Title	**Peri-urban-climate issues and challenges in the Manchester region**
Deliverable	**D4-1b**
Version & Date	**V01.8** **October 2021**
Author(s)	**Jeremy Carter, Joe Ravetz, Mehebub Sahana, Joe Lake Rees,** **with Angela Connelly**

Publication details

Deliverable No.	D4.1b
Work Package	4b
Lead Author(s)	Jeremy Carter (UoM), Joe Ravetz (UoM), Mehebub Sahana (UoM)
Contributor(s)	Joe Lake Rees (UoM), with Angela Connelly (Manchester Metropolitan University)
This version & date	V0.18 : 06/10/2021
Reviewed by (if applicable)	Andy Karvonen (KTH)
Accessed on:	[Project resources (peri-cene.net)](#)

This publication has been produced as part of the Peri-urbanisation and climate-environment interactions (Pericene) project. Pericene is funded by the Natural Environment Research Council (NERC), with the Economic and Social Research Council (ESRC) under the *Towards a Sustainable Earth* programme (2019 – 2021). Other funders include: Formas, a Swedish government research council for sustainable development, and the Department of Biotechnology, India.

NERC is the UK's main agency for funding and managing research, training and knowledge exchange in the environmental sciences. Our work covers the full range of atmospheric, Earth, biological, terrestrial and aquatic science, from the deep oceans to the upper atmosphere and from the poles to the equator. We coordinate some of the world's most exciting research projects, tackling major environmental issues such as climate change, environmental influences on human health, the genetic make-up of life on Earth, and much more. NERC is part of UK Research & Innovation, a non-departmental public body funded by a grant-in-aid from the UK government.

Peri-cene project partners: University of Manchester, UK: KTH Royal Institute of Technology, Stockholm: Indian Institute of Technology, Madras.

Contents

List of tables

List of figures

1 EXECUTIVE SUMMARY

This report provides a 'problem analysis' of the peri-urban areas of the Manchester region, their climate change risk and the adaptation challenges they face.

The following report (D4-2b) explores the potential responses and pathways for strategic action, for climate adaptation in the peri-urban of the Manchester region.

1.1.1 Scope of the Manchester region

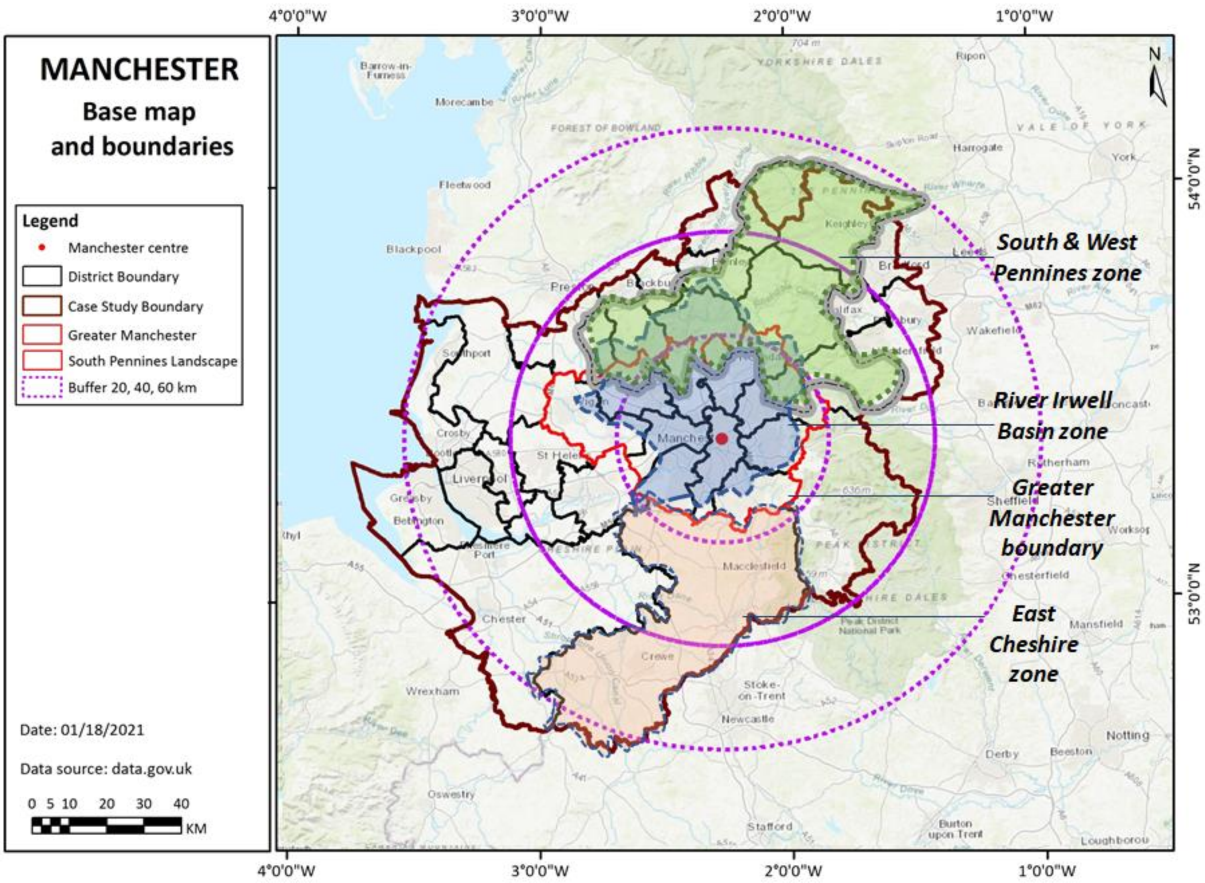
The Manchester region is defined as Greater Manchester (GM) plus its surrounding hinterlands. Our case study zones cover most of this wider region and encompasses:

a) The Irwell river catchment, running from the hills to the north, through the main urban area of GM, to join the Mersey river system towards the south west
b) South and West Pennines (based on Natural England Area 36)
c) Cheshire plain (based on the East Cheshire authority boundary)

The key map (*Figure 1*) shows these three areas of interest. The Irwell river catchment incorporates a cross-section of the region from the Pennine watershed, through the urban fringes and the northern suburbs, through to the urban core of GM. The catchment embraces peri-urban areas and presents peri-urban, rural and urban connections and dynamics.

The South and West Pennines is in a peri-urban gravity field of 3 major conurbations – Manchester, Liverpool and Leeds - and contains various peri-urban types including sparsely populated upland landscapes, steep sided river valleys with settlements along the valley bottoms (which are at risk from flooding), commuter towns and marginal livestock farms. The Cheshire plain represents a contrasting peri-urban landscape, sitting to the south of the GM conurbation, and is an area of (generally) higher income commuter towns and rolling agricultural landscapes.

Figure 1: Manchester Region base map and boundaries



In each case study zone we explore key issues & challenges. For a structure we use the 4 key themes of the Peri-cene framework.

a) Peri-urban development patterns
b) Climate hazards and impacts
c) Social, economic and ecological vulnerabilities
d) Governance and policy

1.1.2 *Where is the Manchester region peri-urban?*

The Peri-cene has used global mapping systems and local consultations to address the question – where is the peri-urban? This is especially complex in a conurbation such as the Manchester region, with its many satellite towns, extended suburbs, urban greenspaces and river-valleys, post-industrial semi-rural hinterland, upland peat bogs and so on.

Overall, a very simple definition of peri-urban in this crowded region, as on the map at Figure 2, includes:

- all locations not in the grey urban areas, but inside the 60km radius:
- yellow and green squares (i.e. between 50-300 persons/km^2) outside the 60km radius.

A more detailed framework for different peri-urban types is shown in Figure 2, which refers to the mapping of FUAs ('functional urban areas': (each case study zone has more detail in Sections 6 & 7):

a) 'Urban edge': suburban / extended settlements / within a 'functional urban area': (*e.g. various lower density suburban areas,*

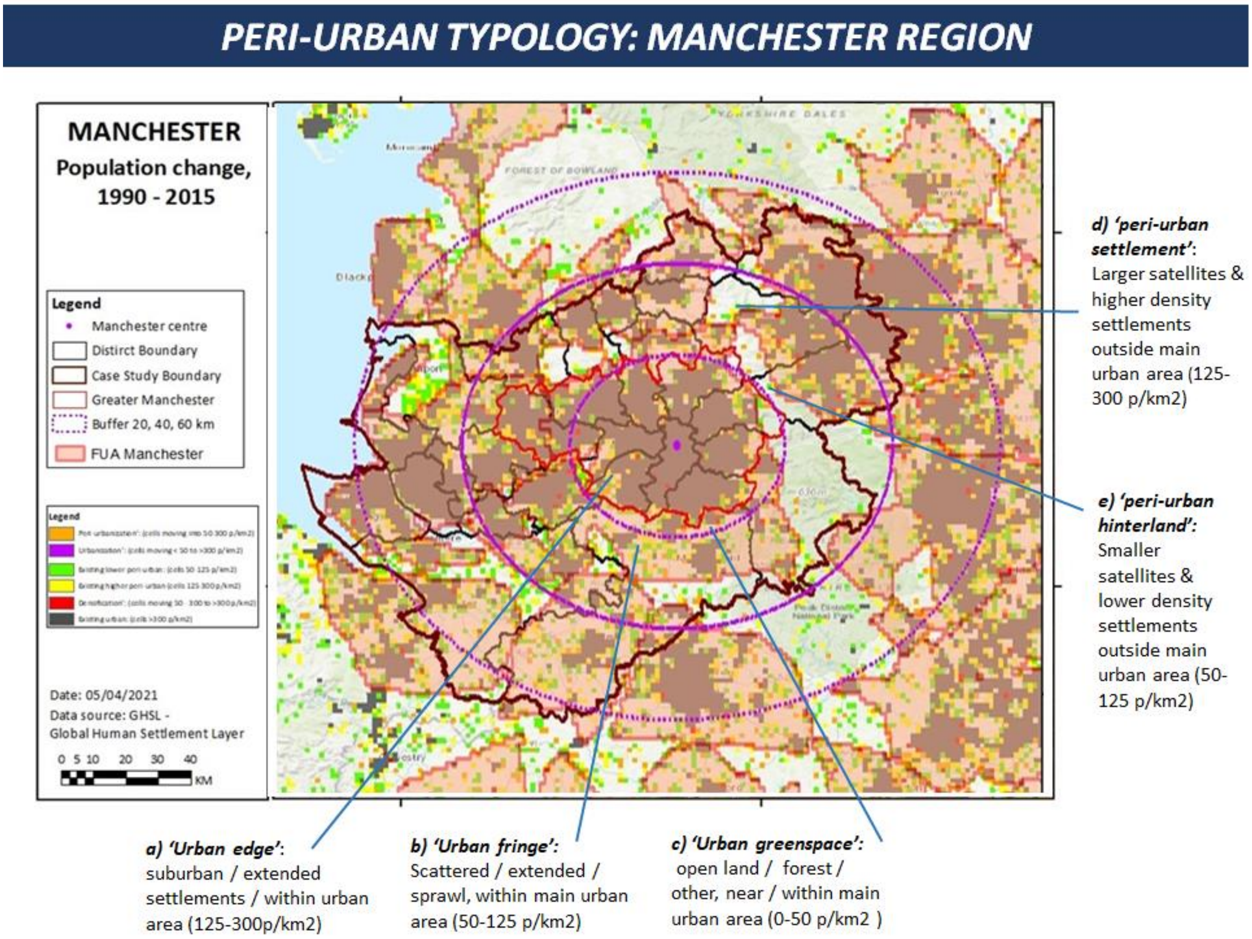
b) 'Urban fringe': Scattered / extended / sprawl, within a 'functional urban area': (*e.g. scattered villages on outskirts of Oldham & Rochdale: or the extended ex-urbs of Stockport / East Cheshire.*

c) 'Urban greenspace': open land / forest / other, near / within a 'functional urban area': (*e.g. Mersey Valley, many other river valleys & country parks.*

d) 'peri-urban settlement': larger satellites & higher density settlements outside main urban area (125-300 p/km2); (*e.g. post-industrial settlements in the Pennines: smaller towns in Cheshire etc*

e) 'peri-urban hinterland': Smaller satellites & lower density settlements outside main urban area (50-125 p/km2): (*e.g. post-industrial scattered villages in the Pennines: smaller villages in Cheshire etc.*

Figure 2: Manchester Region peri-urban typology



The vital statistics are summed up in Table 4 (calculated for the whole 200 x 200km square, as shown in our global map format).

- Open land & peri-rural (<50 p/km²) accounts for nearly half the land area, but just over 1% of the population, however this population has grown by 16% since 1990.
- Lower density peri-urban (<125) covers 15% of land area with 1.6% of the population, with a growth of 13% since 1990.
- Higher density peri-urban (<300) covers 9% of land area with 2.4% of population, with overall zero growth
- By comparison, the urban / suburban areas (>300 p/km²) cover a third of the highly urbanized northern England: they contain 95% of the population with a moderate overall growth of 9% over the period.

The overall picture is of higher population growth in the lower density peri-urban, along with moderate growth in the urban areas.

1.1.3 What are the main climate risks in the Manchester region?

Future projections here assume a relatively mainstream 'worst case' scenario, (based on RCP 8.5), which follows the current trend pointing towards a 3-4 degree average temperature rise. These are the headlines from the UKCP18 for the 2070s (for locations typical of central England):

- summer precipitation change: between **57% drier** and 3% wetter
- winter precipitation change: between 2% drier and **33% wetter**
- summer temperature change: up to **5.8°C warmer**
- winter temperature change: up to **4.2°C warmer**

While these averages are very significant, UKCP18 highlights that the greater risks are from extreme events:

- Return periods for extreme rainfall events (>30 mm/hr) is currently one in 10 years, by 2080 this decreases to one in 5 years, under a 4 °C scenario.
- By 2080 the frequency of days exceeding 40 °C will be similar to days exceeding 32 °C today, under a 4 °C scenario.

These changes in rainfall and precipitation, coupled with sea level rise, will generate risks to all sectors of society and the economy, particularly critical infrastructure networks and vulnerable individuals and communities. Biodiversity and ecosystems will also face significant pressures as the climate changes. The UK Climate Change Risk Assessments (published in 2012 and 2017) provide insights into the nature and severity of these risks.

1.1.4 What are the effects of climate change on the peri-urban?

The next question is - why is the peri-urban so important for climate change, and how do we track this, given the uncertainties of climate projections, and the complexities of the mapping shown above. There are two kinds of answer for this: the first is about the local conditions in the peri-urban, and the second sees the peri-urban as part of a whole city-region system.

For the first, the local conditions in the Manchester peri-urban, many such areas are at high climate change risk:

- Fluvial & surface flooding, particularly in the river valleys where former industrial towns and infrastructure were sited.
- Drought periods, with effects on ecosystems, landscape types and local farming. Upland sheep farms are vulnerable to drought, as are the intensive arable areas of Cheshire.
- Wildfires with impacts on human & ecosystems. Peri-urban wildfires in the Pennines scrub land and peat bogs have increased, and in some cases cast smoke across the entire conurbation.
- Extreme heat, which affects vulnerable social groups, in particular the elderly and outdoor workers.
- In the coastal & estuary peri-urban areas of Lancashire and Merseyside (on the edge of our case study), sea level rise, coastal erosion and saline incursion is a growing problem.

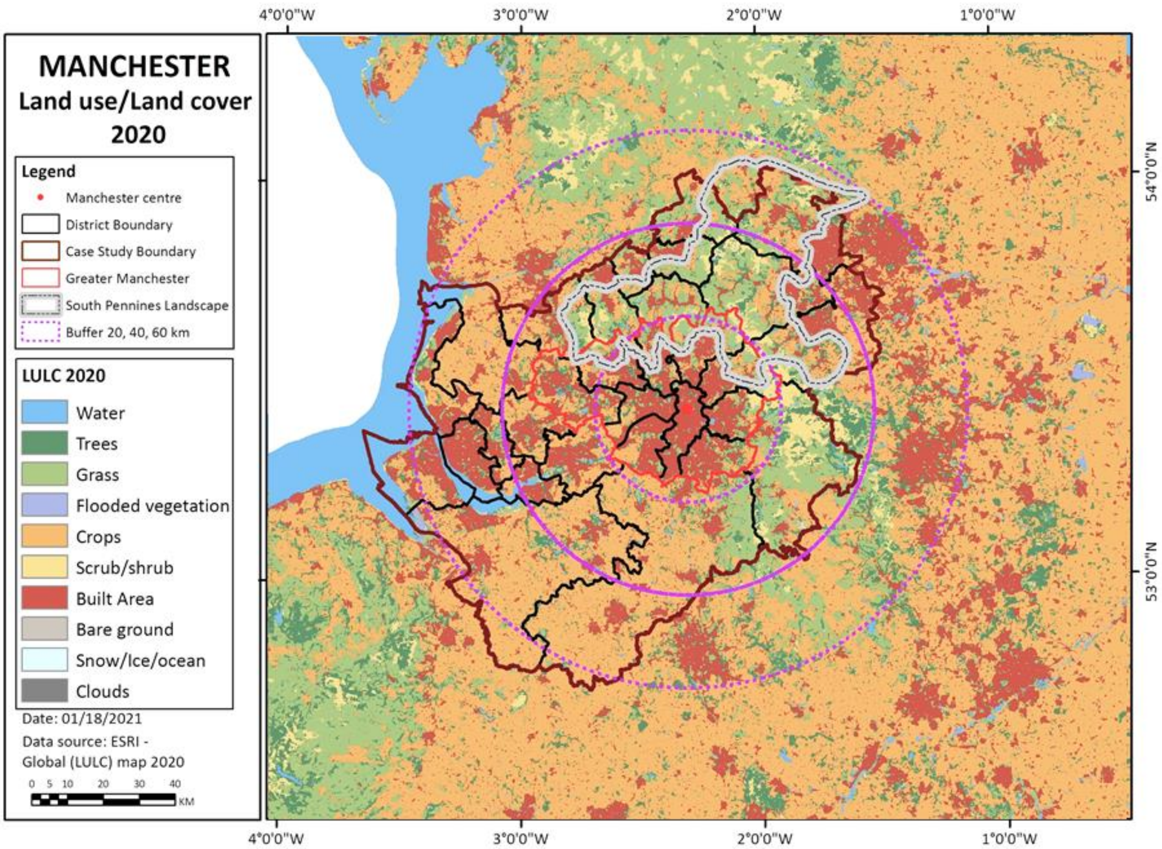
For the second, the MCR peri-urban is also highly inter-connected to the urban and rural areas, as part of an extended city-region:

- Water management in the peri-urban has a direct effect on the flood risk and exposure of downstream urban areas.
- Landscape management in the peri-urban has an indirect effect on water: e.g. where upland land-use and ownership creates problems of storage & run-off.
- Farming practices in the peri-urban create further problems of run-off, chemical pollution, soil erosion, clearance of natural areas etc.
- Housing development in the peri-urban is a direct effect of urban pressure, including urban heat island, and urban natural capital / biodiversity gaps.

Some of these key issues show up on the land-use/cover map (Figure 3):

- Scrub areas – risk of wildfire and loss of peat bog
- Grass & forest areas – risk of drought, soil erosion, ecosystems change, biodiversity loss
- Crop areas – risk of flooding, drought, disruption of agro-ecology systems
- Built area proximity – risk of disruption of ecosystems, water systems

Figure 3: Land-use / land cover map

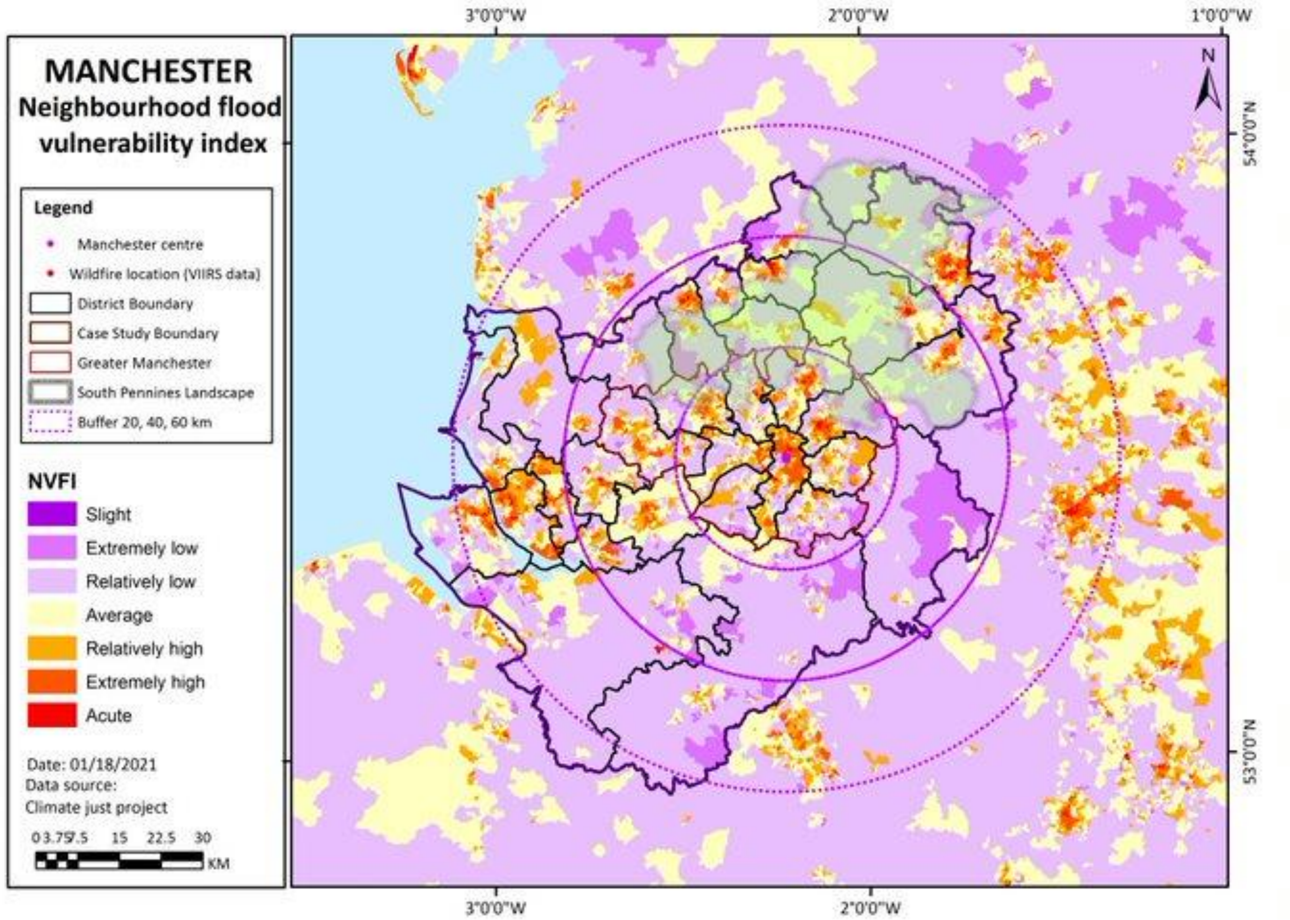


1.1.5 *What are the social / economic vulnerabilities in the Manchester peri-urban?*

There is a tendency for the most vulnerable social groups to be at most risk of flooding, impacted by poverty, dependency, poor health and poor housing conditions. Some groups (elderly, outdoor workers) are also vulnerable to extreme heat. While many vulnerable groups are in the inner cities, there are pockets and patterns across the peri-urban areas, and this may increase with the current trends of out-migration and counter-urbanization.

The spatial distribution is shown in Figure 4, as the 'neighbourhood flood vulnerability index', from the Climate-just project (www.Climatejust.org.uk). This is a composite of indicators including (for both locations and/or social groups): age structure, population health, care / disability, built-up density, dwelling form, employment, dependency, income, rental / ownership, social mix / change, household structure, transport access.

Figure 4: Neighbourhood flood vulnerability index



The broad distribution across the region, as in Figure 4 , shows in general the highest vulnerability for low income groups in urban areas. For the peri-urban the picture is quite mixed:

- For the Pennine zone to the north, there are localized areas of poverty, many in the post-industrial towns in narrow river valleys with much higher flood risk than average for the region;
- For the Irwell river catchment, the headwaters come from more affluent peri-rural areas, with flood risk accruing to the low-income groups in urban areas with high vulnerability.
- For the Cheshire zone to the south, a mainly affluent peri-rural hinterland conceals pockets of poverty in smaller towns and villages, only some of which show on this map.

1.1.6 What is the role of governance in the Manchester region peri-urban?

Overall these diverse peri-urban areas are both generators of climate risks (particularly fluvial flooding) but also providers of climate change adaptation functions (for example related to natural flood management and biodiversity conservation).

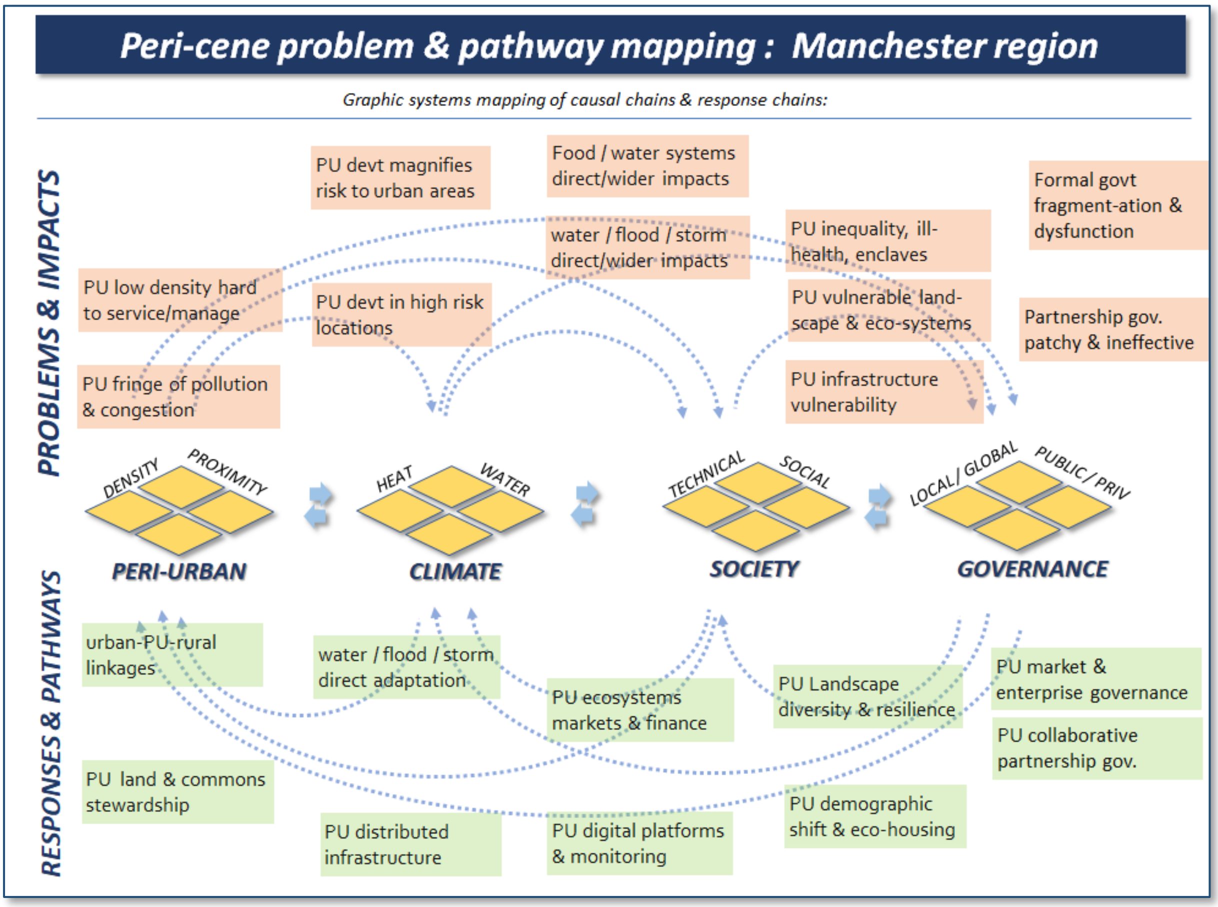
To address these issues, appropriate governance frameworks are needed, encompassing the wide range of sectors and stakeholder groups that have an interest in the future of these areas. Current governance frameworks are fragmented, spatially and sectorally, although emerging good practices do exist. Some examples include (see the Annex for a full listing of water governance institutions in GM):

- Mainly informal partnerships which exist with a mandate and role within larger institutional arrangements: e.g. River Catchment Partnerships;
- Independent third sector formal organizations which play an active role in informal partnerships (e.g. Wildlife Trusts);
- Formal governance partnerships which bring together different levels and units of government: e.g. local authority-based Technical Flood Risk Officers Group
- New formal organizations, in the form of public-private-civic partnerships, which aim at trans-boundary integrated planning: e.g. Pennine Prospects / South Pennine Trust.

1.1.7 How do the many causes and effects connect?

There are many simple cause-effect links in the above: for instance, land management in the uplands may lead directly to soil erosion, run-off and flood risk downstream. There are also other more strategic issues in the background, such as the structure of land ownership, or the funding of local government. The integrated mapping in Figure 5, shows in a very simple form, some of the key cause-effect chains, from peri-urbanization to climate, vulnerability and governance. It also points to some of the potential forward pathways to resolve such inter-connected problems (to be explored in the following report D4-2b). (Details as in the Methods section).

Figure 5: synergistic problem & pathway mapping: Manchester region



1.1.8 *What are the key issues, problems and potential pathways*

For the central case study of the ***River Irwell catchment***, the key focus is fluvial flooding (from rivers and streams), and the use of natural flood management (NFM) responses. Flooding and flood risk management, concerning current flood hazards and also in the context of projected climate change induced increases in flood risk, are key concerns in the Irwell catchment given the risks posed to communities, livelihoods and critical infrastructure. Indeed, recent flood events associated with Storm Eva (in December 2015) have further focused attention on this risk. This theme also raises topical questions on water governance, linked to mismatches between administrative and biophysical boundaries for example.

The potential for natural flood management measures (NFM) to sit as one of the different elements of a broader flood risk management response in the Irwell has risen up the agenda. NFM encompasses measures that aim to, "…protect, restore and emulate the natural functions of catchments, floodplains, rivers and the coast" (Environment Agency 2018: iv). This can involve a range of interventions: from those that help to hold water in upland landscapes (which are a key element of the geography of the northern and eastern areas of the Irwell catchment), to tree planting in river valleys to slow the passage of rainwater into watercourses. These issues are explored, from a spatial perspective, within this deliverable. Working to conserve and enhance the flood risk management functionality of landscapes in the peri-urban uplands of the Irwell catchment can contribute to reducing flood risk in downstream urban areas, whilst also delivering benefits locally. However this raises significant governance challenges that remain unaddressed.

For the ***South & West Pennines***, there are multiple challenges to be balanced: upland peat bogs with carbon stores subject to drought and wildfire: upland and marginal farming post Brexit: fluvial flooding in narrow valleys with critical infrastructure: pressures of local housing, visitor economies, and the many linkages with the large urban areas downstream.

For ***Cheshire***, while in a different watershed, this acts as a 'commuter-shed' for the central conurbation, with likely (post-Covid) growth in outward migration. Under a changing climate and rapidly increasing flood and drought risk, there will be tricky balances between peri-urban pressures, farming systems, local ecosystems.

The follow-on deliverable, D4.2b, builds on the problem analysis outlined within this report, and considers potential adaptive pathways and governance responses that address these challenges.

2 INTRODUCTION

2.1 Report Scope

The Peri-cene project is creating the first ever global assessment of the peri-urban and its climate change risks and adaptation challenges. From mapping of inter-connected problems, it then explores forward 'adaptive pathways', in a Policy Lab with 18 city-regions from around the world, together with two in-depth case studies in India and the UK: Chennai and the Manchester region.

Each has a very different history, development dynamics, socio-economic trends and climate risks. The in-depth findings from Manchester and Chennai will be compared to the analysis of the other 18 cities in the Policy Lab, first via mapping and spatial analysis, and then by design of adaptive pathways. Overall, the Peri-cene project aims to:

- ❖ Provide a state of the art analysis of climate impacts and vulnerabilities in the peri-urban / rural areas.
- ❖ Provide models for adaptive / collaborative governance for climate / peri urban interactions, by facilitating stakeholder dialogue & co-design.

The Manchester region case study focuses on two main objectives:

- To explore peri-urban climate risks and adaptation responses in the Manchester region (D4.1 focuses on this objective).
- To explore adaptive pathways and governance approaches to reduce climate risks in peri-urban areas and connected urban areas (D4.2 focuses on this objective).

The Manchester region case study approaches these objectives from two perspectives, each of which concentrates on different geographical areas, aspects of climate change risk and response approaches.

a) The Irwell river catchment, running from the hills to the north, through the main urban area of GM, to join the Mersey river system towards the south west. Particular attention is paid to fluvial flooding and natural flood management (NFM) problems, responses and governance.
b) South and West Pennines (based on Natural England Area 36): a broad scale review of problems and pathways in a unique landscape of uplands and post industrial valleys
c) Cheshire plain (based on the East Cheshire authority boundary): a broad scale review of problems and pathways in a rolling agricultural landscape and 'commuter-shed' of the conurbation.

This current deliverable (D4.1b) concentrates on a 'problem analysis' of the Manchester Region, which provides the background to the case study. This then sets the context for the related deliverable that explores adaptive governance and pathways focused on addressing peri-urban climate risks (D4.2b).

Generally the Peri-cene project has to work with a complex set of causes, effects and responses, in a wide variety of locations around the world. Peri-urban development, climate risk, and adaptive governance and pathways, are complex and often controversial. This Manchester region case study cannot therefore aim to describe all possible interactions between peri-urban land use and development and climate risk and adaptation, in a large and complex region. It can, however, aim to demonstrate practical and illustrative ways of working with complex information, and creative ways of exploring adaptive governance approaches and pathways for the future.

