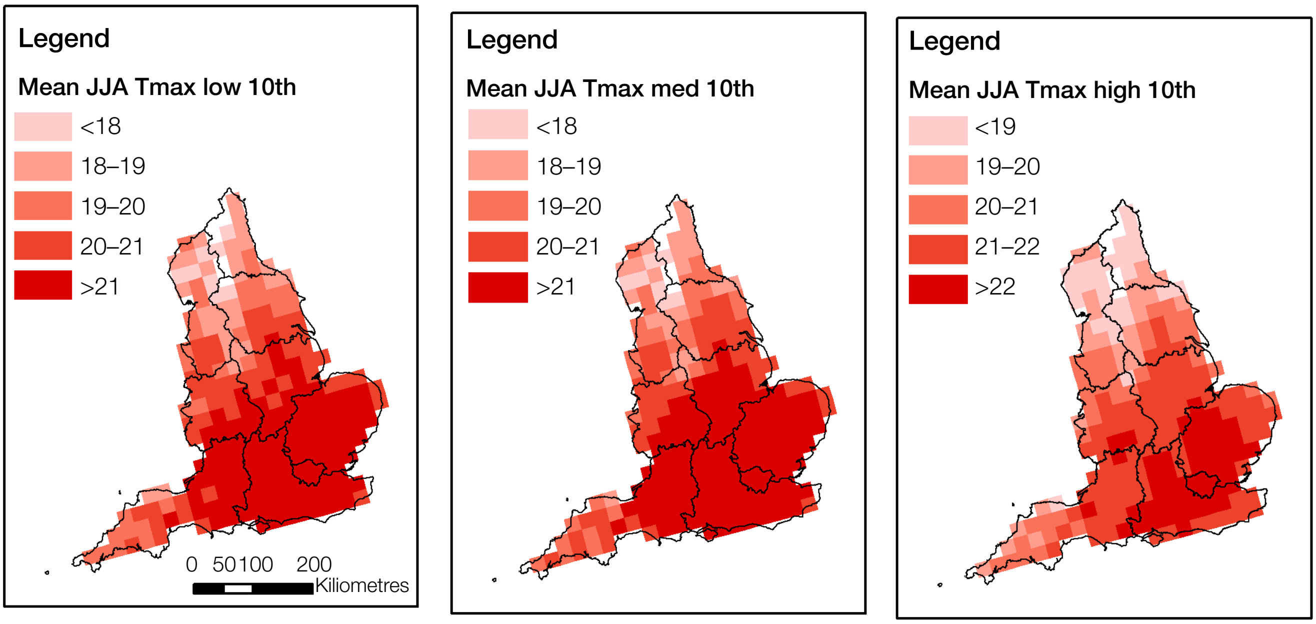
Appendix III

Supplementary outputs associated with alternative heat hazard-exposure and socio-spatial vulnerability metrics

This section provides information on additional metrics for heat related hazard-exposure to complement the material in the main report. The Appendix contains:

- 10th and 90th percentile maps for absolute temperature distributions in the 2050s based on the low, medium and high scenarios. Just the example of England is provided since the results show there is little variation in spatial distributions between scenarios and percentiles;
- 50th percentile low, medium and high scenarios in absolute temperature changes for the temperature of the warmest summer day between 1961 and 1990 and the 2050s for selected examples;
- examples of the influence of using simple mean socio-spatial vulnerability scores compared to scores which are neighbourhood weighted (i.e. means multiplied by the number of neighbourhoods in each 25km cell).

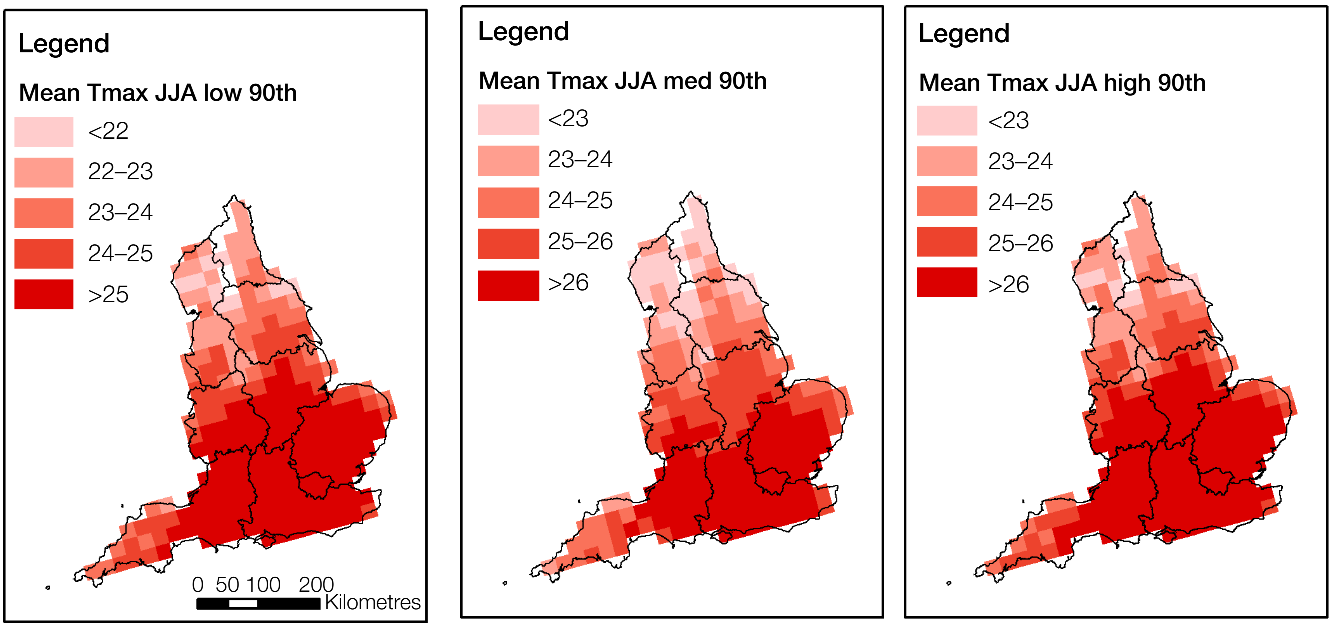
Figure 9: Absolute mean Tmax summer (JJA) temperatures for the 10th percentile low, medium and high scenarios



Note: JJA refers to June, July, August. Tmax refers to maximum temperature.

Source: UKCP09 UK Climate Projections, 2009, Crown copyright

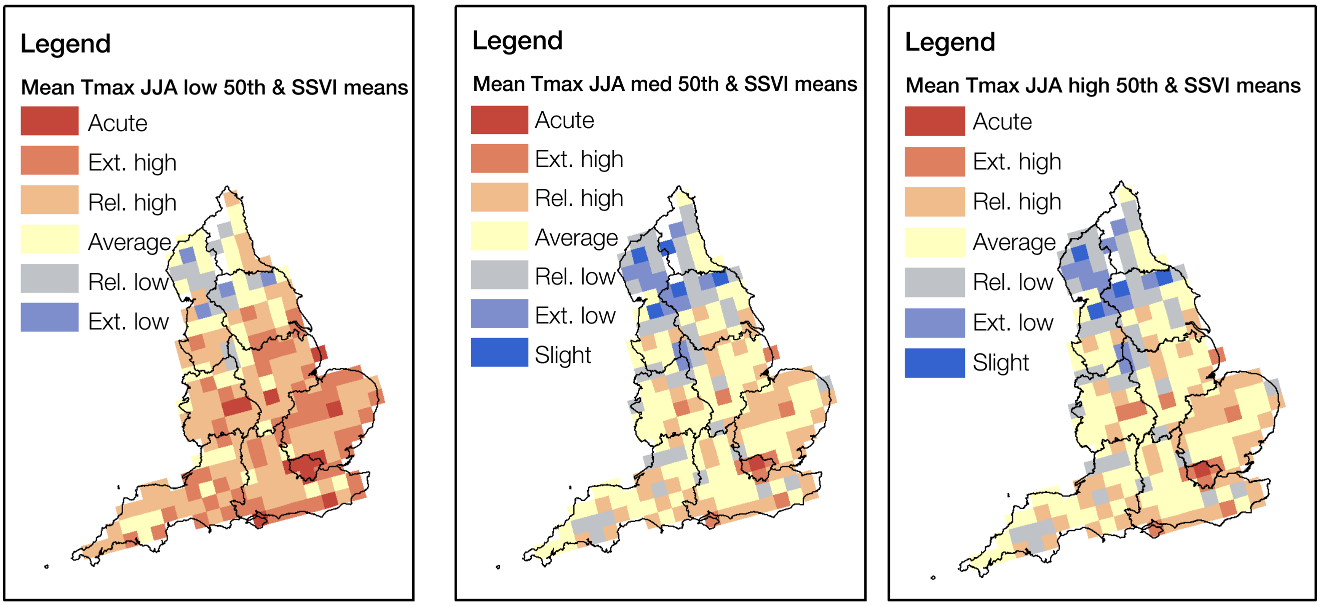
Figure 10: Absolute mean Tmax summer temperatures for the 90th percentile low, medium and high scenarios



Note: JJA refers to June, July, August. Tmax refers to maximum temperature.

Source: UKCP09 UK Climate Projections, 2009, Crown copyright

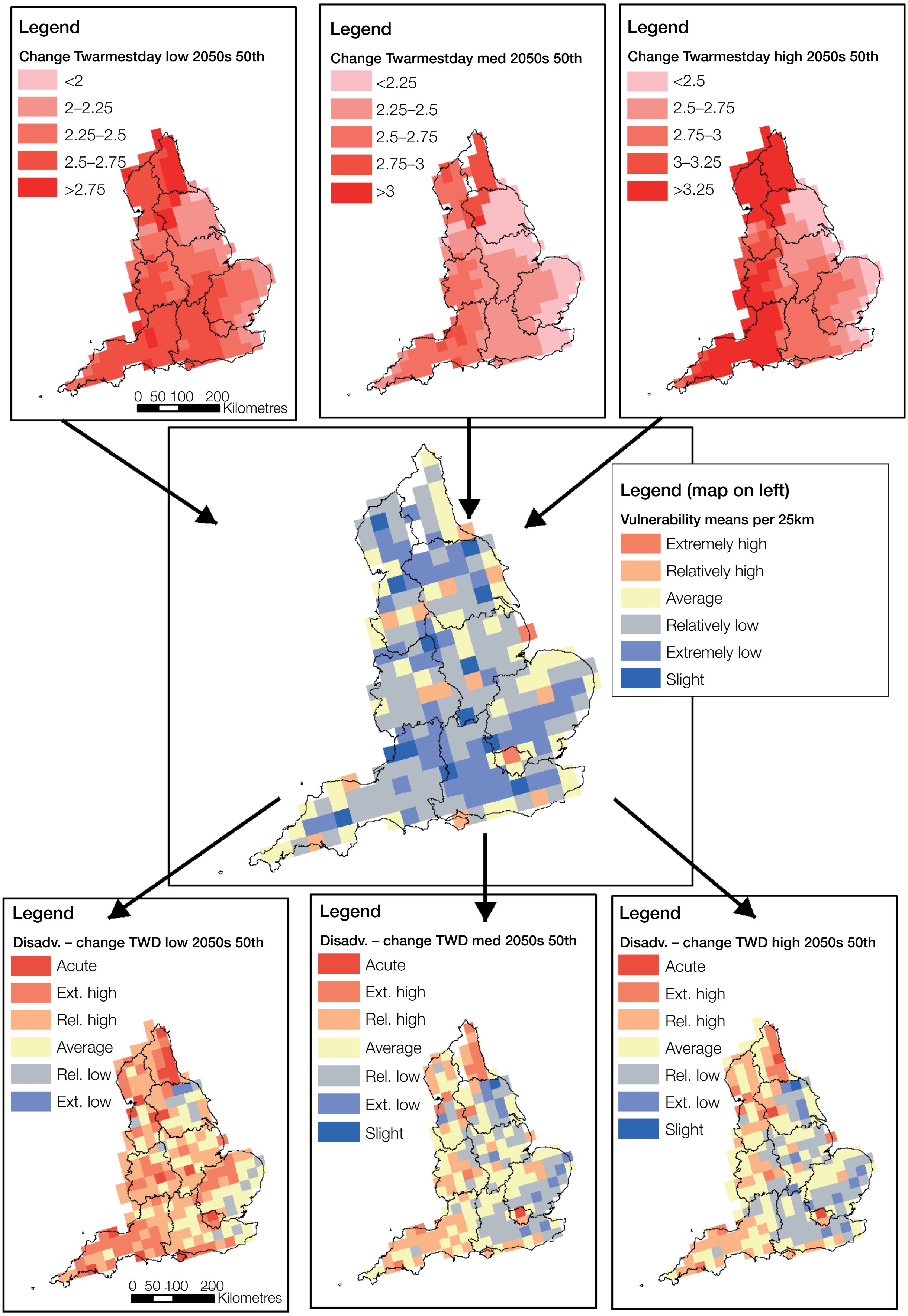
Figure 11: Distributions of climate disadvantage in England in terms of absolute mean Tmax summer temperatures for the 50th percentile low, medium and high scenarios and simple 25km means



