Access to food in a changing climate

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List of Acronyms

4AR	Fourth Assessment Report
CAP	Common Agricultural Policy
CO_2	Carbon Dioxide
DEFRA	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
DH	Department of Health
EA	Environment Agency
EWE	Extreme weather event
FAO	Food and Agriculture Organization
FSA	Food Standards Agency
GDP	Gross Domestic Product
GECAFS	Global Environmental Change and Food Security
GIS	Geographic information system
GMO	Genetically modified organism
IGD	The Institute of Grocery Distribution
IPCC	Intergovernmental Panel on Climate Change
LIDNS	Low Income Diet and Nutrition Survey
LSOA	Lower super output area
OECD	Organisation for Economic Co-operation and Development
PDF	Probability distribution function
PED	Price elasticities of demand
R&D	Research and development
SCAR	Standing Committee on Agricultural Research
SDAP	Scottish Diet Action Plan
SRES	Special Report on Emissions Scenarios
UKCP09	UK Climate Projections ‘09
UKCIP	UK Climate Impacts Programme
WG	Weather Generator

Executive Summary

This scoping exercise has been funded through the Adapting to Climate Change Strategic Evidence Fund, developed to support research using UK Climate Impact Programme (UKCIP) outputs, in this case UK Climate Projections '09 (UKCP09) mapping tool. The following questions were addressed:

- What is the likelihood of changes in vulnerable groups' access to food in a changing climate?
- Are these vulnerable groups more likely to live in areas disproportionately affected by [the direct physical effects of] climate change?

The Global Environmental Change and Food Security (GECAFS) framework, integrating socio-economic and global environmental change drivers to understand future changes in food security, was used. This framework understands vulnerability as a multi-faceted phenomenon, with individuals becoming vulnerable as a result of exposure, high sensitivity and poor adaptive and coping strategies.

In order to set parameters on this research we identified three key vulnerable groups, allowing for different elements of vulnerability to be explored. These groups were: the over 85s, the income deprived, and the disabled and health deprived.

Whilst there has traditionally been an over-emphasis on food production, reports such as the UK Food Security Assessment and the GECAFS programme have highlighted the need to think about food system activities beyond the farm gate when addressing food security. The food access element of food security was the main focus of this research, and was seen to comprise economic and physical access specifically. Breaking these two down further, economic access consisted of food price and purchasing power, the latter of which is the outcome of income, outgoings and savings; physical access was seen to be a consequence of transport systems (availability and ability to access), physical wellbeing, and the retail environment.

In the process of this scoping exercise a number of methods and resources have been employed including desk-based research and literature reviews, examination of case-studies, expert consultation and geographic information system (GIS) mapping.

In relation to the first question we conclude the following. Economic access is potentially an issue for all three vulnerable groups given low or fixed sources of income. However, the influence of changes in mean climate conditions to 2020, and even 2050, was thought to be relatively minor given the large range of other factors that contribute to the price of food and the purchasing power of individuals. After 2050 however, and towards the end of this century, the implications of climate change for food production look to be increasingly negative. Knowledge concerning the response of vulnerable groups

to price increases is patchy and particularly limited in relation to price changes (i.e. volatility). Implications for nutritional outcomes, is even less well understood.

Physical access is again an issue for all three vulnerable groups, but in different ways, given that the very old and health deprived may have more issues with respect physical well being, whilst all three groups are more likely to struggle with access to transport systems in different ways. Transport systems are more at risk of increases in extreme weather, whilst physical wellbeing will also be affected by changes in mean conditions. The balance of climate change impacts on health is not clear, with a reduction in excess winter deaths as temperatures increase, but increases in heat-related illness in summers. Whilst considerable research has been undertaken to understand how climate change will affect transport systems and health, much less is known about the knock on effects for access to food.

With respect to the second research question, there are weak confluences between the current spatial distribution of vulnerable groups and disproportionate exposure to future climate change. However, while this approach can highlight potential future ‘hotspot’ areas, there are a number of issues with mapping that limits its utility in answering the second research question.

In the process of examining the research questions it has become clear that given uncertain and complex futures, including interactions between global environmental change and socio-economic drivers, consideration of future food access of vulnerable groups cannot be confined to a consideration of climate change alone. In the second part of the report we map out key socio-economic drivers which we see to have a strong bearing on the nature of future food access, highlighting the point that vulnerable groups, food systems and society are not static entities. Future changes of particular note were considered to be: demography and settlement patterns, the relative individualism or collectivism of our values and governance systems and the role of technology in mediating climate change impacts.

As well as highlighting specific questions for future research, we have the following recommendations for research in this area in general:

- Attention needs to be paid to interactions between levels and scales (as understood by Cash et al., 2006) when considering the complexity of future change.
- More research effort, in the form of case studies, is required in understanding current coping strategies and adaptive capacity in vulnerable groups’ food access, and what determines deployment of these factors.
- Given uncertainty and complexity in determining the food security of vulnerable groups in the future, scenario based approaches would be useful. They would allow for a systematic exploration of diverse food futures and the robustness of proposed interventions to be tested.

1. Introduction

This report examines the potential impact of future climate change for the food security of vulnerable groups in the UK. Food security[3] is a critical element of societal stability and prosperity, and its attainment is potentially influenced by climate in many ways. Globally, we are already committed to some climate change from emissions currently in the atmospheric-oceanic systems and looking ahead to the 2090s, assuming continuation of current emission trajectories, we can expect global warming of between 2.8 and 4°C (Solomon et al., 2007). Changes in climate at the global level over the coming century include (Solomon et al., 2007): very likely increase in frequency of heat waves and heavy precipitation events with a reduction in cold episodes and the diurnal temperature range. Tropical cyclones will increase in intensity and precipitation generally is very likely to increase at higher latitudes coupled with likely decreases in precipitation across subtropical regions. The chance of drought will increase in mid-continental areas, and sea level rise is expected. All of these changes will have implications for food production, infrastructure, trade and consumption. This commitment to certain levels of warming, and the potential for much greater warming in the future, means it is vital to consider localised impacts and think about adaptation to climate change as well as mitigation.

Increased awareness of likely future environmental changes (climate change being just one of those affecting food systems), recent incidences where shocks have impacted on food security (be that food price rises or natural events such as tsunamis) and future demographic projections have brought the debate around food security closer to home. For example, the UK Food Security Assessment (DEFRA, 2009a) has provided a structured way for the Department for Environment, Food and Rural Affairs (DEFRA) to consider UK food security into the future. It thinks across levels (national, household) and across food system activities (availability, supply, access). The UK Food Security Assessment has been part of a movement to bring the debate around food systems past production, recognising that as a nation there is currently no problem with food availability, yet there do exist households which struggle to access affordable and healthy food. It is the food access element of food security that we concentrate on here, and in the context of future climate change, those households that struggle with food access.

This report seeks to address the questions:

- What is the likelihood of changes in vulnerable groups' access to food in a changing climate? And,

[3] Food security was defined at the World Food Summit (FAO, 1996) as when 'all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy lifestyle'.

- Are these vulnerable groups more likely to live in areas disproportionately affected by climate change?[4]

This scoping exercise has been funded through the Adapting to Climate Change Strategic Evidence Fund, developed to support research using UK Climate Impact Programme (UKCIP) outputs, in this case UK Climate Projections ‘09 (UKCP09) climate mapping tool. The research was carried out over the three months of Spring 2010. Whilst UKCIP maps for the entire UK, food is a devolved issue and so this research solely focuses on food access in England.

In the rest of this introductory section we explain the broad conceptual framework used to guide this research. Vulnerability as it relates to food access[5] in the UK is examined, focussing on two key barriers to food access: physical and economic. We then detail the vulnerable groups around which we ground this analysis. Finally an outline of the rest of the report is given.

1.1. The GECAFS conceptual framework

This report draws heavily from the GECAFS framework[6] in which food systems are set in the context of their multiple socioeconomic as well as environmental change drivers, going on to examine the interactions between food system activities and food security outcomes (not just food availability but also food access and food utility). Figure 1.1 shows the GECAFS schematic of food systems, highlighting the interactions between environmental and socioeconomic drivers (which cannot be considered independently). The GECAFS aim, to integrate food system outcomes and activities in the context of global environmental change, makes it a suitable conceptual framework through which to approach the topic of food access in a changing climate.

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[4] This question was interpreted as referring to the direct physical effects of climate change.

[5] Access is defined as the part of the supply chain between food arriving in the shop and arriving in the home. Whilst it is very important to focus upon pre-retail activities (production, processing and distribution) and post food arriving in the home (cooking and consumption), this is not done here except in considering the way in which these stages impact upon access.

[6] See GECAFS: http://www.gecafs.org/

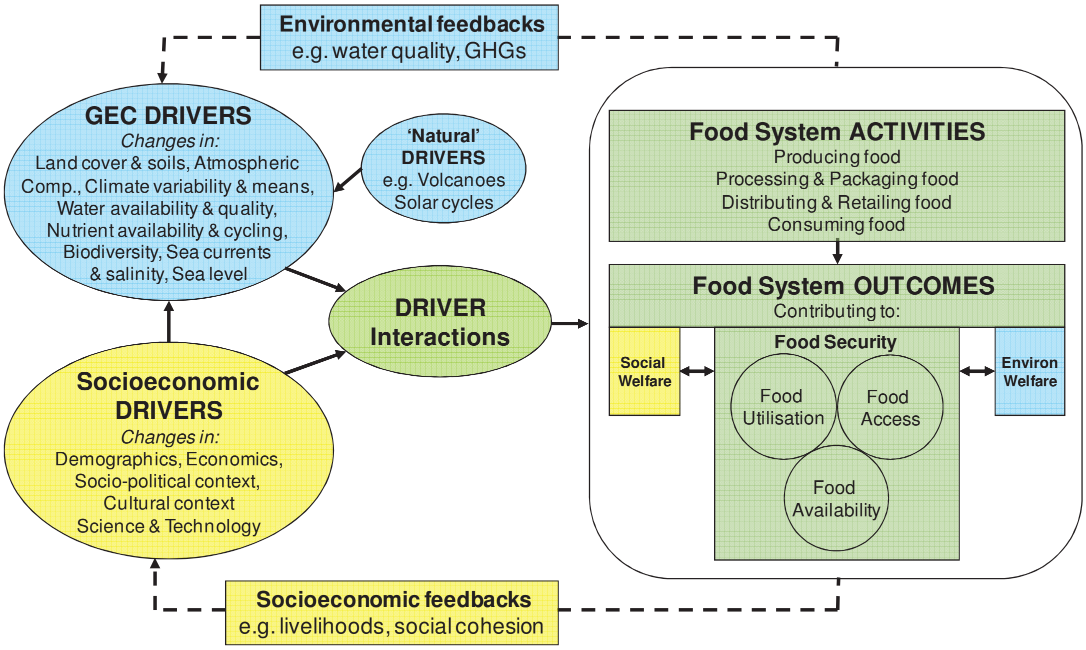

Figure 1.1. Food systems and their drivers (GECAFS 2009, adapted from Ericksen 2008b)

1.2. Vulnerability and Food Security

There is a rich literature exploring the causes of vulnerability of individuals and food systems, particularly in developing or newly developed nations. However, there is a lag in applying many of these concepts to the UK context.

With respect to climate change a useful approach is the idea of vulnerability as a multi-faceted concept (as used by GECAFS, and drawing from the Intergovernmental Panel on Climate Change (IPCC)). Vulnerability is here seen to be the result of exposure, sensitivity and adaptive capacity or coping capacity of individuals/households/systems. To take the words of Ericksen (2008a):

> "Exposure means that a unit must be exposed to a shock, threat, or stress to be vulnerable to it…Sensitivity follows exposure. Although everyone in a place may be exposed to a stress…, they are not equally likely to experience its impacts because some are more sensitive than others…Coping capacity expresses the understanding that people need more than just access to resources to be less vulnerable, but also active strategies to manage resources in the face of risk… The notion of adaptive capacity implies longer term changes in behaviour and livelihood strategies to ensure the maintenance of income or food security for the foreseeable future… It implies the ability to take active steps to reorganize for better management…coping capacity is best understood in relation to managing current stresses and is often reactive, whereas adaptive capacity should refer to the potential to adapt to future uncertain changes without increasing vulnerability and is proactive." (np.)

With regards to this report we are examining the exposure of vulnerable groups (which we identify later in the introduction) to climate change. We assume that these groups have comparatively higher sensitivity and lower adaptive capacity than others. However, it is not *always* the case that exposure, sensitivity and poor adaptive capacity come together. As we illustrate in the following sections, adaptive capacity is not well understood, an individual can be exposed and can be sensitive but with effective adaptive or coping strategies employed they may be buffered from risk and thus less vulnerable. Whilst it seems likely that our vulnerable groups also have reduced adaptive and coping capacity, with fewer strategies in times of stress, this is not axiomatic and needs interrogating.

1.3. Vulnerability and Food Access in the UK

In 1998 The Acheson Report focused attentions on the disparities in food access in deprived groups, with the realisation that food insecurity is not confined to developing countries but rather is present at the individual and household level in the UK. In 2007 the Food Standards Agency's (FSA's) Low Income Diet and Nutrition Survey (LIDNS) showed 29% of the materially deprived sample[7] to be mildly, moderately or severely food insecure, with over one third, 36%, unable to access a balanced diet (Nelson et al., 2007).

This reference to a balanced diet, and the Food and Agriculture Organization's (FAO's) definition of food security (see footnote 3), highlight the need to attend to both the quantity *and* quality of the food being accessed, i.e., whether an individual is receiving enough food *and* if that food is healthy and culturally appropriate. Given this, this research has attempted to consider *healthy* food access. However, as will become obvious, UK-based research analysing access to enough food is limited, let alone research relating to the quality of this food.

1.4. Barriers to healthy food access in the UK

A number of barriers to healthy food access have been highlighted since attention has been drawn to such problems. Systematically thinking through the potential current difficulties in accessing healthy food can help us to thoroughly think through which groups are vulnerable to food insecurity and how future changes (such as exposure to climate change) may act to enhance or reduce these barriers. McEntree (2008) argues that the potential barriers to adequate healthy food access are lack of healthy preferences, information, finances or physical ability. Similarly, The Scottish Diet Action Plan (SDAP) (The Scottish Government, 1996) recognized four major barriers to individuals' access to food:

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[7] LIDNS is a self-reporting survey which, despite name, sampled on a slightly wider basis than low income to include indicators of material deprivation such as car ownership, receipt of benefits. The emphasis, however, is still on material deprivation which may exclude many who experience difficulties with food access, in particular groups who struggle with physical access but not economic such as some disabled and elderly groups.

physical, affordability, preferences and habits, and skills and equipment. The SDAP also highlights overlaps and reinforcements between these factors.

As a result of the scope of this exercise, this research is going to focus upon the barriers of **affordability** and **physical access**. This is because, in terms of food access, most is known about these areas, making the thinking through of future changes easier and more likely to be robust. Whilst we do acknowledge that the impacts of a changing climate on food preferences and skills/equipment[8] may be an interesting future area of research, the focus upon affordability and physical access is also in line with other governmental assessments (such as the UK Food Security Assessment). As affordability and physical access are multi-faceted, we have developed conceptual models of these concepts, outlined below. Whilst we acknowledge that these conceptual models are simplified, they will allow us to more systematically think through changes to food affordability and physical access.

Affordability – By far, the main barrier highlighted in the LIDNS is not having enough money. This is perhaps unsurprising given the material deprivation criteria for those sampled in this survey (which would, for example, ignore elderly who are not materially deprived but still struggle with physical food access), but economic barriers are repeatedly flagged in other research into barriers to UK food access (for example, The Scottish Government, 1996, and McEntree, 2008).

There is considerable disparity in the percentage of earnings spent on food across income groups with lower income groups spending a much higher percentage of earnings on food (17% in the lowest income decile as opposed to 7% in the highest decile, ONS, 2009a). This is despite these groups' absolute spending on food being lower than high income groups. Such disparities put great pressure on the food access of low income groups as the LIDNS results show. The higher proportion of money being spent on food, combined with other essentials such as fuel and transport, leads to financial pressures to reduce spending on food (it also means that some households have smaller margins to cope with price changes). Whilst the costs of other essentials, such as rent, tend to be fixed within the household budget, food is an area within which there is more flexibility. Reduced spending can come through reducing the amount purchased (for example the LIDNS showed 22% of its sample reported reducing or skipping meals in the last year) but it can also come through changing the types of foods purchased (Nelson et al., 2007). As White (2007) showed, on average, a healthy diet is more expensive than an unhealthy diet with less healthy sources of calories tending to be cheaper than healthy ones, encouraging those keeping an eye on price to consume less healthy diets. Therefore food access is about securing not just enough food, but also the right kind of food, for a healthy and balanced diet.

[8]See Nelson et al. (2007) and Dowler and Dobson (1997) for further information on skills and equipment, and Kirkrup et al. (2004) and McEntree (2008) for more information on preferences.

It is important to remember that the ability to afford food is about more than just the price of food. As noted by the Scottish Government (2009) affordability is as much a sociological as economic concept; being influenced by trade, home production, information, prices, income, local and community initiatives and consumption. Whilst we agree that these are all influencing factors, for the purposes of this project a simpler conceptual model has been developed that focuses more on economic elements. Drawing on Ericksen (2008b), Kyte and Hirani, 2008 and Revoredo-Giha et al., 2009 we conceptualise affordability as follows:

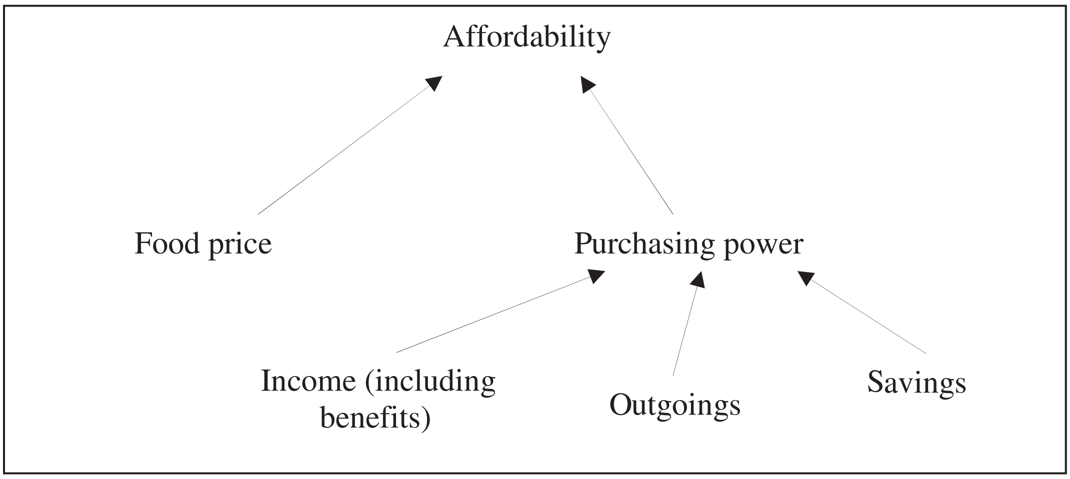

Figure 1.2. Conceptual model for food affordability

Whilst we are focussing on food access, we realise that affordability includes elements of food availability too. In relation to the broader GECAFS framework used here and given the need to set parameters for this research, affordability is used as a prism through which to explore both food access and food availability. This assumes that price of food will encompass changes in production, distribution and exchange (the elements comprising food availability).

Physical access – Many people have highlighted other vulnerable groups, in addition to those who struggle with economic barriers, who have problems with healthy food access, for example the elderly (Meneely et al., 2009; Kelly and Parker, 2005).

In the late 1990s the concept of ‘food deserts’ rose in popularity. Originally the term was used to refer to areas which had poorer distributions of food stores. Later the concept evolved to incorporate transport systems as either buffering or enhancing poor retail environments (e.g. McEntree, 2008; Robinson et al., 2000). While Department for Transport (DfT) research has shown that virtually all households are within 30 minutes of a food store by public transport or walking (2009), and although the concept of food deserts is contested (White, 2007; Beaulac et al, 2009), it is undoubtable that physical access can serve as a barrier to healthy food access (with a wealth of literature at the household level supporting that, e.g. McEntree, 2008; Robinson et al., 2000; Meneely et al., 2009; Kelly and Parker, 2005). In reality we need to think past the presence of retail stores meaning that they will necessarily be used by individuals. Food access is generally more a product of the individual's situation and sensitivity than their physical environment. For example, a lone parent family without car access can struggle with healthy food access, prioritising cost over quality, whilst their neighbour with fewer economic pressures and car ownership has no access problems, despite being situated in exactly the same retail environment.

There is also a need to think of the interactions between problems with physical access on diet and spending. There is evidence that people in lower income groups are less likely to shop in out of town supermarkets and more likely to shop in small local shops compared with those in higher income groups (Caraher et al., 1998). When combined with evidence that small local shops tend to have a smaller range of healthy items and tend to be more expensive (White et al., 2004) this suggests another reason why some groups are struggling to secure healthy food access.

As Lucas (2004) notes in her conceptual model of transport accessibility, accessibility needs to be thought about as being a function of the person, the transport systems and the activity environment. Such logic can be applied to conceive of physical access to healthy food as being a function of physical wellbeing, transport systems (their availability and an individual's ability to access and afford those systems) and finally the retail environment within which they exist. Such a model is shown in Figure 1.3.