2.2 Report Structure

This report is structured according to the following chapters:

4. *The Manchester region:* the Manchester region, and insights and data linked to historic and current development and landscape patterns, are outlined in this chapter. This provides a platform for understanding the Manchester region and its peri-urban areas.

5. *Climate risks & impacts in the Manchester region:* this chapter provides an overview of current and projected future weather and climate risks, and identifies fluvial flood risk (from rivers and streams) as the most significant climate change hazard facing the Manchester region. It also highlights hazards that are currently relatively rare, including droughts and heat waves, which may become more frequent over the coming decades.

6. *Climate risk and adaptation in the peri-urban :* we then look more closely at the interactions between peri-urban, climate change risk and climate change adaptation agendas. We review in outline three major zones of this wider region: the south and west Pennines, the Irwell catchment, and the Cheshire plain to the south.

7. *Fluvial flood risk and natural flood management opportunities in the Irwell catchment:* a key focus of this report is on exploring a spatial perspective of fluvial flood risk in the Irwell catchment. NFM ('natural flood management') is also introduced, and locations offering the potential to implement NFM measures are explored.

8. *The wider region hinterlands - Pennine and Cheshire Landscapes:* In this section we explore the wider region hinterland through two contrasting case study areas, the South and West Pennines and the Cheshire plain, highlighting key themes linked to their peri-urban landscapes and associated climate change risk and adaptation themes.

9. *Conclusions:* this chapter brings together the key issues raised by this research, and points towards the related deliverable (D4.2b). This takes forward the 'problem analysis' outlined here with an outline of adaptive governance and pathways for reducing climate change risk in the peri-urban areas of the Manchester region, and also enhancing the adaptation 'functions' they can provide to neighbouring urban areas.

10. *Annexes:* include a summary of existing governance, review of relevant projects and resources on climate change risk and adaptation in GM, the '20-questions' template for the 3 zones of the wider regions and a list of references.

2.3 Report methodology

The overall approach here is based on the combined Peri-cene framework, with two main levels or 'models' of analysis (see D1-2 for details):

- The '***Cause-effect Model'*** follows a mainly functional frame of cause and effect, in direct problems and functional 'problem-fixing' type responses:
- The ***'Synergistic Model'*** addresses wider systems, with deeper layers of value (social, economic, cultural etc) and potential for transformation, with strategic level problems and responses.

Each Model has a role and purpose. The *Causal Model* is a practical place to start to gather data and explore the tangible peri-urban-climate-environment interactions. The *Synergistic Model* is actually more realistic for real-world problems (with deeper layers of complexity), but more challenging for research and knowledge management, and more suited to creative dialogue and co-design.

The Peri-cene 'cause-effect' model contains four main themes (based on the IPCC 5th Assessment Report (AR5), as in Connelly et al 2018):

- peri-urban development and urban / regional spatial systems
- climate change physical hazards and risks
- climate vulnerability and sensitivity
- governance and adaptive capacity

The causal model builds on the IPCC AR5 (IPCC 2014) climate risk framework, which considers climate risk to be a function of (climate) hazard, exposure to that hazard, and vulnerability to that hazard. Vulnerability is further divided into two components: sensitivity and adaptive capacity. The IPCC definitions are provided (Table 1). The climate risk framework, which specifically separates out exposure to extreme weather and climate change hazards such as flooding and high temperatures, has been demonstrated to be particularly useful in terms of spatial planning and adaptation pathways to increase resilience (Connelly et al. 2018). The Manchester region case study is guided by this approach.

Table 1: Climate risk definitions (Source: IPCC 2014).

Term	Definition
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.
Hazard	The potential occurrence of a natural or human-induced physical event or trend, or physical impact, that may cause loss of life, injury, or other health impacts, as

	well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources.
Exposure	The presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
Sensitivity	The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct … or indirect.
Adaptive Capacity	The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

The Peri-cene Framework is structured around the '20-question' template, which inform interviews, modelling and mapping undertaken within the project.

- Each of the 4 themes in the Causal model (peri-urban, climate, vulnerability, governance) has 4 questions each, making up questions 1-16 in the template.
- The Synergistic Pathway Toolkit model provides questions 17-20, with the results of the 4-part process (baselines, scenarios, synergies, strategies).

The '20-questions' template is used to summarize each of the three zones in this study (see 9.3) This 20-question format cannot fully describe the longer story and detailed analysis of each zone in each city-region. But it does aim to help with summarising and comparing, between zones and between locations around the world.

2.3.1 Application to Natural Flood Management

This report also contains a detailed exploration of issues linked to flood risk and NFM response in the Irwell catchment. It is recognised that NFM is part of a wider suite of flood risk management responses, including structural flood defences, which work collectively to reduce flood risk to people, businesses and infrastructure. This element of the case study responds directly to the Peri-cene agenda, focusing on climate change risk and adaptation themes (flooding and NFM) of particular relevance to peri-urban locations. This detailed investigation enables insights to be developed that complement broader generic analyses undertaken within the project.

Barriers and limitations to NFM, including those linked to funding, siting, governance and maintenance, are explored in D4.2b. Related research questions and methodologies guiding the Irwell catchment study are outlined below (Table 2), which entail a spatial analysis of flood risk and NFM opportunities review and critical evaluation of existing NFM governance. Specifically, this element of the Manchester region case study draws on spatial analysis of themes including built environment extent, flood risk zones and areas of opportunity for implementing NFM measures. It is also informed by a review of national and regional policy related to NFM, and a review of academic literature on NFM and NFM governance.

Further, interviews with and workshops engaging national, regional and local stakeholders explore NFM governance issues from a broad perspective, and in and around the Irwell catchment. The interviews and workshops also enquire into the potential of different approaches for delivering more effective NFM outcomes in integrated peri-urban and urban river catchments settings. The interviews inform the development of adaptive pathways, and the consideration of adaptive governance approaches, linked to expanding NFM across the Irwell catchment (which forms a key focus of D4.2b).

Table 2: Research questions guiding the Irwell catchment element of the Manchester region case study.

Research question	**Research methods**	**Goal**	**Deliverable link**
Which areas of the Irwell catchment are exposed to fluvial flooding, and which locations offer the opportunity to utilise landscapes to deliver NFM functions?	Spatial analysis	Develop a spatial understanding of fluvial flooding problems and NFM opportunity areas within the Irwell catchment. Consider these issues from the perspective of urban, peri-urban and rural areas.	D4.1b
What is the current state of theory and practice concerning NFM and the governance of NFM measures?	Literature review, policy review, interviews	Gain an understanding of NFM, and NFM governance approaches, being developed in theory and applied in practice. Identify key policy driving forward NFM. Identify potential governance options for implementation within the Irwell catchment (and other locations progressing this agenda).	D4.1b, D4.2b
What approaches and structures are currently used to govern flood risk management and NFM in the Irwell catchment?	Interviews	Establish how NFM is currently governed in the Irwell catchment, including reference to specific NFM case studies.	D4.2b
What are the opportunities and constraints associated with different governance approaches for delivering NFM measures in the Irwell catchment?	Literature review, interviews, workshops	The aim is to This element of the study draws on a review and critical evaluation of existing NFM approaches to consider different governance options, in the context of existing approaches and specific challenges and opportunities, for enhancing NFM. Transferable learning for other locations will also be highlighted.	D4.2b
What are the main types of 'adaptive pathways' which can be recommended?	Interviews, workshops	Establish adaptive pathways that could be followed to support the enhancement of NFM in the Irwell catchment over the coming years.	D4.2b

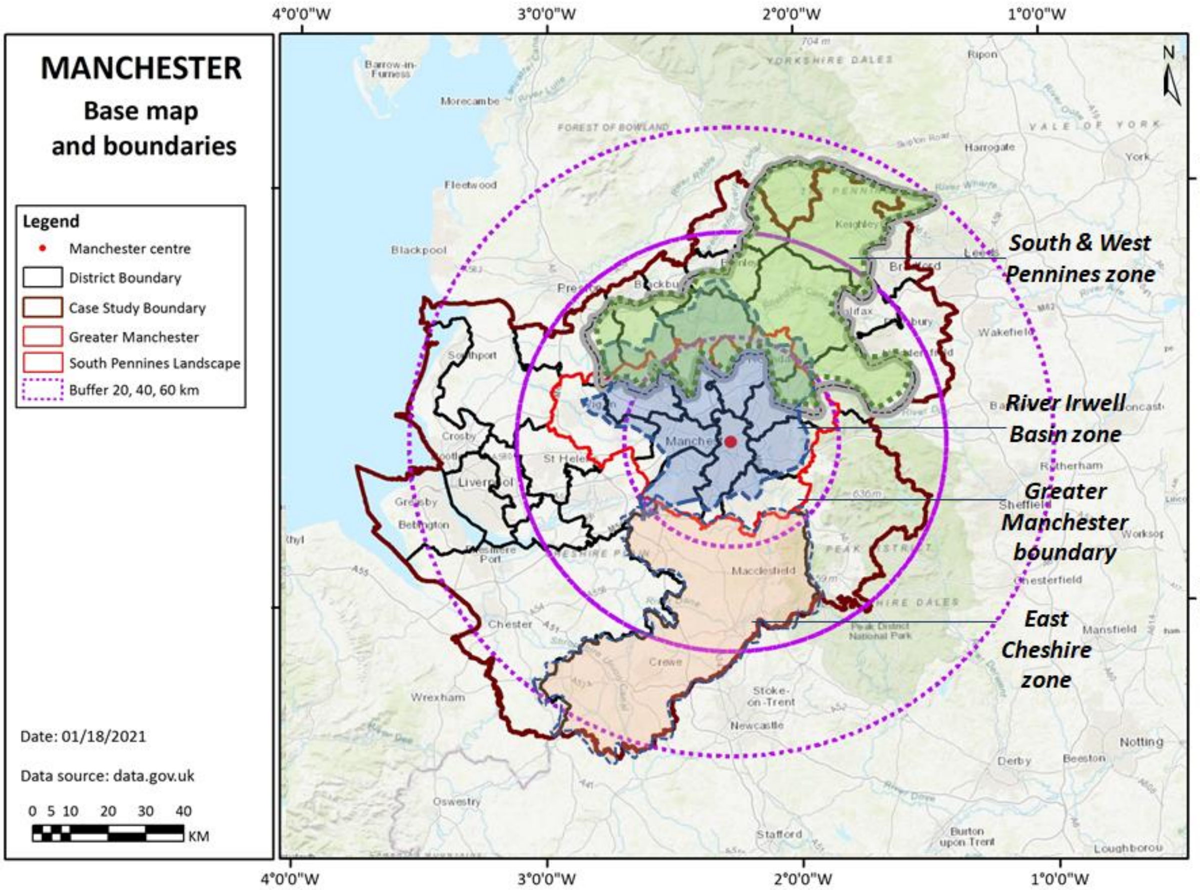
3 The Manchester region

The Manchester region here is framed as Greater Manchester (GM) together with its hinterland of adjacent local authorities. Greater Manchester is a conurbation of over 2.7 million people located in the industrial heart of the North West region of England. It grew rapidly as the world centre of the textile industry, and now has a diverse economy generating over £30 billion GDP, with the UK's largest regional cluster of finance, law, media, creative industries and higher education outside of London. It also contains some of the country's worst unemployment, pollution, crime, social deprivation and unfit housing. GM is split into 10 autonomous Districts (municipalities). The Districts include the Cities of Manchester and Salford, which house some of the worst poverty and deprivation in the country, alongside pockets of wealth and privilege. The key map (Figure 6) shows the wider region in its context, and highlights three overlapping areas of interest.

- South and West Pennines (Natural England landscape area #36)
- River Irwell catchment covering parts of Greater Manchester and adjacent areas to the north
- Cheshire plain, (defined as Cheshire East) representing the commuter belt and peri-rural areas to the south and west of GM.

For illustrative purposes, circles marking a 20, 40, 60km radius from the metropolitan centre are included in Figure 6. This shows the Manchester region areas of interest along a gradient from the Pennine uplands, through the urban fringes and the city centre of Manchester to the southern suburbs and into the open farmland and villages of Cheshire.

Figure 6: Manchester region overview.



At GM's core, the city of Manchester was one of the world's first industrial and global trading cities. Its population grew rapidly from 1750-1900, and then declined after 1950 due to industrial restructuring. Since 1990 the population has begun to return to the city centre and urban regeneration areas. The outer suburbs around the main urban centres were developed mainly from 1920-1980 with lower densities. Some of these are very wealthy, particularly to the south of Manchester city centre, while others are 'peripheral' public housing estates with high levels of deprivation and exclusion.

In its wider region, GM is surrounded to the north and east by hills, the Pennines, and to the south and west by farmland and mixed metropolitan peri-urban areas. The location is at a national crossroads, halfway between Scotland and London, and is well served by motorway and rail networks. In the wider peri-urban area, there is a complex family of satellites – larger towns, smaller towns, new commuting settlements, peripheral public housing, and scattered settlements. In the upland landscapes of the South Pennines around GM's northern and eastern hinterlands, livestock farming has been in decline. Former industrial pollution that degraded upland peat landscapes has been cleaned up to an extent, with peatland restoration projects ongoing linked to themes including improving water quality, reducing flood risk and enhancing biodiversity. In the Mersey Belt area between Manchester and Liverpool, there are post-industrial landscapes impacted by urban infrastructure and commercial development. To the south, in the fertile lowland farming areas of Cheshire, many settlements are dominated by wealthy commuters.

3.1 Where is the Manchester region peri-urban?

The first question is - where is the peri-urban in the Manchester region? This question is not so simple, in a conurbation such as the Manchester region, with its many satellite towns, extended suburbs, urban greenspaces and river-valleys, post-industrial semi-rural areas, and so on. We can list multiple layers of the peri-urban, in a combined 'socio-ecological region':

- Residential density – with peri-urban somewhere between urban and rural
- Proximity to the metropolitan economic zone – again, between urban and rural
- Physical bio-region: water catchments, topography, food zones, climate types;
- Economic region: commuting, labour market, housing market;
- Social region: other layers of local identity, migration, culture etc;

For a simple definition, the Peri-cene typology (Table 3) provides a summary of a complex picture, based on two main factors:

- Residential population density: the peri-urban is defined as between 50-125 and 125-300 persons/km², as defined by the GHSL system (Pesaresi et al 2019)
- The FUA ('Functional Urban Area'), i.e. zones of clustered economic activity, from a global classification (OECD 2020)

Table 3: Peri-urban types in the Manchester wider region.

PROXIMITY	*Within the FUA*	*Outside the FUA*
DENSITY p/km²		
125-300	***a) 'Urban edge'***: suburban / extended settlements / within urban area (*e.g. areas of Bury & Radcliffe within the river Irwell valley;*	***d) 'peri-urban settlement'***: Larger satellites, higher density sprawl / ex-urbs. (*e.g. further towns in the upstream Irwell river catchment;*
50-125	***b) 'Urban fringe':*** Scattered / extended / sprawl near / within urban area: (*e.g. smaller settlements or scattered suburbs in the catchment of the Irwell valley;*	***e) 'peri-urban spread':*** Smaller satellites & further / lower density sprawl / ex-urbs. (*e.g. smaller scattered settlements in the west Pennines and Irwell river catchment.*
0-50	***c) 'Urban greenspace':*** open land / forest / other, near / within main urban area: (*e.g. Salford Mosslands, Lower Irwell Valley;*	-

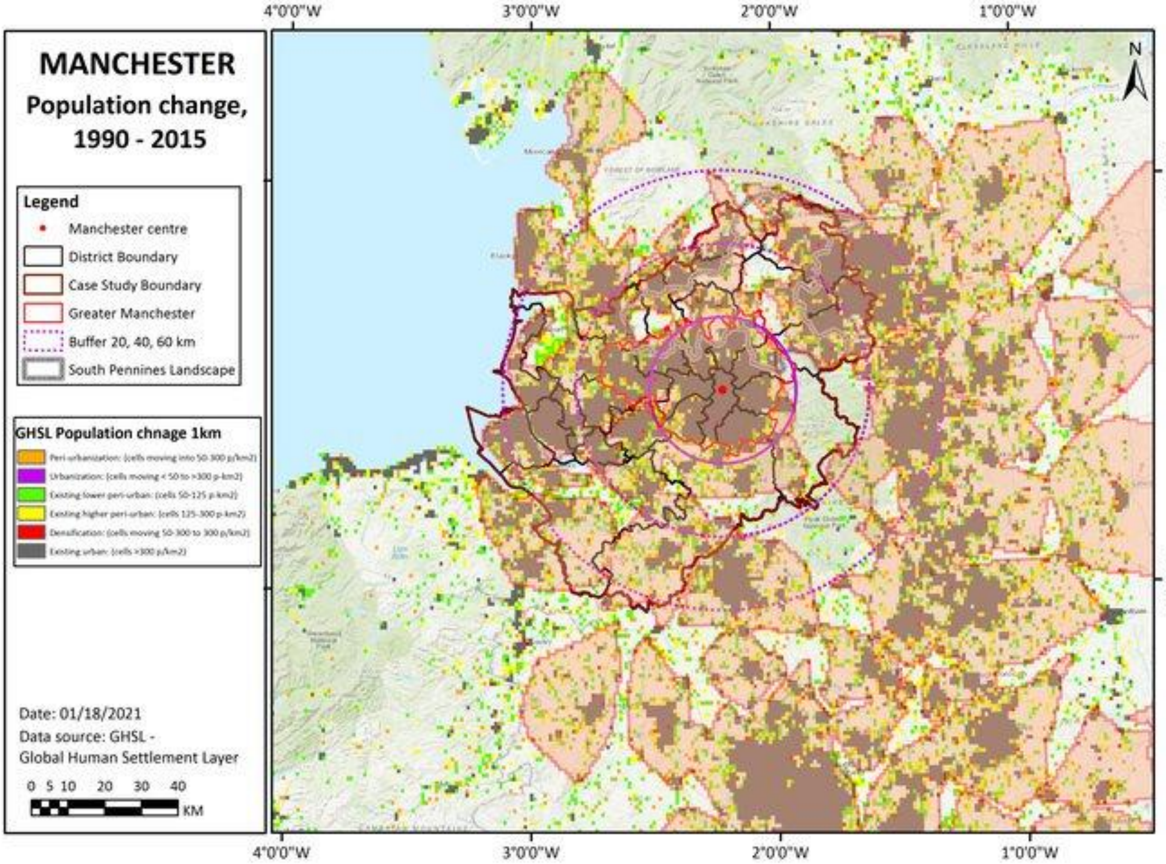
The peri-urban typology map in Figure 7 is based on a global system 'GHSL', which charts all land and urban areas on a 1km square grid.

- Orange shaded areas show the 'functional urban areas', defined by the OECD as areas of most concentrated urban / economic activity.
- Yellow squares show the higher peri-urban densities of 125-300 p/km2
- Green squares show the lower peri-urban densities of 50-125 p/km2
- Orange red and purple squares show changes from 1990-2015 (see the legend on the left)
- The circles of 20, 40, and 60km show a very rough travel time radius of up to 1 hour (from the centre of Manchester)

Overall, a very simple definition of peri-urban in this crowded region, would be -

- all locations not in the grey urban areas, but inside the 60km radius:
- yellow and green squares of between 50-300 p/km2, outside the 60km radius on the map.

Figure 7: Peri-urban typology for the Manchester region.



3.1.1 Where is the peri-urban growth and change?

The polycentric urban agglomeration of the Manchester and Liverpool city regions contains many settlement types and sizes, and the peri-urban area cannot be viewed as a simple urban-rural gradient, but more so an extended geographical type. Urban expansion in the Manchester region has been rapid throughout the 20th century: even when the economy and population was shrinking, many people chose to relocate in the suburbs or peri-urban communities, leaving a perforated and obsolete urban structure in many areas. Many of these peri-urban settlements have also experienced industrial shrinkage, and a rapid transformation from productive working towns, to leisure-based and/or commuting towns. Figure 8 maps built up area change, with areas in red showing new development occurring over the period 2001-2018, at a 30 metre resolution. This map highlights the intensity of, and spatial patterns characterising, new development across the Manchester region. Figure 9maps changing patterns of population density across this area. This presents a picture of areas of shrinkages, particularly within the urban cores of Manchester and Liverpool, set alongside areas of growth within the same urban cores but also notably within peri-urban areas lying between the major urban centres.

Figure 8: Built up change in the Manchester region (2001-2018).

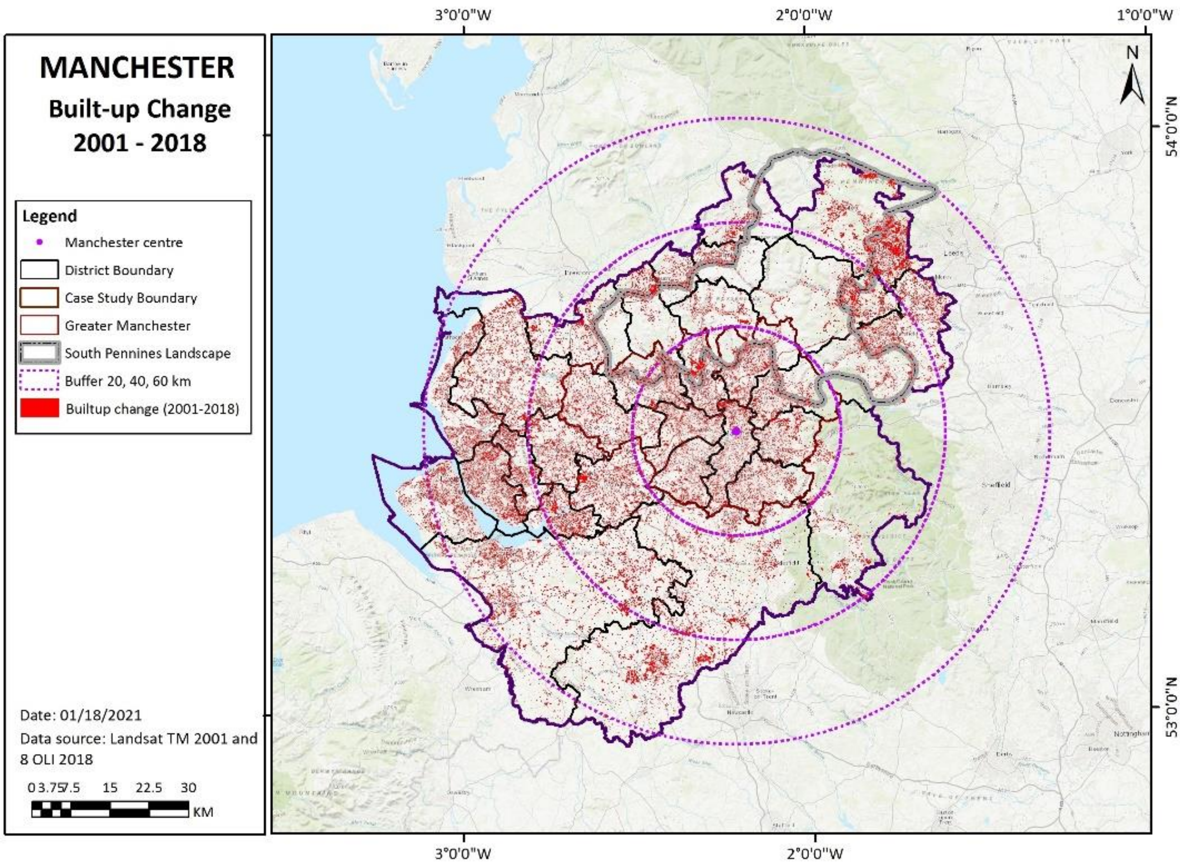
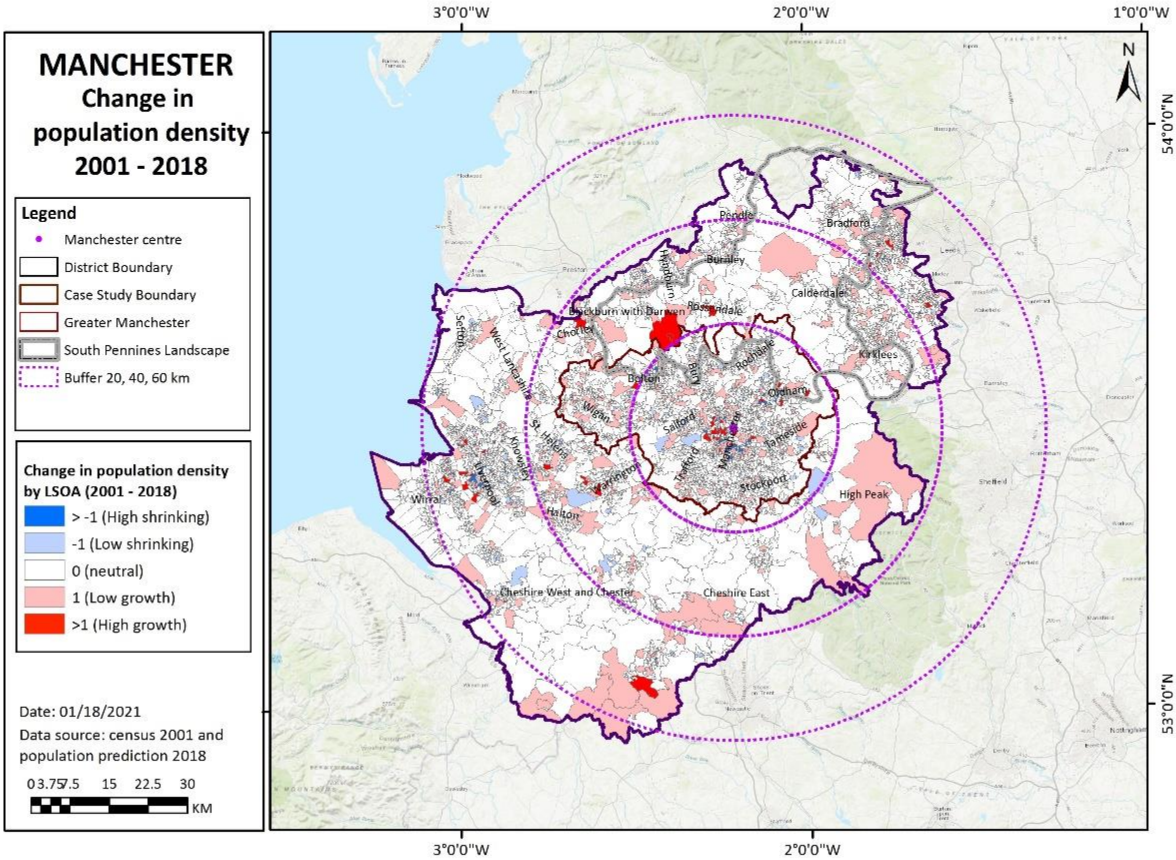


Figure 9: Change in population density in the Manchester region (2001-2018)



The vital statistics are summed up in Table 4 (calculated for the whole 200 x 200km square shown in the map format). The calculation includes Greater Manchester, Merseyside, Lancashire, West & South Yorkshire, and part of the East Midlands, with a current population of 17.3 million. Much of the open and peri-urban land area is within the FUAs (functional urban areas):

- Open land & peri-rural (<50 p/km²) accounts for nearly half the land area, but just over 1% of the population, however this has grown by 16% since 1990;
- Lower density peri-urban (<125) covers 15% of land area with 1.6% of the population, with a growth of 13% since 1990;
- Higher density peri-urban (<300) covers 9% of land area with 2.4% of population, with overall zero growth;
- By comparison the urban / suburban / town areas (>300 p/km²) cover a third of the highly urbanized northern England: they contain 95% of the population with a relatively high growth of 9% over the period.

The overall picture is of higher population growth in the lower density peri-urban, along with moderate growth in the urban areas.

Table 4: Peri-urban 'vital statistics' for the Manchester region.

Peri-urban classes		total land area 2015	total population 2015	25yr population change (% on 1990)	annual % change (compound)
Open land & peri-rural	< 50 p/km	44%	1.1%	15.9%	0.6%
Lower density peri-urban	<125 p/km2	15%	1.6%	12.9%	0.5%
Higher density peri-urban	<300 p/km2	9%	2.4%	0.0%	0.0%
Urban & suburban	urban >300 p/km2	32%	94.9%	9.1%	0.4%
Total	Total area	100%	100%	9.0%	0.3%

Development pressure to provide more housing, infrastructure and commercial space is intense in certain locations. This development pressure is moderated and managed to an extent by Green Belt and spatial planning policies. Despite these policy frameworks, environmental, social, economic and cultural change in the peri-urban area can be rapid (depending on how it is measured). There is a need to respond to new types of problems and opportunities in the peri-urban – not just physical sprawl, but the environmental, social, economic, cultural fallout from the pressures and opportunities presented by a large and complex urban system.

These issues provide a background to this Peri-cene case study, within which the Manchester region is defined as Greater Manchester plus its surrounding hinterland areas. There is no single unit or boundary which covers this region.

4 Current and projected climate risks & impacts

4.1 What are the main climate risks in the Manchester region?

Future climate change projections are all about uncertainty: shaped by issues including global agreements, actual GHG emissions, global tipping points, technology or social change, and further evidence from the science. For the moment we can assume a relatively mainstream 'worst case' scenario, based on the IPCC's RCP 8.5, which follows roughly the current trend pointing towards a 3-4 degree average temperature rise over the course of this century. These are the headlines from the UKCP18 projections for the 2070s (for locations typical of central England):

- summer precipitation change: between 57% drier and 3% wetter
- winter precipitation change: between 2% drier and 33% wetter
- summer temperature change: up to 5.8°C warmer
- winter temperature change: up to 4.2°C warmer

While these averages are very significant the greater risks are from extreme events:

- extreme rainfall events: projections are for 'wetter, wilder and windier'
- extreme heat / drought events: frequency of 'hottest ever' summers such as in 2018 may double by 2050

There follow a series of high-level projections for impacts on the ground:

- By 2080 under 2 °C warming, annual flood damages are projected to increase 50%, at 4 °C warming damages may increase by 150% (CCRA2017)
- River (fluvial) flooding currently contributes 40% of damage costs, fluvial flooding is expected to make up the same % of damage in future scenarios (CCRA2017)
- 45 – 60 days above 26 °C for South East England by 2050's compared to around 10 in 2020's (Arnell et al 2021)
- Projected 50 – 100 cm sea level rise by 2100 depending on scenario considered, which will affect 2.6 million UK residents under a 2 °C scenario, 3.3 million under a 4 °C scenario.

As for spatial patterns and distributions, figures 9 and 10 present the current best available regional map projections, from the CCRA18 online platform (arranged by emissions scenario from RCP4.5-8.5: and by percentile of probability):

Figure 10: UKCP18 seasonal precipitation projections for North West England.