Note: JJA refers to June, July, August. Tmax refers to maximum temperature. SSVI = socio-spatial vulnerability index score means.

These results use simple means instead of neighbourhood weighted means per 25km cell. The results are broadly similar to those discussed in the main report. Some coastal locations with lower population densities are highlighted as having climate disadvantage using this alternative way of representing socio-spatial heat vulnerability averages.

Figure 12: Climate (heat) disadvantage in the 2050s in England relative to the geography of absolute temperature changes associated with the warmest summer day

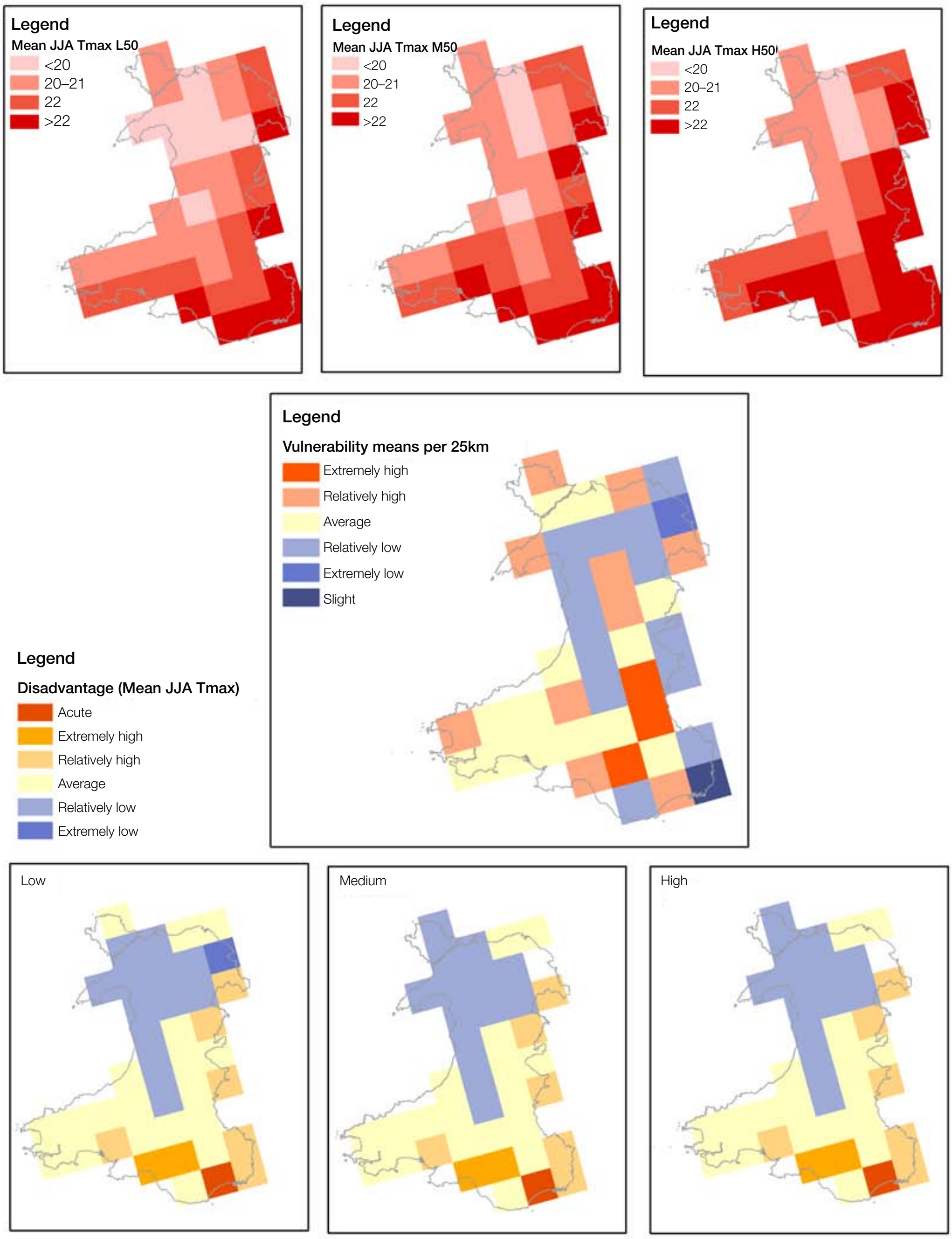


Note: UKCP09 50th percentile estimates for the low, medium and high emissions scenarios relative to the 1961–90 baseline

Source: UKCP09 UK Climate Projections, 2009, Crown copyright

The geographical patterns of changes in the temperature of the warmest day between the baseline and 2050s are different from those shown in terms of absolute temperature distributions in the 2050s. This climate metric suggests that temperature change may disproportionately affect the North and West of England. Therefore with the exception of London and the far south coast, this climate metric tends to result in the northern and western areas of England being at higher climate disadvantage. This different perspective on climate disadvantage may merit further study. However, it should also be noted that the extent of differences in temperature change across England, as implied by the UKCP09 data, is actually very small and may not be significant for assessing future heatwave exposure. It would also be useful to use a metric relating to changes in the warmest summer night.

Figure 13: Distributions of climate (heat) disadvantage in Wales in terms of absolute mean Tmax summer temperatures for the 50th percentile low, medium and high scenarios and raw 25km means



Note: Not neighbourhood-weighted. JJA refers to June, July, August. Tmax refers to maximum temperature.

Source: UKCP09 UK Climate Projections, 2009, Crown copyright

Figure 14: Climate (heat) disadvantage in the 2050s in Wales relative to the geography of absolute temperature changes associated with the warmest summer day

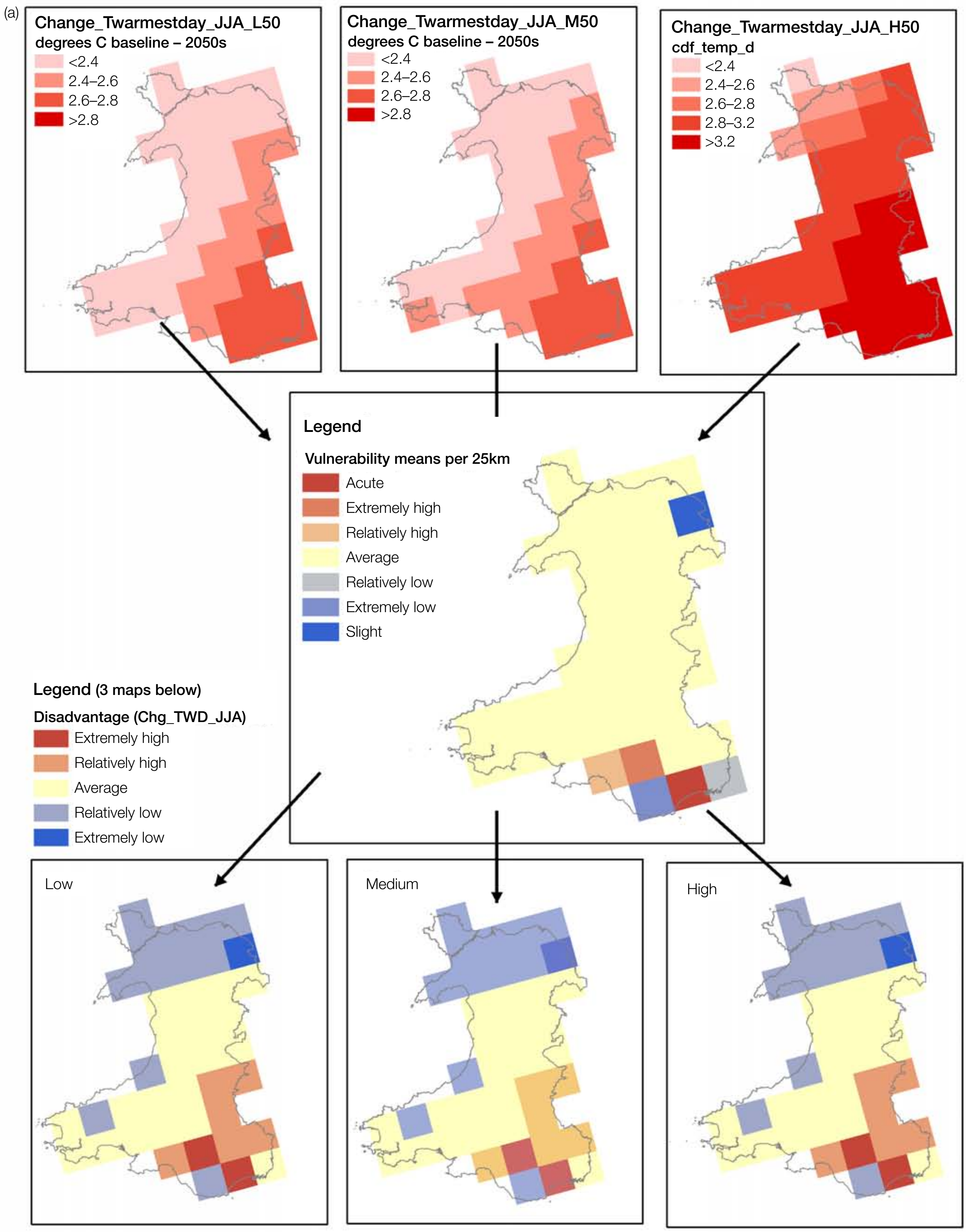
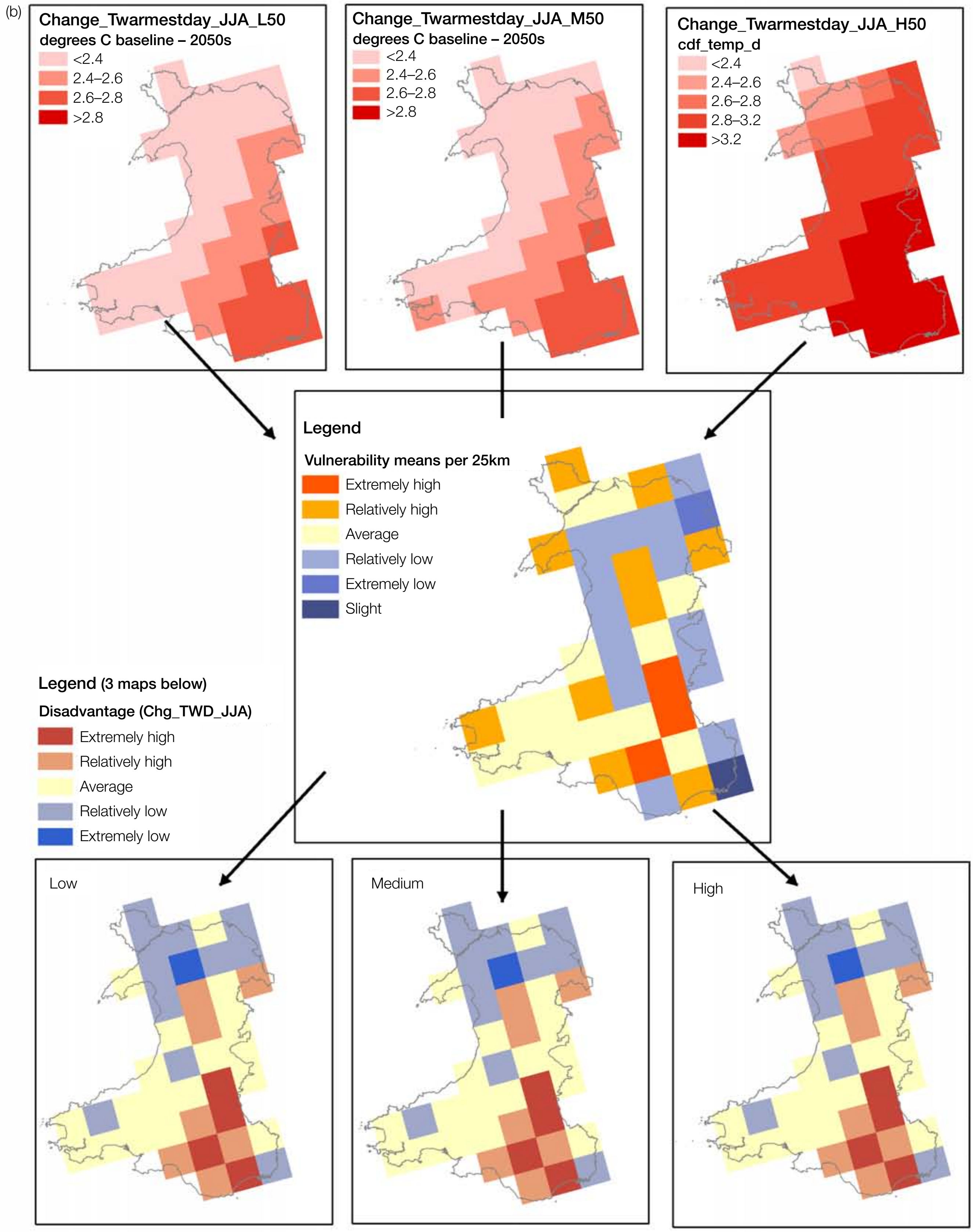


