

Review

Decision-Making and Building Resilience to Nexus Shocks Locally: Exploring Flooding and Heatwaves in the UK

Candice Howarth * and Katya Brooks

Faculty of Art and Social Sciences, University of Surrey, Guildford GU2 7XH, UK; brooks@surrey.ac.uk

* Correspondence: Candice.howarth@surrey.ac.uk

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Abstract: There has been a policy shift towards localism in the UK driving responses and decision-making processes to respond to the impacts of climate change. This shift capitalizes on local expertise and knowledge, empowering communities to take ownership of response strategies, with an increased focus on building resilience to nexus shocks. This comes at a time when the ability of local authorities to lead responses to nexus shocks is decreasing due to lack of capacity, funding and a statutory requirement to better respond to the impacts of climate change. We examine local resilience to nexus shocks and climate impacts as a complex process of collaboration, communication, adaptation, learning from past events and preparing for future shocks. Drawing on examples of resilience to extreme weather events in the UK, this review paper assesses: (1) local responses to nexus shocks in the UK; (2) how and what evidence is used to inform decision-making in response to nexus shocks; and (3) how stakeholders increase local resilience to nexus shocks when faced with gaps in knowledge. We outline possible ways to extrapolate these insights beyond the UK context.

Keywords: climate change; nexus shocks; resilience; local decision-making; communication; collaboration

1. Introduction

1.1. Context

The meanings, applications and implications of the concept of ‘nexus thinking’ in the United Kingdom (UK) natural resource debates are generally found to vary, whilst the evidence base continues to grow rapidly [1–3]. Climate- and weather-related shocks, defined as “low probability, low frequency high impact events” [4], impact the food, energy, water and environment (FEWE) nexus and occur in the UK particularly in the form of flooding and heatwaves. A range of shocks are ranked by the UK Climate Change Risk Assessment (UK CCRA) [5], the London Resilience Risk Register [6] and the UK National Risk Register of Civil Emergencies [7] in the top areas of inter-related climate change risks faced by the UK, requiring more action, research, novel approaches and new strategic partnerships [8]. Flooding and heatwaves in particular are listed as key risks to the UK.

Responses to climate change in the UK are primarily led by a number of government departments: the Department for the Environment, Farming and Rural Affairs (Defra) with the Environment Agency and Natural England lead on adaptation; the Department for Energy and Climate Change (DECC) led on mitigation until merging with the Department of Business, Innovation and Skills (BIS) to become the Department for Business, Energy and Industrial Strategy (BEIS) in 2016; and the Foreign and Commonwealth Office (FCO) and Department for International Development (DfID) are responsible for international action on climate change and responses to impacts abroad. In addition, the UK

Cabinet Office houses the Cabinet Office Briefing Room A (COBRA) committee along with the Civil Contingencies Secretariat and helped set up the National Hazards Partnership in 2011 to provide evidence on natural hazard risk management for civil contingencies, governments and responder communities across the UK.

1.2. Review Approach

Building on findings from a UK project which explores how to better inform decision-making in response to nexus shocks [9], this review paper explores the roles and perspectives of local decision-makers, processes and communication strategies in response to nexus shocks and how these shocks affect the local level. The potential scope of this review paper and the evidence base it could draw upon are broad, deep and evolving, and therefore the research presented here is not intended to be exhaustive but rather a snapshot with signposts to further required research.

In order to identify relevant literature to include in the assessment of evidence which forms the basis of this review, a systematic approach was employed to ensure that the review of evidence draws on a comprehensive and unbiased evidence base that is relevant to the overall focus of the paper. The initial inclusion and exclusion criteria for evidence were defined in alignment with the focus of the paper and through discussions with key experts and authors in the field, identified through an initial literature search (Table 1).

Table 1. Inclusion criteria for the literature search.

Inclusion Criteria
Include grey literature, articles, reviews or conference papers
Include papers published between 2003 and 2016 to capture evidence for the 2003 heatwave.
Include only studies about and examples of nexus OR nexus shock OR food OR energy OR water OR environment AND climate change AND decision making.
Include studies carried out in England OR Northern Ireland OR Wales OR Scotland OR Britain OR UK OR the United Kingdom.

The review focuses on climate and severe weather shocks to the food, energy, water and environment nexus and on the risks of flooding, high temperatures and food production and trade. In order to establish the range, balance and overall weight of evidence, a number of different data sources (practitioner, policy and academic) were examined in order to identify and extract the overarching themes of relevance to each section of this review paper. Through a first manual screening of the titles and abstracts, papers were excluded where it was clear that their focus was not relevant to the review. The remaining papers were then classified by their broad framing, such as their focus on a particular area of the nexus or nexus shock, level of decision-making, or resilience. Full papers were then read, cross-checked with the inclusion and exclusion criteria and a final list produced. Thorough processes, including regular moderation, were established to ensure that the project team took a consistent approach to applying inclusion and exclusion criteria and reviewing papers.