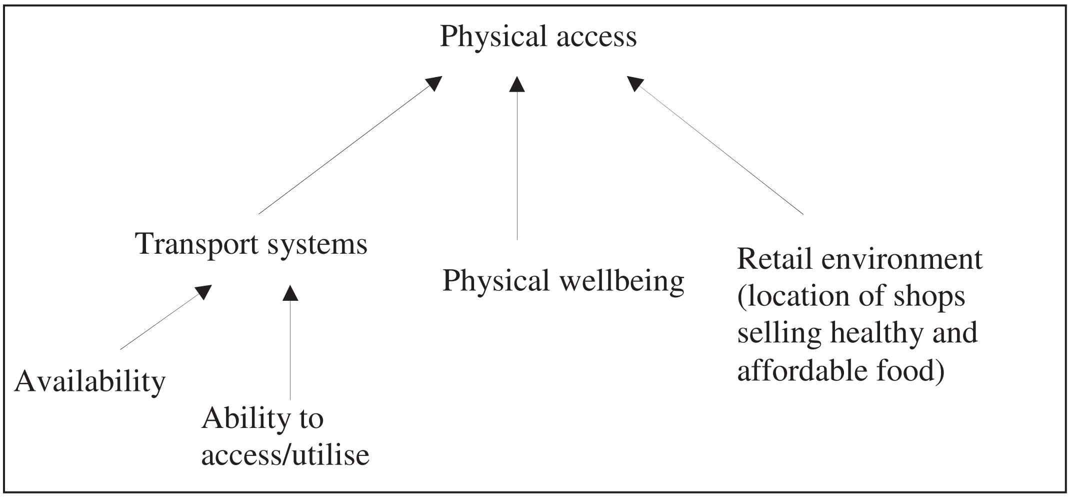

Figure 1.3: Conceptual model for physical access to food

With the aid of these schematics we can think through the ways that different vulnerable groups may be differentially vulnerable. For example, an extremely elderly (85+) individual may have a car available but be unable to use it whilst struggling with their physical wellbeing. In comparison a low income parent may have no access to a car for economic reasons whilst struggling to carry the volume of food shopping they require.

1.5. Defining vulnerable groups

In order to set parameters on the current study we have chosen to focus on a finite number of groups that have characteristics suggesting increased vulnerability to food insecurity. The groups chosen are not exclusive, with justification for their choice laid out below.

There are a number of different groups who have been noted to struggle with food insecurity. The diverse characteristics of these different groups means that they come up against different barriers to food access (are differentially vulnerable) and as such stand at risk to different aspects of climate change in the future (they will also have different adaptive and coping capacities, a theme that runs throughout this report). Breaking vulnerability into different types of groups allows us to think through more thoroughly the different potential risks to these different groups' food access. In the main we aimed to choose groups we considered to be amongst the most vulnerable, as well as including a range of characteristics conveying vulnerability. The ability to map these groups was also given consideration[9].

Having said this, within the food access literature there is an avoidance of signposting which groups are vulnerable to poor food access. Most likely this is because of a need to avoid generalisations and recognise food insecurity as existing at the household level. So the groups chosen are indicative of higher risk rather than an assumption that all members of these groups will suffer poor food access. We also recognise that the use of vulnerable groups may distract from the underlying causes giving rise to their difficulties with food access. As a consequence barriers to food access, as well as group-vulnerability, are a continual theme through the report.

Group 1: The oldest old (>85) Like most developed countries, the population of the UK is ageing with 3.2 million oldest old, or 5% of the population, expected by 2033 (ONS, 2009b).

The oldest old are more likely to have both access and affordability issues. Half of those over 75 in the UK suffer some form of long term illness or disability (The Poverty Site, 8 March 2010a) and one third of those over 95 have dementia (Alzheimer's Society, 8 March 2010). Those who remain

[9] As well as the three groups chosen here, a fourth group was originally conceived that experience poor access to services characterised by comparatively greater distance to services. This group was excluded because we did not feel that distance to services sufficiently described physical access. We have argued here that physical access problems are a result of transport systems, wellbeing *as well as* retail environment.

ambulatory and cogent may still have difficulty accessing services if they have lost their driving privileges or do not own a motor vehicle. This is particularly true in rural areas where over half of single pensioners and one in seven pensioner couples do not own a car. Additionally, one tenth of the rural population does not have a bus service (The Poverty Site, 9 March 2010). If there are no local stores (and in half of the parishes with fewer than 1000 residents, there are not) lack of transportation could be problematic (The Poverty Site, 9 March 2010).

Finally, 1.3 million pensioners currently have no source of income other than their state retirement pensions and means tested benefits, and 20% of all pensioners over 75 are considered low income (The Poverty Site, 8 March 2010b). All of these things combined paint a portrait of a group likely to be very sensitive, and potentially vulnerable, to extrinsic change.

Group 2: The income deprived In 2007 to 2008, 13.5 million British citizens, or 22% of the population, qualified for low income status[10] (The Poverty Site, 8 March 2010c). Though this represents an increase of 1.5 million individuals over the past three years, the previous two decades experienced fluctuations in both directions (The Poverty Site, 8 March 2010c).

Those most likely to fall into low income status are families in which neither parent work, families with three or more children, single parent families, single pensioners, and those disabled and lacking benefits (ONS, 9 March 2010). In 2009, 3.3 million households were without work (The Poverty Site, 8 March 2010d).

Affordability of food and transport is the seminal issue among the income deprived. They may have insufficient resources to pay for food, particularly more expensive items such as meat and fruit, even if such items are physically accessible to them. If food scarcity resulting from climate change drives prices up, adequate and nourishing food may be beyond the reach of this large demographic.

Group 3: The health deprived and disabled - Three and a half million adults aged 45-64 in the UK have long term illnesses or disabilities that restrict their mobility. Moreover, this characteristic is strongly associated with poverty. Over 40% of low income individuals in the 45-64 age range are disabled or have illnesses of long duration. Half of those aged 25-64 and not working are disabled.

Ill health and disability are not exclusive to any age group. But, the extension of life expectancy over the past twenty five years has created a new demographic: those who live with chronic health

[10] Here 'low income' is defined as household income below 60% of the median for any given year. As we explain in section 2.2., our study uses a multi-faceted measure of income deprivation which also takes into account unemployment benefits and working family tax credits amongst other factors.

problems for extended periods of time. Healthy, disability free life expectancy has increased, but not to the same extent as longevity. Women in the UK now have a life expectancy at birth of 81.5 years with a healthy life expectancy of 70.5 years, a difference of 11 years of unhealthy living. Men likewise, have a life expectancy at birth of 77.2 years with 68.5 years of healthy life expectance, a gap of 8.7 years (ONS, 29 March 2010). Mental health is also an important issue, particularly as it is strongly believed to be both a cause and an effect of poverty. Among the poorest 20% of the British population, one in four men and women experience some form of mental health problem (MacInnes et al., 2009).

Health deprivation is likely to lead to increased vulnerability to food insecurity because of the link to lower incomes (impacting on affordability) and the potential impacts on physical wellbeing and ability to utilise transport systems (impacting upon physical access).

1.6. Logic and outline of report

The main question examined in this report is:

- What is the likelihood of changes in vulnerable groups' access to food in a changing climate?

And a sub-section of this broader question which we also seek to examine is:

- Are these vulnerable groups more likely to live in areas disproportionately affected by climate change?

Referring back to the GECAFS framework, we understand food systems and the socio-economic and global environmental change drivers affecting them to be dynamic. Dynamism poses a challenge to this study – whilst the future climate has been reasonably well modelled, to determine how this will interact with changing socio-economic variables into the future is difficult to do with any certainty. For example, what comprises vulnerability in 2050 or 2080 may be very different to that experienced currently. The challenging nature of this research subject means this initial scoping project seeks to understand the issues as much as giving a first stab at answering these questions. The approach being taken in this report comprises three phases (and these make up each of the three following sections of the report).

1. Firstly, seeking to answer 'what do we know of our vulnerable groups ***now*** and how might progressive climate change affect their economic and physical access to food?', we assume that all variables of interest are held constant other than the impacts of a changing climate. We also utilise UKCP09 to examine whether the current spatial distribution of the vulnerable groups mean they are more likely to live in areas disproportionately affected by climate change.
2. Secondly, we explore the uncertainties and complexities involved in understanding changing food access in a changing climate, bringing in the socio-economic variables that in reality will change alongside climate change.

3. Thirdly, building on the previous two sections, conclusions are drawn around the central questions and areas of importance for future research are identified.

1.7 Methods

In the process of this scoping exercise a number of methods and resources have been employed. Initially the food poverty and food security literatures for the UK were reviewed. For economic access the literature was systematically searched and reviewed under the areas of impact of climate change on crop production and prices, transmission of price changes in UK supply chains, and implications of price changes for access to food. A lack of academic literature sources led to indicative evidence gathering on the impact of weather and climate on food prices in the UK. Here Lexis-Nexus searched newspapers and food price statistics were used to build a picture of cause and effect. For physical access, literature on the impacts of climate change for transport and health was reviewed, and searches undertaken into the impacts of changes in these on food access.

As well as desk-based literature searches, expert interviews also revealed useful sources of information[11]. People utilising the UKCIP projections with insights into our work were chosen as expert interviewees, as were individuals contributing to the Foresight Project on the Future of Farming and Food and individuals with expertise in the areas of vulnerable groups and access to services. Discussion focussed mainly around the use of conceptual models, literature sources and the state of current thinking on a topic.

In the second part of section two weather maps were generated using UKCIP's User Interface (UKCP09), a tool allowing tailored map production through a request building process. Using ESRI's ArcMap programme the Lower Super Output Area (LSOA) boundary file (baseline map) was overlain onto the UKCIP maps. Onto each of these, vulnerable group data relating to the top 20% most concentrated LSOAs was mapped. For more information on the datasets used and exact details on choice of UKCIP variables used, refer to Appendix B.

In section 3 we drew from the UKCIP socio-economic scenarios and a range of other scenario/future studies[12] to structure and inform a systematic examination of socio-economic drivers of food access. Coupled with insights gained through undertaking section 1 of the report we then used these to consider impacts on food access and interactions between drivers. Our own judgement was used to draw out what we considered particularly important socio-economic drivers of future change.

[11] Appendix A shows a list of experts consulted in the course of this study.
[12] These were: Steedman and Schultz (2009), Wilkinson et al. (2009), Sheate et al (2007), Rothman et al (2007), Lang et al (2009), GOS (2006a, b, c), and background papers for the Standing Committee on Agricultural Research (SCAR) Foresight Initiative, including: Anania (2006), Downey (2005), Cuhls (2006), Schenkel (2006), Leijten (2006).

2.0. Base-line assessment of access to food in a changing climate

This section seeks to examine access to food in a changing climate attempting to hold other variables constant. The first section addresses the question 'what is the likelihood of changes in vulnerable groups' access to food in a changing climate?', using our conceptual models (outlined above) to think through how climate change may enhance or buffer the barriers to food access of affordability and physical access which many vulnerable individuals already experience. We then utilise UKCP09 climate projections to examine whether the vulnerable groups outlined above are more likely to live in areas disproportionately affected by climate change.

2.1. What is the likelihood of changes in vulnerable groups' access to food in a changing climate?

<u>2.1.1. Affordability</u>

Firstly, we review research into how climate change will affect food production and commodity prices globally. We then consider how this translates into changes in price for consumers in the UK and finally review research on how price interacts with affordability.

Impact of climate change on food systems:

Impacts of climate change on the ability to produce food stem from altered (and in some cases enhanced) growing conditions, biodiversity loss, sea level rise, increased drought, changes in disease patterns, weather pattern shifts, increased flooding, changes in freshwater supply, and an increase in extreme weather events (EWEs). Food distribution will also be affected by EWEs. Feedbacks in both the environmental and socio-economic systems will ameliorate or enhance these impacts, for example through adaptive interventions such as planting alternative crops or crop varieties. Looking at the demand-side, climate change may also affect demand for particular food goods – for example hotter, drier summers may mean there is more demand for salad and barbeque items.

General findings relating climate change to food prices are reviewed here drawn from the IPCC Fourth Assessment Report (4AR) (Parry et al., 2007), Cline (2007), the Stern Review (2006) and Nelson et al. (2009). In considering the results of these studies and in relation to this work, the IPCC SRES scenario basket[13] is used (see Figure 2.1), which assumes an increase in global surface temperatures of about 0.6℃ by 2020, about 1.4℃ by 2050 and between 1.6-3℃ by 2080 (although emissions are currently at the upper end of IPCC predictions (Richardson et al 2009) and post 2080

[13] The 'SRES' scenarios (called such because they come from the IPCC's Special Report on Emissions Scenarios, Nakicenovic et al 2000) are the socio-economic scenarios on which the IPCC base their basket of future global emission and global temperature change profiles. Each scenario is based on different assumptions of socio-economic and demographic change– A1F1, A2, B2 etc.

temperatures may be reaching 4-5 ̊C under business as usual). For a review of the socio-economic changes assumed in each SRES scenario, see Appendix C.

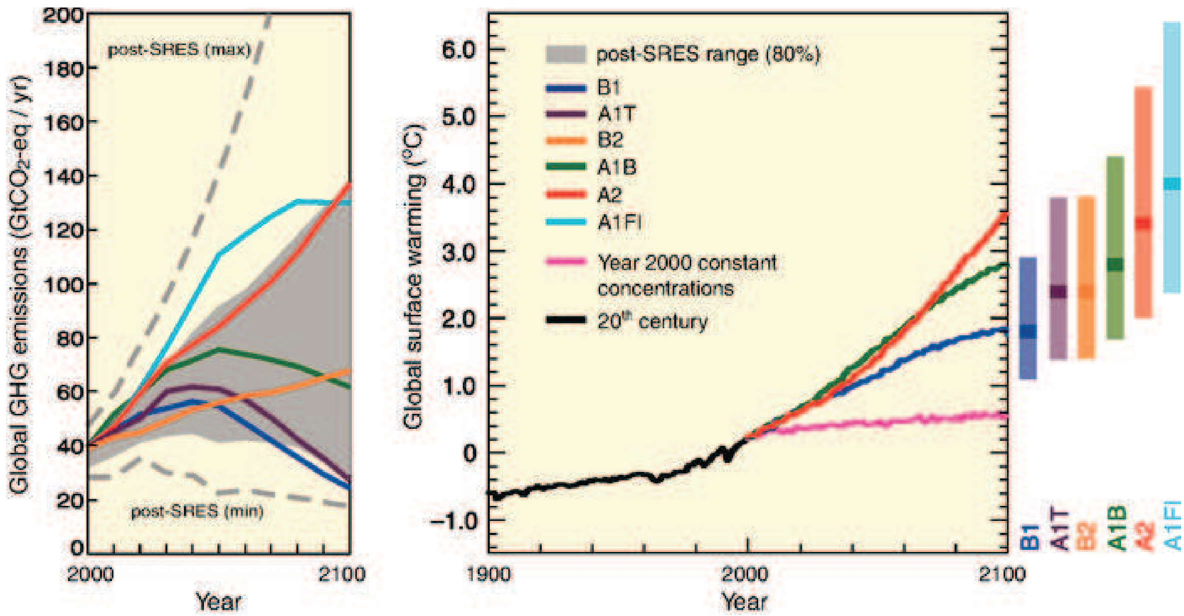

Figure 2.1. Predicted changes in surface temperature, assuming no additional policies, to 2100 (IPCC, 2007, p.104) [14]

The table below summarises predicted changes in agricultural production with increasing temperatures, drawn from the IPCC 4AR and from within this Table 5.7 in particular (Parry et al., 2007). Given that food access in the UK is tied to global markets and via them the impacts of climate change, projections of this sort are important to consider – although they do not look at how stages between global markets and retail are affected. The findings draw from coupled climate-crop-socio-economic models, termed ‘integrated assessments’, at the global scale. Comments on prices therefore are not just related to climate impacts, but whole socio-ecological system changes that include changes in global population, income, production, demand and trade. The price ranges quoted relate to findings across a number of studies (see Table 2.1).

[14] Vertical bars on the right of the graph depict the best estimate (solid colour) and the likely range in potential future temperatures in 2090-2099.

Table 2.1. Implications of climate change for agricultural production and commodity prices at different latitudes

Temp change	Region	Comments
1-2 °C	Mid-High latitude, temperate Low latitude, tropical and arid	Adaptation of maize and wheat increases yields 10-15%; rice yield no change; regional variation is high. Cold limitation alleviated for pastures; seasonal increased frequency of heat stress for livestock Adaptation of maize, wheat, rice maintains yields at or above current levels. Without adaptation, wheat and maize yields reduced below baseline levels (up to15%); rice is unchanged. Seasonal increased frequency of heat stress for livestock. **Commodity prices are thought to reduce by between 10-30% globally.**
2-3 °C	Mid-High latitude, temperate Low latitude, tropical and arid	Adaptation increases all crops above baseline yield, moderate production loss in swine and confined cattle. Reduction in animal weight and pasture production, and increased heat stress for livestock. Adaptation maintains yields of all crops above baseline; yields drops below baseline for all crops without adaptation. **Commodity price changes vary between 10% lower and 20% increases.**
3-5°C	Mid-High latitude, temperate Low latitude, tropical and arid	Adaptation maintains yields of all crops above baseline; yield drops below baseline for all crops without adaptation. Strong production loss in swine and confined cattle. Maize and wheat yields reduced below baseline regardless of adaptation, but adaptation maintains rice yield at baseline levels. Reduction in animal weight and pasture growth; increased animal heat stress and mortality (arid), no change for tropical bar heat stress. **Agricultural prices: +10 to +40% and cereal imports of developing countries to increase by 10-40%.**

The Organisation for Economic Co-operation and Development (OECD)-FAO Agricultural Outlook, to 2018, suggests that production of agricultural commodities will shift away from developed and towards developing countries, particularly in meat and dairy production (OECD-FAO 2009). If this trend continues, and assuming the impacts of climate change on food production will be stronger here, this may increase exposure of global prices to climate related shocks in the medium term.

Projecting changes in agricultural production is complex and highly uncertain in parts, with the implications for global commodity prices even more so. The graph below illustrates findings from a number of studies that draw from a range of integrated assessment models of climate, crop and socio-economic change at the global scale.

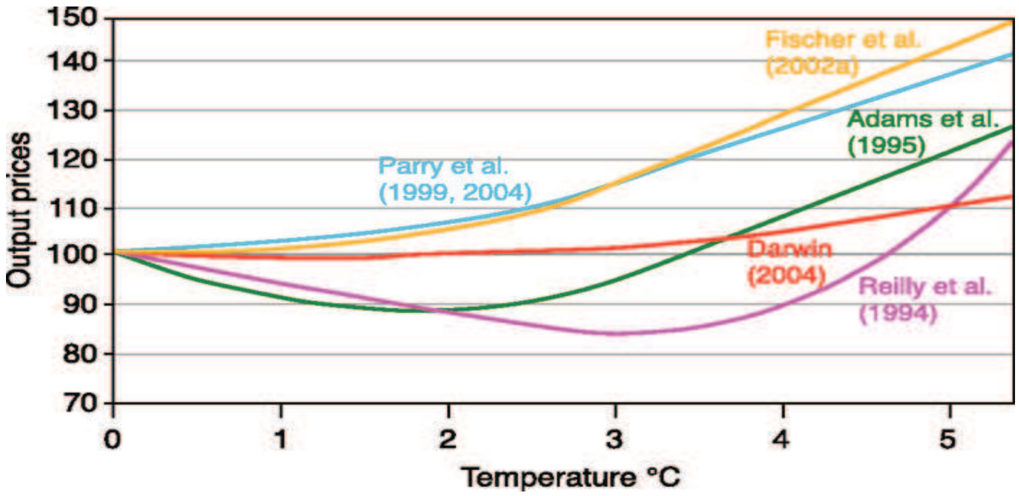

Figure 2.2. A range of price change predictions for agricultural commodities with different levels of global warming (Parry et al., 2007).

A broad conclusion is the relatively small net effect of climate change on crop production at the global level[15]. For example, Fishcer et al. (2002) find that cereal production changes as a result of climate change[16] fall within 2% of the results for reference simulations without climate change – with climate change reducing crop production globally in the majority, but not all, of the SRES emission scenarios and global climate models used. For Parry (2004), the effect of SRES socio-economic scenarios also tends to have a greater impact on crop prices than climate change, particularly for A1 and A2 SRES scenarios. 'No climate change' prices in 2080 are between 60-170% higher than 1990 with climate change adding a further 7-20% on cereal prices. Importantly, however, this assumes a CO_2 fertilization effect[17]. Without this, Parry et al. calculate additional climate change induced price changes to be much greater - between 225-375% across A1-A2 scenarios by 2080 (2007). A further study, not included in the graph in Figure 2.2, by Nelson et al. (2009) finds a more mixed picture across crop types, with the A2 scenario explored to 2050 generally producing larger changes in price without climate change (62-72% for rice, maize and soybeans) than with (adding between 11 and 55% onto prices), except for wheat whose price was calculated to increase 39% without climate change and between 94-111%[18] with.

Clearly there are considerable uncertainties associated with predicting crop production, demand and prices into the future. Three warrant further emphasis: carbon dioxide fertilization, the impact of EWEs and the role of adaptation. Alterations in assumptions around these variables potentially alter findings.

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[15] However, there are considerable differences in effect on production between the North and Global South.
[16] They base their climate change projections to 2080 on the IPCC SRES emissions scenarios.
[17] CO_2 fertilisation describes the benefit that plant growth experiences with enhanced levels of CO_2 in the atmosphere.
[18] Nelson does not assume carbon fertilization and assumes that prices would reduce 10% to those quoted here if it was in effect – a much smaller change compared to Parry's assumed influences of CO_2 fertilisation on price.

As has already been touched upon above, the influence of CO_2 fertilization on plant growth in some cases influence findings considerably. This is a controversial and as yet still not fully understood dynamic (Stern 2006). The crop models informing the graph above seem to be within consensus range, if at the upper end of the assumed benefits of CO_2 to plant growth (Tubiello et al., 2007, Parry et al., 2007).

EWEs are generally not explored in global socio-ecological agricultural simulations. The IPCC 4AR says, with high confidence, that projected changes in the frequency and severity of EWEs will have a *greater* impact on food production than changes in mean climate variables (Parry et al, 2007). The consequences of these extremes may over-ride any benefits derived from average changes in temperature and precipitation as described in the table above. However, there is as yet insufficient research looking into extreme weather and food production.