Figure 14 continued



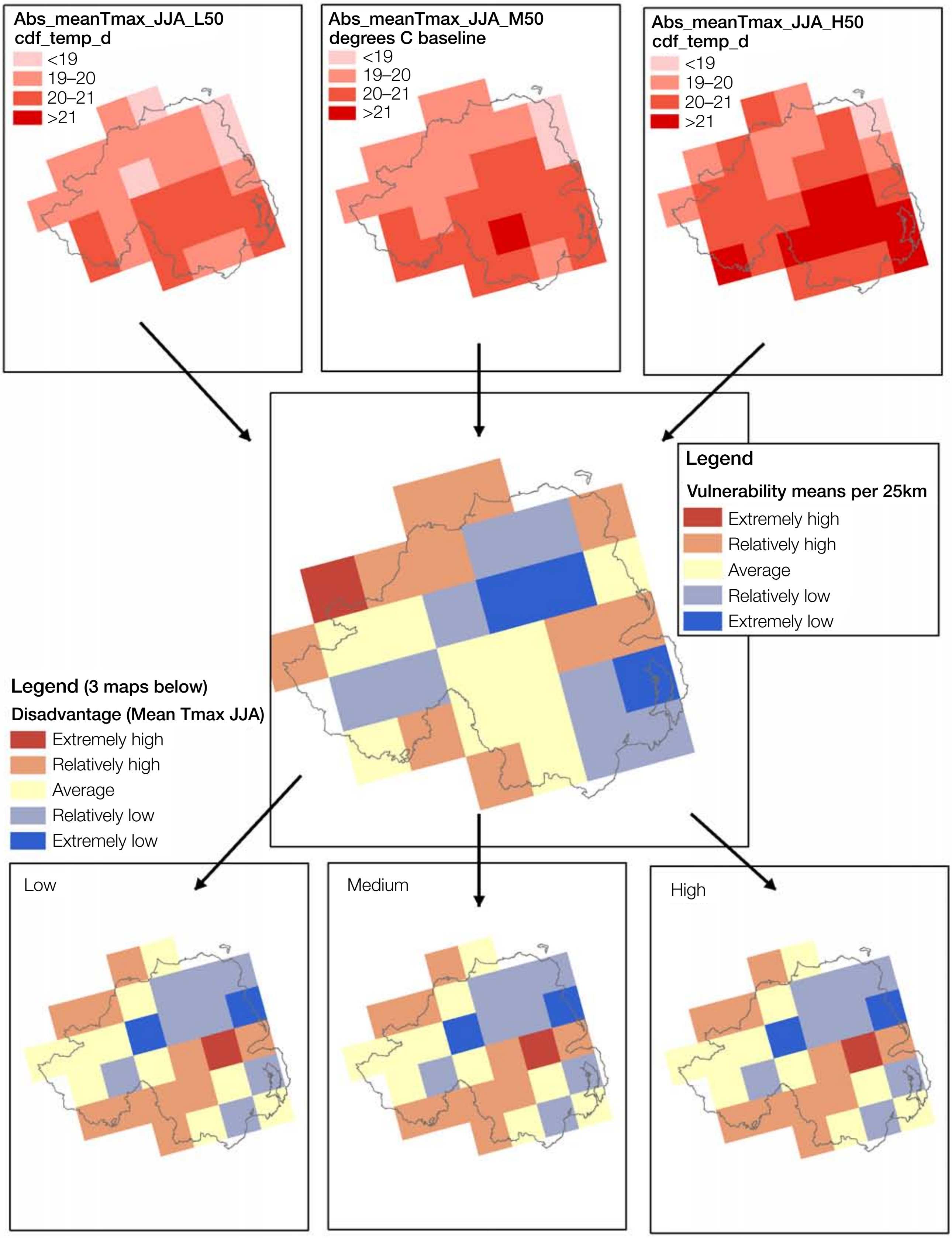
Notes: UKCP09 50th percentile estimates for the low, medium and high emissions scenarios relative to the 1961–90 baseline.

JJA refers to June, July, August.

Data is combined with neighbourhood weighted (a) and simple mean vulnerability (b) scores

Source: UKCP09 UK Climate Projections, 2009, Crown copyright

Figure 15: Distributions of climate (heat) disadvantage in Northern Ireland in terms of absolute mean Tmax summer temperatures for the 50th percentile low, medium and high scenarios and simple 25km means



Note: Not neighbourhood-weighted. JJA refers to June, July, August. Tmax refers to maximum temperature.

Source: UKCP09 UK Climate Projections, 2009, Crown copyright

Figure 16: Climate (heat) disadvantage in the 2050s in Northern Ireland relative to the geography of absolute temperature changes associated with the warmest summer day

