COMMUNITY RESILIENCE TO CLIMATE CHANGE

THEORY, RESEARCH & PRACTICE

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[Decorative cover image]

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AUTHORS' NOTE

This reader is an Open Educational Resource, meant to accompany a graduate or higher-level undergraduate university course in climate change resilience, adaptation, and/or planning. While the material is geared toward students in urban and regional planning, it may also be of interest to students of urban studies, public health, geography, political science, sociology, risk management, and others.

Each section of this volume includes (1) an introductory summary, (2) a reading list with full text articles*, (3) student exercises meant to enhance understanding and facilitate in-class discussion, and (4) additional discussion prompts or activities for instructors to use in class. The format of materials is intended to convey key concepts, while leaving ample space for student exploration, discourse, and creativity. Lessons may culminate in an applied, imaginative final project, a sample framework of which is provided at the end of Section VI.

*For your convenience, this reader includes full-text reproductions of articles which are available through an open access, creative commons license. Other relevant materials are included on the reading list under "Alternative Selections" and may be obtained and incorporated into the course at the discretion of the instructor. Each reading list represents a broad sample of available material, and should not be taken as a concrete course plan; instructors are encouraged to rework the lineup, select only the most pertinent readings for a given course, and exclude list items as appropriate.

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Introduction & Key Concepts

Global climate change is arguably one of the most pervasive issues in our modern world, drawing in everyone from politicians, planning practitioners, and researchers to academics, social activists, and average citizens. Depending on who you ask, climate change is among the greatest threats facing humanity and the planet as a whole [1,2]. Since the 1980s, considerable attention and resources have been directed toward climate models, which project the physical, ecological, and biogeochemical effects of a changing planet [3-5]. Recent priorities include shoring up of urban infrastructure to withstand those changes: efforts such as building a seawall to combat sea level rise [6], upgrading a sewer system to accommodate heavy precipitation [7], and lightening road surfaces to reduce heat absorption [8]. More recently, researchers and practitioners have come to focus on the human outcomes of climate change [9,10]; those aspects that are crucially important but harder to tackle: mental and physical illness, economic inequity, and displacement, to name a few [11-13].

With all of this in mind, we must ask ourselves, "How do we make a city **and** its inhabitants resilient to climate change?" We will go deeper into this question throughout the present text, exploring various perspectives on resilience; theoretical and practical descriptions; regional climate resilience plans; and opportunities for integrating salient concepts into climate resilience planning efforts. As you will see, resilience is a tricky, variably-defined, flexible notion. You will be asked to develop, discuss, and revisit your own perspectives on the subject throughout the course in order to cultivate a better understanding of this complex topic.

Climate Science & Manifestations of Change

Climate science is an intricate discipline unto itself, and we will not cover it in too much depth here. Rather, the following information should serve as a refresher for some, and basic orientation for others. For a helpful visual overview of the information included below, please visit the Planet Nutshell Climate Science Series at https://planetnutshell.com/climate-science/.

Climate change is commonly associated with an increase in global temperatures, and is sometimes used synonymously with "global warming," though the latter is only one facet of the larger issue. While "climate change" refers to long term weather patterns encompassing temperature, precipitation, and humidity, both natural and anthropogenic, "global warming" refers specifically to human-induced warming since the pre-industrial period. Though climate change is a natural process, its progression and global warming have reached unprecedented levels in our post-industrial world [14]. Research, conducted over many decades, points to carbon dioxide (CO_2) emissions as the primary culprit, resulting mainly from combustion of fossil fuels, deforestation, and land cover change [15]. While a certain amount of CO_2 - from respiration, decomposition and other natural processes - would not be cause for concern, excessive amounts as we have today accumulate in the atmosphere, producing a greenhouse effect which traps heat, warms the planet, and disrupts known weather patterns [14].

Changes in weather - hotter or colder days, drought, heavy rain, snow and storms - are just some of the manifestations of climate change on our planet and in our lives. Others include melting glaciers and sea level rise; extreme flooding, erosion and wildfires; altered growing seasons which affect food security; disruption or collapse of ecosystems; water contamination; destruction of infrastructure including buildings, roads, and ecological resources; and spread of disease [15,16]. All people and places will not experience the same effects to the same degree, but the global reach of climate change is undeniable. It is imperative that cities and communities understand their unique risks, and explore opportunities to maintain vital physical infrastructure, ecosystem services, and social supports in the face of an uncertain future.

Thinking about Resilience

Resilience, specifically climate change resilience, is at the core of this volume. The word has become ubiquitous across numerous disciplines - engineering, ecology, urban planning, and various social sciences, to name a few - but still lacks a clear, universally-accepted definition or interpretation. Indeed, the exact parameters of resilience tend to change considerably depending on the academic discipline or practical context within which it is applied. Is resilience to maintain the status quo and resist change, or to roll with the punches, adapt, and recalibrate? Is a resilient system rigid or flexible; diverse or specialized; well-connected or self-contained? Is a resilient city one in which buildings remain standing; capital is uncompromised; humans are able to thrive in body and mind? In section II, you will have the chance to explore various conceptions of resilience, but for the moment, consider what you know about this word and what it means to you.

As an additional point of consideration, practical work with resilience is sometimes impeded by the lack of a universal interpretation or assessment framework. Plans or research projects across disciplines and sectors may appear to address resilience in spirit, but use inconsistent language such as "adaptation," "stability," or "recovery." Furthermore, variability in identifying and measuring resilience provides challenges when comparing data or even trying to assess the situation in a single case [17]. Examples of various assessment frameworks, and practical iterations of resilience in planning, will be covered in sections III and IV.

Though resilience is often propped up as an ideal state or condition of systems (infrastructural, social, ecological, or otherwise), the concept has not been without critique. Namely, with regard to climate change, activists and scholars have pointed to the potential for a goal of resilience to reify socio-economic inequity and environmental injustice [18]. Though newer developments in the field

of "resilience thinking" seek to go deeper than the obvious status quo-based concerns, and account for nuanced political or socio-economic facets of resilience, there is arguably much room for improvement. More details and opportunity for discussion on this point will be provided in section V.

Why Does it Matter?

Many of us have heard climate change horror stories; apocalyptic accounts of how bad things could get if we allow the earth to warm beyond a critical tipping point. This is indeed a frightening prospect for the future, but the reality is that millions of people, at home and abroad, are already feeling the devastating effects of these changes. The impacts of climate change are not evenly distributed, but have been and will be felt most intensely by those in less wealthy, less developed regions of the world [11]. Notably, these locations contribute relatively little to the problem, but suffer for our behavior in the "developed" world. Here in the United States, socially and economically marginal communities often bear the brunt of climate change extremes, from heatwaves and flooding [19,20] to drought and air pollution [21,22]. As planners, scholars, and human beings, it is within your purview to consider these realities and pursue action. Your community may not yet have experienced a Hurricane Katrina, a Paris heatwave, a Somali drought, or Kiribati coastal flooding; you yourself may not have faced starvation, conflict, loss of home and family as a result of such occurrences, but a future without action is bleak for us all. It is important to address climate risks and opportunities for resilience now, not only for those already severely impacted, but for yourself and future generations.

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STUDENT EXERCISES

[To be completed prior to reading assigned articles]

(1) Based on your current understanding of the concept, define "resilience." You may use diagrams, words, or sentences to describe your understanding.

(2) Choose a newsworthy, climate-related event and place from the past few years (examples: Camp Fire in Paradise; Hurricane Maria in Puerto Rico; heat wave in Europe). Using your working definition, identify factors that advance or limit climate resilience in those communities (examples: access to housing, healthcare or recovery support; supportive built infrastructure; land use or zoning codes)

Please complete these exercises before reading additional assigned material. Try to articulate your position on this topic before you are influenced by other writers. You will revisit your responses at the end of this course to see how they change.

FOR INSTRUCTORS: CLASSROOM ACTIVITIES

(1) Ask students to share and compare their working definitions of "resilience."

(2) Ask each student to share their selected newsworthy event (Exercise 2) with the class. Alternatively, if most students have selected similar events, you may choose to form small groups for discussion.

(3) Bring a few news articles from recent years to add to the students' discussion. Rather than focusing on specific past events, these could highlight future conditions and possible adaptations. Examples:

- New York Times, 2019, "As Phoenix Heats Up, the Night Comes Alive"
- NPR, 2019, "Building For An Uncertain Future: Miami Residents Adapt To The Changing Climate"
- National Geographic, 2019, "Massive 8,000-mile 'Dead Zone' could be One of the Gulf's Largest"
- Chicago Tribune, 2018, "Federal Climate Change Report Paints Grim Picture for Midwest"
- CNN, 2019, "California Wildfires Burn 500% more Land because of Climate Change"

READINGS INCLUDED

[Open access articles; Full text included]

Hebbert, M., and Jankovic, V. (2013). Cities and climate change: The precedents and why they matter. Urban Studies, 50(7), 1332-1347.

Herrera, H. (2017). Resilience for whom? The problem structuring process of the resilience analysis. Sustainability, 9(7), 1196.

Meyer, R. (2019, January 15). Are we living through climate change's worst-case scenario? The Atlantic. Retrieved from https://www.theatlantic.com/science/archive/2019/01/rcp-85-the-climate-change-disaster-scenario/579700/
[due to copyright, a full-text reproduction of this article is not included in the volume, but it may be accessed online.]

ALTERNATIVE SELECTIONS

[Full text not included; May be accessible through your university library or elsewhere]

Cretney, R. (2014). Resilience for whom? Emerging critical geographies of socio-ecological resilience. Geography Compass, 8(9), 627–640.

Wallace-Wells, D. (2019). Chapter 1: Cascades. In The uninhabitable earth: Life after warming (pp. 1–36). New York: Random House, LLC.

Cities and Climate Change: The Precedents and Why They Matter

by Michael Hebbert and Vladimir Jankovic

This article was originally published in *Urban Studies,* 50(7), 2013. https://doi.org/10.1177/0042098013480970

ABSTRACT

This paper reviews the long tradition of city-scale climatological and meteorological applications prior to the emergence in the 1990s of early work on the urban/global climate change interface. It shows how 'valuing and seeing the urban' came to be achieved within modern scientific meteorology and how in a limited but significant set of cases that science has contributed to urban practice. The paper traces the evolution of urban climatology since 1950 as a distinct research field within physical geography and meteorology, and its transition from observational monographs to process modelling; reviews the precedents, successful or otherwise, of knowledge transfer from science into public action through climatically aware regulation or design of urban environment; and notes the neglect of these precedents in contemporary climate change discourse—a serious omission.

INTRODUCTION

It is an indisputable fact that cities were initially overlooked in the IPCC process. The science consisted of climatic forecasts framed at a global scale and the policy stakeholders were international or state actors. Scientists involved in global climate forecasting were slow to engage with the urban phenomenon except as an anomaly, city weather stations being a source of data distortion within the synoptic grid. The initial techniques for calculating national greenhouse gas inventories were based on the sectors of energy, industry, land use, agriculture and waste, making it hard to detect the role of urbanisation. Cities were not mentioned in the Kyoto Protocol. A similar sectoral logic applied to the periodic Global Environmental Outlook published by the United Nations Environment Programme. Governmental actors reinforced this predisposition: it was natural for the process of international negotiation to frame the climate change issue in terms of ministerial portfolios. The conventions of intergovernmental diplomacy discouraged consideration of urbanisation as a forcing factor and cities as distinct territorial stakeholders within the IPCC process.

Today, these exclusions are breaking down, bringing a sense of fresh opportunity at the urban level. The increasingly fine resolution of models of the earth's atmosphere (down to 25 km globally) means that cities are for the first time visible within general circulation systems. The environment of the city with its three-dimensional geometry, heat-absorbing materials, impermeable surfaces and pollution concentrations, is beginning to be resolved in weather models. Governmental actors have realised that mayors may be able to maintain progress where international agreement had stalled. Urbanisation entered for the first time as a climate change consideration in the fourth assessment report of 2007 and the fifth report due in 2014 will contain a separate chapter on cities and attempt a full-scale assessment of their role in carbon pollution and their potential adaptability to climate risk. The contemporary literature on cities and climate change—not least this Special Issue of Urban Studies—shows cities at last incorporated into global climate policy both as causal agents in greenhouse gas emissions/mitigation and as vulnerable targets.

In thinking about cities and climate change, it is hard to avoid the word 'unprecedented'. Everything hinges on recent scientific discovery and response to projected future threat. The time-frame stretches back no further than 1988, the year of UN General Assembly Resolution 43/53 and the establishment of the Intergovernmental Panel on Climate Change; or 1994 and the United Nations Framework Convention on Climate Change; or 1997, year of the Kyoto Protocol. All the C3 actors are new-born—ICLEI in 1990, the Climate Alliance in 1991, UNCED's Rio Conference in 1992, ICLEI's Climate Change Programme in 1993, energie-cités in 1994, the UN's Cities and Climate Change in 2008, the World Bank's Mayors' Task Force on Urban Poverty and Climate Change in 2009. It is often remarked that the discovery of global climate change has coincided with the tipping point to a world in which city-dwellers outnumber rural folk. So UN-Habitat summarises the threat to humanity

> Fuelled by two powerful human-induced forces that have been unleashed by development and manipulation of the environment in the industrial age, the effects of urbanization and climate change are converging in dangerous ways which threaten to have unprecedented negative impacts upon quality of life and economic and social stability (UN-HABITAT, 2011, p. 1).

This paper challenges none of the above except to put a question mark by the word unprecedented. It was at the scale of the urban heat island that anthropogenic effects—many linked to carbon combustion—were first systematically studied. The seminal contribution came from Albert Kratzer whose Das Stadtklima (1937) originated as a PhD thesis under the supervision of the geographer Edward Fels. Fels's own work on environmental impacts of economic progress—the businessman as shaper of the earth, Der wirtshaftende

Mensch als Gestalter der Erde (1954)—stood directly in line between the pioneering conservation science of George Perkins Marsh (1882)The Earth as Modified by Human Action or Nathaniel Shaler (1905)Man and the Earth, and modern environmental conservation represented by the Wenner-Grenn Foundation's symposium Man's Role in Changing the Face of the Earth (Thomas, 1956), Rachel Carson's (1962)Silent Spring, Carrol Wilson's (1971)Report of the Study of Man's Impact on Climate and Ward and Dubos's Only One Earth (1972). Urban climatology has a long pedigree in the conservation movement.

Since the study of urban weather systems is explicitly a science of anthropogenic cause, it has always challenged cities to assume responsibility for their role as "co-patterners of their climate" (Kratzer, 1956, p. 170). So there is also a prequel in the realm of collective action. Greenhouse gas mitigation is prefigured in municipal energy provision and public health action against soot and smog. The history of modern town planning can be written in terms of a collective response to the externalities of carbon-based industrialisation—as Patrick Geddes defined it in the early 20th century, substituting the clean-energy 'Neotechnic' city for the black pollution and physical concentration of 'Paleotechnic' capitalism (Geddes, 1915). Adaptation strategy has much older antecedents. The design of cities embodies local knowledge of wind, sun, humidity and precipitation, and of what is needed to survive in a given geographical setting against the contingencies of weather and human enemies. The history of urban habitats is not just one of passive adaptation to regional climate but of active transformation to produce microclimates radically unlike their surrounding terrain—hotter, cooler, drier, moister, less windy, more ventilated, or whatever is most conducive to human comfort at a given latitude. City design is the oldest type of anthropogenic climate change (Egli, 1951).

These precedents are explored in order, the next section dealing with the science of cities as climatic singularities, and subsequent sections with antecedents of urban policy response. The purpose of these historical excursions becomes apparent in the final section of the paper where we compare the prequel with the sequel and ask if and how it matters.

THE SCIENTIFIC PRECEDENTS

Scientific interest in the atmospheric effect of urbanisation extends more than 200 years. As a nation of pioneers, Americans contributed early research into the effects of deforestation, agriculture and town-building on seasonal change (Fleming, 1998). Thomas Jefferson suggested in 1824 that anthropogenic impact should be monitored through climatic surveys 'repeated once or twice in a century' (Landsberg, 1956). However, it was the great cities of Europe that contained the sites with the longest instrumental measurement series and here that the climatic changes produced by industrialisation, densification and suburban growth were most readily visible. Patterns of urban temperature, precipitation and wind circulation were studied for sites around London by Luke Howard between 1806 and 1830, for Paris in the 1870s by Emilien Renou, and for Berlin and Vienna in the 1890s by Gustav Hellmann and Julius Hahn respectively. The physicist Sir Arthur Schuster set up a University of Manchester observatory that allowed comparison with a municipal weather station two miles north. He commented:

The remarkable differences which appear in the temperature records in different parts of the city furnish an additional proof, if proof were wanted, that observations taken in or near a large town cannot be taken to represent correctly the meteorological character of the surrounding districts, but it by no means follows that these observations are of no value. On the contrary, they may lead to some important conclusions on what may be called town weather as distinguished from country weather (Schuster, 1893, p. 168).

Manchester, of course, epitomised the spectacular environmental contamination achieved by free industrial enterprise in the absence of pollution control. Whatever the season, town weather was foul. Its evil reputation was compounded by the orthodox medical assumption that infection occurred miasmatically—germ theory prevailed only in the final quarter of the century. Some of the 19th century's most detailed urban heat island studies were done by doctors—Barles (1999) for example discusses the work of Pierre Foissac, author of De l'influence des climats sur l'homme (1837) and De la météorologie dans ses rapports avec la science de l'homme et principalement avec la medicine et l'hygiène publique (1854). Ventilation and sunlight became overriding concerns of the movement for public health and hygiene, and so for early modern town planning.

The literature on the atmospheric environments of cities and their effects on citizens was swelled in the 20th century by a growing number of monographs from regional geographers, for whom the physical environment of the city offered an ideal object of study as a cultural artefact in a natural landscape. An increasing interest in micro-climates amongst meteorologists was pioneered by Gregor Kraus (Boden und Klima auf kleinstem Raum, 1911) and Rudolf Geiger (Klima der bodennahen Luftschicht, 1927). Much of this research was German, as was Albert Kratzer's earlier-mentioned synoptic text Das Stadtklima (1937). Written as a doctoral thesis in the philosophy faculty of the University of Munich by a Benedictine monk and geography teacher from the Ettal Abbey, Das Stadtklima was a definitive state-of-the-art review, based on 225 studies and extensive analysis of comparative data, documenting the differences between urban and non-urban climates, and explaining the mechanisms of the urban heat island, wind systems, ventilation and stagnation, precipitation anomalies, pollution and its dispersion, and the downwind effects of urbanisation. By the publication of the second edition in 1956, its reference list had grown to more than double the original size, incorporating a mainly English-language bibliography by the British public meteorologist Charles Brooks (1952).

Subsequent translation of Kratzer's second edition into English by the US Air Force in 1962 confirmed the internationalisation of the

science in post-war years. The leading protagonist was the German-born Helmut Landsberg who moved to the US from Germany in 1934 to teach the first graduate course on bioclimatology. A major figure in American meteorology, he served as director of the US Weather Bureau office of climatology from 1954 to 1967 and was a key architect of the modern-day NOAA. As US representative, he became a leading light in the early decades of the World Meteorological Organisation, chairing WMO's Committee for Special Applications of Meteorology and Climatology from 1971 to 1983. Landsberg had a particular interest in the science of urban climates, eventually authoring his own successor volume to Krazter's Das Stadtklima, The Urban Climate (1981). One of his most distinctive contributions to the literature was a longitudinal study of the new town of Columbia, Maryland, monitoring for the first time the emergence of an urban heat island as a greenfield site with 200 residents in 1968 was developed into a town of 20,000 population by 1975 (Landsberg, 1979).

Heat island studies at every scale continued to be a central object of research as the field of urban climatology developed in the second half of the 20th century. The geographer Tony Chandler analysed the entire metropolitan climate of Greater London, combining the German technique of automobile-mounted instrumental traverses with a British-style field survey involvement of schools, training colleges and volunteers (Chandler, 1965). The ambitious $10 million Metropolitan Meteorological Experiment METROMEX monitored an area of more than 4000 square kilometres around St Louis and controversially attributed anomalous patterns of thunderstorms, hailstorms and heavy rain to pollution drift east of the city (Changnon, 1979). Other researchers were tracking the Chicago dust plume 150 miles north-west to Madison Wisconsin (Bryson and Ross 1972, p. 64) and demonstrating the radical impacts of Houston's post-war development boom upon its rainfall pattern (Ferrar, 1976, pp. 60–98).

Belying Patrick Geddes's expectation of the clean technologies of the 20th century, pollution concerns continued to dominate the post-war climate agenda thanks to rapidly rising traffic levels and complex new types of industrial emissions—including lead, asbestos, micro-organisms, NOx, SOx, hydrochloric acid, particulates, aerosols and radioactivity—which dispersed under free wind conditions but could be trapped and combined into chemical soups under conditions of thermal inversion. At the conclusion of the second edition of Das Stadtklima, Albert Kratzer defined air pollution as the outstanding issue of the urban environment:

Enormous amounts of gases as well as liquid and solid matter are poured into the air every day by urban industry, household heating and traffic. It is not too far-fetched to compare the city to a volcano which continuously spews forth clouds of gas, dust and ashes (Kratzer, 1956, p. 166).

London experienced deadly smogs in 1952 and 1955, and New York on Thanksgiving Day of 1966 and in July 1970 (Bach, 1972). The first international conference on air pollution took place in New York in 1955 and Helmut Landsberg convened a major scientific gathering in St Louis in 1961, under the title 'Air over cities' (Landsberg, 1961). In these Cold War years, urban climate research also had the stimulus of the Soviet Union's known use of weather engineering technologies, and military concern for climatic dispersal of chemical and radioactive hazards (Derrick Sewell, 1968; Ferrar, 1976; Fleming, 2010).