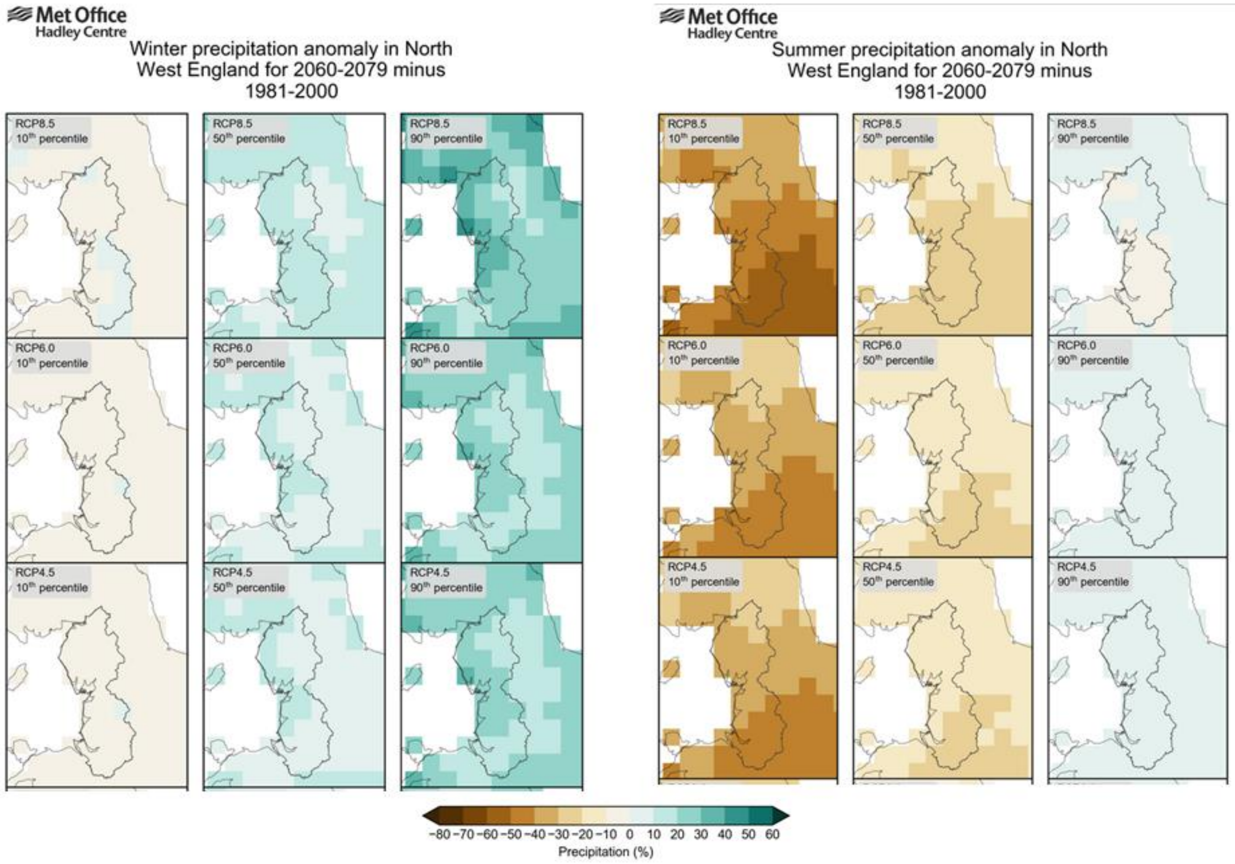
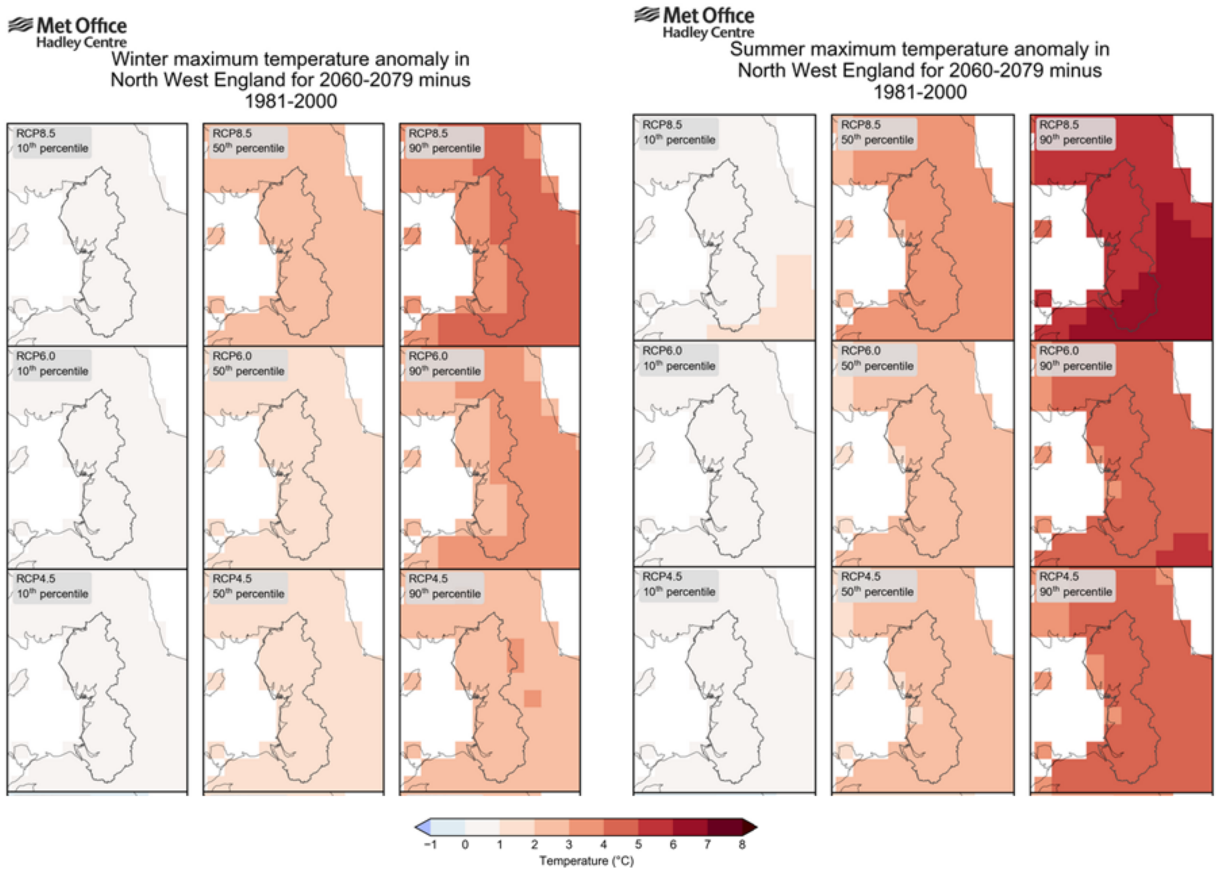


Figure 11: UKCP18 seasonal temperature projections for North West England.



More detailed local projections for future change to temperature and precipitation in GM are summarised below (drawing on Cavan 2010; Carter et al., 2015). Here, data is provided for the 2050s in comparison to a baseline figure covering the period 1961- 1990. The central estimate (50th percentile) for a high greenhouse gas emission scenario is given.

- Average summer precipitation is projected to decline by 20%
- Average winter precipitation is projected to increase by 16%
- Rainfall volumes during the wettest day in winter are projected to increase by 14.6%
- Mean annual temperature is projected to increase by 2.5°C.
- Warmest day in the summer is projected to increase by 3.4°C.
- Coldest night in the winter is projected to increase by 2.4°C

More weather extreme events are also a feature of climate change projections for GM (Carter et al 2015) and other parts of the world (IPCC 2012), with flood risk projected to intensify in GM and its surrounding areas. Indeed, it is extreme weather and climate change events that cause the greatest damage to people, infrastructure and ecosystems.

A review of relevant projects and resources on climate change risk and adaptation in GM is provided as an annex (10.1). Many of these research projects and resources provide spatial data linked to identifying and responding climate risks, whilst a much smaller proportion examine social scientific issues such as the governance of climate risk (e.g. Foster et al., 2018; Ravetz and Connelly 2018). A significant proportion of the available research and resources links to flooding. Recent flood events, associated policy priorities and statutory duties, and research into past and projected extreme weather events, highlights that flooding is the most prominent extreme weather and climate risk affecting the Manchester region. Table 5 summarises recorded incidences of extreme weather and climate change hazard events across GM over recent decades. This highlights that although GM is exposed to a range of extreme weather and climate hazards, including heat and drought events which are becoming more frequent, flooding has consistently been the most frequently recorded hazard event across GM over recent decades. There is detailed spatial data available on fluvial flooding for the Manchester region provided by the Environment Agency and via specific commissioned consultancy research, and includes details of current and projected future flood risk. Figure 12 identifies areas currently exposed to fluvial and coastal flooding across GM and surrounding areas. Surface water (pluvial) flooding is also a major challenge in urbanised areas.

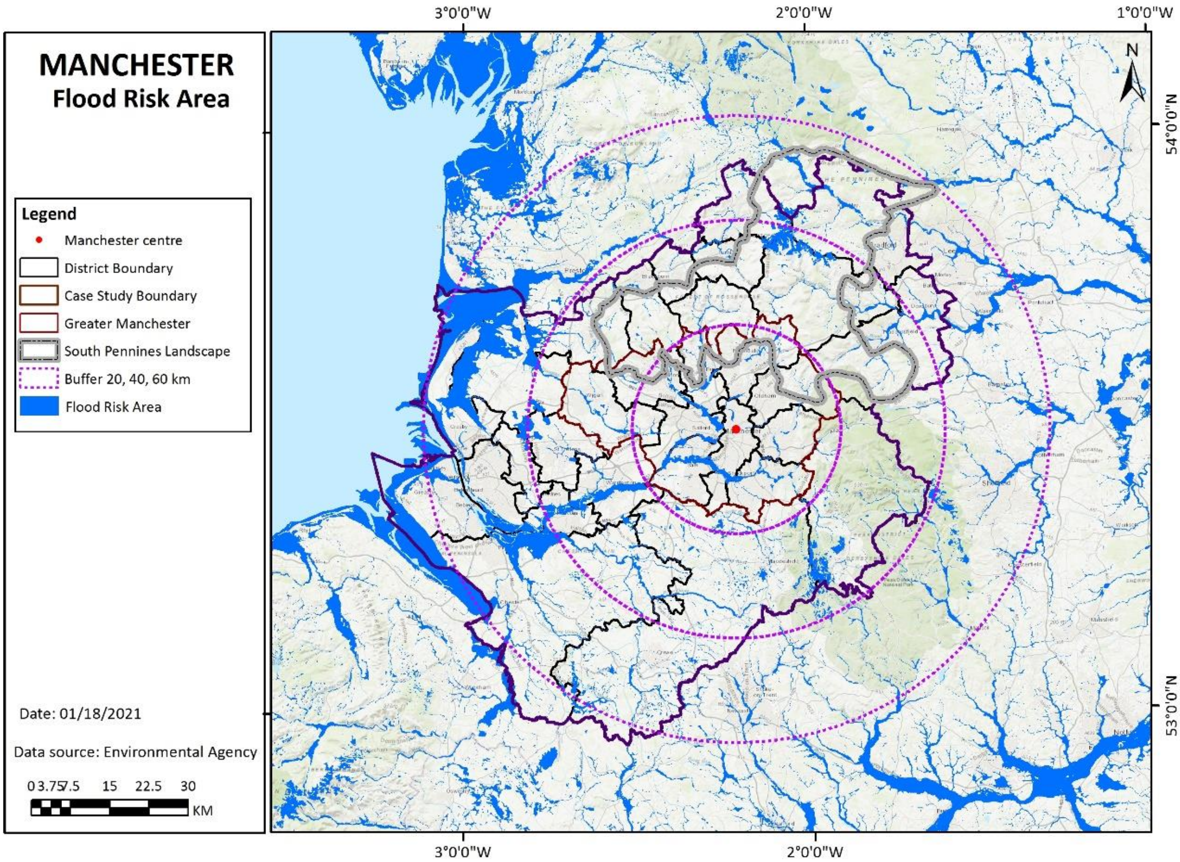
Table 5: Past occurrence of extreme weather and climate change hazard events across GM (Source: Carter et al 2018).

Event	1945-1969 Events	1970 – 1993 Events	1994 - 2017 Events
Flood (all forms)	36 (44%)	24 (36%)	109 (52%)
~ Pluvial floods	~ 8	~ 8	~ 54
~ Fluvial floods	~ 17	~ 10	~ 27
~ Pluvial, Fluvial and Flash	~ 11	~ 6	~ 28
Storm	18 (22%)	24 (36%)	44 (21%)
Cold	17 (21%)	11 (16%)	27 (13%)
Heat	2 (2%)	4 (6%)	10 (5%)
Fog	8 (10%)	2 (3%)	15 (7%)
Drought (water shortages)	1 (1%)	2 (3%)	5 (2%)
TOTAL EVENTS	82	67	210

Notes on forms of flooding:

- Fluvial floods include flooding from rivers, streams and brooks.
- Pluvial flooding is surface water flooding caused by extreme rainfall, where excess water cannot be absorbed or drained effectively.
- Flash flood events are included with pluvial events where evidence thereof is clear. However where evidence is ambiguous floods described as having been flash are included in the combined Fluvial + Pluvial + Flash category.
- Where the type of flood source is unclear it has been included in the Fluvial, Pluvial + Flash category

Figure 12: Manchester region flood risk from rivers and the sea.

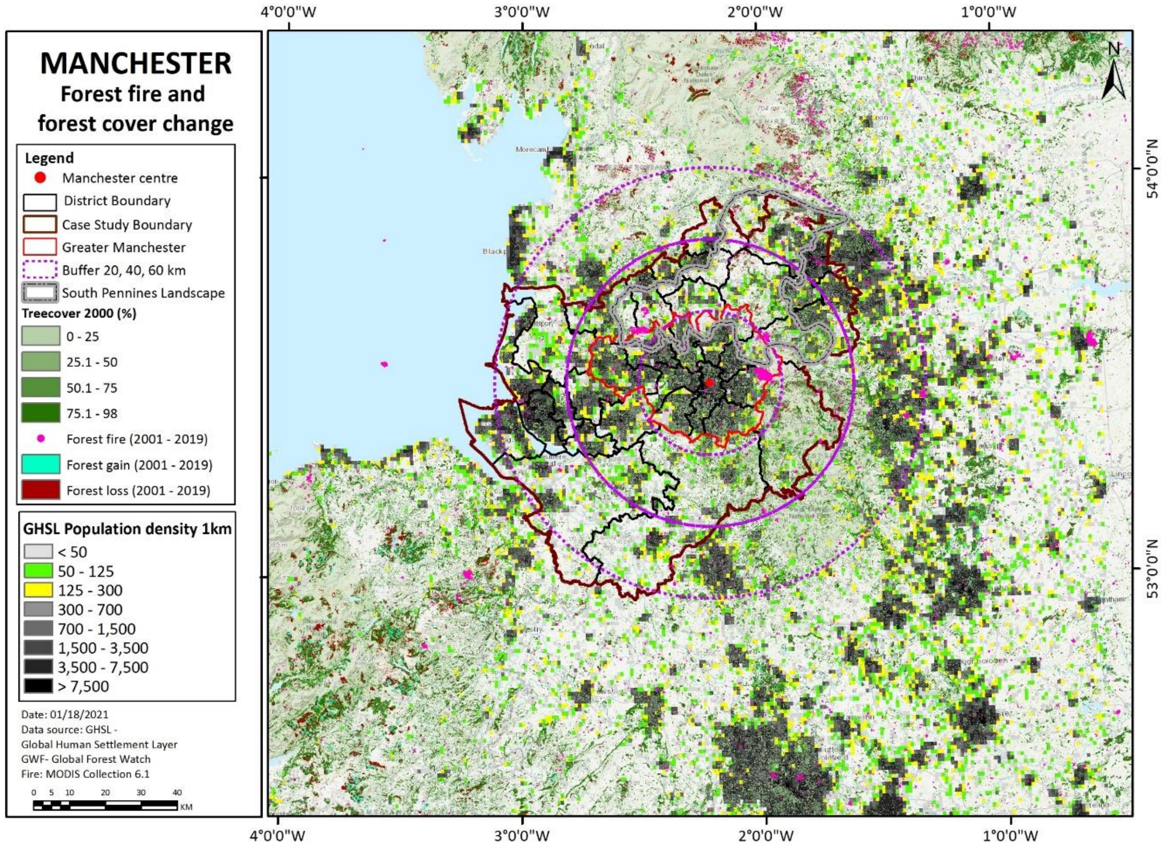


Responsibility for flooding is a statutory requirement for a number of organisations. The Environment Agency (EA) deals with flooding from rivers and sea, groundwater and ordinary watercourses; local authorities are responsible for surface water flooding; whilst water companies are responsible for sewer flooding. Other responsibilities are set down to riparian owners. Driven by the Floods Directive (2007), England has publicly available flood risk maps. Lead Local Flood Authorities (LLFAs) are responsible for preparing flood risk management plans for their jurisdiction. Therefore, different agencies operating at different spatial scales deal with different types of floods; this situation can be confusing to those whose remit does not include dealing with flooding.

Looking beyond flood risk, the forestry and wildfire map (Figure 12), overlays records of these hazard events occurring between 2001 to 2019 on the peri-urban typology (based on Global Forest Watch data):

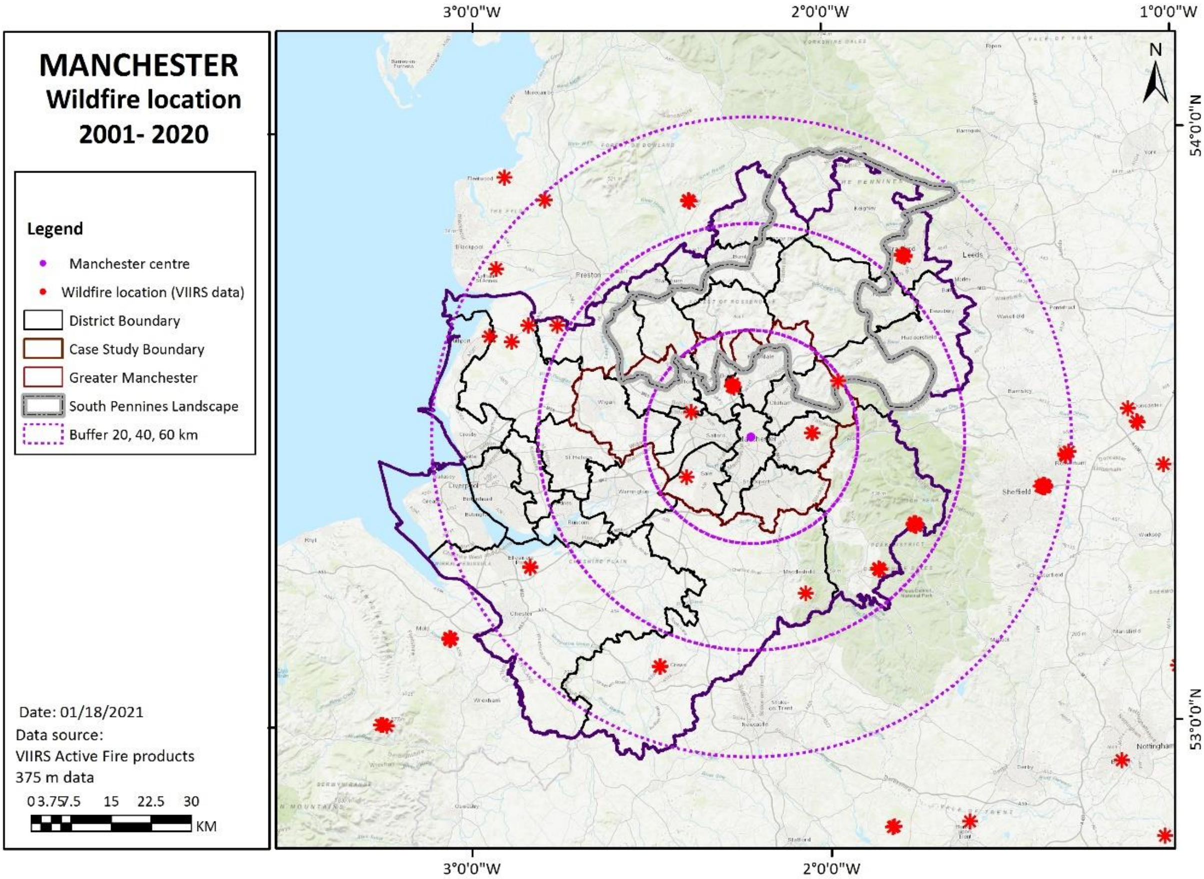
- Most peri-urban areas, both in the urban fringe and hinterland, contain numerous small areas of woodland
- Some of the hinterland, both in the Pennines and Cheshire, contain larger areas of woodland, mainly mixed or deciduous;
- Major wildfires are increasing even within the GM boundary (the fire on Saddleworth Moor being the 3rd largest in England in 2018): the upland peat bogs are especially at risk in dry or drought conditions, where fires can smoulder underground.

Figure 13: Forest coverage & wildfires in the Manchester region



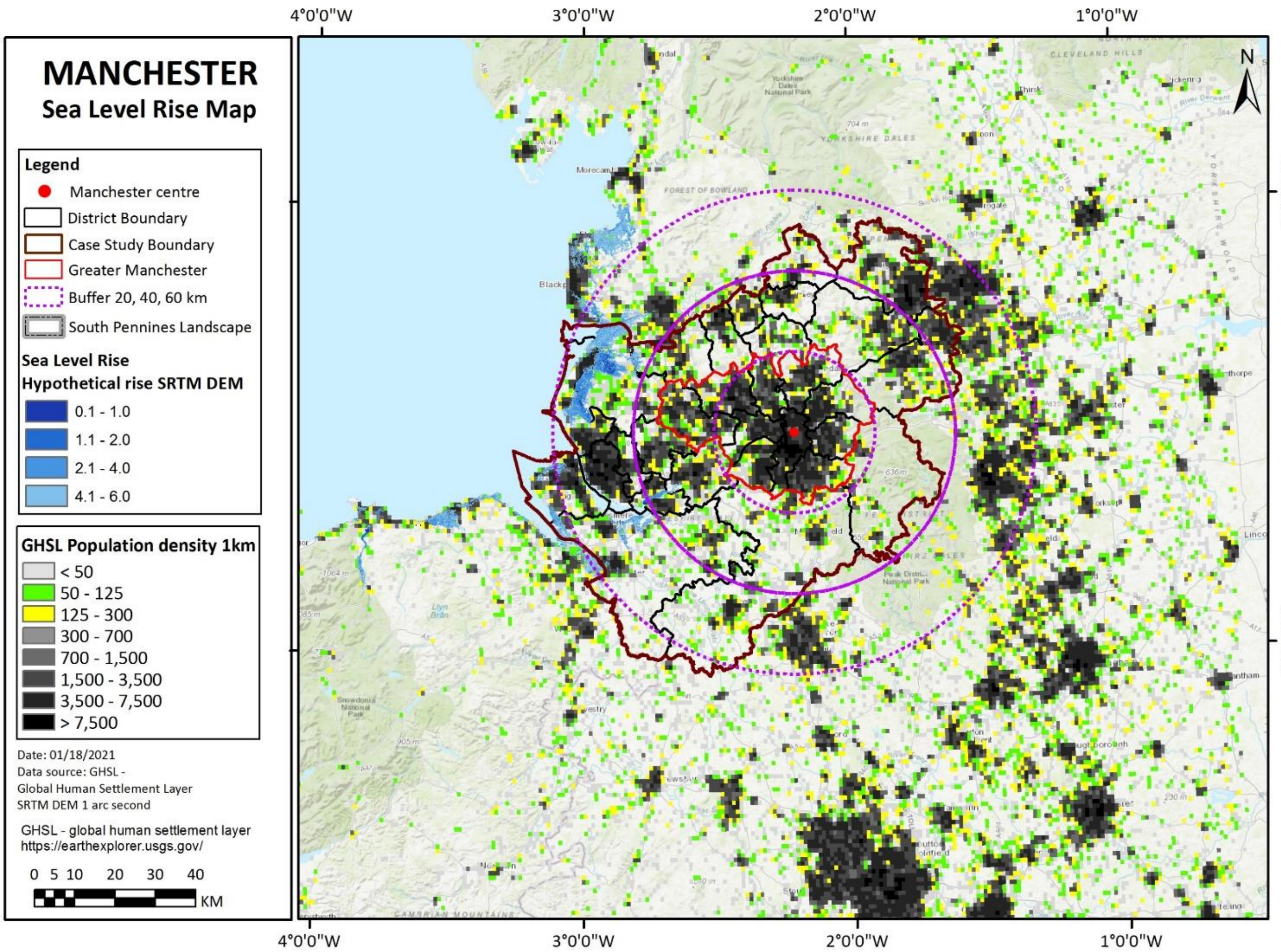
Other extreme weather and climate hazards such as heat and drought, which although are becoming more frequent are nevertheless relatively uncommon occurrences, and where available mapping is generally at a coarser spatial scale in comparison to fluvial flood risk (Carter et al. 2017). However, climate change projections indicate that heatwaves and associated heat stress may become a more serious concern in the urban areas of GM over the coming decades (Cavan 2010). Wildfire risk has emerged onto the agenda with recent examples of wildfires within the GM boundaries (e.g. Saddleworth Moor, 2018), and research is compiling a GIS-based monitoring and detection tool of peat moorland and heathland wildfires (http://www.envirosar.com/). Figure 13 highlights the locations of major wildfires around GM over the period 2010-2020. Fires often occur in upland peri-urban and rural areas during the summer months when surface vegetation and peat layers dry out and become susceptible to fire, which is often caused by human activity. Different climate change risks are connected. For example, wildfires can facilitate soil erosion and consequently reduce the capacity of upland landscapes to store rainwater leading to increased runoff, and also reduced capacity of peat soils to store carbon. There is a risk of a reinforcing cycle emerging, leading to increased prevalence and intensity of climate change risks.

Figure 14: Major wildfire locations in the Manchester region



Sea level rise is a major issue on the western coast side of our study area (i.e. the Manchester wider region including Merseyside and south west Lancashire). There are many associated effects, including saline incursion, disruption of subsoils and building foundations and damage to critical infrastructure. Figure 14 is a 'first base' assessment of sea level rise, drawn simply on the elevation of land (excluding modelling of any tides, surges, defences etc). This highlights risks to estuarine locations, coastal towns in Lancashire, and low lying fertile agricultural land on the coastal zone to the west of GM.

Figure 15: Sea level rise vulnerability in the Manchester region.



4.2 Social & economic vulnerabilities

Likely impacts / risks for key economic sectors in the Manchester peri-urban:

- Risk of water shortages; extreme weather; risks to soil function, through aridity and loss of organic matter, alongside sea level rise; loss of pollinators all affect our farming & forestry sectors
- Extreme weather events; water and energy supplies; embankment failures; high temperature on transport impacting passengers; landslide disruption will all have an impact on our transport infrastructure
- Risk of water shortages; flooding and coastal change; extreme heat will all impact our energy & water sectors
- 2000 heat-related deaths per year could triple by 2050, building fabric can be affected by damp due to flooding and intense rain, or structural damage through high winds or subsistence

In terms of climate change impacts and risks, an evidence-based climate change risk assessment for GM's critical infrastructure, which built on established risk assessment frameworks used by organisations including the Intergovernmental Panel on Climate Change and the UK Government's Cabinet Office, identified flooding as the most significant generator of climate change risks to critical infrastructure (Carter et al 2018). The top five climate risks to critical infrastructure emerging from this study were:

- Fluvial flooding of energy infrastructure (particularly substations)
- Fluvial flooding of power stations
- Impact of storm damage to energy infrastructure
- Pluvial flooding of energy infrastructure (particularly substations)
- Fluvial flooding of road network

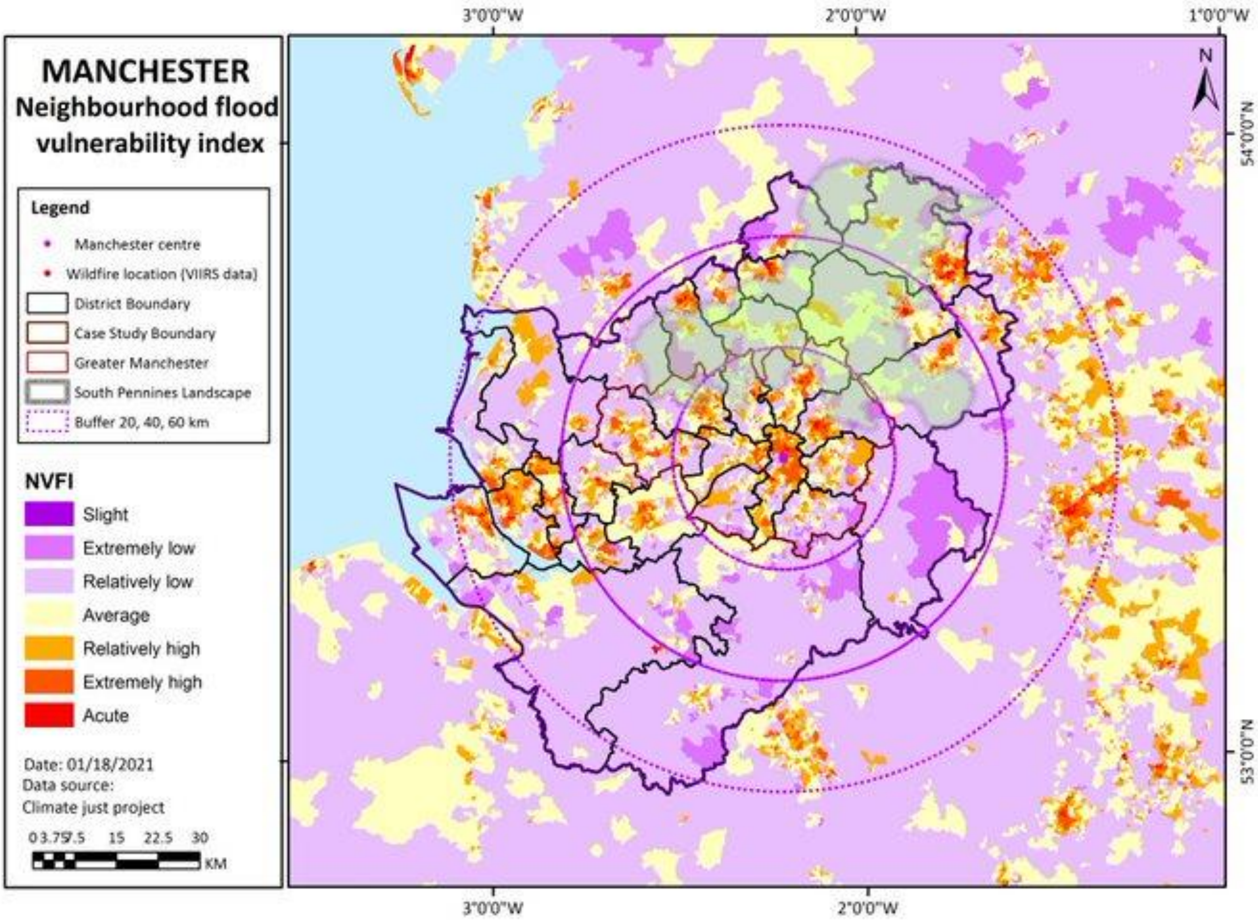
From a social perspective, there is a tendency for the most vulnerable groups (impacted by poverty, dependency, poor health and poor housing conditions) to be at most risk of flooding, and in other ways to extreme heat. While many such groups are in the inner cities, there are pockets and patterns across the peri-urban areas, and this may increase with the current out-migration and counter-urbanization.

The spatial distribution is shown in Figure 15, as the 'neighbourhood flood vulnerability index', from the Climate-just project. This is a composite of indicators including (for both locations and/or social groups): age structure, population health, care / disability, built-up density, dwelling form, employment, dependency, income, rental / ownership, social mix / change, household structure, transport access.

The broad distribution across the region, as in Figure 15, shows in general the highest vulnerability for low income groups in urban areas. For the peri-urban the picture is quite mixed:

- For the Pennine zone to the north, there is localized areas of poverty, many in the post-industrial towns in narrow river valleys with much higher flood risk
- For the Irwell river catchment, the headwaters come from more affluent peri-rural areas, with flood risk accruing to the low income groups in urban areas with high vulnerability.
- For the Cheshire zone to the south, a mainly affluent peri-rural hinterland conceals pockets of poverty in smaller towns and villages, only some of which show on this map.

Figure 16: Neighbourhood flood vulnerability index.



5 Peri-urban climate risk and adaptation

The previous chapter has highlighted the nature of the climate change risks facing the Manchester region over the coming decades, and links to themes including critical infrastructure and vulnerable communities. Flooding is the key risk going forwards, although hazards linked to rising temperatures, including heatwaves with related implications for people and critical infrastructure, are also a potential risk. An important point to acknowledge is also the risk from extreme weather events, in addition to gradual climate change. Although they are less likely to occur, it is extreme events such as exceptionally heavy rainfall or periods of high temperature that cause the greatest impacts.

Chapter 3 introduced the peri-urban areas of the Manchester region, which are often fragmented landscapes of marginal farming and urban settlements punctuated by waste tips, transport and energy infrastructure networks, commercial and retail parks and golf courses.

In practice, peri-urban landscapes are constantly evolving. Initiatives such as Community Forest projects aim to convert peri-urban fringe land to multi-functional woodlands. Notably for GM, the City of Trees initiative aims to plant 3 million trees (one for every person in GM) over the coming years. To the north and east, the mostly empty and treeless landscape of the South Pennine uplands conceals rapid social-economic changes, with the shift from low intensity livestock farming to leisure industries and nature conservation, and from multi-generational local communities to commuters and teleworkers. This has contributed to social polarization, widening income gaps, gentrification and rising property values in some areas.

The Covid 19 pandemic has recently accelerated trends towards home working and the desirability of living in peri-urban and rural areas, thereby intensifying these issues.

5.1 What are the effects of climate change on the peri-urban?

The next question is - why is the peri-urban so important for climate change, and how do we track this, given the uncertainties of climate projections, and the complexities of the mapping shown above. There are two kinds of answer for this: the first is about the local conditions in the peri-urban, and the second sees the peri-urban as part of a whole city-region system.

For the first, the local conditions in the Manchester peri-urban, many such areas are at high climate change risk:

- Fluvial & surface flooding, particularly in the river valleys where former industrial towns and infrastructure were sited.

- Drought periods, with effects on ecosystems, landscape types and local farming. Upland sheep farms are vulnerable to drought, as are the intensive arable areas of Cheshire.
- Wildfires with impacts on human & ecosystems. Peri-urban wildfires in the Pennines scrub land and peat bogs have increased, and in some cases cast smoke across the entire conurbation.
- Extreme heat, which affects vulnerable social groups, in particular the elderly and outdoor workers.
- In the coastal & estuary peri-urban areas of Lancashire and Merseyside (on the edge of our case study), sea level rise, coastal erosion and saline incursion is a growing problem.