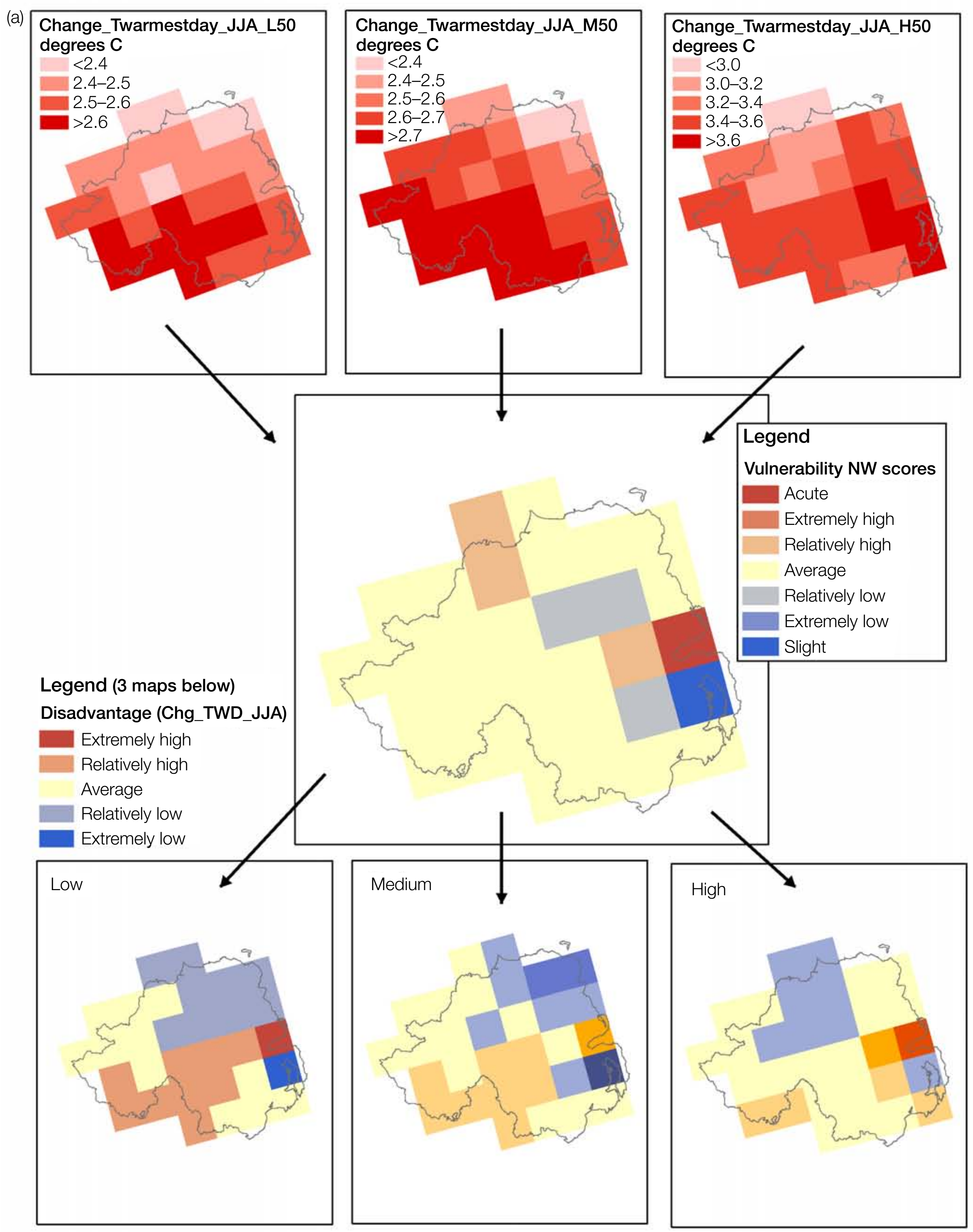
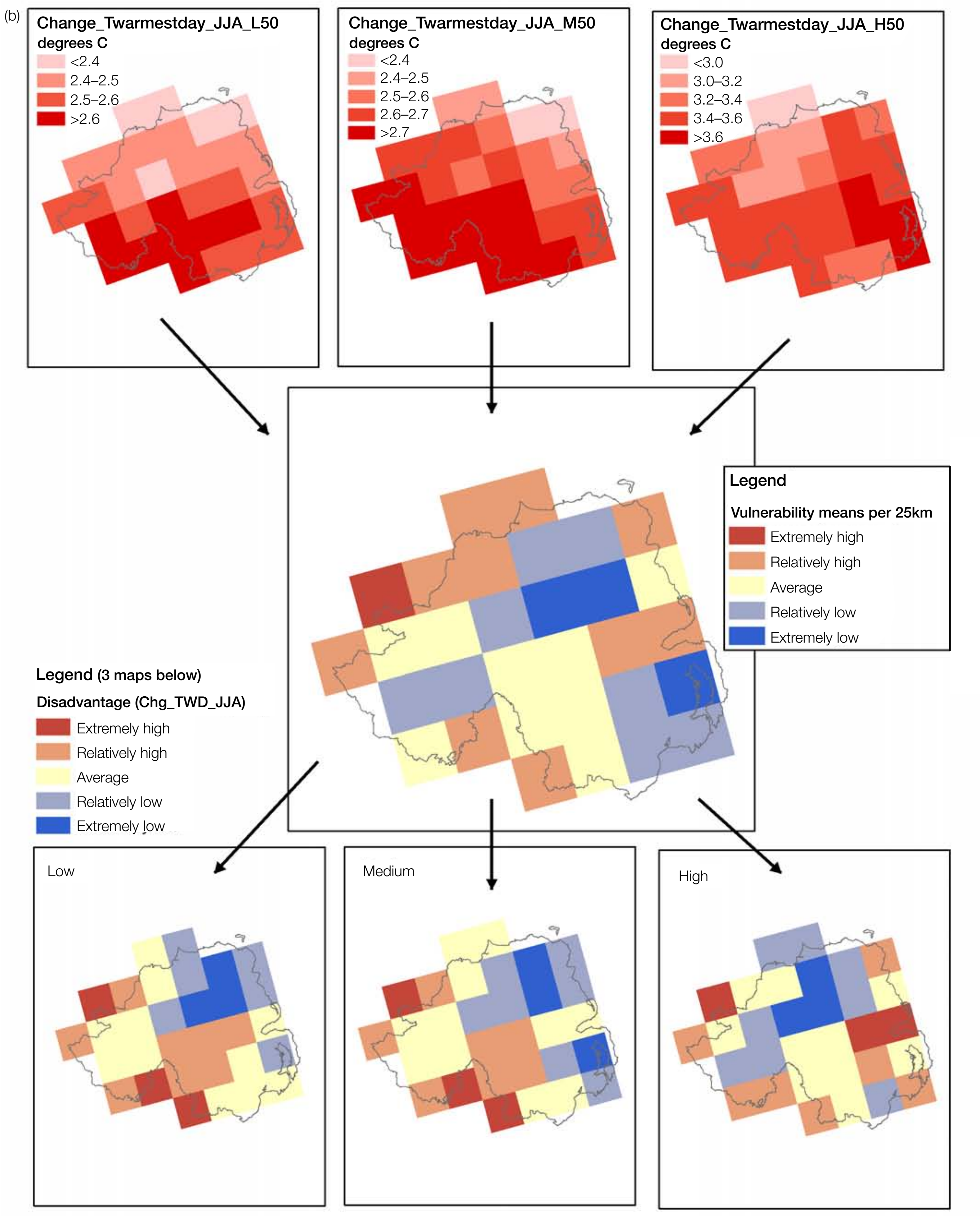


Figure 16 continued



Notes: UKCP09 50th percentile estimates for the low, medium and high emissions scenarios relative to the 1961–90 baseline. JJA refers to June, July, August. Data is combined with neighbourhood weighted (NW) (a) and mean vulnerability (b) scores

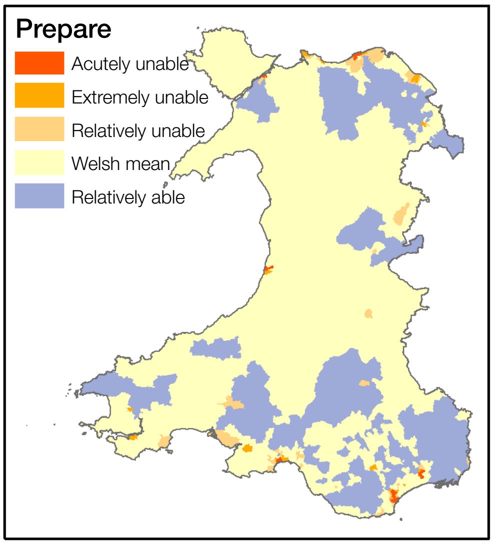
Source: UKCP09 UK Climate Projections, 2009, Crown copyright

Appendix IV

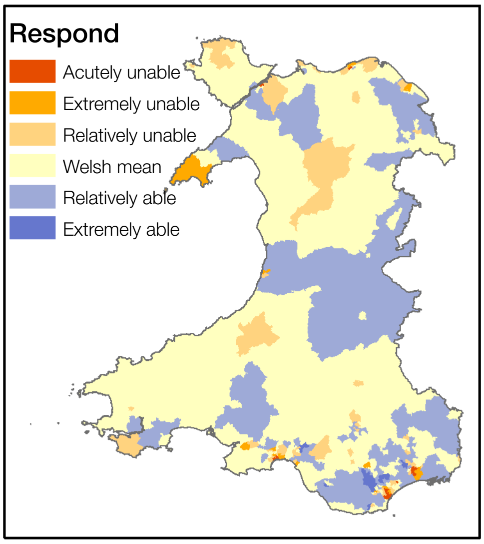
Supplementary maps showing geographical distributions in the five dimensions of socio-spatial vulnerability

Figure 17: The three dimensions of adaptive capacity in Wales with respect to flood: (a) ability to prepare (b) ability to respond (c) ability to recover

(a)



(b)



(c)

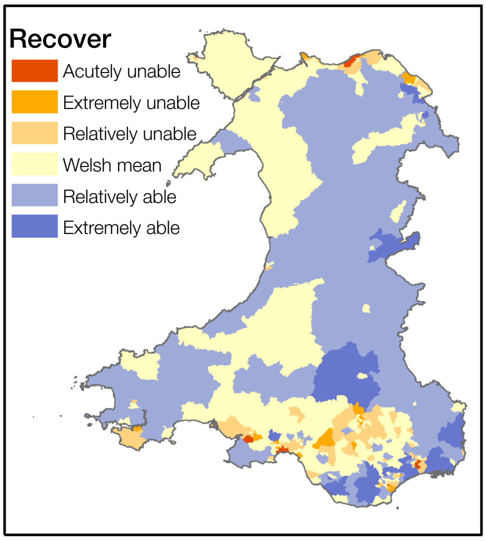


Figure 18: The five dimensions of socio-spatial heat vulnerability in Wales: (a) sensitivity (b) enhanced exposure (c) ability to prepare (d) ability to respond (e) ability to recover