Based on the above approach, we structure the paper in the following way: Section 2 provides an assessment of definitions of nexus thinking and nexus shocks, Section 3 explores the local relevance of nexus shocks with particular emphasis on heatwaves and flooding, Section 4 discusses responses and resilience to these shocks locally, and Section 5 concludes with a call for more research on specific areas that would further increase the evidence base on decision-making with respect to local nexus shocks.

2. Defining Nexus Thinking and Nexus Shocks

A large body of work explores a variety of aspects of the nexus, “all [of which] seek to describe interactions across and between relevant systems” [10] (p. 1). There is consensus that the ‘nexus’ of water, energy, food and environment systems has gained prominence internationally, particularly in science and environmental policy, governance and business spheres and across academic research

disciplines [1–3,9–17]. The food-energy-water-environment (FEWE) nexus is also referred to as the ‘water-energy-food nexus’ (WEF), ‘water-energy-food-climate nexus’ or ‘energy-food-environment nexus’ and as to the origins of nexus terminology, consensus is less strong. The term ‘nexus’ has been used to describe interactions between the food-energy-water-environment systems since the 1980s [1] (Box 1).

Box 1. Emergence of the concept of ‘nexus shocks’ at the international level.

The term ‘nexus shocks’ featured at the 2008 and 2011 World Economic Forums and in 2009 former Chief Scientific Advisor to the UK Government Sir John Beddington made reference to the ‘Perfect Storm’

... of interlinked challenges facing humanity and a number of prominent international institutions (such as the World Bank, the UN World Water Assessment Programme, the European Commission, the OECD and the Global Water Partnership) subsequently produced policy and perspective papers on the nexus [13]. According to much of this literature, the solution to the interlinked challenges outlined by Beddington, was [‘nexus thinking’ or a ‘nexus perspective’]. [3] (p. 164)

Nexus thinking was a main focus of the Bonn 2011 Conference, the 6th World Water Forum in Marseilles in 2012, the Rio +20 negotiations 2012, and the 2014 Stockholm Water Week.

The nexus is a useful concept to frame the complexities of resources, sectors, stakeholders and methods of thinking and working (Box 2). It represents “... a multi-dimensional means of scientific enquiry which seeks to describe the complex and non-linear interactions between water, energy, food, with the climate, and further understand wider implications for society with interdependencies and tensions across sectors” [1–3,11,13,14].

Box 2. Why ‘nexus’ is a useful concept [4].

The nexus concept:

- Provides a lens through which we can gain a deeper understanding of how these resources are linked, how changes in one can affect another, and it highlights how complex the processes are that connect them.
- Provides a way to capture the interactions and interdependencies between the elements that define it as well as how stakeholders involved in nexus issues interact with each other.
- Enables a better understanding of (un)intended consequences of policies, technologies and practices that may arise around nexus issues whilst simultaneously shining light on areas of opportunity that may merit investigation.
- Provides a natural frame for rethinking sustainability as a way of analysing problems which can be approached more effectively when considered as a whole.
- Represents a multi-dimensional means of scientific inquiry which seeks to describe the complex and non-linear interactions between water, energy and food systems with the climate.

When considering the complexities of the nexus, we see that it has two dimensions related to: (1) food-energy-water-environment resources; and (2) the trans-disciplinary approach linking different actors, sectors and decisions that are made across these resources [9]. Whilst it captures the trans-disciplinary nature of nexus resources, interactions, sectors, stakeholders and associated decision-making processes, Cairns and Krzywoszynska [3] (p. 164) argue that the term is “a buzzword: a term whose power derives from a combination of ambiguous meaning and strong normative resonance”. The term is simultaneously used to refer to integrated ways of thinking however, as discussed by Allouche et al. it may act to confuse the debate [13]:

The nexus is an immature concept in need of a more critical conceptualisation [and] ... although it is difficult to disagree with a vision of integration between water, food and energy systems, there are fewer consensuses about what it means in reality. While some consider its framing to be too restrictive (excluding climate change and nature), particular actors see it as linked to green economy and poverty reduction, while others emphasise

global scarcity and value chain management. The nexus debates, however, mask a bigger debate on resource inequality and access, contributing to social instability [13] (p. 617).

The need to address these considerations has inspired additional lenses [13] to those proposed by Howarth and Monasterolo [9] which would enable a more effective and holistic approach to understanding nexus thinking: better consideration for the local context, decision-making across scales, the role of science and technology, and the importance of understanding how plural ways of thinking can inform decision-making processes.

Building on this, a ‘shock’ is defined as the “manifestation of risk” [18] (p. 4) and uninsured shocks specifically are defined as “adverse events that lead to a loss of household income, a reduction in consumption and/or a loss of productive assets” [19] (p. 1). In the system reliability modelling world, the term ‘shock’ “is usually defined by the time between two consecutive shocks, the damage caused by a shock, the system failure and the dependence relationship among the above elements” [20] (p. 405). However, “there is no one agreed method for quantifying or categorizing when a country has experienced a food production shock” and differences can be seen in the “levels, countries and timings for shocks” [21] (p. 8) used by different studies. Ultimately, the key characteristics of a nexus shock [9], which we adopt in this review paper, include: a low-probability, low-frequency, high-impact event with multi-scale, multi-stakeholder and multi-resource impacts that span food, energy and water systems. Due to the relatively recent development of ‘nexus’ terminology and frameworks as well as context dependency, the lack of evidence specifically related to nexus shocks underlines the need for further research.