One effect was to bring more atmospheric chemistry and physics into the urban arena. New measurement techniques such as constant-height balloons and remote sensing were added to the traditional repertoire of meteorological observation. The focus of analysis shifted towards measurement and modelling of energy fluxes on the meso-scale of the urban boundary layer and the micro-scale of the street canyon. Seminal contributions such as Ted Munn's Descriptive Micrometeorology (1966), Werner Terjung's The energy balance climatology of a city–man system (1970) and Tim Oke's Boundary Layer Climates (1978) laid the basis for progressively more sophisticated numerical modelling of the urban climate as computing power increased (Arnfield, 2003). Urban climatology was enriched by cross-disciplinarity: fluid mechanics contributed the techniques of CFD (computational fluid dynamic) modelling to simulate air flow in the complex three-dimensional urban environment; geography contributed GIS (geographical information system) methodology, allowing datasets on urban land use to be combined with atmospheric variables at high levels of resolution; architecture contributed CAD (computer assisted design), providing the link between urban-scale climatology and the burgeoning fields of environmental engineering and passive and low-energy architecture (PLEA); environmental management contributed modelling software such as the ENVI-met freeware which allows three-dimensional surface–plant–air interactions to be simulated at high levels of resolution. Last but not least, increased computing power and speed within the parent discipline of meteorology brought greater spatial precision to weather modelling so that for the first time urban-scale climatology could begin to be integrated with the synoptic mainstream (Masson, 2000).

The scientific consolidation of urban meteorology was matched at the institutional level. Helmut Landsberg played a key role in establishing urban climatology networks within the World Meteorological Organisation. A meeting on Urban Climates and Building Climatology jointly sponsored with the World Health Organisation in Brussels in 1968 was the first in a regular and continuing series of scientific conferences and state-of-the art reviews, led first by Tony Chandler and then by the Vancouver-based urban meteorologist Tim Oke. Significant features at the international level have been the continuing strength of the German research tradition, the emergence (with direct German links) of an equally vigorous scientific culture in Japan, the linkage to other UN-related agencies such as WHO, UNEP, UN-HABITAT, and the CIB, and the co-sponsorship of non-governmental bodies such as the International Federation for Housing and Planning (IFHP) and the International Society for Biometeorology (ISB). Conscious of the need to establish their group identity, urban climate scientists formed their own International Association for Urban Climatology (IAUC) in 2001 under the leadership of Tim Oke. IAUC's website and three-yearly conferences are the principal focus for urban climatology today. So the organisation is relatively new, but the scientific community has a 200-year track record of work on anthropogenic climate change.

THE POLICY PRECEDENTS—ATTEMPTED

Research in urban climatology was never just about 'blue skies' thinking. Scientists knew from the outset that they were studying an anthropogenic system with opportunities for positive feedback. In the words of M. Parry:

the urban climate deserves the interest of climatologists as an element of the physical background of town life, and as an artificial climate which may be modified by suitable planning (Parry, 1956, p. 45).

The duty of knowledge transfer from science to urban practice was a constant theme throughout the influential career of Helmut Landsberg:

The knowledge we have acquired about urban climates should not remain an academic exercise on an interesting aspect of the atmospheric boundary layer. It should be applied to the design of new towns or the reconstruction of old ones. The purpose is, of course, to mitigate or eliminate the undesirable climate modifications brought about by urbanization (Landsberg, 1981, p. 255).

The science-based call to action was given urgency by on-going trends (Douglas, 1983). The motor-car, once regarded as a clean technology, was found to be a significant chemical polluter and a forcing factor in the urban heat island, with each vehicle emitting as much heat as a domestic boiler; rates of stormwater run-off grew in direct relation to post-war highway construction and surface parking; loss of vegetation and permeable surfaces also reduced the moisture available for evaporative cooling in the urban heat island; the growing height and mass of urban buildings increased aerodynamic roughness and complex turbulence effects at ground level, while denser building materials with high thermal admittance, absorbed and retained heat; public health concerns over photochemical smog were compounded by the issues surrounding nuclear power generation. Reid Bryson and John Ross wrote:

The time is at hand to begin planning and redesigning of urban areas with much more attention to climatic considerations (Bryson & Ross, 1972, p. 52).

In terms of recommendations, urban climatology had begun (as in Kratzer, 1937, p. 95) with simple advice about sunshine and shadow, and the need to locate residential districts upwind of industry, in the 'climatically beneficial direction'—klimatisch begünstigte Luvseite. In post-war years, it developed a progressively more sophisticated critique of current urbanisation practices. In November 1972, Helmut Landsberg's plenary address to the American Meteorological Society Conference on the Urban Environment in Philadelphia set out an agenda for city-building:

Widely divergent views have come from architects, engineers, economicsts, political scientists and real estate developers. To this chorus of intellectual bricklayers the meteorologist is a Johnny-come-lately … Sound meteorological principles … must begin to penetrate the planning process (Landsberg, 1973, p. 86).

Attacking the fatalistic attitude of decision-makers towards weather effects of their own making, he offered a set of meteorological rules for urbanism that could be reprinted verbatim today: do not build on flood plains; mitigate heat island effects with shade trees; reduce surface parking lots; introduce vegetation into urban surfaces; capture waste heat for district heating; promote natural outdoor ventilation through urban design; promote electric transport and discourage the private automobile in cities; promote energy-efficient housing which makes use of solar power for space and water heating, with reflective external paint to reduce albedo. Since topographic and synoptic conditions vary widely, and with them temperature patterns, wind speeds and ventilation rates, Landsberg emphasised the need for local analysis: the 'air resource' of every city is unique.

As an international science community, urban climatologists tried to reach decision-makers through global intergovernmental networks and NGOs. Urban climate was recognised as an issue quite early in the history of global environmental governance ('world family housekeeping' in the phrase of Max Nicholson, 1987). Under Landsberg's leadership, the World Meteorological Organisation promoted research into cities through its Commission for Climatology, one of eight established at the first WMO Congress in 1951. An international study group on urban climates was set up as early as 1959 in partnership with the International Federation of Housing and Planning (IFHP), the International Society for Biometeorology (ISB) and the UNESCO-funded Conféderation Internationale du Bâtiment (CIB). Subsequent collaborations included the World Health Organisation, which co-sponsored a 1968 Conference on Urban Climates in Brussels and a 1984 Mexico City congress on Urban Climatology and its Applications with Special Regard to Tropical Areas; and the United Nations Environment Programme (UNEP) co-sponsor of a 1992 meeting on Tropical Urban Climates in Dhaka. Helmut Landsberg summarised the anthropogenic effects of urbanisation on climate for the World Meteorological Orgaisation in a Special Environmental Report of 1976. Interestingly, he noted in the same report that WMO was also beginning to study anthropogenic alteration of the global climate of the earth, adding prophetically: "it is to be hoped that this surveillance will give an early warning of untoward happenings" (Landsberg, 1976, p. 26). At the urban scale, of course, evidence of the untoward was already abundant.

All these meetings featured appeals to decision-makers to become aware of anthropogenic climate effects. "The acquisition of more knowledge about the climate of cities", wrote William Lowry in a consciousness-raising feature for Scientific American, "may in the long run be one of the key's to man's survival" (Lowry, 1967, p. 24). The international climatological community made repeated efforts

to raise awareness through meetings, institutional links, training initiatives and publications. Examples from a single year include two World Meteorological Organisation reports, Weather, climate and human settlements (Landsberg, 1976) and Urban climatology and its relevance to urban design (Chandler, 1976), as well as published proceedings on Planning and construction in conformity with the climate (CIB, 1976) and The role of local and regional government in improving the environment of human settlements (IFHP, 1976). Climate experts researched the training of architects and town planners and campaigned to improve the almost non-existent coverage of meteorological factors within the curricula of built environment schools. Remarkably, their lobbying effort extended to an unsolicited mail-out of 1500 copies of the text Fundamental knowledge in urban and building climatology to Europe's architecture and planning schools (Frommes, 1980).

The scientific community was repeatedly disappointed by the lack of response to its efforts at knowledge transfer. The political scientist Richard Tobin explained the reasons: urban decision-makers would resist evidence of inadvertent anthropogenic climate change until public opinion forced them to do so (Ferrar, 1976, p. 255). Standards for an optimised built environment could perhaps be applied to new towns (as in Olgyay, 1963) or post-disaster reconstructions but were of little use for actually existing cities. WMO Technical Note No. 149 acknowledged the problem:

Many ancient towns of Europe and elsewhere still retain their basic mediaeval plan in their central areas and this resistance to fundamental change, in spite of urban renewal, imposes a severe constraint upon the successful application of urban climatological principles to city design … Urban climatology is relevant only in cases of major expansion, urban redevelopment, or most obviously, in new town design (Chandler, 1976, p. 39).

The author, Tony Chandler, had compiled the WMO's first comprehensive bibliography of urban climatology (1970). His account of optimised climatic design drew extensively on the meteorological state-of-the-art but, tellingly, contained not a single reference to city planning literature. Even more remarkably, the same was true of a bibliography of 250 entries on The Urban Environment: A Climatological Anomaly (Berlin, 1972) compiled specifically for use in planning education and research by the Council of Planning Librarians. The difficulties of translation were compounded as post-war climatology shifted from empirical observation towards more sophisticated mathematical understandings of energy budget, radiation and street canyon properties. Melvin Marcus's presidential address to the AAG in New Orleans in 1979 reproached his physical geography colleagues for their tendency to operate in:

a natural science isolation booth expressing little concern for the relevance their microclimatic fluxes and anomalous precipitation statistics may have to urban planning or quality of life (Marcus, 1979, p. 531).

The problem was two-way. Urban professionals, for their part, had become strangely uninterested in the three-dimensional environment, especially its invisible atmospheric layers (Spirn, 1984). It was not always so—the nexus between human wellbeing and physical setting had been a central concern of early 20th-century planning theory. Planning meant a physical shaping of morphology, density, layout, street form and land use pattern. Yet the tendency of planning theory after 1970 was to regard 'environmental determinism' as a fallacy. The mainstream of planning, particularly in the Anglo-Saxon world, was being redefined as a mode of social intervention based upon the methods of social science (Hebbert, 2006). An equally significant shift was occurring at the scale of building design as professional responsibility for many aspects of thermal performance shifted from architects to heating, ventilation and air conditioning engineers. Neither of the two main target audiences for Fundamental Knowledge on Urban and Building Climatology was in receptive mode for insights into their climate-shaping role.

POLICY PRECEDENTS—ACHIEVED

Cities which did incorporate urban climatic analysis into planning were the exception rather than the rule: but some did. The Building Research Station at Haifa Technion provided important climatological support of new settlement design in Israel (Givoni, 1969). The Japanese architect Kenzo Tange undertook wind-tunnel experiments of different layout options for his successful entry for the reconstruction of the Yugoslavian city of Skopje after the earthquake of 1961 (Tange, 1967). Major cities tended to commission climatic investigations episodically in response to critical events. Concern over urban 'dust domes' or 'haze hoods' was a typical trigger (Lowry, 1967). A three-day inversion episode in 1966 caused 168 deaths in New York City. Mayor John Lindsay appointed the public health expert Austin N. Heller as the Commissioner of the Department of Air Pollution Control (DAPC). Heller set up an 'air resource management' (ARM) network of 37 aerometric stations across the five boroughs to measure sulphur dioxide, carbon monoxide, smoke shade, suspended particulates, dust fall, wind direction and air temperature. University partners were also involved in the interests of "cross-fertilization of the academic and operational branches of applied science and basic research". Heller noted that "our department is probably the first city agency in the nation to effect such an arrangement" (DAPC, 1968). For a brief while, New York was a climate-aware city. As Mayor Lindsay commented in a TV broadcast:

A few years ago, it would have taken a meteorologist to tell you what an 'inversion' of the weather was. Now any New Yorker can tell you that it's when the layers of air above us arrange themselves in such a way that our pollution can't float away—and instead just hangs at street level in a stagnant pool … Until [Heller] came, the department never had a meteorologist on its staff. Imagine that. No meteorologist in a department whose job is the air around us. Not only do we now have a meteorologist, but a department is already working with Columbia,

NYU, and Cooper Union in developing basic studies of our traffic pattern, our weather and air currents, and a host of new devices that may hold down pollution at its source.

With a change of mayor, climate policy went off the agenda in New York City for four decades and the leading urban climatology unit on the Bronx campus of New York University was disbanded. The city's observation networks and the research partnerships were only revived after 2002 with the election of Mayor Michael Bloomberg, who positioned New York for leadership of the new wave of global climate change awareness (Corburn, 2009; Rosenzweig et al., 2011).

For consistent long-term application of climatological principles to urban management, we must look to German-speaking countries, particularly the southern zone of Germany, together with neighbouring Swiss cantons and Austria. This is the only part of Europe which has an extensive literature of urban climatological monographs and where city plans will routinely cite air movement as a basis of planning policies. Both theory and practice having common origins in a national culture of weather sensitivity—Wetterfüligkeit—which extends far beyond awareness of Licht und Luft and the atmospheric dimension of public health. Factors include a conscious reaction against the negative object-lesson of industrial Britain in Germany's late industrialisation; collective memory that Stadtluft has cultural as well as chemical properties; a legal system that clearly allows constraint of private property rights in the environmental interest; and a decentralised constitution which requires the Deutsches Wetterdeinst to engage more than most national meteorology agencies with services to state and local governments. Two examples can be mentioned.

Munich has an important place in the history of climatology. Max Joseph v. Pettenkofer, creator of the Archiv für Hygiene, founded the first institute for urban hygiene in Munich in 1879. Several of the foundation texts of micro-climatology originate in the city's university, especially the seminal The Climate Near the Ground of Rudolf Geiger—first published in 1927 and still in print today (Geiger et al., 2009) and the Das Stadtklima of his pupil Albert Kratzer.

Planning regulation has been shaped by considerations of light and air ever since the late 18th century, when Prince Elector Karl Theodor declared Munich an 'open city', demolished the 17th-century fortifications, created the Englischer Garten as a public park and instituted building regulations based on separation distance. The 1904 Staffelbauplan der K.Haupt- und Residenzstadt München by Theodor Fischer was a remarkable synthesis of enclosed street corridors along principal roads with open layout along side streets—both elements reflecting the climatic principles of his mentor Camillo Sitte (Collins and Collins, 1965). Fischer's plan remained in effect until 1980, Munich having deliberately decided to rebuild the gaps in its ruined street plan after World War II rather than open them up, as Hanover and Berlin did, into a modernist 'stadtlandschaft'. Under the city's Stadtentwicklungplan of 1963 (the Jensen Plan) the built-up extensions of the growing metropolis were to alternate with green environmental fingers. And, coming up to date, the city's present overall strategy die Perspektive München 1998 is based on a triad of principles—kompact–urban–grün—that echo Fischer's early 20th-century synthesis of urbanity and nature (City of Munich, 2010).

Munich's design strategy is underpinned by climate science. In 1986, the Bavarian urban climate unit Stadtklima Bayern undertook a comprehensive measurement and modelling campaign that demonstrated Munich's dependence for summer ventilation on cold night-time air draining off the Alps to the south and daytime flows of fresh air from the Danube plain to the east (Bründl, 1988). Soon afterwards, it was decided to relocate the airport from the east to the north of the city, releasing its huge site for a trade fair and urban extension, the Messestadt Reim, which would be the first demonstration project of the ground-rules set out in the city's 'compact–urban–green' strategic vision (City of Munich, 2010).

The airport redevelopment concept was devised by one of the three climatologists behind the 1986 study of Munich, Professor Helmut Mayer, now of the University of Freiburg. The entire layout is configured to protect the quality of that slow wind that blows from the Danube plain on sticky summer days. A landscaped band 400 metres wide from east to west of the site serves as a 'fresh air glade' (Frischluftschneise) to guarantee the ventilation of the city centre from the east. Then, within the residential neighbourhoods, a secondary system of open spaces runs into the housing blocks to pour cool nocturnal alpine air from the south (City of Munich, 1995, pp. 11–12). It is an unusually direct application of climate analysis to urban design.

The seminal example of long-term application of climatology to the practice of urban design is found in Stuttgart, state capital of Baden-Württemberg. As a manufacturing town surrounded by steep hills, Stuttgart has always suffered from air quality problems, exacerbated by exceptionally low wind speeds and weak circulation—locals refer to the city centre as the Kessel (cauldron). Its planning history shows a level of awareness of climatic factors exceptional even by German standards. 'Unhindered access of light and air' was the design basis of the first workers' suburb—das Postdörfe—laid out by the Württemberg authorities for postal and railway workers in 1868. The city extension plan devised by Karl Friedrich Kölle in 1897 was based on through-ventilation (Durchlüftung) principles with houses spaced along one side only of the new streets along the valley sides (City of Stuttgart, 2007, pp. 16–17). The extension plan approved by Mayor Gauss in 1901 included a technical appendix by Dr Fritz Erk on the natural patterns of wind movement in the city's valleys: this science provided the basis for detailed regulation of building separation and height. As the Daimler-Mercedes works grew along the River Neckar in the first half of the 20th century, so did concern for air-hygeine, to the point where the municipal council decided in 1938 to appoint an in-house meteorologist to ensure that climatic factors were given full weight in the implementation of its 1935 Urban Construction By-law.

Paradoxically, with the outbreak of war, Karl Schwalb's first task was to create a network of rooftop chemical nebulisers and 'fog

catapults' that would shroud the entire city and its factories from the view of Allied bombers. Yet the camouflage tactic also provided valuable experimental data on the pattern of air-flows in and around Stuttgart. After the war, Schwalb built up a specialist team which continues today as the Urban Climatology Unit. Dr Jürgen Baumüller succeeded him in 1971 and Dr Ulrich Reuter in 2008. Stuttgart's municipal team of 10 urban climatologists maintains a small number of weather stations, carries out ad hoc measurement campaigns—such as an experimental release of tracer-gas SF in the hills above the city in 1981—and operates a comprehensive set of computer models of the city climate. Baumüller and Reuter are both active scientists, well connected not only with research units in German universities but with urban climatologists world-wide (Hebbert et al., 2011).

Stuttgart first attracted international attention through a documentary film entitled Urban Development and Urban Climate: Stuttgart—an example from the Federal Republic of Germany, presented with voice-over in Chinese, Russian, Japanese and English as the official German contribution to the United Nations Habitat I Conference in Vancouver in June 1976. The film's vivid imagery included long shots of shimmering thermal hazes and three dimensional animations of cold air flows—streams of blue gel pouring down valley sides until blocked by buildings. Above all, the documentary displayed real-life city-scale climate management in the person of Oberbürgermeister Manfred Rommel, pipe-smoking son of the World War II general, scrutinising city maps with his staff of meteorologists and planners. It caused a stir in North America (Spirn, 1984) and yielded extensive long-term links with Japanese scientists and municipalities.

Stuttgart's most significant policy contribution has been a translation device, the Klimaatlas or urban climate map, connecting meteorological analysis of the city's 'climatopes' to policy guidelines for planning. High-resolution mapping of air flows and thermal exchanges provides an evidence base for controls over the siting and massing of buildings, the management of open spaces and the reservation of unbuilt zones as catchments and conduits of the strategic ventilation system (Hebbert and Webb, 2012). It is useful equally for the determination of individual sites and for the spatial planning of the metropolitan region of 2.6 million inhabitants (VRS, 2008).

The prosperous Schwabian capital in the Neckar valley, where vineyards co-exist with high-technology car production, might be a special case. Yet under the heading of Environmental Meteorology Climate and Air Pollution Maps for Cities and Regions, its methodology has been adopted as national standard VDI 3787-1 by the Verein Deutscher Ingenieure, the German Institute of Engineers, and applied domestically in (for example) Berlin, Kassel, Freibourg, Frankfurt and Bochum. Its success has prompted international interest, led by Japanese cities such as Osaka, Kobe, Yokohama, Fukuoka, Okayama and Sakai, with many others following world-wide (Ren et al., 2011). The Klimaatlas focus on topography, roughness and the katabatic and anabatic systems of air circulation has particular appeal in dense hot-humid centres such as Hong Kong, Kaohsiung City, Singapore and Phom Pehn, where even the slightest acceleration of air flows may have significant implications for ventilation and human thermal comfort (Hebbert et al., 2011). So a methodology evolved in the temperate zone has found a following in the southern hemisphere—playing a part, for example, in the Hong Kong government's response to the SARS crisis (McCann and Ward, 2011, ch. 6; Ng, 2012).

Recalling the historical precedents, the potential for knowledge transfer which Richard Tobin doubted in 1976 now seems strong. In a context of widespread awareness of urban climatic factors and their significance, the appeal of climate mapping is obvious. Less so are the institutional requirements that underpin it—the resources to mount high-density weather observation campaigns, expertise and computing power for models, institutional capacity to derive and enforce planning guidelines. It remains to be seen how 'mobile', in McCann and Ward's terms (2011), this technology of urbanism really is.

CONCLUSION

How might these precedents affect our understanding of urban climate change? First, obviously, they shift the time-frame. The urban heat island appears not as an anomalous discovery of the 1990s but in its true light as the longest-studied category of anthropogenic climate change. Instead of seeing adaptation planning as "still only a novelty" (Rosenzweig et al., 2011, p. 238), we have many decades of experiment to draw upon, and not just the overhyped handful that crop up repeatedly in the urban climate literature, such as Mayor Lee Myung-bak's Cheong-gye stream in Seoul and ARUP's unbuilt master plan for Dongtang, Shanghai.

Secondly, the perspective of urban climatology brings into relief a different set of climate factors. The risk-resilience model highlights high-impact risks such as storm-surge, drought, typhoons and temperature extremes, but has less to say about everyday and localised weather phenomena such as rainfall and wind patterns. Air movement, perhaps the most important micro-climatic variable affecting human thermal comfort, occurs in every city at every hour of day and night and is directly affected by building form and urban layout. Ventilation is not just of interest in heat-waves, it enhances liveability in all weathers.

Thirdly, all the successful examples of urban climate management depend upon fine-grained spatial mapping. The repeating patterns of urban weather (i.e. their climates) are complex and spatially specific, requiring observation and analysis of local particularities. Diurnal patterns of urban wind circulation have an intricate spatial distribution linked to topography, building form and landscape. Solar radiation and shade patterns relate directly to street canyon dimensions and the spacing of buildings. Human comfort levels are highly sensitive to air flows and humidity levels dependent on presence or absence of street trees. So the level of resolution is a vital consideration: the urban climate is a meso-scale phenomenon but it can only be usefully understood in micro. The micro-climatic variables at the

centre of VDI 3787-1 methodology cannot be derived from coarse-gridded models derived from IPCC forecasts of annual average temperature, precipitation and sea level rise. Ren et al. (2011) show how a city's geographical information system (GIS) base can support the integration of three broad categories of data: analytical maps of climatic elements such as air temperature, atmospheric humidity, wind velocity and direction, precipitation, fog and mist, and air pollution; geographical terrain information derived from topographic, slope/valley and soil type maps; and a third layer of data on land use, landscape and buildings, with associated planning parameters. The climatic analysis map translates into site-specific recommendations—proactive, to improve and maintain desired micro-climates, and reactive, to deal with undesirable consequences of development. The methodology reveals potentials that may be missed by a risk-resilience approach: potential to reduce urban thermal loads; to optimise existing urban ventilation paths and chart new air paths where needed; to protect cold air production and drainage areas in the peri-urban landscape; to harness topography, land–sea breezes and the internal thermal circulation of the urban heat island. Again, Stuttgart's climate change adaptation strategy offers a nice example of the global–local coupling in practice (City of Stuttgart, 2010).