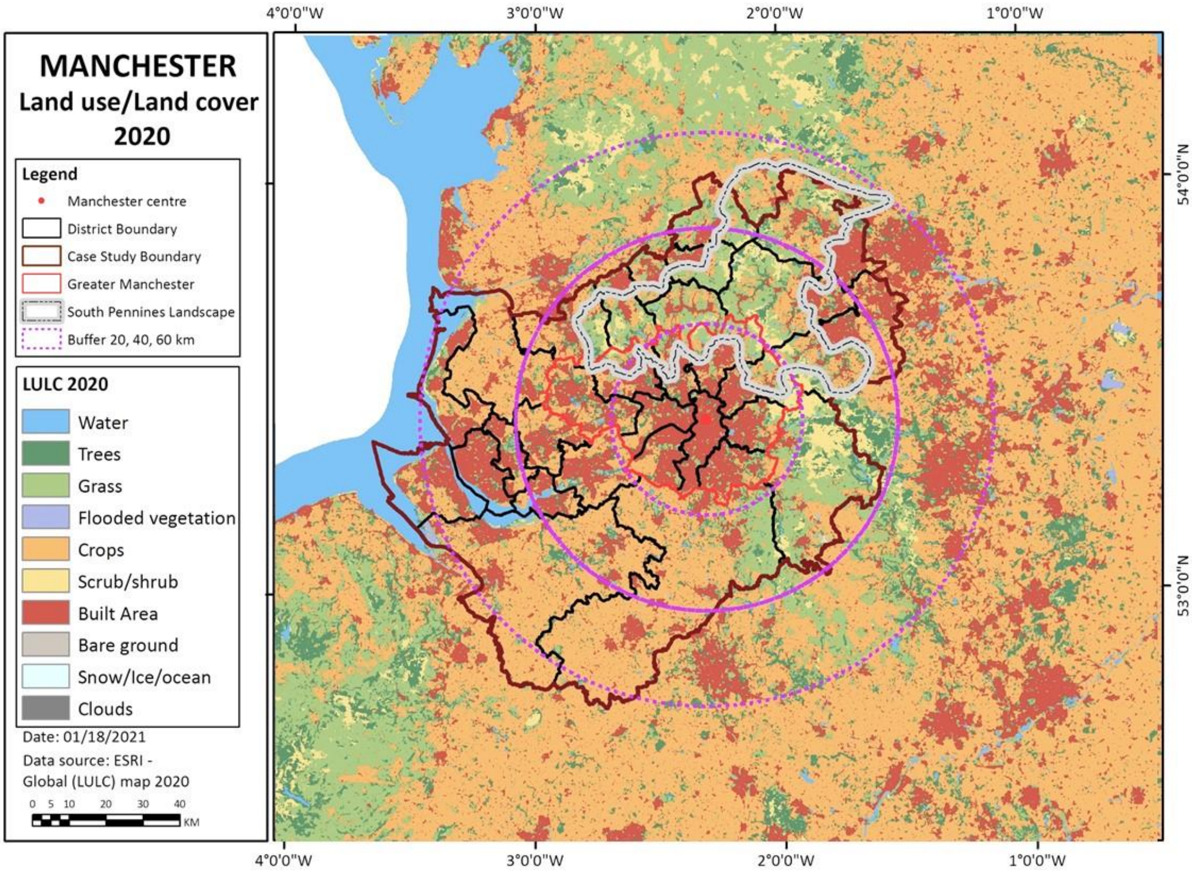
For the second, the MCR peri-urban is also highly inter-connected to the urban and rural areas, as part of an extended city-region:

- Water management in the peri-urban has a direct effect on the flood risk and exposure of downstream urban areas.
- Landscape management in the peri-urban has an indirect effect on water: e.g. where upland land-use and ownership creates problems of storage & run-off.
- Farming practices in the peri-urban create further problems of run-off, chemical pollution, soil erosion, clearance of natural areas etc.
- Housing development in the peri-urban is a direct effect of urban pressure, including urban heat island, and urban natural capital / biodiversity gaps.

Some key issues can be seen on the land-use/cover map (Figure 16):

- Scrub areas – risk of wildfire and loss of peat bog;
- Grass & forest areas – risk of drought and soil erosion especially on sloping land;
- Crop areas – risk of drought and change in agro-ecology;
- Built area proximity – risk of disruption of landscape and soil, ecosystems, water systems.

Figure 17: Land-use / land cover map.

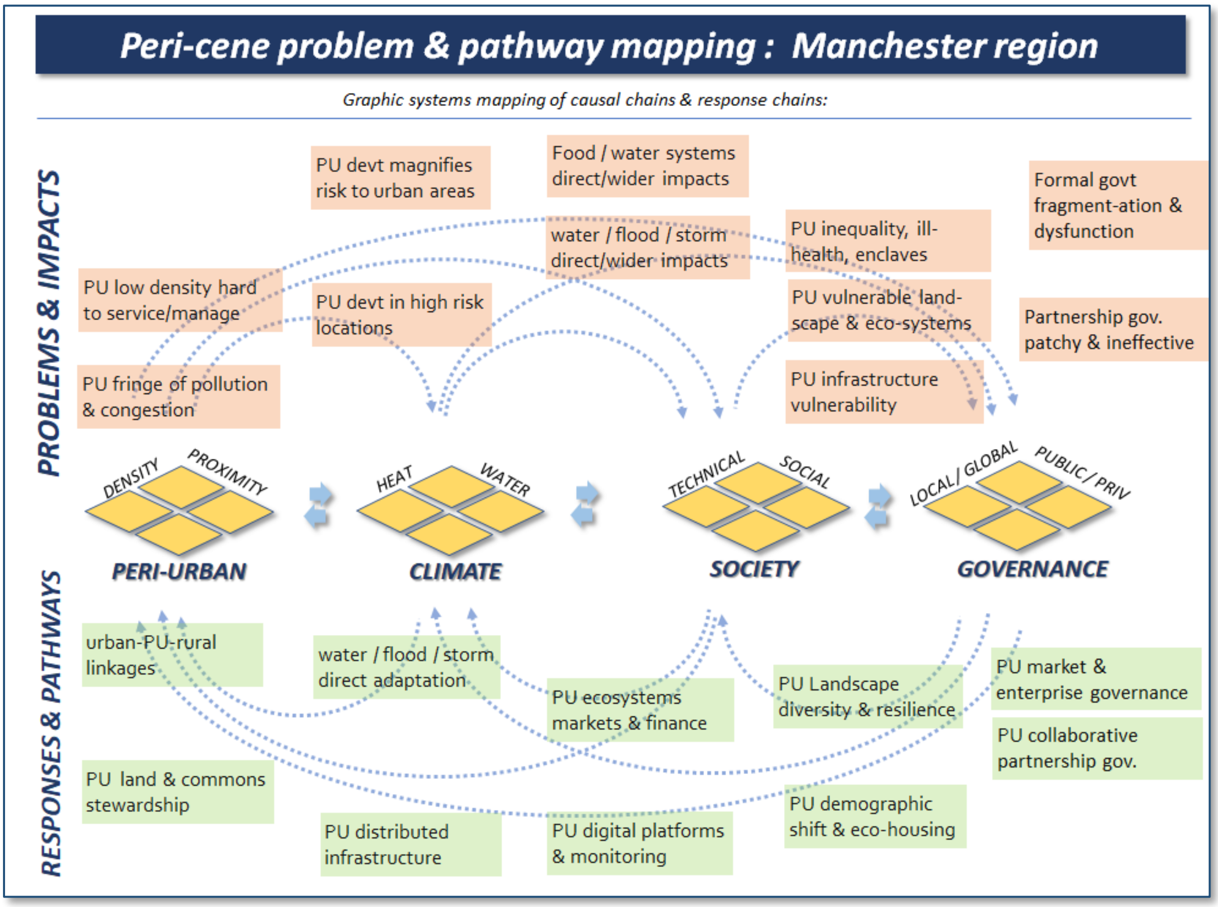


5.1.1 System mapping of peri-urban climate interactions

The Peri-cene focuses on the key aspects of peri-urban development that are most relevant to climate change risk and adaptation, and vice-versa. Such linkages can be identified in a number of ways, structured as "peri-urban development impacts on hazard, exposure, vulnerability / capacity, or governance": (based on the IPCC risk framework, as per Connelly et al 2018). Each of these can (in principle) be traced on the Peri-urban-climate model in Figure 17. Each of the four main themes of this model has a typical set of variations, or common types, which offer a simple and generic description of the likely range of issues. These are:

- ***Peri-urban:*** Proximity to urban (near / far): Density of population: (low / high)
- ***Climate hazard***: Spatial scale (local-direct / external-indirect): Time horizon (short / long term)
- ***Vulnerability – sensitivity and adaptive capacity***: Physical ecosystems & infrastructure: (organized / fragmented): Socio-economic: (organized-cohesive / fragmented-unequal)
- ***Governance / pathways***: Scale: (local & internal / global & external): Structures (public-social values / private-techno-economic values)

Figure 18: Peri-urban-climate systems mapping: Manchester region



The peri-urban climate model for the Manchester region is not intended to represent more detailed and complex causal chains or systems diagrams, but this figure does provide a summary of notable peri-urban climate change themes for the Manchester region. Here, climate change hazards may interact with receptors (e.g. people, infrastructure, landscapes), which therefore become exposed to the hazard (e.g. flooding). Spatial changes influenced by drivers and stressors related to changing peri-urban types, patterns and dynamics, can act to increase or reduce exposure of receptors to climate hazards (e.g. by increasing/reducing impermeable surface cover). Vulnerability factors exacerbate or moderate overall levels of climate risk. Actions can also be put into place through (adaptive) governance arrangements (e.g. formal government and regulation, informal networks, and other institutional collaborations) to build adaptive capacity to influence each of the climate risk components. Whilst the framework shows a logical flow between each element of climate risk, it is important to emphasise that reality is much more complex. The arrows between each component are intended to emphasise that there are multiple interconnections between the elements of the framework.

5.1.2 Summary of peri-urban climate interactions

Peri-urban impacts on climate change 'hazard':

a) Peri-urban development >>> sealing of soil & landscape change and degradation (e.g. of woodlands, pasture, scrub etc), which would otherwise help to protect urban areas from climate-related events or stresses. This particularly affects the upstream areas of river catchments such as the Irwell, i.e. hills to the north and west, with problems then displaced to downstream urban areas.
b) Peri-urban development >>> adds to urban heat island and leads to the fragmentation of land-use and land cover, with a loss of adaptive capacity and ecosystems services (e.g. suburban development all around the metropolitan area).

Peri-urban impacts on 'exposure & vulnerability':

a) Peri-urban development itself is sometimes in high risk flood zones, particularly where it is located in river valleys, which are zones where risk will intensify with climate change.
b) Peri-urban development >>> increased dependency on critical but vulnerable infrastructure systems (i.e. car dependency).
c) Peri-urban development of enclaves >>> can often link with social vulnerability (e.g. seniors, low income groups).
d) Peri-urban development >>> lowers the overall population density where adaptation and risk reduction is more difficult (e.g. isolated dwellings in fire risk zones in moorland areas).
e) Peri-urban economic development >>> disruption of lower income rural livelihoods and communities, leading to increases social & ecological vulnerability.

Peri-urban impacts on 'governance'

f) Peri-urban areas often have fragmented governance in political units which do not fit with ecological zones and landscape boundaries (e.g. river catchments): e.g. the S Pennine area type is in 13 different municipalities.
g) Peri-urban development is often more polarized into higher / lower income enclaves, making collaborative governance more difficult.
h) Peri-urban populations are often in smaller settlements and/or lower density, where it becomes more difficult to finance defence / adaptation.

5.2 Scenario framework

Future climate change and impact projections are all about uncertainty, influenced by global agreements, actual GHG emissions, global tipping points, along with other changes in societies, economies, urbanization and governance. As the prediction of future climates is not possible we use scenario development. This is generally the best way to generate forward thinking on climate problems, and on adaptive pathways. Scenarios are not forecasts, more like 'what if' questions, or 'stress testing' of policy. Simple narratives and visualizations can work alongside systems mapping and technical modelling.

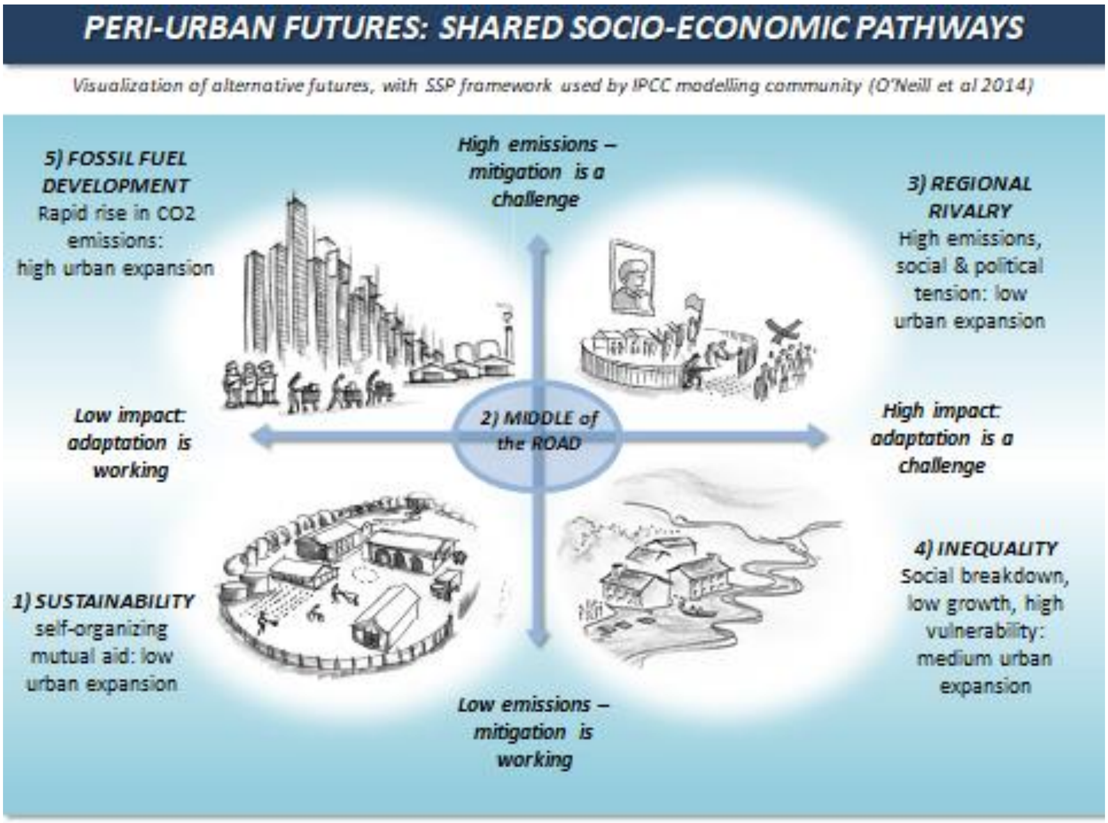
The Peri-cene uses the SSP (Shared Socio-economic Pathway) scenarios, as these are compatible with global climate modelling (see Figures 18, 19 and 20). The SSP scenarios are 'exogenous', i.e. outside the city-region system & decision frame. The city-region can then work out what to do in response to these uncertainties.

To simplify we focus on 2 critical scenarios: SSP#4 ('inequality') and SSP#5 ('fossil growth'). These have been worked up in some detail by the UK-SSP project for the Met Office, with technical reports and a state-of-the-art online systems mapping resource, with further details available here:

(https://www.ukclimateresilience.org/projects/uk-socioeconomic-scenarios-for-climate-research-and-policy/).

The summaries shown below are then fitted to the conditions and trends of the Manchester region. This is then a vital tool for the 'adaptive pathways' to be explored in the next report D4-2b: as these pathways are projected into future decades, we use the SSP scenarios for 'stress-testing' and sensitivity analysis.

Figure 19: Peri-urban futures from the SSP

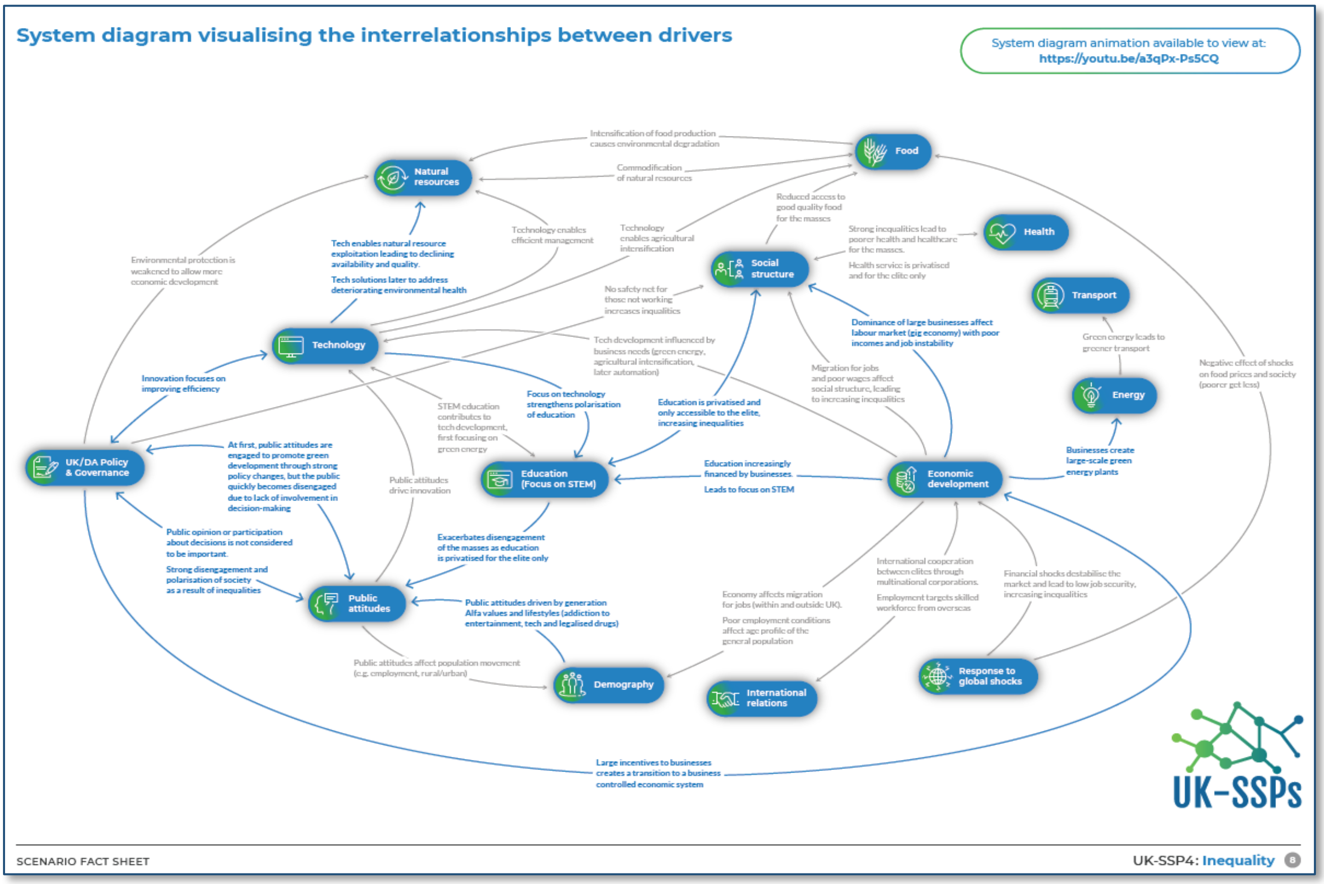


5.2.1 UK-SSP4 : 'Inequality' scenario

To boost economic growth, public support increases for a UK-wide decentralisation plan that aims to foster environmentally sustainable business and economic opportunities across the different regions of the UK. The National Strategy Development Plan is implemented through large-scale public investments that promote economic prosperity through greening the energy sector and stimulating technological development. This leads to numerous businesses growing in importance and power as they profit from increased financial support and access to land resources. The new Plan also boosts investment in STEM and novel ways to work and live flexibly. However, this growth comes at the expense of social and wellbeing-oriented policies, which results in an increasing divide between wealthy and poorer segments of the population as well as regions of the UK. Eventually the welfare state collapses and large businesses dominate economic and political systems. A small proportion of rich individuals working in large businesses and government control economic and natural resources, while the majority of the UK population lives with low incomes and poor living and environmental conditions.

In the peri-urban Manchester region, *there is some protection against flood and heat through new technology, but this is heavily privatized. Climate proof locations in the higher and greener peri-urban reach sky-high prices, and most housing is in private security-controlled enclaves. Emergency services are also privatized, and climate impacts on housing and infrastructure are seen as part of the economic growth model.*

Figure 20: system mapping of UK-SSP-4: 'inequality' scenario

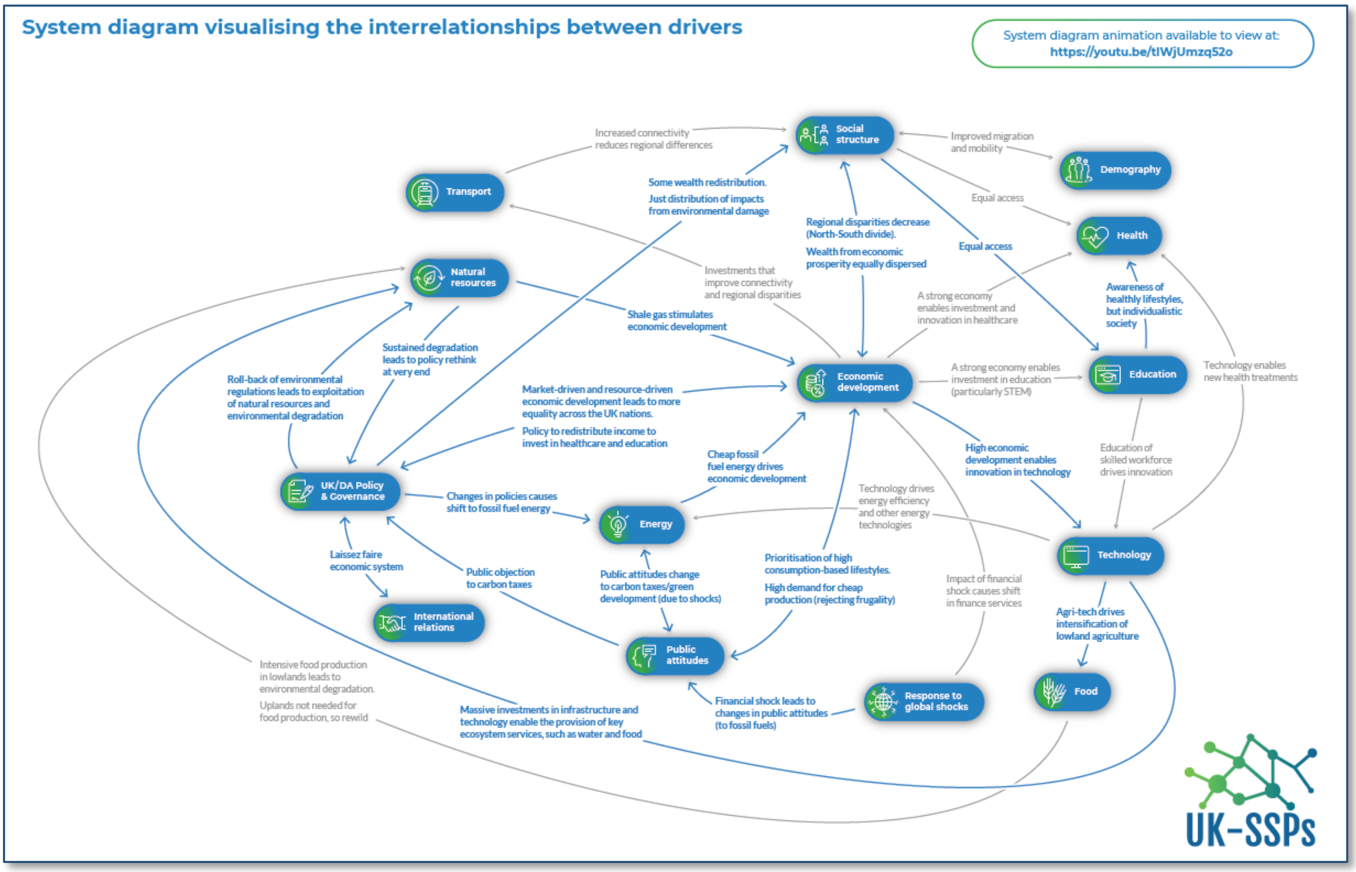


5.2.2 UK-SSP5 : ‘Fossil-fuelled Development’ scenario

Reduced public support for carbon taxation and taxes to finance green transformation of infrastructure, lead to continued demand for cheaper and more readily available fossil fuels. Strong development in domestic manufacturing is supported by UK discoveries of shale gas, which leads to reduced energy costs. Increasing public investments in shale gas production in northern England heavily contributes to the removal of the North-South divide. The economy increases rapidly providing benefits for all people. Environmental protection is reduced and agriculture intensifies in lowland areas, whilst uplands are rewilded for tourism. Technological solutions are used to counter the impacts of large-scale environmental degradation. Large increases in population lead to rapidly expanding "city-states" and massive urban sprawl.

***In the peri-urban Manchester region,** large housing developments are scattered across agricultural areas, and the Pennine valleys and uplands. Water systems and landscape types are heavily disrupted, leading to increased flood and fire risk. The more affluent houses are ‘climate proofed’ with raised construction (for flood events) and sealed air-conditioned interiors (for extreme heat and smoke).*

Figure 21: system mapping of UK-SSP-5: ‘fossil growth’ scenario



6 Case study A: the Irwell river basin

A central focus of the Manchester region case study is on fluvial flood risk, and moderating this risk through natural flood management (NFM) in the river Irwell catchment. NFM is generally seen as an element of a wider flood risk management response where, for example, structural flood defences and emergency response also feature. Concentrating on NFM connects the case study to emerging research and policy agendas, that are increasingly looking at this approach as a means of supporting flood risk management goals, in addition to providing other socio-economic and biophysical benefits including climate change adaptation. The focus on NFM measures, which are often located in peri-urban areas in the Manchester region, therefore connects this element of the case study directly to the Peri-cene agenda.

This case study provides a route into exploring interactions between peri-urban and urban areas concerning climate change risks and adaptation responses. Areas most at risk from flooding are often urban in nature, whereas NFM opportunity areas are often peri-urban and rural in character. Within this section, the problem of flood risk from rivers in the Irwell catchment is outlined and the opportunities presented by NFM are introduced, with maps provided to highlight spatial themes and patterns related to these issues. The following Peri-cene deliverable (4.2b) takes this element of the Manchester region case study forward, and pays specific attention to issues around the implementation and governance of NFM measures.

6.1 The Irwell Catchment

The river Irwell rises in the Pennine peri-urban uplands to the north of Greater Manchester and flows through the city centre and into the river Mersey, which then flows out into the Irish Sea at Liverpool Bay. The Irwell catchment incorporates peri-urban and urban areas, is criss-crossed by multiple administrative boundaries. Figure 21 visualises the proportion of the Lower Super Output Areas (LSOA) within the Irwell Catchment that are covered by built up areas.

NOTE: LSOA's are a statistical geography at which data is reported, including the census and Index of Multiple Deprivation. LSOAs have an average population of 1500 people, or 650 households. LSOAs are therefore smaller and more tightly packed in densely populated areas, with the opposite being true in more sparsely populated areas. There are 952 LSOAs in the Irwell Catchment. They provide a valuable spatial unit for visualising and analysing data, and are the basis for much of the spatial analysis undertaken within the Irwell Catchment element of the Manchester region Peri-cene case study.

Figure 21 highlights a clear gradient from more heavily urbanised areas to the south of the catchment and around the main urban areas (including Rochdale, Bury, Salford and Manchester) to the less developed and sparsely populated areas in the uplands to the north of the catchment (which are dominated by open landscapes and river valleys). This map highlights that although the Irwell catchment contains one of the UK's biggest cites, Manchester, it also has peri-urban and rural characteristics. Figure 22 demonstrates that new urban development occurring over the period 2001-2018 has been widespread across the Irwell catchment. New development has been particularly intense in the peripheries of town centres including Rochdale and Bury, and to the north of Manchester city centre. New development has also stretched up the river valleys that run into towns including Bolton, Bury and Rochdale from the upland areas to the north and east, along the river Irwell flowing into Salford and has led to urban infill in a range of other locations across the catchment.

Figure 22: Proportion of built up area within the Irwell Catchment

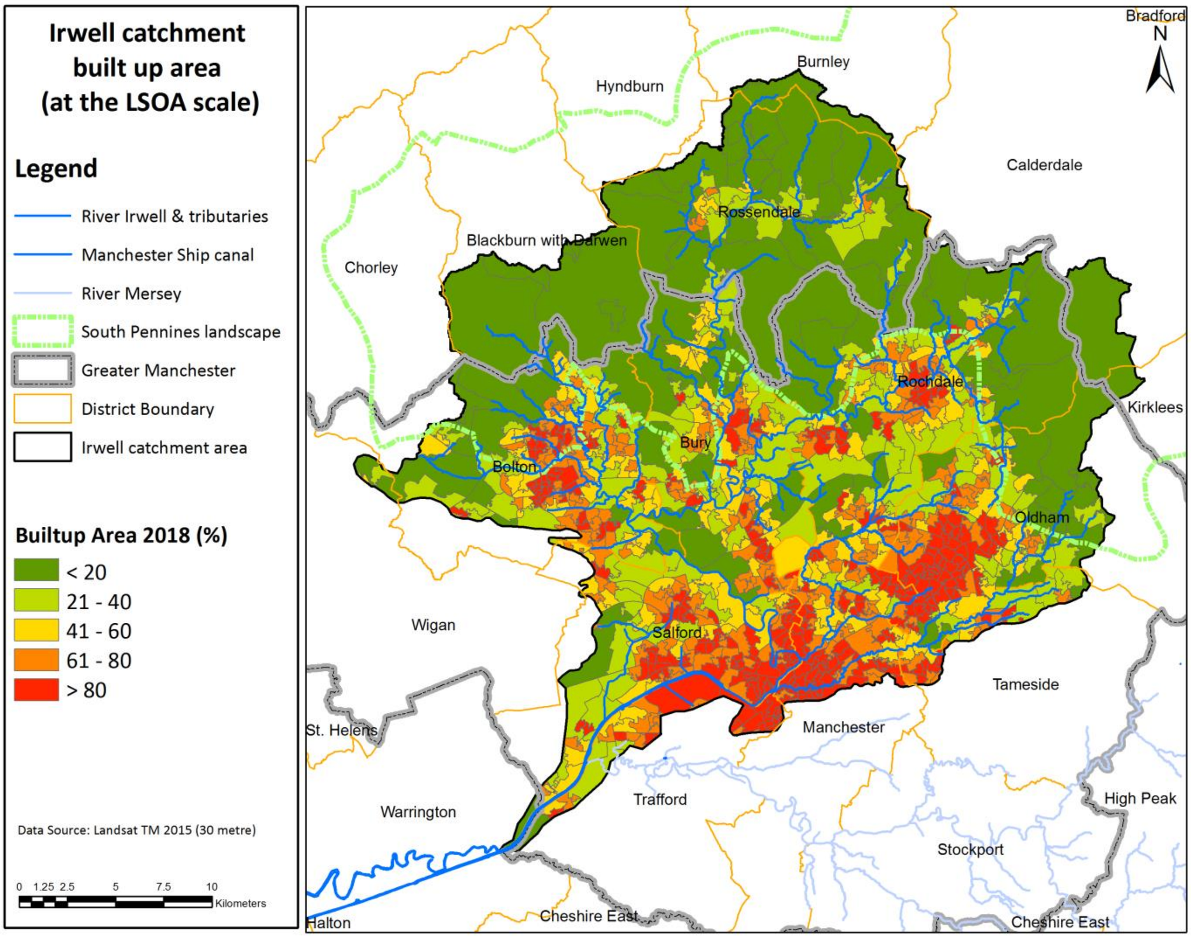
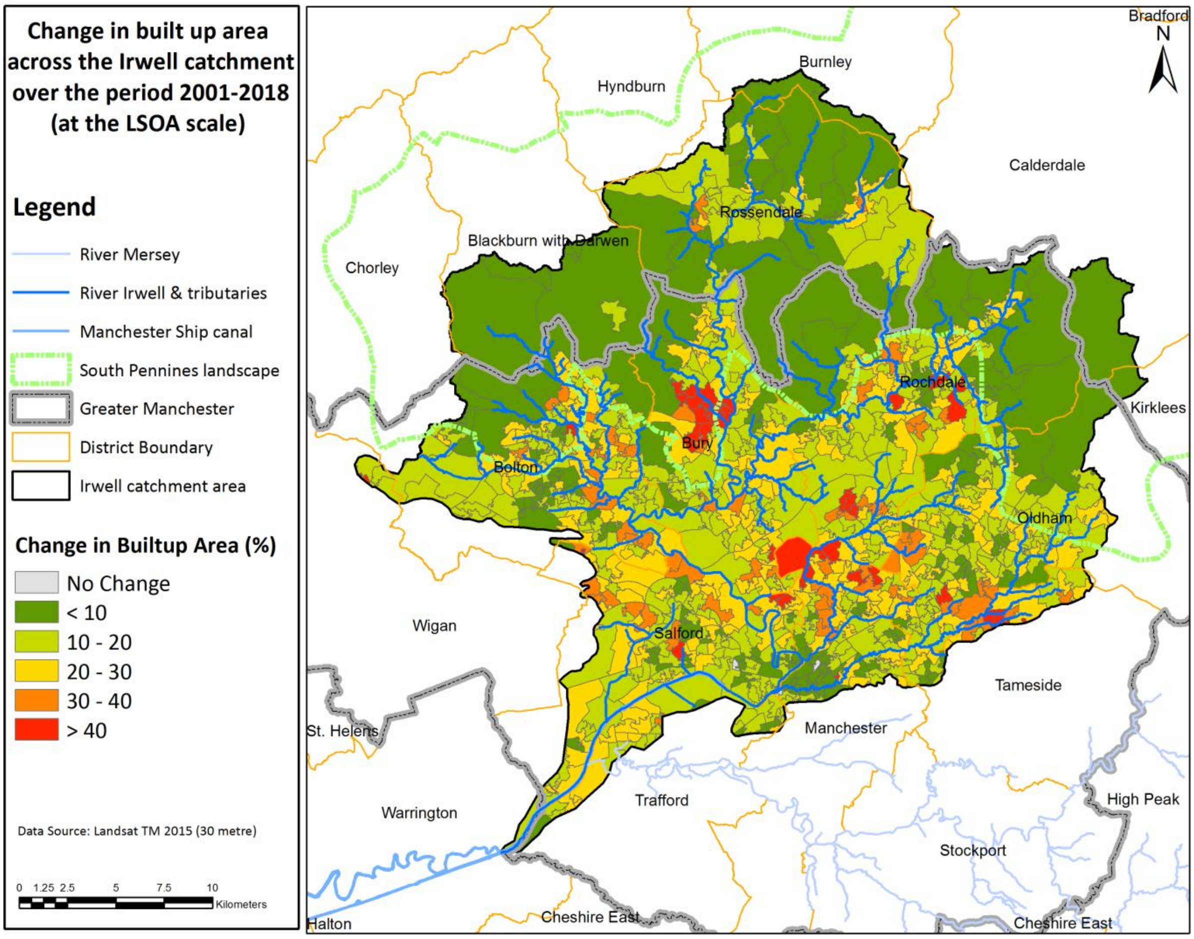


Figure 23: Change in built up area across the Irwell catchment 2001-2018



6.1.1 Flood risk in the Irwell catchment

Historic development patterns, with industry and associated worker housing concentrated around the Irwell and its tributaries, has left a legacy of flood risk in a number of urban areas across the Irwell catchment. The risk of flooding has been further enhanced by previous and ongoing development and associated hard surfacing (as highlighted by Figure 22), which has altered the hydrology of the Irwell catchment leading to higher volumes of water reaching watercourses following periods of prolonged or intense rainfall.