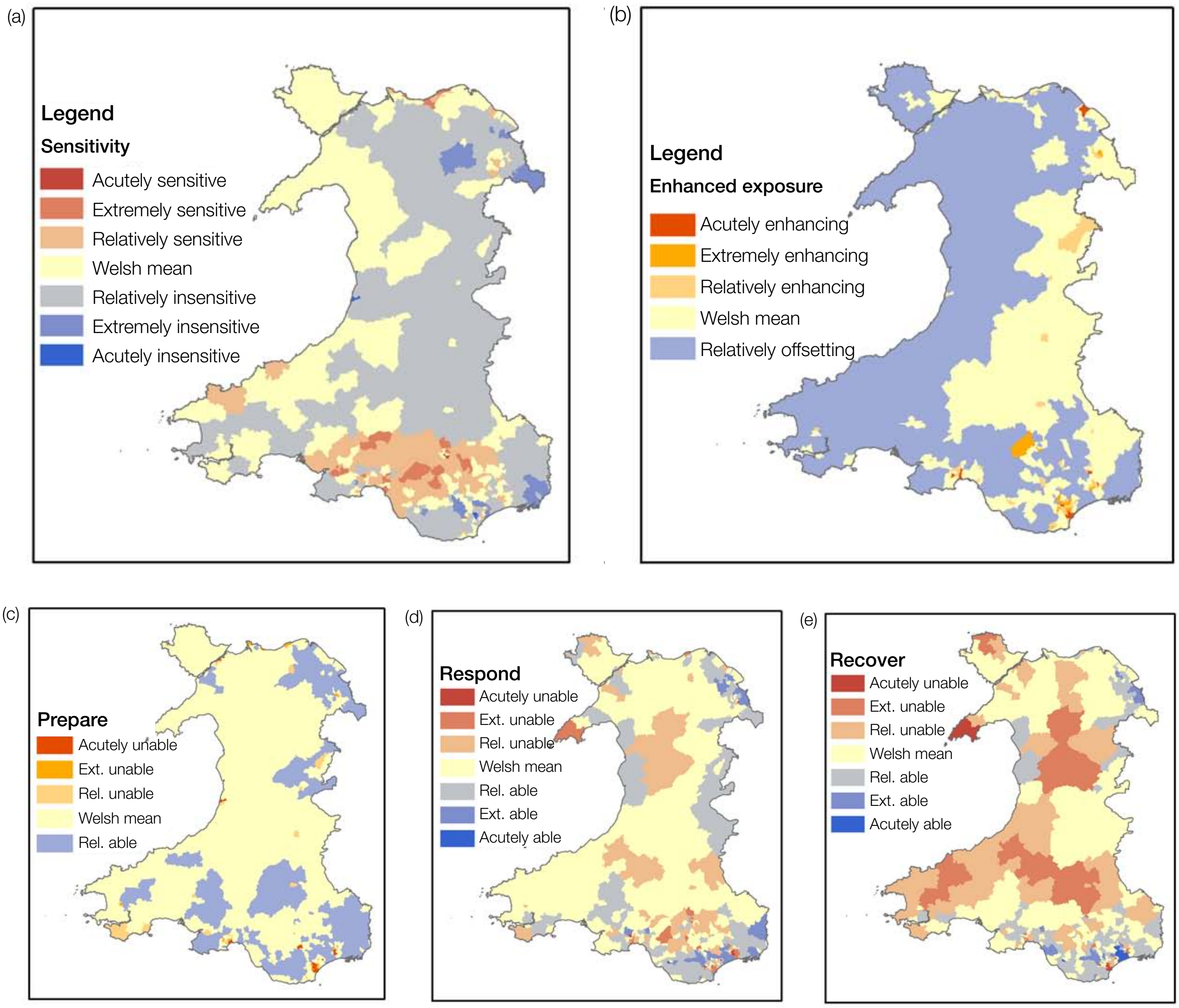
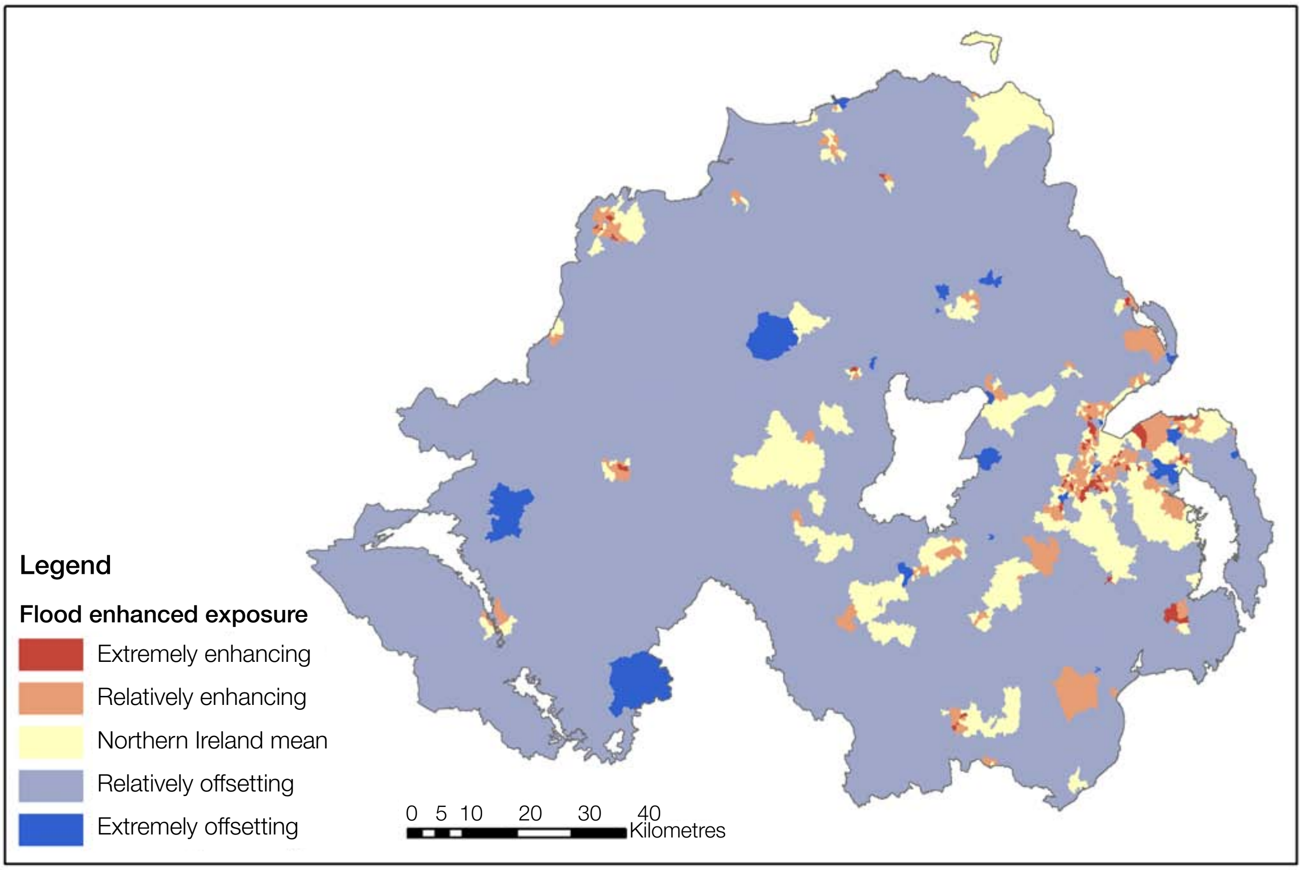
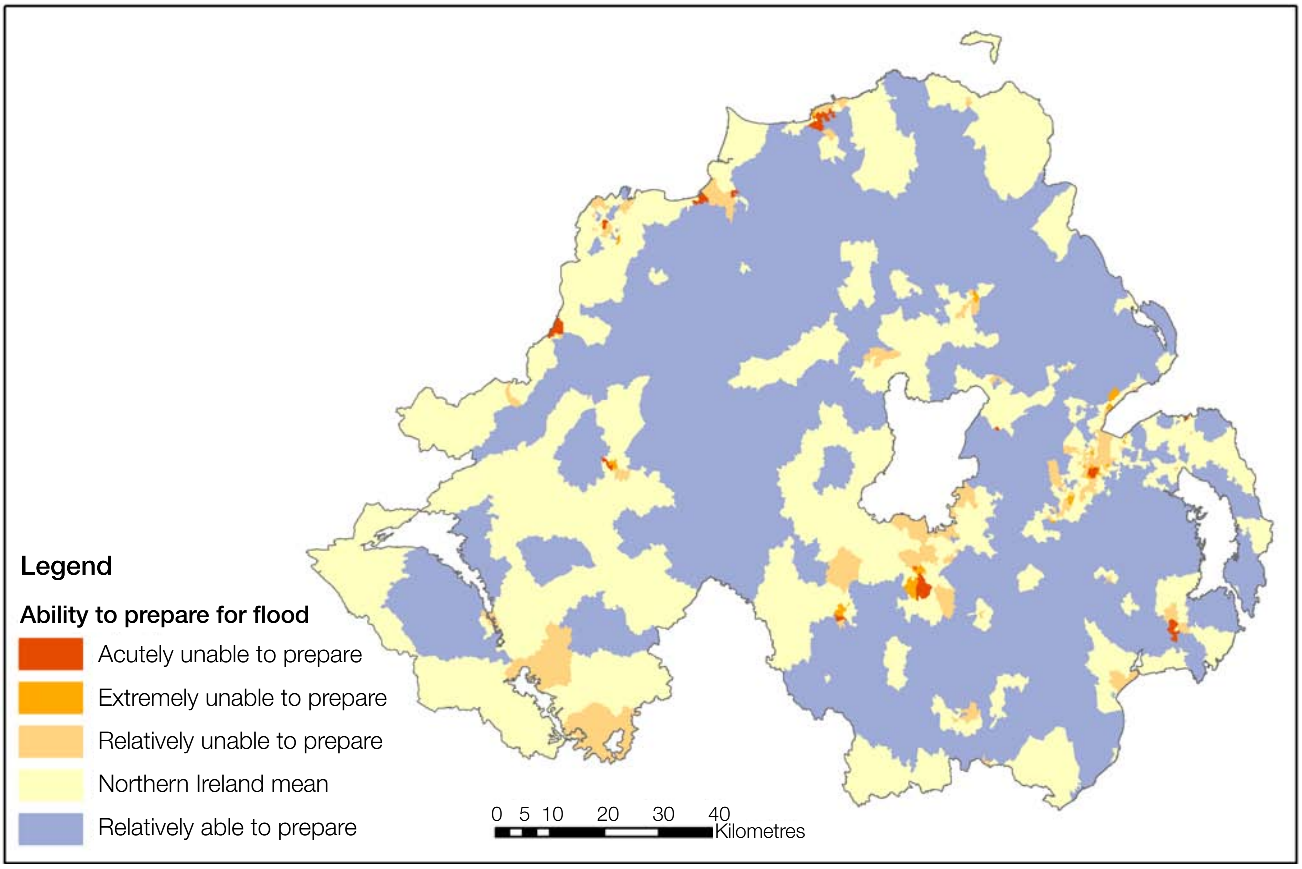


Figure 19: Dimensions of socio-spatial flood vulnerability in Northern Ireland: (a) enhanced exposure (b) ability to prepare (c) ability to respond (d) ability to recover

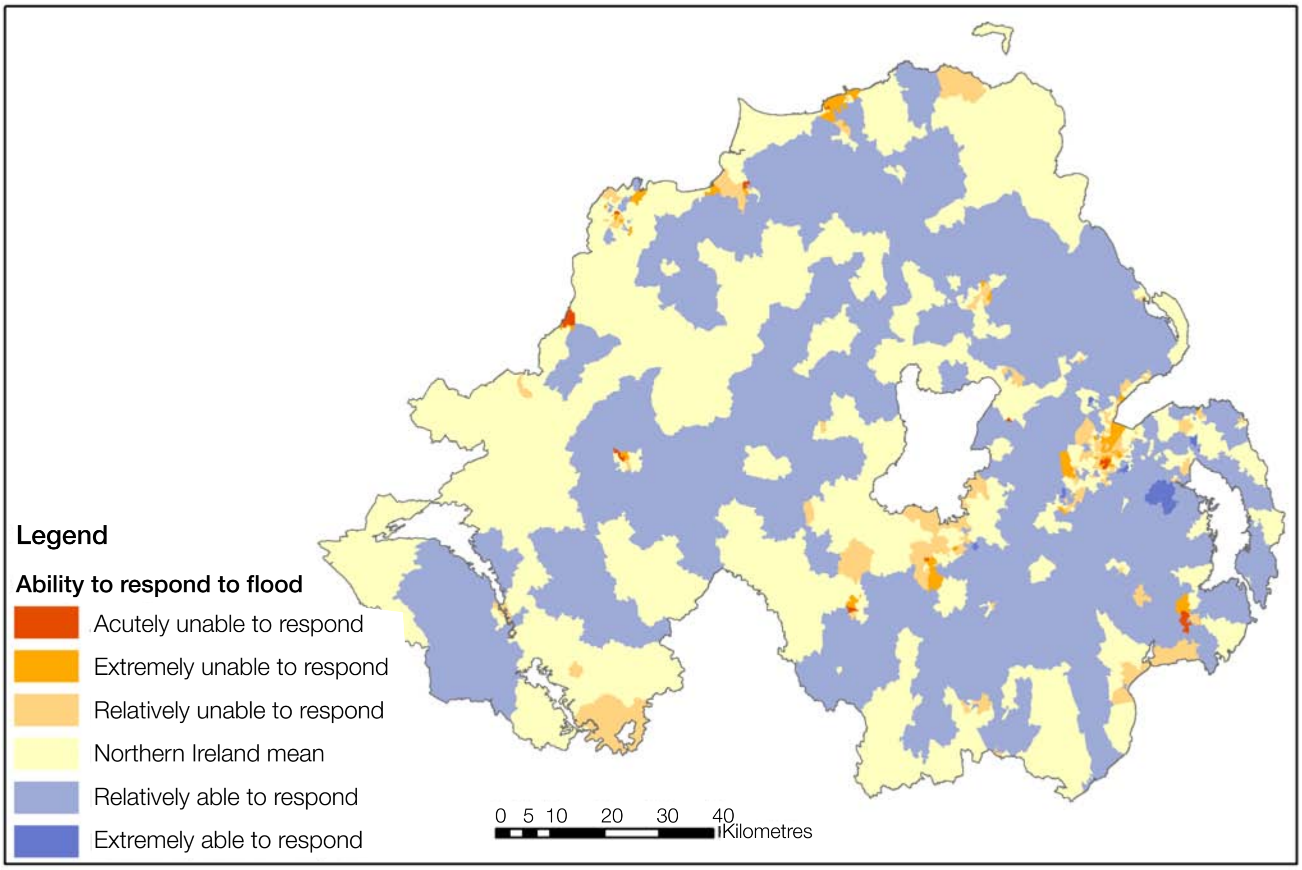
(a)