Fourthly, urban climatology offers a different perspective on mitigation and adaptation. UN-HABITAT has argued that the surest way to mitigate carbon emissions is by planning for compact, mixed-use urbanism, "delinking high living standards and high quality of life from high consumption and high greenhouse gas emissions" (UN-HABITAT, 2011, p. 61). Yet the same report fails to explain how urbanists are to become climatically informed, except by compiling lists of previous extreme weather events and small disasters (UN-HABITAT, 2011, p. 147). We argue the equal importance of understanding everyday weather. Approximately half the urban heat island is caused by human energy use, and half is solar energy trapped in the urban form. Both aspects can be affected, for better or worse, by physical planning and landscape. This spatial, diagnostic approach is most urgently required in tropical cities where present planning and design practices still aggravate instead of mitigate (Emmanuel, 2005).

And finally, the story of urban climatology has an institutional dimension. It is true that the urban climate awareness campaigns mounted over four decades by the World Meteorological Organisation, UNEP, the World Health Organisation and the International Federation for Housing and Planning had disappointingly little impact: but perhaps they should be remembered precisely because they demonstrate the limits of declaratory international action. For successful examples of applied climate science, look to City Hall. Mayor Bloomberg's strategic vision for New York City, PlaNYC, makes the point: released in 2007, updated in 2011 and put to the test in dramatic fashion by Hurricane Sandy in 2012 (PlaNYC, 2012).

Urban climate management is a classic instance of municipalism in action: it depends upon local capacity, competences and political autonomy—on a pipe-smoking mayor poring over the detailed city map with local expert staff. Cities which understand and manage their local climate have a head start in responding to global climate change. We can almost invert the famous mediaeval German proverb 'city air makes free' to say that a free city can make its air. Which cities can realistically hold out that hope is a topic for another day.

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Resilience for Whom? The Problem Structuring Process of the Resilience Analysis

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ABSTRACT

Resilience is a flexible concept open to many different interpretations. The openness of resilience implies that while talking about resilience, stakeholders risk talking past each other. The plurality of the interpretations has practical implications in the analysis and planning of resilience. This paper reflects on these implications that have so far not explicitly been addressed in the literature, by discussing the problem structuring process (PSP) of a modelling-based resilience analysis. The discussion is based on the analysis of food security resilience to climate change in Huehuetenango, Guatemala, jointly undertaken by the author, governmental authorities, small-scale farmers and academics of the national university. The aim of this discussion is to highlight the underestimated challenges and practical implications of the resilience concept ambiguity and potential avenues to address them. The contributions of the results presented in this paper are twofold. First, they show that, in practice, the resilience concept is constructed and subjective. Second, there remains a need for a participatory and contested framework for the PSP of resilience.

Keywords: food security; resilience; power; system dynamics; problem structuring process

1. INTRODUCTION

Climate change effects start to be recognised as threats to food system sustainability and food security [1]. Sustainability involves maintaining the functionality of the system without compromising its capacity to do so in the future [2]. However, undergoing effects of climate change compromises food system functionality by contributing to water scarcity and pest exacerbation [3]. Resilience is understood as the system adaptive ability of maintaining its functionality even when the system is being affected by a disturbance [4,5,6]. For this reason, resilience is a compelling framework for researchers and policymakers seeking to understand how socio-ecological systems (SESs) adapt and transform to withstand changes in the environment. In practice, resilience is often used as a measure of a SES's capability to respond and adapt to new conditions (e.g., climate change). Like Tendall et al. [2] (p. 18) describe, "sustainability is the measure of system performance, whereas resilience can be seen as a means to achieve it". Resilience has the potential to contribute to food security by enhancing farmers, and other stakeholders, capacity "for foreseeing and adapting to possible changes" [5] (p. 270). For instance, in the food systems literature, a number of studies have used resilience as framework for understanding how systems can adapt and transform in the presence of disturbances in the environment while still providing required amounts and quality of food [2,7]. Applications of resilience can be found in numerous disciplines, ranging from engineering to psychology to disaster risk management [8]. The increased popularity of resilience is due, at least partially, to the flexible meaning of the concept [8,9]. Resilience definitions have often been characterised as vague and unprecise in practical terms [2,9]. While the flexibility of resilience has moved it to the category of mainstream concepts and buzzwords, the same ambiguity represents a challenge to its application in prescriptive and normative settings. These challenges manifest when practitioners need to operationalise the concepts described in the literature to the context in which resilience will be applied. Unsurprisingly, different stakeholders of the analysed system have different and sometimes conflicting interpretations of what resilience means in practical terms.

Since each stakeholder interprets resilience differently, the scope of the analysis to be undertaken is not a given but is constructed through a problem structuring process (PSP). The term PSP is used in this paper to describe the "process by which a presented set of conditions is translated into a set of problems, issues sufficiently well-defined to allow specific research action" [10]. During the PSP, stakeholders interpret the available information in light of their values and knowledge and negotiate what is the purpose and the boundaries of the study to commence (referred to from now on as the "scope of the resilience analysis") [11,12]. The cognitive, social and political components, involved in the construction of the scope of analysis, condition its development and outcomes. The social and political nature of the PSP make it impossible to separate the conclusions and recommendations produced from the context in which they were produced. When talking about resilience, we cannot avoid the question: resilience for whom?

Literature has recently started to recognise some of the practical challenges of resilience ambiguity [2,9,13]; however, it still lags behind on recognising the political implications of resilience ambiguity in the analysis and its outcomes [8,14]. While some progress has been made by operationalising the definition of resilience (see for example [2,13]), resilience frequently continues to be presented

as a "politically neutral approach" [9] (p. 134). The influence of stakeholders' agendas and power relationships are often overseen by practitioners [8,14]. Although these dimensions of the PSP have been discussed for a long time in the literature regarding problem structuring methods (PSMs), their implications for the resilience analysis are still unexplored.

This paper contributes to closing these gaps by discussing the political and social implications of resilience ambiguity in the PSP. To this purpose, this paper looks at the PSP of a modelling-based analysis of food security resilience to climate change. This case is used to discuss some of the cognitive and political challenges of resilience. This discussion is informed by the personal construct theory [15] and enriched by a post-normal science epistemology [16] for managing a wide range of perspectives. The aim of this discussion is to reflect on (a) the implications of having a diversity of resilience interpretations in the PSP and (b) the potential avenues to mediate stakeholder engagement and mitigate the challenges this diversity entails.

2. CASE STUDY: ANALYSING THE RESILIENCE OF FOOD SECURITY TO CLIMATE CHANGE IN GUATEMALA

This research was conducted within the qualitative paradigm of case study research [17,18] and is part of an independent modelling-based discussion for the analysis of and planning for food security resilience to climate change in Guatemala. Specifically, this case study describes the PSP followed to define the scope of the resilience analysis undertaken in the district of Huehuetenango. As part of this PSP, the author conducted a series of semi-structured interviews among relevant stakeholders in the local maize production system.

2.1. Background

Guatemala, similar to other developing countries, faces food security challenges that will only increase as climate change affects small-scale farmers' capabilities to produce food. Guatemala's chronic malnutrition, an accepted measure of food insecurity, is one of the highest in the world [19], reaching 55% in rural areas [20]. Climate change effects, such as severe droughts and increased average temperatures, already compromise the food production in Guatemala, especially among small-scale farmers [21].

Recognising this as problematic, some studies that explore potential means to mitigate climate change effects have been commenced separately by academics, nongovernmental organisations (NGOs) and the local and central government in Guatemala. This research is part of these initiatives, independently conducted by the author with the cooperation of numerous stakeholders in the district of Huehuetenango.

Huehuetenango is located in the Northwest region of Guatemala, on the border with the South of Mexico. Huehuetenango is one of the poorest, most vulnerable districts in Guatemala. In 2014, its population was estimated at 1,150,000 people, with 67.6% of these people under the line of poverty [22]. Huehuetenango's main economic activities are the mining industry of silver and gold and the production of coffee [23]. Nevertheless, the production of maize is an important activity for self-consumption. The majority of the population is indigenous, from the ethnics of Mam and Quechi, with a cultural dependence on maize as the main source of calories. Among indigenous groups, maize represents a 71.2% of share in basic grains consumption).

2.2. Methodology

The intention of the study was to discuss potential policies to enhance food security resilience and to explore in an operational manner the impacts of these policies on different parts of the system. The author, with the support of two academics from the Universidad de San Carlos de Guatemala (national university in Guatemala), started by identifying (mapping) and engaging relevant stakeholders as early as possible and throughout the PSP. The following stakeholder groups accepted the invitation to participate in the PSP: (i) the central government; (ii) NGOs; (iii) farmers from Huehuetenango and (iv) academics and agronomists from the University. The number of delegates from each group and their backgrounds are presented in Table 1.

Table 1. Stakeholders' group representatives.

Stakeholder Group	Number of Delegates Participating	Background
Central Government (CG)	4	Agronomists Policymakers
Non-Governmental Organization (NGO)	3	Agronomist Project Managers
Farmers (F)	6	Maize Farmers
Academics (AC)	2	Agronomist Professor Researcher

During the PSP, the author conducted semi-structured interviews to gather stakeholders' perspectives about the food security resilience of the small-scale maize production system of the region. In the first part of the interviews, the author asked the delegates of the different stakeholder groups about the agendas they have for the local food system. Subsequently, causal loop diagrams (CLDs) were used to capture stakeholders' broad understanding of the underlying causes of system vulnerability (the extent to which the system will be affected by) climate change. Finally, the delegates were also asked to rank the stakeholders in the system in terms of influence on and interest in the local food system.

The elicitation of stakeholders' agendas for the local food system was done by discussing the following general questions with the delegates of each stakeholder group:
What would you like to get from the small-scale maize production system?
In this context, what does resilience of food security to climate change mean?
What are the critical success factors of policies enhancing food security?

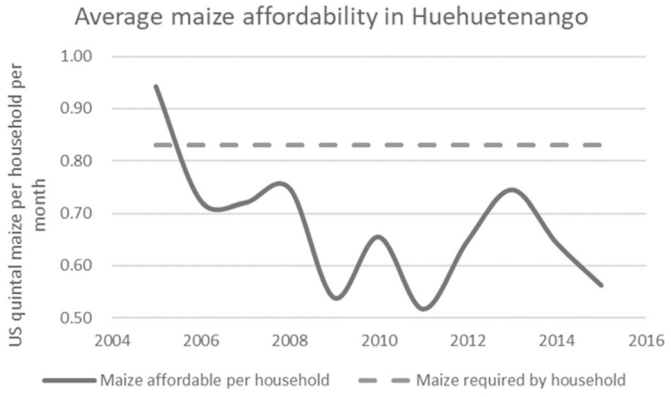
After the interviews, the author compiled and summarised the different answers. Similar answers were grouped in the same variable or short statement to simplify further analysis. The resulting statements were discussed in further interviews with each delegate to ensure they reflected their own perspectives. When needed, changes were made and again discussed with the specific delegate requesting the change.

Beside the narratives provided by the delegates, this paper uses CLDs as a means for capturing stakeholders' assumptions. CLDs are diagrams representing, in a simple manner, a possible set of causal relationships between different variables of the systems [24,25]. CLDs are particularly useful for identifying circular relationships known in the systems' literature as feedback loops. The rigor of diagramming forces the participants to "carefully and consistently" make their assumptions explicit and to "put their problem definition to test" [26] (p. 384). Thus, CLDs are a suitable way to represent and compare different interpretations of the problem and the causal explanations held by the stakeholder groups participating in the PSP.

CLDs might be employed in the PSP (also known as the conceptualisation stage of the modelling process) [27,28] to elicit participants' understanding of the problem. During the conceptualisation, the modeller focuses on "a verbal description of the feedback loops that are assumed to have caused the reference mode" [19] (p. 119). Namely, in this paper, the CLDs were used to diagrammatically represent the causal explanations for the lack of resilience of food security in the region. This elicitation might be done, as it was in the case of this paper, during one to one interviews with experts in the field, in our case an agronomist from the university, and stakeholders of the problem at hand.

During the semi-structured interviews, the author drafted CLDs representing what the delegates were describing. The author started by asking the delegates what were the main causes of the decrease and fluctuations of the affordability of maize (as a measure of food security [29]) experienced in the past 10 years in the region of Huehuetenango (see Figure 1). The causes stated by the delegates were summarized by the author in relevant variables while transcribing them to the diagram. Then, the author asked delegates to explain how those variables influenced each other. These causal links between different variables were represented in the diagram by arrows connecting the cause with its effects. When needed, new variables were added to the diagram.

Figure 1. Maize affordability in Huehuetenango.



At the end of the interview, the delegates were asked to complete the CLDs drafted by the author by adding variables, causal relationships or any elements missing in the diagram. Later, the author worked on his own by summarising all the CLDs produced by each delegate into a single CLD per stakeholder group. The single CLDs were validated and discussed with the delegates of each stakeholder group in separate interviews to ensure all of their views were appropriately captured in the diagrams. If participants found important issues

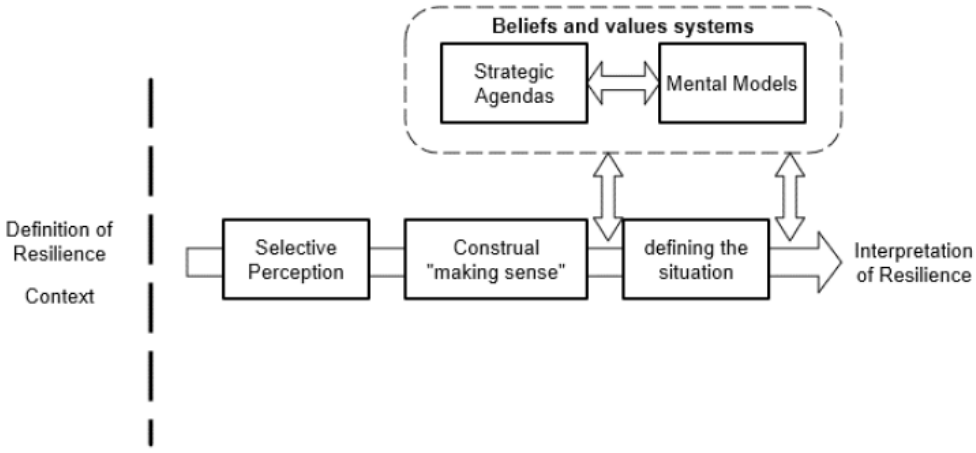
missing in the diagram, those issues were added to the final version.

Finally, delegates were asked to characterise the different stakeholders in the system. To be precise, participants were asked to rank from 1 (low) to 5 (high) the level of influence each stakeholder group has on the local food system. During this characterisation, participants were invited to consider in their assessment what resources each stakeholder can allocate for this purpose and the level of organisation and the reputation of each. Similarly, participants were asked to rank the stakeholders from 1 (low) to 5 (high) according to their interest in the problem (i.e., resilience of food security). The author tabulated the results into a single chart showing the average level of influence of each stakeholder group.

Analytical Framework

The results were analysed in light of personal construct theory (PCT) [15]. PCT is based on the assumption that a person needs to make sense of the problem to address it: "a person's processes are psychologically channelized by the ways in which he anticipates events" [30] (p. 7). Thus, to analyse resilience, stakeholders need first to make sense of what resilience means. To illustrate how this cognitive process unfolds, this paper adapts the simplified model proposed by Eden [31] to examine how stakeholders construct their own interpretations of resilience (see Figure 2). According to Eden's [31] model, stakeholders make sense of the concept of resilience by selecting particular elements that are applicable to the problem at hand and its context. This perception is then filtered through the individual system of values and beliefs to articulate its own interpretation of what resilience means in practical terms. This separation of selective perception and construal follows the personal construct theory of Kelly [15].

Figure 2. Construction of stakeholders' interpretation of resilience. Note: Adapted from Eden [31].



There is no clear distinction between values and beliefs, as they are closely interconnected [31]. However, for analysis purposes, this paper explores two separate interconnected aspects of the beliefs and values systems: strategic agendas and mental models. The term strategic agenda is used here to describe the set of goals each stakeholder has for the system. Similarly, the term mental model is used to describe the conceptual representations each stakeholder has about how the system works [32]. Strategic agendas and mental models are not separate entities. They support each other, and together, they are supported by wider individual value systems [31].
In policymaking settings, closely linked to the understanding of what resilience means in practical terms, is the concept of adaptability or the "the capacity of actors in the system to influence resilience" [33] (p. 5). Stakeholders' adaptive actions depend on how they perceive the disturbance is changing the conditions of their system. Since timing, magnitude and origin of the disturbance are, at least to some extent, unpredictable, the nature of the change that the disturbance produces deviates from the normal system-near-equilibrium analysis [34]. In these conditions of high uncertainty, identifying the mechanisms driving adaptation is not straight forward but depends on the stakeholder's mental models about how the system works.

To analyse how stakeholders' understand the system, this paper uses the reflections of Mayumi and Giampietro [35] about self-modifying systems and the theories of Funtowicz and Ravetz [36] on emergent systems. According to the aforementioned sources, the explanations each stakeholder group gave to the system behaviour were classified into:
(a) endogenously driven: the observed effects of disturbances affecting the system are the result of the functional links between its different elements. Adaptation emerges from the mechanisms the system has to regulate itself and can only be enhanced by strengthening them [35]. The solution to the problem is within the system boundaries.
(b) exogenously driven: the disturbance affecting the system comes from outside the system and, to adapt to the new conditions introduced, the system needs of external interventions that "push" it back to its equilibrium state. The solution is outside the system boundaries.

(c) chaos: the uncertainty about the disturbance affecting the system and complexity of the system itself are perceived so high that it is impossible to identify links between actions (outside or within the system) and their consequences. The solution is unknown.

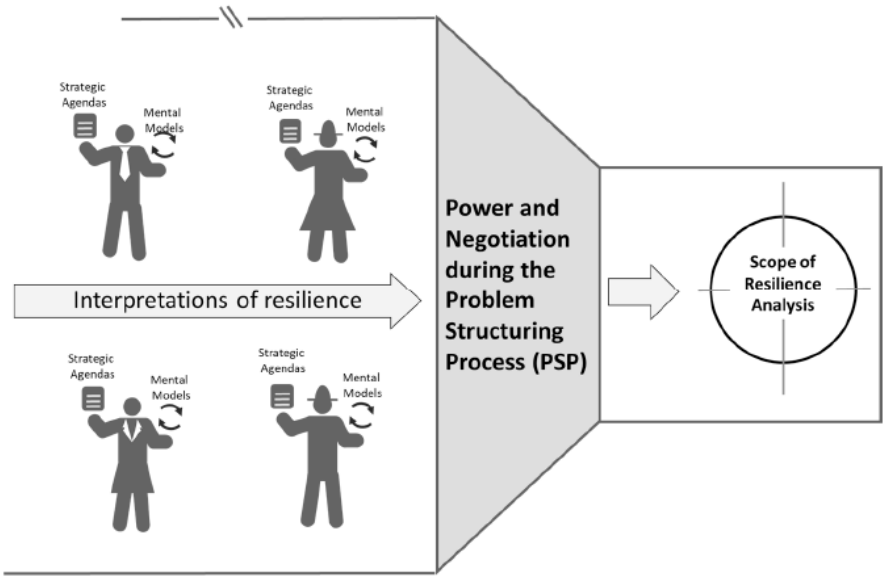
This classification offers a helpful analytical framework to explain how delegates from different stakeholder groups understand the system and the differences in the policies they will propose in further stages.

Nonetheless, the agendas and mental models used by stakeholders to construct their own interpretation of resilience are only some of the ingredients for the scope of the resilience analysis. The manifestation of power in the PSP is indeed critical analytical lens to understand complications of resilience ambiguity. In fact, power effect on resilience is one of the most unexplored but most contested characteristics of resilience [14].

Case study research shows that in prescriptive settings, the PSP of resilience is predominantly a negotiation endeavour. For instance, Lebel et al. [37] describe that in many case studies undertaken by the Resilience Alliance, the scope of resilience analysis reflects, to a large extent, the interest of powerful stakeholders, undermining perspectives of ethnic minorities and small-villages (powerless stakeholders). Similarly, Larsen et al. [38] highlight the tensions regarding roles, control and ownerships between powerful stakeholders during the process of building resilience in Thailand tourism-dependent communities.

These cases studied in the literature show that during the PSP of resilience, stakeholders will try to persuade the others to join or accept their own interpretation of resilience and to articulate the scope of the resilience analysis accordingly. As illustrated in Figure 3, the scope of analysis is a negotiated outcome of the PSP that reflects not only the interpretations of each stakeholder in the system but also the power relationships between them.

Figure 3. Simplified representation of the problem structuring process (PSP) of resilience analysis.



2.3. Results

2.3.1. Strategic Agendas

Tabulated results from the interview show that delegates from the same group coincide to a large extent in the answers they provided about their agendas. Table 2 summarizes these tabulated answers. In Table 2, it is noticeable that most of the delegates of the same group agreed on a similar answer.

Based on the interviews results, the strategic agenda held by each stakeholder group can be summarized as follow:

Central Government (CG): The purpose of the analysis is to identify how to increase the household's wealth and particularly the money available to buy food so that households can afford enough food even when droughts reduce the yields of maize in the region.

Non-Governmental Organization (NGO): The purpose of the analysis is to identify how to enhance crop productivity so that households can produce food and revenues constantly despite the droughts. Note that in the words of the NGO delegates, crop productivity is understood as the amount of crop (not exclusively maize) produced from each Guatemalan Quetzal invested by the farmers.