Terms such as ‘climate’, ‘climate-related’, ‘severe weather’ or ‘extreme weather’ shocks, or a prefix of a specific shock impact area such as on food, production, energy, price or supply and the term ‘risks’ instead of ‘shocks’ tend to be more commonly used in academic, grey and practitioner literature but have slightly different meanings and implications [22–29]. For example, the United Nation’s Development Programme’s (UNDP) 2007 report *Climate Shocks and their Impact on Assets* [22] employs the term ‘climate shocks’ and explores the relationship between shocks and risks:

Risks are prospects of a shock or, alternatively, shocks can be thought as the realization of risks. [T]he term ‘shocks’ has already a very specific connotation that encompasses: (i) unexpectedness (i.e., the risky damaging fluctuation already happened, though it had low ex-ante probability); (ii) size; (iii) high damage due to concentration on persons with high vulnerability and low resilience; (iv) exogenousness in the source; and (v) physical or psychological strain to one or more individuals due to that stress. Thus, the term climate shock would already cover what the disaster literature considers to be a natural disaster: those events that outstrip the capacity of a society to cope with it [22] (p. 1).

This distinction is useful, providing endorsement for using the term nexus ‘shocks’ and the need for building resilience and capacities of a society, system or structure to cope with and adapt to respond better to a shock. It is a reminder of the continual need to avoid using terms as if they are self-evident in their implications, to ask questions of why a term is being used returns to the argument that ‘nexus’ is another buzzword [3].

3. The Local Context and Responses to Nexus Shocks

The UK was the first country to have a Climate Change Act and a National Adaptation Programme focused on addressing the consequences of climate change, suggesting a strong drive from central government in response to nexus shocks. However, since 2010 and the UK Government’s launch of the ‘Big Society’ agenda, the local context has been characterised by a policy shift towards localism [30] which has had two important impacts in relation to decision-making in response to nexus shocks in the UK. Firstly, local authority (LA) requirements to report against national indicators ended, between 2008 and 2010 there were national performance indicators on carbon emissions reductions and climate

change adaptation for LAs. Instead, much of what is in place now is reliant on voluntary actions [30,31]. Secondly, responsibility for action (including on climate change) has been devolved to the local level with “the need to enhance risk ownership by communities” ([32], p. 1). The resulting implications are that the agenda capitalizes on local expertise and knowledge with a focus on building community resilience to nexus shocks. As stated by Howarth and Painter ([33], p. 10), “climate change is a local and context-specific issue” and therefore much work in practice on responses to nexus shocks occurs at the local level. Furthermore, with the withdrawal of the state and its funding from the local level, combined with the projected increases in magnitude and frequency of nexus shocks due to climate change in the UK, the need for effective local level responses, collaboration and communication between tiers of society and government as well as research on this area is urgently required [34].

3.1. Nexus Shocks at the Local Level: A Focus on Flooding and Heatwaves

To build local resilience to nexus shocks, research points to the importance of confronting the politics and power inside the concept of ‘resilience’. The Department for International Development’s (DfID) 2011 *Resilience Framework* raises important questions to consider whenever resilience is being used [31,32,35,36], such as resilience ‘to what’ (for example, to what kinds of threat? What types of shock or stress?), resilience ‘of what’ (e.g., a structure of function; a community, an institutional structure or infrastructure or the qualities of services being resilient), and resilience ‘for whom’ (i.e., those who are likely to benefit or those who may be excluded). Current UK Government policy in relation to resilience and nexus shocks mainly centres on emergency planning and a reactive decision-making process to build resilience *to* specific climate-related (e.g., floods) and non-climate-related (e.g., industrial action, terrorist attacks) nexus shocks and on *resilience of* a wide range of entities such as communities, institutions and structures in the short term [37]. Emergency events are not necessarily assessed and responded to proactively or in the wider context of climate change. There is therefore a need to move beyond a reactive decision-making process in order to adapt and transform with respect to future nexus shocks, “understand the importance of local action for global impacts” ([9], p. 59) and build long-term resilience.

In the UK, resilience has been the focus of a number of research activities, funding calls and cross-research council initiatives [38–42]. Therefore, it is posited that where the terminology has filtered down to the local level “it tends to provide only a framing, rather than being used to assess project progress or success, or as a way to develop interventions” ([31], p. 64), perhaps as a means to adapt to funders’ frameworks.