With regards adaptation, the studies by Parry et al (2004), Fischer et al (2002), Darwin (2004) and Nelson et al. (2009) incorporate it to differing degrees, generally assuming farmer adaptation and response to changes in economic conditions. There is less consideration of adaptation at the institutional level, and future (bio)technological innovation will inevitably be uncertain. In the IPCC 4AR, local temperature increases past 3°C lead to adaptive capacity being exceeded (Parry et al, 2007)

In summary, according to current socio-ecological projections of food systems, changes in mean climate conditions in the short to medium term (2020-2050) can be seen as an added benefit or burden with regards future food prices, rather than a key driver of prices in and of themselves. Projected climate changes at 2080 and beyond are expected to be increasingly influential in creating upward pressure on prices. In the shorter term for the UK, and unexplored in global studies or here, is the potential influence of mitigation policies on food prices for example via carbon markets, taxation, regulation, and biofuel targets (Anania 2006). EWEs are also likely to be a more important factor in the short-term than changes in mean climate, with the potential for associated price increases and volatility – particularly when they occur in conjunction with other drivers of price, such as fuel cost increases and biofuel production. However, in general it is difficult to quantify price effects of EWEs on the shop floor. Integrated assessments of climate and food systems do not consider price volatility, which is potentially important for the maintenance of food secure households. This is by its nature a complex phenomenon to which climate change will only contribute. However, as discussed further below the role of the post-farm gate supply chain is important in mediating these impacts.

There also remain a number of uncertainties within these studies and the underlying science (see Tubiello et al., 2007 for a review of some). Furthermore, greater than expected warming, for example along an A1F1 SRES trajectory or more, has not been explored in the integrated assessments reviewed, nor how climate change will affect production of non-commodity crops (fruits, vegetables); and there is a dearth of research that has sought to understand the impact that climate change may have for all food system activities and the multiple elements comprising food security (again, see Figure 2.2.).

What implications might this have for the price of food as experienced by consumers in the UK? In order to consider changes in the future, it is important to understand how price, paid by the UK consumer, is related to changing conditions of production. Firstly, it is necessary to note that the farm gate price of goods – where we might assume a 'climate signal'[19] to be the strongest – comprises a relatively small proportion of the final price paid by consumers. Value adding at each stage of the supply chain leads to the farm gate value comprising between 9-50% of the retail value (DEFRA 2008a), with an average of 37% (this has been stable since the late 1980s) (DEFRA 2009b). A lower farm gate value is more likely for heavily processed foods in particular, which may be disproportionately consumed by some in the vulnerable groups considered here.

Secondly, supply chain actors, particularly large retailers or food processors, can act to smooth or dampen farm-gate price fluctuations through sourcing from multiple channels, using buying power to depress prices or choosing to pass on costs to consumers gradually rather than all at once. An example of this is shown below in Figure 2.3. with respect to carrots. The blue line, normalised to 1 in 1991, shows the FAO sourced commodity price for carrots in the UK to 2007 whilst the red line, also normalised, indicates the price paid by consumers, derived from the Family Food report. The latter, whilst following the former, shows less fluctuation and change over time.

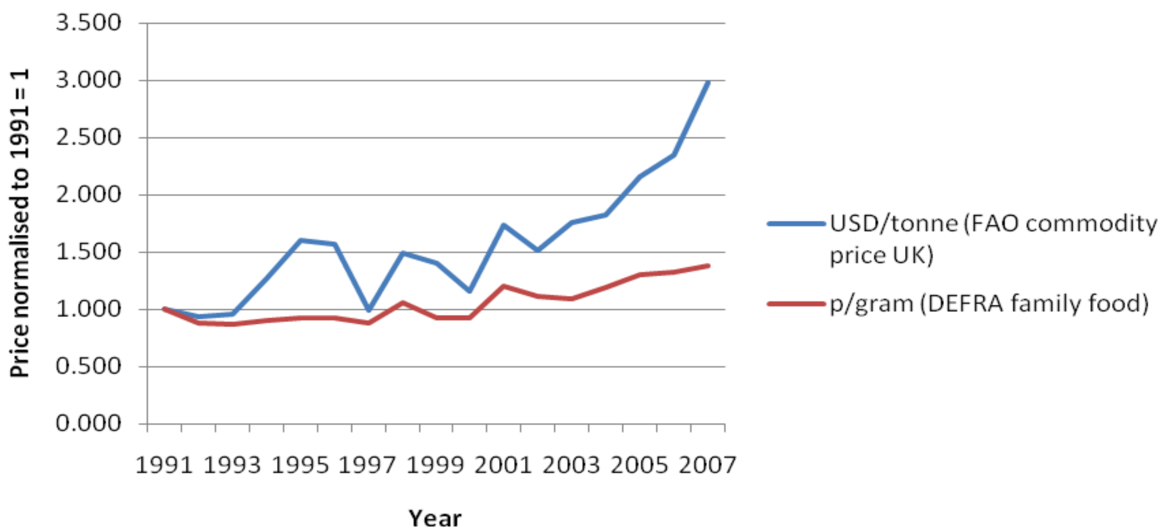

Figure 2.3. Change over time in the commodity versus retail price of carrots (FAOSTAT 2009, DEFRA 2008b).

[19] For example relatively low prices due to conducive weather conditions and thus abundant supply, or high prices due to drought and shortages in supply.

Having said this, smaller outlets and convenience shops are likely to have a much lower ability to dampen price changes. These shops are used more by those on lower incomes (Caraher 1998).

Farm gate price trends show weather and the associated influence on pests, local hydrology and harvests is an ever-present force in determining volumes and quality of production, however, 'picking this up' at the retail stage is much more difficult as many other factors simultaneously influence price.

Nevertheless, there are some instances of price changes that can be drawn from to illustrate the kinds of changes we may see in the future. Using a combination of DEFRA's agricultural statistics[20], newspaper reports gathered through Lexis Nexus and a study of the 1995 heatwave and warm year (Palutikof et al., 1997), we can see some evidence of how weather and climate affect food prices[21].

Table 2.2. Instances of retail and wholesale price changes as a consequence of EWEs/periods.

Year	Weather/climate variable	Price impact
1995	Warmest and driest year on record at the time (Palutikof et al., 1997). Mean July and August central England temperature was 3°C above the 1961-1990 average. Rainfall in these months was only 47mm compared to a '61-'90 average of 139mm.	Retail potato prices increased by 35% in 1995 compared to 1994. We are 85% self sufficient in potatoes, and as Kennedy explains in his newspaper article (6 January 2001), UK consumers prefer UK produced varieties of potato only otherwise available from Italy or Israel. Price transference from farm gate to retail stages may therefore be stronger for potatoes compared with, for example, cereals which are sourced from global markets. Other root crop yields also underperformed (Subak, 1997). Retail price increases can be seen in onions which increased 21% on the year before (with an average price change of 2% reductions over the previous 3 years) and carrots increased 5% on the year before (average price reduction of 4% over the previous 3 years). Brassicas also required more irrigation, and a price increase of 17% can be seen in cauliflower (compared to an average price rise of 8% over the preceding 3 years). Again, other drivers of price change have not been investigated and so weather may be only one contributing factor. Tomatoes and cucumbers had a bumper yield.
2003	Pan-European heatwave with temperatures up to 6°C above long-term means, and precipitation deficits up to 300 mm (IPCC 2007).	Cereal crops were reduced across the UK, France and Italy. For UK consumers a 7p-8p rise in the price of a loaf was reported in the Guardian and Times (Vidal and Stewart, 6 September 2003; Marsh and Schoonenberg, 2003). This was between 7-9% of the price of a loaf then (DEFRA, 2008a). The price of vegetables was reported as potentially affected also, however looking across carrots, tomatoes, cauliflower, potatoes and onions there is no clear signal.
2006	Four hurricanes in the 2004-05 season across the Gulf of Mexico.	Orange concentrate prices increasing 150%, with 'expected' price increases at the retail stage of 25% in soft drinks, squashes etc. As well as damaging trees the winds helped spread disease (Clarke, 11 December 2006).
2007	Warmest April since records began followed by summer floods in Northern Europe, heat waves in Southern Europe, as well as continuing drought in Australia.	The warm April, coupled with the beginning of the commodities boom (i.e. influences of high oil prices and biofuels also) lead to newspaper reports of increases in lettuce prices (38% increase), tomatoes (30% increase), onions (40% increase), carrots (23% increase) (Wallop, 22 May 2007). Summer floods affected peas and brassicas, with an 'expected' increase in broccoli prices of around 24% (Elliott, 4 July 2007). General negative impacts on potatoes, cabbages, lettuce, sweet corn and livestock (Vidal and Connolly, 28 July 2007). Hovis bread prices increased.

[20] Looking at cauliflower, carrots, onions, tomatoes, apples, milk, beef, chicken, bread.
[21] This is against a backdrop of generally reducing prices over time.

The retail sector clearly plays a role in evening out price changes over time and large swings in farm gate prices are often not replicated at the retail stage, or are dampened considerably. To further complicate discerning any weather induced price signal at the retail stage, weather can lead to both increases and decreases in price as both yield and quality are affected and this will be different across food goods. What has not been investigated here is the impact of extreme weather on the post-farm gate pre-retail stages of production. Outside the remit of this report, it is important to consider these also, for example cooling costs during heat waves, and how lost stock during floods affects pricing.

Although patchy, these case studies illustrate that the weather in the short-term and climate in the longer term does have a role to play in the prices that consumers pay in the UK. The likely increase in weather extremes suggests increasing volatility of prices for those goods that are less attractive if sourced elsewhere to the norm, or are considerably more expensive in this instance. How this translates to prices over the long-term through recouping of costs is not clear. What is even less clear is how this affects the whole food basket and the nutritional status of food insecure groups.

Implications of price changes and volatility:

What can we say about the implications of future price increases and greater price volatility for the ability of households to afford food? A review of the literature suggests that the impact of climate change on food prices for those in the UK and in the shorter term is minor, but may become increasingly negative towards the end of the century, and that it may contribute towards price volatility. However, with respect to the affordability conceptual model (see Figure 1.2.), it is very difficult to foresee changes in income, outgoings and the savings of individuals and therefore distil likely impacts on affordability over time. Instead this section assumes that lower income, higher relative outgoings and limited savings will continue to be a characteristic of some groups in society. It then reviews existing case studies and research into how price changes in the past have affected the affordability of food, and the behavioural response by people in this situation. The recent 2007/08 price spikes, which were closely followed by the credit crunch and recession, are focussed on.

Broadly food is price inelastic – that is a 1% increase in the price of food leads to a less than 1% change in purchasing of the product. But when prices do go up, less is bought – the price elasticity is negative.

Research on the impact of price changes on purchasing behaviour for those on a lower income, or who have a reduced ability to change their income, is thin and patchy. A more common approach has been to look at a macro-level at changes in income versus food prices – and make inferences from this, or at the micro-level through food elasticities, but often without disassociating between income groups. A further complication is that research and commentary documenting changes in purchasing behaviour over the last couple of years covers both increases in price of food and then the credit crunch, affecting earnings. The impact of price rises in relation to changes in income is often not disassociated, making it difficult to distil the cause of changes in purchasing. Nevertheless, a broad picture of the implications of price rises can be developed.

As has already been said in the introduction to this report, those in the lowest income decile spend a considerably higher percentage of earnings on food, housing and fuel than those in the highest deciles, with food insecurity experienced by 29% of those on a low income[22] (Nelson et al., 2007). 'Not having enough money' was cited most often as the reason for not always having enough to eat and for not always having enough of the kinds of food the low income population wanted to eat (Nelson et al., 2007). Cost of food is also more of a concern for shoppers in lower income bands than higher ones (White et al., 2004). The elderly (80+) also spend a greater proportion of their income on 'necessities' (food, fuel and clothing) than other age groups. Fuel poverty is generally higher in this age group than others – about 10.2% of men and 13.4% of women (Banks and Leicester, 2006), suggesting insufficient resources to cover basic needs for about one in ten in this age group.

As a consequence, any increases in the price of food – particularly if it is across a number of food goods, as with the 07/08 price spikes – will disproportionately affect the elderly and those on a lower income (Revoredo-Giha et al., 2009, O'Dea, 2009). This is illustrated by the differential experiences of inflation across these groups. From about March 2008 households in the lowest income quintile and pensioners experienced higher inflation (higher rates of general price increase) compared to other income quintiles and non-pensioners. Over 80 year olds in particular have suffered relatively higher inflation (O'Dea, 2009).

The 07/08 price spikes saw food commodities increasing in price by an average of 120% between January 2007 and the peak of the market in mid-2008 (HM Government 2009). In the UK retail food prices increased by 12% between August 2007 and December 2008 (*ibid*). No specific assessment of changes in household food security in the UK has been undertaken since the price spikes and recession. However evidence from America (Yngve, 2009, Usborne, 1 April 2008) and Scotland suggest that there has been an increase in those considered food insecure. The Scottish Government observed, "There is evidence that the rises in the price of food which were seen in 2008 had a major impact on the proportion of the population who can be classed as food poor" (p.3 Scottish Government 2009).

[22] This was self-reported, and the survey sampled in materially deprived areas, so did not look at food insecurity in populations experiencing other dimensions of deprivation.

What can be said about the responses of people to these changing circumstances? Amongst the lowest income quintile in London and in response to price increases, spending on food generally increased as a proportion of total expenditure (Kyte and Hirani 2008). There is a lot of evidence from retailers and industry publications that across income groups people have changed their shopping habits in relation to price rises and the credit crunch including switching retail outlet, switching to cheaper brands and consuming less red meat (Revoredo-Giha et al 2009, the Institute of Grocery Distribution (IGD) 2008, and GfK Social Research 2009) Increasing fuel, utility and food prices are cited as the main drivers for behaviour change in the IGD study (2008). GfK Social Research (2009) also report that 3% of respondents said they were skipping meals due to food price rises – meaning these people are experiencing food insecurity. Reporting of behaviour change in response to price rises was highest among those of social group DE, but not significantly more compared to 'middle social classes' C1 and C2.

Larger than usual changes in consumption patterns (not disaggregated by income) were also documented by the Family Food Report (DEFRA 2008b). Altogether, less beef, lamb, cheese and fruit were purchased, while more was spent on bread, biscuits and cakes, bacon, butter, milk and sugar and preserves. For cereals, pork, poultry, eggs, vegetables, potatoes and sweets and chocolate, people traded down. As a result the DEFRA UK Food Security Assessment (2009a) concluded that 'healthy eating continues to be adversely affected by overall food price rises' (p. 126).

There is a lack of research analysing how vulnerable groups in particular have responded to recent food price rises beyond an understanding that they will have been disproportionately affected given proportionally larger outgoings spent on food. In other words, little is known of the adaptive and coping strategies of vulnerable groups to price changes, and what the implications are for the nutritional intake of vulnerable households. Save the Children research suggests that of the poorest parents (defined as such), 48% have had to cut back on food (Save the Children, 2009). However, how much this is solely a response to food prices is not clear[23]. In a study by Seefeldt and Castelli (2009), conducted with 35 women in low income households in the Detroit area of the US (nearly 70% of them were below the poverty line) between 2006 and 2008, it was noted that almost every respondent had changed their purchasing behaviour in response to food price rises. The women traded down and 14 reported cutting back on cereal, fresh fruit, vegetables, red meat, and/or milk. There was also strong substitution of red meat and fish for chicken. Running out of food 'happened fairly regularly' amongst these women (but they did not report a rise in incidence between 2007/08).

[23] This may well be part of a strategy to deal with multiple stresses including the recession, severe shortages in council and social housing, high debt levels on the back of previously cheap credit and high energy costs.

Moving away from the 07/08 price spikes, there seems to be an incomplete picture regarding price elasticities of demand (PED) for particular vulnerable groups. The price elasticity of demand gives the percentage change in purchase of a food given a 1% increase in price[24].

Winkler (2008), in a literature review, notes "[it is generally agreed that] food prices are more elastic in low-income countries and for low-income households compared with their higher income counterparts" (Winkler, 2008). However, consistently quantifying PEDs between income groups or vulnerable groups more broadly and across time and space does not seem to have been undertaken[25]. In a review of 160 studies conducted in the US between 1938 and 2007, Andreyeva et al. (2010) found only nine studies estimated food price elasticities specifically for low-income groups, with three examining a wide range of foods. From this small sample, they were not able to identify consistent differences in estimated price elasticities between low-income consumers and consumers as a whole. Consequently, understanding the implications of price rises/variability for vulnerable groups is difficult.

In conclusion, the relationship between price, affordability and outcomes for food security and nutrition for vulnerable groups are complex. The much greater proportion of expenditure allocated for food amongst low income and elderly households mean that these groups will be hit the hardest by price rises and volatility, and in cases may reduce the amount of food consumed as a result. In 2007 food insecurity was experienced by just under a 1/3rd of low income households in the UK, and so this will most likely have increased. There is some published evidence from Scotland and the USA that this is the case. Adaptive and coping mechanisms are known to include trading down, shopping elsewhere and altering what is eaten. However, ascertaining from the literature *who* exactly and *how* the food basket has changed for these people is not currently possible. Furthermore, examining the more complex relationships between all elements of what comprises affordability (i.e. assets, savings, informal income etc) and changing prices is yet to be undertaken in a UK context as far as can be ascertained.

Final conclusions about affordability and climate change are given at the end of section 2.1.

2.1.2. Physical access

This sub-section examines potential future changes in physical access to food as a result of climate change. As outlined in the introduction, physical access here is seen to be a composite of retail

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[24] Whilst elasticity shows vulnerability overall to price changes, it does not itself show threshold effects which, in her review of the literature, Winkler found evidence of (see Fitzpatrick et al 2007, in Winkler 2008).

[25] This is perhaps not surprising given the data intensity, confidential nature of much sales data, and the multiple confounding factors such as endogeneity of prices and demand, changes in income, variation in personal preference, spatially variable food prices and things like shop-specific promotions that vary prices for short periods.

environment, transport systems and physical wellbeing[26]. We focus upon transport systems and physical wellbeing as the impact of climate change upon these areas is more tangible. Whilst there may be impacts on the retail environment, or the location of shops, patterns in this area are felt to be very hard to predict irrespective to climate change, making it near impossible and merely speculative to examine the additional impacts of climate change. Below we first consider the impacts of climate change on transport systems and then draw out implications for the food access of vulnerable groups. Next impacts on physical wellbeing are examined, again drawing out the repercussions for vulnerable groups' food access.

Examining the impact of climate change on the transport access of vulnerable groups:

- Impact of climate change on UK transport systems

As highlighted in the introduction, transport systems are an integral part of ensuring access to healthy and affordable food for many UK consumers, and barriers to transport access can often translate into barriers to food access (as indicated by greater difficulties with food access for non-car owners (White, 2007)). As such disruptions to transport systems will undoubtedly have an effect on households' ability to access food.

Much of the work examining links between transport and climate change focuses on the impact of transport on climate change, highlighting mitigation strategies. What we, however, are interested in is the impact of climate change on transport systems, a far less scrutinized topic. Broadly climate change has the potential to both negatively (e.g. road damage) and positively (e.g. more people cycling and walking) affect transport and physical access to food as explained in this section. As a result this section will draw upon international and regional evidence and at points state where there is too little evidence to draw firm conclusions.

Caraher et al. (1998) show most consumers use roads when travelling to food stores, be that on a bus, walking on the pavement or in a private car[27]. As such this section will in the main focus on potential impacts on road networks and transportation using those networks. Impacts on the London underground are also briefly considered because in cities where such transport networks exist they are inevitably being used to access food. Wider impacts of climate change on distribution networks, although outside the parameters of this research (which has a focus on consumer physical access and affordability, and as such on transport systems post retail), are briefly considered in Box A. as they

[26] In looking at physical access we have decided to focus on the period in between food purchase and the household. This means we have not examined impacts of climate change on food preparation in house.
[27] Although the suggestion of Caraher et al.'s (1998) data that the categories of car, walk or bus, encompass all sampled consumers seems unlikely (ignoring cyclists and tram or underground users) it does seem to make sense that most consumers fall into these categories.

are deemed to be potentially very important in UK Food Security, and may have knock on implications for food prices.

Box A. Impact of EWEs on retail distribution networks.

Whilst failures in retail distribution networks can result in damages and loss of goods, of greatest concern in "an age of just-in-time inventory management" is delays in getting food onto shop shelves (Peck, 2006, p.6). EWEs could result in disruption and delays in distribution networks, leaving shelves under-stocked and consumers unable to access healthy food (despite potentially no problems with physical access or affordability).

Retail distribution is subject to many similar disruptions to road networks that consumers may face (as detailed below) but where as consumers will more often rely upon localised networks, distribution networks are dependent upon major road networks. Whilst infrastructure will encounter similar climatic problems, responses may be different due to differences in governance (for example, responsibility for gritting motorways and A-roads falls upon the highway agency, whilst responsibility for gritting local road networks falls on the lap of local government). In addition to reliance upon road networks, distribution networks are also dependent upon rail and ports, in particular the latter, with 91% of food imports coming through ports (DEFRA, 2009a). (Airports are not so much of an issue as a very small percentage of foods are flown into the UK). A recent report for the UK Government's cross departmental Infrastructure and Adaptation project (URS, 2010) has examined in detail the vulnerabilities of wider transport infrastructure to climate change. The report highlights the following areas as key issues. For rail infrastructure (URS, 2010, p.48):

- "Flooding from increased precipitation and/or storminess;
- Scour of bridges due to increased precipitation and/or storminess;
- Moisture fluctuation in road embankments in south east England – due to wetter winters and drier summers, and
- Overheating of underground trains due to increased temperatures."

For port infrastructure (URS, 2010, p.52):

- "High tides/storm surges causing increased sea level at ports, and
- High winds at ports due to an increase in storminess"

As such the report suggests a future environment of increased risk for retail distribution networks. An era of just-in-time inventory management amplifies these risks as they are transferred to retailers and consumers. In worst case scenarios of severely under stocked supermarket shelves it seems that low income groups, less likely to have well-stocked cupboards to act as a buffer to under stocked shelves, may be more at risk.