There have been several significant flood events within the Irwell catchment over recent years. The 2015 Boxing day floods (26-12-15) provide a recent example of the type of extreme rainfall event that can cause major flood damage to communities and infrastructure in an around the river Irwell catchment. During this event, the upland areas within Greater Manchester's peri-urban hinterlands received significant volumes of rainfall which saturated and ran off the moorland, flowing down the Irwell and its tributaries causing major flood damage. This flood event resulted in 2250 properties being flooded and £11.5 million of damages to infrastructure alone (GMCA 2016). This same flood event caused significant damage in other peri-urban locations around the Irwell catchment. For example, the towns of Hebden Bridge and Todmorden in the adjacent river Calder valley were badly flooded. Here, attention subsequently turned to the contribution of issues including the ownership and management of the upland areas around these towns to flooding in the valley floors, and also to NFM as part of the response to manage future flood risk.

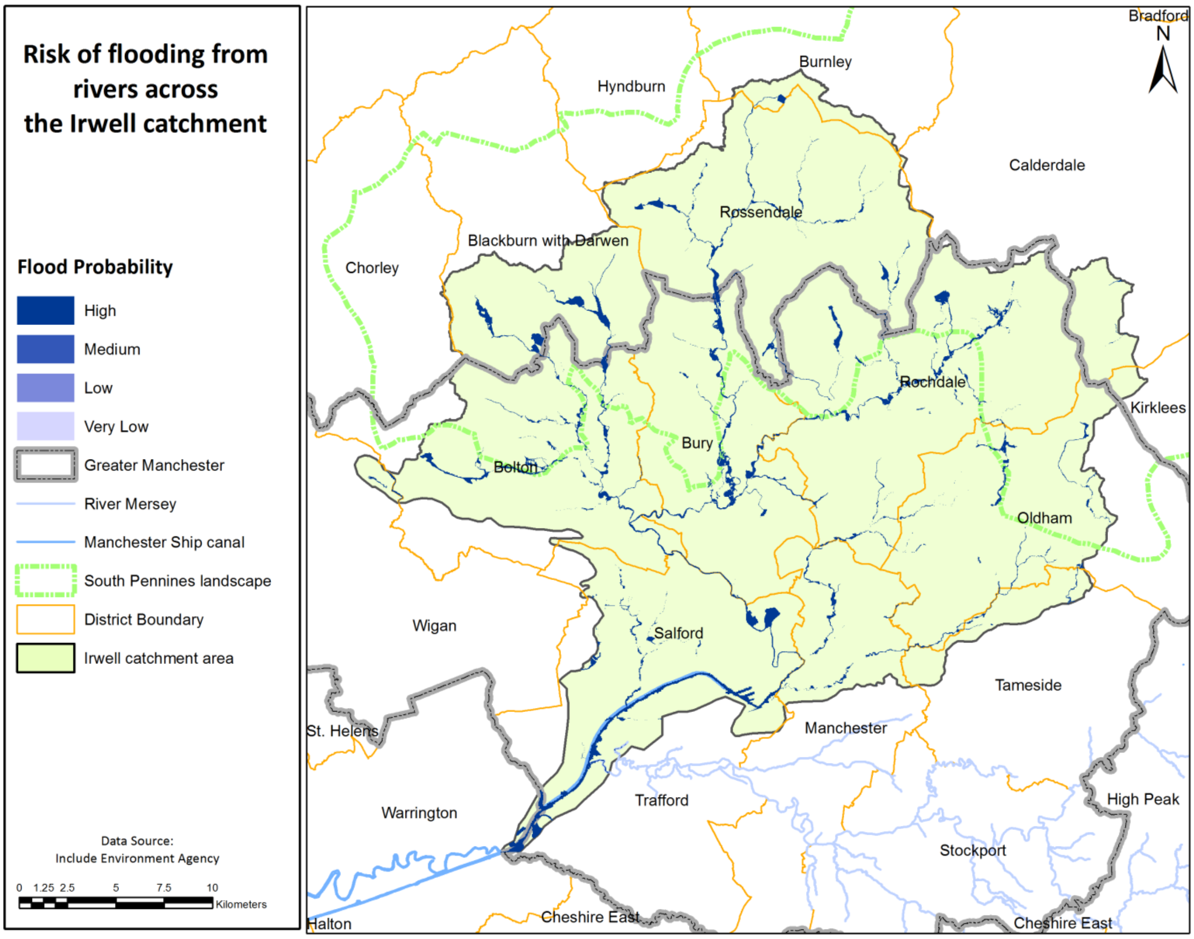
The Irwell and its tributaries place a number of peri-urban and urban areas at risk of flooding including locations within Bury, Rochdale and Salford. Figure 24 visualises data from the Environment Agency that shows locations at medium and high risk of flooding. Areas at high risk of flooding have a greater than 1 in 30 annual probability of flooding, and this figure is between 1 in 30 and 1 in 100 for areas at medium risk of flooding. This map indicates areas that remain at the highest risk of flooding after taking into account flood defences and their current condition, and incorporates input from experts who provide additional contributions related to their local knowledge and experience of the risk of flooding. Figure 23 therefore provides a clear indication of areas at risk of flooding in the Irwell catchment.

Modelling from the Environment Agency provides a good understanding of the locations within the Irwell catchment that are currently at risk of fluvial flooding. Although national scale projections for changes in flood extent are not produced by the Environment Agency, change in precipitation patterns and intensity induced by climate change will lead to changes in the spatial extent of flood risk across the Manchester region. It is generally accepted that the risk associated with fluvial flooding in the Manchester region is set to grow over the coming decades due to the influence of climate change, and modelling is available for certain areas within the Irwell catchment that projects how exposure to flooding may intensify with climate change induced uplift in river flows. This modelling essentially highlights that the locations that are currently most exposed to fluvial flood risk will become even more exposed to this climate hazard in the future, and that a flood risk management response is therefore essential.

6.1.2 The challenge of governance for flood risk

In addition to highlighting areas at risk of high flooding, Figure 23 also demonstrates the complex institutional and administrative landscape that characterises the Irwell catchment. The catchment houses a number of districts (or municipalities) and straddles the boundary of the Greater Manchester administrative city-region. Greater Manchester and district authorities have differing governance arrangements and responsibilities. This mismatch between the catchment and administrative boundaries reduces the capacity of organisations to develop joined up and holistic responses to flood risk. The Irwell catchment is also situated partially within the South Pennines Landscape Character Area which is the geographical unit that forms the focus of Pennine Prospects, a third sector organisation that concentrates on making this location a better place for people and nature. A series of interrelated governance and administrative challenges and potential opportunities flow from this situation, the nature of which form an additional focus for the Peri-cene project (and are explored in D4.2b).

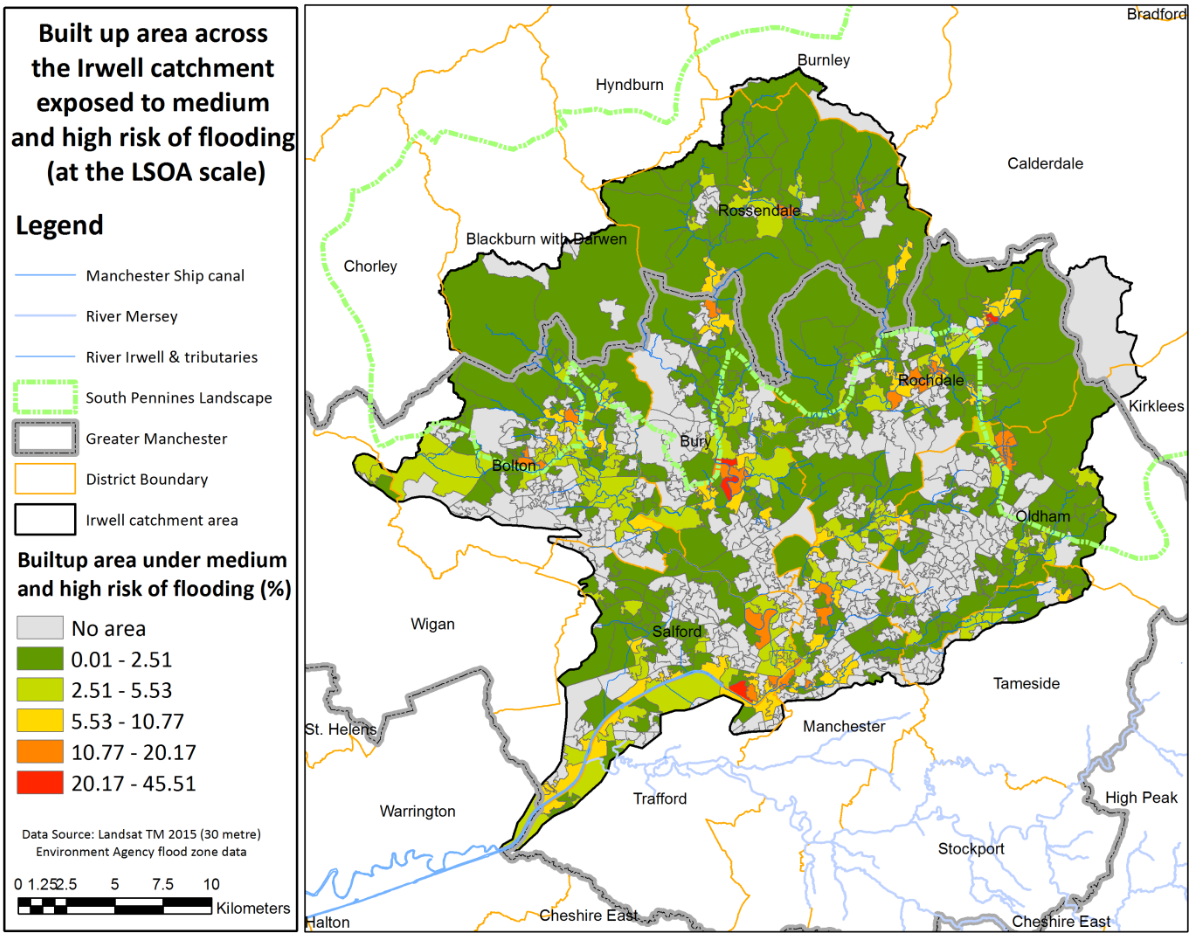
Figure 24: Risk of flooding from rivers across the Irwell catchment.



6.1.3 *Interaction of flood risk and built up areas*

Figure 24 visualises the outcome of an analysis of the percentage of built up areas in the Irwell catchment's LSOAs that are located in areas that the Environment Agency deem as being at medium and high risk flooding. This analysis also draws on Landsat data that identifies built up areas in the Irwell catchment. It is in built up areas, which contain housing, businesses and critical infrastructure (e.g. transport networks), where flooding results in major negative impacts to people's health and wellbeing and generates the most significant economic impacts. This map therefore highlights the key areas of concern regarding flood risk in the Irwell catchment. These are concentrated in urban areas (including Bolton, Bury, Rochdale and Salford) and in some cases built up areas in the peripheries of these urban centres. These areas are exposed to flooding, and also contain built up areas that could be damaged if flooding occurs. Following the IPCC's AR5 risk-based approach, there is a spatial coincidence between exposure to floods and vulnerability to damage from flooding (due to the presence of buildings and therefore people) which increases the level of associated risk.

Figure 25: Built up area across the Irwell catchment exposed to medium and high risk of flooding.

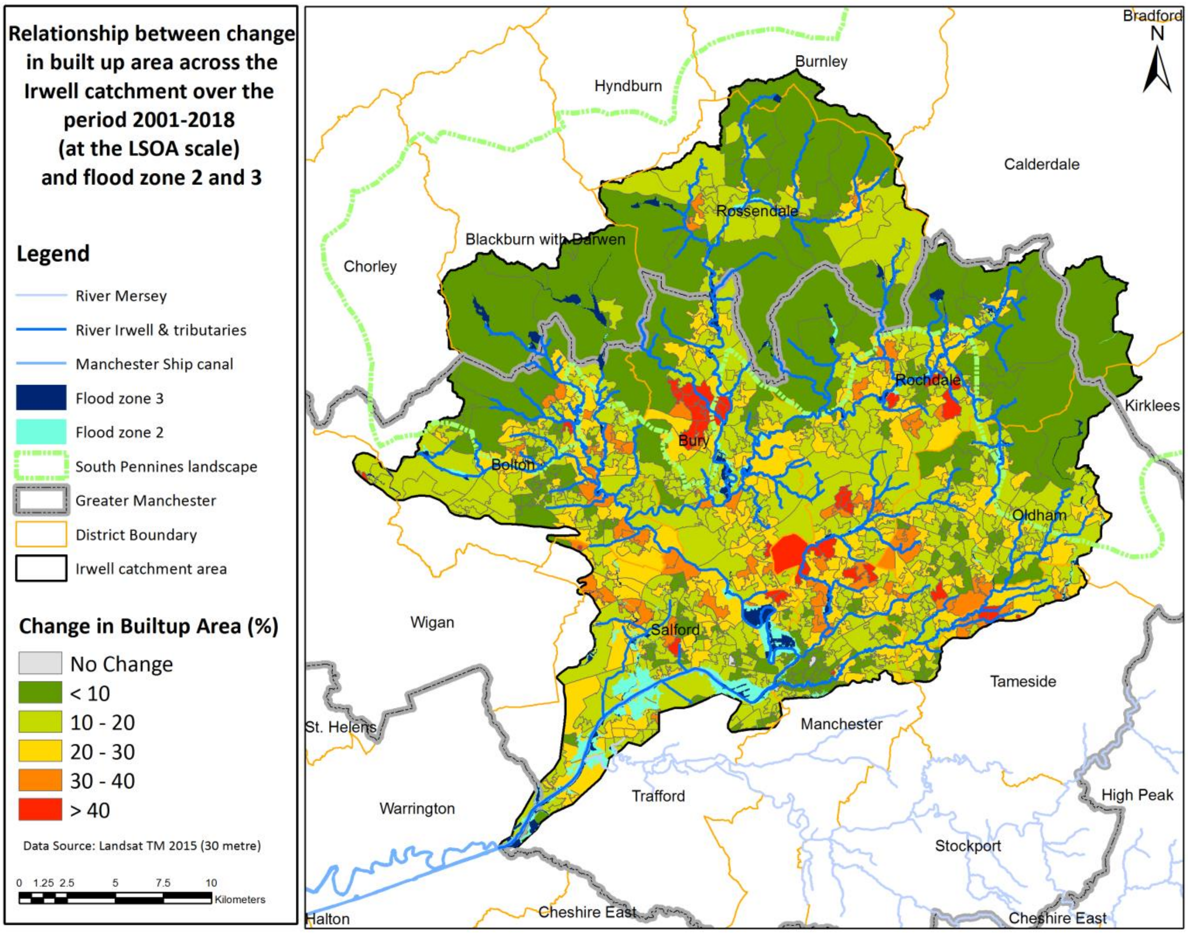


The Irwell catchment has seen a considerable amount of new development take place over recent decades (Figure 25). Figure 25 highlights the relationship between areas of new development and the Environment Agency's flood zones 2 and 3. Flood zone 2 represents land assessed as having an annual probability of flooding from rivers of between 1 in 100 and 1 in 1000. Flood zone 3 is land assessed as having a greater than 1 in 100 annual probability of flooding. The district of Bury contains several locations where a relatively high amount of newly built up area is exposed to medium and high risk of flooding (as demonstrated by Figure 25). Figure 25 indicates that there has been a significant amount of new development immediately to the north of locations in Bury that are exposed to flooding (flood zones 2 and 3). These areas are close the river Irwell and its tributaries, increasing the risk of rainwater runoff from hard surfaces reaching these watercourses and potentially increasing downstream flood risk.

6.1.4 Interaction of new development and flood risk

Similarly, a chain of LSOAs situated along the river Irwell and its tributaries running through Bolton and Salford, down towards sites in Salford that have large areas exposed to flood zones 2 and 3, have also seen notable amounts of new development over recent decades. Although there have been flood defence works around Bury and Salford, the implications of this new development on the hydrology of the river Irwell and its tributaries, coupled with climate change induced uplift in rainfall volumes during extreme rainfall events, increases the likelihood that more communities and infrastructure will be exposed to fluvial flooding, and potentially increases the level of exposure (in terms of depth of flood water) in places that already experience flooding from rivers. Not only has new development potentially contributed to higher river flows with associated implications for enhanced flood risk, new development has also occurred in areas already exposed to flood risk, for example in Salford and Rossendale. However, planning guidance is in place to steer development away from sites at high flood risk and to encourage building design to reduce flood risk if development does take place in such locations.

Figure 26: Change in built up area across the Irwell catchment (2001-2018) and flood zones 2-3.



6.2 Natural Flood Management in the Irwell basin

It is widely recognised that the risk of flooding needs to be addressed at several connected scales in a holistic manner, from the building to the catchment scale. This means that in some cases flood reduction benefits to urban areas can be achieved by measures located upstream in peri-urban areas. The European Environment Agency notes that: 'Flood risks in a city can be strongly influenced by factors outside the city boundaries such as upstream river management. It requires a regional approach for solving the urban flood problems' (EEA 2012, 35). As part of this approach, much academic and policy interest is directed towards the examination of natural flood management (NFM).

European and UK policy has been moving towards the adoption of NFM as part of a holistic flood risk management strategy that can address numerous goals around climate change adaptation, biodiversity and health and well-being. In the UK, the NFM agenda has become more pronounced since 2004 following the Foresight Future Flooding project and Making Space for Water (2005) which signalled the adoption of a new approach to flood risk management in the UK that sought to work with water rather than against it. In 2017, the UK government allocated a further £15 million of funding to NFM projects and the approach is cemented in the UK Government's 25-Year Plan (25 YEP) for the Environment which was published in 2018. This has entailed an increased focus on how upstream land management, for example, can help to moderate flood risk further downstream.

NFM, which is also referred to using terms including Working with Natural Processes and Nature Based Solutions (Lane 2017), encompasses measures that aim to, "...protect, restore and emulate the natural functions of catchments, floodplains, rivers and the coast" (Environment Agency 2018: iv). The UK Government's 25 year plan for the environment, published in 2018, is the most recent in a sequence of policy statements that have progressively embedded NFM as a constituent element of the flooding response alongside traditional engineered flood risk management approaches. Researchers are increasingly exploring NFM, with Wingfield et al (2019: 743) describing it as "...a progressive holistic flood management approach..." In addition to its role in flood risk management, the potential offered by NFM to deliver other socio-economic and biophysical benefits, including climate change adaptation (Iacob 2014), is key to its broadening appeal. From the perspective of climate change adaptation, NFM not only offers the potential to reduce future flood risk, but can also support adaptation goals related to biodiversity and wildfires. Further, NFM can be more successful when integrated with land management, farming and urban design sectors, for example, and especially where long term financial arrangements for maintenance are put in place.

6.2.1 NFM in the South Pennine uplands

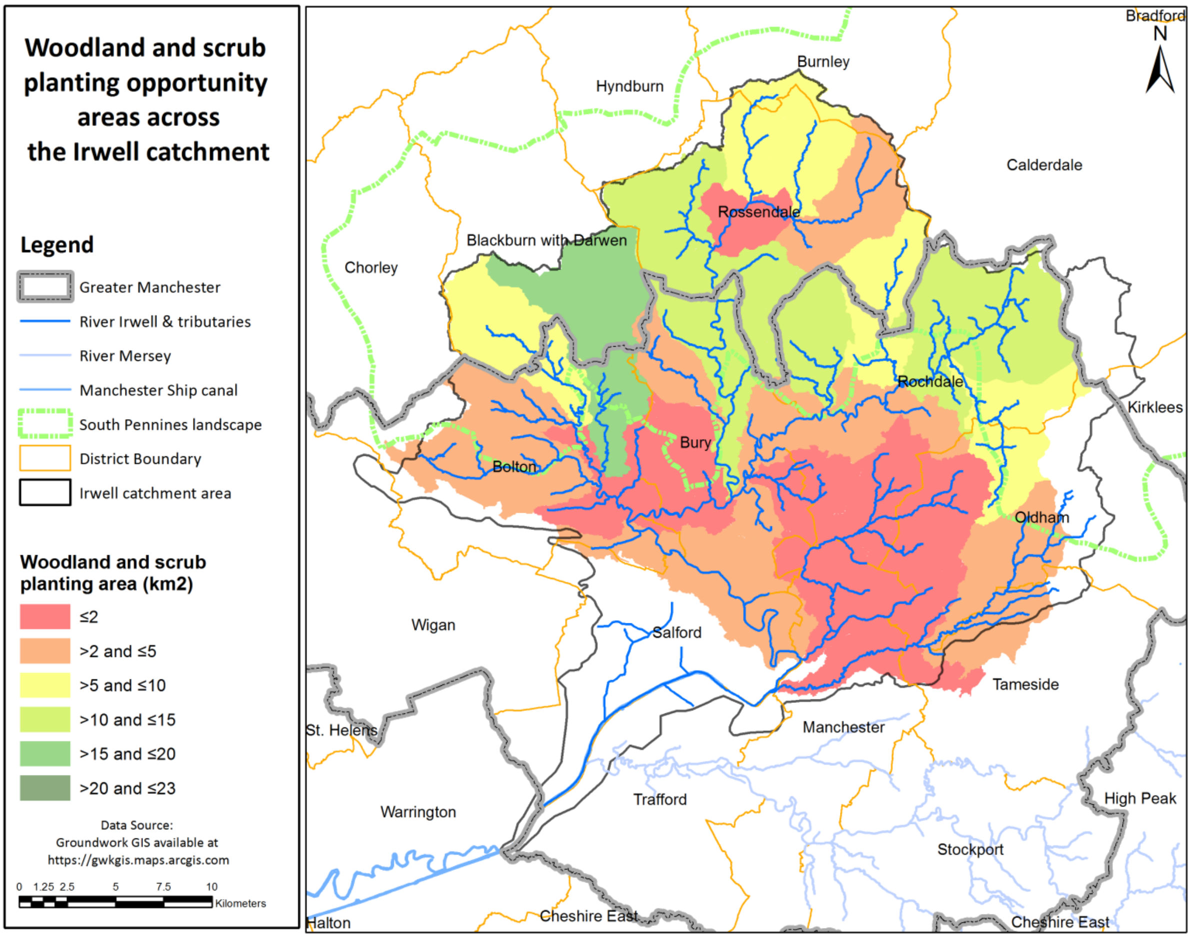
Ongoing research is examining the effectiveness of NFM in the South Pennine uplands to moderating downstream flood risks (https://protectnfm.com/), with emerging schemes including the South Pennines Park opening up the potential for related activities including re-wilding and reforestation. The Irwell catchment contains landscapes that offer varying degrees of potential to provide NFM functions. Previous research highlighted the spatial distribution of existing green infrastructure (GI) landscapes across the river Irwell catchment that provide different flood risk management functions (Carter et al. 2018). This research demonstrates that much of the GI with high flood risk management functionality is situated in the north of the Irwell catchment, in the peri-urban and rural areas that border and in some cases lie beyond the administrative boundary of the Greater Manchester conurbation. These peri-urban upland landscapes have a role to play in alleviating flooding in towns such as Rochdale, Bury and Bolton and also lower down the Irwell Valley in Salford.

There is increasing recognition that it is not appropriate or feasible, particularly in the context of climate change, to protect areas at risk of flooding in places such as Rochdale, Bury and Salford solely with traditional 'hard' flood defence approaches such as building embankments and straightening rivers. Greater attention is now being paid within policy and practitioner communities to NFM as part of a wider suite of approaches to manage flood risk. Following the IPCC AR5 framing of climate change risk, NFM can act to reduce exposure of locations to flooding by lowering the volumes of water reaching river channels and thereby the spatial extent and depth of flood waters in downstream areas.

6.2.2 Typical NFM options

Tree and scrub planting is one type of NFM approach. Trees and scrub (lower 'bushy' vegetation) can trap rainwater, some of which then evaporates or is released slowly into the surrounding landscape. The presence of trees and scrub therefore reduces the volume of water released into rivers and streams and lessens the speed at which this water reaches these watercourses. Tree and scrub root systems also act to increase the permeability of soils, raising their capacity for infiltration of rainwater hence slowing the flow of rainwater runoff into rivers and streams. Trees and scrub also perform this function by providing physical barriers that slow the flow of rainwater across the landscape. Figure 26 shows the extent to which different sub-catchments within the Irwell catchment provide opportunities for tree and scrub planting. It highlights that areas that present greater opportunity in this respect are situated in peri-urban and rural upland and river valley landscapes to the north of the Irwell catchment. In this case, it is apparent that areas of flood risk, and those areas of flood risk management opportunity offered via NFM provision, may be located some distance apart. This emphasises the value of catchment based approaches to flood risk management where natural functions and hydrological processes are considered and planned for at wider spatial scales.

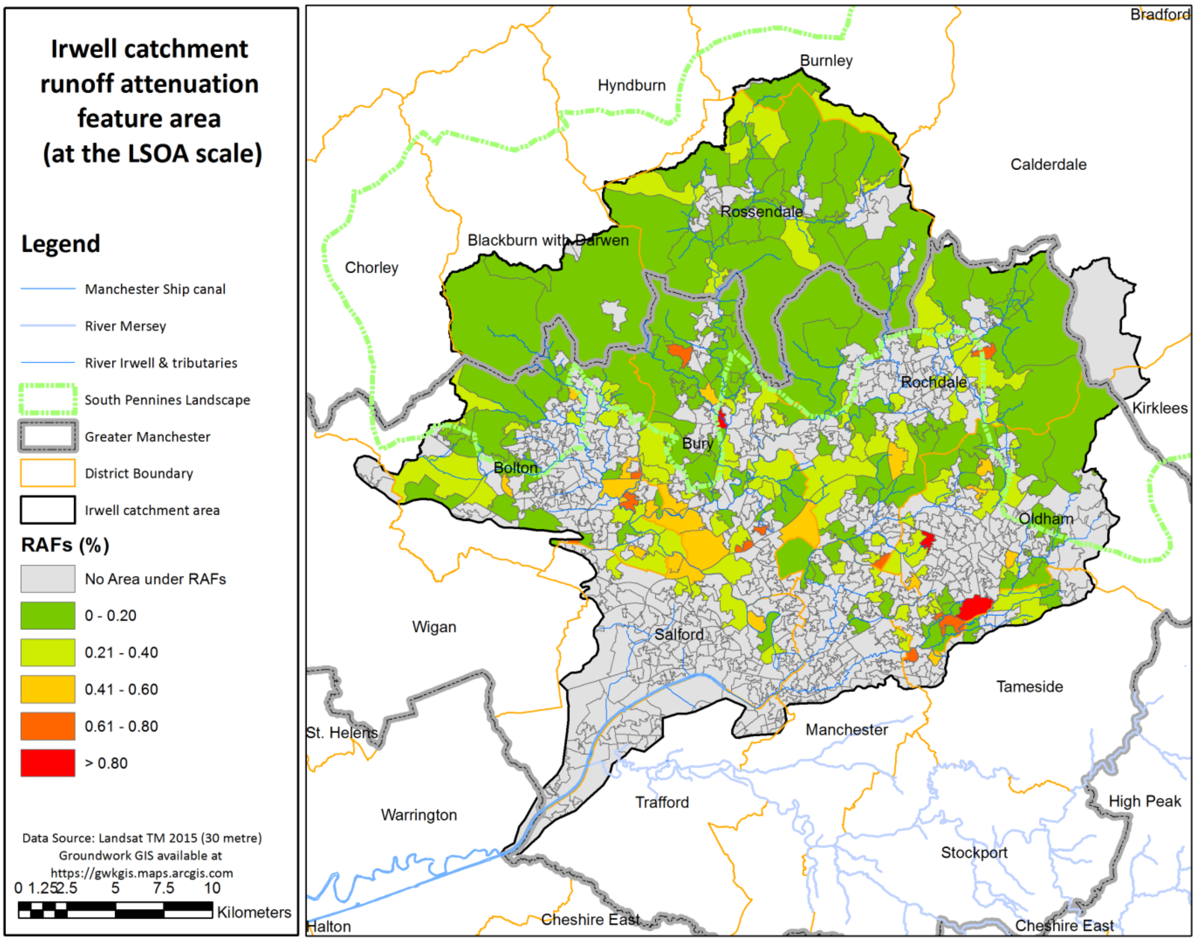
Figure 27: Woodland and scrub planting opportunity areas in the Irwell catchment.



Runoff attenuation features are another form of NFM. They are characterised as small scale, low cost and 'soft' flood risk management approaches. In addition to slowing the flow of and collecting (or attenuating) rainwater, thereby reducing the volume and speed at which this rainwater reaches water courses, runoff attenuation features can also filter rainwater runoff bringing associated water quality benefits. Types of runoff attenuation features include bunds (stone, wood, earth) to intercept and store flows of rainwater in the landscape, 'in-channel' instillations such as 'woody dams' and barriers, and ponds that temporarily store water diverted from streams or rivers before releasing it slowly back into the channel.

Figure 27 shows runoff attenuation feature coverage at the LSOA scale and highlights that, from a general perspective, opportunities for implementing runoff attenuation features are concentrated in the upland areas to the north and east of the Irwell catchment and in river valley corridors. A clear example of the latter concerns the opportunity for locating runoff attenuation feature within the upper reaches of the River Medlock running into Manchester city centre from the upland areas to the south of Oldham. This map also highlights particular LSOAs with a higher proportion of their area that could be dedicated to runoff attenuation features. In some cases these coincide with locations at high risk of flooding, for example around Bury and Rochdale and upstream of sites exposed to high flood risk in Salford. The proportion of the total area of LSOAs in the Irwell catchment that could be utilised for runoff attenuation features is relatively low. However, multiple runoff attenuation features can be implemented strategically across the catchment to collectively to manage overland flow of water following heavy or prolonged rainfall and therefore reducing downstream flood risk.

Figure 28: Irwell catchment runoff attenuation features (LSOA scale).



7.3. NFM governance in the Irwell basin

There is an increasing appreciation within the scientific, policy and practitioner communities of the contribution that NFM can make to the reduction of flood risk (Environment Agency 2018, Lane 2017), although researchers do caution that NFM effectiveness in this respect is context and scale dependant (Dadson et al 2017). Indeed, NFM should be regarded as an element, currently under-utilised, of a wider set of flood risk management responses, as outlined above.

Existing research demonstrates that landscapes offering higher potential for NFM are often situated in the upland areas to the north and east of Greater Manchester (Carter et al 2018).

However, there are multiple competing visions for these upland landscapes. Aside from providing potential capacity for developing NFM schemes, they are also areas where agriculture, recreation, water industry, biodiversity, game bird shooting and housing development have an interest and a stake their future. There is also growing controversy on upland land management practices in privately owned estates. For example, it appears that the intensification of drainage and burning linked to grouse shooting could be directly contributing to increased run-off from these landscapes, contributing to downstream flood risk (Avery, 2015).

Multiple public, private and third sector organisations are engaged in the management of these landscapes, and in flood risk management more generally in and around Greater Manchester (Ravetz and Connelly 2019). A range of organisations will therefore need to be engaged in the development, implementation and maintenance of NFM measures in the Manchester region for this agenda to be more commonly applied. The multiple and sometimes overlapping administrative boundaries within which these organisations operate provide an additional complication concerning the development and governance of NFM measures in this context (see Figure 27 which highlights the range of administrative boundaries present within the Irwell catchment).

More broadly, governance challenges around flooding and climate change have been identified e.g. 'scalar mis-match' (e.g. Cumming et al. 2006) and 'institutional spaghetti' (e.g. Ravetz and Connelly, 2019). Further work is needed on potential governance approaches and adaptive pathways for delivering NFM within peri-urban areas (and other adjoining areas), as part of wider catchment scale flood risk management responses. These issues are explored within the Peri-cene project and reported in D4.2b.

7 Case studies B&C: Pennine and Cheshire hinterlands

In this section we explore the wider region hinterland, with two contrasting case study areas: the South and West Pennines, and the Cheshire plain.

The context is shown by the land cover map in Section 6 (Figure 16), which highlights that:

- To the north and east, land cover mainly consists of marginal grassland, pockets of tree cover, and moorland scrub / bog. These land uses dominate the South and West Pennines area, defined as 'Natural Area 36' in the Natural England landscape classification.
- To the south and west, pasture and agricultural crops dominate. These land uses are prominent in the Cheshire and Mersey plains area. As this is a quite extensive landscape type, we refer simply to the East Cheshire District boundary as a representative unit.

7.1 South & West Pennines

This area is one of low hills (<500m) with moorland peat bogs, upland hill farming, steep valley sides, former industrial towns in the valley bottoms, overlaid with newer suburban type developments. The whole area has several key relationships / functions for the 3 metropolitan areas which surround it (Greater Manchester, West Yorkshire and East Lancashire):

- Location of headwaters which feed the rivers in the urban areas, and some water resources.
- Location of key infrastructure: transport, water, energy.
- Location for old & new high quality housing.
- Niche economies as in market towns (e.g. Hebden Bridge).
- Zone for lifestyle eco-gentrification and new awareness of ecosystems.
- Location for tourism and leisure.
- Unique landscape and ecosystem types (defined as Natural England area 36).