The UK is affected by a number of climate- and weather-related shocks, two of which have been ranked as most important to the UK [25] and hence we explore these in more detail in the context of local decision-making: flooding and heatwaves. We do so by exploring the following questions: Firstly, what is the shock? Secondly, how does it affect at the local level? Thirdly, what are the local responses to the shock (and evidence of this)? Finally, how could this be improved? Table 2 provides an overview of the actors involved in decision making in response to the nexus shocks of flooding and heatwaves at the local level and examples of the work they undertake.

Table 2. Overview of the actors involved in decision making in response to the nexus shocks of flooding, heatwaves and food price spikes at the local level.

<i>Institution</i>	<i>Sector</i>	<i>Examples of Work on the Ground</i>	<i>Flooding</i>	<i>Heatwaves</i>
Local authority (LA)	Public	<ul style="list-style-type: none"> Community and business engagement Provide information, resources and guidance to raise awareness about risks, mitigation and adaptation action Provide resilience infrastructure, e.g., property level protection, sandbag stores, etc. Develop resilience strategies to be used by communities Identify opportunities and constraints of the planning process for shock management Help communities/businesses develop resilience plans Work with partners to collect data to map flood risk and vulnerable groups 	✓	✓
National Flood Forum (NFF)	Civil society	<ul style="list-style-type: none"> Trusted intermediary between LAs and communities Offer a resource hub, flood surgeries and guidance Facilitate and support community flood groups Help communities prepare for and recover from floods 	✓	
Community groups (including flood groups)	Civil society	<ul style="list-style-type: none"> Train flood wardens or other community champions Raise awareness of nexus shocks Communicate nexus shock warnings Support communities and businesses in developing emergency and resilience plans Identify/support vulnerable community members/groups 	✓	✓
Local Resilience Forums (LRF)	Public	<ul style="list-style-type: none"> LRFs were formed as a requirement of the Civil Contingencies Act (2004), comprising key emergency responders and specific supporting agencies. Facilitate multi-agency meetings and training Share information and lessons learned from exercises, emergencies and emerging policies to facilitate planning and response to shocks Produce Community Risk Registers 	✓	✓
Internal drainage boards	Private	<ul style="list-style-type: none"> Manage and maintain water levels and flood defence Operate and maintain 30 onshore wind farms, 1 bio-energy power station, over 500 pumping stations, 22,000 km of watercourse, 175 automatic weed screen cleaners, etc. 	✓	
Utilities	Private	<ul style="list-style-type: none"> Water and sewerage companies clear up spills from public sewers and pumping stations, restore drinking water supplies Electricity companies restore infrastructure and supplies, supply generators to customers and refuel 	✓	✓

3.1.1. Flooding

The UK CCRA 2017 Evidence Report “presents compelling evidence that climate change may lead to increases in heavy rainfall and significantly increased risks from fluvial and surface flooding by mid-century” ([5], p. 11) making flooding the most prominent climate change adaptation issue faced by communities in the UK [7,8,37,43–45]. If the current levels of adaptation continue, and assuming a 2 °C global increase in temperatures, annual damages are expected to rise by 50% [44] with related project costs of flooding reaching £10 billion in the next 25 years [37] leading to increased risks of cascading infrastructure failures in terms of energy, transport, water and communication links. Longer-term stresses across the nexus can also be generated, such as: negative impacts on food and energy security (e.g., energy outages) and loss of, or pollution of, agricultural land and food crops leading to rising costs of living including increases in home insurance premiums, energy bills and food price spikes [46,47]. The Committee on Climate Change warns that the impacts of flooding and coastal change shocks to communities, businesses and infrastructure “are already significant” with “more action needed” ([8], p. 4); further evidenced by the severe floods experienced in Boscastle (2004), Carlisle (2005), Hull (2007), Cumbria (2009) and the winter floods of 2013–2014 and 2015 in the UK [48].

Alongside these events there has been a shift in policy, attitude, roles and responsibilities and a change in paradigm from one of flood *resistance* to *resilience* that now drive responses and decision-making in flood risk management (FRM) in the UK [48]. Within this shift, “... stakeholder engagement and public participation are seen as central to effective FRM” ([49], p. 275) and to

developing more accurate and effective flood risk planning, solutions and responses at the local level, such as community flood groups and flood plans; property level protection; mapping and identifying need and vulnerability, and so forth [49]. This is further reflected in the UK government's national response plans to flooding events: Making Space for Water strategy [50], the Pitt Review [43], the Water and Flood Risk Management Act, UK Climate Change Risk Assessment 2017: Projections of Future Flood Risk [44], and the National Flood Resilience Review [45]. As a result, in 2016, the Government established Flood Re to make affordable flood insurance available to households in flood risk areas and the *National Flood Resilience Review* was published in response to the severe floods of 2014–2015 ([45], p. 2). The review identifies “530 sites around the country where key local infrastructure (e.g., clean water, electricity, health and telecoms) is still vulnerable to flooding” ([45], p. 17), each potentially affecting at least 10,000 people. As part of the review, Government “secured commitments from the water and telecommunications industries to make their infrastructure more resilient” and, in collaboration with the Met Office, developed plausible extreme rainfall scenarios of 20–30% more than previously; evidence that Government now fully recognizes the impact of climate change on increasing flood risk ([45], pp. 1–3) at the local level.