Of key importance in moderating the impact of EWEs on distribution networks is the coping capacity of retailers, distributers, and governments during times of shock; the extent to which distribution systems are diverse and flexible enough so that alternatives can be sought. As the UK Food Security Assessment highlights there is uncertainty in this area (DEFRA, 2009a). Although one thing that seems obvious is that some drives for efficiency in the last 20yrs (including moves towards just-in-time operations, and increased centralisation of distribution networks and centres) may have served to increase dependence upon transport systems, and as such stand to increase the vulnerability of food systems when transport systems are threatened (Peck, 2006). A point of hope comes from acknowledgement amongst different layers of governing (state and private sector) of the need for adaptive capacity within the transport sector (as the DfT's "Climate Change Adaptation Plan for Transport 2010-2012" report highlights (2010)).

As the likelihood of EWEs increases with climate change, it seems likely that transport systems already sensitive to such events will become more so[28]. Table 2.3 below shows the vulnerabilities of different aspects of the roads networks at the hands of different weather variables.

This report (URS, 2010, p.44) highlights key risks for roads due to:

- "Flooding from increased precipitation and/or storminess; and
- Scour of bridges due to increased precipitation and/or storminess."

A report on the potential impacts of climate change on Scottish road networks (Scottish Executive, 2005) goes into much detail, and many of these findings can be applied to England[29]. They too identify increased precipitation as a key area of concern. More generally they conclude that whilst the impacts of climate change to 2020 are relatively small, these are significant enough to call for a response. The recommendations they propose focus on this shorter time frame highlighting the greater uncertainty (although larger impacts) with longer term impacts. There are a number of papers looking at the London transport system and climate change. Potential additional stressors for London's transport systems, on top of impacts on road networks, are: flooding of rail and underground tracks and stations leading to delays and disruptions, fewer delays as a result of impacts of freezing on rail tracks and more delays as a result of buckling of rail tracks as a result of increased temperatures, potential passenger discomfort as a result of high temperatures on the underground, and potential tidal and river flood risk around the Thames Gateway impacting on transport in the Gateway area (London Climate Change Partnership, 2002, 2005).

What most reports around climate change and transport systems avoid doing, however, is attempting to comment upon the overall impact of climate change, in particular how negative and positive impacts on transport systems will balance with one another. That said, as stated above, it seems likely that transport systems already sensitive to EWEs will become more sensitive as the likelihood of these events occurring increases with climate change. For this reason it seems that EWEs are likely to have more bearing for transport systems, and thus food access, than gradual changes.

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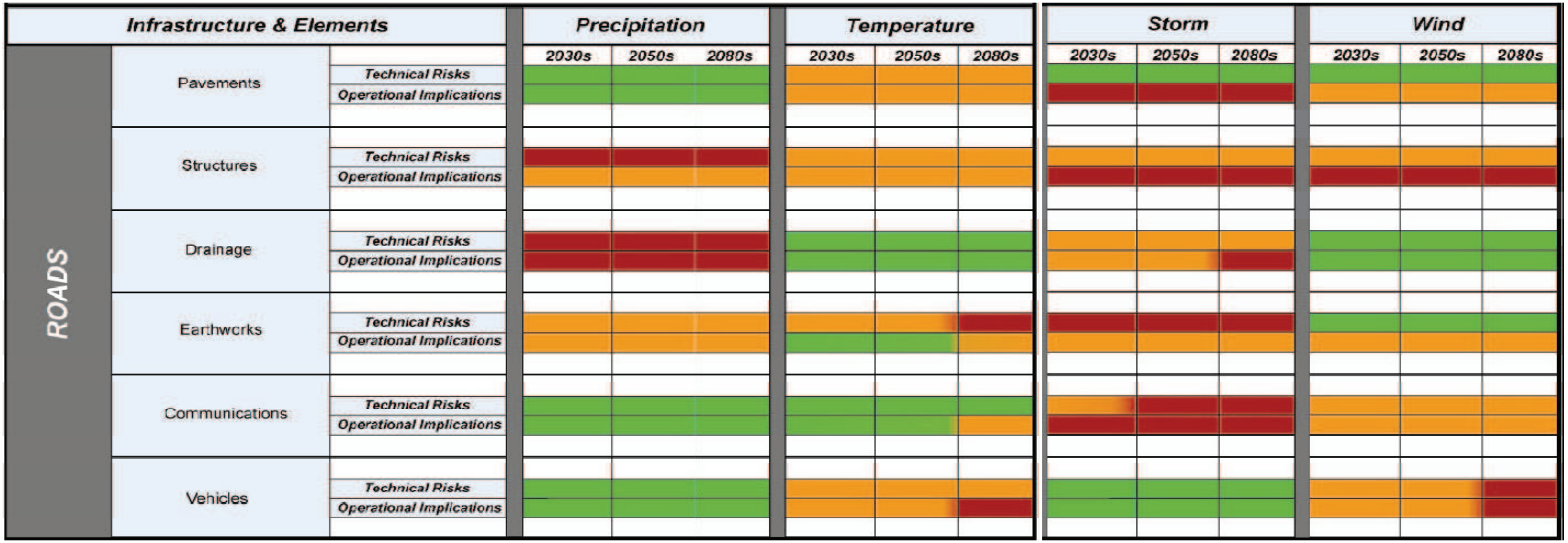
[28] Experience of past EWEs highlights the vulnerability of our road networks during these times. Wooller highlights how high temperatures in the UK in 2003 brought deformations in road surfaces (2004). Similarly the Pitt Review (2008) showed how flooding in July 2007 closed eight motorways and many minor roads.

[29] Many of the impacts listed are similar to those reported above for retail distribution networks. Again highlighting that it's not all change for the worse, the Scottish Executive's paper also points to reduced (but more variable) delays and disruptions as a result of reduced snow and ice on roads. Impacts on local coastal road networks as a result of sea level rise and coastal erosion are highlighted as needing consideration. Interestingly this was thought to impact on smaller local roads, those potentially important for retail access.

Table 2.3 Roads Vulnerability matrix. Taken from URS (2010, p.42-3).



Here green represents low impact, orange medium impact and red high impact.

- Potential impacts on food access and differential impacts on vulnerable groups' food access

What it is harder to know, however, is how this may affect food access. There needs to be much more research into how will passengers react to and cope with the changes outlined above. Will there be modal shifts as people move from one type of transport to another (London Climate Change Partnership, 2005, suggests that current passenger demand models show there is little modal shift between bus and tube in high temperatures)? Will certain types of (more vulnerable groups), already more limited in their transport choice, be less able to engage in this modal shift? How will transport systems in urban vs. rural areas (where people in the latter tend to have fewer transport options to switch between and are generally further from a food store and more dependent upon transport) cope in times of extreme weather?

In thinking through differential impacts upon vulnerable groups there is also a need for more knowledge about people's current behaviour and how these behaviours change when exposed to stressors such as limited transportation to shops (their coping capacity). For example whilst Caraher et al.'s (1998) research showed that over two thirds of their sample travelled by car to food shops, there were significant differences in mode of transport between different income groups with lower income groups being more dependent on bus and foot. With these different groups more dependent on different modes of transport there is a need to understand how different modes of transport (within road based transport) cope with EWEs related disruptions[30]. Similarly, Meeneley et al. (2009) showed that 35% of elderly consumers in the UK rely upon someone else for a lift. The diversity in people's current shopping behaviours suggests there is also likely to be diversity in people's coping strategies. In general, vulnerable groups often have a lower ability to cope and recover from stressors. For example, low income groups have fewer financial resources to use to recover from flooding, the elderly are less able to prepare for and recover from flooding, and those with disabilities may have real difficulty receiving and reacting to flood warnings. Yet, as we come onto in the next section, there is a real need to interrogate further the adaptive and coping strategies affecting vulnerable groups.

[30] In thinking through the impact of transport disruption on food access of vulnerable groups, an important distinction lies between impacts upon operations and impacts upon infrastructure (as highlighted by Haurie et al., 2009). Although both stand to impact food access, it is important to remember that whilst most consumers are using the same infrastructure (roads, bridges etc), different groups are more likely to be using different modes of transport (or operations) and as such stand to be differentially at risk to disruptions in different types of operations. In the main research looking at impacts on transport systems divides by road/rail, so it is harder to say differential impact on car vs. bus (where we assume that the latter is more likely to be used by certain of our vulnerable groups) as both operate on same roads. It appears there is currently little evidence to suggest that the types of transport more likely to be used by our different vulnerable groups (public rather than private transport) will be more at risk as a result of climate change but this seems to be more a result of it being an under researched area than evidence of no difference.

Box B. Coping during the Cumbria floods
Long spells of heavy rainfall (a month's rainfall in 48 hours) in mid November 2009 saw the collapse of several road bridges, closure of roads and closure of the port of Workington as a result of damage of key infrastructure (DfT, 2010; URS, 2010). Although not necessarily attributable to climate change, this sort of winter rainfall event is predicted to be more likely in a future changing climate. Cumbria saw widespread flooding during this time and there were a great number of people cut off from key services and reports of people struggling to access food (BBC News, 23 November 2009; Armstrong, 23 November 2009).

During this time a number of coping strategies were employed to provide key services to those affected. Emergency relief centres were set up which amongst other things provided food. A temporary rail station was set up by Network Rail, helping to reconnect a community effectively split by collapsed bridges and allowing people access to the central retail district (BBC News, 30 November 2009). And Tesco's built a pop up store in just 13 days in order to provide food over the festive season (Ridge, 13 December 2009). These examples highlight the role that a range of non-governmental actors can play in reacting to EWEs (and as such the need to engage all these actors in pre-emptive planning). Here in particular the private sector (big retailers) has shown itself capable of innovating in order to gain competitive advantage.

In summary, it seems that there are likely to be significant impacts upon transport systems, particularly as a result of EWEs. It is, however, very hard to predict how this will then impact upon the food access of vulnerable groups. What we can say is that as our vulnerable groups are already vulnerable and their buffering capacity is likely reduced, any additional stressors will see them left even more sensitive to future stressors. As such we can expect a differential impact on these groups, however much more needs to be done to examine this in more detail. Particular gaps in research remain around the coping strategies employed by people and the impacts of EWEs on different modes of transport and thus upon the food access of different groups. In the future it is important that more qualitative research be carried out examining adaptive capacity during and after EWEs. Much more needs to be understood about how networks (governments, retailers, communities and households) currently react during these times, the extent to which there is pre-emptive planning, the impacts of such events upon food systems and the differential impacts of these events upon vulnerable groups.

As the future holds increased risks for transport systems there is a great need for pre-emptive emergency planning (as many governmental and non-governmental transport bodies are starting to realise and respond to). With transport systems vital in accessing services, particularly food, there is a need to accommodate adaptation plans to maintain food access during times of stress. Just as importantly there is a need to acknowledge that the impacts will be felt more intensely by already vulnerable groups who generally have less coping capacity.

As such pre-emptive emergency planning needs to build in strategies to support these groups.[31]

Physical wellbeing and climate change:

The impacts of climate change and past EWEs on health are well documented. One of the most comprehensive explorations of the health impacts of climate change in the UK is in the Department of Health's (DH's) 'Health Effects of Climate Change in the UK' (2008). This report, a follow up to a 2001 report of the same title, utilises the UKCP02 climate scenarios for a more robust analysis of potential impacts. A summary of this information is presented in Table 2.4.

Table 2.4 Summary of health effects of climate change in the UK. Information taken from DH (2008)

Climate stressor	Health risk	Magnitude of threat
Warmer summers on average	Heat-related deaths Food poisoning Vector-borne diseases (malaria, tick-borne diseases)	Despite increasingly warm summers 1971-2003, the number of heat-related deaths has not changed suggesting that the UK population has adapted. Temperature does impact on salmonellosis whilst impact on campylobacter transmission is uncertain. A 3°C increase in temperature might result in about a 14.8% increase in food poisoning (an extra 14,000 reported cases) but other advances are suggested to have a bigger impact, such as hygiene behaviour. Malaria outbreaks thought to be rare and small scale. Tick infested areas more likely to be changing as a result of land management practices and individual leisure pursuit changes, uncertainty remains around impact of climate change.
Drier summers	Infectious intestinal diseases, (due to reduced water availability and quality)	States that risk of most concern for elderly, disabled and less mobile, and more of an issue in the South-East, but does not suggest magnitude of risk.
Heat waves	Heat-related deaths	DH "*estimate that the increasingly variable as well as higher summer temperatures will create, by 2012, a 1 in 40 risk every year (a 1 in 4 risk in the decade centred on 2012) of a 9-day heatwave at 27°C in South-East England. Without preventive action, this could cause more than 3,000 immediate deaths with more than 6,350 heat-related deaths throughout that summer.*" (p.88). Incidences of heat stroke (although not reported in the 2008 document, the DH's 2001 report highlights increases in heat strokes and other non-fatal cases of heat stress).
Warmer winters	Cold-related deaths	Highlight that 'falls by more than a third in cold-related mortality in all regions as winters grew warmer' from 1971-2003
Increased rainfall leading to flooding	Deaths, chemical hazards, mental health, infectious disease and indirect effects via impacts on health service delivery	Too much uncertainty to say level of risk overall. *"Due to the complexity of the causal pathways on the route from surface or groundwater to the household, it is difficult to detect what may be a small contribution to the overall burden of disease"* (p.77)

[31] As plans are made to adapt transport systems to future gradual climate change, and to build in coping strategies to deal with EWEs, it is crucial that we think this through alongside future mitigation plans. With regards to vulnerable groups and transport, it is important to think through the added burden of mitigation efforts on transport *costs* and the impact of this on vulnerable groups.

	Waterborne infectious diseases	
Windstorms	Deaths and injuries	They conclude "*that climate change will not significantly affect health via changes in windstorms*" (p.30)
Air pollution	Respiratory diseases	"*The increases are likely to be significant: with the least constraining assumptions (no threshold of effect assumed) up to about 1,500 extra deaths and hospital admissions p.a. might be expected*" (p.viii)
Longer summers	Skin cancers (as a result of increased exposure to ultra-violet light)	Skin cancers incidences are expected to rise

As the table shows there are a wide range of potential health impacts as a result of climate change. Some climate changes are likely to result in fewer health problems (e.g. reductions in winter cold related deaths) whilst many are likely to result in more health problems (e.g. incidences of heat stroke). The overall balance between these is, however, not discussed. As indicated in the table, there still remain great uncertainties in many of these areas.

- Potential impacts on food access and differential impacts on vulnerable groups' food access

Analysis of how these health problems might impact more specifically on the ability of individuals to physically access food stores has not been conducted. The impacts of climate change on health are reported above because in general health problems are likely to lead to individual mobility problems such as walking to shops and carrying shopping. Yet it goes without saying that some health problems will have a much greater impact than others and that some will have short term impacts (food poisoning) whilst others have long term effects (respiratory diseases). Whilst there is some literature examining the specifics of how transport systems can buffer poor retail environments, there is much less on the specifics of how physical wellbeing impacts upon food access other than via difficulties walking and carrying shopping. It is clearly more complex than this: we know for example, that mental health issues, at times, contribute to problems with food access. This shows that links between health and food access are complicated and that generalisations, given these gaps in the literature, should not be made. This seems to be an area for much needed work in the future. We could intuitively say that more health problems will increase the likelihood of food access problems, yet it is hard to even make this claim considering the unknown balance between the health benefits and costs of climate change.

In thinking through specifically the impacts upon our previously defined vulnerable groups it is important to remember the multi-faceted nature of vulnerability (as outlined in the introduction). Our three key vulnerable groups are already vulnerable with regards to health problems. The elderly, (by definition) the disabled and the health impaired and income deprived groups are all more likely to suffer health problems which may in turn affect their physical ability to get to shops, carry shopping, and choose, cook and prepare food. As such potential additional health problems as a result of climate change will increase this burden. There is also evidence to suggest that these three vulnerable groups may be *more* vulnerable to the health problems associated with climate change, and thus that it is not just the added burden that we must consider but that this added burden may also be greater (as DH 2001 shows for heat waves).

Table 2.5 below, taken from the Environment Agency's (EA's) report on The Social Impacts of Heat waves (2007) highlights an overall increase in excess deaths of 13.2% during the 2003 heatwave. This shows the differential impact of the 2003 heatwave on the elderly (figures are not available for disabled). Interestingly affects are considerably compounded within Greater London, highlighting a significant urban heat island affect[32].

Table 2.5 Excess deaths (%) by age group for three heat wave events. [Taken from EA, 2007, p.19]

Age group	England & Wales 1976	England & Wales 1995	England & Wales 2003	Greater London 1976	Greater London 1995	Greater London 2003
0–14	5.9	4.5	-9.9	13.5	13.1	0.8
15–64	7.2	8.2	9.4	12.0	15.6	14.7
65–74	7.2	8.4	2.0	10.2	13.2	14.1
75–84	11.5	8.5	17.7	19.5	14.9	44.7
85 and over	14.8	10.3		21.6	20.1	
All ages	9.7	8.9 (8.6)§	13.2	15.4	16.1 (15.4)§	33.3

§ Values are age-adjusted to the age-at-death distribution of 1976. 2003 estimates for 75-plus. Baseline mortality estimated as average deaths for same heat wave calendar period in previous five years. Source: Rooney *et al.* (1998), McMichael and Kovats (1998) and data from ONS.

Similarly, the EA (2007) have highlighted those with physical and mental illnesses, the elderly, and those in jobs requiring heavy labour (more likely to be low income) as being overly vulnerable in heat waves. It also seems likely that those with obesity problems (the levels of which are higher in low income groups, Wardle et al, 2002) are more likely to be vulnerable in heat waves.

Just as we need to attend to differential vulnerabilities we also need to consider differential **coping and adaptive capacities** (as we come onto in section 3.4). We are assuming that our already vulnerable groups, already stretched, are likely to find it harder to cope with climate

[32] The urban heat island effect describes the intensification of warming by the built environment and land cover in urban areas, as well as heat from buildings and vehicles resulting in higher day time and night time temperatures in many urban areas. In London, Graves et al. (2001) and Threlfall (2001) have reported an urban heat island effect of up to 7°c. The urban heat island effect may also reduce the chance for night time respite from daytime heat which is thought to be particularly important for vulnerable groups.

related changes in health - "underlying the demographic risk factors are some behavioural risk factors such as living alone, being confined to bed, not being able to care for oneself, having no access to transportation, not leaving home daily and social isolation" (EA, 2007, p.15). Such characteristics, many of which are more likely to be found in all of our previously defined vulnerable groups, are likely to reduce the ability to cope with health and mobility problems as a result of climate change.

Yet, as we come onto in the following section, we cannot just assume that our groups have lower adaptive and coping capacities. There is a need to carry out research further examining strategies for buffering the impacts of poor physical wellbeing on food access[33].

2.1.3. Concluding remarks

Impact of climate change on economic access to food: Given the projected benefits of climate change to production in northern latitudes to 2020, and possibly 2050, and the strong contribution of socio-economic variables to food prices, including considerable post-farm gate value adding and the smoothing function of supply chain power dynamics, it is thought that progressive climate change to 2050 - assuming current projections are correct - will only play a minor part in contributing to UK food prices. To 2050 then, the impact of progressive changes in mean climate variables for vulnerable groups' economic access to food will also consequently not be considerable.

More research is needed to understand whether EWEs have any effect on access to a nutritional diet for vulnerable groups. Particularly for those who do not shop in, or have access to, large multiple retailers who can better respond to these events through alternative sourcing or having substitute foods available. Similarly, EWEs in the UK may have economically detrimental effects in localised areas that affect income or assets, with knock-on effects for purchasing power. This is as yet an un-researched topic. Furthermore, this review has not considered the impact of climate change for post-farm gate, pre-retail food systems. This may have negative implications for price and is an area in need of future examination.

Post 2050, and particularly towards the end of this century, there is a much greater potential for climate change to create upward pressure for food prices assuming higher emissions scenarios such as the A1 group (see Figure 2.1.). If all else remains the same, this will

[33] For example, the elderly have sighted deliveries from supermarkets as being a potential way around problems carrying shopping yet delivery services (outside of internet shopping) are reducing (Kelly and Parker, 2005). Kelly and Parker's (2005) work in Ireland suggests that a telephone ordering service would be preferred to internet services by the elderly.

detrimentally affect the ability of the income deprived to afford food. However, two factors limit the ability to make further and more concrete conclusions about the impacts of climate change in the medium to long term for access to food. Firstly, there is a lack of clarity concerning how changes in price affect the nutritional outcomes of vulnerable groups in the UK. Secondly, and as is further explored in section 2 of this report, the nature of society and socio-economic drivers change over time. This means our understanding of what constitutes sensitivity, adaptive capacity and vulnerability may change.

Impact of climate change on physical access to food: It thus seems that pre-2050 climate change may have more of an impact upon food access via impacts upon physical access than via impacts upon affordability. In the case of transport systems it seems that most severe impacts for food access will come as the result of EWEs. In the case of impacts on health and physical wellbeing it is very hard to say how the plethora of predicted climate related impacts will then impact on food access, and even what the balance between positive and negative outcomes is likely to be.

It is likely that the food access of vulnerable groups (already sensitive and most likely with reduced buffering capacity) will be detrimentally affected by climate change. It is important to note that this could be a downward cycle, as vulnerable groups are more exposed they may in turn become more vulnerable and more sensitive and less able to adapt to future exposure. However, it is hard to say to what *extent* we will see this differential impact, given the need for much more detailed research upon adaptive and coping strategies employed in EWEs (of individuals, retailers and communities) and a more in depth understanding of current behaviours in accessing food.

As is a continuing theme throughout this report, there is a need for research attempting to understand the coping patterns of individuals, particularly in our vulnerable groups, when faced by events likely to rise with climate change such as EWEs and price shocks.

2.2. Are these vulnerable groups more likely to live in areas disproportionately affected by climate change?

It is important to think spatially about climate change impacts as they are not uniform over the UK, with some areas more affected by changes than others. There is the potential that vulnerable groups live in areas that will experience greater changes in climate. They are also more sensitive to these changes – as referred to in the introduction. Whilst we do not consider our vulnerable groups to be static over time in their distribution, there are not future geographical projections of these groups available. This approach provides an initial understanding of where vulnerable groups may be and potential ‘hotspots’, where high densities of people in vulnerable groups coincide with proportionally greater changes in climate.