Academics (AC): The purpose of the analysis is to identify how to increase maize yields and reserves as a mean to prevent starvation by increasing farmers revenues and food supply to the region.

Farmers (F): The purpose of the analysis is to identify how to increase food production (not limited to maize or crops in general) and maize reserves to have food year round.

Table 2. Summarized answers to the semistructured interviews.

Delegate Code		CG1	CG2	CG3	CG4	NGO1	NGO2	NGO3	AC1	AC2	F1	F2	F3	F4	F5	F6
What would you like to get out from the small-scale maize production system?	Increase households' wealth	X	X		X										X	
	Produce revenues			X		X	X	X		X			X			
	Produce food								X		X				X	
	Produce food for locals						X			X		X	X	X		X
In this context, what resilience of food security to climate change means?	Being able to afford food even when droughts	X	X	X				X								
	Produce food constantly in despite of the droughts	X			X	X	X		X	X		X			X	
	Don't starve during the bad years								X							
	Have always enough food										X	X	X	X	X	X
What are the critical success factors of policies enhancing food security?	Money available for purchasing food	X	X	X												
	Crop productivity		X		X	X		X								
	Maize Yield				X		X		X	X			X			
	Maize reserve										X	X	X	X	X	X

Note: CG: Central Government; NGO: Non-Governmental Organization; AC: Academics, F: Farmers.

2.3.2. Causal Loop Diagrams

Figure 4 presents the CLD's prepared jointly by the author and delegates of each group. In general, diagrams are relatively simple and focused (with the exception of diagram in Figure 4c) on one or two main causal explanations of the problem to address (decrease and fluctuations of maize affordability in the region).

Next, there is a brief explanation of each diagram.

Central Government (CG): Farmers productivity increases the incomes and, therefore, the wealth of the farmers. Higher wealth increases farmers' capacity to use fertilizers (fertilizers are more affordable). Usage of fertilizers is directly related to the productivity and, therefore, the more fertilizers the farmers use the more productive they become in a virtuous cycle represented by the R1 feedback loop in Figure 4a. This loop, however, is perturbed by droughts (disturbances of the system) that reduce farmers productivity, reducing their overall wealth and hence their capacity to acquire food (food affordability).

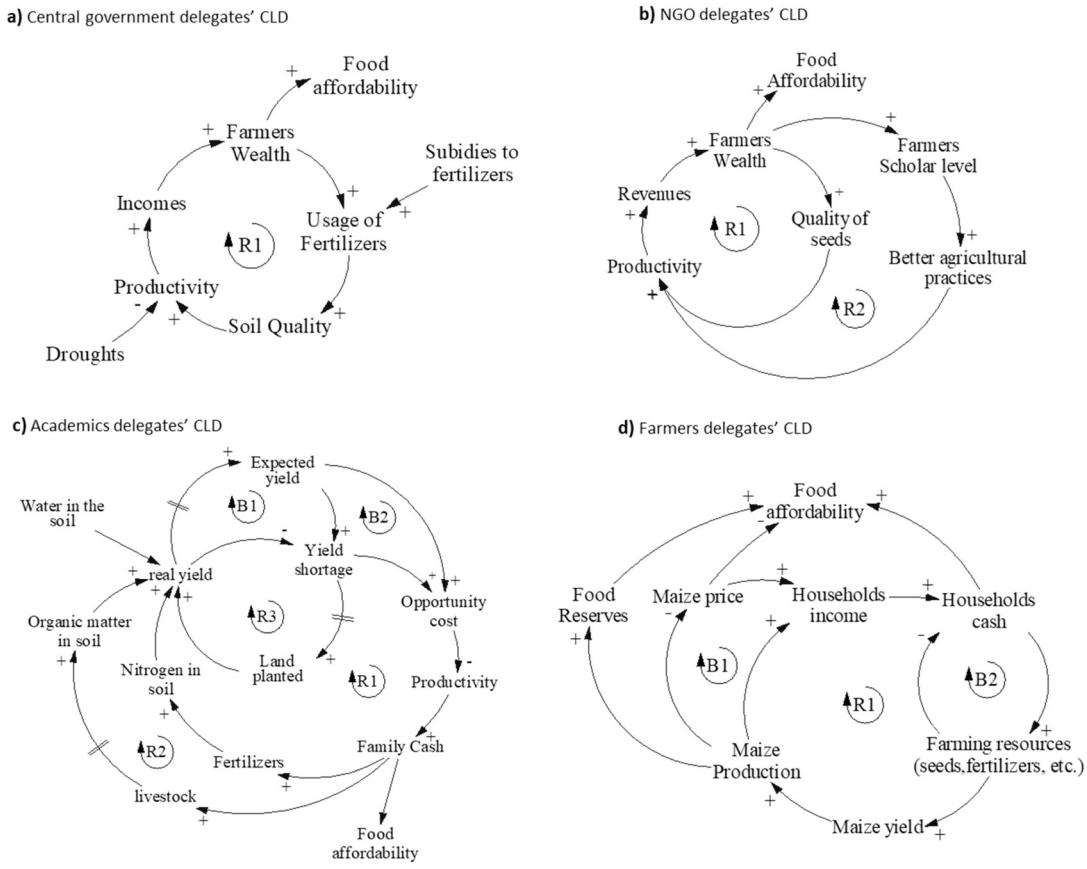
Non-Governmental Organization (NGO): Farmers productivity increases the incomes and therefore the wealth of the farmers. Higher wealth increases farmers' capacity to access better seeds and formal education. Seeds of improved varieties, the ones that require less water, are assumed to increase crop productivities, especially during drought seasons, compared to seeds coming from informal sources (on farm save seeds for example). Better seeds increase wealth in the virtuous cycle represented by R1 in Figure 4b. Access to formal education is assumed to be linked to better agriculture practices (e.g., appropriate usage of fertilizers and land planning). Better agriculture practices increase revenues and wealth in the virtuous cycle represented by R2 in Figure 4b.

Academics (AC): The causal explanation represented in Figure 4c focuses on the variation of the real yield against the expected one (yield shortage in the diagram). Yield shortage results into lower productivities and opportunity costs that reduce families' cash and their capacity to invest in fertilizers and livestock (see feedback loops R1 and R2 in Figure 4c). Higher yield shortage also translates into a reduction of the land planted each season (see R3 in Figure 4c), because farmers need to spend more time on other activities (e.g., working on coffee plantations) and less time farming. The expected yield eventually gets adjusted, decreasing the yield shortage and opportunity costs (see loops B1 and B2 in Figure 4c). The increase in droughts occurrence increases yield shortage by affecting the maize system and its real yield, reducing at the same time the land planted and the cash available for the next season's harvest.

Farmers (F): Maize production increases incomes and households' cash, allowing farmers to acquire more resources needed in farming activities (seeds, fertilizers, etc.). This eventually increases the maize production. Higher production results in a) higher food reserves

and b) higher incomes (see feedback loop R1 in Figure 4d). However, there are two drawbacks from the feedback loop R1. First, the acquisition of resources decreases households' cash (see feedback loop B1 in Figure 4d) thereby reducing the food affordability. Second, higher production will eventually translate into lower maize prices, reducing farmers' income and profit margins (see feedback loop B2 in Figure 4d).

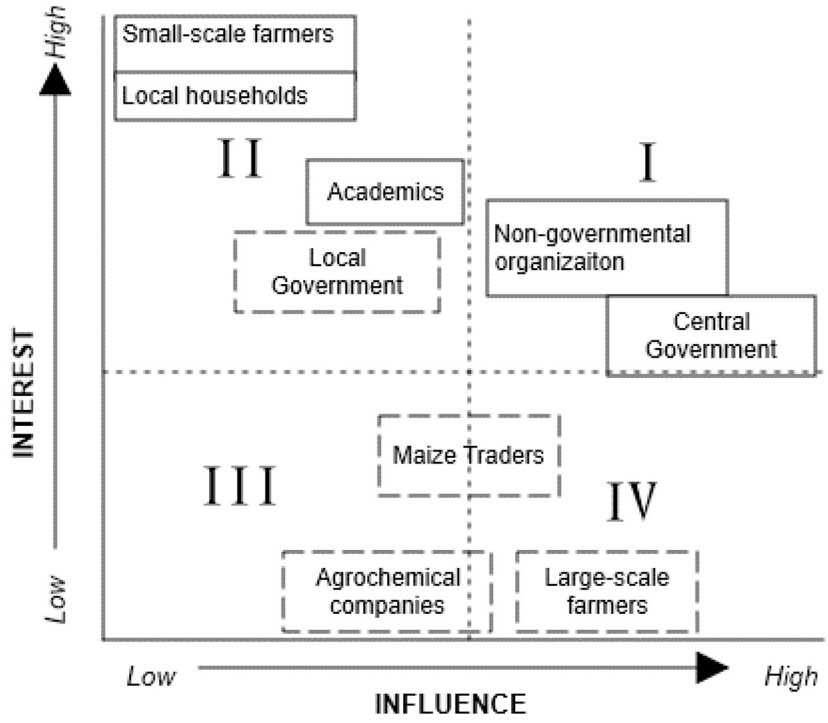
Figure 4. Causal loop diagrams (CLDs) explaining the decrease and fluctuations of maize affordability in Huehuetenango. CLDs were produced by (a) central government delegates; (b) NGO delegates; (c) academics delegates and (d) farmers delegates; during one-to-one semi structured interviews.



2.3.3. Influence-Interest Grid

Figure 4 presents the stakeholders' grid produced by the delegates. The four stakeholder groups participating in this case study were consistently identified by all the delegates as those with the highest interest in the problem (see Figure 5). The central government and NGO working in the area were described as being the stakeholders in a better position to solve the problem or those with higher influence on the problem (see quadrant I in Figure 5). Other stakeholders, like the large-scale farmers producing food in the region and traders, were also recognised as highly influential. However, there was an agreement among delegates of all the stakeholder groups participating that, unfortunately, large-scale farmers and maize traders have no interest in enhancing food security in the region (quadrant IV in Figure 5). While recognized as those with higher interest in the problem, small-scale farmers were portraited as the group with the lowest influence on it (see quadrant II in Figure 5). Academics and stakeholders not participating in the PSP (local government) were also portrayed as interested parties with low influence.

Figure 5. Influence/interest diagram summarizing stakeholders rank in the small-scale maize production system in Huehuetenango. Note: stakeholders in dotted lines did not take part in this research.



3. COMPLICATIONS OF THE PSP IN THE ANALYSIS OF RESILIENCE

The results presented in Section 2 offer relevant evidence to discuss the ambiguity of resilience and its complications. The ambiguity of resilience, in this case, does not arise from the differences between many definitions of resilience [13], but from the way in which stakeholders interpret it for their specific context and problem. The differences that emerged during the PSP might already be noticeable for the reader, but the analytical lenses proposed in this paper offer a perspective of the deeper and more conflicting differences in the agendas and mental models held by each stakeholder group.

These cognitive differences set the scene for analysing the conflict that could unfold during the negotiation of a single scope of resilience. The more mutually exclusive agendas and mental models are, the harder it is to reach a scope of resilience that satisfies all the stakeholders. As Eriksen et al. [39] pointed out, adaptation will change social, political and economic relationships between stakeholders, "yet not all these changes are desirable for everybody".

This section concludes by discussing the practical implications of resilience ambiguity in the policymaking process. These implications are not only political but also methodological and require thoughtful planning of the PSP. While it might be possible to mitigate some drawbacks, more research is needed before outlining a comprehensive framework for addressing the political challenges that resilience entails.

3.1. Constructing an Interpretation of Resilience

The experience in the district of Huehuetenango in Guatemala shows that different stakeholders have different interpretations of resilience. These interpretations of resilience are context specific [40,41] and reflect the values and beliefs of the stakeholders involved. In other words, stakeholders make sense of what resilience means in their particular context and frame the analysis process accordingly. In this case study, different interpretations of resilience are reflected in (a) the different goals and desired outcomes (strategic agenda) stated during the interviews (see Table 2) and (b) the different descriptions of the causes of the problem (mental models) captured in the CLDs (see Figure 1).

When looking at the strategic agenda, stakeholders see the maize production system at different levels of aggregation (household level vs. regional level). As presented in the results section, delegates from the same stakeholder group share similar perspectives about the purpose of the system (see Table 2). With the exception of the farmers, the groups also share some alignment among themselves. The

answers in Table 2 and summarized strategic agendas in the Results section show that most of the delegates have local/regional goals for the system, namely to promote local economic development. Alternatively, farmers focus on their current urgent problem of living in insecure food conditions.

In other words, there are two main strategic agendas for the system. One agenda (shared by many stakeholders) is seeking to use the system as a tool for local and/or regional economic development. The other agenda, held by the farmers, is to have food all year round. While there might be different arguments in favour of one agenda over the other one, it is unlikely that regional solutions will have any impact unless urgent issues challenging the farmers' own subsistence are addressed. Similarly, small-scale solutions, addressing farmers immediate needs, might prove to be unsustainable in the mid-term if the wider problem is not tackled.

Wider differences are found when looking at stakeholders' mental models reflected in the CLDs developed. Academics and NGO delegates describe the system in endogenous terms. This endogenous perspective is reflected in the feedback loops identified in the CLD they drafted (see Figure 4b,c). They look at the problem in a systemic way and try to find solutions within the system boundaries. They have, however, a different understanding of the vicious circles constraining food security. On the one hand, academics focus on the management of the water resources and reservoirs as a potential leverage point.

"The obvious cause of the problem is the deficiencies the communities face to access water…. This is why that, now that droughts are becoming more common, farmers face more problems."

(Academic delegate 1)

On the other hand, NGO delegates blame farmers' lack of technical skills and training as the cause of their poor productivity and, hence, food insecurity. The solution they propose is to increase training and to provide farmers with better seeds to increase their productivity in a sustainable way.

"You see, there are several complications in the situation of these poor people because their culture doesn't let them move forward. They use the same techniques they have been using since pre-colonial times. They have no formal education. You know that most of them cannot read. It is really difficult to teach them and change their minds. We need to make an effort to provide them with the right seeds and the proper instruction to use them well."

(NGO delegate 2)

The government delegates describe the system as exogenous driven. These delegates think the way to influence the system is through the artificial enhancement of farmers' productivity (see Figure 4a). Even though they identified a feedback loop in the system, their proposed solution focuses on ways to quickly boost the system performance, namely by using more fertilizers to increase productivity.

"The government is committed to provide a sustainable and plausible solution by providing the fertilizers they (farmers) need to increase their productivity and become more competitive…. Once they (farmers) level up with the market, the food affordability should be a natural condition."

(Central government delegate 2)

Farmers perceive the problem in a very different way. In their perspective, the increasing uncertainty about rainfall is transforming the system into a chaotic one. From their perspective, using more expensive seeds or more fertilisers will be useless if the weather conditions are not good. Farmers do not feel in control of the system. They feel they are victims of the uncertainty of the yields that they will get at the end of the season.

"The problem is you don't know if the yield is going to be good or not…. Now you never know…. If the yield goes bad, we lost the money we spent on seeds and fertilizers."

(Farmer delegate 4)

"The weather now cannot be predicted…. You gamble every time you plant."

(Farmer delegate 1)

Furthermore, the farmers do not see higher production as a means to increase their revenues but only as a means to increase their food reserves (see Figure 4d). In their view, the region is isolated, and they do not have access to other markets to trade. The benefit they perceive from higher production is in having more maize to build food reserves for the future.

Understanding and acknowledging different goals and mental models about the system will lead to a wider scope of analysis and might result in a more balanced decision-making process [34]. Short-term solutions and systemic interventions could provide a balanced view between achieving short-term outcomes and their long-term consequences. Farmers' chaotic view of the world challenges the mechanistic understanding other stakeholders might have and balances their deterministic view by the acknowledgement of uncertainty. The system cannot be assumed mechanistically following economic rules since human behaviour under stressful situations adapts in sometimes unexpected ways [7]. An oversimplified understanding about how different groups will react during a crisis might lead to

policy failure [42]. For instance, while most of the stakeholders expect farmers to use a potential production surplus to increase their revenues, farmers will use it to increase their food reserves, affecting the policy's effectiveness.

3.2. Negotiating the Scope of Analysis

The power to influence the final outcome is not symmetrical among stakeholders, with those holding key resources being in an advantageous position to impose their own interpretations in the final scope. System adaptation will "influence social relations, governance and distribution of resources in any given population or place" [39] (p. 2). However, as shown in this case, there is not always agreement about the changes and the scale at which those changes should be made. Those with higher level of influence in the scope of analysis might not be those directly affected by its outcomes. For instance, the small-scale farmers in Huehuetenango are the stakeholders directly affected by potential decisions about how to enhance resilience, but they are also those with the least influence on the decision-making process (see Figure 5).

Power differences have contentious repercussions considering that those with a higher level of influence have different strategic agendas than those suffering the larger impacts of the policies implemented. This is particularly relevant since there is a clear difference between the farmers' interpretations and those held by the rest of the stakeholders. Considering the different interpretations of resilience, the power to set agendas about what issues are to be addressed needs to be an important consideration during the PSP.

Competitive agendas and mental models set the scenario for a game of power where different stakeholders seek to impose their own agendas on the scope of the analysis that will follow. The allocation and distribution of the access to natural resources have been, historically, an expression of power tension between different groups [14,39]. While building the resilience of the system outcomes, the resilience of the institutions and relationships defining those outcomes are also enhanced [43]. Many stakeholders perceive the resilience analysis as an opportunity to gain power or to influence the system towards their own interests [14]. This power might be exercised in many ways. For instance, stakeholders might scope the problem in isolation, ensuring their interpretations are the only ones represented. Alternatively, some groups could try to undermine those with competitive or opposite views by diminishing their credibility as shown in this case. For instance, note the comment above from NGO delegate 2 in which the delegate undermines farmers' practices because they have no formal education. Any analysis that does not account for these tensions would result in an incomplete understanding of the scope of potential responses [14,44].

In short, recognising that there might be different interpretations of resilience implies accepting the PSP as a negotiation and political process. Seeing the PSP as a negotiation forum means that practitioners need to acknowledge the social and political factors (e.g., inequality and legitimacy) shaping the scope of analysis and need to be transparent about the implications of these factors on their recommendations. Otherwise, the resilience analysis risks being used, possibly inadvertently, as a way to legitimise the power of particular groups and to impose particular means to manage natural resources [43].

3.3. What Are the Potential Implications?

There are at least two implications resulting from the flexibility of resilience to interpretation. First, it seems unlikely that a proper analysis would result in a PSP that does not account for the many different interpretations of resilience in each particular context. If the scope of analysis has been defined by only a few groups, it risks being too narrow, excluding important elements from the analysis and reducing the range of solutions explored. For instance, the analysis might focus on short-term solutions, ignoring important feedback loop mechanisms of the system. Alternatively, a pure systemic view of the problem might fail to recognise uncertainty and might oversimplify decision rules and human behaviours.

Second, stakeholders who have a different understanding of the problem will rarely support or get actively engaged in the implementation of a solution that is not addressing their initial understanding of the problem [45]. The contribution of any solution is null if those ultimately responsible for implementing them are not willing to do so [46]. For instance, stakeholders might sabotage the policies proposed at the end of the analysis by refusing to participate in the implementation (e.g., training and the introduction of new practices) or, even worse, by explicitly opposing them (e.g., demonstrations against the introduction of new seeds).

3.4. Potential Avenues for Mitigation

Recommendations are not conclusive, but it is possible to outline avenues for further development with the aim of reducing the potential drawback of power in the PSP. A possible avenue is to advocate for more participatory settings. So far, the SES literature has extensively discussed stakeholders' participation as a requirement for the enhancement of resilience in the SES. However, very little has been elaborated on the role of participation in the formulation of the problem as such. Facilitated modelling approaches, such as Group Model Building [47] or Cognitive Mapping [48], might contribute to mediating this process (e.g., by introducing the CLD as a transitional object that helps to leverage power differences) [49,50]. These methods contribute in leveraging the power between groups by forcing participants to make their assumptions explicit in a diagram that is challenged by the group [47,51,52]. In this case, the diagram is used to jointly represent the problem definition shared by and agreed upon by different stakeholders through a process of negotiation and dialogue [49].

Alternatively, another option is to aim for a broader perspective in the analysis of resilience and to consider possible trade-offs and asymmetries in resilience between different groups and communities within the system. A broader perspective might be particularly useful when there is a conflict between long-term and short-term goals or when the boundaries of the system are not clear [53]. By using computer simulations, for example, it is possible to uncover long-term unintended consequences that might result from short-term perspectives. Uncovering unintended effects is possible because computer simulations are especially useful when the delays between the policies and their results are too large to allow for assessment by simple intuition. Simulations might also uncover unexpected and unintended consequences of policies that are beneficial to one group but negative for others.

The latter is particularly important when analysing climate change problems because there are time lags or delays between policy measures (or non-action), and effects often extend beyond the normal period of analysis [54,55]. When important consequences of current policies materialise several years later (in some cases decades later), significant future stakeholders will not be present to voice their concerns and weigh in when preferences are aggregated into policy decisions. Present stakeholders might be willing to compromise the overall future detriment of the system for short-term benefits. Namely, in the resilience analysis, present stakeholders might favour policies that yield more efficiency in the short term but diminish the capability of the system to continue providing the desired outputs in the long term. The benefits for the few who are defining the problem now might be preferred over the benefits for the many tomorrow.

4. CONCLUSIONS

The ambiguity of resilience is a challenge for practitioners that want to implement it as an analytical and policymaking framework in real life problems. This paper addresses the ambiguity of resilience from a cognitive and political perspective by focusing on how resilience is interpreted in practice instead of its theoretical definition. This paper argues that the interpretation of what resilience means in a specific context (resilience of what?) and the ways to achieve it are results of the values and beliefs of those with a stake in the system. In this light, the case study presented methods to identify and highlight some of the challenges and practical implications of resilience ambiguity. Specifically, this paper focuses on strategic agendas and mental models as observable expressions of stakeholders' values, beliefs and knowledge about the system. The results discussed in this paper show that, in practice, different agendas and mental models compete during the PSP to be part of the scope of resilience analysis. The question of what outcome of the system needs to be resilient has many answers (revenues, yield, food supply).