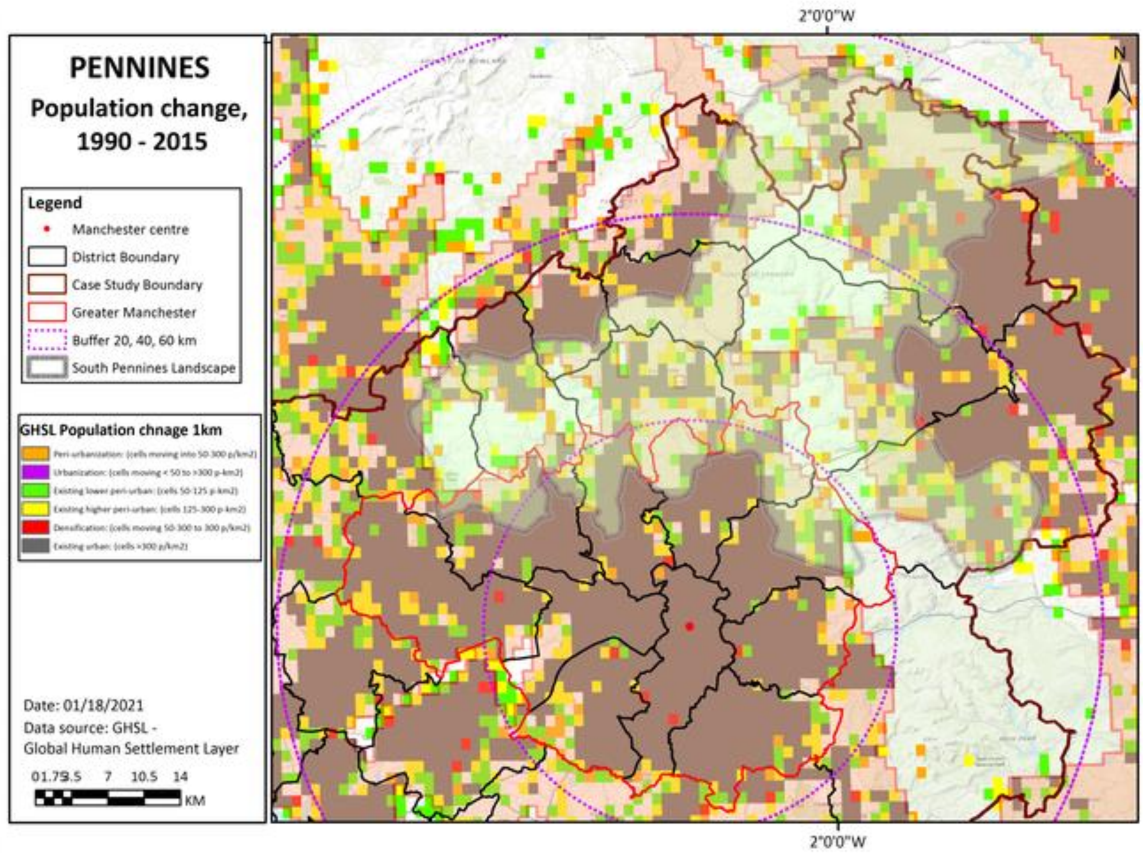
This makes the area a very relevant Peri-cene case study, particularly as a new organization has been set up to address the problems and mobilize the opportunities. Pennine Prospects (shortly to be the South Pennines Trust) is a unique partnership agency supported by 13 municipalities, various government agencies, the water utilities and many local business and social organizations. With ongoing dialogues this case study has explored many of the inter-connected problems and potential opportunities or pathways going forward. .

7.1.1 Where is the Pennine peri-urban?

The South and West Pennines is defined as a landscape type by Natural England (Natural Area 36), a unique combination of upland peat bog, upland farming, steep sided valleys and industrial towns. This covers parts of 13 different local authorities, with challenges on cross-boundary governance. Figure 28 shows the general mapping of this area:

- The area includes the edges of large urban areas on 3 sides.
- Smaller areas of peri-urban densities (50-300 p/km2) are located along the river valleys.
- There is widespread peri-urbanization (conversion of open / sparse areas into peri-urbanization: this reflects the repopulation of areas which previously declined along with local industry and farming.
- The whole area lies within the 60km radius of GM and also of the other conurbations to east and west.

Figure 29: South and West Pennines population change 1990-2015.



7.1.2 Climate-peri-urban issues & challenges

Key issues & dynamics

- Landscape of low heather moors & peat bogs, with former industrial towns in steep sided river valleys, in the peri-urban hinterland of large conurbations to the east and west.
- Economic change via industrial decline & shift to services & commuting economies: some new land-based activities, horsiculture etc.
- Social change via indigenous decline & incoming migrants, polarization & widening income gaps, gentrification & rising asset values, eco-alternative cultures.
- Policy trends are for small state withdrawal of public services & welfare benefits.
- Direct vulnerability to climate change is increasing mainly by drought, wildfire, soil erosion, & fluvial flooding.
- Indirect vulnerability to induced effects is increasing with a range of possible causal impact chains.

Key impacts & multipliers

- Food price rises due to overseas climate change may put pressure on lower income households on reduced benefits.
- Housing pressure & rising values pushes some new housing into areas at higher risk of fluvial flooding.
- Forest species are threatened by rising temperatures and low water availability, exacerbating soil erosion on valley slopes, combined with post-CAP farm subsidy withdrawal, increases fluvial flooding risk & intensity, lower areas of towns are no longer cost-effective to defend.
- Social polarization & peri-urban in-migration widens the income gap & housing shortage, some higher ground is high value enclaves with private fire insurance, lower income households are forced into flood risk areas where insurance is not available.

Key questions & challenges

These issues and multipliers raise difficult questions & challenges, where peri-urban development and climate change are mutual 'threat multipliers' (and also, potentially 'opportunity multipliers'). These questions were explored in various interviews and also a conference workshop hosted by Pennine Prospects, in November 2019. Key emerging questions include:

- With increasing pressures of climate change who is the S&W Pennines for – local residents (rich or poor?), incoming residents, incoming visitors?
- With increasing pressures of population and housing, combined with climate change disruption – should the S&W Pennines:

(a) expand with population coming from urban areas?
(b) maintain existing population levels?
(c) plan to reduce population in areas of high risk & high ecosystem value?
(d) look for new synergies & combinations of people, economic activity & climate proof ecosystems?

7.1.3 Peri-urban climate change risk and adaptation

To understand the effects of peri-urban development on climate risk (and vice-versa), this section draws on the 5-part Peri-cene Framework, based on the IPCC risk & vulnerability framework (see Section 3.3). The focus here is on peri-urban climate change risk, adaptation and resilience themes from a broad perspective as it is not feasible to undertake a detailed multi-sectoral analysis at these spatial scales.

Firstly we can explore the different elements of this unique peri-urban landscape of the south and west Pennines. Some key peri-urban determinants include:

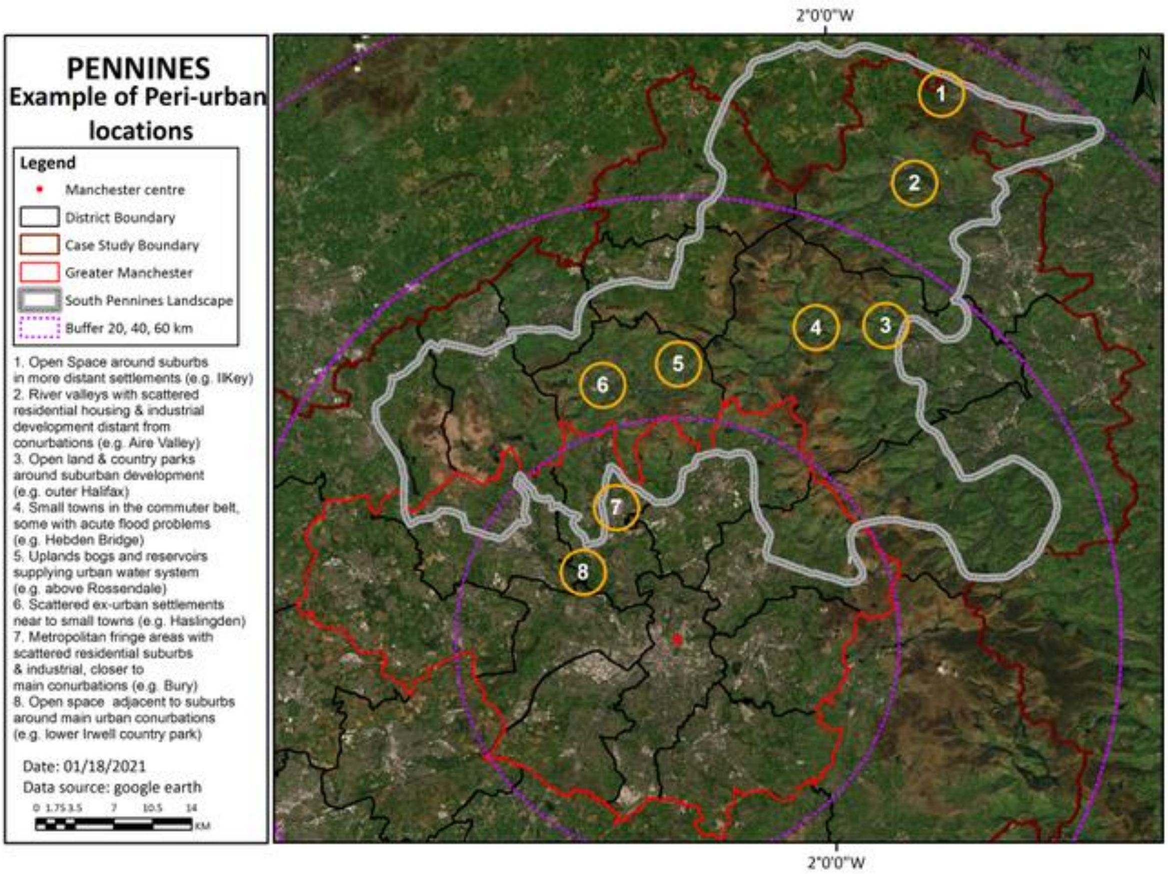
- Proximity (outward) to conurbations for services & work.
- Proximity (inward) to conurbations for tourism & leisure & housing markets.
- Demographic change as a key factor in local livelihoods, demand for services etc.
- Development pressure and housing change and as a key determinant of demographic change.
- Access to open space adjacent to settlements is key for amenity / leisure / new forms of urban rural linkages.

This is provides some insight on how different peri-urban land-use 'types' present different climate change risk challenges and adaptation response opportunities. Within this area there are various peri-urban types including:

1. Open space around suburbs in more distant settlements (e.g. Ilkey).
2. River valleys with scattered residential housing and industrial development distant from main urban conurbations (e.g. Aire Valley).
3. Open land and country parks around suburban development (e.g. outer Halifax).
4. Small towns in the commuter belt, some with acute flood problems (e.g. Hebden Bridge).
5. Uplands bogs and reservoirs supplying urban water system (e.g. above Rossendale).
6. Scattered ex-urban settlements near to small towns (e.g. Haslingden).
7. Metropolitan fringe areas with scattered residential suburbs and industrial developments, closer to main urban conurbations (e.g. Bury).
8. Open space areas adjacent to suburbs around main urban conurbations (e.g. lower Irwell country park).

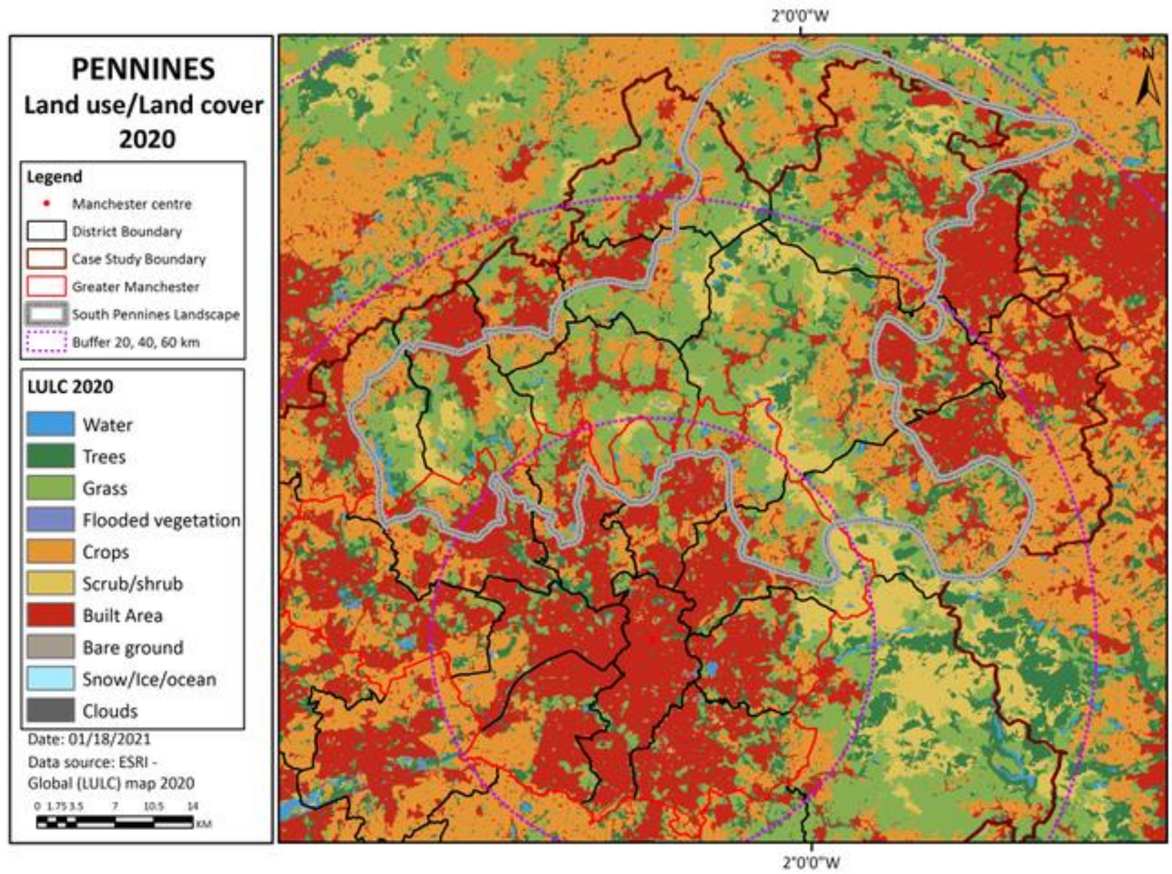
These different peri-urban types can be visualised spatially (Figure 29).

Figure 30: South and West Pennines: example peri-urban locations.



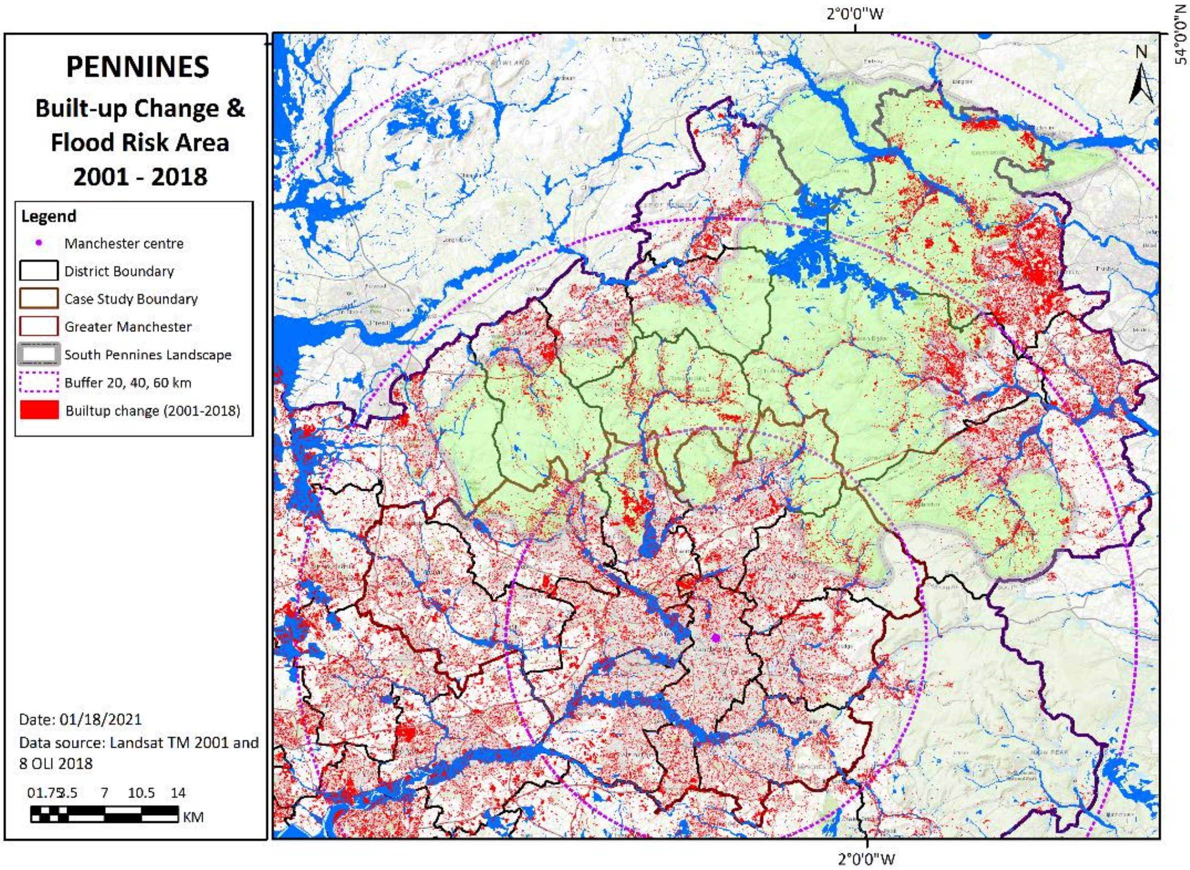
Land use & land cover in the Pennine area is a mixture of upland peat bogs, marginal pasture land / scrub, steep sided valleys with pasture and woodland, some arable farming at lower altitudes (see Figure 30).

Figure 31: Land use and land cover in the Pennines.



All rivers in the Pennine area show some degree of flood risk, due to their particular geography. Surface water flooding is also a major risk. There are critiques of the upland land ownership and management regime, which puts the interests of game shooting ahead of the need for water retention. The map in Figure 32 shows an overlay with new housing development 1990-2015: many of the new peri-urban areas are within or close to known flood risk zones.

Figure 32: Flood risk overlaid with new housing 1990-2015

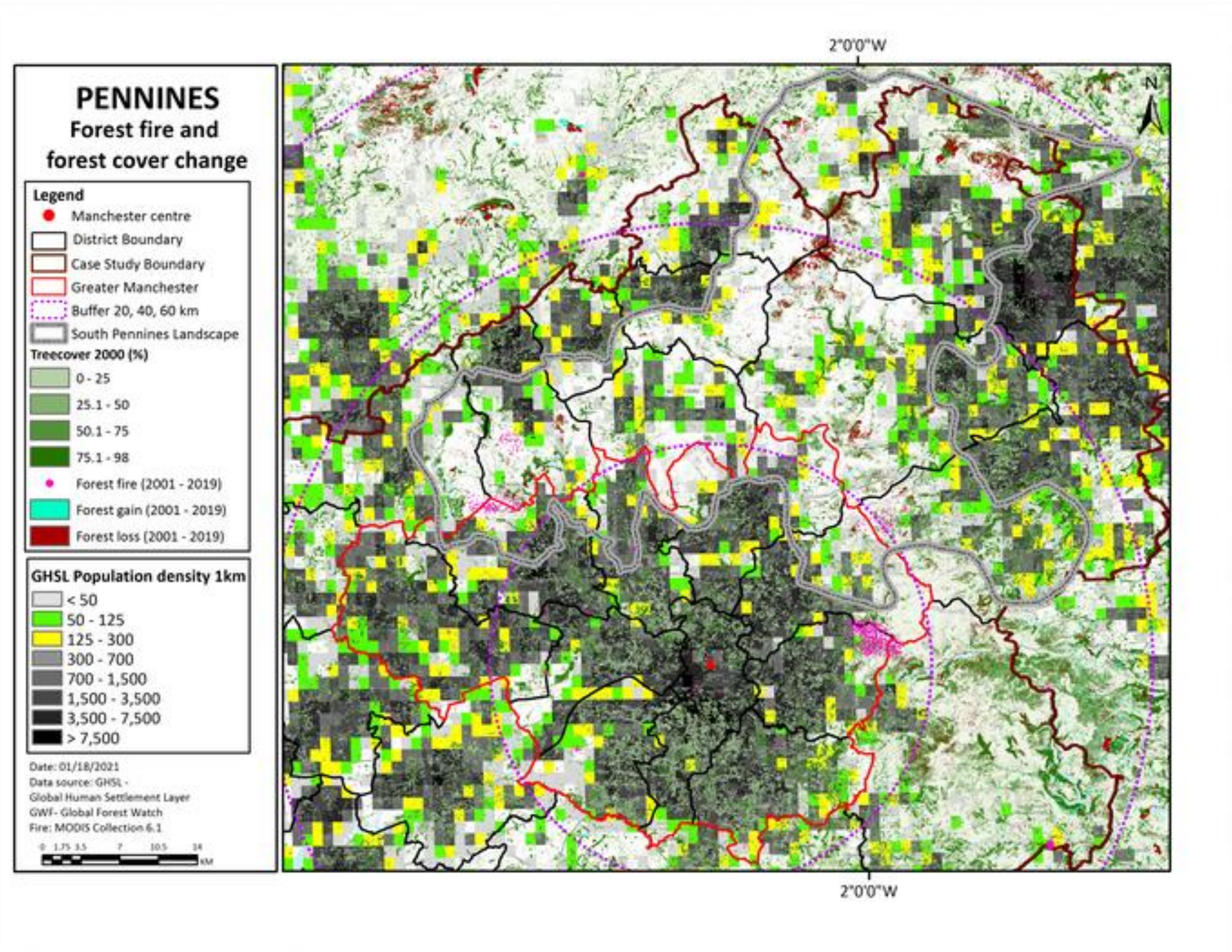


7.1.4 Flood & fire risk in the Pennines

Forest cover in the Pennines is mainly found in small woodlands, interspersed with the marginal farmland, and on the sides of valleys. There are some larger protected areas of ancient woodland, for instance the Crags north of Hebden Bridge, along with some areas of coniferous plantation. Many argue the need for large scale reforestation, for landscape and ecosystems restoration.

Wildfires occur mainly on upland areas of scrub and peat bog, and the map shows something of a 'ring of fire' on the hills surrounding GM (Figure 32).

Figure 33: Forest fire and forest cover change, Pennines.

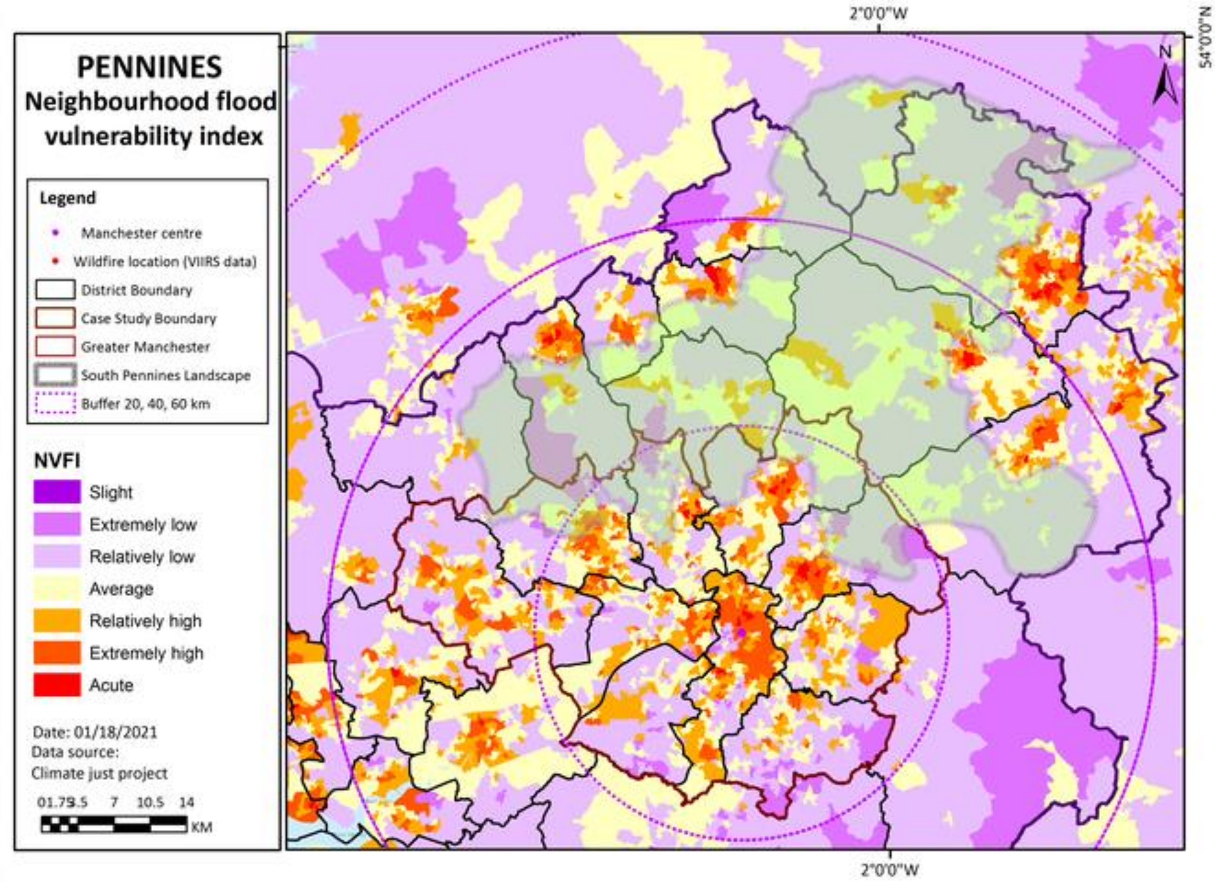


7.1.5 Vulnerability in the Pennines

Concerning social and economic vulnerability, the mapping here of the 'neighbourhood flood vulnerability index' is a starting point (Figure 34). Many of the Pennines valleys are locations of former industry, with typically large numbers of small terrace houses, with inadequate construction and little protection from either fluvial or surface water flooding. These combine with high levels of dependency, ill-health and low incomes for certain sections of the population, who are also less likely to have adequate insurance. In contrast there are some higher income areas with low vulnerability, mainly in suburban or ex-urban developments, to the west and north.

Meanwhile the larger areas of highest social vulnerability are mainly just downstream, in the inner areas of the surrounding conurbations: this demonstrates the inter-dependency of peri-urban and urban.

Figure 34: Neighbourhood flood vulnerability index



7.1.6 Overview of climate impacts, adaptation & governance in the Pennines

Taking forward this analysis, Table 6 opens up issues linked to variations in climate risk and adaptation themes that emerge depending on peri-urban type. The Peri-cene '20 questions' template (Appendix 10.2) provides a further layer of analysis, and this resource enables comparison to other cities engaged in the Peri-cene network.

Key emerging themes for the south and west Pennines include:

The peri-urban areas of the south and west Pennines have a strong connection to climate change agendas. These areas are at risk from climate change hazards (e.g. flooding, drought, wildfires). Open landscapes in the uplands to the north and east of GM present adaptation opportunities, particularly linked to flood risk management and 'slowing the flow.' This theme is discussed in more detail in Chapter 7. These areas also have a role to play in climate change mitigation, particularly given that upland peat landscapes are an important carbon sink.

In addition to being exposed to extreme weather and climate hazards (particularly fluvial flooding) communities living in former industrial towns and smaller settlements within peri-urban areas are also vulnerable to such hazards due to factors linked to poor health and socio-economic deprivation. In GM, as in other urban areas, the most vulnerable communities tend to be located in areas with highest exposure to climate change impacts (in this case flooding) with their vulnerability further enhanced by challenges accessing flood insurance. These drivers of vulnerability are intensified by policy trends towards small state withdrawal of public services and welfare benefits. This increases levels of risk faced by communities should they be exposed to floods, for example, the prevalence of which are projected to increase over the coming decades with climate change.

In addition to the direct impacts of climate change, multiple complex and uncertain indirect impact connected to climate change impacts operate at various interconnected spatial scales. For example, food price rises due to overseas climate change events puts pressure on lower income households which further erodes capacity to adapt to climate hazards should they occur thereby increasing their level of risk.

There has been significant economic change in south and west Pennine peri-urban areas driven by industrial decline and an associated shift to services and commuting economies. Some new land-based activities have emerged including grouse shooting estates and housing development. These have generated tensions with local communities, in some cases linked to the worsening of climate change risks, particularly flooding. For example, heather burning on grouse moors degrades the landscape reducing its capacity to store water, and new housing development increases hard surfacing and associated rainwater runoff into water courses. Further, some new houses are built in areas already known to be exposed to flood risk, although the planning system includes some measures to help moderate this risk linked to building location and design.

There are competing demands on peri-urban landscapes in the south and west Pennines area. Key tensions include managing the demands for land to provide farming and recreation opportunities versus calls for the same landscapes to provide undisturbed areas for conservation of biodiversity.

Given the multiple land uses present in these peri-urban landscapes, governance and stakeholder engagement are key to any prospective transitions in the south and west Pennines. This activity is challenged by silo thinking and working, austerity cutbacks in budgets of public sector organisations agencies, mismatch between administrative and biophysical boundaries and difficulties in engaging 'hard to reach' stakeholders and communities.

Table 6: Climate change governance issues and challenges in the Pennines.

	NEAR URBAN (within FUA	***FURTHER HINTERLAND (Outside FUA***
Higher density 125-300	***a) 'Urban edge'***:	***d) 'peri-urban settlement'***:
Peri-urban forms & locations	Urban / suburban fringe landscapes encompassing land cover types including built environment, formal and informal recreation, transport corridors, modified river channels.	Urban / suburban extended sprawl and built up areas encompassing retail, industrial and residential land use types. Desakota type rural and urban land use combinations. Urban-rural exchange of local food and resources, supporting visitor economy.
Climate change risk & adaptation issues / challenges	Exposed to hazards including fluvial and pluvial flooding and heat stress. Natural/semi-natural landscapes provide adaptation functions linked to urban cooling and flood risk management.	Fluvial flood risk to communities living in steep sided river valleys. Provision of recreation opportunities to inhabitants of urban centres during periods of high temperature.
Typical governance issues / challenges	Strategic management of conurbation open space via the planning system. Conflict linked to green belt preservation and housing targets. Challenges include competing levels of government and demands from private ownership / public goods. Landscapes also offer co-benefits linked to health and wellbeing etc, bringing associated need for wide stakeholder and community engagement.	Management of diffuse urban sprawl in outer hinterland (ex-urban settlements and/or former industrial settlements). Greenbelt in place to offer some protection to landscapes from development pressure. Planning system has a role to play in reducing climate risk and conserving areas providing adaption functions.
Lower density 50-125	***b) 'Urban fringe':***	***e) 'peri-urban spread':***
Peri-urban forms & locations	Dispersed built land cover types including retail, industrial, residential and open natural/semi-natural land used for agriculture, woodland regeneration, recreation.	Open upland landscapes and internationally significant peat bogs. Utilised for marginal livestock farming and recreation. Desakota type rural and urban land use combinations.
Climate change risk & adaptation issues / challenges	Exposed to hazards including fluvial and pluvial flooding. Natural/semi-natural landscapes provide adaptation functions linked to provision of biodiversity corridors, urban cooling and flood plain water storage.	Wildfire risk in upland heather moor and peat landscapes. Receive high levels of rainfall which is transmitted via river systems to downstream urban areas. Upland areas provide adaptation functions, e.g. linked to natural flood management provision and biodiversity conservation.
Typical governance issues / challenges	Multi-stakeholder governance of open / semi-rural land with high amenity value, agricultural demand and industrial pollution legacies. Role for the planning system in guiding the development and use of land. Challenges associated with multiple and overlapping administrative boundaries that do not recognise biophysical realities (e.g. river catchments).	Need for transboundary governance frameworks to link across administrative areas/districts and stakeholder networks to resolve competing visions for upland landscapes, e.g. marginal farming, recreation, biodiversity conservation. Planning system has limited influence over farming land use decisions.

7.2 Cheshire Plain

This area represents a more rural zone of relative affluence, urban expansion and commuting, together with productive farmland. There is some industrial infrastructure to the north side, and some larger towns, in particular Crewe, have high levels of deprivation. Climate change risks affect both these social groups, and the surrounding landscape of mainly arable farming, tangible risks to present day agricultural systems, along with riverine flooding, landscape and ecosystems disruption.

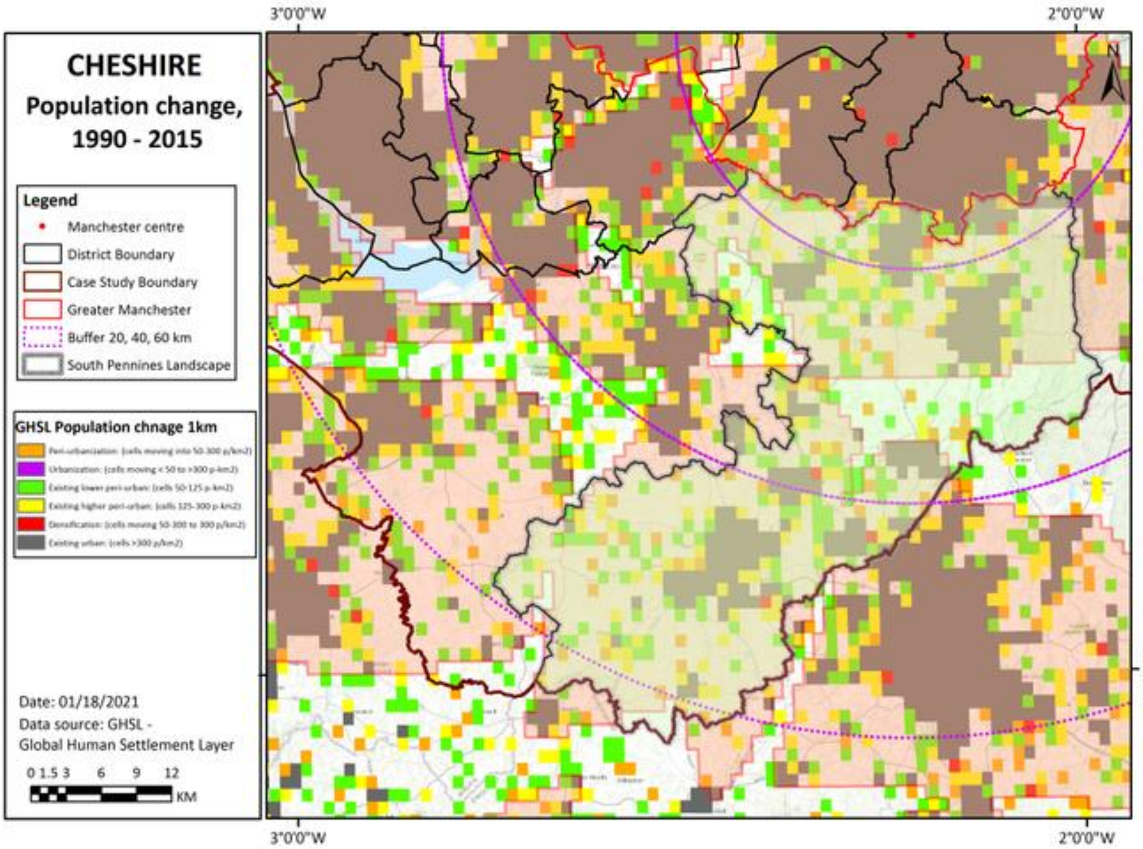
This case study focuses on the part of the East Cheshire district in proximity to GM, while many of the West Cheshire and surrounding areas are similar.