Maps of current distributions in the very elderly, income, disabled and health deprived will be overlaid with UKCP09 generated climate projections at 2020 and 2050. This section will seek to answer the second question of this report and consider the implications of any geographical confluences between weather and deprivation/age variables for access to food.

2.2.1. Using UKCP09

Box C: UKCP09 Overview (see http://ukclimateprojections.defra.gov.uk/)

UKCP09 provides information on how the UK’s climate is likely to change in the 21st century, as it responds to rising levels of greenhouse gases in the atmosphere. This is relative to a baseline of observed climate between 1961-1990.

Splitting the UK into 25km^2 boxes, a range of climate projection maps have been developed for each time frame (2020, 2050, 2080). Different climate variable (e.g. mean summer temperature change, or mean winter precipitation) and emissions scenario (low, medium, high) combinations can be explored. Because climate projections are uncertain, each time-variable-emissions scenario combination is represented by a range of maps relating to different levels of probability in a probability distribution function (PDF) (10%, 33%, 50%, 67% and 90%).

Sources of uncertainty include natural internal variability of the climate system, incomplete understanding of earth systems processes and representation in models, and uncertainty in future emissions.

Climate change can be seen to manifest in two ways – firstly a national and gradual change in climate variables (for example higher annual mean temperatures) and secondly increasing frequency of EWEs, which will manifest at a regional/local scale. UKCP09 maps can help to understand how the former – more gradual changes – are geographically distributed at the national scale.

Although not undertaken here, in areas where hotspots between ageing/deprivation and large changes in climate variables are seen to occur, further investigation can be undertaken to explore the likelihood of EWEs in this area. Characteristics of weather extremes in any one season can be gauged through looking at projections for the 1st and 99th percentiles of a

Probability distribution function (PDF)[34], at a given emissions level and time frame (although it is also worth noting that these points on the PDF also carry greater uncertainty), or alternatively by using UKCIP's 'weather generator' (WG) (see Jones et al., 2009).

2.2.2. Mapping

The following tables and maps provide an overview of findings from this exercise. For 85+ groups, the mapping data was derived from the Office for National Statistics mid-2008 population estimates (ONS 2010). For the income deprived and the disabled and health deprived, datasets from the DCLG Indices of Deprivation survey were used (Department of Communities and Local Government 2007).

Although initially medium and high scenarios were mapped for winter precipitation, we determined that there is no discernable difference between the outcomes to 2050, and so only a medium scenario was included. Similarly, to 2020 there is no difference in medium and high emissions scenarios for temperature, so only a medium scenario was examined. Altogether 30 maps were generated. We have included some illustrative ones here.

The Oldest Old:

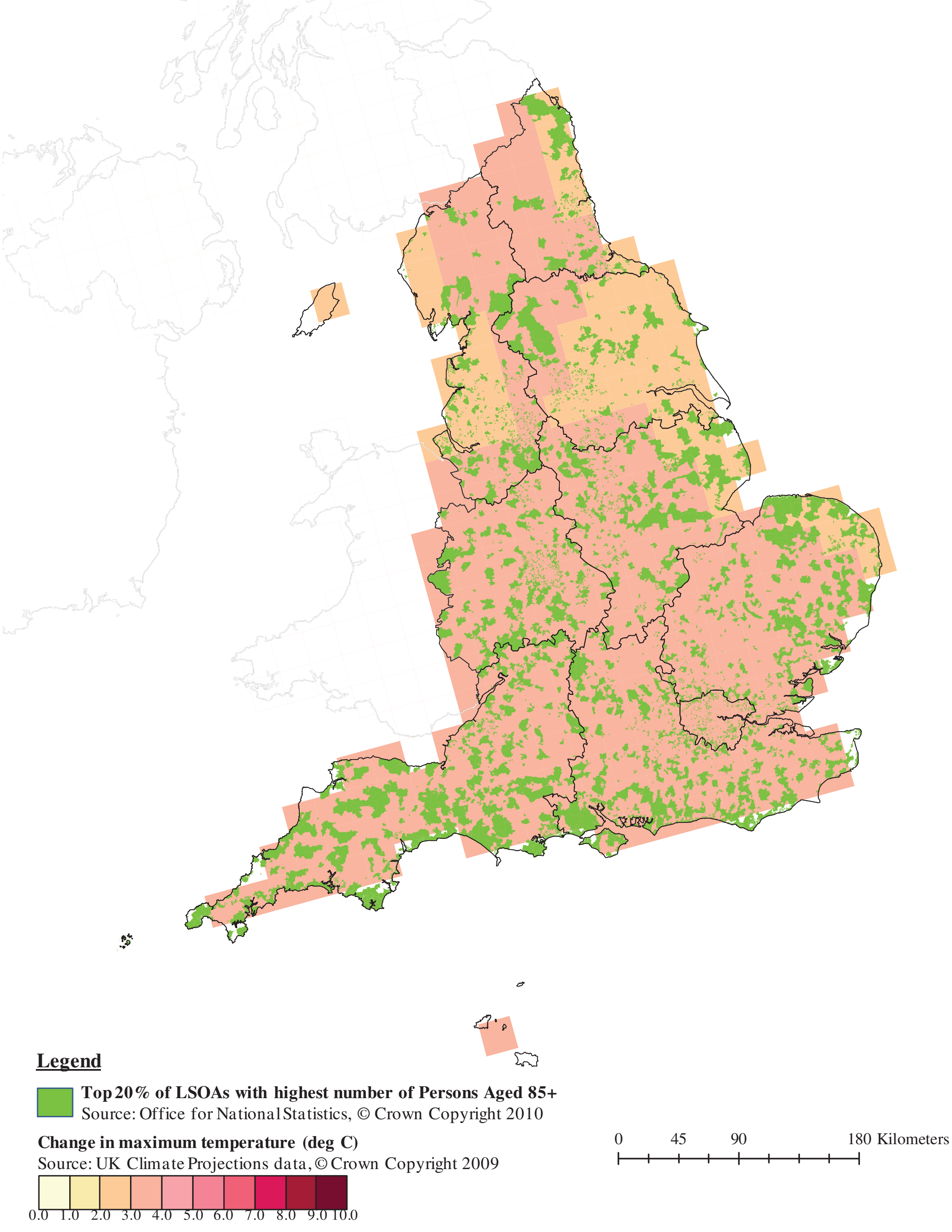
The geographical distributions of the areas where high concentrations of people aged 85 and over live is relatively broad and even (green areas Figure 2.4. and 2.5.). There is a weak trend towards more 85+ living in coastal areas in the south, and Norfolk. There are also many relatively rural LSOAs with higher concentrations of 85+ people living in them. A future mapping exercise may also want to explore LSOAs in which the concentration of 85+ inhabitants is in the top 10%.

[34] Probabilities can be seen as the relative degree to which each possible climate outcome is supported by the evidence available, taking into account our current understanding of climate science and observations, as generated by the UKCP09 methodology.

Oldest Old	**2020**		**2050**	
	50th Percentile	90th Percentile	50th Percentile	90th Percentile
Change in average summer daily maximum temperature	Medium scenario sees a 1-2℃ increase on the baseline over most of the country. A band of 2-3℃ increase around Dorset, Somerset and Avon, parts of Hampshire and Gloucestershire overlaps with a slightly higher density of 85+ living along Southern coastal regions.	Medium scenario: Here most of the country experiences a 3-4℃ in temperatures, with no clear overlap with relatively more concentrated instances of this vulnerable group.	Medium Scenario suggests a very similar outcome to the 90th percentile of 2020. No particular areas are prone to relatively greater exposure. High Scenario: finds a SW and S-central band of warming of 4-5℃, compared to 3-4℃ elsewhere.	Medium Scenario – here temperatures increase 5-6℃ over most of the country, but with a SW-S Central band of warming of between 6-7℃. [Mapped in Figure 2.4.] High Scenario: generally 6-7℃ increase over most of the south and central northern regions, and a 7-8℃ increase over Dorset, Somerset and Avon, Wiltshire and Hampshire.
Change in mean winter precipitation	Medium scenario sees a 0-10% increase in winter mean precipitation all over the country.	Medium scenario: sees a 10-20% increase over most of the country with areas of 20-30% increase along the south coast of Hampshire and Dorset. This area has a relatively high number of concentrated 85+ LSAOs.	Medium scenario: sees a 10-20% increase over most of the country. Small areas of lower rainfall projected in central northern regions and western Somerset/central Devon.	Medium scenario: 30-40a% increases in precipitation over most southern, central regions. 40-50% increase in winter precipitation around south Hampshire, the Isle of Wight, coastal Dorset – Lyme Regis, Weymouth, and northern Cornwall. [Mapped in Figure 2.5.]

To 2080, **SUMMER TEMPERATURE**: (M, 50th)General increases of 4-5℃, but a SW area of 5-6℃ warming over Dorset, Somerset and Avon, Wiltshire, Hampshire and Sussex. For the 90th percentile, all southern and central areas warm 8-9 ℃, but with a smaller SW area increasing to 9-10℃, again overlapping with higher concentrations of 85+ inhabitants currently.
RAINFALL: (Medium emissions scenario, 50% probability) most of the country will experience increases in winter precipitation of the order of 20-30%. Areas of higher rainfall (20-30%) include the NE and NW coastal regions, and a central band stretching from the central south coast to just north of Oxfordshire. At the 90th percentile, there is a much clearer band of higher mean rainfall (50-60% increase) along the south coast and northern Cornwall, including pockets of 60-70% increases in precipitation, similarly the coasts of Cumbria and Lancashire. High emissions scenario at the 90th percentile shows large areas of the south coast, central southern areas and Cornwall may experience increased rainfall of 60-70%. The Southern coastal areas in particular have higher concentrations of 85+ inhabitants currently.

Figure 2.4. Top 20% Mid-2008 Population Estimates for Lower Layer Super Output Areas in England for Persons Aged 85plus overlaid on Summer mean daily maximum temperature, medium emissions, 2050, 50th Percentile



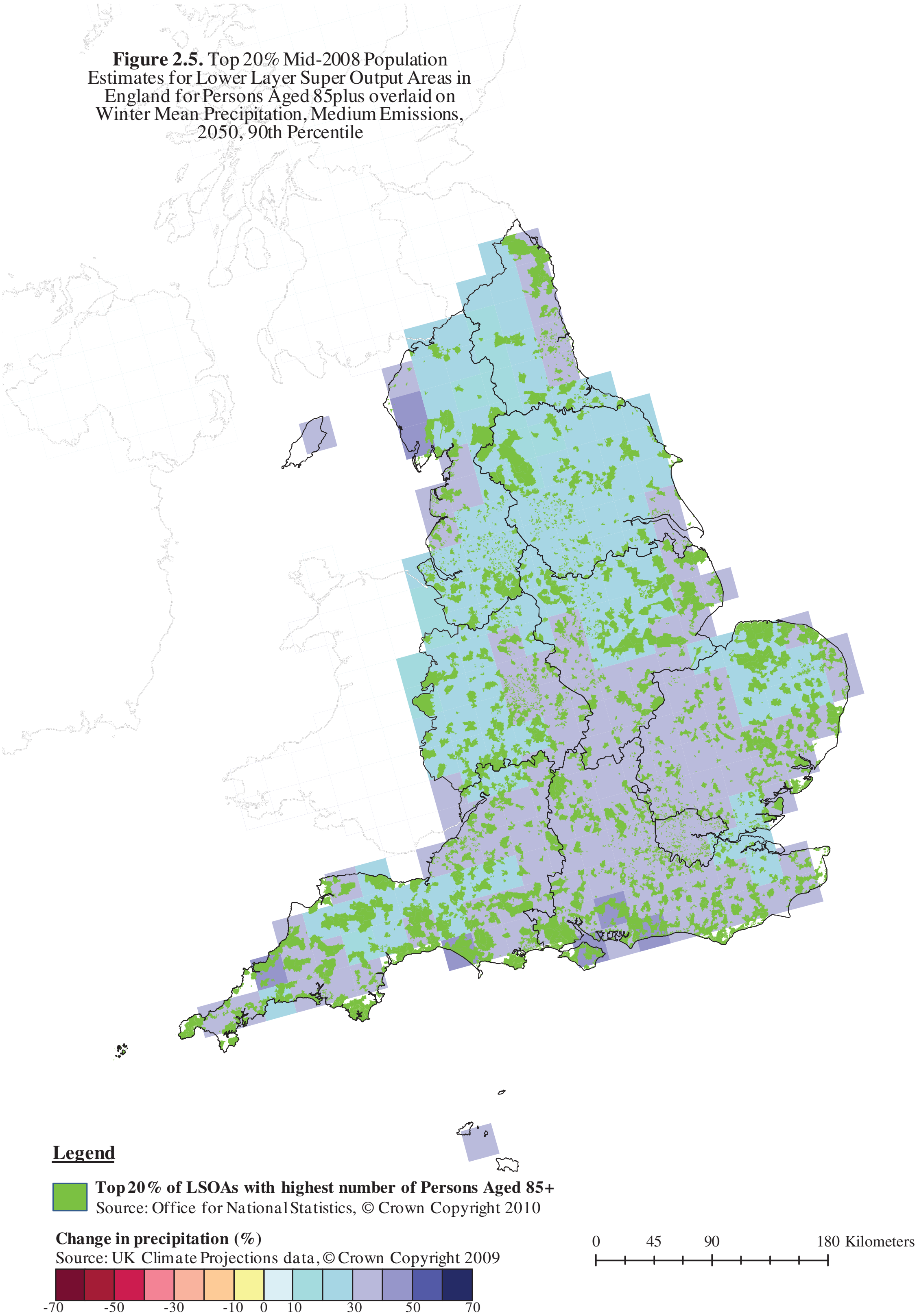
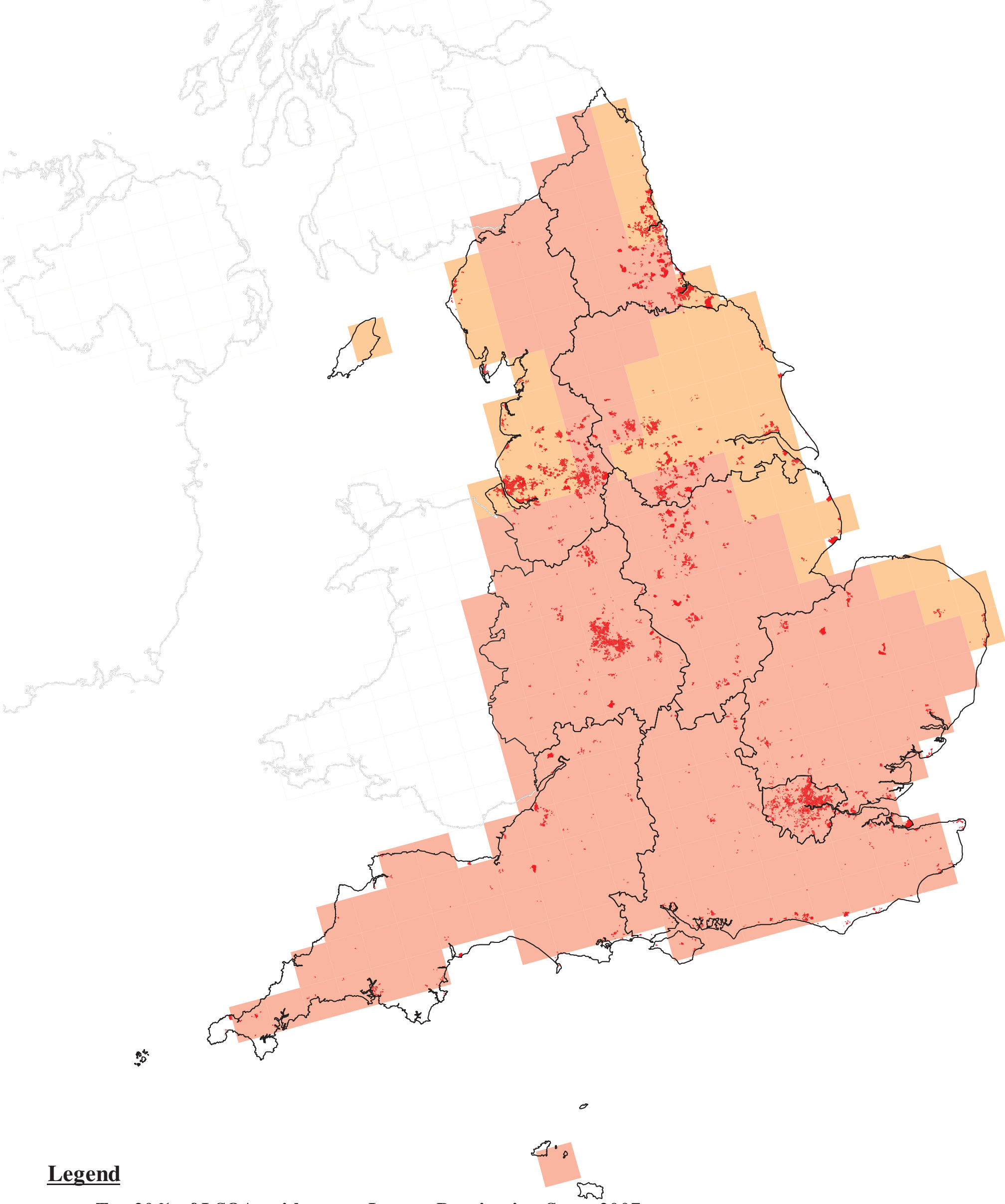


Figure 2.5. Top 20% Mid-2008 Population Estimates for Lower Layer Super Output Areas in England for Persons Aged 85plus overlaid on Winter Mean Precipitation, Medium Emissions, 2050, 90th Percentile

Income deprived, and disabled and health deprived: These two groups overlap heavily in their distribution and thus are discussed together in this table. These vulnerable groups are closely associated with major UK cities including London and Birmingham and then Liverpool, Manchester, Leeds (a north-western grouping) and Sheffield, Derby, Nottingham (forming a central strip), and a north-eastern grouping around Sunderland, Middlesbrough and Newcastle areas. A small difference is the slightly greater concentration of disability and health deprivation in the northern cities, compared with London and Birmingham. There are also smaller pockets of income and health deprivation and disability elsewhere in the country.

Income deprived and disabled and health deprived	**2020**		**2050**	
	50^{th} Percentile	90^{th} Percentile	50^{th} Percentile	90^{th} Percentile
Change in average summer daily maximum temperature	Medium scenario sees a 1-2℃ increase on the baseline over most of the country. There is no discernable overlap between increases in summer temperature and both vulnerable groups, other than a few pockets in the SW which overlap with the area of 2-3℃ warming.	Medium scenario: Most of the country experiences a 3-4℃ in temperatures, into which most of England's major cities fall.	Medium Scenario suggests a very similar outcome to the 90^{th} percentile of 2020. No particular areas are prone to relatively greater exposure bar pockets of health and income deprivation along the south coast and Somerset and Avon. [See Figure 2.6 for map of income deprivation areas in this category]	Medium scenario – here temperatures increase 5-6℃ over most of the country, but with Birmingham and London in an area of warming of between 6-7 ℃. High scenario: Small pockets of high concentration LSOAs are affected by 7-8 ℃ warming in the SW.
Change in mean winter precipitation	Medium scenario sees a 0-10% increase in winter mean precipitation all over the country.	Medium scenario: sees a 10-20% increase over most of the country including all areas of concentrated income deprived and disability and health deprived households.	Medium scenario: broadly a 10-20% increase over the whole country. No variation in relation to concentration in vulnerable households [mapped in Figure 2.7 for disabled and health deprived areas]	Medium scenario – 30-40% increase includes Birmingham and London, and NE cities strip, with 20-30% increase elsewhere in the north.