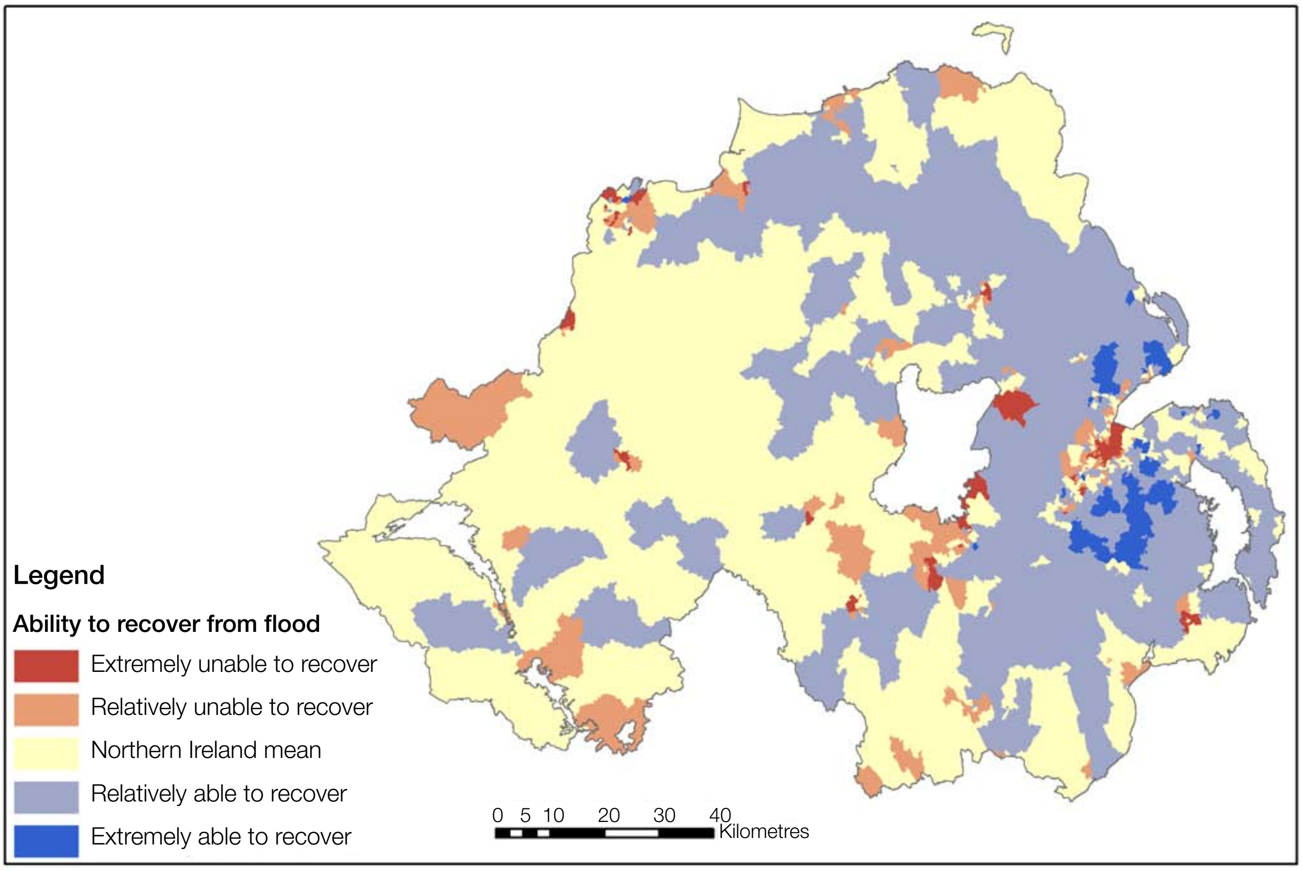
(b)



(c)



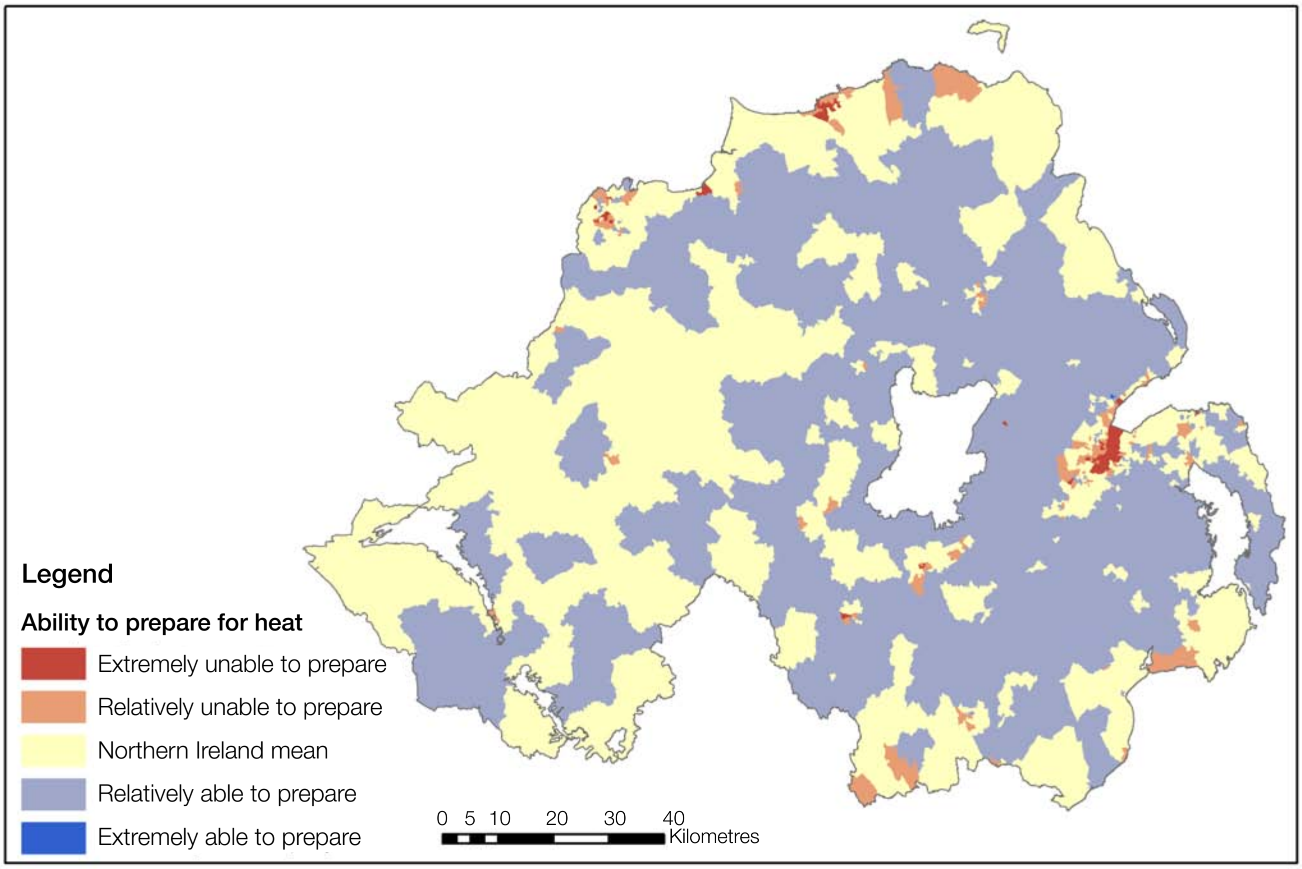
(d)



Note: Sensitivity is shown in the main report

Figure 20: Two further dimensions of adaptive capacity in Northern Ireland with respect to heat: (a) ability to prepare and (b) ability to respond

(a)



(b)

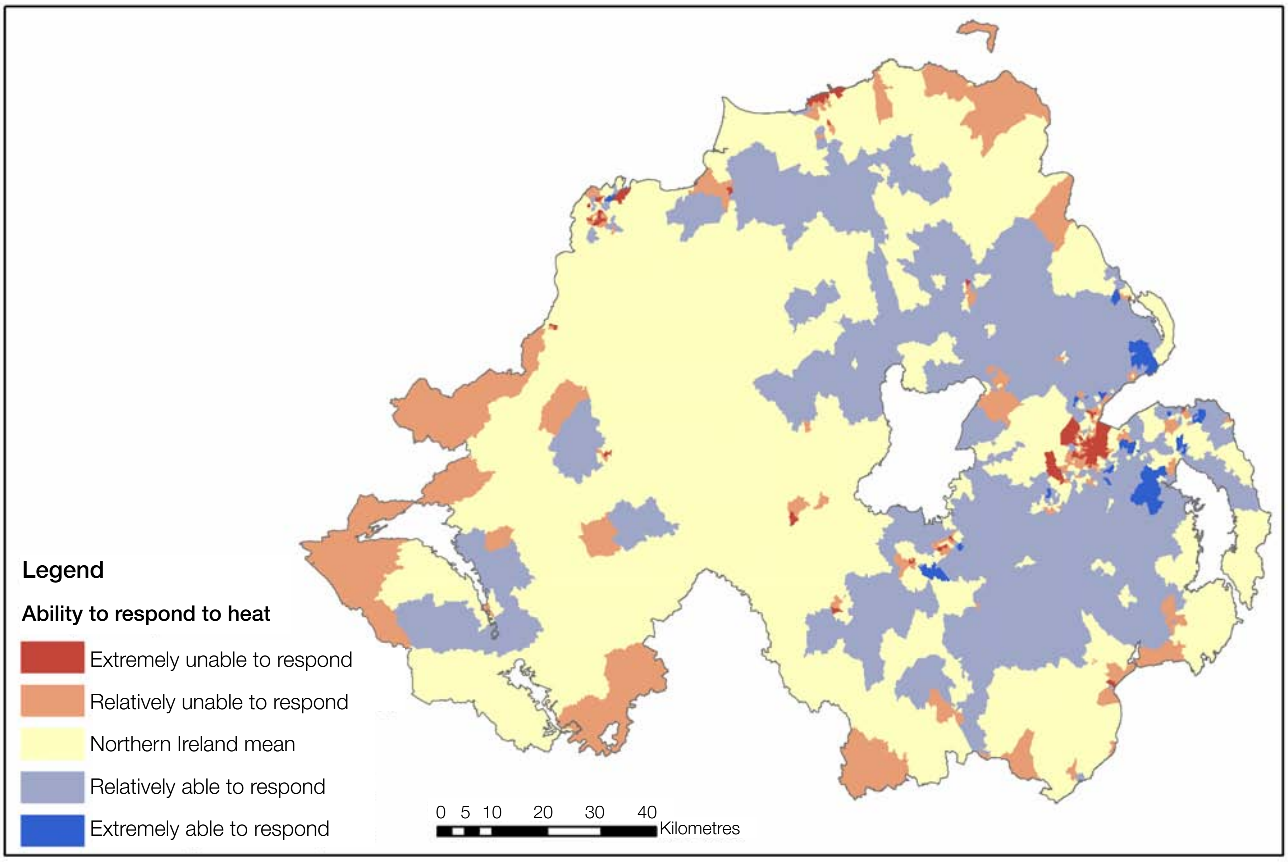
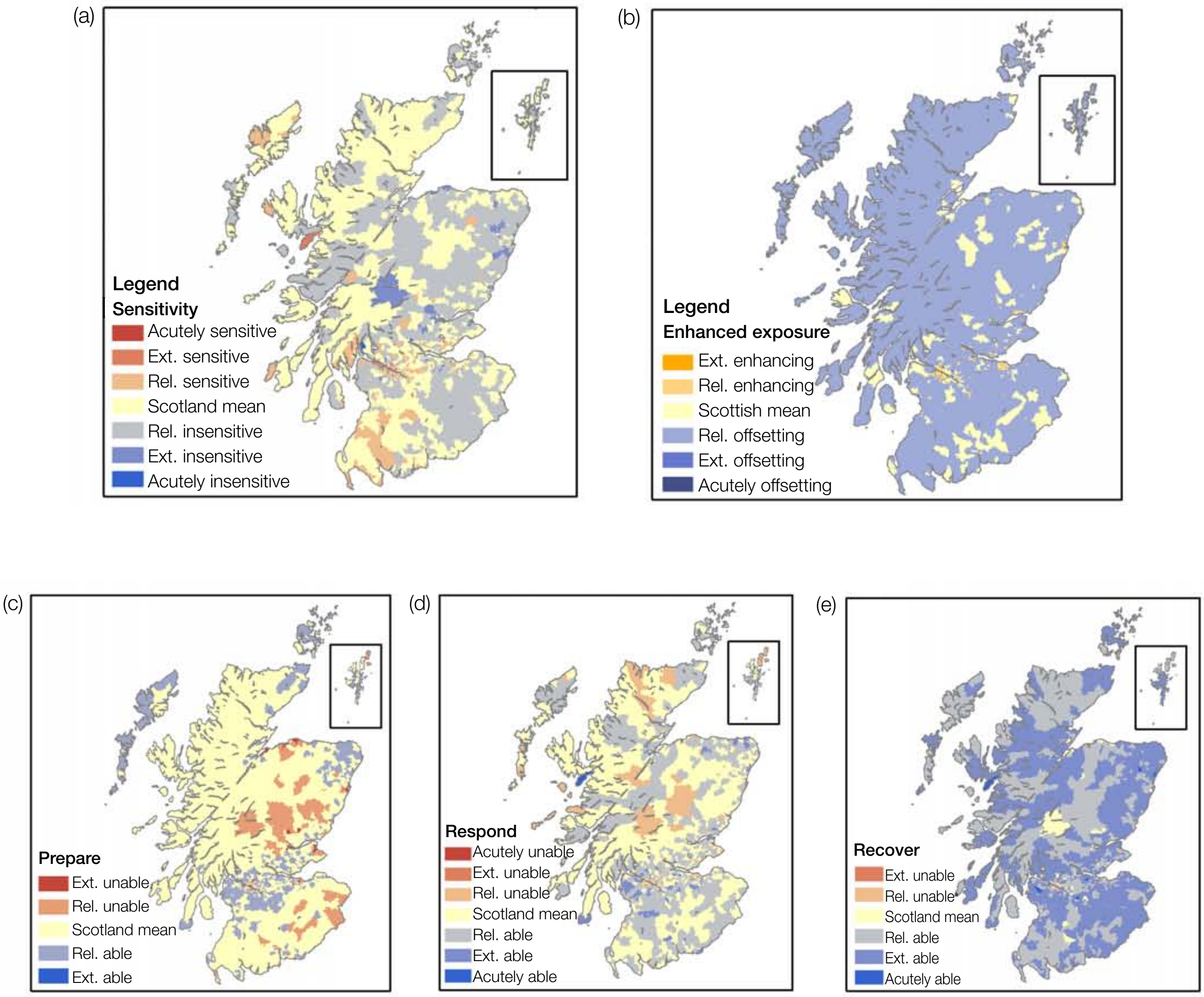