7.2.1 Where is the Cheshire peri-urban?

Peri-urban types and population change are visualised in Figure 34. This highlights insights including:

- The northern section close to the GM boundary shows large areas of peri-urban densities (50-300 p/km^2) (shown as yellow and green), and these also spread between larger towns such as Wilmslow, Congleton and Knutsford.
- For the changes over 25 years, many formerly rural cells have 'peri-urbanized' (i.e. developed into the 50-300 band, shown as orange), often coalescing around smaller settlements, also with some new housing estates around the new economic corridors.
- very few areas have 'urbanized' (i.e. developed directly from rural into the urban >300 band, shown as red): and none have 'densified' (from peri-urban to urban).
- Overall this suggests a pattern of peri-urban population growth, alongside strong green belt and white land planning policies.

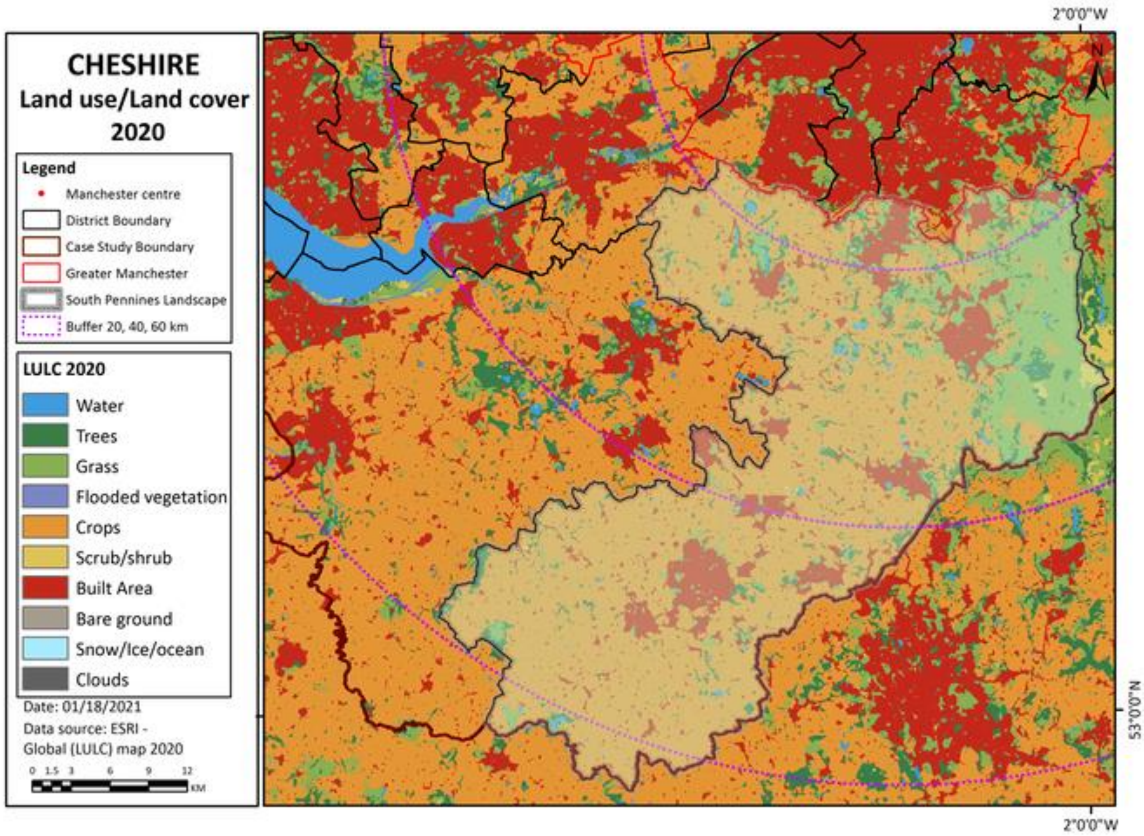
Figure 35: Cheshire population change (1990-2015).



7.2.2 Climate impacts on landuse and agriculture in Cheshire

Landuse and land cover in the Cheshire area, according to the overview in Figure 36, show a predominantly arable farming county. There are larger areas of pasture towards the hills in the east, and numerous areas of woodland, mainly mixed and deciduous. Much of this agricultural land and livelihood is at increasing risk from climate change, particularly via flooding throughout the year and rising temperatures and falling water availability during the summer months.

Figure 36: Cheshire land use and land cover.



Climate change brings possibly profound impacts for landuse, landscape and farming in the Cheshire plain. For soil erosion (with the summary below taken directly from the CCRA18):

- *"Future projections indicate that hazards such as heavy rainfall or wind (leading to erosion) and drought (leading to increased soil moisture deficits, peatland drying and potentially the degradation of soil microbial communities) will exacerbate the loss of soil resources.*
- *The current rate of erosion is estimated at 2.9Mt/yr in England and Wales with productivity losses estimated at £40million/yr. Severe degradation of soil quality would be very likely to have long-term, potentially irreversible, implications particularly given the critical importance of soil in underpinning biodiversity, providing high-quality farmland and a range of ecosystem services.*
- *There is the potential for major threshold effects at higher levels of warming (i.e. in a 4°C scenario). The risk is considered medium magnitude now, rising to high by the 2050s across the UK.*

For risks to agricultural productivity:

- *Weather hazards, including heat, cold, wetness and drought, affect the viability of agricultural land through its yields of crops and livestock, and hence productivity overall.*
- *For example, after the hot dry summer of 2018, UK carrot yields were reportedly down 25-30% and onion yields down 40% on a normal year.*
- *Agricultural activities on floodplains are also likely to suffer more disruption as they become flooded more frequently, to greater depths and extents.*

- *Conversely, opportunities for other crops or livestock types are also possible in a changing climate, for example an increase in blackcurrant yields was observed in 2018 due to lower frost frequency.*
- *The magnitude of this risk and opportunity is expected to increase from medium at present to high by the 2050s and beyond across the UK.*

Risks to agriculture from pests, pathogens and invasive non-native species

- *Pests, pathogens and invasive non-native species (INNS) present serious risks to agricultural productivity, with consequences for livelihoods and businesses.*
- *One such example is the Septoria tritici blotch which costs UK wheat growers alone around £100-£200 million per year in yield losses.*
- *Large-scale outbreaks or invasions may also have ramifications for food security.*
- *The combined risk factors, both climatic and non-climatic, clearly suggest that the magnitude of this risk is increasing from medium at present to high by the 2050s and beyond across the UK."*

7.2.3 Fire and flood risk in Cheshire

For water issues, flood alert and risk zones 2 and 3 are shown in Figure 37. It appears that every major river and watercourse is in some way a flood alert zone, which is borne out by the low lying landscape, highly vulnerable to saturation and water logging. Figure 37 highlights the interaction between new built up area and flood zones, indicating that new development has been taking places in areas at risk of flooding.

Figure 37: Cheshire flood alert and risk zones 2 & 3.

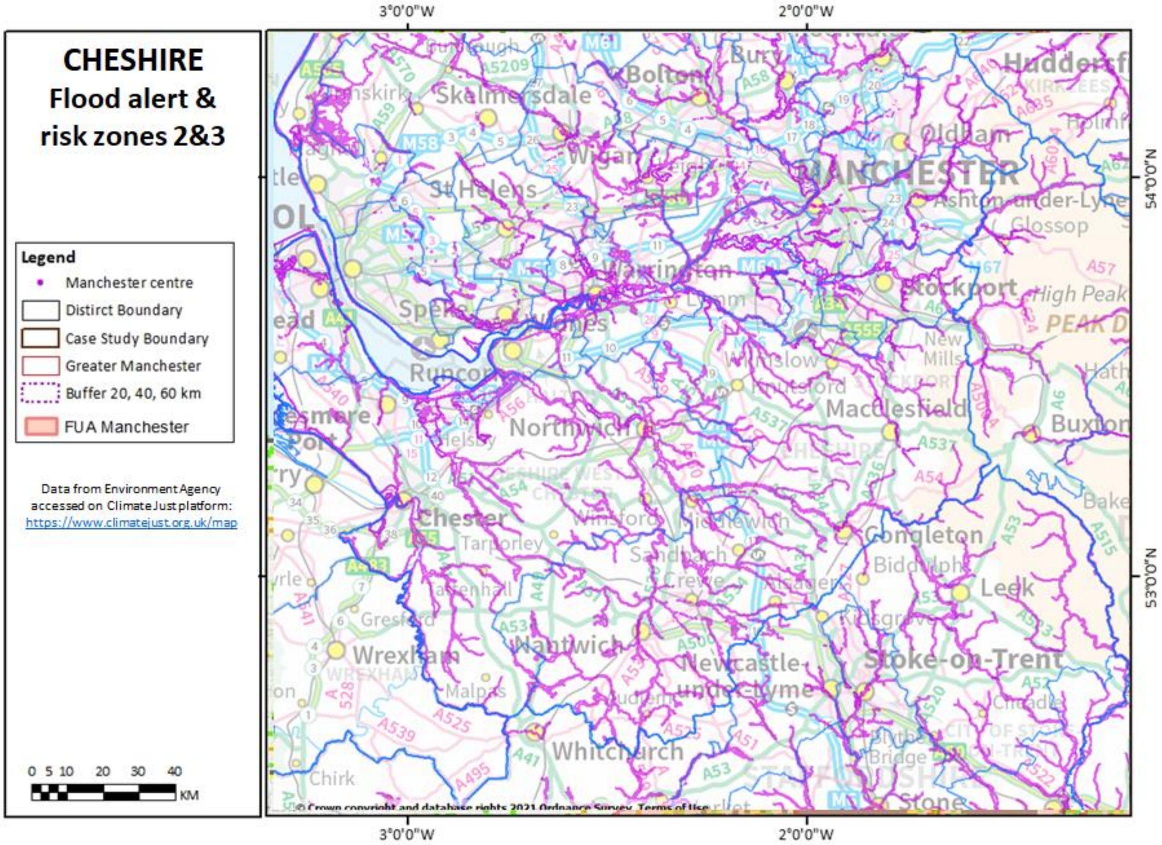
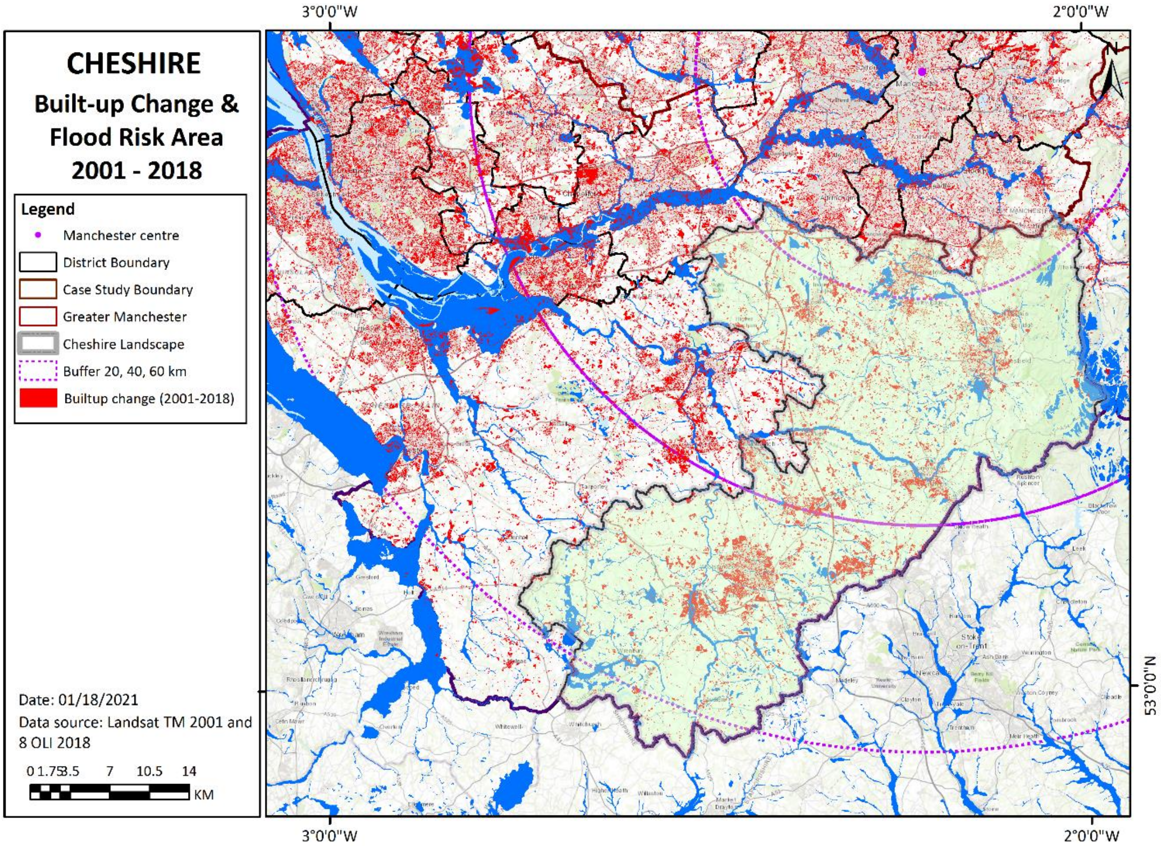


Figure 38: Cheshire Built-up change and flood risk area

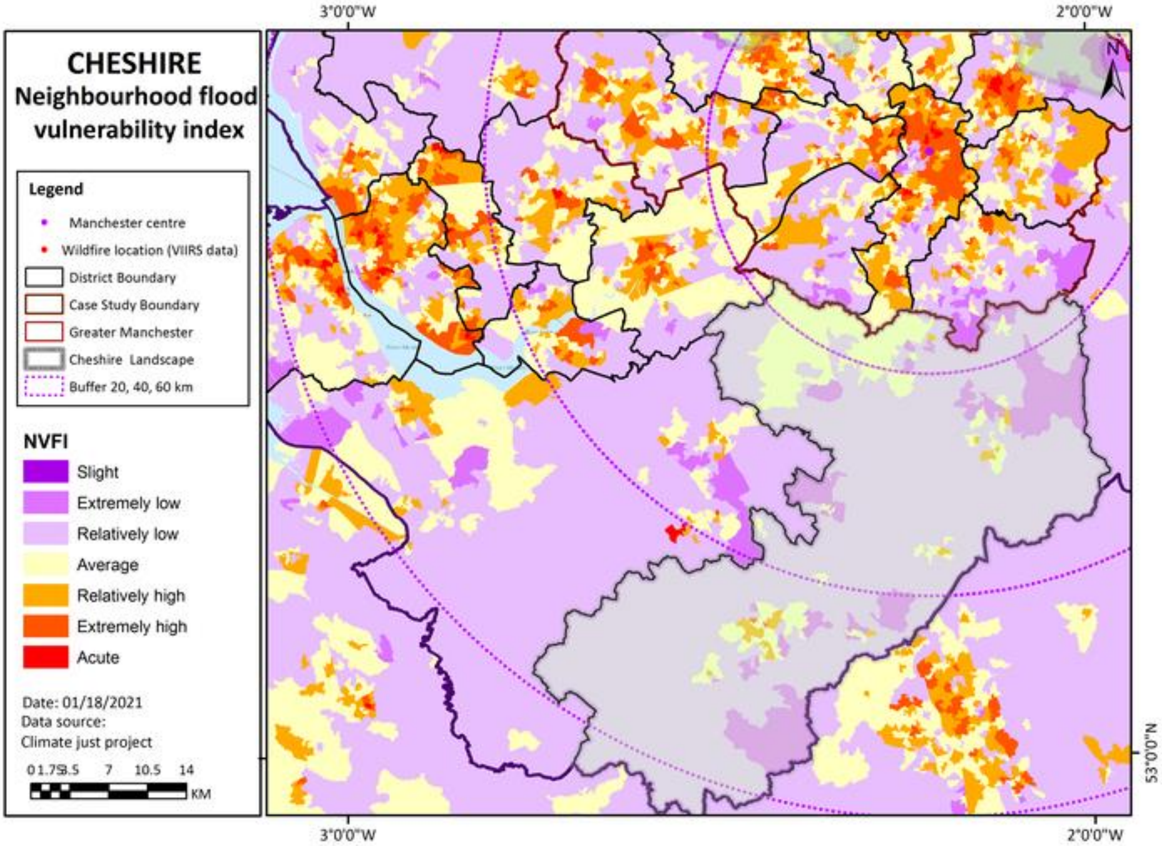


7.2.4 Climate vulnerabilities in Cheshire

For the social and economic vulnerability, the mapping here of 'neighbourhood flood vulnerability index' is a starting point (Figure 38). Some areas of larger towns such as Macclesfield, Northwich and Crewe have large numbers of small terrace houses, with often inadequate construction and little protection from either fluvial or surface water flooding. These combine with high levels of dependency, ill-health, low incomes and low rates of insurance for certain sections of the population.

Most of the county has relatively low vulnerability, a reflection of average incomes, household structures and housing forms, in both suburban and peri-urban locations. Critical infrastructure may be one of the highest risks (not shown here): where an already overloaded road network is easily blocked by riverine flooding.

Figure 39: Cheshire Neighbourhood flood vulnerability index.



7.2.5 Climate-peri-urban issues & challenges in Cheshire

General climate change issues & dynamics

- Climate change is projected to bring wetter winters & hotter drier summers, both with fluvial and pluvial flooding.
- Housing pressure, from both local and incoming residents. Containment policies contribute to housing shortages, especially for local residents & services.
- The road network is inadequate in many places, but road improvements may not catch up with growing demand and rural areas remain difficult to serve with public transport.
- Farming & farmland is under short term threat from Brexit, and medium term threat from climate change. Possible new models include precision farming and agro-ecology.
- Biodiversity and natural areas are under medium term threat from climate change, particularly from the perspective of higher temperatures and reduced water availability during the summer months.
- Social polarization is generated by presence, sometimes in close proximity, of areas of high affluence and deprivation.

Key impacts and multipliers:

- Some new housing is cited in flood risk zones, driven by market forces & containment policy.
- Farming (mixed / arable) struggles with climate impacts (heat, drought, storm & flood): combined with post-Brexit disruption, generating secondary effect on the rural economy.
- Social polarization & peri-urban in-migration widens the income gap & contributes to housing shortage effects. Some social groups are more vulnerable to direct climate impacts (elderly, unemployed or insecure jobs, long term sick or disabled).
- Peri-urban development is part of a larger & complex set of problems.

Questions & challenges for discussion

- What could be the future climate landscape of Cheshire, with best or worst outcomes?
- Is there a climate-proof model of farming which also brings social & economic inclusion?
- Can new climate-proof zero-carbon industries contribute to the skills and growth agenda?
- Are there smart technology opportunities which could be promoted?
- Urban development options for Cheshire: -
  (a) Expand with population coming from urban areas.
  (b) Maintain existing population levels.
  (c) Plan to reduce population in areas of high risk.
- How to frame the climate / urban interactions, in a way which brings together different social groups?
- Are there new potential modes of adaptive – collaborative governance?
- How to organize collective dialogue & action in a highly decentralized area?

Continuing work on Cheshire will take place via stakeholder discussions, with the benefit of the mapping analysis. Outcomes will be reported in D4.2b.

8 CONCLUSIONS

This deliverable has focused on providing a 'problem analysis' centred on peri-urban areas in the Manchester region, and relevant climate change risks and adaptation themes. The key emerging issues can be summarised as:

- Peri-urban areas within the Manchester region are diverse and represent a wide ranging combination of landscapes, industries and communities. These areas are constantly evolving, buffeted by multiple drivers of change operating from global to local scales.
- The Manchester region's peri-urban areas are generator of climate risks, particularly fluvial flooding, and to a lesser extent hazards such as wildfires. These risks arise due to a combination of factors linked to themes including land use management and ongoing climate change. Approaches are needed to lessen the contribution that peri-urban areas make to generating and worsening climate change risks.
- Peri-urban areas within the Manchester region are also providers of climate change adaptation functions. These will become particularly significant in the coming decades as the climate continues to change and extreme weather events become more frequent and intense. A key example relates to opportunities to implement NFM measures, which is explored within this report. Other adaptation functions include the provision of habitats to support biodiversity conservation in a changing climate and offering recreation space to provide a retreat from hot urban centres under heat wave conditions. Strategies are needed to encourage and progress these opportunities.
- The climate change risk and adaptation agenda clearly highlights the connections between peri-urban areas and urban areas. In the Irwell catchment case study, the most severe fluvial flooding events (such as Storm Eva in 2015) often involve heavy rainfall in the peri-urban (and rural) uplands to the north and east of the urbanised areas of the GM conurbation, with this rainfall transmitted downstream via the river network and generating flooding and associated damage in urban areas. Recognising and planning for these relationships via holistic and spatially appropriate (in the sense of river catchments in this case) plans and strategies is needed. However these arrangements are not currently in place the Manchester region where administrative boundaries do not recognise biophysical realities and catchment-based approaches are only just starting to emerge.

For the other zones in the hinterland:

- The South and West Pennines area is one of low hills (<500m) with moorland peat bogs, upland hill farming, steep valley sides, former industrial towns in the valley bottoms, overlaid with newer suburban type developments. Climate change risks focus on flooding, both fluvial and surface water, and heat / drought / wildfires particularly in the upland landscapes and peat bogs. The area demonstrates the inter-dependency of landuses, where the upland land ownership / management contributes to downstream flood risk, both locally and further into the surrounding conurbations.
- The Cheshire plain represents a more rural zone of relative affluence, urban expansion and commuting, together with productive farmland. There is some industrial infrastructure to

the north side, and some larger towns, in particular Crewe, have high levels of deprivation. Climate change risks affect both these social groups, and the surrounding landscape of mainly arable farming. There are tangible and increasing risks to present day agricultural systems, along with riverine flooding, landscape and ecosystems disruption.

The next Deliverable D4.2b takes this exploration of the Manchester region forwards, and explores issues of adaptive governance and adaptive pathways, in the search for positive interactions between peri-urban and climate risk themes. Particular attention is paid to governance approaches that can engage stakeholders, collaboratively and across administrative boundaries, in the development, implementation and maintenance of NFM measures in the Irwell catchment and wider Manchester region. Attention also needs to be paid to the issue of how NFM measures, and activities linked to their future maintenance, can be operationalised. It is these governance challenges, framed within the context of developing and implementing NFM measures, which provide a key focus the Manchester region case study and form the basis of D4.2b.

9 ANNEX

9.1 Abbreviations

CO_2	Carbon dioxide
CBD	Central Business District
CSR	Corporate Social Responsibility
EC	European Commission
EU	European Union
FUA	Functional Urban Area
GDP	Gross Domestic Product
Ha	Hectare
Hh	Household
HDI	Human Development Index
IOT	Internet of Things
IPCC	Inter-Governmental Panel for the Scientific Assessment of Climate Change
KIBS	Knowledge Intensive Business Services
LED	Local Economic Development
LSOA	Lower Super Output Area
Manchester	(Shorthand for Greater Manchester and its wider hinterland / region)
MEA	Millennium Ecosystem Assessment
NGO	Non-governmental organization
OECD	Organization of Economic Cooperation and Development
Pph	persons per hectare
RUI	Rural-urban interface
SDG	Sustainable Development Goals
STEEPC	Futures / foresight domains for analysis and debate ('socio-technical-economic-ecological-political-cultural'), with many variations
WEF	World Economic Forum
WHO	World Health Organization
UN, UNEP etc	United Nations, UN Environment Program etc
URL	Urban - Rural Linkages

9.2 Summary of water governance in GM

A summary & analysis of the various government / governance structures, for water and flood management in Greater Manchester (Ravetz & Connelly 2018).

9.2.1 GM Floods and Water Management Board

General profile of the case study – basic description of institutions & stakeholders

GENERAL PROFILE		
Name, location, area, population		*Flood and Water Management Board*
Sectors mainly involved	Public / private / civic / academic / citizens	*Public*
Powers & resources	Statutory / delegated / lobby / voluntary. Public funding / private enterprise / partnership / membership	*Delegated*
Territory covered	Region / catchment / water body / landscape body / admin unit	*Admin Unit*
General functions	Formal planning / regulation / investment. Informal partnership / networking. Knowledge, learning, communications.	*Formal planning/regulation* *Knowledge, learning, communications*

Which sectors are involved at which levels?? Are these relationships formal / informal ?

STAKEHOLDERS	*PUBLIC SECTOR*	*PRIVATE SECTOR*	*CIVIC SECTOR*	*CITIZENS*
	National govt *Govt agencies* *Public services* *Local govt*	*Primary, utilities* *Industry, construction* *Services, utilities* *Finance, development*	*Research / innovation* *Professions* *Culture / media* *NGOs & interest groups*	*Owners / residents* *SMEs, social enterprise* *Special groups* *Community groups*
NATIONAL LEVEL	*Environment Agency* *GM RFCC Members* *NW RFCC Chair*			*National Flood Forum*
MESO-LEVEL	*GM CCRU* *GM Low Carbon Hub* *GM New Economy* *GM Planning and Housing* *TfGM*	*United Utilities*		
LOCAL LEVEL	*Rochdale MBC* *Bolton MBC* *Bury MBC* *Manchester CC* *Oldham MBC* *Salford CC* *Stockport MBC* *Tameside MBC* *Trafford MBC* *Wigan MBC* Derbyshire County Council			

Which types of water systems does the case study work with? What are the factors of success / gaps?

WATER SYSTEMS	*SECTORS INVOLVED*	*GAPS & CHALLENGES*	*SUCCESS & OPPORTUNITIES*
Rivers & water bodies			
Ground water, soil etc	*Yes*	*Unconnected to water quantity agenda*	*Potential for more private sector/citizen involvement in an informal capacity*
Flood & extreme events	*Yes*	*Unconnected to water quantity agenda*	*Potential for more private sector/citizen involvement in an informal capacity*
Potable water supply			
Industrial / agri supply			
Drainage & waste	*Yes*	*Unconnected to water quantity agenda*	*Potential for more private sector/citizen involvement in an informal capacity*

Which governance systems qualities are shown in the case study? What are the factors of success / gaps?

GOVERNANCE	*CAPABILITIES*	*GAPS & CHALLENGES*	*SUCCESS & OPPORTUNITIES*
Territorial agenda	integrated – multi-scale – localism & bio-regional	Operates at the admin unit rather than the watershed	Includes representatives from neighbouring local authorities
Ecological agenda	anticipatory / precau-tionary / multi-functional	Could be connected to the water quality agenda	
Economic agenda	entrepreneurial / service model / asset management	Few opportunities to be entrepreneurial because of statutory functions	Includes representation from New Economy but the impact is unclear
Social agenda	transparent / participative / inclusive / associative /	Could include more representation from private sector/ citizens in an informal capacity	
Technical agenda	efficiency / effectiveness / efficacy	Needs to be connected to other partnerships and groups (focussed on flood risk only)	Focussed technical agenda
Institutional agenda	multi-functional / multi-level / multi-sector /	Could cover more sectors Could be connecred to more functions (i.e. water quality)	

9.2.2 GM Irwell Catchment Partnership

General profile of the case study – basic description of institutions & stakeholders

GENERAL PROFILE		
Name, location, area, population		Irwell Catchment Partnership
Sectors mainly involved	Public / private / civic / academic / citizens	All sectors
Powers & resources	Statutory / delegated / lobby / voluntary. Public funding / private enterprise / partnership / membership	Voluntary/ partnership
Territory covered	Region / catchment / water body / landscape body / admin unit	Catchment

General functions	Formal planning / regulation / investment. Informal partnership / networking. Knowledge, learning, communications.	Informal partnership, investment, knowledge and learning, regulatory

Which sectors are involved at which levels?? Are these relationships formal / informal?

STAKEHOLDERS	*PUBLIC SECTOR*	*PRIVATE SECTOR*	*CIVIC SECTOR*	*CITIZENS*
	National govt Govt agencies Public services Local govt	Primary, utilities Industry, construction Services, utilities Finance, development	Research / innovation Professions Culture / media NGOs & interest groups	Owners / residents SMEs, social enterprise Special groups Community groups
NATIONAL LEVEL	Environment Agency Natural England		RSPB	The Conservation Volunteers National Union of Farmers / Canoe England
MESO-LEVEL	GMEU GMCA / Natural Course Moors for the Future Partnership Greater Manchester Archaeology Advice Service NW Regional and Flood Coastal COmmittee	United Utilities	Lancashire Wildlife Trust Slow the Flow / Cumbria Wildlife Trust Irwell Rivers Trust Healthy Rivers Trust	
LOCAL LEVEL	Manchester City Council Oldham Council Rochdale Borough Council Rossendale Council Salford City Council Bolton Metropoilitan Borough Council Bury Council		City of Trees University of Salford Manchester Met. University University of Manchester	Groundwork MSST Salford Friendly Anglers / Mersey Basin Rivers Trust Groundwork BBOR

Which types of water systems does the case study work with? What are the factors of success / gaps?

WATER SYSTEMS	*SECTORS INVOLVED*	*GAPS & CHALLENGES*	*SUCCESS & OPPORTUNITIES*
Rivers & water bodies	Yes	Lack of private sector involvement	Charged with developing and implementing a plan Citizen groups involved – could bring in more Wide administrative boundary with representation from neighbouring public bodies
Ground water, soil etc	Yes	Lack of private sector involvement	Charged with developing and implementing a plan Citizen groups involved – could bring in more Wide administrative boundary with representation from neighbouring public bodies
Flood & extreme events	Yes	Lack of private sector involvement	Charged with developing and implementing a plan Citizen groups involved – could bring in more Wide administrative boundary with representation from neighbouring public bodies
Potable water supply	Yes	Lack of private sector involvement	Charged with developing and implementing a plan Citizen groups involved – could bring in more Wide administrative boundary with representation from neighbouring public bodies
Industrial / agri supply	Unsure		
Drainage & waste	Yes	Lack of private sector involvement	Charged with developing and implementing a plan Citizen groups involved – could bring in more Wide administrative boundary with representation from neighbouring public bodies

Which governance systems qualities are shown in the case study? What are the factors of success / gaps?

GOVERNANCE	*CAPABILITIES*	*GAPS & CHALLENGES*	*SUCCESS & OPPORTUNITIES*
Territorial agenda	integrated – multi-scale – localism & bio-regional	Catchment partnerships do not match onto GM admin boundaries	Looks to work across scales
Ecological agenda	anticipatory / precau-tionary / multi-functional		Takes a broad approach to maintaining healthy water environments and is driven by an ecological agenda
Economic agenda	entrepreneurial / service model / asset management		Partnership model allows funding to be drawn in.
Social agenda	transparent / participative / inclusive / associative /		The ICP is relatively inclusive across most groups and has an open and participative agenda
Technical agenda	efficiency / effectiveness / efficacy		
Institutional agenda	multi-functional / multi-level / multi-sector /	Multi-sector but could include more private sector involvement	Has a multi-functional and wide remit.

9.2.3 Natural Capital Group

General profile of the case study – basic description of institutions & stakeholders

GENERAL PROFILE		
Name, location, area, population		Natural Capital Group
Sectors mainly involved	Public / private / civic / academic / citizens	Public/private/academic
Powers & resources	Statutory / delegated / lobby / voluntary. Public funding / private enterprise / partnership / membership	Public funding Delegated powers
Territory covered	Region / catchment / water body / landscape body / admin unit	Admin unit
General functions	Formal planning / regulation / investment. Informal partnership / networking. Knowledge, learning, communications.	Formal planning, investment, networking

Which sectors are involved at which levels?? Are these relationships formal / informal?

STAKEHOLDERS	*PUBLIC SECTOR*	*PRIVATE SECTOR*	*CIVIC SECTOR*	*CITIZENS*
	National govt Govt agencies Public services Local govt	Primary, utilities Industry, construction Services, utilities Finance, development	Research / innovation Professions Culture / media NGOs & interest groups	Owners / residents SMEs, social enterprise Special groups Community groups
NATIONAL LEVEL	Environment Agency	Co-operative Group		
MESO-LEVEL	New Economy GMEU GM Environment Team CCRU Planning and Housing Team	United Utilities	Canals and Rivers Trust CPRE The Wildlife Trust for Lancashire, Manchester and North Merseyside	
LOCAL LEVEL	Oldham Council Salford City Council	Bruntwood	The University of Manchester University of Salford City of Trees	

Which governance systems qualities are shown in the case study? What are the factors of success / gaps??