Figure 2.6. Top 20% of Lower Layer Super Output Areas in England with worse Income Deprivation Score 2007 overlaid on Summer mean daily maximum temperature, medium emissions, 2050, 50th Percentile



Legend

Top 20% of LSOAs with worse Income Deprivation Score 2007
Source: Department of Communities and Local Government, Indices of Deprivation 2007

Change in maximum temperature (deg C)
Source: UK Climate Projections data, © Crown Copyright 2009

0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

0 45 90 180 Kilometers

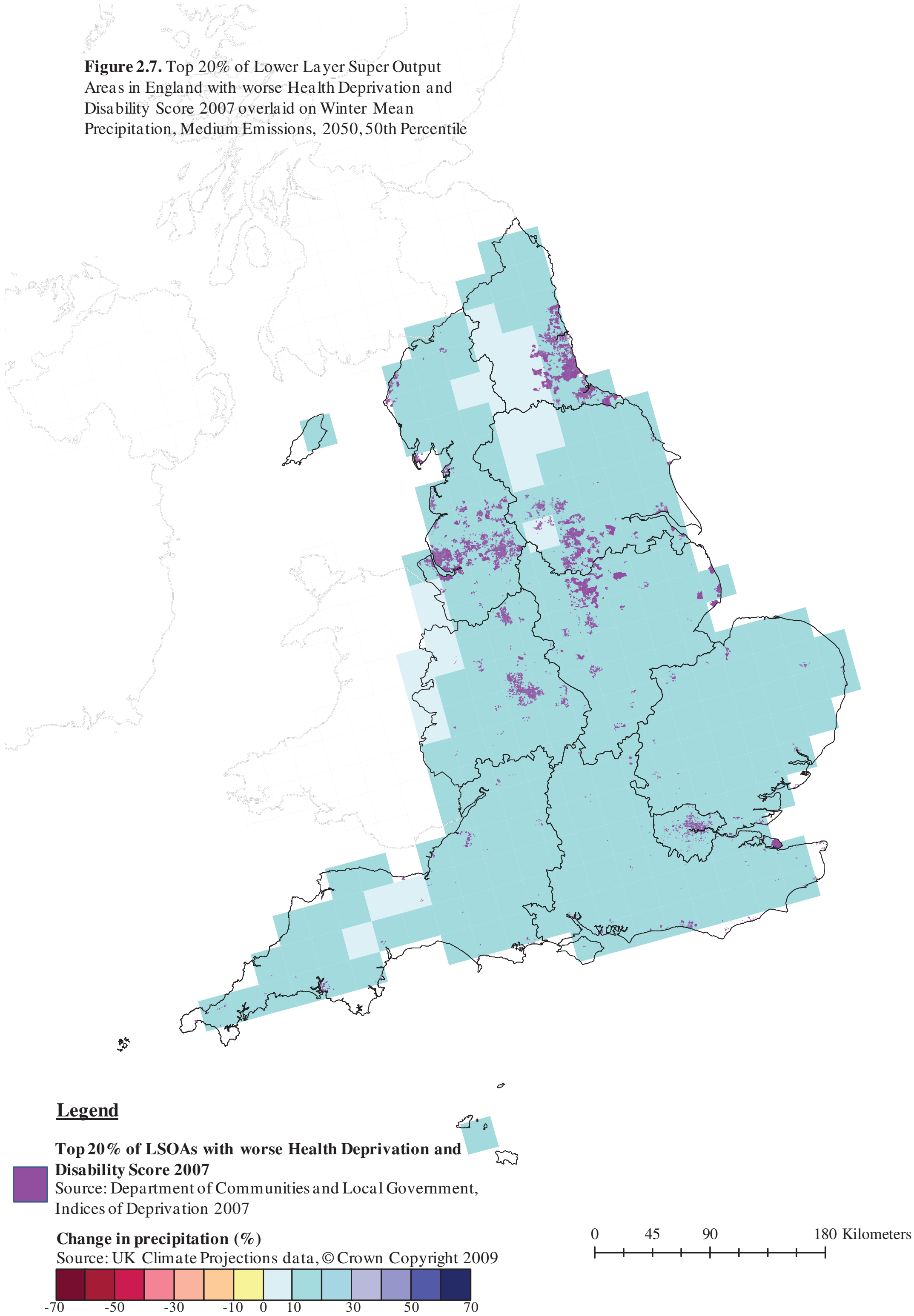


Figure 2.7. Top 20% of Lower Layer Super Output Areas in England with worse Health Deprivation and Disability Score 2007 overlaid on Winter Mean Precipitation, Medium Emissions, 2050, 50th Percentile

To 2080, SUMMER TEMPERATURE: At the 90th percentile medium scenario there is greater increases in temperature in the south (8-9℃ compared with a degree lower elsewhere), and similarly for the 50th percentile in the high scenario where a 6-7 ℃ rise is projected compared to 5-6℃ elsewhere. Birmingham and London, in which there are high concentrations of income deprived households, will experience this.

RAINFALL: (M, 50th) Areas of higher rainfall (20-30%, compared with 10-20% elsewhere) include the NE grouping of cities, and the Liverpool area. At the 90th percentile Liverpool may experience disproportionate rainfall of 50-60% increases in winter mean precipitation, compared to 40-50% elsewhere. The central band of northern cities is in an area of relatively lower increases of 20-40%.

Importantly the urban heat island effect is not well characterised by UKCP09, and therefore warming in cities is likely to be considerably higher than related here. A graph from Wilby (2003) on the UKCIP website[35] suggests the *nocturnal* urban heat island effect in London is between 1.75 and 1.85℃. Furthermore, the urban heat island effect can change over time with the nature of the landscape, materials and technology use, so this will also be a factor looking forward to 2080.

Having mapped the vulnerable groups with projected changes in climate for the UK, and assuming that current distributions in these groups remain relatively stable into the future, we can ask whether these groups are more likely to live in areas disproportionately affected by climate change. These maps suggest the potentially disproportionate exposure of the 85+ group in southern coastal areas, and an area of the Southwest more generally, to an increase in mean summer maximum temperatures. This also somewhat co-incides with increases in winter rainfall, particularly in the Lyme Regis-Wymouth area, and parts of southern Hampshire. The relatively higher mean daily maximum temperature in the Dorset, Somerset, Wiltshire and Hampshire areas is more pronounced towards 2080 (although only ever a degree higher than elsewhere), when temperatures will be on average 5-6℃ warmer at the highest point during the day. Again, in 2080 (at the 50th percentile probability) pockets of the south coast are also relatively wetter (20-30% increases) compared with elsewhere (10-20% increases). Although in the high emissions scenario and 90th percentile – and so much less likely to represent changes in the mean - winter rainfall increases across large areas of the south coast and Cornwall in the region of 60-70%. It is important to remember that these temperature and rainfall measures reflect variation around an average, and that weather experienced will be variable around this.

With respect the income deprived and the disabled and health deprived, there is less of a clear confluence between household distribution and changes in climate conditions. However, the Liverpool and Newcastle areas are both relatively wetter towards 2080 than other areas,

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[35] http://ukclimateprojections.defra.gov.uk/content/view/2092/517/

whilst London and Birmingham are more at risk of greater increases in summer daily maximum temperature, which will be exacerbated by the heat island effect. This is also an issue for small pockets of disability and health deprivation and income deprivation along the south coastal areas and Somerset and Avon areas.

2.2.3 Conclusions and utility of UKCP09

This brief analysis suggests that a number of areas inhabited by relatively high concentrations of the very elderly, and some pockets of disabled, income and health deprived, in central southwestern and south coastal areas may experience greater increases in summer temperatures in the future compared with the rest of the country (particularly around the 2020s and again 2080s). Smaller pockets along the south coast are also more exposed to greater winter rainfall by 2050 and 2080. The Liverpool and Newcastle areas, in which higher concentrations of health and income deprived live, are projected to be disproportionately wet towards 2080. However, these correlations are weak rather than substantial, and further analysis would be required to draw firmer conclusions.

The implications for food access however will clearly be mediated by the adaptive capacity of individuals, food providers and services in those areas (as we come onto in section three). There is also the potential for thresholds (both in climate and adaptive capacity) to exert non-linear outcomes for food access vulnerability which is not well represented in maps.

Having used UKCP09 outputs for the mapping of vulnerable groups to climate exposure, it has been possible to reflect on what this tool can and cannot tell us in relation to how food access may change with climate change.

Firstly, we are defining food security as being a function of economic and physical access, with the former a globally driven and locally mediated variable. Physical access however is very much a locally variable phenomenon, dependent on the individual, their access to transport and the physical environment. UKCIP projections are therefore more helpful in understanding variation in physical rather than economic access, other than where these may overlap as a result of the weather limiting access to affordable food.

UKCP09, and modelling capabilities generally, are much better equipped to consider general changes in climate over space rather than extreme events. Yet it is these extremes which will potentially most affect access to food, particularly in the shorter term. The effects of extreme weather are also very much dependent on the physical infrastructure and preparedness of the population. Climate maps are therefore useful in highlighting risk hotspots of vulnerability to changes in different weather variables – as may be the case here with regions in the south and southwest, and north-western and north-eastern urban areas. They are not able to show who will experience what in the future. Some EWEs can be explored further through using tools like the WG which can show forecast increases in the frequency of extremes. The WG, however, does not show you how hot the heatwave might be, how long it might last and does not capture the extremes of the phenomena well (Ferguson, 2010).

Flooding, which is even more a consequence of weather, the physical environment and management interventions, is only partly captured by UKCP09 which focuses on portraying changes in climate and not its mediation by people/infrastructure. Combining the vulnerable group maps with EA flood risk maps may be alternative route to explore.

Finally, there is somewhat a mismatch in resolution between changes in climate variables – here mapped at 25km^2, and household food security which is so much an outcome of multiple interacting factors. It is important to strike a balance between ascertaining areas disproportionately exposed to a changing climate, and understanding where there are limitations to adaptive capacity across groups (much harder to map). A household with low adaptive capacity might experience the same or lower levels of climate change (exposure), but have a greater vulnerability.

3.0. Uncertainties and complexities in future food access

The first section of this report focussed on understanding how climate change relates to economic and physical access to food by vulnerable groups. Whilst we looked at climate to 2050 and beyond, we understood vulnerability as it manifests today. However, whilst the climate is changing, so is the socio-economic and cultural context, "our vulnerability to climatic changes and the way in which we choose to respond to it will be influenced to a large extent by the nature of the economic, social and technological world in which we live" (p.i, Gawith and Brown, 2009). And, as noted by Parry et al. (2007), "the choice of the SRES scenario (i.e. future socio-economic and demographic pathways taken) has as large an effect on projected global and regional levels of food demand and supply as climate change alone". This second section therefore seeks to unpack elements of the future socio-economic context that will mediate the effects of climate change as it pertains to food access. This section is not attempting to map *all* future changes and predict what society *will* look like in 2020, 50 and 80, but rather highlight the complexities and uncertainties in future changes. Having opened up the debate in this way, the following concluding section (section 4.0) provides suggestions for moving past this uncertainty and complexity.

To structure this section and our thinking five 'dimensions of change' that UKCIP distilled from a review of the global futures literature are used (UKCIP, 2001). These dimensions are the same as or similar to those used in many other scenario or futures studies (see for example the review by Wilkinson et al., 2009):

- Demography and settlement patterns
- The composition and rate of economic growth
- The rate and direction of technological change
- The nature of governance
- Social and political values

Each dimension is summarised, rather than comprehensively reviewed[36], through a table of key drivers, trends, uncertainties and outcomes for food access, with reference to the conceptual frameworks characterising affordability and physical access. These can be found in Appendix D. In the discussion below we choose a few key drivers relating to each dimension that we see as critical, and discuss these in relation to future climate change and food access for vulnerable groups.

[36] Were a full scenario analysis to be undertaken, a range of expertise, insights and opinions would be used to collectively determine what are considered the most important uncertainties.

Following this the interactions between drivers is briefly considered, including in relation to climate change. The importance of attending to adaptive and coping capacity and the uncertainties and complexities that relate to this is discussed. Subsequently one further area of complexity around examining food access into the future is outlined, that of cross-level and cross-scale interactions.

3.1. Socio-economic drivers

3.1.1. Demography and settlement patterns

Demographic and settlement patterns are at the core of understanding how people might live in the future and the challenges that could face them. The ageing population and household structure are considered to be particularly important future trends with implications for future food access in a changing climate.

Population ageing - The English population is ageing. By 2017, 18.2% is projected to be 65 or over (ONS, 2009c), and by 2031 32% of all English households will have as their head someone older than 65 (DCLG, 2009). This ageing population may experience profound effects from climate change, both positive and negative. Warmer winters are conducive to an active lifestyle which promotes healthy ageing, allowing the elderly to remain independent longer. Conversely, extreme heat can pose a potential health risk to the elderly who have difficulty maintaining homeostasis with temperature fluctuations.

Existent projections for 2016 foresee an increase in the >65 population of greater than 30% in many areas of south or southwest England (ONS, 2008). This trend is expected to continue until at least 2031 leading to higher densities of the oldest old along the southern coast where temperatures are expected to be the highest[37] (ONS, 8 March 2010). Already vulnerable, prolonged exposure to heat extremes could result in older persons becoming housebound, thereby limiting or severing access to food. At the same time, however, if (as has happened in the past) the future health of elderly groups is relatively better than today's, this will result in the elderly of tomorrow being less vulnerable than the elderly of today.

Household structure - In England, single person households are expected to grow at a rate of 163,000 per year with 18% of the English population living alone by 2031 (DCLG, 2009). With more elderly likely to be living alone there are great implications for the food access of these individuals, particularly in times of stress.

[37] As noted in section 2.2.2.

The vulnerability of these individuals could be reduced by a rise in non-traditional intergenerational housing. For example, lower fertility combined with greater longevity is resulting in “Beanpole” families, characterized by more generations with fewer people in each generation. An alternative might be similar supportive environments but between unrelated individuals. The presence of a co-housing movement (multi-generational communal living arrangements) in the UK has been noted (Goff, 25 July 2005), following on from successes in Denmark. Group living has the potential to mediate issues of affordability and physical access with pooled financial resources, mutual assistance, and greater mobility, amongst other things.

In conclusion, the most physically, financially, and emotionally resilient will be the best able to adapt to and cope with climate change. Household structures of the future will play an important role in enhancing or reducing the social capital of vulnerable individuals, but some uncertainty surrounds future household structures.

3.1.2. The composition and rate of economic growth

Economic variables clearly intersect with the economic and physical access to food models at all stages. The following were considered to be particularly pertinent.

The nature of economic development, both globally and in the UK – A central factor in determining future food prices according to Alexandratos (2008) and the World Bank (2009). Globally, economic development will increase demand for food as incomes increase. Depending on rate, rate of population growth and type of food sought, as well as supply dynamics, this has the potential to create upward pressure on commodity prices globally. A tighter supply-demand relationship will also increase the sensitivity of prices to shocks or other influences. Nationally economic development primarily affects incomes and investment in public services as well as prices indirectly.

Importantly however, where returns on economic growth accrues, the nature of redistribution and the degree to which money is invested in transport systems and health care provision is central to defining the relative sensitivity and adaptive capacity of the income and health deprived and elderly. In this sense there is a strong overlap between the nature of economic development, welfare governance and social values. Trends in inequality over time are notoriously difficult to ascertain (Cirera and Masset, pers comm.10/03/10), however past experience suggests that at least in relation to income, inequality can increase considerably over a decade (Sheppard, 2003).

Energy prices – this is somewhat linked to the above, with high economic growth globally contributing to increased demand for energy. Given the importance of energy prices to food prices, and that energy is also a core part of household expenditure in terms of heating and transport, the cost of energy is extremely important in shaping food access. In addition, there are strong links between the price of energy and the demand for biofuels, which currently competes with food production for land.

Future projections suggest increasing prices over time (IEA, 2008). However, importantly both income, behavioural and technological change can mediate the impact of energy prices. And furthermore, shorter-term increases in energy (and/or carbon) prices as part of a strong climate governance strategy will help ensure longer-term food security by reducing the negative impacts of climate change.

3.1.3. The rate and direction of technological change

Technological changes during the 20th century saw vast reductions in the relative price of food for consumers. For example, advances such as high yield seed hybridisation, pesticide and fertiliser use, and increased mechanisation in agriculture heralded a so-called green revolution, enabling higher yields and more intensive production. Technological changes have also impacted upon physical access to food, namely advances in transport systems (in part allowing changes to retail environments) and technological changes impacting on physical wellbeing. As such, the impact of past technological change highlights the potential importance of future technological changes in tackling the barriers of physical access and affordability problems and thus the food access of vulnerable groups.

According to Sheate et al. (2007, p.32) the key uncertainties surrounding technological change can be grouped into three rough areas:

- the pace of technological development (i.e. innovation)
- social (and political) acceptance of new technologies
- the impacts of new technologies, including the wider indirect impacts and influence on other drivers.

A lot of complexity and uncertainty also surrounds the extent to which new technologies are spread across populations or distributed. Many scenarios assume that once new technologies are discovered they are quickly disseminated, however experience suggests otherwise. It seems particularly important to attend to disparities in access to technologies.

As well as positive impacts, technology can have longer-term negative impacts that also need to be considered. The impacts of past technological ‘advances’ can be seen to have created vulnerabilities in current food systems, for example in depleted nutrient cycles, water quality/quantity and soil quality (Reid et al., 2000).

Energy technologies and internet shopping are technological changes of import in relation to food access.

Energy technologies - Modern food systems are highly dependent upon energy. Future innovations and continued uptake of recent energy technologies (in areas including extraction, energy efficiency, power storage, decentralisation and renewable technologies) will impact on the costs of energy. In turn energy costs will impact on food access in three ways. Firstly, they will affect food price and thus affordability through changes to input and transport costs at all stages of the supply chain. Secondly, changes will impact the disposable incomes of households by reducing or increasing other outgoings (particularly household fuel) and thus impact on affordability. And lastly, they will impact on the costs of transport and thus stand to affect physical access to shops, especially for low income groups. As noted in The Nature of Governance driver table in Appendix D, research and development (R&D) is important in this respect.

Internet shopping –The use of internet shopping has risen considerably in the last 15 years. This has come about as a result of much higher levels of internet access and knowledge. Yet there are still disparities in internet access and skills in using the internet, with low income and very elderly groups in particular likely to be lacking in this regard[38]. Trends suggest that broadband access is expanding but whether or not that is being used is another question (GOS, 2009a). Current indications that today’s baby boomers and tomorrows elderly have become a lot more internet savvy in the last ten years, suggest that internet shopping may become increasingly practiced (McClellan, 18 November 2004). A further uncertainty is the knock-on effect of internet shopping on local retail provision, with the potential for fewer local shops. The resilience of this new configuration in EWEs may then be an issue.

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[38] For example Meneely et al. (2009) and the Welsh Consumer Council (2006) found that very few older people were using the internet for food shopping.

3.1.4. The Nature of Governance

Governance touches on all aspects of the food system and through different means and including different parties. Many scenario exercises consider key uncertainties in governance to pertain to axes of relative inward-outward/cooperative-non-cooperative governance stances.

An over-riding uncertainty is the relative strength of government in relation to the private sector, third sector and general public and what this means for food access. Its capacity to implement and see through change or prevent change where necessary is an outcome of this. Another important driver is biofuels markets and land-use.

Public vs. individualist policy philosophy and systemic governance– This theme runs across food, climate and welfare policy provision, with implications for the supply and demand elements of food. Outcomes on this front are also related to the strength and willingness of actors to intervene in production-consumption systems.

An example of a public policy philosophy with a systemic framework is that proposed by Lang et al. (2009), of governing food systems according to an 'ecological public health philosophy'. With respect to food this approach suggests a greater emphasis on responsibility and systemic vision at the state level (although not precluding private and third sector participation) with higher minimum standards, an emphasis on drivers of equal provision (not just income) and upstream choice editing. An individualist philosophy suggests informed choice given your means is paramount (Lang et al., 2009, suggest that income is increasingly the focus of enhancing food access within this paradigm), with an emphasis on information, price competition and perhaps a less systemic approach to food production-consumption governance. Welfare and transport governance can also be seen to embody this continuum. A systemic and public approach suggests a relatively greater role for publicly funded services, safety nets and intervention at multiple points versus an emphasis on private responsibility, provision[39]. The role of social values with respect community cohesion and co-operation will be an important mediating factor however.

With regards systemic governance, previous experience has shown that too much emphasis on agricultural production and food availability at the expense of the rest of the food system does not necessarily equate to food security for all.

[39] That is not to say that public=systemic. The degree to which an individualist governance style cannot be systemic is also debatable.

Global climate change and biofuel governance and how food-fuel trade-offs are treated – The important role that biofuel production played in the 2007-08 food price spikes suggest that land-use in relation to this is a critical issue for pressure on food prices. The governance of this issue and global coherence of strategy has important outcomes for food prices at the national level. How much this filters down to variation on the shop floor is difficult to say, but it is at the very least a variable that can amplify other pressures on food price, and tighten the supply-demand dynamic.

A future with much greater competition for land (and assuming strong protection of currently forested/non-agricultural habitats) would increase the exposure of people to higher and more volatile food prices.

More broadly, climate change governance may affect food prices through affecting the price of carbon. As emissions caps come down, the price of carbon should increase. However the effect on food and transport prices, and outgoings over the longer term, is also a consequence of technological investment (by the supply chain in energy efficient technologies and individuals/local government, for example in efficient houses) and behaviour change (for example through changing diets, a consequence of social values).

3.1.5. Social and political values

Social and political values are seen to be of key importance, in part shaping other dimensions of change. In the UKCIP socio-economic scenarios (2001), of the five dimensions of change identified (which are used to structure this section), it is values and governance which are taken to be the two axes from which four future scenarios are created. It is assumed that the other dimensions of change (demographic, economic, and technological) are primarily "an outcome of the relationship between values and interests" (UKCIP, 2001, p.19). In one of the few scenario exercises specifically focused on UK food systems, the Food Ethics Council also place culture and values as one of their two axes in creating scenarios. As such we can see that social values are considered to be hugely important in shaping food systems and thus food access, in particular the three onto which we now come.

Individualism, collectivism and ethical consumption - It is under this split between individualism and community where most uncertainty lies regarding how future values will shape food systems and thus food access. UKCIP (2001), in their future scenarios report (discussed above), postulate two possibilities for future values:

> "At one end of the spectrum ('CONSUMERISM'), values are dominated by the drive to private consumption and personal freedom. The rights of the individual and the

> present are privileged over those of the collective and the future…At the other end ('COMMUNITY'), values are shaped by concern for the common good. The individual is seen as part of a collective, with rights and responsibilities determined by broadly-defined social goals. There is greater concern about the future, equity and participation." (p.19)

There is much evidence for increased individualism and reduced community activities (GOS, 2009b), yet at the same time, more specifically in terms of food, there seem to be increased numbers of food systems which are trying to think of food in a more holistic manner (GOS, 2009c). Individualistic and collective values have huge implications for food access. It could be argued that it is, in part, the individualistic demand for cheaper food now, more choice and more convenience which has drastically improved access to food from the view point of the consumer, in the last 20yrs. However, it could also be argued that this trend has also resulted in many negative externalities of food systems (e.g. environmental degradation and the demise of fair prices for farmers) with knock on effects for future food access through food prices.

More tangible perhaps, is the impact of individualism on non-food related practices. For example, the huge rise in car ownership and usage and the consequent changes in the spatial distribution of retail. Access to out of town retail can be difficult for those reliant on public transport. The trend towards individualism also impacts heavily upon support networks for those who may struggle with physical access. More cohesion and social capital between relatively more and less vulnerable groups would help alleviate poor physical access (with tactics such as lifts, and help carrying and doing shopping). Yet there are suggestions that these are on a downward spiral (GOS, 2009b).

Given the need for more sustainable food systems which consider the collective, there is then a question of how to make a transition to more sustainable food systems in an equitable way. Here there are debates over the role that ethical consumption has to play. Ethical consumption in some ways marries individualistic and collective values. In a way ethics have become another thing into which people can opt, entering that beacon of choice (and individualism) the supermarket. Yet they are promoting collective ideals of looking outwards to society and forwards to the future. However, with generally higher costs involved in ethical consumption in mainstream supermarkets (organics and fair trade for example), this often means that groups vulnerable to problems with accessing food are not engaging with these changing social values, because they are not (in the main, and the mainstream) making food more affordable. Whilst it seems that sustainable systems (which consider the future and society wider than the individual) are necessary to ensure food access into the future, it is a lot harder to say how these systems affect food access of vulnerable groups in the now. As such, the future balance in UK society between individualistic and collective values has important implications for future food access.