The results presented in this paper show that stakeholders have different understandings of how the system works. For instance, while academics and delegates from the NGO participating in the study focused on enhancing virtuous cycles within the system, the central government delegates proposed solutions outsides the system's boundaries. All of these solutions, however, ignored the bounded rationality of the farmers and the premises of their decision-making process. Including only a few stakeholders in the process risks leaving many important aspects out of the scope of the analysis and therefore undermining its results.

It is also necessary to acknowledge the role of power shaping and filtering different interpretations of resilience into a formal scope of analysis. It is expected that those with more power will attempt to influence the PSP to reflect their views and agendas. In the case presented in this paper, farmers have little influence in the PSP and their agendas might, intentionally or accidentally, be bypassed by experts (e.g., academics and researchers) and policymakers. For instance, as discussed in this paper, farmers bounded rationality and socioeconomic position might be used as an argument for disregarding their knowledge and their claims.

In short, results show that the practical meaning of resilience is socially constructed by those participating in the PSP and the way this process is conducted will affect the result of the analysis. There are at least two practical implications of underestimating resilience ambiguity while structuring the scope of the resilience analysis. First, including only a few stakeholders in the process risks leaving many important aspects of the system out of the scope of the analysis to be undertaken. Second, poor stakeholder management also risks obstructing the implementation of proposed policies and, in the worst case, unintentionally harming those in more vulnerable positions. While literature starts to acknowledge the challenges and contentious implications of power in the resilience analysis (see for instance [7,14,39]), more research is needed toward defining a framework of how to facilitate negotiation during the PSP.

If resilience is to play a significant role in climate change adaptation, policymakers should be careful when structuring the scope of the resilience analysis and should seek for broader participation. Such broadening is not a simple case of bringing more perspectives. Instead, it is a "fundamental shift in how knowledge is understood to operate and consequences of this for the kinds of questions we formulate prior to our analyses" [14] (p. 484). Increasing participation is not a normatively uncontroversial route either, but at least it acknowledges that resilience-based policy solutions and institutions will have distributional and, thereby, moral consequences (as most other forms of public policy do).

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SECTION II:
RESILIENCE IN THEORY

Engineering resilience
Ecological resilience
Social/Social-Ecological resilience
Ecosystem services resilience
Resilience thinking & adaptation

Resilience in Theory

Underpinning all present discussions about resilience and related goals are theories; conceptual frameworks which have shaped our general understanding of what the word really means. You may feel that these conceptions should be the intellectual domain of academics and scholars, particularly if you are interested in a more practical, applied approach to urban climate change resilience. However, we suggest that even the most practice-oriented student can benefit from understanding a few of these basic theoretical genealogies. Resilience theory may help you understand what is meant when the word appears in an urban development or climate adaptation plan. Furthermore, these theoretical conceptions may provide clarity to your own ideas about what a resilient city, society, or system actually looks like.

One of the reasons that a universal conception of resilience has been so elusive is that it appears across a broad range of disciplines, each offering its own framing and interpretation of the term. These disciplines include, but are not limited to engineering, ecology, psychology, sociology, disaster management, and economics [1]. A theoretical conception is more than a simple definition, and also includes the boundaries, characteristics, and appropriate applications of the concept in question. For the purpose of this course, we will focus on conceptions of resilience which are commonly applied to the subject of climate change resilience, including both formative and more recent theoretical framings.

Engineering resilience is one of those early formative concepts, which defines resilience as the ability for a system to withstand change, to bounce back quickly from disturbance, and to retain its status quo. This definition assumes that the systems of interest are stable, linear, and predictable [2]. Although this conception is better suited to machines than fluid human and natural systems, its influence remains. Many people still think of resilience in these terms ("bounce back," "status quo"), regardless of the subject. Tenets of engineering resilience still appear in practice, particularly regarding physical infrastructure and the built environment [3]. Another formative concept is that of ecological resilience, introduced by C.S. Holling in the 1970s. Unlike engineering resilience, the ecological conception focuses on natural system dynamics which are constantly exposed to disturbance, unpredictable and liable to change. According to Holling, resilience is the amount of disturbance that an ecosystem can withstand before losing function and switching to an alternative state (a forest becoming a desert, for example). While certainly relevant to the effects of climate change on ecosystem function and change, ecological resilience does not quite address all of the complex problems faced by people and cities.

Recent literature often frames climate change issues in terms of socio-ecological resilience. This perspective retains ideas of disturbance and flux found in ecological resilience, but further acknowledges the feedbacks that exist between human and natural systems. Human dependence and influence on natural processes ("ecosystem services") are at the core of this theoretical conception, and a key point is that humans continue to get what they need to survive and/or thrive [4]. Unlike both engineering and ecological resilience which favor persistence, socio-ecologically resilient systems are encouraged to work with change in order to make survival possible. This perspective, which includes not only the ability to withstand disturbance, but also to adapt and transform as needed, is known as resilience thinking [5]. Adaptability and many other features which have been theorized to enhance socio-ecological systems may alternatively be characterized as general resilience [6].

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6. Carpenter, S., Arrow, K., Barrett, S., Biggs, R., Brock, W., Crépin, A.-S., … Zeeuw, A. (2012). General resilience to cope with extreme events. Sustainability, 4(12), 3248–3259. https://doi.org/10.3390/su4123248

READINGS INCLUDED

[Open access articles; Full text included]

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. Ecology and Society, 15(4), art20.

Carpenter, S., Arrow, K., Barrett, S., Biggs, R., Brock, W., Crépin, A.-S., … Zeeuw, A. (2012). General resilience to cope with extreme events. Sustainability, 4(12), 3248–3259.

Brand, F. S., & Jax, K. (2007). Focusing the meaning(s) of resilience: Resilience as a descriptive concept and a boundary object. Ecology and Society, 12(1), art23.

Rajkovich, N. B., & Okour, Y. (2019). Climate change resilience strategies for the building sector: Examining existing domains of resilience utilized by design professionals. Sustainability, 11(10).

Meerow, S., & Stults, M. (2016). Comparing conceptualizations of urban climate resilience in theory and practice. Sustainability, 8(7).

ALTERNATIVE SELECTIONS

[Full text not included; May be accessible through your university library or elsewhere]

Biggs, R., Schluter, M., & Schoon, M.L. (2015). Chapter 1: An introduction to the resilience approach and principles to sustain ecosystem services in social-ecological systems. In R. Biggs, M. Schluter, & M.L. Schoon (Eds.), Principles for building resilience: Sustaining ecosystem services in social-ecological systems (pp.1-31). Cambridge, UK: Cambridge University Press.

Holling, C.S. (1996). Engineering resilience versus ecological resilience. In P. Schulze (Ed.), Engineering within ecological constraints (pp. 31-43). Washington, DC: The National Academies Press

Walker, B., & Salt, D. (2006). Chapter 1: Living in a complex world. In Resilience thinking: Sustaining ecosystems and people in a changing world (pp. 1-14). Washington, DC: Island Press.

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STUDENT EXERCISES

[To be completed after assigned reading]

(1) Consider some of the different ways that resilience is conceptualized in the literature. Which of these appeals most to you, or aligns most closely with your understanding of resilience?

(2) Is there anything you feel is missing from these conceptualizations? Anything you would like to add?

(3) What do you think is the relationship between RESILIENCE, ADAPTATION and TRANSFORMATION?
It may help to draw a simple diagram showing how these ideas relate to one another.

Tip for instructors: We suggest that students be given the opportunity to read each other's responses prior to class. This will alleviate the need for students to summarize for each other what they have written, and leave more class time for deeper, exploratory discussions.

FOR INSTRUCTORS: CLASSROOM ACTIVITIES

(1) Discussion Prompt:
Imagine you are speaking with a community group (e.g., neighborhood association, religious group, climate rally, etc.) about climate change and resilience. How would you frame the concept? What examples might you use? How could you describe climate resilience in a way that makes sense to non-experts, without getting too technical?

Think of a metaphor you would use to convey this concept. Consider the opportunities and challenges of using this metaphor when speaking with a community group.

Resilience Thinking: Integrating Resilience, Adaptability and Transformability

by Carl Folke, Stephen R. Carpenter, Brian Walker, Marten Scheffer, Terry Chapin and Johan Rockström

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ABSTRACT

Resilience thinking addresses the dynamics and development of complex social–ecological systems (SES). Three aspects are central: resilience, adaptability and transformability. These aspects interrelate across multiple scales. Resilience in this context is the capacity of a SES to continually change and adapt yet remain within critical thresholds. Adaptability is part of resilience. It represents the capacity to adjust responses to changing external drivers and internal processes and thereby allow for development along the current trajectory (stability domain). Transformability is the capacity to cross thresholds into new development trajectories. Transformational change at smaller scales enables resilience at larger scales. The capacity to transform at smaller scales draws on resilience from multiple scales, making use of crises as windows of opportunity for novelty and innovation, and recombining sources of experience and knowledge to navigate social–ecological transitions. Society must seriously consider ways to foster resilience of smaller more manageable SESs that contribute to Earth System resilience and to explore options for deliberate transformation of SESs that threaten Earth System resilience.

Keywords: adaptability; adaptation; resilience; social-ecological systems; transformability; transformation

INTRODUCTION

One of the most cited papers in Ecology and Society was written to exposit the relationships among resilience, adaptability and transformability (Walker et al. 2004). That paper defined resilience as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker et al. 2004:4).

Discussions since publication of that paper have exposed some confusion about the use of the term resilience. The idea that adaptation and transformation may be essential to maintain resilience may at first glance seem counterintuitive, as it embraces change as a requisite to persist. Yet the very dynamics between periods of abrupt and gradual change and the capacity to adapt and transform for persistence are at the core of the resilience of social–ecological systems (SESs). We therefore strive to develop a theoretical framework for understanding what drives SESs, centered around the idea of resilience. We term this framework resilience thinking. Here we rephrase the three core elements of resilience thinking to embrace these ideas.

RESILIENCE: THE HISTORY OF A CONCEPT

Resilience was originally introduced by Holling (1973) as a concept to help understand the capacity of ecosystems with alternative attractors to persist in the original state subject to perturbations, as reviewed by e.g. Gunderson (2000), Folke (2006) and Scheffer (2009). In some fields the term resilience has been technically used in a narrow sense to refer to the return rate to equilibrium upon a perturbation (called engineering resilience by Holling in 1996). However, many complex systems have multiple attractors. This implies that a perturbation can bring the system over a threshold that marks the limit of the basin of attraction or stability domain of the original state, causing the system to be attracted to a contrasting state. This is qualitatively different from returning to the original state, and Holling's (1996) definition of ecological or ecosystem resilience has been instrumental to emphasize this difference.

The concept of alternative stable states with clear-cut basins of attraction is a highly simplified image of reality in ecosystems. Attractors may be stable points or more complicated cycles of various kinds. Intrinsic tendencies to produce cyclic or chaotic dynamics are blended in intricate ways with the effects of environmental stochasticity, and with trends that cause thresholds as well as the nature of attractors to change over time. Nonetheless, we observe sharp shifts in ecosystems that stand out of the blur of fluctuations around trends. Such shifts are called regime shifts and may have different causes (Scheffer et al. 2001, Carpenter 2003). When they correspond to a shift between different stability domains they are referred to as critical transitions (Scheffer 2009). All of these concepts have precise definitions in the mathematics of dynamical systems (Kuznetsov 1998, Scheffer 2009).

However, despite their elegance and rigor, they capture only part of reality. One of the main limitations of the dynamical systems theory

that forms the broader underlying framework is that it does not easily account for the fact that the very nature of systems may change over time (Scheffer 2009). This implies that, in order to understand the dynamics of an intertwined social–ecological system (SES), other concepts are needed.

In many disciplines, human actions are often viewed as external drivers of ecosystem dynamics; examples include fishing, water harvesting, and polluting. Through such a lens the manager is an external intervener in ecosystem resilience. There are those who suggest constraining the use of the resilience concept to ecosystem resilience, for conceptual clarity, as the basis for practical application of resilience within ecological science and ecosystem management (e.g. Brand and Jax 2007). However, many of the serious, recurring problems in natural resource use and management stem precisely from the lack of recognition that ecosystems and the social systems that use and depend on them are inextricably linked. It is the feedback loops among them, as interdependent social–ecological systems, that determine their overall dynamics.

ADAPTABILITY AND TRANSFORMABILITY AS PREREQUISITES FOR SES RESILIENCE

Social–ecological resilience is about people and nature as interdependent systems. This is true for local communities and their surrounding ecosystems, but the great acceleration of human activities on earth now also makes it an issue at global scales (Steffen et al. 2007), making it difficult and even irrational to continue to separate the ecological and social and to try to explain them independently, even for analytical purposes. To put the issue in context, ice core data reveal that humanity has for the last 10,000 years lived in a relatively stable climate, an era referred to as the Holocene. This era has allowed agriculture and all major human civilizations to develop and flourish. The future of human well-being may be seriously compromised if we should pass a critical threshold that tips the earth system out of this stability domain (Rockström et al. 2009). It is plausible that current development paradigms and patterns, if continued, would tip the integrated human–earth system into a radically different basin of attraction (Steffen et al. 2007). Preventing such an undesired critical transition will require innovation and novelty. Profound change in society is likely to be required for persistence in the Holocene stability domain. Alas, resilience of behavioral patterns in society is notoriously large and a serious impediment for preventing loss of Earth System resilience. SES resilience that contributes to Earth System resilience is needed to remain in the Holocene state.

It should be immediately clear from this example that social change is essential for SES resilience. This is why we incorporate adaptability and the more radical concept of transformability as key ingredients of resilience thinking (Table 1).

Adaptability captures the capacity of a SES to learn, combine experience and knowledge, adjust its responses to changing external drivers and internal processes, and continue developing within the current stability domain or basin of attraction (Berkes et al. 2003). Adaptability has been defined as "the capacity of actors in a system to influence resilience" (Walker et al. 2004:5). Thus, adaptive capacity maintains certain processes despite changing internal demands and external forces on the SES (Carpenter and Brock 2008). By contrast, transformability has been defined as "the capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable" (Walker et al. 2004:5).

Extending the use of resilience to social–ecological systems makes it possible to explicitly deal with issues raised by Holling (1986) about renewal, novelty, innovation and reorganization in system development and how they interact across scales (Gunderson and Holling 2002). This is an exciting area of explorative work broadening the scope from adaptive management of ecosystem feedbacks to understanding and accounting for the social dimension that creates barriers or bridges for ecosystem stewardship of dynamic landscapes and seascapes in times of change (Gunderson et al. 1995). Are there deeper, slower variables in social systems, such as identity, core values, and worldviews that constrain adaptability? In addition, what are the features of agency, actor groups, social learning, networks, organizations, institutions, governance structures, incentives, political and power relations or ethics that enhance or undermine social–ecological resilience (Folke et al. 2005, Chapin et al. 2006, Smith and Stirling 2010)? How can we assess social–ecological thresholds and regime shifts and what governance challenges do they imply (Norberg and Cumming 2008, Biggs et al. 2009)?

Similarly, it helps to broaden the social domain from investigating human action in relation to a certain natural resource, like dairy or fruit production, or environmental issue, like climate change, to the challenge of multilevel collaborative societal responses to a broader set of feedbacks and thresholds in social–ecological systems (Chapin et al. 2009). For example, governance of the Goulburn-Broken catchment in the Murray Darling Basin, Australia has had to solve problems, adapting to change while continuing to develop, connecting the region to global markets. Dryland cropping, grazing, irrigated dairy and fruit production is widespread and the catchment produces one quarter of the State of Victoria's export earnings (Walker et al. 2009). At a first glance, economically lucrative activities seem to be thriving. But if the analysis is broadened to a social–ecological approach to account for the capacity of the landscape in sustaining the values of the region, the picture looks quite different. Widespread clearing of native vegetation and high levels of water use for irrigation have resulted in rising water tables, creating severe salinization problems; so severe that the region faces serious social–ecological thresholds with possible knock-on effects between them. Crossing such thresholds may result in irreversible changes in the region (Walker et al. 2009). Hence, strategies for adaptability that are socially desirable may lead to vulnerable social–ecological systems and persistent undesirable states such as poverty traps or rigidity traps (Scheffer 2009). Will the adaptability among people and governance of the Goulburn-Broken catchment be sufficient to deal with environmental change, like salinization and interacting thresholds, and avoid being pushed into a poverty trap, or does the social–ecological system need to transform into a new stability landscape, forcing

people to change deep values and identity (Walker et al. 2009)?

Table 1. Glossary of resilience terms.

Term	Definition
Active transformation	The deliberate initiation of a phased introduction of one or more new state variables (a new way of making a living) at lower scales, while maintaining the resilience of the system at higher scales as transformational change proceeds.
Adaptability (adaptive capacity)	The capacity of actors in a system to influence resilience.
Adaptive cycle	A heuristic model that portrays an endogenously driven four-phase cycle of social-ecological systems and other complex adaptive systems. The common trajectory is from a phase of rapid growth where resources are freely available and there is high resilience (r phase), through capital accumulation into a gradually rigidifying phase where most resources are locked up and there is little flexibility or novelty, and low resilience (K phase), thence via a sudden collapse into a release phase of chaotic dynamics in which relationships and structures are undone (Ω), into a phase of re-organization where novelty can prevail (α). The r-K dynamics reflect a more-or-less predictable, relatively slow "foreloop" and the Ω - α dynamics represent a chaotic, fast "backloop" that strongly influences the nature of the next foreloop. External or higher-scale influences can cause a move from any phase to any other phase.
Forced transformation	An imposed transformation of a social–ecological system that is not introduced deliberately by the actors.
General resilience	The resilience of any and all parts of a system to all kinds of shocks, including novel ones.
Panarchy	The interactive dynamics of a nested set of adaptive cycles.
Regime	The set of system states within a stability landscape
Regime shift	A change in a system state from one regime or stability domain to another
Resilience	The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks, and therefore identity, that is, the capacity to change in order to maintain the same identity.
Social–ecological system	Integrated system of ecosystems and human society with reciprocal feedback and interdependence. The concept emphasizes the humans-in-nature perspective
Specified resilience	The resilience "of what, to what"; resilience of some particular part of a system, related to a particular control variable, to one or more identified kinds of shocks.
Stability domain	A basin of attraction of a system, in which the dimensions are defined by the set of controlling variables that have threshold levels (equivalent to a system regime)
Stability landscape	The extent of the possible states of system space, defined by the set of control variables in which stability domains are embedded
Threshold (aka critical transition)	A level or amount of a controlling, often slowly changing variable in which a change occurs in a critical feedback causing the system to self-organize along a different trajectory, that is, towards a different attractor.
Transformability	The capacity to transform the stability landscape itself in order to become a different kind of system, to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable.

SPECIFIED AND GENERAL RESILIENCE

In practice, resilience is sometimes applied to problems relating to particular aspects of a system that might arise from a particular set of sources or shocks. We refer to this as specified resilience. In other cases, the manager is concerned more about resilience to all kinds of shocks, including completely novel ones. We refer to this as general resilience.

In social–ecological systems, specified resilience arises in response to the question "resilience of what, to what?" (Carpenter et al. 2001). However, there is a danger in becoming too focused on specified resilience because increasing resilience of particular parts of a system to specific disturbances may cause the system to lose resilience in other ways (Cifdaloz et al. 2010). This is illustrated by the HOT (highly optimized tolerance) theory (Carson and Doyle 2000), which shows how systems that become very robust to frequent kinds of disturbance necessarily become fragile in relation to infrequent kinds. For example, international travel in Europe became increasingly focused on improving and elaborating air travel, with less emphasis on international ground and water transportation. The Icelandic volcano of 2010 exposed the low resilience of this travel system to an extensive cloud of airborne ash that interfered with the operation of passenger jets.

General resilience, in contrast, does not define either the part of the system that might cross a threshold, or the kinds of shocks the system has to endure. It is about coping with uncertainty in all ways. The distinction is important, because our experience in

working with groups who are interested in using a resilience approach suggests that they tend to focus on specified resilience, and in doing so they may be narrowing options for dealing with novel shocks and even increasing the likelihood of new kinds of instability. Recognizing that efforts to foster specified resilience will not necessarily avoid a regime shift is a first step to understanding the need for transformational change. Getting beyond the state of denial, particularly in SESs with strong identity or cultural beliefs, is not easy and often requires a shock or at least a perceived crisis. Resilience thinking suggests that such events may open up opportunities for reevaluating the current situation, trigger social mobilization, recombine sources of experience and knowledge for learning, and spark novelty and innovation. It may lead to new kinds of adaptability or possibly to transformational change.

MULTISCALE RESILIENCE AND TRANSFORMABILITY

As defined in Walker et al. (2004), transformational change involves a change in the nature of the stability landscape, introducing new defining state variables and losing others, as when a household adopts a new direction in making a living or when a region moves from an agrarian to a resource-extraction economy. It can be a deliberate process, initiated by the people involved, or it can be forced on them by changing environmental or socioeconomic conditions. Whether transformation is deliberate or forced depends on the level of transformability in the SES concerned.

The attributes of transformability have much in common with those of general resilience, including high levels of all forms of capital, diversity in landscapes and seascapes and of institutions, actor groups, and networks, learning platforms, collective action, and support from higher scales in the governance structure. Transformational change often involves shifts in perception and meaning, social network configurations, patterns of interactions among actors including leadership and political and power relations, and associated organizational and institutional arrangements (e.g. Folke et al. 2009, Huitema and Meijerink 2009, Smith and Stirling 2010).

Deliberate transformational change can be initiated at multiple scales, and perhaps gradually, as suggested by recent experience with applying resilience thinking to catchment planning and management in SE Australia (Walker et al. 2009). Deliberate transformational change at the scale of the whole catchment, of all the component parts at the same time, is likely to be too costly, undesirable or socially unacceptable. Transformational changes at lower scales, in a sequential way, can lead to feedback effects at the catchment scale, which is a learning process, and facilitate eventual catchment-scale transformational change. Actors and organizations that bridge the local to higher social–ecological scales are often involved in such processes (Olsson et al. 2004).

Forced transformation, however, is likely to occur at scales larger than the scale of the management focus and therefore be beyond the influence of local actors. Changes in regional tax structures, for example, may precipitate transformations from farming to suburbanization. Loss of summer sea ice may transform the geopolitical and economic feedbacks among Arctic nations. Systems with high transformative capacity may deliberately initiate transformational changes that shape the outcomes of forced transformations occurring at larger scales.