GOVERNANCE	*CAPABILITIES*	*GAPS & CHALLENGES*	*SUCCESS & OPPORTUNITIES*
Territorial agenda	Integrated – multi-scale		Works across local authorities and different sectors involved in managing drainage
Ecological agenda	Anticipatory; multi-functional	Focus on championing the natural environment, so not specifically focussed on water per se.	Has a broad remit which can bring in a number of issues under its umbrella
Economic agenda	entrepreneurial		Seeks to enhance the economic resilience of GM
Social agenda	Not clear	No citizen bodies included	
Technical agenda	efficiency	No real technical expertise on the panel	
Institutional agenda	multi-functional / multi-level / multi-sector /	Multi-functional/multi-sector	

9.2.4 Technical Flood Risk Officers Group

General profile of the case study – basic description of institutions & stakeholders

GENERAL PROFILE		
Name, location, area, population		Flood and Water Management Board
Sectors mainly involved	Public / private / civic / academic / citizens	Public
Powers & resources	Statutory / delegated / lobby / voluntary. Public funding / private enterprise / partnership / membership	Delegated
Territory covered	Region / catchment / water body / landscape body / admin unit	Admin Unit
General functions	Formal planning / regulation / investment. Informal partnership / networking. Knowledge, learning, communications.	Formal planning/regulation Knowledge, learning, communications

Which sectors are involved at which levels?? Are these relationships formal / informal?

STAKEHOLDERS	*PUBLIC SECTOR*	*PRIVATE SECTOR*	*CIVIC SECTOR*	*CITIZENS*
	National govt Govt agencies Public services Local govt	Primary, utilities Industry, construction Services, utilities Finance, development	Research / innovation Professions Culture / media NGOs & interest groups	Owners / residents SMEs, social enterprise Special groups Community groups
NATIONAL LEVEL	Environment Agency			National Flood Forum
MESO-LEVEL	GM Assistant Planning Strategy Manager GM Strategic Flood Risk Management Co-ordinator	United Utilities		
LOCAL LEVEL	Rochdale MBC Bolton MBC Bury MBC Manchester CC Oldham MBC Salford CC Stockport MBC Tameside MBC Trafford MBC Wigan MBC			

Which types of water systems does the case study work with? What are the factors of success / gaps?

WATER SYSTEMS	*SECTORS INVOLVED*	*GAPS & CHALLENGES*	*SUCCESS & OPPORTUNITIES*
Rivers & water bodies		Unconnected to water quantity agenda	
Ground water, soil etc	Yes	Unconnected to water quantity agenda	
Flood & extreme events	Yes	Unconnected to water quantity agenda	In-depth technical expertise
Potable water supply			
Industrial / agri supply			
Drainage & waste	Yes	Unconnected to water quantity agenda	

Which governance systems qualities are shown in the case study? What are the factors of success / gaps?

GOVERNANCE	CAPABILITIES	GAPS & CHALLENGES	SUCCESS & OPPORTUNITIES
Territorial agenda	integrated – multi-scale – localism & bio-regional	Operates at the admin unit rather than the watershed	
Ecological agenda	anticipatory / precau-tionary / multi-functional	Could be connected to the water quality agenda	
Economic agenda	entrepreneurial / service model / asset management	Few opportunities to be entrepreneurial because of statutory functions	
Social agenda	transparent / participative / inclusive / associative /	in an informal capacity	
Technical agenda	efficiency / effectiveness / efficacy	Needs to be connected to other partnerships and groups (focussed on flood risk only)	Focussed technical agenda
Institutional agenda	multi-functional / multi-level / multi-sector /	Could cover more sectors Could be connected to more functions (i.e. water quality)	

9.3 Review of relevant projects and resources on climate change risk and adaptation in GM

Project/study	Focus	Author/project leader	Date	Spatial scale	Climate hazard	Time-scale	Spatial data	Other relevant information
Adaptation Strategies for Climate Change in the Urban Environment (ASCCUE)	Development of a risk based approach to urban climate change adaptation.	University of Manchester (UoM)	2006	GM	Flood, heat	Future	GM urban morphology types map (1997 data), GM heat related risk, GM surface water runoff.	Journal papers house key project outputs. Particular focus on the role of green infrastructure in GM for reducing climate risk.
Sustainable Cities: options for responding to climate change impacts and outcomes (SCORCHIO)	Development of adaptation data and tools, particularly linked to heat and human comfort.	UoM	2010	GM (+ other cities)	Heat	Future	Heat island map for GM.	SCORCHIO focused principally at the building scale. Journal papers provide details of the key project outputs.
EcoCities	The development of data and tools to support adaptation planning and action in GM.	UoM	2012	GM	Particular focus on flood and heat	Recent, current and future	A 'spatial portal' projects data onto a map of GM, including a heat island map, flood maps, critical infrastructure [currently unavailable]	Data on historic climate-related events impacting on GM. Provides future climate projections for GM. Report on risk of flooding to GM infrastructure. Journal paper summarising key outcomes.
Evidencing and spatially prioritising Climate Change in GM	Assessment of climate-related risks to the GM Strategy.	UoM	2013	GM	Flood and heat	Future	Assessment of flooding and heat risk to selected key GM economic development locations.	The risk assessment covers housing development areas, GM's regional centre and eight town centres, strategic employment locations and future transport development sites.
University of Salford Climate Change Adaptation Study	Climate risks and adaptation responses to three buildings and public realm on the campus.	Buro Happold	2013	Building	Flood and heat	Current and future	No	Although the principal focus of this report is on adaptation responses to flooding and heat stress, there is some useful data provided on hazards at the building scale.
ClimateJust	The provision of evidence to support local action to reduce climate related inequality and disadvantage.	UoM with input from other partners	2014	National	Flood and heat	Current and future	The Map Tool presents the opportunity to visualise climate hazard and vulnerability data at a local scale.	Some of the spatial data that can be mapped is of a course resolution (e.g. the heat exposure layer is a 25km grid) reducing its utility for local scale planning.
Flooding of Transport and Infrastructure Networks and Assets (FINA)	Understanding of flooding to GM's transport networks and assets to strengthen responses to related risks.	UoM	2015	GM	Flood	Recent trends	Mapping of patterns of recent flood events to the road network and heavy rail. Mapping of rail and Metrolink stations in flood zones.	The project focused on roads and heavy rail, sectors where historical flood data was available. Records suggest that flooding to the Metrolink network is uncommon.
The climate of the UK and recent changes	Assessment of changes to the UK's climate over recent decades.	UK Met Office	2008	National	Climate variables particularly temperature and rainfall	Historic trends	Trends data is provided at the regional scale. Maps of the UK are provided visualising changes in certain climate variables.	Changes in GM's climate over recent decades can be interpreted from the maps provided in this report.
UK Climate Projections 2009	The development of a range of future climate change scenarios for the UK.	UK Met Office	2009	National, Regional	Climate variables, particularly temperature and rainfall	Future	Customisable maps can be produced at a $25km^2$ grid scale representing different scenarios and probabilities for selected climate variables.	The UKCP09 projections are produced at a relatively course spatial scale. The EcoCities projections provide a slightly more refined picture for GM, but for a smaller number of climate variables, scenarios and probabilities.
UK Climate Projections 2018	Includes a climate analysis tool that provides the most up-to-date assessment of	UK Met Office	2018	National, Regional	Climate variables, particularly temperature	Future	UKCP18 provides a set of high-resolution spatially-coherent future climate	UKCP18 data can be used to support climate change risk assessment processes, with a user interface provided. This

	how the UK climate may change over the 21st century.				and rainfall		projections for the UK at 12 km scale. A further downscale to 2.2km scale is available, allowing realistic simulation of high impact events such as localised heavy rainfall in summer.	can inform adaptation planning processes and decisions.
UK Climate Change Risk Assessment **(UKCCRA 2017)**	Assessment of climate risk to 5 priority themes, and insights into actions to reduce risks, as required by the Climate Change Act of 2008.	Defra	2017	National	Various weather and climate hazards	Future	No	Identification of risks associated with climate change to 5 themes/sectors - Agriculture and Forestry; Business, industries and Services; Health and Wellbeing; Natural Environment and Buildings and Infrastructure.
UK Climate Change Risk Assessment 2017 Evidence Reports **(UKCCRA Evidence Reports)**	The Climate Change Act of 2008 requires a UK government assessment of climate risk every 5 years. This collection of evidence is targeted at informing the 2017 assessment.	Defra	2016	National	Various weather and climate hazards	Current and Future	Some spatially oriented projections and mapped outputs are included in 4 new assessments developed for the evidence report. This is generally at large scales, including regions (inc. GM, Merseyside and Cheshire) and water company footprints.	The evidence base reviews published data on a range of different themes including infrastructure, business and global security. The evidence base also contains 4 new assessments focusing on future projections for flood risk, water availability, impacts on the UK's natural assets and extreme climate change scenarios.
Developing extreme climate scenarios for various climate hazards	The report focuses on extreme scenarios, termed H++, which fall outside the range presented by UKCIP09.	Met Office, CEH, University of Reading	2015	National	Various weather and climate hazards	Future	No	Extreme scenarios can be used to support analysis of low probability high impact events. Report covers heat waves, cold snaps, low and high rainfall, droughts, floods, windstorms. The scenarios will be used to support the second UKCCRA. The first UKCCRA did not use H++ scenarios.
A Summary of Climate Change Risks for North West England	A regional assessment to support the UKCCRA.	ClimateUK	2012	NW region	Various weather and climate hazards	Future	No	High level regional overview of key climate-related risks to the 5 themes covered by the UKCCRA.
Climate Change Impacts on Key Sectors and Public Services in Northwest England	Assessment of climate risks to 18 themes within the public and private sectors.	ARUP	2009	NW Region	Various climate variables and hazards	Future	No	Utilises climate change data from UKCP09, and UKCIP's BACLIAT tool. Sector specific awareness raising and briefing materials are available. GM is considered as a sub-region.
Economic impacts of increased flood risk associated with climate change in Northwest England	Assessment of economic impacts of flood risk under a changing climate.	URS Corporation Ltd	2009	NW region	Flood	Future	No	Although the report does not focus specifically on GM, it does provide a regional insight into flooding costs to key business sectors and helps to build the case for action.
Greater Manchester Ecosystems Services Pinch Point Study	Understanding and mapping GM's priority Ecosystem Services (ESS), and assessing ways to progress this agenda.	Red Rose Forest and Countryscape	2014	GM	Various themes including flood and cooling	Current	Mapping of priority GM ESS, available on GMODIM (see below).	Many of the priority ESS connect to climate change adaptation and resilience. The report identifies 'pinches', some of which are spatial, that are critical to maximising the potential contribution of GM's ESS.
Green Infrastructure to Combat Climate Change	Provides a framework for organisations in NW England to deliver GI responses to achieve adaptation goals.	The Mersey Forest	2011	NW Region	Various adaptation and resilience themes	Current	Spatial data related to certain climate-related risks that could be addressed via GI responses.	GM is considered as one of five sub-regions within the NW.
North West Flood	Sets out where and	Environment	2014	NW	Flood	Current	Connects to the	Highlight the flood hazards

Risk Management Plan (Consultation draft)	how to manage flood risk for the benefit of communities and the environment.	Agency and Lead Local Flood Authorities		Region			Environment Agency's interactive online flood maps	and risks from rivers, the sea, surface water, groundwater and reservoirs. The impact of climate change is considered. Final draft is imminent. GM and its districts are covered by some flood analysis.
Vulnerability of North West's natural environment to climate change	Assessment of the vulnerability of National Character Areas (NCAs) to climate change.	Natural England	2010	NW Region	Various weather and climate hazards	Future	Mapping, at the regional scale, of NCA's vulnerability to climate change	The spatial scale of this study is relatively course. There are 29 NCAs in the region, several of which are included partially or wholly in GM.
Greater Manchester Open Data Infrastructure map (GMODIN)	Provides environmental, infrastructure and housing data across GM on a single map.	GM Combined Authority	2015	GM	Flood	Current	Provides an online map of physical, social and green infrastructure, and flood hazards.	The map enables EA flood zones to be overlaid with infrastructure data. The map will be updated as further data is accessed and becomes available.
Level 1 GM Strategic Flood Risk Assessment (GM SFRA)	Assesses flood risk from all sources, looking across GM and its districts.	Scott Wilson (consultancy firm)	2008	GM and its districts	Flood	Current and future	The SFRA is spatial in nature and include maps of locations at risk of flooding.	This initial city region wide SFRA, developed collaboratively by GMs 10 districts, has subsequently been built on at the GM and districts scales (Level 2).
Level 2 Strategic Flood Risk Assessments	Produced by GM's districts, sometimes jointly, to assess flood risk from all sources.	JBA and Scott Wilson (consultancy firms)	2011	Local authority	Flood	Current and future	SFRAs are spatial in nature and include maps of locations at risk of flooding.	These SFRAs provide a more detailed view of this hazard in GM's districts than the Level 1 assessment. They also provide a more comprehensive view of climate change effects.
District Local Flood Risk Management Strategies	These strategies are focused on managing flood risk, and provide local assessments of flood risk.	Lead Local Flood Authorities	2013 - 2015	Local authority	Flood	Current	Strategies include maps of different forms of flooding.	These strategies have been produced in response to requirements within the Flood and Water Management Act of 2010. They have been approved by GM districts between 2013 and 2015.
Preliminary Flood Risk Assessments (PFRAs)	PFRAs identify flood risk areas where floods have happened in the past and may do in the future	PFRAs have been produced by consultancy firms for lead local flood authorities	2011	Local authority	Flood	Historic and future	A range of spatial data related to flooding and flood risk areas is mapped.	PFRAs for the North West River basin district, which contains GM, can be downloaded here. PFRAs cover fluvial, pluvial and groundwater flooding.
Catchment Flood Management Plans (CFMPs)	CFMPs provide an overview of flood risk and strategies to manage this risk over the coming decades	Environment Agency	2009	River catchments	Flood	Current and future	Some mapping is provide, although CFMPs are more focused on developing policy frameworks to manage flood risk.	CFMPs can be downloaded here.
Local Climate Impacts Profiles (LCLIPs)	LCLIPs identify past extreme weather events and assess their impacts on the area of focus.	Local Authorities, UoM	2009 - 2010	GM and its districts	Various weather and climate hazards	Historic events	Generally, LCLIP results are not mapped.	9 out of 10 of GM's districts had completed LCLIPS by 2009/2010. An LCLIP for GM was produced by the University of Manchester within EcoCities, the key findings of which are summarised here.
Flood risk management: information for flood risk management authorities, asset owners and local authorities	Guidance support the assessment of flood risk and the development of responses by lead local flood authorities.	Defra and the Environment Agency	Last update 2014	Various	Flood	Current and future	Reservoir flood maps have been made available to Local Resilience Forums. Climate change information for the NW River Basin District is available here.	This resource collects together relevant guidance, and is focused on supporting the implementation of the Flood and Water Management Act of 2010.
Climate Change Act Adaptation Reporting	The Climate Change Act of 2008 requires organisations, principally infrastructure providers, to publish climate risk assessments.	Infrastructure companies	2010 - 2016	Various	Various weather and climate hazards	Future	The risk assessments are often underpinned by spatial analysis, the results of which are generally made available e.g. number of sub-stations in different flood zones.	Reports produced during the first (2010-2011) and second (2015-2016) rounds of this cycle are available from Defra. These reports provide insights into the extent of extreme weather and climate risk

								faced by infrastructure companies that provide critical services to urban areas.
Optimising natural flood management in headwater catchments to protect downstream communities (Protect NFM)	Protect-NFM is an innovative £1.2 million NERC funded project which aims to demonstrate that upland restoration offers a low-cost way to reduce the risk of flooding in vulnerable rural communities, and to optimise multi-benefit restoration work for natural flood management.	NERC	2017 – 2021	South Pennines	Flood	Current	None	Ongoing work
Water Governance in Greater Manchester	This report reviewed current governance of water quality and flooding in Greater Manchester. Recommendations were made for future governance arrangements	Oldham MBC	2018	GM	Flood	Current	None	Final report is available here: https://naturalcourse.co.uk/uploads/2018/10/Water-governance-in-GM-final-report1.pdf
Climate Adaptation and Water Governance	Research used the River Irwell Catchment Partnership to test two conceptual models that move towards good water governance	Natural Course	2018	Catchment	Flood	Current	None	The final report is available here: http://oro.open.ac.uk/54030/
Managing wildfire disturbance in moorlands and heathlands (Envirosar)	A national monitoring and detection tool of peat moorland and heathland wildfires.	UoM	Ongoing	National	Wildfire	Current	Unclear access to spatial data	http://www.envirosar.com/
Understanding the likelihood and impact of UK wildfires	This project will undertake the fundamental science and analyses required for building a UK-specific Wildfire Danger Rating System (WFDRS), informed by key stakeholders who will act as project partners.	NERC [check]	2020 – 2023	National	Wildfire	Current	Not yet available	No outputs available

9.4 '20-questions' template

The application of the Peri-cene Framework to the Manchester region and its three case study zones, is shown in four main stages. This is based on the 'peri-urban-climate-risk' cause-effect model: a fifth stage covers some of the 'synergistic model', i.e. the deeper and wider impacts and potential responses or pathways. Each stage has 4 topics, making a total of '20 questions', high level responses to which are outlined in the Table below.

THEMES	***SOUTH & WEST PENNINES***	***RIVER IRWELL CATCHMENT***	***CHESHIRE PLAINS***
PERI-URBAN FRAMEWORK:			
("drivers / stressors / exposures")	***Upland landscape with former industrial valley development***	***Urban edges & in-between spaces***	***Lowland landscape with high-value farming & economy***
Spatial peri-urban types & patterns:	Geographical type: small-medium industrial towns in river valleys, scattered upland villages & small farm settlements. Upland open peat bog, marginal agricultural landscapes and steep-sided river valleys.	Upland open peat bog, marginal agricultural landscapes and steep-sided river valleys. Large towns and smaller settlements, transport and energy infrastructure, housing estates and retail.	Small-medium villages and towns, locations from pre-industrial agrarian economy, overlaid with commuter / retirement settlements.
Spatial peri-urban functional dynamics (growth / restructuring / transition).	Post-industrial economy in transition to niche production, semi-retired livelihoods, hobby farming, commuter towns and local tourism.	Post-industrial economy in transition to niche production, semi-retired livelihoods, hobby farming, commuter towns and local tourism.	Outward metropolitan spread is mostly contained by strict planning policies and related greenbelt land allocations.
Other drivers (STEEP: social, technical, ecological, policy, culture etc)	Middle class in-migration & eco-gentrification, decline of family farming, enclaves of deprivation, post-industrial landscapes and associated pollution, promotion of green infrastructure.	Competing visions for upland landscapes, ambitious housing development targets, high levels of deprivation, economies in transition, promotion of nature conservation and green infrastructure.	Middle class in-migration & eco-gentrification. Industrialisation of farming and related decline of family farming.
Global-local dynamics & inter-dependencies	S+W Pennines covers parts of 13 municipalities, provides water supply and flood water retention capacity, and offers visitor & ecosystem services to 3 city-regions.	The uplands provides water supply and flood risk management functions to downstream urban areas. This is significant in the context of climate change adaptation.	Economic imperative for high value industries in greenfield settings, which then demands infrastructure & housing.

THEMES	***SOUTH & WEST PENNINES***	***RIVER IRWELL CATCHMENT***	***CHESHIRE & MERSEY PLAINS***
CLIMATE FRAMEWORK			
("causes / hazards"):	***Fluvial flood, wildfire, heat & drought, soil erosion, landscape***	***Green infrastructure, buildings impacts & social greenspace***	***Damage to farming, rural ecosystems, ancient woodlands***
Climate change direct effects:	Summer rising temperature and falling precipitation volumes. Winter rising temperature and precipitation volumes.	Summer rising temperature and falling precipitation volumes. Winter rising temperature and precipitation volumes.	Rising temperatures across the seasons. Summer drought & storm, winter precipitation & storm.
Climate change direct hazards & impacts:	Fluvial, pluvial & flash flooding (especially in valley bottoms), upland & valley soil erosion, summer drought and wildfire, storm and high winds, more extreme weather events.	Fluvial, pluvial & flash flooding (especially in valley bottoms), upland & valley soil erosion, summer drought and wildfire, storm and high winds, more extreme weather events.	Fluvial and pluvial flooding and connected soil erosion. Changing temperature and precipitation patterns and increasing frequency and severity of extreme events.
Indirect hazards & nexus effects	Impacts on vulnerable landscapes through ecosystems degradation, soil loss, air pollution, GHG emissions. Increased visitor pressure. Upland farming is already marginal and may become more so with policy and climate shifts.	Impacts on vulnerable landscapes through ecosystems degradation, soil loss, air pollution, GHG emissions. Increased visitor pressure. Upland farming is already marginal and may become more so with policy and climate shifts. Higher exposure of vulnerable communities to extreme weather events (particularly flooding).	Impacts of flooding, temperature, storm events on the more marginal farming areas, may compound with other stresses.
Causal loops (impacts of peri-urban on climate change)	Degradation of peat bog & vegetation reduced carbon sequestration capacity, as does loss of (some) ancient woodlands, transport emissions are high due to location, geography and gaps in public transport provision.	Degradation of peat bog & vegetation reduced carbon sequestration capacity, as does loss of (some) ancient woodlands. Peri-urban development and hard surfacing can increase downstream flood risk.	Low density peri-urban development is mainly car dependent with rising CO_2 emissions.

THEMES	***SOUTH & WEST PENNINES***	***RIVER IRWELL CATCHMENT***	***CHESHIRE & MERSEY PLAINS***
VULNERABILITY FRAMEWORK			
'sensitivity / adaptive capacity'	***Landscape sensitivity & marginal livelihoods***	***Housing growth impacts green & blue infrastructure & adaptive capacity***	***Social inequality may link to climate vulnerability in commuter-shed***
Physical-ecological vulnerability-sensitivity	Upland compacted agricultural land with rapid run-off, steep-sided river valleys magnify flood risk, upland semi-wild vegetation, thin & acidic soils, degraded ecosystems.	Upland compacted agricultural land with rapid run-off, steep-sided river valleys magnify flood risk, upland semi-wild vegetation, thin & acidic soils, degraded ecosystems. Building and infrastructure development negatively impacts on ecosystems and natural processes.	Pasture & arable land, with reducing woodland areas. Increasing disruption from climate change and associated changes to temperature and precipitation patterns.
Functional-economic-infrastructure layers of vulnerability-sensitivity:	Privatized land management methods increase run-off & flood risk. Low cost housing and vulnerable communities situated in areas exposed to flood risk. Deprivation in post-industrial towns.	Privatized land management methods increase run-off & flood risk. Low cost housing and vulnerable communities situated in areas exposed to flood risk. Deprivation in post-industrial towns. Upstream/downstream tensions linked to flooding processes and management.	Many peri-rural roads already over capacity, with risk of major disruption. Public transport is thin in the hinterland increasing car dependency.
Eco-social-cultural layers of vulnerability-sensitivity:	Polarization of local residents vs incomers who tend to live in more affluent areas on higher ground less at risk from flooding.	Polarization of local residents vs incomers who tend to live in more affluent areas on higher ground less at risk from flooding. Greater demand for space and access to natural landscapes post-Covid 19.	Pockets of rural deprivation and major urban clusters. Increasing elderly population also vulnerable to weather and climate hazards.
Adaptive governance capacity-vulnerability-sensitivity-	Fragmented & shrinking local governance, austerity cutbacks to public services, community under change & stress. Privatized infrastructure.	Mismatch between river catchment and administrative boundaries presents barriers catchment scale activity.	Government & public services are thinly spread further into hinterland areas.

THEMES	*SOUTH & WEST PENNINES*	*RIVER IRWELL CATCHMENT*	*CHESHIRE & MERSEY PLAINS*
GOVERNANCE FRAMEWORK			
Adaptive action & governance	***Fragmentation of governance: self-help tradition & eco-social innovation***	***Fragmentation of governance in systems including water and housing***	***Fragmentation of governance, gaps filled by other networks***
Formal government, (governance, regulation)	Main opportunity for regulation is planning and greenbelt policies to aid containment of urbanization in areas under housing pressure. The area encompasses elements of 13 municipalities with planning frameworks, which lack joined-up approaches. But, the area remains at the fringes of the policy agenda.	Planning system regulates the development and use of land, and has a role to play in conserving landscapes. Limited influence of the planning system over farming reduces capacity to affect change in upland environments.	Apparently strong local government in a (on average) affluent area with rich farmland and a significant concentration of high value industries.
Adaptive governance & institutions: (networks, coalitions, partnerships)	Local history of cooperatives, many examples of environmental, economic and social networks and partnerships, eco-innovations such as tree planting schemes. Big challenges in governance for in-between areas covering multiple municipalities, and for governing ecological agendas that cross administrative boundaries.	Catchment partnerships in place to drive water and flood governance activity. Innovative governance partnerships test and demonstrate models for collaborative knowledge sharing and progressive action.	Various forums, partnerships, networks & alliances are in operation.
Informal governance, (corruption, development, community, livelihood,)	Tradition of social enterprise, self-help, creative action. Landowning is centralized with the majority excluded from decisions, most farmers are tenants.	Major land owners in the upland areas are often detached from local agendas, and in some cases are not resident in the UK.	Centralized landowning system, which tends to exclude lower income groups.
System effects, resilience, collective intelligence	Enhanced social resilience with small town effect housing many synergistic enterprises and networks. However there are class & cultural divides.	Marginalised and under-resourced communities can struggle to mobilise collectively, with austerity governance removing layers of interaction that previously offered opportunities for collaboration and collective action.	In a large decentralized area it may be more difficult to get 'critical mass' to generate positive transition and change.

THEMES	***WIDER CITY-REGION***	***SOUTH & WEST PENNINES***	***RIVER IRWELL CATCHMENT***	***CHESHIRE & MERSEY PLAINS***
SYNERGISTICS				
Based on synergistic process	***General overview:***	***Growing pressure on fragile landscapes & settlements: potential for growing socio-eco-resilience***	***New forms of landscape planning and governance, with new forms of community***	***Can a new eco-social order emerge?***
Systems / syndromes / baselines (present)	Main cross-cutting issues: e.g. • Airport / port cities: • Rural livelihoods: • Informal development	Increased private land management in upland, intensifying flood risk in river valleys due to insensitive land use management. Urban dependency increases, with adaptive capacity decreasing where social safety nets are not present.	Increased private land management in upland, intensifying flood risk in river valleys due to insensitive land use management. High social deprivation in hinterland peri-urban landscapes. High development pressure to deliver on housing targets.	Increasing social polarisation as wealthy commuter towns and enclaves consolidate post-Covid 19. Intensification of agricultural industry, which faces threats from issues including Brexit and climate change.
Scenarios (future possibilities, wild cards & tipping points)	Critical themes: (STEEP): e.g. • Social cohesion declines • AI / IOT emerges • Climate change accelerates	Climate change accelerates, degrading upland ecosystems & farming opportunities. Some settlements in valley bottoms are abandoned due to repeated flood risk. Food prices increase driven by costly imports, and social divides and tensions increase.	The role of landscapes and natural processes is increasingly recognised as crucial to climate change adaptation. River valleys and upland peat bogs in peri-urban areas are afforded greater protection and resources and channelled into restoring and capturing the benefits these areas have for connected urban and rural areas.	Climate change intensifies, and finally elicits a concerted response from the world's governments. Cheshire benefits from its established concentration of high tech industries, which engage in and prosper from the transition to the low carbon economy. Increased job opportunities and shared prosperity encourage a wider social shift towards ecologically conscious lifestyles, which are underpinned by strategy and policy.
Synergies (future vision & opportunities)	Potential ideas, connections, opportunities	Attention paid to synergies of ecosystems & social systems. New semi-rural livelihoods emerge, facilitated by digital solutions suited to fringe location. Possibilities for	Catchment and landscape scale governance to support the delivery of nature based solutions and the restoration of natural functions in peri-urban areas, benefiting local	Farming communities transition towards more ecologically sensitive modes of activity focused on adaptation to increasingly unpredictable and extreme weather

		new forms of collaborative and adaptive 'co-governance' for in-between area are explored.	communities and urban areas. Planning system increasingly oriented towards supporting these agendas.	patterns.
Strategies (present pathways for action)	Goals, objectives, targets for ways forward.	Integrated adaptive upland landscape management building in climate change adaptation, agro-forestry & eco-social innovation. Innovative urban / building design for unstable & high risk locations. Support for prototype co-governance models.	Strategic catchment and landscape scale approaches informed by collaboration and spatial analysis. Increased engagement of communities, landowners and other relevant stakeholders in the development and delivery of shared approaches and solutions.	Nature and landscape conservation and enhancement take a more central position within spatial planning policy and strategy in recognition of their role in adaptation to climate change impacts.

9.5 References

Avery, M, (2015): *Inglorious: Conflict in the Uplands:* London, Bloomsbury

Carter, J.G., Connelly, A., Handley, J., Lawson., and Ellis, M., 2018. Climate change risk assessment of Greater Manchester's critical infrastructure. RESIN project. https://resin-cities.eu/fileadmin/user_upload/Resources/City_report_GM/GMCCRA_report_final.pdf

Carter, J.G., Cavan, G., Connelly, A., Guy, S., Handley, J., and Kazmierczak, A. 2015. Climate Change and the City: Building Capacity for Urban Adaptation. Progress in Planning 95, 1-66.

Carter, J.G., Handley, J., Butlin, T., and Gill, S. 2017. Adapting cities to climate change: exploring the flood risk management role of green infrastructure landscapes. Journal of Environmental Planning and Management 61(9), 1535-1552.

Carter, J. G., Connelly, A. and Labib, S.M. 2019. Assessing and responding to flood risk – a study of Greater Manchester's transport infrastructure. RESIN Project, University of Manchester. Available at: https://resin-cities.eu/cities/tier1/

Dadson, S.J., Hall, J.W., Murgatroyd, A., Acreman, M., Bates, P., Beven, K., Heathwaite, L., Holden, J., Holman, I.P., Lane, S.N. and O'Connell, E., 2017. A restatement of the natural science evidence concerning catchment-based 'natural 'flood management in the UK. Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, 473(2199), p.20160706.

Environment Agency. 2018. Working with Natural Processes – Evidence Directory. Environment Agency, Bristol. Available at: https://www.gov.uk/government/publications/working-with-natural-processes-to-reduce-flood-risk

Greater Manchester Combined Authority (GMCA). 2016. Flood investigation report – Greater Manchester – 26th December 2015. Greater Manchester Combined Authority, Manchester. Available at: https://www.greatermanchester-ca.gov.uk/media/1261/boxing-day-flood-report.pdf

Greater Manchester Combined Authority (GMCA). 2018. Greater Manchester Strategic Flood Risk Management Framework - Final report. GMCA, Manchester. Available at: https://www.greatermanchester-ca.gov.uk/media/1726/gmca-final-strategic-sfra-framework-january-2019.pdf

Iacob, O., Rowan, J.S., Brown, I. and Ellis, C., 2014. Evaluating wider benefits of natural flood management strategies: an ecosystem-based adaptation perspective. *Hydrology Research*, *45*(6), pp.774-787.

IPCC. 2012. Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA.

IPCC, 2014: Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 117-130.

Karpouzoglou, T., Marshall, F., Mehta, L., 2018. Towards a peri-urban political ecology of water quality decline. Land Use Policy 70, 485–493. https://doi.org/10.1016/j.landusepol.2017.11.004

Lane, S.N., 2017. Natural flood management. Wiley Interdisciplinary Reviews: Water, 4(3): 1211.

Lin, J., Cai, J., Han, F., Han, Y., Liu, J., 2016. Underperformance of planning for peri-urban rural sustainable development: The case of Mentougou District in Beijing. Sustainability (Switzerland) 8. https://doi.org/10.3390/su8090858

OECD / European Commission (2020), *Cities in the World: A New Perspective on Urbanisation*, OECD Urban Studies, OECD Publishing, Paris, *https://doi.org/10.1787/d0efcbda-en*

Piorr A, Ravetz, J, Tosics I, (2011), *Peri-urbanisation in Europe: Towards a European Policy to Sustain Urban-Rural Futures*: (Synthesis report of the PLUREL project): Luxembourg, European Commission Communications Unit, with University of Copenhagen. Available on https://trimis.ec.europa.eu/sites/default/files/project/documents/20130619_102649_92107_Peri_Urbanisation_in_Europe_printversion.pdf

Ravetz, J. (2011), Peri-urban ecology: Green infrastructure in the twenty-first century metro-scape: In: Douglas, I. Goode, D, Houck, M.C, Wang, R (Eds) *The Routledge Handbook of Urban Ecology*, Abingdon, Routledge

Ravetz, J, Fertner, C, & Nielsen, T.S, (2013): The dynamics of peri-urbanization: In: Pauleit, S., Bell, S., and Aalbers, C., (eds), *Peri-Urban Futures: Land Use and Sustainability*, Berlin: Springer. Available on http://link.springer.com/chapter/10.1007%2F978-3-642-30529-0_2

Ravetz, J & Warhurst, P (2013): Towards the new local-global: the emerging peri-urban of the Manchester city-region: In: Pauleit, S., Bell, S., and Aalbers, C., (eds), *Peri-Urban Futures: Land Use and Sustainability*, Berlin: Springer. http://link.springer.com/book/10.1007/978-3-642-30529-0/page/1

Ravetz, J (2015*): The Future of the Urban Environment & Ecosystem Services in the UK*: (Report to the Government Office of Science, Future of Cities programme): London, Government Office of Science. Available on: https://www.gov.uk/government/publications/future-of-cities-ecosystem-services

Ravetz, J, (2015): From ecosystems to eco-urban systems. *Environmental Scientist*, Vol 124, Sept 2015

Ravetz, J. and Connelly, A. (2018) *Water Governance in Greater Manchester*, Manchester, Natural Course.

Wingfield, T., Macdonald, N., Peters, K., Spees, J., and Potter, K. 2019). Natural Flood Management: Beyond the evidence debate. Area, 51(4): 743–751.