Figure 21: The five dimensions of socio-spatial flood vulnerability in Scotland: (a) sensitivity (b) enhanced exposure (c) ability to prepare (d) ability to respond (e) ability to recover



Appendix V

Local authority rankings

Table 15: Relative flood disadvantage, socio-spatial flood vulnerability and flood hazard-exposure for Welsh local authorities (LAs)

Local authority (neighbourhood count)	Flood disadvantage	Socio-spatial flood vulnerability	Flood hazard-exposure	NW socio-spatial flood vulnerability	NW flood disadvantage
Blaenau Gwent (9)	L	H	L	M	M
Bridgend (19)	M	M	M	L	M
Caerphilly (24)	L	M	L	M	L
Cardiff (47)	H	H	M	H	H
Carmarthenshire (26)	H	M	H	M	H
Ceredigion (10)	M	L	M	M	M
Conwy (15)	H	H	H	H	H
Denbighshire (16)	H	H	H	H	H
Flintshire (20)	L	L	H	L	L
Gwynedd (17)	M	M	M	M	M
Isle of Anglesey (9)	M	M	M	M	M
Merthyr Tydfil (7)	M	H	L	M	M
Monmouthshire (11)	L	L	M	L	L
Neath Port Talbot (19)	H	M	H	H	H
Newport (20)	H	H	H	H	H
Pembrokeshire (16)	M	M	M	M	M
Powys (19)	L	L	L	L	L
Rhondda, Cynon, Taff (31)	M	M	L	H	L
Swansea (31)	H	H	H	H	H
The Vale of Glamorgan (15)	M	L	M	L	M
Torfaen (13)	L	L	L	L	L
Wrexham (19)	L	L	L	L	L

Notes: Neighbourhood-weighted (NW) scores are the product of LA mean scores and neighbourhood count.

Shading denotes positive scores (above national mean).

L = low M = medium H = high

The main point of the neighbourhood-weighted scores is not to give a complete ranking but to identify extremes of disadvantage where both means and neighbourhood numbers come together to give high aggregate scores.

Table 16: Relative socio-spatial heat vulnerability for Welsh local authorities

Local authority (neighbourhood count)	Socio-spatial heat vulnerability	NW socio-spatial heat vulnerability
Blaenau Gwent (9)	H	H
Bridgend (19)	L	L
Caerphilly (24)	L	L
Cardiff (47)	H	H
Carmarthenshire (26)	M	M
Ceredigion (10)	M	M
Conwy (15)	M	M
Denbighshire (16)	M	M
Flintshire (20)	L	L
Gwynedd (17)	M	M
Isle of Anglesey (9)	M	M
Merthyr Tydfil (7)	H	H
Monmouthshire (11)	L	L
Neath Port Talbot (19)	M	M
Newport (20)	H	H
Pembrokeshire (16)	H	H
Powys (19)	M	M
Rhondda, Cynon, Taff (31)	H	H
Swansea (31)	H	H
The Vale of Glamorgan (15)	L	L
Torfaen (13)	L	L
Wrexham (19)	L	L

Notes: Neighbourhood-weighted (NW) scores are the product of LA mean scores and neighbourhood count.

Shading denotes positive scores (above national mean).

L = low M = medium H = high

The main point of the neighbourhood-weighted scores is not to give a complete ranking but to identify extremes of disadvantage where both means and neighbourhood numbers come together to give high aggregate scores.

Table 17: Relative socio-spatial flood and heat vulnerability in Northern Ireland local authorities

Local authority (neighbourhood count)	Socio-spatial flood vulnerability	Socio-spatial heat vulnerability	NW socio-spatial flood vulnerability	NW socio-spatial heat vulnerability
Antrim (25)	ML	M	ML	M
Ards (46)	L	L	L	L
Armagh (25)	M	ML	M	ML
Ballymena (29)	ML	ML	ML	ML
Ballymoney (16)	L	ML	ML	M
Banbridge (19)	L	L	L	ML
Belfast (150)	H	H	H	H
Carrickfergus (20)	ML	ML	M	ML
Castlereagh (33)	L	L	L	L
Coleraine (29)	MH	MH	MH	MH
Cookstown (16)	M	MH	MH	MH
Craigavon (44)	H	H	H	H
Derry (57)	H	H	H	H
Down (36)	M	ML	ML	L
Dungannon (22)	M	MH	M	MH
Fermanagh (25)	M	M	M	M
Larne (16)	L	M	M	M
Limavady (18)	MH	MH	MH	MH
Lisburn (58)	MH	M	ML	L
Magherafelt (21)	L	L	L	ML
Moyle (9)	MH	H	MH	H
Newry and Mourne (47)	MH	MH	MH	MH
Newtownabbey (47)	ML	L	L	L
North Down (40)	ML	L	L	L
Omagh (24)	H	M	H	M
Strabane (18)	H	H	H	H

Notes: Neighbourhood-weighted (NW) scores are the product of LA mean scores and neighbourhood count.

Shading denotes positive scores (above national mean).

L = low ML = medium-low MH = medium-high H = high

The main point of the neighbourhood-weighted scores is not to give a complete ranking but to identify extremes of disadvantage where both means and neighbourhood numbers come together to give high aggregate scores.

Table 18: Relative socio-spatial flood and heat vulnerability in Scottish unitary authorities

Unitary authority (neighbourhood count)	Mean flood vulnerability	Mean heat vulnerability	NW flood vulnerability	NW heat vulnerability
Aberdeen City (268)	H	MH	H	MH
Aberdeenshire (302)	L	L	L	L
Angus (142)	ML	ML	ML	ML
Argyll and Bute (147)	MH	MH	ML	MH
City of Edinburgh (550)	H	H	H	H
Clackmannanshire (65)	MH	ML	MH	MH
Dumfries and Galloway (194)	MH	ML	ML	ML
Dundee City (179)	H	H	H	H
East Ayrshire (154)	ML	MH	ML	MH
East Dunbartonshire (127)	L	L	L	L
East Lothian (120)	ML	L	L	L
East Renfrewshire (119)	L	L	L	L
Falkirk (197)	ML	ML	L	L
Fife (454)	MH	MH	ML	L
Glasgow City (694)	H	H	H	H
Highland (317)	ML	MH	L	ML
Inverclyde (110)	H	H	H	H
Midlothian (112)	L	L	L	L
Moray (116)	H	MH	H	MH
Na H-Eileanan an Iar (53)	L	H	MH	H
North Ayrshire (179)	H	H	H	H
North Lanarkshire (418)	MH	H	MH	H
Orkney Islands (42)	L	L	MH	MH
Perth and Kinross (176)	MH	MH	H	ML
Renfrewshire (214)	MH	ML	ML	ML
Scottish Borders (131)	ML	MH	ML	MH
Shetland Islands (31)	L	L	MH	MH
South Ayrshire (148)	MH	ML	MH	ML
South Lanarkshire (399)	ML	ML	L	L
Stirling (112)	ML	ML	MH	ML
West Dunbartonshire (119)	H	H	MH	H
West Lothian (211)	L	L	L	L

Notes:

Neighbourhood-weighted (NW) scores are the product of LA mean scores and neighbourhood count.

The historical flood zone dataset used for Scotland was incomplete so some authorities may not be well represented.

Shading denotes positive scores (above national mean).

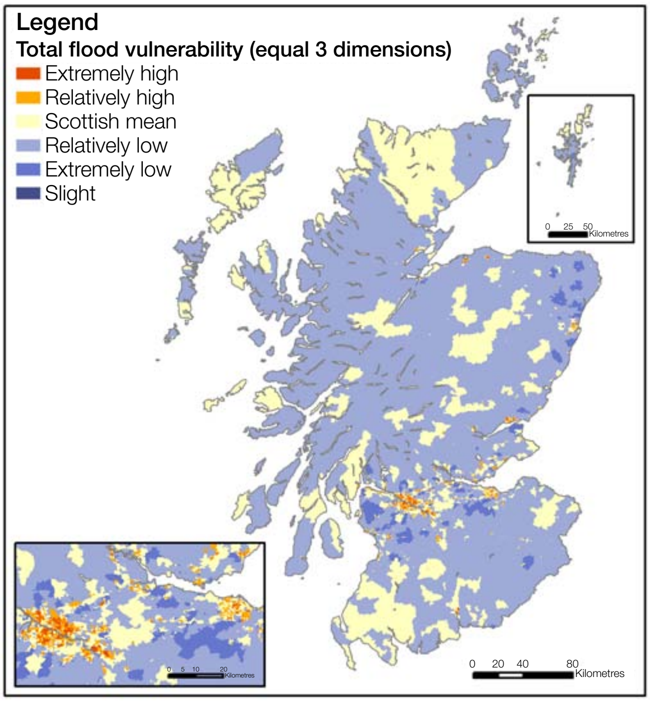
L = low ML= medium-low MH = medium-high H = high

The main point of the neighbourhood-weighted scores is not to give a complete ranking but to identify extremes of disadvantage where both means and neighbourhood numbers come together to give high aggregate scores.