Transformation trajectories are the subject of a growing literature (Gunderson and Holling 2002, Buchanan et al. 2005, Geels and Kemp 2006, Chapin et al. 2010), A resilience perspective emphasizes an adaptive approach, facilitating different transformative experiments at small scales and allowing cross-learning and new initiatives to emerge, constrained only by avoiding trajectories that the SES does not wish to follow, especially those with known or suspected thresholds. The first part of this process is much the same as that proposed in the socio-technical transitions literature, which encourages arenas for safe experimentation (e.g. Loorbach 2007, Fischer-Kowalski and Rotmans 2009). However, where the transition model then determines the new goal and adopts a particular process for reaching it, a resilience approach would allow the new identity of the SES to emerge through interactions within and across scales.

For example, declining agricultural productivity in several Latin American countries due to land degradation reached an unsustainable level in the 1970s. This breakdown prompted some farmers to start experimenting with unconventional methods for land management, in particular low-till alternatives to plowing that enhanced soil organic matter and fertility (Derpsch and Friedrich 2009). Responses to the land productivity crisis and subsequent social crisis of deteriorated livelihoods were first pursued by individual farmers and researchers in Brazil, Paraguay, and Argentina. Experimentation with new innovative breakthroughs in technologies were necessary, as the shift from then-dominant methods to no-tillage required major changes in land management practices, such as weed management, mulch-farming and green manuring techniques, as well as new machines for direct planting. The experimental learning approach at small scales, with processes for emergence and cross-scale learning, caused a transformation of the whole farming system. Currently, more than 25 million ha of agricultural land is under no-tillage in Brazil alone, and in Latin America the transition from conventional plow-based agriculture to no-till systems has reached a scale where one can talk of an agrarian revolution or a social–ecological transformation (Fowler and Rockström 2001).

Case studies of SESs suggest that transformations consist of three phases: being prepared for or even preparing the social–ecological systems for change, navigating the transition by making use of a crisis as a window of opportunity for change, and building resilience of the new social–ecological regime (Olsson et al. 2004, Chapin et al. 2010). Such transformations are never scale-independent, but draw on social–ecological sources of resilience across scales (Gunderson and Holling 2002). For example, at the Great Barrier Reef a governance transformation across multiple levels of natural resource management took place from protection of selected individual

reefs to stewardship of the large-scale seascape. The transformation was triggered by a sense of urgency induced by threats to the reef of terrestrial runoff, overharvesting, and global warming. The Great Barrier Reef Marine Park Authority was crucial in the transformation and provided leadership throughout the process. Strategies involved internal reorganization and management innovation, leading to an ability to coordinate the scientific community, to increase public awareness of environmental issues and problems, to involve a broader set of stakeholders, and to maneuver the political system for support at critical times (Olsson et al. 2008).

Multiscale resilience is fundamental for understanding the interplay between persistence and change, adaptability and transformability. Without the scale dimension, resilience and transformation may seem to be in stark contrast or even conflict. Confusion arises when resilience is interpreted as backward looking, assumed to prevent novelty, innovation and transitions to new development pathways. This interpretation seems to be more about robustness to change and not about resilience for transformation.

The resilience framework broadens the description of resilience beyond its meaning as a buffer for conserving what you have and recovering to what you were. Beyond this concept of persistence, resilience thinking incorporates the dynamic interplay of persistence, adaptability and transformability across multiple scales and multiple attractors in SESs. Fruitful avenues of inquiry include the existence of potential thresholds and regime shifts in SESs and the challenges that this implies; adaptability of SESs to deal with such challenges, including uncertainty and surprise; and the ability to steer away from undesirable attractors, innovate and possibly transform SESs into trajectories that sustain and enhance ecosystem services, societal development and human well-being.

CONCLUSIONS

In a nutshell, resilience thinking focuses on three aspects of social–ecological systems (SES): resilience as persistence, adaptability and transformability. Resilience is the tendency of a SES subject to change to remain within a stability domain, continually changing and adapting yet remaining within critical thresholds. Adaptability is a part of resilience. Adaptability is the capacity of a SES to adjust its responses to changing external drivers and internal processes and thereby allow for development within the current stability domain, along the current trajectory. Transformability is the capacity to create new stability domains for development, a new stability landscape, and cross thresholds into a new development trajectory. Deliberate transformation requires resilience thinking, first in assessing the relative merits of the current versus alternative, potentially more favorable stability domains, and second in fostering resilience of the new development trajectory, the new basin of attraction.

Transformations do not take place in a vacuum, but draw on resilience from multiple scales, making use of crises as windows of opportunity, and recombining sources of experience and knowledge to navigate social–ecological transitions from a regime in one stability landscape to another. Transformation involves novelty and innovation. Transformational change at smaller scales enables resilience at larger scales, while the capacity to transform at smaller scales draws on resilience at other scales. Thus, deliberate transformation involves breaking down the resilience of the old and building the resilience of the new. As the Earth System approaches or exceeds thresholds that might precipitate a forced transformation to some state outside its Holocene stability domain, society must seriously consider ways to foster more flexible systems that contribute to Earth System resilience and to explore options for the deliberate transformation of systems that threaten Earth System resilience.

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General Resilience to Cope with Extreme Events

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ABSTRACT

Resilience to specified kinds of disasters is an active area of research and practice. However, rare or unprecedented disturbances that are unusually intense or extensive require a more broad-spectrum type of resilience. General resilience is the capacity of social-ecological systems to adapt or transform in response to unfamiliar, unexpected and extreme shocks. Conditions that enable general resilience include diversity, modularity, openness, reserves, feedbacks, nestedness, monitoring, leadership, and trust. Processes for building general resilience are an emerging and crucially important area of research.

Keywords: extreme events; general resilience; polycentric governance; resilience; social-ecological system

1. INTRODUCTION

Extreme events sometimes have long-lasting effects on social-ecological systems. Examples include storms such as Hurricane Katrina, wildfires like those in eastern Australia in 2009 or western North America in 2012, deep droughts such as the North American dust bowl, and the earthquake and tsunami that triggered the Fukushima disaster. Each of these events caused extensive losses and evoked searching reassessments of policies and practices for managing social-ecological systems.

Resilience, in the context of environmental management and sustainability, is the capacity of a social-ecological system to absorb disturbance, reorganize, and thereby retain essential functions, structures and feedbacks [1]. A rich and growing literature addresses specified resilience, the resilience of a particular aspect of a social-ecological system to a particular kind of disturbance [2]. For example, management of catchments in Australia seeks to avoid a water-table threshold that salinizes the soil and thereby destroys the fertility of agricultural land [1]. Vulnerability is a related concept that considers the stresses that lead to threshold changes in social-ecological systems. More specifically, "vulnerability is the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt" [2,3].

For well-characterized shocks, there is often a good deal of information that is relevant to specified resilience. Risk analyses for large storms, earthquakes, floods, fires and other kinds of disturbance regimes are informed by existing knowledge. Even though each event is random, similar events have been seen before, and experience provides a basis for building specified resilience. For rather well-characterized hazards, The World Economic Forum [4] identifies several strategies that build specified resilience. These include monitoring hazards and communicating risk (through early warning systems, for example), social-physical strengthening (such as protection of power, water and sanitation plants, diversification of supply chains, and establishment of ecological buffers), sharing of financial risk (using insurance as well as instruments such as weather derivatives or catastrophe bonds), and disaster preparedness (e.g. training, or establishing reserves of pharmaceuticals). Numerous case studies provide practical information for building specified resilience to particular shocks [1,5].

Other large-consequence events are outside the scope of experience. For example, no one foresaw that changes in animal feeding practices would lead to emergence of bovine spongiform encephalitis or mad cow disease [6]. In another recent case, the Honshu earthquake of 2011 was unusually powerful. It triggered a tsunami of 14 m that breached seawalls designed for the expected maximum wave height of 5.7 m. The tsunami damaged nuclear power stations by shutting down back up diesel generators which were situated on the assumption that the sea walls would hold [7]. Extreme events that are unusually intense or extensive require a more all-purpose kind of resilience. General resilience is the capacity to absorb shocks of all kinds, including novel and unforeseen ones. The challenge of building resilience to unknown disturbances is far more difficult than planning for known types of disturbance, and like any management strategy it has a cost [1]. In this article, we discuss some approaches for building general resilience of social-ecological systems. We begin by discussing perceptions of extreme events that increase the need for general resilience. Next we summarize nine elements of general resilience based on the literature. We conclude by discussing some of the problems of implementing general resilience.

2. DATA AND PERCEPTIONS ABOUT RECORD-BREAKING EVENTS

Extreme events are challenging because the probabilities are hard to measure and because decisions about rare events with important consequences pose special challenges. Profound uncertainty makes rational responses difficult, and makes it easier for irrational approaches to take hold.

Extreme events are not only uncertain, but the measure of uncertainty (e.g. the tail of the probability distributions) also is itself uncertain. In some cases probabilities may be fundamentally unknowable, due to the complex interactions between human and environmental systems. The probability is obviously unknown for completely new events, such as the emergence of a particular new disease. However, probabilities may be poorly known even for events that have occurred only occasionally in the past. In the tails of probability distributions, observations are rare and therefore data are sparse for fitting models. As a consequence, trends in extreme events are hard to discern. For example, large data sets and extensive analysis are needed to establish trends in extreme rainfall events, flood damages or sizes of forest fires [8,9,10,11,12]. Where limited data make it hard to measure the probability of a certain kind of extreme event, assessing a trend in that probability is even more difficult.

Some classes of extreme events, such as flood damages, earthquake magnitudes, and wildfire sizes, have 'fat-tailed' probability distributions. In fat-tailed distributions the probability densities of extreme events are much larger than in more familiar distributions such as the normal distribution [13,14]. In these cases it is highly misleading to estimate the magnitude of the next record-breaking event from the record-breaking events that have been observed so far [13,15]. Sometimes two or more kinds of extreme events co-occur, for example if flooding causes landslides in a watershed previously denuded by fire. In ecology such multiple impacts are called compound disturbances [16]. Fat-tailed distributions tend to magnify the correlations of extreme events and thereby increase the probability of compound disturbances [17].

In addition to these statistical challenges of anticipating extreme events, there are cognitive biases that can lead to irrational decisions when the stakes are high and probabilities are near zero or one [18,19]. For example a 'tyranny of recent events' (availability heuristic, [20]) causes people to misjudge risk, as when fears of terrorism are exaggerated for a time after a terrorist attack [21]. In contrast, when risks are familiar there is a tendency to underestimate the danger and overestimate one's ability to control the situation [21,22]. Sometimes inconsistent decisions are made about gains versus losses [18]. Different preferences for gains or losses of similar magnitude are the subject of prospect theory [23]. Perceiving gains and losses differently is a 'bias' in the context of rational choice theory, but not if prospect theory is instead used as the benchmark for expected behavior. Nonetheless, with respect to rational choice theory people can make poor decisions about risk of extreme events. People in isolation have their limits; collectively, however, people can create an institution to improve on these cognitive limits to rational behavior. The challenge is to design institutions so that the aggregate decision creates more good outcomes for the group. These (and other) behavioral phenomena inevitably affect societal decision making about extreme environmental events [24].

These interactions between complex aspects of natural systems and human cognition add to the challenges of understanding and managing extreme events, and make general resilience important. General resilience should protect social-ecological systems against vagaries of human volition as well as uncertainty about the relevant probabilities. In the remainder of the paper we discuss characteristics of institutions that contribute to general resilience of social-ecological systems.

3. GENERAL RESILIENCE AS A STRATEGY

Extreme events, including record-breaking extremes and new kinds of shocks, have been with us forever and may intensify in the future. General resilience—the capacity of social-ecological systems to adapt or transform in response to unfamiliar or unknown shocks—is essential for sustainability in the face of extreme events. However, the wide-ranging nature of general resilience makes it difficult to define specific steps for creating it. Instead it is possible to identify conditions that can enable or support the development of general resilience (Table 1).

Diversity provides for different kinds of processes within a social-ecological system (functional diversity). It also provides for components that have similar functions but different responses to disturbance (response diversity), so the function is maintained even if one component is damaged. When teams of people are solving complex problems, diversity of perspectives and experience matters as much as individual ability [25]. The cumulative adverse effects of factors that diminish human wellbeing may also reduce the capacity of a society to respond effectively to disasters. There is a strong relationship between various aspects of human well-being and income inequality [26], suggesting that high income inequality reduces the general resilience of a society.

Modularity helps contain disturbances by compartmentalizing social-ecological systems [27]. For example, land management with prescribed fire uses firebreaks to limit the spread of the fire. This makes it possible to manage burn units independently, and thereby build landscape diversity. Similarly, quarantine mechanisms may restrict the spread of epidemics or invasive species. Modularity relates

to the connectivity of a system, whereas diversity relates to the variety among elements of the system.

Table 1. Enabling conditions for general resilience [1,27,45]

System Property	Elements or Examples	Questions
Diversity	Species, functional, and response diversity Cultural diversity Heterogeneity of social-ecological system types on the landscape or seascape	Can multiple elements of the system perform similar functions if one element is knocked out? Can different elements of the system respond in different ways to shocks?
Modularity	Quarantine mechanisms for pathogens or invasive species People with different approaches to problem-solving Independent organizations with similar functions in society	Are subsets of the system insulated so that shocks cannot spread? Does the insulation prevent spread of ideas or technologies?
Openness	Strength of connection between a social-ecological system and neighboring social-ecological systems	Can the social-ecological system maintain free trade with neighboring systems? Can the social-ecological system muffle shocks that originate outside the system? Is there an optimal solution to the tradeoff of openness and modularity?
Reserves	Capacities to re-mobilize features of the system that have been lost to disturbance, such as seed banks, recolonization from neighboring systems, or social memory.	Can key components of the social-ecological system be regenerated?
Feedbacks	Nutrient cycles and over- or under-enrichment of ecosystems Networks of economic transactions Consequences of decisions	Are control variables linked directly and effectively to response variables? Are sanctions and incentives tightly connected to human actions?
Nestedness	Subwatersheds within watersheds Township, County, Province, National, Global interacting levels of governance systems	Can the societal response to an opportunity or problem be tuned to the natural scale?

Openness of a social-ecological system is related to modularity at larger scales. Free trade among social-ecological systems often improves human well-being, for example. In ecosystems, seed dispersal plays a key role in recovery from large infrequent disturbances [28]. On the other hand, too much openness can transmit harmful shocks, as when bank collapses spread from country to country or an invasive species moves easily across a rather homogeneous and connected landscape. Tradeoffs between modularity and openness with respect to system fragility are understood for some ecosystems [27,29], and ecological principles have been applied to banking networks [30]. However the analysis of modularity versus openness is a research frontier for social-ecological systems.

Reserves—of organisms, knowledge, or skills for example—also contribute to recovery from disturbance. Residual plants and animals are important in ecological recovery from disturbance, even in extraordinarily devastating fires and volcanic eruptions [31]. Social memory and residual social networks play somewhat similar roles in recovery of social systems after major disasters [2].

Feedbacks in social-ecological systems are sometimes manageable, at least in part. Where it is possible, feedbacks should be managed to move the social-ecological system away from thresholds that trigger harmful outcomes. For example, reductions in soil phosphorus content move watersheds farther away from the threshold that causes toxic algae blooms and fish mortality in lakes and reservoirs [32]. In social-ecological systems, incentives or sanctions to conserve common-property resource stocks should be transparent, effective, and tied closely to the human actions that affect the resource, but implementation of such practices is not easy [33,34].

Nestedness of social-ecological systems enables polycentric governance [35]. This allows management systems to be scaled appropriately for the problems they are aiming to solve, capitalizing on the advantages of a particular governance arrangement while simultaneously having institutional backup systems [36]. Polycentric governance among global actors is now emerging as a response to shocks and new cross-scale connections. For example, interactions among climate change, ocean acidification, and marine biodiversity are addressed by the Global Partnership on Climate, Fisheries and Aquaculture (PaCFA) initiative. PaCFA currently includes representatives from FAO, UNEP, WorldFish, The World Bank's Profish Programme and 13 additional international organizations. The program involves deliberate attempts for mutual adjustments and self-organized action, with mechanisms ranging from information sharing to coordinated action and conflict resolution. PaCFA operates at the international level through the interplay of individuals, international organizations and their collaboration patterns [37].

Monitoring—the provision of transparent, relevant information about status and trends of the social-ecological system—is essential for building and maintaining resilience. Indicators of social processes and the ecosystem help users and managers understand status and trends of critical ecosystem services. Sometimes indicators may provide early warnings of approaching thresholds [38,39].

Leadership and trust confer resilience on social-ecological systems and social relations in general. Often a mere handful of key individuals (e.g. institutional entrepreneurs that manage the context, complex as it is), help shape management and governance trajectories, developing shared visions, building trust, connecting social networks across levels, and seizing windows of opportunity for social-ecological transformations towards adaptive governance that nurture general resilience [40,41]. Nonetheless, resilience can be undermined by social dilemmas such as the incentive to cheat on agreements. This tendency can be countered if trust is built up through repeated interactions among people [42]. This aspect of trust construction plays a role in self-organizing regulation of environmental commons [33]. Trust is a component of social capital that sometimes helps to overcome such social dilemmas [43,44].

4. FOSTERING GENERAL RESILIENCE

General resilience is the area of research currently receiving most attention from those involved in applying resilience in practice. Resilience assessments have tended to focus on aspects of the specified resilience of a particular region. The principles for enhancing resilience of individual social-ecological systems [1,5,45] are consistent with the types of enabling conditions for general resilience just described. For example, Biggs et al. [45] suggest seven principles for enhancing resilience, which address diversity, connectivity, feedbacks and slow variables, polycentric governance, learning and experimentation, breadth of participation, and the complex adaptive characteristics of social-ecological systems. In this section of the paper, we touch upon some general-resilience implications of recent studies in other literatures, including those on natural disasters, social vulnerability, scenario planning, and adaptive management.

Some elements of general resilience are implicit in the literature of natural disasters. A recent report from the World Bank [46] focused on four policy needs for managing environmental disasters: (1) make information about environmental disaster risk more easily accessible; (2) use land and housing markets to induce people to locate in appropriate areas and take preventive measures; (3) provide adequate infrastructure and public services to reduce vulnerabilities; and (4) build institutions that permit public oversight of disaster preparedness and disaster response. These are important practical steps at the level of national governance. Consideration of general resilience reminds us that additional factors must be considered, such as polycentric governance to match scales of problems and solutions.

After a disaster occurs, rapid response is crucial but it is also important to rebuild resilience, as detailed in a recent meeting of disaster experts [47]. Disturbance erodes capacity to organize and respond, and induces new feedbacks that tend to keep the system in the disturbed state. The longer a community stays in a disturbed state after a disaster the more difficult recovery becomes, and eventually it may not be able to recover at all. Yet quick-fix responses may lead to superficial outcomes that are harmful in the long run [48]. Thus response strategies for disasters must also consider rebuilding of resilience against possible future disturbances.

The attributes that confer social-ecological resilience to shocks are often unrecognized, and they may be eroded or lost over time unless they are actively fostered and managed [49]. Increased awareness, learning and collaboration across sectors [50,51], improved education, mobilization of experience and social capital, leadership, and multi-scale governance are critical elements in reducing vulnerability and building resilience to shocks [2,50,52]. All of these factors affect social vulnerabilities. Failure to reduce social vulnerabilities can amplify risk more than the escalation of physical hazards does [46].

Scenario planning is a method of exploring the resilience of a social-ecological system to a wide range of factors. Scenarios are a coordinated set of stories that reveal sharply different alternative futures for a social-ecological system. The alternate scenarios within a set diverge as a result of human decisions, diverging drivers, and large-consequence events. The purpose of the set of scenarios is to evoke conversations about thresholds that separate different future pathways of a social-ecological system. The alternative pathways often have different implications for resilience to future shocks that are outside the scope of the scenarios. For example, the Millennium Ecosystem Assessment [51] described four different states of the world in 2050. Each state has different resilience to climate changes that are expected to unfold after 2050. In regional environmental assessment and planning, the scenario process has many similarities to adaptive ecosystem management [53], a pioneering form of resilience analysis.

Adaptive management is always embedded in institutions and governance systems. Extreme events call for governance systems that provide incentives for resilience building and are themselves resilient to such events [54]. Adaptive governance systems with polycentric arrangements and bridging organizations connecting scales enable adaptive management [45,55]. For general resilience such attributes should not be subject to planning and control in a narrowly prescribed way [33], but instead supported by enabling legislation and economic incentives that allow for self-regulation and innovation. Critical features of wellfunctioning adaptive governance systems for social-ecological resilience include the role of key actors, bridging organizations, flexible institutions, and social networks that serve to connect the dynamic responses and strategies [56,57].

5. CONCLUSION

General resilience has a valuable role in managing rare extreme events with large consequences for social ecological systems. Of necessity, the guidelines for general resilience are rather non-specific. Nonetheless, in applications of general resilience it is essential to tailor policies and practices to the particular characteristics (governance, social interactions, ecosystem processes, etc.) of the social-ecological system that is being managed. In some cases, actions to build resilience against specific extreme events also contribute to general resilience.

The greatest challenge of general resilience is to design and implement concrete policies and actions. Unless incentives are constructed properly, short-term decision making will tend away from the long-term view that is needed to build and maintain general resilience. How can long-term practices be woven into actions that also meet the immediate needs of people and ecosystems? This is the crucial challenge of general resilience, a challenge that faces many real limits of costs and political barriers. General resilience is a public good that has a cost. How much resilience is needed, in what dimensions, and at what cost? Policies for general resilience must overcome budget limitations, address trade-offs, be acceptable to competing interests, and overcome barriers in politics and the structure of existing agencies and institutions. It may well be the case that costs are too great to justify more investment in general resilience. Such practical limitations may be the greatest barrier to policies for general resilience.

Research and practice have built some insight about how to build general resilience. Nonetheless, much research is needed to understand practices for general resilience in diverse situations. For example, how general is general resilience? Are certain characteristics of social-ecological systems (Table 1) more or less effective for building general resilience? Are some characteristics particularly well suited to building resilience for certain classes of social-ecological problems? So far there are only a few case studies that reveal long-run effectiveness of strategies for general resilience. Further research on general resilience is a high priority, in view of the rapid rates of change and emergence of new interactions and feedback in social-ecological systems.