An example of a government-led initiative to build resilience to flood risk at the local level was Defra's £5 million Flood Resilience Community Pathfinder (FRCP) scheme (2013–15). Supporting 13 projects led by LAs in areas of significant or greater risk of flooding across England, the scheme aimed to assess the factors that help to build resilience, support the implementation of physical interventions (e.g., property level protection) and encourage new approaches to partnership working, collaboration and communication, particularly between LAs and communities [31]. Key outcomes across the FRCP projects included the establishment and maintenance of 111 community flood groups as well as community flood forums and networks which add to the existing governance arrangements for FRM at the local level ([51], p. 1). Setting these up through multi-agency partnerships involving other LA departments, national agencies (e.g., Environment Agency), civil society and communities proved invaluable to developing these institutional structures, governance processes and networks which have been important for building institutional resilience and linking with the wider resilience agenda [31,48].

3.1.2. Heatwaves

There is currently no universally accepted definition of a heatwave ([52], p. 15) with important implications for communication, decision-making and shared understanding. The Met Office uses the World Meteorological Organisation's definition (WMO): “... when the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5 degrees Celsius, the normal period being 1961–1990” [53]. Heatwaves are currently rare in the UK, however the frequency, intensity and length of heatwaves are predicted to be exacerbated by future climate and demographic changes and increasing urban development [8,54–56]. However, “hot weather already presents a risk to people and property”, particularly ‘urban heat risk’ in cities in the UK ([54], p. 1) making this an important shock to explore.

Public Health England's (PHE) publishes its UK Heatwave Plan annually since 2004 as a result of the devastating heatwave experienced across Europe in August 2003. The shock of a severe and prolonged heatwave such as this can negatively impact food, water and energy supplies as well as businesses, transport, health and social care services with effects felt at the local level. Preston et al. report the impact in England: “... where peak temperatures reached 38.5 °C, in the hottest period of August 2003 there were 17% (2091) more deaths than expected, given the average for the same period in the previous five years; a 42% increase in deaths was noted in London...” ([47], p. 23). The UK CCRA 2017 predicts summer heatwaves like those experienced in 2003 to become the norm by the 2040s and premature heat-related deaths to more than triple by the 2050s ([8], p. 4). PHE's plan describes the five-tiered (Levels 0–4) heat–health watch system which operates annually in England from 1 June to 15 September, supported by heatwave alerts co-produced with the Met Office. The decision to issue a

Level 4 alert and to declare a national emergency “is made at national level and will be taken in light of a cross-government assessment of the weather conditions, coordinated by the Civil Contingencies Secretariat (Cabinet Office)” ([57], p. 33).

The factors that make people, systems and structures vulnerable to high temperatures are complex and dynamic, and include quality of housing and the built environment, local urban geography, household income, employment, tenure, social networks and self-perception of risk [58]. In a manner similar to the risks of flooding and food price spikes, “These factors influence an individual’s exposure and sensitivity to high temperatures, as well as their ability to anticipate, respond and adapt to conditions to avoid heat stress” ([52], p. 8). Perhaps due to a lack of perceived immediacy or severity of the shock that heat waves currently present, Lefevre et al. find that adults in the UK “perceive heat protection methods as ineffective and unnecessary” ([55], p. 282). As such, “[a]lthough hot weather poses potential health threats, many UK adults seek the outdoors during hot weather without protecting themselves [or their property] against the heat” ([55], p. 282). Heat risks tend not to be perceived as personal risks and “therefore planned preventive measures by individuals are largely elusive. . . . Policy related to heat relies on early warning and public information programmes and does not reduce underlying vulnerability” ([59], p. 2721). To address this issue, PHE and the Met Office are collaborating with the National Health Service (NHS), AgeUK and Cancer Research campaigns to communicate health advice to vulnerable groups. However, vulnerability can derive from limited awareness of such advice and capacity to respond and this places a responsibility on actors at the local level to monitor vulnerable community members [60].

In his work on the social impact of heatwaves, Benzie finds that “Community champions have been shown to be particularly effective in building flood resilience and could be similarly successful in building resilience to heatwaves” ([52], p. 74). This raises the question as to whether building resilience to one nexus shock (such as flooding) requires the same capacities as others (such as heatwaves) as proposed by Benzie, particularly due to the multidimensional nature of different nexus shocks impacts and the distinctive knowledge needed and actions required. It may be taken as a given that a community with strong social capital will be good at resilience building in response to any shock but this is an area needing further testing and research.