Appendix VI

Weighting supporting evidence

Figure 22: Flood vulnerability in Scotland using an equal weighting three-dimension approach and an example using weighting derived from the Scottish Index of Multiple Deprivation



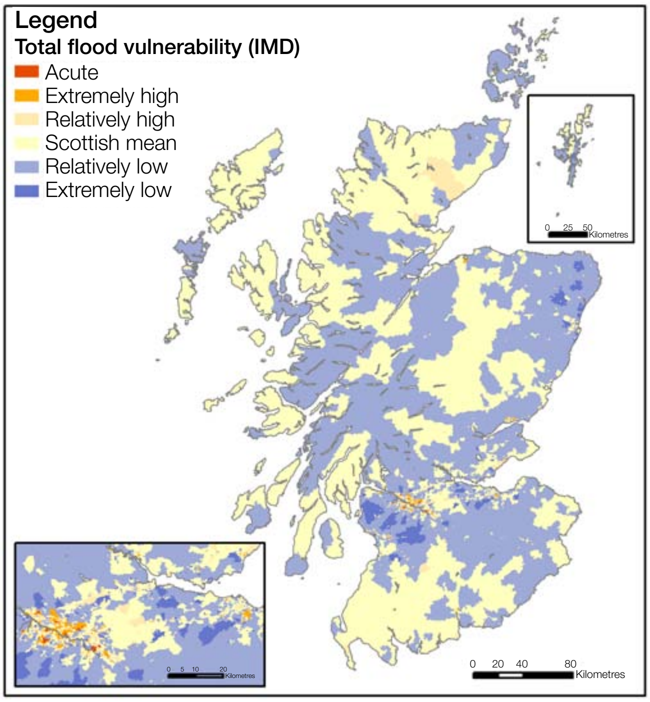
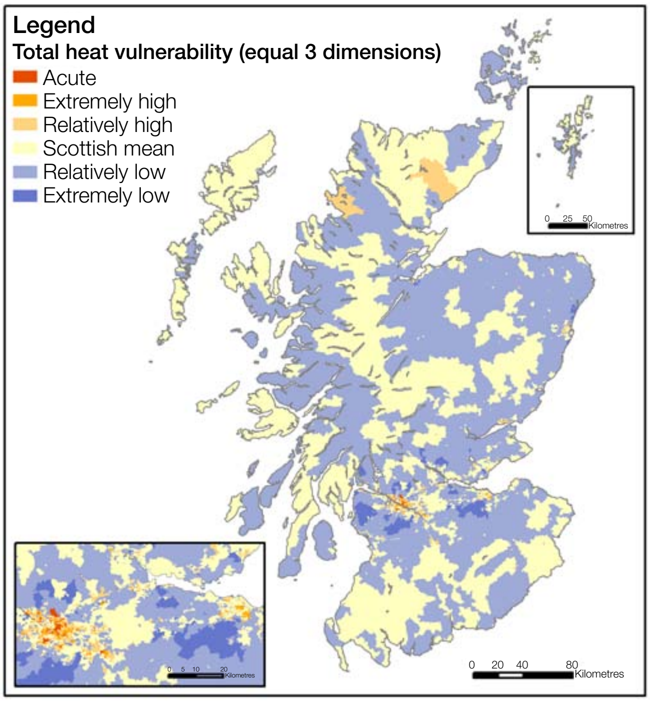


Figure 23: Heat vulnerability in Scotland using an equal weighting three-dimension approach and an example using weighting derived from the Scottish Index of Multiple Deprivation



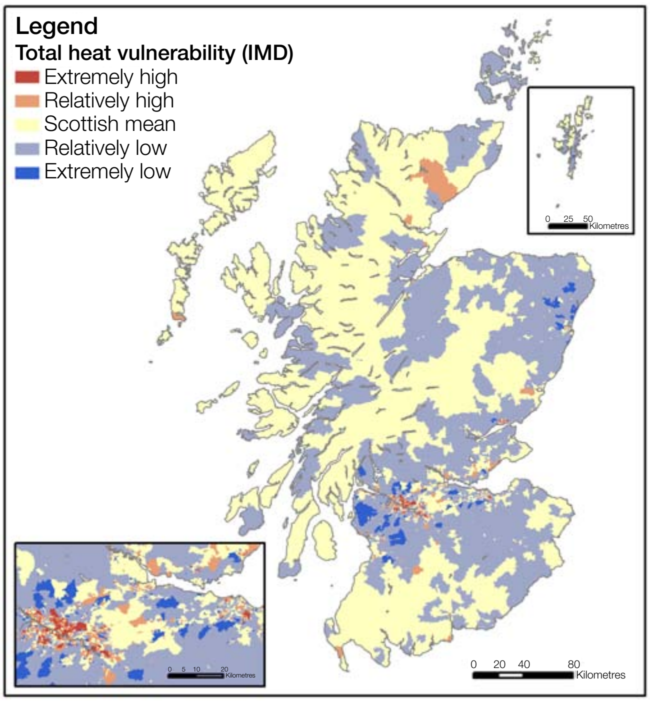


Table 19: Alternative weighting scheme for the socio-spatial index for Scotland

Scottish IMD domain	IMD ratio	Flood	Heat	Socio-spatial index domain
Income	12	0.4	0.44	Income and employment
Employment	12			
Health	6	0.1	0.1	Sensitivity
Education, skills and training	6	0.1	0.111	Information use (local knowledge)
Geographic access to services	4	0.1	0.08	Mobility and access
Housing	1	0.07	0.11	Enchanced exposure and tenure
Crime	2	0.03	0.04	Crime
		0.1	0.11	Social networks
		0.1		Insurance

Table 20: Agreement (%) between three weighting options (against top/bottom 10% in the equally weighted five-dimension scheme used in the main report)

	Top 10% most vulnerable	Top 10% most resilient
Heat equal 3	79.73	78.97
Heat IMD	72.31	76.70
Flood equal 3	72.77	78.06
Flood IMD	71.56	72.47
Total neighbourhoods	661	661

Acknowledgements

The authors would like to thank Salford City Council, Wigan Metropolitan Borough Council and Hampshire County Council for reviewing some of the early findings from this work. The report also benefits from the input of several reviewers. Thanks are particularly owed to Kevin Anderson, Katharine Knox, Richard Starkey, Hillel Steiner, Josh Stott and Gordon Walker, who made several helpful comments on earlier drafts.

Finally, we would like to take the opportunity to acknowledge the many providers of geospatial data used in the empirical work. The maps used in this report are derived from a range of sources, full details of which are given in the Notes and Appendix I. The associated acknowledgements are listed below.

This work is based on data provided through EDINA UKBORDERS with the support of the Economic and Social Research Council and Joint Information Systems Committee, and uses boundary material which is copyright of the Crown. Source: 2001 Census, Output Area Boundaries. Crown copyright 2003. Crown copyright material is reproduced with the permission of the Controller of HMSO.

The following data sources are also acknowledged:

- Environment Agency NaFRA 09/10 Spatial FLC Grid product data under Special Licence – Non-Commercial Ref: A1539
- Environment Agency Historic Flood Map data under Special Licence – Non-Commercial Ref: A1631
- Northern Ireland Historical Flood Extents, Rivers Agency, Department of Agriculture, Rural Development Northern Ireland (DARDNI)
- Scottish Environment Protection Agency historical flood zones. The Scottish Environment Protection Agency reserves all copyright and database rights
- UK Census 2001, Crown copyright
- Land Use Statistics (Generalised Land Use Database), 2005, Office of National Statistics
- Model-based Estimates at Middle Super Output Area (MSOA) Level, 2004/05, Office of National Statistics
- VAT-based Enterprises by Broad Industry Group, 2005 and 2007, Office of National Statistics
- Accessibility statistics, 2008, Office of National Statistics
- Changes of Ownership by Dwelling Price, 2008, Office of National Statistics
- Accessibility indicators, www.dataunitwales.gov.uk
- Mean elevation, Northern Ireland Neighbourhood Information Service (NINIS), www.ninis.nisra.gov.uk
- US Geological Survey Digital Elevation Model (1km)

- Locations of GPs and emergency hospitals from geospatial data provided by Northern Ireland Neighbourhood Information Service (NINIS), www.ninis.nisra.gov.uk

- English Indices of Multiple Deprivation 2004, Office of National Statistics

- Multiple Deprivation Measure 2005, Northern Ireland Neighbourhood Information Service (NINIS), www.ninis.nisra.gov.uk

- Scottish Index of Multiple Deprivation 2004/5, Scottish National Statistics

- Welsh Index of Multiple Deprivation, www.dataunitwales.gov.uk

- UKCP09, UK Climate Projections, 2009, Crown copyright

About the authors

Sarah Lindley is Senior Lecturer in the School of Environment and Development (Geography) at the University of Manchester. She specialises in the use of geospatial analysis to understand the outcomes of human–environment interactions with a particular emphasis on urban air pollution and climate adaptation. Her research into climate adaptation covers physical and social dimensions and the development of adaptation solutions. Her funding sources include UK research councils and the European Union.

John O'Neill is Hallsworth Professor of Political Economy at Manchester University and co-director of the Political Economy Institute. He has written widely on philosophy, political economy and environmental policy. His books include *Markets, Deliberation and Environment* (Routledge, 2007), *The Market: Ethics, Knowledge and Politics* (Routledge, 1998) and *Ecology, Policy and Politics* (Routledge, 1993). He is co-author of *Environmental Values* (Routledge, 2008) with Alan Holland and Andrew Light.

Joseph Kandeh recently completed his PhD on quantitative social vulnerability analysis in the School of Environment and Development (Geography), Manchester University. He is now deputy head of the Inter-Agency Information and Analysis Unit that provides support on evidence-based analysis and planning to the UN agencies, the UN Mission and NGOs working in Iraq. He manages the GIS/RS and Database/Web development team and is based in Amman, Jordan.

Nigel Lawson is an Honorary Fellow and a member of the Centre for Urban and Regional Ecology at the University of Manchester, and is Secretary of the UNESCO UK Man and Biosphere Urban Forum. In recent years he has specialised in the risk and the management of urban flooding. His particular interests include the role and the responsibilities of the state, the private sector and the individual in flood risk management.

Richard Christian is a research assistant in the School of Social Sciences at Manchester University. He recently completed his DPhil on ideas of economic justice at Oxford University. He previously studied philosophy at Lancaster and Edinburgh.

Martin O'Neill is Lecturer in Political Philosophy at the University of York. He was previously Hallsworth Research Fellow in Political Economy at the University of Manchester. His research addresses questions of liberty, responsibility, equality and social justice, and issues at the intersection of political philosophy and public policy.

The Joseph Rowntree Foundation has supported this project as part of its programme of research and innovative development projects, which it hopes will be of value to policy-makers, practitioners and service users. The facts presented and views expressed in this report are, however, those of the authors and not necessarily those of JRF.

A pdf version of this publication is available from the JRF website (www.jrf.org.uk). Further copies of this report, or any other JRF publication, can be obtained from the JRF website (www.jrf.org.uk/publications).

A CIP catalogue record for this report is available from the British Library.

First published 2011 by the Joseph Rowntree Foundation

ISBN: 978-1-85935-865-8 (pdf)

Original design by Draught Associates
Project managed and typeset by Cambridge Publishing Management Limited

Joseph Rowntree Foundation
The Homestead
40 Water End
York YO30 6WP
www.jrf.org.uk