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Focusing the Meaning(s) of Resilience: Resilience as a Descriptive Concept and a Boundary Object

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ABSTRACT

This article reviews the variety of definitions proposed for "resilience" within sustainability science and suggests a typology according to the specific degree of normativity. There is a tension between the original descriptive concept of resilience first defined in ecological science and a more recent, vague, and malleable notion of resilience used as an approach or boundary object by different scientific disciplines. Even though increased conceptual vagueness can be valuable to foster communication across disciplines and between science and practice, both conceptual clarity and practical relevance of the concept of resilience are critically in danger. The fundamental question is what conceptual structure we want resilience to have. This article argues that a clearly specified, descriptive concept of resilience is critical in providing a counterbalance to the use of resilience as a vague boundary object. A clear descriptive concept provides the basis for operationalization and application of resilience within ecological science.

Keywords: boundary object; definition; descriptive concept; ecological resilience; resilience; sustainability; typology.

INTRODUCTION

The concept of resilience is one of the most important research topics in the context of achieving sustainability (Perrings et al. 1995, Kates et al. 2001, Foley et al. 2005). First introduced as a descriptive ecological term (Holling 1973), resilience has been frequently redefined and extended by heuristic, metaphorical, or normative dimensions (e.g., Holling 2001, Ott and Döring 2004, Pickett et al. 2004, Hughes et al. 2005). Meanwhile, the concept is used by various scientific disciplines as an approach to analyze ecological as well as social-ecological systems (Anderies et al. 2006, Folke 2006). As such, it promotes research efforts across disciplines and between science and policy.

However, both conceptual clarity and practical relevance are critically in danger. The original descriptive and ecological meaning of resilience is diluted as the term is used ambiguously and in a very wide extension. This is due to the blending of descriptive aspects, i.e., specifications of what is the case, and normative aspects, i.e., prescriptions what ought to be the case or is desirable as such. As a result, difficulties to operationalize and apply the concept of resilience within ecological science prevail. This, in turn, impedes progress and maturity of resilience theory (cf., Pickett et al. 1994:57). The success of the concept in stimulating research across disciplines on the one side and the dilution of the descriptive core on the other raises the fundamental question what conceptual structure we want resilience to have.

This article is divided into four parts. The first section offers a typology to structure the numerous definitions of resilience proposed within sustainability science. Using this typology as a background, the second section investigates in more detail a descriptive, ecological concept of resilience viewed from both a formal and an operational perspective. Subsequently, the third section examines the use of resilience as a rather vague boundary object and points to some chances and pitfalls. The fourth section concludes with final thoughts on the recent conceptual development and a fruitful conceptual structure of resilience.

A TYPOLOGY FOR DEFINITIONS OF RESILIENCE

In what follows we suggest a typology for the variety of definitions of resilience used in sustainability science. The typology is based on the analysis of key papers published in the last 35 yr (cf., Janssen et al. 2006). It provides the background for discussing the conceptual development of resilience.

Before turning to the definitions in detail some words on the terminology used are in order. First, two distinct meanings of resilience must be distinguished. The first one refers to dynamics close to equilibrium and is defined as the time required for a system to return to an equilibrium point following a disturbance event. It has been coined engineering resilience (Holling 1996) and is largely identical to the stability property, i.e., elasticity (Grimm and Wissel 1997). The second meaning of resilience refers to dynamics far from any equilibrium

steady state and is defined as the amount of disturbance that a system can absorb before changing to another stable regime, which is controlled by a different set of variables and characterized by a different structure. It has been termed ecosystem resilience (Gunderson and Holling 2002) and it is applied almost interchangeable with the words ecological resilience (e.g., Holling 1996, Holling et al. 1997, Gunderson 2000, Gunderson and Pritchard 2002, Anderies et al. 2006) or resilience (e.g., Holling 1973, 1986, Arrow et al. 1995, Perrings et al. 1995, Carpenter and Cottingham 1997, Carpenter et al. 2001, Walker et al. 2002, 2004, Bellwood et al. 2004, Folke et al. 2004, Carpenter and Folke 2006). It is this second kind of resilience to which we refer in this text.

The result of our analysis is displayed in Table 1. It shows 3 categories, 10 classes, and correspondingly 10 definitions of resilience. The three categories reflect whether the definition is in accordance with either a genuinely descriptive concept (Category I), a hybrid concept, in which descriptive and normative connotations are intermingled (Category II), or a genuinely normative concept (Category III). Thus, our scheme in the first place emphasizes the degree of normativity included in the different definitions that fit under the overall category of resilience as characterized above. However, we also found it useful and necessary to distinguish between purely ecological definitions, i.e., Class 1–4, and those which are also used in the context of other fields such as economy and sociology, i.e., Class 5–10.

In the following, each definition of resilience is explained in more detail with respect to its category and class, respectively. Note that the proclaimed titles do not correspond to the particular references.

Category I: Descriptive concept

Sub-category Ia: Ecological science

Class 1: Original ecological definition

In his seminal paper, Holling (1973) defines resilience as a "measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" (Holling 1973:14). In this original-ecological meaning, resilience focuses on the persistence of populations or communities at the ecosystem level and corresponds to both the overall area and the height of the lowest point of a population's domain of attraction. A relative measure is a population's probability of extinction.

Class 2: Extended ecological definition

Subsequent work published from the late 1980s (Holling 1986, 1996, Walker 1999, Gunderson 2000, Gunderson and Holling 2002, Gunderson and Pritchard 2002, Walker et al. 2002, 2004) is strongly influenced by theory on complex adaptive systems (e.g., Levin 1998) including the cross-scale morphology of ecosystems (Holling 1992). According to the extended keystone hypothesis originally proposed by Holling (1992), the hierarchical structure of ecosystems is primarily regulated by a small set of plant, animal, and abiotic processes each operating over different scale ranges. Important changes in ecosystem dynamics can be understood by analyzing a few, typically no more than five, key variables (Walker et al. 2006). In this interpretation, the scientific focus is on the critical structure and processes of an ecosystem. Individual species can be replaced if the critical structure and key processes persist (Walker et al. 1999, Elmqvist et al. 2003, Nyström 2006). In this extended-ecological meaning, resilience is defined as "the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behaviour" (Gunderson and Holling 2002:4) or "the capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity" (Walker et al. 2006:2).

Class 2a: Three characteristics

Some authors interpret the extended-ecological meaning as comprising three characteristics. Those are: (1) the amount of change a system can undergo and still remain within the same domain of attraction, i.e., to retain the same controls on structure and processes; (2) the degree to which the system is capable of self-organization; and (3) the degree to which the system expresses capacity for learning and adaptation (Carpenter et al. 2001, Walker et al. 2002, Folke 2006).

Class 2b: Four aspects

One line of research emphasizes the concept of alternative stable regimes (Scheffer and Carpenter 2003, Folke et al. 2004, Walker and Meyers 2004). Note that the term "regime" is preferred to avoid the static connotations of the term "state" and to describe the actual dynamic situation of a specified ecosystem (Scheffer and Carpenter 2003). Formally, alternative stable regimes exist within alternative basins of attraction (Walker et al. 2004). Four aspects of a basin of attraction are crucial. Those are: (1) latitude or the maximum amount the system can be changed before losing its ability to recover, e.g., the width of the basin; (2) resistance, which matches the ease or difficulty of changing the system, e.g., the topology of the basin; (3) precariousness, i.e., the current trajectory of the system and proximity to a limit or threshold; and (4) cross-scale relations, or how the above three aspects are influenced by the dynamics of the systems at scales above and below the scale of interest (Folke et al. 2004, Walker et al. 2004).

Class 3: Systemic-heuristic definition

Some scholars have worked on the presuppositions of the concept of resilience, which include a heuristic for the dynamics of productive, self-organized systems, the "panarchy." This metamodel (Cumming and Collier 2005) of ecosystem dynamics consists of four-phase

Table 1. Ten definitions of resilience with respect to the degree of normativity.

Categories and classes	Definitions	References
(I) DESCRIPTIVE CONCEPT		
(Ia) ECOLOGICAL SCIENCE		
1) Original-ecological	Measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables	Holling 1973:14
2) Extended-ecological	The magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behavior and The capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity	Gunderson and Holling 2002:4 Walker et al. 2006:2
2a) Three characteristics	capacities i) to absorb disturbances, ii) for self-organization, and iii) for learning and adaptation	Walker et al. 2002
2b) Four aspects	1) latitude (width of the domain), 2) resistance (height of the domain), 3) precariousness, 4) cross-scale relations	Folke et al. 2004:573
3) Systemic-heuristic	Quantitative property that changes throughout ecosystem dynamics and occurs on each level of an ecosystem's hierarchy	Holling 2001
4) Operational	Resilience *of* what *to* what? and The ability of the system to maintain its identity in the face of internal change and external shocks and disturbances	Carpenter et al. 2001 Cumming et al. 2005
(Ib) SOCIAL SCIENCES		
5) Sociological	The ability of groups or communities to cope with external stresses and disturbances as a result of social, political, and environmental change	Adger 2000:347
6) Ecological-economic	Transition probability between states as a function of the consumption and production activities of decision makers and The ability of the system to withstand either market or environmental shocks without loosing the capacity to allocate resources efficiently	Brock et al. 2002:273 Perrings 2006:418
(II) HYBRID CONCEPT		
7) Ecosystem-services-related	The underlying capacity of an ecosystem to maintain desired ecosystem services in the face of a fluctuating environment and human use	Folke et al. 2002:14
8) Social-ecological system		
8a) Social-ecological	The capacity of a social-ecological systems to absorb recurrent disturbances (...) so as to retain essential structures, processes and feedbacks	Adger et al. 2005:1036

8b) Resilience-approach	A perspective or approach to analyze social-ecological systems	Folke 2006
(III) NORMATIVE CONCEPT		
9) Metaphoric	Flexibility over the long term	Pickett et al. 2004:381
10) Sustainability-related	Maintenance of natural capital in the long run	Ott and Döring 2004:213f

adaptive cycles, i.e., r-, K-, Ω-, and -phases, which occur on each level of a system's hierarchy. Against this background, resilience represents a quantitative property that changes throughout the adaptive cycle and principally occurs on each level of a system's hierarchy (Holling 2001, Gunderson and Holling 2002).

Class 4: Operational definition

To apply the concept of resilience to empirical cases, it is critical to specify resilience of "what to what" (Carpenter et al. 2001). This operational definition constitutes the first step to make resilience concrete. Further operational steps suggest focusing on the concept of identity and defining resilience as "the ability of the system to maintain its identity in the face of internal change and external shocks and disturbances" (Cumming et al. 2005).

Sub-category Ib: Social sciences

Class 5: Sociological definition

Some scientists apply the concept of resilience to social systems. Social resilience is defined as "the ability of groups or communities to cope with external stresses and disturbances as a result of social, political, and environmental change" (Adger 2000:347).

Class 6: Ecological-economical definition

In addition, the concept of resilience is used to analyze economy-environment systems (e.g., Perrings and Walker 1997, Perrings and Stern 2000, Brock et al. 2002, Perrings 2006). Resilience matches the "transition probability between states as a function of the consumption and production activities of decision makers" (Brock et al. 2002:273) or "the ability of the system to withstand either market or environmental shocks without loosing the capacity to allocate resources efficiently" (Perrings 2006:418).

Category II: Hybrid concept

Class 7: Ecosystem services-related definition

In this hybrid sense, resilience corresponds to the underlying capacity of an ecosystem to maintain desirable ecosystem services in the face of human use and a fluctuating environment (Carpenter 2001, Folke et al. 2002). Studies focus on desirable ecosystem services of an ecological system, e.g., food production, water purification, or aesthetic enjoyment (MEA 2005).

Class 8: Social-ecological system.

Many scientists state that it is critical to apply the concept of resilience to coupled social-ecological systems, as it may be a fundamental error of environmental policy to separate the human system from the natural system and treat them as independent (e.g. Folke et al. 2002, Anderies et al. 2006, Walker et al. 2006). The nature-culture split is seen as arbitrary and artificial; humans are regarded as part of the ecosystem (Westley et al. 2002, Berkes et al. 2003).

Class 8a: Social-ecological definition

Social-ecological resilience is defined as "the capacity of social-ecological systems to absorb recurrent disturbances (...) so as to retain essential structures, processes and feedbacks" (Adger et al. 2005:1036). In this approach, a system analysis tends to incorporate specific values, e.g., cultural diversity or international aid. Consequently, there is an increase in the degree of normativity, i.e., resilience gets more and more desirable as such.

Class 8b: Resilience approach

Recently, resilience has been increasingly conceived as a perspective, as a way of thinking to analyze linked social-ecological systems (Folke 2006). No clear definition is suggested. Rather, resilience is conceived as a collection of ideas about how to interpret complex

systems (Anderies et al. 2006).

Category III: Normative concept

Class 9: Metaphorical definition

In a metaphoric interpretation, the concept of resilience means "flexibility over the long term" (Pickett et al. 2004:381) and is viewed as desirable as such.

Class 10: Sustainability-related definition
Resilience has been suggested as to be one of the guidelines for a conception of strong sustainability (Ott 2001, 2003, Ott and Döring 2004). Hereby the term refers to the maintenance of natural capital in the long-term in order to provide ecosystem services that provide instrumental as well as eudaemonistic values for human society.

These ten definitions together represent the intension of the term resilience. Even though they are all related to the original, descriptive concept of resilience, as introduced by Holling (1973), the term has been transformed considerably. The conceptual development of resilience has been recently reviewed by Folke (2006), who made a distinction between an early interpretation of resilience, which focuses on the robustness of systems to withstand shocks while maintaining function, i.e., ecosystem or ecological resilience, social resilience, and a subsequent interpretation, which refers more to the interplay of disturbance and reorganization within a system as well as to transformability, learning and innovation, i.e., social-ecological resilience. Although Folke (2006) points to the change in the specific meaning of resilience our own interpretation of the conceptual development of resilience highlights the distinct use of the concept of resilience within the spectrum of scientific disciplines. Thus, the subsequent sections contrast (a) a clearly specified concept of resilience that is merely used in ecology with (b) a vague and malleable concept of resilience that is used as a communication tool across different scientific disciplines and between science and practice.

RESILIENCE AS A DESCRIPTIVE ECOLOGICAL CONCEPT

This section describes a descriptive, ecological concept of resilience in more detail. By definition a descriptive concept of resilience excludes normative dimensions. Resilience may be viewed as either desirable or undesirable in a specific case; this depends on the state of concern. This means, a degraded savannah or a polluted lake can be highly resilient but at the same time undesirable from an anthropocentric perspective (Carpenter et al. 2001, Carpenter and Cottingham 2002, Walker et al. 2002).

In a descriptive sense, the concept of resilience points to a nonequilibrium view on ecological systems (Wallington et al. 2005), that is, it assumes the existence of alternative stable regimes (Holling 1996). For example, a savannah may exhibit either a locally stable grassy regime or a locally stable woody regime depending on the value of some driving factors, such as rainfall, grazing pressure and fire events (Walker 2002). There is strong evidence that most ecosystem types can exist in alternative stable regimes, for instance lakes, coral reefs, deserts, rangelands, woodlands, and forests (Folke et al. 2004, Walker and Meyers 2004). However, the weight of empirical evidence shows that the relative frequency of the occurrence of alternative stable regimes across systems is higher for systems controlled by environmental adversity, e.g., deserts, arctic tundra, or savannahs, than those controlled by competitive adversity, e.g., forests or coral reefs (Didham 2006).

A mathematical model of this behavior termed "bistability" is provided by phase plane and bifurcation diagrams proposed by Ludwig et al. (1997, 2002). Formally a system exhibits alternative basins of attraction when a fast state variable, e.g., annual grasses, macrophytes, responds to changes in a slow variable, e.g., long-lived organisms, nutrient storages, by a backward-folding curve, as shown in Fig. 1. Because of the backward fold, two stable basins overlap, separated by an unstable one over a given range of the slow variable (Scheffer et al. 2001, Scheffer and Carpenter 2003, Schröder et al. 2005).

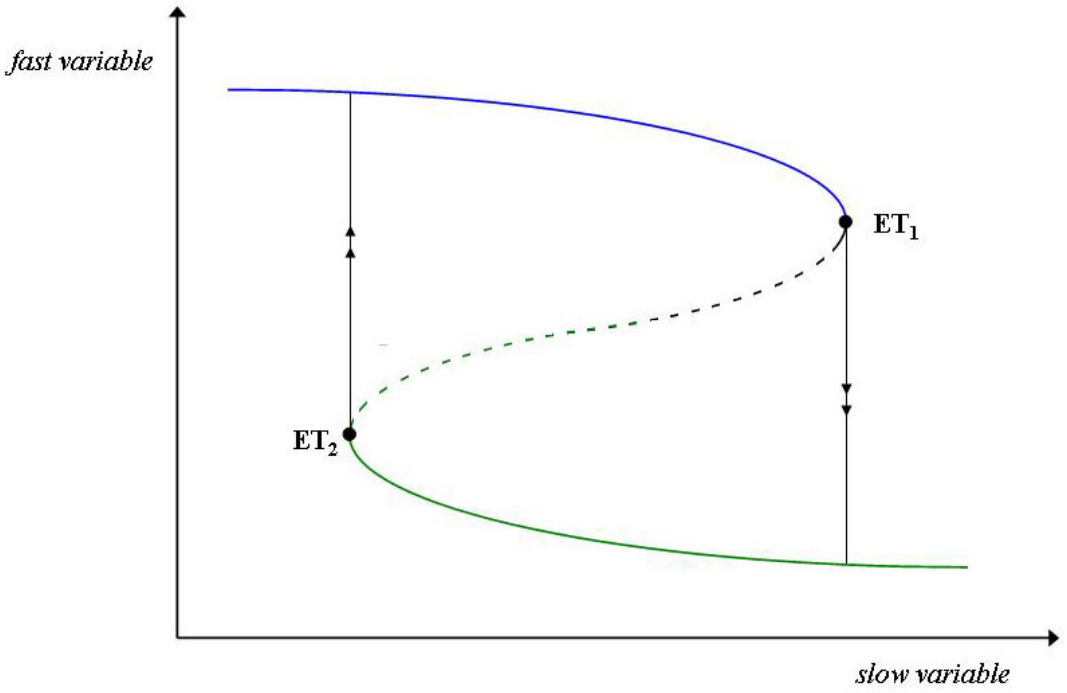
When the system is in a regime on the upper blue branch of the folded curve in Fig. 1, it cannot pass to the lower green branch smoothly. Instead, when the slow variable changes sufficiently to pass the critical value, i.e., the ecological threshold (ET1), a catastrophic transition to the lower branch occurs, either caused by only an incremental change in conditions or due to a bigger disturbance. To induce a switch back to the upper branch it is not sufficient to restore the slow variable to the value before the collapse. Instead, one needs to go back further, beyond the other switch point (ET2), at which the system recovers by shifting back to the upper branch, a pattern known as "hysteresis" (Scheffer and Carpenter 2003, Groffman et al. 2006, Briske et al. 2006). In contrast to a narrow equilibrium view, this indicates the importance of the boundaries of a basin of attraction and the ease or difficulty with which a system could be moved out of this basin (Holling 1973, 1996, Gunderson and Holling 2002).

For example, shallow lakes can exhibit two stable regimes with respect to nutrient load, i.e., a clear-water regime with aquatic plants and a turbid regime without vegetation. If the lake is in the clear-water regime, an increase of the nutrient level will lead to a gradual and moderate rise in turbidity until the critical turbidity for plant survival is reached. At this point, vegetation collapses and the lake shifts to the turbid regime. Reduction of nutrients after this catastrophic transition does not result in a return of plants immediately. However,

the backward switch happens at much lower nutrient level than the forward switch. Thus, often reduction of the nutrient level to values at which the lake used to be clear and vegetated will not lead to restoration of that state (Dent et al. 2002).

Correspondingly, in a descriptive sense the resilience of an ecological system can be defined as "the magnitude of disturbance that can be absorbed before the system shifts to another basin of attraction" (cf. Class 2 in Table 1; Gunderson and Holling 2002, Bellwood et al. 2004, Nyström 2006). In addition, some authors distinguish several characteristics or aspects of resilience, respectively (cf. Class 2a and 2b in Table 1). The descriptive ecological definitions described above (Class 1–4 in Table 1) differ with respect to the criteria they provide as means to determine if a system is resilient and to what degree. In this article we focus on the extended-ecological definition of resilience in order to point to the concept of slow controlling variables, which can be used to operationalize resilience, and thus to the importance of a quantitative and measurable approach to resilience.

Fig. 1. Bifurcation diagram of a system described by a fast variable and a slow variable: the stable regimes are given by the blue and green solid lines and the boundary of the basins of attraction, i.e., unstable state, by the dashed line. ET1 and ET2 represent ecological threshold points (modified from Scheffer and Carpenter 2003)



Indeed, a crucial question for scientific progress is: are there any possibilities to estimate or measure the resilience of an ecosystem? Any operational interpretation of resilience means to specify resilience "to what" and "of what" (cf., Class 4 in Table 1; Carpenter et al. 2001) and channels into a comprehensive resilience analysis (Walker et al. 2002, Brand 2005). This also means to inquire which of the criteria for resilience described in definition Classes 1–4 are in fact meant as criteria that must be measured to assess and/ or quantify the resilience of an ecosystem.

The"to-what part" of the analysis explicates to what exactly a certain regime of an ecosystem should be resilient. This corresponds to specifying the disturbance regime, e.g., the kind of disturbances, their frequency, and intensity (Pickett and White 1985, White and Jentsch 2001), which may include both human disturbances, e.g., pollution pulses or habitat fragmentation, and natural disturbances, e.g., hurricanes or floods, as well as possible multiplicative effects (Vinebrooke et al. 2004).