Flooding and heatwaves are characterised by multiple meteorological, environmental and geographic complexities and impact society and the energy-food-water-environment nexus in a number of ways, both directly and indirectly. The overview we have provided here demonstrates the potential severe impacts they can have, the resulting processes that have been put in place to respond to them, and the range of stakeholders involved (see Table 2). These have often been the result of a shock event (e.g., the 2013–2014 winter floods or the 2003 European heatwave) and have involved leadership, communication, and collaboration across sectors, scales and stakeholders, with scientific advice underpinning much of this process [33]. However, when these types of shocks occur, due to their ‘shock-like’ nature, decision-making may not ‘follow the norms of rationality’ ([61], p. 14) and information provided to inform that decision making may not necessarily meet the needs of those using it [62]. The importance of communication and collaboration therefore merit deeper thought to challenge the linear processes of information dissemination that are often in place (e.g., producing a report or assessing evidence assumed to be sufficient to inform attitudes and decision making) and adopt more co-production approaches to ensure decisions align with the needs of end users and those most vulnerable to the impacts of these shocks.

4. Informing and Building Local Resilience to Nexus Shocks

4.1. Informing UK National Resilience

Increased investment in scientific research since the early 2000s has led to an abundance of evidence enabling LAs to be “much better-informed, and more confident about their own personal knowledge of climate change and their ability to access and use the ‘right’ kind of

information” ([63], p. 1). The UK Climate Projections 2009 (UKCP09), a climate analysis tool which helps decision-makers assess risk exposure to climate, and the UK CCRA, which addresses the urgency of further action to climate change, are useful examples of this. However, these have not led to “tangible adaptation actions” ([63], p. 1), with the needs of end users, particularly those at the local level, not fully taken into consideration [33]. This section further considers the implications from this, particularly in relation to what local responses to nexus shocks entail and how these could be improved.

The ability of governmental structures at any level to plan in advance effective responses to disasters, emergencies, extreme events or shocks and to support community resilience if events are uncertain and unpredictable has been called into question [64]. Recognizing that nexus shocks are uncertain and unpredictable by their very nature, particularly when explored in the context of complex adaptive systems (CAS), calls for a deeper understanding of what effective governance is. This would need to incorporate an understanding of the importance of strong collaboration, communication and connections between actors and institutions across levels and sectors for better decision-making and building of resilience in response to a nexus shock. With this in mind, Duit and Gallaz [65] identify five key characteristics for effective governance structures and resilience that could assist planning:

1. *Diversity*—of actors and structures in the governance structure: greater diversity is likely to mean a wider range of resources to be drawn on in emergencies;
2. *Autonomy*—actors and structures: autonomous components are likely to be more resilient;
3. *Interdependence*—of actors and structures: ability of each actor/structures to support each other;
4. *Adaptability*—of actors and structures to learn from experience: more adaptable actors and structures will increase resilience;
5. *Collaboration*—between actors and institutions: partnership working between sectors brings in a wide array of resources to draw on.

There is a wide range of literature on the concept of governance and multi-level processes with recognition that “initiative and decision-making processes do not take place exclusively at the state level but within an increasingly pluralistic structure of agents at different spatial scales,” with different levels of cross-sector authority [13,66,67]. This aspect is raised by literature on decision-making specifically in response to nexus shocks too. For example, Howarth [4] and Benzie [58] warn that decisions should incorporate cross-sector and stakeholder needs and processes, and also consider the implications of decisions for other levels (i.e., international, national, local, community), thereby adopting a co-production process [68]. In doing so, the needs of end users would be better considered and characteristics of the decision-making process, such as those outlined by Gallaz [65], would more effectively interact with each other thereby contributing to better aligned processes and being more directly useful to decision makers on the ground. This need for ‘bottom-up’ action is further recognized as invaluable as it identifies and supports people most at risk at the local level from a nexus shock and emphasizes co-production, collaboration and communication in designing sustainable and resilient responses with communities.

4.2. Devolving Responsibilities for Resilience to the Local Level

The concept of the ‘Big Society’ in the UK is seen as an attempt to reduce the role of the state and devolve responsibilities for action to the local level, bringing with it significant cuts to public sector budgets. This has led to LAs facing a cumulative cut of revenue per person between 2009–2010 and 2015–2016 of 26.1% [56] affecting progress in adaptation and resilience by LAs in the UK ([30], p. 24). Therefore, despite there being widespread concern about the impacts of and responses to nexus shocks, a key contextual issue for decision-making and building resilience in response to these shocks stems from the fact that the resources, priorities and evidence to support long-term sustainability and the necessary collaboration and communication are not necessarily available. Calls for building resilience to nexus shocks at the local level have been challenged as an “appropriation of the climate challenge

by neoliberalism” [69] and research undertaken by Stevenson ([70], p. 697) concludes that regional and policy documents that plan for nexus shocks, such as PHE’s Heatwave Plan, “... focus on institutional emergency responses and infrastructure development. In these documents, communities are passive recipients and have resilience bestowed on them by active local institutions—the top-down hierarchy is clear.” Further, while use of the term ‘resilience’ by UK Government departments, and more widely, has increased over the past decade, critics suggest that a resilience framing can dangerously move focus away from addressing societal vulnerability to climate or severe weather-related shocks [71]. Consequently, an important local and community voice necessary for decision-making processes on nexus shocks, providing an understanding of implementation on the ground, whilst not adequately covered, could nonetheless help overcome challenges of adopting a ‘nexus approach’ [70].