Changing patterns in meat consumption (nationally and globally) - Recently, despite population increases, UK consumption of meat has remained fairly stable (having fallen per person) (Food Ethics Council, 2007). There are movements amongst some environmental groups to encourage people to reduce their meat consumption, suggesting pressure for changes in social values. Changes in diet and preferences have implications for the cost of food.

On a global scale projections are for large increases in the amount of meat being consumed, with much of this demand coming with increasing populations and affluence in developing countries. Due to the high inputs of grain and other fodder, increases in meat consumption stands to heavily impact upon more than just meat prices. It is likely to also put upward pressure upon food prices more generally, energy prices and demand for land. As well as implications for food affordability, this also has potential impacts for transport costs and thus on physical access. Increased livestock rearing will also increase carbon emissions.

Increased concerns for health and safety - The last fifteen years have seen increased concerns for health and safety in the food sector. Such perceptions of risk must be attended to, as we can tell from the current consumer resistance to genetically modified organisms (GMOs) in Europe. Social values can stop technological change and diffusion, with citizens refusing to allow new technologies to engage in food systems. Many would argue that GMOs stand to reduce food prices by increasing yields. Whilst this relationship isn't linear and the long term impacts of GMOs are controversial, perceptions of risk do stand to indirectly affect food access. The perception of risk is an overarching theme relating to social values. The division between individualist or collective values is also related to perceptions of and concerns for risk.

3.2. Interactions between climate and socio-economic drivers of change

As we have highlighted in the sub-sections above, there are numerous interactions between the different drivers of change, and importantly, into the future a key driver will be climate change. Consideration of drivers as independent from one another will result in miscalculations of risks, as the GECAFS conceptual framework suggests (Ericksen, 2008a). There are a number of potentially very important interactions, whereby socio-economic factors enhance or reduce the impacts of climate change on physical and economic access to food.

Interaction of socio-economic factors with climate change highlights a number of key issues affecting physical access. In terms of physical well being, the impact of climate change is potentially amplified by an ageing population, with the elderly more at risk to climate change related health problems. The trend towards migration of elderly people to southern coastal areas where disproportionate warming is expected re-enforces this. Yet an uncertainty surrounding this point is whether tomorrow's elderly will be healthier longer, potentially mediating these affects. Technological change also stands to mediate the impacts of climate on physical wellbeing and physical access to food via medical progress reducing mobility problems, as could mobility aids. And, as noted a number of times already, changes to internet shopping could remove the need for physical access to food stores altogether. In terms of transport, improved weather forecasting and climate modelling tools can serve to improve coping and adaptive capacities in times of EWEs. This is just as much about governance of technological diffusion and ensuring equal access as it is technological improvements. More broadly economic changes (partly economic growth but more importantly reductions in economic disparity) could aid the ability of vulnerable groups to afford transport (public or private) as well as increasing their purchasing power if faced with rising transport and food costs.

In terms of impacts on price, and thus on affordability, technological advances, such as drought resistant crops, could serve to mediate the impacts of climate change on food production and thus on prices. Another big factor, as noted in the previous section, is supply chain governance. Retailers currently play a large role in smoothing prices as experienced by consumers, and as such (assuming a continued dominant position in the food system) will decrease price variability caused by weather extremes. Yet, as we highlight above, the extent to which low prices (in part the result of social values which value low cost food) feed into food systems which are unsustainable (including being more vulnerable to climate change) in the long term, and thus impact upon future food systems, is an issue of concern here. Finally, there are obviously a whole host of socio-economic factors which impact upon purchasing power (including climate change itself) which again serves to interact with any price rises due to climate change.

Although there is not space here to go into a detailed analysis of interactions between climate change and other drivers, all of the points made above serve to highlight just how necessary it is consider drivers as dynamic and interacting, rather than as independent entities.

3.3. The complexities of levels and scale

A further complexity in examining the impact of climate change on future food access surrounds the issue of cross-scale and cross-level interactions in socio-ecological systems. Just as we need to be aware of driver interactions, so too do we need to consider cross-scale (across scale) and cross-level (within scale) interactions. Cash et al. (2006) define 'scale' as, "the spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon, and "levels" as the units of analysis that are located at different positions on a scale", in line with Gibson et al. (2000).

Most widely examined are spatial, temporal and jurisdictional scales, although Cash et al. (2006) highlight a number of other scales which may be relevant, for example social networks (ranging from trans-society to family), interactions amongst which may be particularly important when thinking through adaptive and coping capacity. Cash et al. define a scale challenge as "a situation in which the current combination of cross-scale and cross-level interactions threatens to undermine the resilience of a human-environment system", citing lack of knowledge about interactions as being a major factor in adding to this risk.

It is important to highlight a few scale challenges of relevance to future food access. Within spatial scales we can think of levels extending down from global, via regional and local, to the household level. In food access literature, there are increasingly moves to talk about these issues at the household level. The conceptual models we postulated in the introduction highlight the need to consider an individuals' sensitivity (i.e. purchasing power or physical wellbeing) in addition to factors external to them (such as retail environment and food prices). At the same time, climate change is often discussed at the global level. The UKCP09 moves this agenda across spatial levels, projecting changes at a localised level ($25km^2$ resolution) but there are still great disparities between our spatial level of focus for food access issues and for future climate projections. This makes it complicated to consider future changes to food access, as a result of interactions between different spatial scales.

Complexities in relation to temporal scale can be seen by the difficulties in marrying long term predictions of climate change with much shorter term outlooks on socio-economic drivers and food access. Here it is particularly hard, but vital, to relate long term climate changes to the short term everyday behaviours of accessing food. Another point of interest lies in the onset times of gradual climatic changes vs. EWEs. Whilst one may require long term adaptation the other may just require short term coping, but these factors interact -

coping strategies (like using savings) in response to short term EWEs can leave individuals' food access more vulnerable to long term climate stressors.

The complexities of the 07/08 food price crisis can be seen as a good example of these interactions (Misselhorn, forthcoming). Here regional events (e.g. Australian drought) fed into global commodity prices which in turn impacted at the household level in prices experienced by UK consumers. Here we also see a number of temporal levels involved (long term yet sustained fuel price increases vs. relatively short term event of drought).

As this section highlights examining cross-level and cross-scale issues is very difficult. Cash et al. (2006) suggest the importance of institutional interplay (aided by cross level networks), co-management (across levels) and boundary organizations (to aid the spread of knowledge across levels and scales and to facilitate the co-production of knowledge) in overcoming the complexity and unknown nature of cross-scale and level interactions.

3.4. Adaptive capacity and coping capacity

This report is examining the vulnerability of the food access of certain groups to exposure to climate change. As highlighted in the introduction, vulnerability is a function of exposure, sensitivity and adaptive and coping capacity. Whilst policy interventions must seek to decrease the sensitivity of individuals to problems with food access more generally (e.g. increasing purchasing power and transport access of individuals), policies must also be devised that enhance adaptive and coping capacities. We must build food systems (and the energy, transport systems which feed into them) which can aid individuals in adapting to long term gradual change and coping with short term shocks. In short, systems which are resilient to future changes.

The need to attend to adaptive and coping capacity is a theme which has run throughout this report being a vastly under-examined area - quite simply we know very little about the current coping strategies people employ (and how institutions enhance or reduce these), let alone how these may change into the future. Whilst it seems logical to suppose that more sensitive individuals are going to lack adaptive and coping capacities, it is not axiomatic that their reduced resources (be that economic, social, political) will necessarily lead to reduced adaptive and coping strategies being employed. Rather there are a whole host of factors affecting adaptive and coping capacities. According to the IPCC Third Assessment Report (Smit and Pilifosova, 2001, p.905) 'The ability to adapt and cope with climate change impacts is a function of wealth, scientific and technical knowledge, information, skills, infrastructure, institutions, and equity'. As such it is subject to all of the complexities and uncertainties discussed above with regard to a changing world (demographic, economic, technological, governance and value changes).

A full consideration of the adaptive and coping capacities operated by vulnerable groups when faced with climate threats to food access (and the formal and informal support networks within which they operate) is outside the scope of this report but this is a vital area of consideration for future research. Below we consider a few examples where capacities are potentially reduced or enhanced, areas that it is of key importance that we understand more about.

Given the potential for more volatility surrounding food prices, it is important that we understand about the coping strategies employed by people during these times. Where weekly food spend is reduced there is a need to understand if this is achieved through reducing quantity (and potentially going without meals), quality, substitution items bought (moving to less healthy cheaper food). There is also a need to understand to what extent people are relying on a support network during times of stress (formal, e.g. more benefit seeking, and informal, e.g. relatives feeding them). For example, there is evidence that free school dinner claimants drastically rose in Birmingham following the recession, putting severe strain on council budgets (Collins, 30 July 2009). Whilst this was due to decreased purchase power rather than increases in price, it shows a strategy employed with changes to food affordability. It also highlights the impacts upon institutions that aid coping[40].

Another area of importance relates to planning for, and forecasting of, EWEs. As highlighted in section 2, EWEs stand to have a number of impacts upon food access. In light of past EWEs, pre-emptive emergency planning is increasingly taking place in a range of institutions. There is, however, a need to incorporate consideration of food access into such plans, taking into account all actors (including retail) and taking a long term approach (EWEs do not leave people more vulnerable for solely the duration of the EWE but also for some time after). Here early warning systems can play an important role in allowing individuals, communities and institutions to prepare[41]. Following the 2003 heat waves the DH launched its National Heatwave Plan which led to the establishment of a ‘Heat-Health Watch’ System run by the met office over the summer months, acting as a warning system to enhance coping capacity (Met Office, 10 April 2010). Such warning systems are likely to increase coping capacity in future heat-related events.

[40] As we touched upon above, this is dependent upon the balance between a public and an individualist policy philosophy.
[41] Here we could see the role of technology mediating exposure to climate change.

A final and important point with regard to adaptive and coping capacities is the extent to which policies and practices to enable these capacities will and can marry with mitigation policies. As a nation we are committed to an 80% reduction in greenhouse gas emissions by 2050. With food systems currently contributing a significant amount of greenhouse gas emissions, cuts will not be met without large changes to the way current food systems operate. Given the need to both mitigate and adapt to future climate change it is vital that we think through how mitigation efforts may enhance or reduce adaptive and coping strategies.

The above discussion highlights the need to carry out research further examining strategies for buffering the impacts of climate change on food access.

3.5. Conclusions

Changing socio-economic context is as important as climate change and stands to have a myriad of impacts upon the food access of vulnerable groups. For this reason we cannot consider society to be stagnant as climate changes into the future.

Although our driver tables (in Appendix D) are far from a comprehensive review of socio-economic drivers, a number of the factors discussed above stand out as being particularly important in shaping food access of vulnerable groups into the future. Variables highlighted in the demographic section (household structure, population, and in particular ageing) stand to be of utmost importance. Likewise the future nature of governance (with a public or individualist philosophy) seems to be another crucial issue shaping food systems and food access. This is a point which is equally important with social values, as highlighted above with a discussion of individualist vs. collective values. Finally, it appears that the rate, direction and diffusion of technological change are particularly important for future food access. This seems to be a cross-cutting theme that intersects with many other drivers (creating complexity) and is by its nature uncertain.

It is not only important to consider the nature of socio-economic change into the future, but their interactions with each other and climate change, both in ameliorating and exacerbating food access issues. Likewise an appreciation of scale and level interactions is imperative with regards to socio-ecological systems such as the food system.

Finally, the amount and nature of adaptive and coping capacity is clearly an important factor that will determine whether climate change will alter vulnerable groups' access to food in the future. Current and future adaptive and coping capacities are an area of huge uncertainty.

4.0. Conclusions and future directions

This report aimed to answer two central questions. Firstly, within England, what the likelihood of changes in vulnerable groups access to food is given progressive climate change; and secondly, whether these vulnerable groups are more likely to live in areas disproportionately affected by climate change. Three groups were studied – the very elderly (85+), the income deprived, and the disabled and health deprived.

The approach taken in section two was to explore these questions given what we know about vulnerable groups today – the nature of their vulnerability in relation to economic and physical access and their geographical distribution – in the context of future progressive climate change. However, given that society is dynamic, as is climate, section three sought to unpack potentially important socio-economic drivers of change over time that will alter the nature of exposure, sensitivity and adaptive capacity of our groups of interest. The implications of this complexity and uncertainty were then discussed regarding interactions with a changing climate, the nature of adaptive capacity and how coupled climate-socio-economic dynamics manifest across scales and levels.

This section of the report seeks to ‘close down’ the complex and uncertain elements introduced previously. We highlight areas currently under-researched, the nature of research questions with regard food security and adapting to future climate change, and suggest a research agenda.

4.1. Reviewing sections two and three

Climate change has broadly been understood as changes in mean climate conditions as well as increases in the frequency and severity of EWEs. Looking specifically at the consumer elements of food access and within this economic and physical access, we review the concluding points from sections two and three.

For economic access – potentially an issue for all three vulnerable groups given low or fixed sources of income - the influence of changes in mean conditions to 2020, and even 2050, was thought to be relatively minor given the large range of other factors that contribute to the price of food and the purchasing power of individuals. After 2050 however, and towards the end of this century, the implications of climate change for food production look to be increasingly negative. With regards extreme weather and price, again, markets and other variables act to smooth impacts over longer time scales, however, they can contribute an added momentum to price volatility (such as the Australian drought adding to the 08/09 food price spikes).

Knowledge concerning the response of vulnerable groups to price increases is patchy and particularly limited in relation to price changes (i.e. volatility). Implications for nutritional outcomes, is even less well understood.

Physical access is again an issue for all three vulnerable groups, but in different ways, given that the very old and health deprived may have more issues with respect physical well being, whilst all three groups are more likely to struggle with access to transport systems in different ways. Transport systems are more at risk of increases in extreme weather, whilst physical wellbeing will be affected by changes in mean conditions also. The balance of climate change impacts on health is not clear, with a reduction in excess winter deaths as temperatures increase, but increases in heat-related illness. Whilst considerable research has been undertaken to understand how climate change will affect transport systems and health, much less is known about the knock on effects for access to food and thus it is difficult to draw concrete conclusions here regarding climate induced changes in access. Related to this, there is little understanding of adaptive and coping capacity of our vulnerable groups given changing conditions of physical access.

With regards to whether vulnerable groups live in areas disproportionately affected by climate change, it was concluded that within a general trend of warming summers and wetter winters, areas of the south coast and central southwest, in which a slightly higher concentration of 85+ inhabitants live, may experience more warming than other areas in England. Areas of the south coast, and more discernibly to 2080, are also projected to experience greater rainfall compared with other areas, again affecting the 85+ group. Small pockets of disability and health deprivation as well as income deprivation are also to be found in these areas. These two groups currently also live in high concentrations in areas in and around Liverpool and Newcastle, which look to experience greater winter precipitation compared with the rest of the country, and thus are at higher risk of flooding. However, as we explain, there are a number of issues regarding the utility of these findings and more generally the use of mapping in examining future food access.

Section two highlighted the equal or greater importance of socio-economic dynamics in mediating the impact of climate change over time. However, just as the impacts of climate change for food access will increase in uncertainty towards the end of this Century, so too is there uncertainty regarding the impact of socio-economic factors on vulnerability to food insecurity. Section three explored uncertainty and complexity in drivers of change, re-iterating the many factors that will act to mediate exposure to food insecurity through climate change in the future. Here a range of drivers were explored and three in particular drawn out by the authors, considering them to be particularly important. Demography and settlement patterns (relatively more certain), the relative individualism or collectivism of our values and governance systems (uncertain) and the role of technology in mediating climate change impacts (highly uncertain). It is highlighted that drivers of food access cannot be considered independently but rather the complexity of the interactions between drivers must be understood. Finally we highlighted the need to attend to adaptive and coping capacity. There is importantly also a need to consider the impact of mitigation efforts on these. As such climate change policy is likely to be just as important as climate change itself, particularly in the shorter term.

4.2. Questions for future research

There are a number of questions which the report suggests are in vital need of future research:

- Firstly, the need for a better understanding of how food price changes affect the nutritional outcomes of vulnerable groups and the coping/adaptive behaviours in relation to this.
- Secondly, the knock-on effects of impacts of climate change on health and transport systems for physical access to food, particularly during EWEs, require elaboration.
- Considering the notion that adaptive and coping capacities can mediate the additional burden of climate change, and that the location of future vulnerable groups is complicated, it seems that questions surrounding these adaptive and coping capacities and strategies are more important than examining the highly uncertain geographical differences in exposure to future climate change. Specifically we need to ask questions around the ways in which adaptive and coping capacities can be enhanced at different scales and levels, and the most appropriate models of governance for this (considering the current complexities in food system governance).
- Given the magnitude of emissions reduction targets, one area in great need of research is the potential impacts of mitigation policies upon UK food systems (we know of none of these in the present), with a particular focus on the implications for food security and adaptive and coping capacity.
- Whilst we have examined a number of drivers of food access and the key uncertainties surrounding these, we have not had the resources to robustly examine the relative importance of these. It seems that one final important question (given the suggestion below of a scenarios approach for placing parameters on future changes) is what are the *key* drivers of future food access and what are the *key* uncertainties?

4.3. Moving past complexity and uncertainty

Section three highlights great uncertainty and complexity surrounding future food access but the necessity of ensuring resilient and equitable food systems into the future means we must reduce and (where not reducible) deal with uncertainty, and understand interactions and complexity but not become paralysed to act by these factors. Having outlined above the questions that we feel are most pertinent, we now outline a future research agenda.

4.3.1. Reducing uncertainty and understanding complexity

Many of the complexities with regard to food systems now (and into the future) are a result of interactions between, firstly, climate and socio-economic drivers, and secondly, scales and levels. Cash et al (2006) suggests that failures in accounting for level and scale interactions arise in part from the non-integration of academic, policy and institutional worlds. Greater institutional interplay, co-management of issues and development/use of boundary organisations are proposed to remedy this situation. Research interdisciplinarity is also clearly to be encouraged.

This report has highlighted that little is known about the impact of past events, such as we are increasingly likely to see with climate change - specifically food price shocks, transport system disruptions, and changes to physical wellbeing, on food access for vulnerable groups. We feel that qualitative, case study based, research is the best approach to examine strategies of vulnerable groups in these situations. Additionally research is required to better understand how and why coping strategies are practiced by those currently vulnerable to food insecurity in the UK, as well as instances where adequate strategies are not employed resulting in food insecurity.

4.3.2. Looking to the future in a complex and uncertain world

Whilst we can reduce uncertainties and seek to understand complexities, the future is inherently uncertain to a degree. Yet, it is vital that we attend to future changes, rather than considering the additional impacts of climate in an otherwise static world.

A common tool to dealing with uncertainty is to use a scenario approach that allows for a systematic exploration of alternative socio-economic futures, and how they impact on the question at hand. Not meant to reflect current reality or be predictive, scenarios help in considering the implications of diverse future contexts for achieving food access in the UK. Through this process, interventions - in this case improving food access for households vulnerable to food insecurity - can be explored to ensure robustness in spite of different contexts. While it is more common to have a four storyline approach across a quadrant, additional shock or unexpected events can also be looked into.

The interdisciplinary nature of food access in relation to climate change means input from a range of experts and stakeholders would be necessary. One potential drawback of the scenarios approach is that they can be of such a broad scope that they do not fully interrogate disparities between societal groups, focussing a scenarios exercise particularly on vulnerable groups' food access would ameliorate this.

Further research, as suggested above, to better understand how already vulnerable people, and service providers, cope and adapt with respect to food access under certain circumstances can help inform any scenarios process. We propose qualitative case study based research *coupled with* future scenarios, as these approaches are complimentary - each helping us to think about the other.

Appendix A: Experts consulted through the course of research and areas of expertise

Person	**Project/ Expertise**
Sarah Anderson	Climate Change Programme Manager, Kent County Council. Overlaying UKCP09 and locations of vulnerable groups in Kent.
Xavier Cirera	Institute of Development Studies, Sussex University. Foresight project on the Future of Farming and Food: income inequality and implications for the price of food via changes in demand, globally.
Jane Cony	Sustainability & Climate Change Team, Department of Work and Pensions. Working on a Strategic Evidence Fund project on climate change and vulnerable groups generally with the MET Office. Also generally involved with scoping issues of climate change for the DWP.
Liz Dowler	Department of Sociology, University of Warwick. DEFRA project on Consumer insights into food prices and food security
Karen Lucas	Transport Studies Unit, University of Oxford. Research into transport, accessibility and social exclusion.
Edoardo Masset	Institute of Development Studies, Sussex University. Foresight project on the Future of Farming and Food: income inequality and implications for the price of food via changes in demand, globally.
Wyn Morgan	University of Nottingham. Foresight project on the Future of Farming and Food: Food price volatility and transmission.
Gwilym Price	Professor of Urban Economics, University of Glasgow. Carrying out socio-economic modelling work stream on the CREW (Community Resilience to Extreme Weather) project. Modelling house prices and employment as result of flood risk estimates
Mike Rayner	Director of the British Heart Foundation Health Promotion Research Group. Public health and nutritious food expert
Anna Steynor	Science Officer at UKCIP

Appendix B: Mapping methods

The following elaborates decisions made around which maps were used, what climate variables were considered and information used to map the vulnerable groups.

Emissions scenarios used:
Medium and high emission scenarios are used to inform this mapping exercise. These are based on the IPCC SRES emissions profiles and correspond to A1F1 for high, A1B for medium (and B1 for low, which is not considered here). This is because globally we are currently emitting greenhouse gas emissions at a rate somewhere between these two projections, and are also observing biogeophysical responses consistent with these emissions scenarios (Richardson et al., 2009). Differences in climate outcomes are also relatively similar between emission scenarios to 2050, particularly for temperature. It is only at 2080 that differences begin to become starker.