Collaboration and communication between the public sector and civil society play an important role in the effectiveness of both top-down and bottom-up decision-making in response to nexus shocks through the provision of information, voluntary action and joint implementation of local projects ([72], p. 857). Decisions at a national level may fail to consider implications for the local level or in the long-term, and sectorial input in nexus shocks and grassroots participation from local communities is needed to design sustainable and resilient responses to these shocks [4]. Social science literature stresses that practical difficulties in using climate science to inform decision-making in response to nexus shocks at the local level are two-way [30,33]. For example, Howarth and Painter ([33], p. 10) recommend that the Intergovernmental Panel on Climate Change (IPCC), a UN-body which assesses the large evidence base on climate change with respect to (1) the science; (2) adaptation and vulnerability; and (3) mitigation options, ensure “a two-way communication process by which it synthesizes evidence to inform local decision-making on climate change whilst simultaneously drawing on more localized expertise...” This is also applicable to the wider climate science evidence base, such as the UKCP09 and the UK CCRA.

4.3. Building and Informing Local Capacity and Resilience to Nexus Shocks

The increasing focus on resilience within policy and decision-making requires greater investigation and “necessitates a better understanding about the capacities of communities on a local level” [48] (p. 2). Drawing on international environmental literature, Cutter et al.’s resilience categories have been applied to research on building resilience to nexus shocks at the local level [73]. These capacities focus on factors that can be used to measure a baseline in order to assess the impact of an intervention on reducing the consequences of disasters, these include [74]:

- *Social*—demographic information (e.g., age, number of people in a household, level of education, people with physical and learning disabilities);
- *Economic*—employment, home-ownership, income levels, value of property;
- *Institutional*—formal and informal arrangements and experience in place, emergency response plans;
- *Infrastructure*—what is in place to aid responses (e.g., property-level protection (PLP), flood defences);
- *Community capital*—social glue and bridging capital (e.g., knowing neighbours, participation in community groups, local understanding of risk).

Ultimately, in order to maximise resilience to a range of nexus shocks, communities need to be empowered to develop and possess “the capabilities and capacities...to thrive in response to uncertainty, threats, disturbances and shocks...including the ability of individuals, and the communities they live in, to develop the capacities needed to promote social justice in relation to any resilient strategies” ([70], p. 695). By examining capacities, it is possible to identify commonalities that can lead to explicit framing of transformative social change [35,70] whilst remaining aware that the most socially and climate vulnerable communities are likely to possess less capacity to draw on in response to a nexus shock [14,48,75]. With limited capacity and funding, and statutory requirements

for LAs to address climate change, there is now an essential and wide-ranging role for communities and civil society organizations in response to nexus shocks to fill the resultant gaps in knowledge and action. Civil society organizations are particularly important intermediaries in facilitating cross-sector and cross-level communication and collaboration between LAs, businesses and communities, but there is a role for all actors to drive resilience-building activities.

There is a clear misalignment between the needs of decision makers at the local level and evidence and scientific information available to help inform their decision making processes. For example, in the UK, the late 1990s to early 2000s were characterized by the widespread challenges faced by LAs in identifying suitable and robust evidence on climate science and impacts of climate change, referred to as the ‘climate information usability gap’ [30]. In response to this the UK government established national services that would help address this knowledge gap through the UKCP09, the CCRA, and the Environment Agency’s Climate Ready Programme (see Section 3). While it could be argued that this was an example of the ‘information deficit approach’ in practice, it nonetheless led to increased understanding, awareness and capacity to inform decision-making processes around climate impacts at the local level [33]. In spite of increased production and availability of science and evidence to inform decision making at the local level, demand for this remains low due to existing policy, legal and regulatory frameworks which are misaligned with (1) the needs of decision makers to constructively design processes that facilitate robust solutions to climate change; and (2) the scientific complexities of climate projections produced [76].

Whilst research and scientific evidence are relied upon to inform decision-making processes, practitioner evidence can also play an important role in filling gaps in knowledge on adaptation to climate change [77]. Initiatives such as the global Programme of Research on Climate Change Vulnerability, Impacts and Adaptation (PROVIA) [78] and Country Level Impacts of Climate Change (CLICC) help assess the impacts of climate change at the national level and work to provide relevant information to decision makers on adaptation and vulnerability to climate change [79]. Other city-based approaches, such as ICLEI (the International Council for Local Environmental Initiatives), the C40 Cities Climate Leadership Group, weADAPT, the online platform on climate adaptation issues, and CLIMADAPT [80] demonstrate the impact of collaborative programmes between scientists, government and practitioners to produce effective responses to climate change. In light of local funding cuts [81] and with the intricacies and complexities of working across the energy-food-water nexus [82,83], these programmes are particularly useful to address the needs of those working on the ground [84]. This aligns with the United Nations Framework Convention on Climate Change (UNFCCC) Adaptation Committee which set up the Nairobi Work Programme and recognizes the value of incorporating “activities that build upon each other and are linked to issues that are practical and that engage adaptation practitioners” [85]. Incorporating practitioners and those working at a city level for example, into climate decision-making processes could bring opportunities to address concerns about scale, of particular relevance when considering the complex and multi-scalar impacts of nexus shocks [68]. In doing so, processes would therefore incorporate those uniquely placed to provide evidence regarding best practice at the local level supported by case studies and lessons learned from an international perspective which may be of relevance when explored in different geographical contexts.