Climate variables used:
With respect to climate variables of interest, the following are focussed on here:
Change in winter mean precipitation: Given that winters are expected to become wetter, this will help to ascertain areas more at risk of flooding from increased rainfall[42]. Heavy rainfall events can affect access to shops, transport and during floods, even the kitchen.
Change in average summer daily maximum temperature: this is the average of highest day-time temperatures during the summer. It allows for an understanding of how day-time temperatures will change over time which is potentially important for the elderly and health deprived who may have difficulty cooling themselves or experience exacerbation of health problems.

Due to the large number of maps that can be generated, changes in average winter daily minimum temperature, and change in summer daily minimum temperature were not mapped. But these are two further variables that would merit further investigation. The former is of interest given the potential for reduced icy and wintery weather (where T min is <0°C) which can prevent people from leaving their house, the benefits of higher temperatures leading to fewer excess winter deaths and morbidity, and an indication of reduced heating needs which effect purchasing power. The latter, summer daily minimum temperature, is important because sufficient changes in diurnal temperature range are important for cooling amongst the

[42] Flooding is a result of a combination of factors, only one of which is rainfall. UKCP09 maps can show where the risk of flooding increases, but cannot quantify that risk.

elderly (Environment Agency, 2007). Although UKCP09 has the facility to project sea level rise and storm surges we are not investigating this because it is locally dependent on the coastline profile and previous records of storm surges for an area are required to analyse future projections. However, again, this is potentially insightful for future research.

Probabilities explored:
Probabilities of interest here are the 50th and 90th percentile maps. Climate change at the 50% probability level (half way along the cumulative distribution function) is that which is as likely as not to be exceeded. UKCIP refer to the 50% probability level as the central estimate. Alongside this the 90% probability level will also be explored. Although there is only a 10% chance this scenario will be exceeded, it is important to consider given that this output is likely to characterise some of the weather experienced over the given time frame, and for adaptation purposes it is necessary to explore lower risk but higher impact scenarios.

How are we measuring our vulnerable groups?
In order to overlay the locations of the vulnerable groups with climate projections, we need to have an accurate portrayal of where they live. However for most of our groups (with the exception of 85+) it is worth dwelling upon the degree to which the indicators used fully capture membership of these groups. How we measure each group has bearings on where we will show them to be located. For example, generally people define income deprivation by low income on the basis of earnings, however indices of multiple deprivation are more likely to include multiple indicators including 'adults and children in income support households, households in receipt of national asylum support service vouchers'.

For mapping we have chosen to use the following datasets:

- **The oldest old** – Office of National Statistics data on the location of 85+ groups.
- **The income deprived** – Income deprivation domain of the indices of multiple deprivation (English IMD, 2007)
- **The health deprived and disabled** – Health deprivation and disability domain of the indices of multiple deprivation (Ibid)

Scores within these data sets are calculated at the lower super output area, or LSOA (based not on geographical size but upon population: mean 1500 people) so resolutions within cities are higher than within rural areas. Those LSOAs with a concentration of people in our vulnerable groups in the top 20% of all LSOAs have been mapped. This allowed us to overlay areas with a high concentration of vulnerable people with changing climate variables over time.

Appendix C: Review of SRES scenario characteristics

Scenario	Global socio-economic characteristics
A1F1/ High	Fossil energy intensive and very rapid economic growth. Greater convergence in Gross Domestic Product (GDP) globally, population peaking in mid century and then declining, rapid introduction of new and more efficient technologies.
A1B/ Medium	See above, but rather than fossil intensive growth, the energy portfolio is balanced.
A1T	See above, but rather than fossil intensive growth, the energy portfolio is based on clean technologies.
A2	This describes a heterogeneous world, strong on self-reliance and localism economically and culturally. Fertility converges slowly. Technological and economic development is fragmented and slower than other storylines.
B1/ Low	Population assumptions the same as above, however, rapid changes in economic structures towards a service and information economy are assumed, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. Global solutions are found to economic, social and environmental sustainability.
B2	Here solutions to economic, social and environmental problems are local. Population increases, but at a slower rate than A2 with intermediate rates of economic development, diverse and relatively slow technological change. Environmental protection and social equity, with a regional focus, are strong themes.

Appendix D: Socio-economic driver tables

The following tables explore the key trends, uncertainties and outcomes for food access relating to the areas of demography and settlement patterns, the composition and rate of economic growth, the rate and direction of technological change, the nature of governance and social and political values.

Driver: DEMOGRAPHY AND SETTLEMENT PATTERNS				
Key Issues	**Key trends**	**Uncertainties and complexities**	**Impacts on food access (affordability & physical access)**	**Interactions with other drivers**
Population growth	Globally up to 9 billion by 2050. Internally UK population expected to increase.	Whether population trends will remain constant. Effect of global population growth on resource demand (related to balance between globally and locally produced food in UK food basket) and the efficiency with which said resources are used.	More people (nationally and globally) means greater demand on food and fuel resources (to produce food) which may put upward pressure on prices. Higher demand (globally and nationally) for other resources (e.g. energy) could also reduce purchasing power by raising other outgoings and thus impact on food affordability.	**Governance**: Variables will include cooperation among governments (globally) and government resources (UK) committed to food production. **Economic growth**: both globally and nationally. **Social values and technology**: will mediate consumption patterns of populations and thus resource demands.
Ageing	More old people. Fewer younger people.	Whether fertility will remain below replacement and enhance imbalance in ratios between elderly and young people. Whether ageing elders will be healthier for longer or live longer with chronic disease/disability.	People living longer will likely place them at greater risk to problems of physical access and affordability, particularly if they are living with disease or disability. Working longer could mitigate these effects. Low fertility will mean fewer caregivers and workers to fund pensions with potential implications for household purchasing power. However this will be mediated by migration and economic growth.	**Governance**: Level of government services and ability to fund pensions will determine risk level. **Technology**: May assist elders in remaining independent longer. **Economic growth**: will impact upon benefits of retirees.

Migration and immigration	International migration expected to remain constant or increase slightly. UK more multicultural. Rural depopulation. Urbanisation. Growing coastal communities (more at risk from climate change).	Level of external migration. Where internal migration will take place regionally. Extent to which rural-urban migration will continue.	Cultural diversity may lead to changing food preferences. Productivity of the UK's rural economy will affect food prices and will also impact upon income in those communities and thus on purchasing power. Where people live, at what density, and the quality of housing mediates provision of services in relation to food access – e.g. greater need for cars in rural areas, greater utility costs in poor quality housing. Reductions in numbers in rural areas could reduce number of people at distance from food outlets and reductions in services for those remaining.	**Governance**: Heavily dependent upon government immigration policy, rural affairs and planning policy. **Economic growth**: More low income households are found in cities **Social values**: Extent to which urban growth continues. Extent to which social capital in ruralities will buffer impacts of remoteness.
Household structures	More people living alone. More bean pole families.	Whether the trend toward independent living will continue or family households will become more intergenerational. Extent to which different forms of social networks will fill the gaps created by independent living. Impact of changing household structures upon food preferences (continued desires for quick prepared and convenience food). Will people be living in supportive communities?	Potentially vulnerable people living without a support network to aid physical food access (and to loan capital in times of need) could be mitigated by rise in intergenerational households and new forms of social networks.	**Governance**: Growth of intergenerational households may depend on availability of support for sandwich generation. **Technology**: Move into new models of "family" living and new home designs, e.g., "smart" homes. **Social values**: Strong two-way relationship, with trends in household structures, in part, both forming and formed by our values.

Driver: THE COMPOSITION AND RATE OF ECONOMIC GROWTH				
Key Issues	**Key trends**	**Uncertainties and complexities**	**Impacts on food access (affordability & physical access)**	**Interactions with other drivers**
Economic development	**Globally**: Economic growth in transition and rapidly developing countries. **UK**: Economic growth has recently been stalled by the recession, but longer term projections predict a return to growth (DEFRA, 2009a, DECC, 2009).	**Globally**: The strength of economic growth in transition, rapidly developing and developing countries. **UK**: The strength and breadth of economic cycles and how this filters down to affect employment and service investment levels. Levels of income disparity in the UK. GBP value and exchange rates[43].	Economic development affects the nutrition transition, its form, speed and strength. This will help determine demand for food, particularly meat and dairy. High food demand will place upward pressure on food prices, but is clearly mediated by supply. In the UK, unemployment and welfare outcomes increase sensitivity to food prices. Negative economic development will reduce government subsidisation of transport and welfare services and infrastructure, reducing physical access. High levels of income disparity suggest reduced purchasing power of those on a relatively much lower income, reduced access to transport systems and fewer economic resources for adaptation.	**Governance** – the governance of economic development, education, skills, attractiveness for economic investment by companies, transport systems. And food governance that shapes availability of healthy and affordable food. **Technology** – economic growth impacts on R&D.
Economics of natural resource use	For energy: variable prices over time, but assumed increasing price trends in the future. Costs associated with water may also increase.	The price of energy and, related, the development of the biofuels market. The price of carbon.	High energy and ecosystem service prices increase the cost of food, household expenditure and the cost of transport. This would increase exposure to food insecurity in the short term, but may well reduce exposure in the longer term were this to lead to reduced	**Demography**– global population growth and affluence are factors determining the demand for resources. **Technological change** – energy efficiency, ability to exploit energy

[43] Speculation is also a further uncertainty here. However it was not included in the table given the debate surrounding its influence on food prices, for example see Alexandratos (2008), Fattouh (2007).

	Trend towards increased pricing of ecosystem services. Investment required in renewable energy, low-carbon generation & the grid.	The price of ecosystem services.	emissions/resource use globally. This impact is mediated by our reliance on energy/resources, in turn influenced by behaviour and technologies.	sources. **Governance** – biofuels, land-use, grid investment, R&D and technology investment, sustainable exploitation of resources.
Welfare economics	More elderly, fewer working age people to support elderly. Welfare provision increasingly mixed public/private and directed.	The approach to welfare provision given changing political, social and economic circumstances, and the effectiveness of the resulting welfare system to provide for society's needs and correctly identify the most vulnerable.	Indirectly the provision of state-pensions and benefits is affected which determine income for the elderly and benefit recipients, particularly those heavily reliant on this as an income stream. A reduction in income will negatively affect the affordability of food. Lower investment in public transport would also hamper physical access.	**Demographic** – more elderly and fewer working adults affect taxation income for government. **Governance** – The degree to which welfare is prioritised affects welfare economics. **Social and political values** – shape the priorities of welfare spending.

Driver: THE RATE AND DIRECTION OF TECHNOLOGICAL CHANGE				
Key Issues	**Key trends**	**Uncertainties and complexities**	**Impacts on food access (affordability & physical access)**	**Interactions with other drivers**
Technological change in production	Increased use of and reliance on technology in farming (particularly in the areas of biotechnology, nanotechnology, information and communication technology, robotics and pharmaceuticals). Continued agricultural intensification. Increased innovation relating to precision farming (e.g. satellite imaging and wireless communication).	Pace of development of new technologies. Extent to which technologies will be disseminated. Extent to which intensification and technology advances can continue to raise yields. And the feedbacks these processes will have on current/future ecosystems (and thus on yields). Impacts of public perceptions (and levels of opposition) relating to risks involved in the use of certain technologies (particularly GMOs in Europe).	Technological advances have the potential to reduce prices by raising yields. However, other supply chain factors can mediate this. The (negative and positive) impacts on ecosystems may affect price via impacting on yields but again are highly complex and uncertain. Potential impacts on nutritional content in foods (e.g. functional foods) and food safety (e.g. GMOs) – uncertainty in these areas.	Heavily dependent on **governance** (what R&D is being funded and is it being funded publicly or privately). **Social values** at times shape what technologies are deemed safe in food systems (in highly public issues such as GMOs) **Demographics**, in the form of population growth, **in part** drive the need for food and technological change to fuel that.
Technological advances in other stages of the supply chain	Increased integration of technology into and between every stage of the food system, e.g. Radio Frequency Identification (tracking systems), IT advances in distribution systems (e.g. increased use of Just In Time systems).	Pace of development of new technologies. Extent to which technologies can and will be integrated into current systems. Extent to which usage and its benefits will spread. Extent to which increasingly complex and integrated systems can cope in EWEs.	Argued to add convenience and increase efficiency, potentially reducing costs. Creating more complex systems with potentially more points at which problems may occur. Technology may aid or hamper food access at times of stress (e.g. EWEs).	As above.
Internet shopping	Increased use of the internet in shopping.	Extent to which internet access and competency will extend to most vulnerable groups and effect on	Cuts out need for physical access to retail stores, potentially very useful for vulnerable groups with physical access	Dependent on policies and **governance** to roll out internet access into rural areas.

		presence of shops in cities, towns and villages. How this will change into the future. Extent to which new shopping practices can cope in EWEs.	problems. Can reduce costs for retailers which may be passed onto customers.	**Social values** – extent to which face to face interaction, via the trip to the food store, will be deemed important.
Energy	Increased scarcity of energy. Increased technological advances and dependence on technology in areas relating to extraction, energy efficiency, power storage, decentralisation and renewable technologies	Rate at which current (non-renewable) energy reserves are diminishing relative to changes in demand. Rate of development and dissemination of technology advance relating to energy. Impacts of technological changes on other resources (e.g. biofuels on land use and efficiency of resource use). Impact upon energy prices and in turn impact on food prices.	Impacts upon affordability via food costs and purchasing power via other household outgoings. Impacts upon physical access to shops via transport costs.	**Demographics** and **economic development** drive demand for energy (nationally and globally). Heavily dependent upon policies and **governance**. Similarly **social values**.

Drivers: THE NATURE OF GOVERNANCE				
Key Issues	**Key trends**	**Uncertainties and complexities**	**Impacts on food access (affordability & physical access)**	**Interactions w/ other drivers**
Economic gov'nce	Towards globalisation, liberalism, increasing reliance on hybrid and private provision of services.	Continuation of supra-national governance, [semi-] cooperation and markets, or a move to regional/local focus and/or non-cooperation/insularism/bi-lateralism? Relatively more free or regulated markets. The competitiveness of the UK economy and as a place for business investment in the future.	Protectionist trade policies are likely to contribute to price volatility and upward pressure on prices as seen during the food price spikes. Decreases in trade-barriers may reduce prices for some. Low competitiveness will impair economic growth and may in turn affect exchange rates, personal income and physical access through investment in public transport services[44].	**Economic development**: governance helps to shape its development. **Social values**: will shape governance priorities.
Food gov'nce	Multi-level, increasingly market based and individualist. Changing emphasis of Common Agricultural Policy (CAP) towards multi-functionality, increasing role for retailers, private enterprise and 3rd sector, with State providing minimum standards. Increasingly food is being seen as a system in how it is perceived in government and governed.	Ecological public health vs. individualist food policy philosophy (e.g. regarding obesity, uneven access, environmental impact etc)? And strength and willingness of government to intervene. Strength of CAP support and focus - will food security concerns lead to a productivist CAP strategy? Relative supply chain power of food production/provision actors. Will there be an enabling institutional environment for adaptation both globally and nationally?	No/low levels of intervention (in whatever form) and/or limited efficacy: • Fewer food access variables are under government control or remit (e.g. cost of a healthy diet). • Risks uneven provision of food services and increasing evidence of food-based externalities, such as obesity (which feeds back to physical access issues). • Potentially greater choice of foods. • Less regulation and perhaps cost. A productivist CAP system would lead to increases in production and may add to market volatility, and lower prices.	**Economic development**: given that food is increasingly governed through private means, economic development coupled with **social values** can determine food governance priorities. **Social values** generally will help direct emphasis of food governance.
Gov'nce of	Increase in public R&D	Sufficiency of investment and what	Sufficiency of investment indirectly affects the cost	**Technological change**: the

[44] The implications for food access laid out here assumes and are contingent on a continuation of the current political-economic model whereby economic growth is of paramount importance to countries.

R&D	spending since 1997/8 (The Royal Society 2010).Increase in private R&D in real terms, but decrease as proportion of GDP (Lord Sainsbury 2007).	biological and technological innovations arise from this. Ethos, balance and structure of R&D nationally (e.g. public: private sourced funding ratio, role of government etc). Degree of dissemination of innovation.	and variety of food production, transport and processing. May affect physical access through affecting access to transport and levels of physical health. Ethos, balance and structure of R&D affects who does and does not benefit from innovation/ research, with a risk that vulnerable groups are less able to take advantage of outcomes.	nature of emerging technologies influences governance needs and vice-versa. **Economic development**: affects levels of public: private R&D investment, and dissemination globally. **Social values** feed into government ethos.
Climate change and energy governance	Market and fiscal instrument based. A political-economic problem in framing. Towards broad energy portfolio, emphasis on no/ low-carbon technologies, general push towards biofuels use but more cautious of late. Attempts at global climate governance are currently faltering.	The price of carbon and energy in the future and how much this affects food and household fuel bills. Global biofuel governance and how food-fuel trade-offs are treated. The degree to which future climate governance has a distributional emphasis and is focussed on individuals (such as personal carbon allowances).	Increases in the price of carbon and/or energy will put upward pressure on food prices, household outgoings and the cost of transport systems. Within-UK redistributive climate policy would provide an additional income stream for those responsible for emitting fewer greenhouse gas emissions. Land-use for biofuels puts pressure on food production and upward pressure on prices.	**Technological change**: there is a recursive relationship between the cost of technologies, dissemination and climate change & energy governance needs. **Social values**: will determine somewhat the strength and nature of climate change governance.
Welfare governance	Health and education central to welfare provision. Also economic safety-net. Increasingly directed, with mixed public-private provision.	The emphasis, ethos and efficacy of welfare governance. For example a move towards personal rather than public responsibility.	A move towards private provision of welfare support risks being uneven. This would impair income and access to transport systems.	**Social values**: will determine the direction of welfare provision.

Driver: SOCIAL AND POLITICAL VALUES

Key Issues	**Key trends**	**Uncertainties and complexities**	**Impacts on food access (affordability & physical access)**	**Interactions with other drivers**
Individualism	Rights of individual and the present prioritised over collective and the future. Manifesting in: - Desire for healthy eating and low cost food whilst ignoring wider social and future costs of unsustainable food systems - Increase in car ownership - Reducing social capital. At the same time small pockets seeking new forms of collective (e.g. online communities) and addressing new issues (e.g. organic growing).	Future balance between individualism and collective. The nature and extent to which social capital will continue to diminish/change. Extent to which the focus on the individual and their choices distracts from (and gives less moral imperative to helping) those who aren't able to afford healthy food.	Reduced social capital means less support for those that struggle with barriers to food access (be that carrying shopping or short term unofficial loans). Pressure of individualism on lower food costs in the short term has likely led, with the aid of retailer power, to lower food prices (increasing food access) in the present for individuals. Long term food access threatened as future given less priority.	Two-way interaction with policy and **governance**. Values shape governance and are in turn shaped by governance. Individualism has risen with **economic growth** but this is dependent upon nature of **governance**. Drives certain policies and practices that affect **demographics and settlement patterns** (e.g. immigration and household structure).
Ethical consumerism	Increasing attempts by small pockets of society to create socially and environmentally just food systems. Mainstreaming of ethical consumerism (as enters supermarkets).	To what extent ethical consumption will continue to rise and effect change. To what extent can ethical consumerism be brought to all consumers at an affordable price (and thus made equitable). Whether localised food systems and networks of actors can be utilised to tackle problems with physical access (e.g. veg. box schemes).	In the long term, creating sustainable systems to aid future food access. In short term, however, such systems sometimes involve higher direct costs (to the consumer) and can exclude those who are economically challenged. Some systems reduce need for physical access (such as delivered vegetable boxes).	Highly related to **economic development** and education levels. **Governance** is linked with retailers taking an increasingly lead role in shaping ethical consumption. Also the role of governance in creating a supportive and enabling environment for alternatives
Overconsumption	Increased levels of resource consumption and waste.	Extent to which overconsumption and high levels of waste will be	In the long term the health impacts (e.g. obesity) of overconsumption and the	Linked to **governance** and **economic development**.

		reduced.	impact of this on mobility and ability to earn. Long term food access threatened by overconsumption and waste today.	Potential for **demographic changes** (nationally and globally) to put pressure on consumption levels.
Culture surrounding food[45]	Diversification of what we eat (as increasing exposure to other cultures). More eating out. More eating on the go (and less time spent cooking) and more emphasis placed on convenience.	To what extent these trends will continue. To what extent these trends vary across populations. Impacts of convenience food and shopping on healthy diets.	Culture surrounding food affects our food preferences which affect willingness to pay and to travel further for food. Also impact heavily on the types of foods stocked in food stores which in turn impacts on preferences and diets (cyclical).	**Demographic changes** can impact on desires for diversification of diet (by increasing exposure to more cultures). **Settlement patterns** (particularly more people living alone) may increase emphasis on convenience food. **Economic growth and disparity** affect and shape what we can afford to purchase.
Changes in diet preferences	Move towards consumption of more processed foods with higher sugar content. Calls for low cost foods, rise of the discount supermarket. Past increases in meat consumption (now reflected in similar shift in transition nations) Increased interest in healthy and 'safe' foods	How do changes in preferences affect willingness to pay? Will low cost and convenience continue to be valued over quality? Will demand for meat continue to rise or diminish with ethical concerns? How will increased consumption of meat (and the related need for grain feed) in the developing world impact on affordability here? Changes in perceived food risks and the extent to which these vary across groups	As a result of demand, preference changes prices of foods and willingness to pay. Changing patterns of meat consumption may have significant and unknown impacts on food prices. Significant impact on desire for, and thus access to, *healthy* diets	Changing (global and national) preferences related to (global and national) **demographic** and **economic changes**. **Technology** advances and risks involved (e.g. GMO) feed perceived fears about health and safety.

[45] Many of the social values above can be seen to impact heavily on preferences (e.g. desire for convenience, meat, cheap food). Whilst the impact of preferences on food access is likely very significant and is an important area for future research, it is not discussed in detail here, falling into hazy ground outside of food access.

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