5. Conclusions

The FEWE nexus “displays a number of complexities, opportunities and challenges which are inter-disciplinary, cross-cutting and multi-sectoral” ([9], p. 59), further recognized by the UK CCRA 2017 which differs in approach to that of the UK CCRA 2012 in several ways by including “international risks that could have national consequences” ([25], p. 19). A nexus approach by (1) examining the impacts of these shocks to FEWE resources; and (2) adopting an interdisciplinary and collaboration approach, can help facilitate the sharing of knowledge, skills, expertise, best practices and lessons learned to improve communication and collaboration in decision-making and building resilience in response to nexus shocks at the local level.

With the number of nexus shocks predicted to grow both in the UK and globally, characterised by their unpredictability and with significant impacts for the local level, the need for effective local level responses, collaboration and communication between tiers of society and governments as well as research on this area is urgently required. This review paper provides the basis for further research having built a solid basis collating and discussing the wide range of evidence on effective mechanisms to inform decision making in response to nexus shocks, lessons learned and implications for collaboration and communication. Further evidence sharing across boundaries would enable a system of 'knowledge exchange' facilitating the exchange of lessons learned and successes in different contexts (e.g., sector, industry, policy, community) and extrapolation of these findings to different geographical, social, economic and cultural settings.

The body of evidence reviewed in this paper demonstrates that collaboration and communication between the public sector and civil society play an important role in the effectiveness of decision-making in response to nexus shocks through the provision of information, voluntary action and joint implementation of local projects. In particular, co-production provides many benefits incorporating cross-sector and stakeholder needs and processes, resulting in the needs of end users to be better considered. This ultimately leads to a better alignment with the needs of end users with more salient decision making processes for those implementing resilience to nexus shocks on the ground. However, decisions made to shape responses to nexus shocks formulated at the national level may fail to consider implications for the local level, longer term, or broader sector implications. Nonetheless, the examination of capacities across scales can help identify commonalities leading to clearer and more relevant framing of transformative social change. Furthermore, there is a misalignment between the needs of decision makers at the local level and evidence and scientific information available to help inform their decision-making processes (which are channelled through national processes) which must subsequently be addressed.

Whilst the review of evidence presented in this review paper has focused on the UK, the insights drawn are applicable and valid beyond this context. These may indeed be transferable and scalable to other countries faced with similar shocks to those experienced by the UK and vice versa, facilitating a two-way exchange alongside internal communication and collaboration processes across scales, sectors and stakeholders. However, the inherent unavoidable challenges and barriers involved must be acknowledged, such as the fact that impacts will be felt differently in different contexts and by different stakeholders, the understanding of risk and knowledge needs of different communities will vary along with their capacities to respond, and that there is a lack of trust in decision-makers and those informing them [9]. Currently, as noted by Matyas and Pelling [86]: "Case studies on resilience and shocks that do exist tend to be based in North America and Europe, leading to questions about the transferability of knowledge when applied to emerging economies/polities in the developing world. This limited geographic scope, however, is rapidly expanding as experiments with resilience continue elsewhere in the world and ongoing policy is reframed in the language of resilience."

This review paper has explored how responses to nexus shocks at the local level occur in the UK and within that the roles of communication, collaboration and ultimately co-production as a mechanism for inclusive, reflective and pro-active decision-making. There are limitations to capturing and providing a comprehensive account of the state of play due to the breadth and depth of the scope of the topic and the vast amount of evidence available (and continually being added to). Simultaneously however, there is limited evidence and formal evaluation around actions at the local level, particularly related to flood and heatwave risk management, which hinders comparative learning. The topic therefore is not without its challenges, which leads the authors to conclude this review with questions that would build on the findings from this paper and help to advance and guide thinking in this space. By addressing the following questions and forging collaborations to explore these through the variety of lenses explored in this paper, the evidence produced would better align with the needs of decision makers on the ground:

- The role of co-production: How can evidence of resilience to nexus shocks be co-produced in a way that is meaningful, useful and clear for all stakeholders?
- Local community resilience: Does promoting the idea that local communities can be climate-resilient create a false sense of security given the uncertainties around climate change, nexus shocks and the consequences?
- Limits to local decision making: What are the limits of decision-making at the local level and how does this affect the effectiveness of broader decision-making to build resilience to nexus shocks?

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