The subsequent "of-what part" explicates the specific regime that is meant to be resilient to the identified disturbance regime. This part of the analysis is comprised of several steps. Step one means to assess which ecosystem processes or ecosystem services (see Jax 2005) of the regime are of primary concern on which spatial and temporal scale (Walker et al. 2002). Step two explicates the self-identity of the selected regime delimited in step one. This includes explicating the precise boundary of the regime, the set of variables of interest, and the expected internal degree of relationships, as well as the component resolution (Jax et al. 1998, 2006, Cumming et al. 2005). Step one and step two are dependent on societal values or normative judgments and should therefore incorporate environmental assessment procedures and participative deliberations (Plachter 1994, Jax and Rozzi 2004).

Apparently, the overall aim is to assess if the ecosystem is and remains within the regime of concern, which has been identified in the previous steps. Thus, step three specifies the variables and mechanisms that control the specific position of an ecosystem within state space. There are two options. The first option is to investigate empirically the value of the slow variables of a regime and plot it in a bifurcation diagram, as considered in Fig. 1. The amount of resilience is then measured as the distance between the current value of the slow variable and the critical value (Carpenter et al. 2001, Walker et al. 2002, Peterson et al. 2003, Bennett et al. 2005), which is termed precariousness (Walker et al. 2004). It may be possible to predict the position of an ecological threshold either by studying return time and standard deviations of a fast variable (Wissel 1984, Carpenter and Brock 2006) or by the repeated calculation of the Fisher information of a regime (Mayer et al. 2006).

The second option of step three refers to the amount of resilience mechanisms inherent in the desirable regime. Resilience mechanisms include (a) critical functional groups and functional important species, such as top predators or keystone species (Folke et al. 2004, Bellwood et al. 2004, Micheli and Halpern 2005), (b) ecological redundancy and response diversity within functional groups (Walker 1995, Peterson et al. 1998, Elmqvist et al. 2003, Hooper et al. 2005, Nyström 2006); and (c) the existence of a matrix of support areas at the landscape scale that provide potential colonists to compensate for the loss of species at the local scale (Bengtsson et al. 2003, Hughes et al. 2005). The amount of resilience mechanisms may be a measure to assess the relative resilience of the desirable regime to the given disturbances (cf., Allen et al. 2005).

The message of this section is that in a descriptive interpretation resilience can be a clearly specified and delimited stability concept. It is in this sense that resilience represents a quantitative and measurable concept that can be used for achieving progress in ecological science.

RESILIENCE AS A BOUNDARY OBJECT

In contrast to the use as a descriptive concept, resilience is increasingly viewed in a rather vague and malleable meaning. In the 1990s several scholars discovered the concept as an important tool to measure sustainability (Arrow et al. 1994, Perrings et al. 1995, Folke et al. 1996, Levin et al. 1998). Since then resilience has been used by various scientific disciplines, for instance economics (Farber 1995, Batabyal 1998, Perrings and Stern 2000, Brock et al. 2002, Perrings 2006), political science (Olsson et al. 2006), sociology (Adger 2000), or planning (Pickett et al. 2004), and each discipline has provided specific definitions (cf., Class 5–10 in Table 1). Moreover, resilience has been related to other scientific concepts such as carrying capacity (Seidl and Tisdell 1999), critical natural capital (Deutsch et al. 2003), strong sustainability (Arrow et al. 1995, Ott 2003, Ott and Döring 2004), globalization (Armitage and Johnson 2006), justice (Adger 2003), and adaptive co-management (Berkes et al. 2003, Olsson et al. 2004).

In particular, resilience is increasingly interpreted in a broader meaning across disciplines as a way of thinking, a perspective or even paradigm for analyzing social-ecological systems (Folke et al. 2002, Folke 2003, Anderies et al. 2006, Folke 2006, Walker et al. 2006). Some authors expand theories or concepts drawn from ecological systems, e.g., alternative stable regimes, panarchy, or ecological redundancy, to examine social, political, and institutional systems (e.g., Gunderson and Holling 2002, Berkes et al. 2003, Allison and Hobbs 2004). Much research aims at a general theory for the resilience of whole social-ecological systems (cf., Class 8 in Table 1, Anderies et al. 2006). It is in this sense that resilience incorporates the capacity of social-ecological systems to cope with, adapt to, and shape change and learn to live with uncertainty and surprise (Folke 2003, 2006).

Thus, we suggest that resilience has become a "boundary object." Within the field of science and technology studies, this signifies a term that facilitates communication across disciplinary borders by creating shared vocabulary although the understanding of the parties would differ regarding the precise meaning of the term in question (Star and Griesemer 1989). Boundary objects are able to coordinate different groups without a consensus about their aims and interests. If they are both open to interpretation and valuable for various scientific disciplines or social groups, boundary objects can be highly useful as a communication tool in order to bridge scientific disciplines and the gap between science and policy (Eser 2002, Cash et al. 2003). Indeed, it is this vagueness and malleability, i.e., the potential variety of interpretations or applications of the term that makes boundary objects politically successful (Eser 2002). For example, the boundary object sustainability has been highly successful in providing the common ground for ecologists and economists, which were formerly thought contrary, to engage together for the needs of future generations. In addition, the concept has helped to reconcile contrasting interests of industrial and developing countries (UNEP 2002).

But there is a fundamental drawback to this. Boundary objects can in fact be a hindrance to scientific progress. For example, the meaning of the term sustainability is highly diluted and unclear. The three-pillar conception of sustainability, i.e., development in economic, social, and ecological systems, has been reduced to a listing of any societal objectives that agents happen to think important. That means that the extension of the term has become extremely wide. This is due to the fact that the catchword sustainable development enables different scientific disciplines or social groups to justify their particular interest with respect to an accepted and ethically legitimated, societal goal (Ott 2003, Grunwald 2004b). It may thus even hide conflicts and power relations when different persons agree on the need for sustainability when in fact meaning different things by it. Therefore, sustainability is generally conceived as arbitrary or as an illusion and within sustainability science there is confusion on how to operationalize and apply the concept (Grunwald 2004a). To

foster conceptual clarity and practical relevance some authors have suggested a clear and specified theory of sustainability, which is characterized by both a narrow extension and a clear intension of the term (Kopfmüller et al. 2001, 2006, Ott 2003, Ott and Döring 2004, Kates et al. 2005).

These insights indicate that, metaphorically spoken, boundary objects are Janus-faced, i.e. they are inherently ambivalent. They may have positive and negative aspects in terms of scientific progress and political success. What does that mean for a scientific concept of resilience?

DISCUSSION

In this section we synthesize the points made in the previous sections and discuss some implications for a fruitful conceptual structure of resilience. Resilience is a two-faced concept. On the one hand, the concept is used as a descriptive, ecological concept (e.g., Walker 2002, Gunderson and Holling 2002, Bellwood et al. 2004, Nyström 2006) whereas, on the other hand, it represents a boundary object with a rather wide and vague meaning (e.g., Gunderson and Holling 2002, Adger et al. 2003, Folke 2003, Hughes et al 2005, Folke 2006, Walker et al. 2006). As a result, the original ecological concept of resilience first defined by Holling (1973) has been transformed considerably. This becomes apparent in several points.

First, the specific meaning of resilience gets diluted and increasingly unclear. This is due to the use of the concept (a) with many different intensions and (b) with a very wide extension. For example, Hughes et al. (2005) suggest several key components of resilience for marine regions. These include leadership and insight, sustained mobilization of national and international aid, cultural and ecological diversity, development of multiscale social networks, and the resolution of local civil unrest. Apparently, Hughes et al. (2005) apply both the social-ecological definition and the metaphoric definition of resilience (cf., Classes 8a and 9 in Table 1) in order to link an ecological-descriptive meaning of resilience to governance structures, economics and society. As a result, however, the concept of resilience includes very much, from international aid and leadership to ecological diversity, and it is for this reason why the meaning of resilience gets diluted and unclear, as for logical reasons any concept that encompasses very much, i.e., wide extension, must lose specific meaning, i.e., clear intension (Ott 2003). Indeed, regarding the interpretation of resilience put forward by Hughes et al. (2005), it gets difficult to decide whether a certain state is resilient or not or to specify the particular degree of resilience inherent in a certain state.

Second, a broad concept of resilience often includes normative dimensions. Following the interpretation of Hughes et al. (2005) resilience represents a hybrid concept containing a blending of descriptive and normative aspects, as international aid, cultural diversity, and the resolution of local civil unrest represent instrumental and eudaemonistic values. The fact that a broad concept of resilience includes normative dimensions is not surprising. We see other boundary objects floating between descriptive and normative meanings, as in the case of biodiversity, i.e., biodiversity in the specific scientific sense of diversity at the level of genes, species, and ecosystems vs. biodiversity in the sense of the ominous value of life on earth (Eser 2002). But the important point is that these normative aspects within a broad concept of resilience ought to be made explicit and, whenever possible, justified ethically (U. Eser and T. Potthast, personal communication).

Third, the term resilience is used ambiguously as divergent conceptions of resilience are proposed. There are at least 10 different approaches to resilience. Each approach emphasizes different aspects of resilience with respect to the specific interest. The ecological aspect is stressed by ecologists, whereas the political and institutional aspects are stressed by sociologists, etc. Thus, the term resilience is used ambiguously for fundamentally different intensions (cf., Class 1–10 in Table 1). The direct consequences are trade-offs between social and environmental objectives within a conception of resilience, which may be difficult to handle.

Fourth, the original ecological dimension of resilience is about to vanish. Our impression is that recent studies increasingly stress the social, political, and institutional dimensions of resilience (e.g., Folke 2002, Olsson et al. 2004, 2006, Janssen 2006) or address whole social-ecological systems (e.g., Adger et al. 2005, Hughes et al. 2005, Folke 2006, Walker et al. 2006), whereas genuinely ecological studies of resilience get rare (but cf., Bellwood et al. 2004, Nyström 2006).

Finally, resilience is increasingly conceived as a perspective, rather than a clear and well-defined concept. Recently, resilience has been conceived either as a way of thinking, as an approach to address social processes, such as social learning, leadership and adaptive governance (cf. Class 8b in Table 1; Folke 2006) or as a metaphor for the flexibility of a social-ecological system over the long term (cf., Class 9 in Table 1; Pickett et al. 2004). According to Anderies et al. (2006), resilience is better described as a collection of ideas about how to interpret complex systems. As a result, the meaning of resilience gets increasingly vague and unspecified.

How to evaluate this conceptual development of resilience? We suggest on the one side that both conceptual clarity and practical relevance of resilience are critically at stake. A scientific concept of resilience must have a clear and specified meaning that is constantly used in the same way. In particular, it must be possible (a) to specify the particular objects the concept refers to, (b) to decide whether particular states in nature are resilient or nonresilient and it should be possible (c) to assess the degree of resilience of a certain state (cf., Grunwald 2004a,b, Jax 2006). In fact, the quality of the term resilience is strongly dependent on the ability to exclude phenomena that

do not meet this term, as both operationalization and application with respect to environmental management are strongly dependent on a clear and delimited meaning of the term (Pickett et al. 2004).

On the other side, however, we propose that the increased vagueness and malleability of resilience is highly valuable because it is for this reason that the concept is able to foster communication across disciplines and between science and practice (cf., Eser 2002). Therefore, it is not the suggestion to eradicate this vagueness and ambiguousness entirely but to grasp the ambivalent character of boundary objects and, hence, of a wide and vague use of resilience.

To counterbalance the positive and negative aspects of the conceptual development of resilience we, thus, argue for division of labor in a scientific sense. Resilience, conceived as a descriptive concept, should be a clear, well defined, and specified concept that provides the basis for operationalization and application within ecological science. For the sake of clarity, this meaning may be dubbed ecological resilience/ecosystem resilience, for ecological systems, or just resilience if applied to systems other than ecological, e.g., climatic systems. In contrast, resilience conceived as a boundary object should be designed in a manner to foster interdisciplinary work. In this sense, resilience constitutes a vague and malleable concept that is used as a transdisciplinary approach to analyze social-ecological systems. For greater clarity this meaning may be termed social-ecological resilience (as in Folke 2006).

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Climate Change Resilience Strategies for the Building Sector: Examining Existing Domains of Resilience Utilized by Design Professionals

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ABSTRACT

Recently, climate change resilience efforts in the building sector have increased. Previous studies have examined the theoretical frameworks that have shaped the concept development of resilience. However, little is known about the theoretical approaches adopted by building professionals in their climate change resilience work. A literature review identified climate change resilience across four academic domains: ecology, engineering, disaster risk reduction, and the social sciences. To better understand how resilience is defined in the building sector, we examined eighteen climate change resilience documents developed to provide guidance to building sector professionals in the United States. Our analysis of these documents helps to understand how professionals are framing and possibly incorporating these strategies in their work, though we did not measure the adoption rate of each of the documents. We find that resilience is mostly a discourse on bouncing-back, preserving the status quo, and/or developing emergency responses to major hazards. Fewer documents incorporated an ecological or social science-based logic. This highlights the challenges of translating resilience from four academic domains into building strategies for the professional community. In closing, we discuss how competing conceptions of resilience may impact the implementation and effectiveness of climate change resilience strategies in the built environment.
Keywords: building sector; building codes; building standards; building design; climate adaptation

1. INTRODUCTION

Recent climate-related events, such as Hurricane Sandy that struck New York City and the Northeastern United States in 2012, have highlighted the resilience, or lack thereof, of the building sector. Events like Hurricane Sandy, and other weather-related phenomena, illustrate that the climate is shifting rapidly in many parts of the globe; planning for future building stock can no longer rely solely on historical data.

After Hurricane Sandy, the New York City Housing Authority (NYCHA) reported loss of power, heat, and hot water in approximately 35,000 housing units; 94% of the 62,000 damaged properties inspected by the Federal Emergency Management Agency (FEMA) experienced flooding damage [1]. In response, the City of New York proposed a comprehensive plan titled "A Stronger, More Resilient New York", with the goal of increasing the resilience of infrastructure and buildings in communities across the city.

New York City and New York State are not the only U.S. locations grappling with this threat. Due to multiple large-scale events in recent years, resilience efforts to reduce risks related to the building stock have been deployed by policy- and decision-makers [2]. These organizations are disseminating reports, toolkits, voluntary standards, and other "how-to" information to build resilience in the built environment.

While the interest in resilience in the public and political sphere has largely been in reaction to climate disasters, literature on climate change resilience in the built environment is growing rapidly. According to Longstaff et al., due to its recent popularity, resilience risks turning into another buzzword with no meaning [3]. Some argue that the diversity and ambiguity in resilience thinking challenges its operationalization [3,4], while others have suggested that resilience's conceptual vagueness facilitates interdisciplinary communication [5]. Reaching a holistic definition may be difficult, however efforts to explore how different definitions of resilience modify the approach of professionals is important. To this end, this paper examines how resilience is translated from four academic domains into practical guidance currently in use by built environment professionals.

In the following three subsections of this paper, we provide an overview of the concept of resilience across four academic domains identified within the resilience literature. Next, we illustrate how resilience is translated into practice. In the final subsection, we highlight how the building sector approaches and conceptualizes climate change resilience by analyzing existing climate change resilience documents providing guidance to building professionals.

1.1. Understanding Resilience: Four Academic Domains

The word resilience originates from the Latin word "resiliō" meaning to "spring back." Resilience generally refers to the ability of a system to withstand an array of shocks and stresses. Within the literature, resilience has overlapped with concepts such as stability and robustness [6] and is considered a complementary approach to sustainability [7,8]. Definitions of resilience are grounded in a diverse array of disciplinary perspectives.
While the definitions of resilience across domains overlap, it is important to explore the differences in how resilience is framed in each individual domain. This allows one to grasp how resilience definitions may shape policy and professional efforts to adapt the building stock to climate change. A review of the literature has identified four main academic domains of resilience: ecology, engineering, disaster risk reduction, and the social sciences.

1.1.1. Ecology

Perhaps the most prominent researcher on resilience is Holling, who introduced the concept of resilience to the field of ecology in 1973. Holling defines resilience as a, "measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" [9]. In this definition, ecological systems are viewed as having multiple equilibrium or stable states; ecological resilience examines the threshold required to move a system from one equilibrium state to another [10,11].

In recent years, literature on ecological resilience has explored notions of constantly changing systems, or nonequilibrium systems. As such, resilience reflects a process of continuous adaptation to stresses and disturbances rather than an attribute or outcome. Nonequilibrium notions of resilience shift from reinforcing the ability to bounce-back towards exploring opportunities for transformation and change or "bouncing forward."

This literature also acknowledges interactions between social and ecological systems. This conception of resilience in the ecological domain was essential to understanding change in social-ecological systems (SES). Resilience in SES is defined as, "the capacity of linked social-ecological systems to absorb recurrent disturbances such as hurricanes or floods so as to retain essential structures, processes, and feedback … the degree to which a complex adaptive system is capable of self-organization (versus lack of organization or organization forced by external factors) and the degree to which the system can build capacity for learning and adaptation" [12].

In this way, resilience in the ecological domain also embraces a potential for change and highlights the capacity of systems to reorganize. Disturbances can create (or force) opportunities for decision-makers and stakeholders to innovate and adapt [13]. Ecological resilience addresses both acute and chronic stresses, meaning it does not focus primarily on temporary disturbances, but requires a shift in practices that respond to long term impacts and chronic vulnerabilities within a system.

1.1.2. Engineering

Engineering resilience describes the capacity of a system to withstand disturbances and return to a steady state. To engineers, systems have only one equilibrium state that they return to after a shock or disturbance. Engineering resilience thus emphasizes a system's resistance to disturbances, the speed of return to a resilient state, and its overall ability to bounce back [4,11]. This contrasts with the concept of ecological resilience which recognizes systems as having multiple states of equilibrium. Generally, engineering resilience is appropriate when a stable state is desired; the bearing capacity of building foundations and the robustness of a building's structure are examples.

While engineering resilience has limitations in capturing the dynamics of a system under stress, because the desired state is defined, the operationalization of resilience may be easier to attain [14]. In the built environment, the idea of recovery and bouncing back, or engineering resilience, underpins many resilience efforts and is well-represented in government documents [2]. For example, the Department of Homeland Security defined resilience as, "the ability to adapt to changing conditions and withstand and rapidly recover from disruption due to emergencies" [15].

However, recovery to the norm and speed of return alone are not sufficient measures of resilience [16]. Generally, single-equilibrium viewpoints do not adequately account for multiple pathways that retain essential structures within a system [16]. These other resilience strategies may be better explored under a disaster risk reduction or social science-based approach.

1.1.3. Disaster Risk Reduction

While engineering and ecological resilience are dominant domains of resilience [11,13], resilience has been growing in other fields, notably disaster risk management/reduction and the social sciences. A disaster-risk reduction approach, like engineering, generally adopts a single-state equilibrium viewpoint of resilience [10]. Resilience in the disaster risk reduction domain attempts to quantify the probability of a hazardous event and understand internal and external vulnerabilities of cities/communities/buildings, and measures

resilience in terms of economic, physical, and social recovery from a disturbance back to a single state [10,17].

The importance of resilience in disaster risk management/reduction was highlighted by the adoption in 2005 of the Hyogo Declaration: Building the Resilience of Nations and Communities to Disasters, by the United Nations International Strategy for Disaster Risk Reduction (UNISDR). The 10-year Hyogo framework for action provided guidance to various sectors and stakeholders on developing legislative and institutional frameworks to reduce disaster risk. The actions comprised the assessment and monitoring of risks, building a culture of safety and resilience, reducing risk factors, and improving disaster preparedness. In 2015, the strategy was superseded by the 2015–2030 Sendai Framework for Disaster Risk Reduction (DRR).

The Sendai Framework action priorities include understanding disaster risk, strengthening disaster risk governance, investing in DRR for resilience, enhancing disaster preparedness and building back better. The fourth priority in the Sendai Framework highlights a shift from recovery to the norm or status quo (bounce back), to recovery to an improved state by building better and improving response to future risk (bouncing forward).

1.1.4. Social Sciences

Resilience studies in ecological, engineering, and disaster risk reduction domains have yet to account for the underlying socioeconomic inequities that shape the resilience of vulnerable populations to harm and have mostly focused on the physical resilience of infrastructure [18]. As such, resilience in the social sciences domain emerged to explore the factors that shape how individuals and communities respond to climate change hazards and risks [19].

The emphasis on preserving a steady state frequently shapes how governments, cities, and professionals frame climate change resilience and respond to hazards. It also highlights the need to evaluate if the status quo is meeting the needs of vulnerable populations [20]. Can a community be considered resilient if it bounces back to a state that reinforces structural inequities across race, class, gender, and income levels? For example, research has shown that low-income communities are particularly vulnerable to heatwaves because of limited access to air-conditioning, utility poverty, and low housing quality [21,22]. In this scenario, recovery to a norm where low-income communities remain vulnerable does little to prepare them for future events.

In a study on the relationship between social and ecological resilience, social resilience was defined as, "the ability of groups and communities to cope with external stresses and disturbances as a result of social, political, and environmental change" [19]. Specifically, questions of resilience to what, of what, and for whom are explored. By recognizing differential vulnerabilities to climate change impacts due to existing inequities within communities, resilience efforts move away from only focusing on short-term recovery to "support the immune system of social systems" [14].

1.2. Resilience in Practice

As discussed above, the debate on resilience definitions has mainly emerged from four academic domains: ecology, engineering, disaster risk reduction, and the social sciences. Most efforts currently adopted are driven by one or two resilience academic domains, mainly engineering and disaster risk reduction. However, as Lorenz states, "given the nature of cross-scale problems that do not adhere to system boundaries or can even arise from interacting systems, disciplinary approaches reach their limits" [14].

More specifically, because how we define and understand resilience impacts how we operationalize, apply, measure, and evaluate the resilience of systems, efforts from these four academic domains have resulted in divergent resiliency measurements and applications. As such, understanding the multiple theoretical frameworks (academic domains) of resilience in the development of strategies and guidance tools is critical.

Despite this challenge, there are limited efforts to examine how resilience has translated into practice. Do professionals employ a bouncing-back approach to resilience, as in the engineering and disaster risk domains, or do they adopt other approaches, as in the ecology and social sciences domain?

In their study comparing conceptualizations of urban climate resilience in theory and practices, Meerow and Stults found that amongst practitioners working for local United States governments, resilience was mostly defined through an engineering perspective [23]. They also found that practitioners indicated robustness as an important characteristic of resilience [23]. Similar approaches to resilience were also found in interviews with construction stakeholders and local authorities in the UK [24].

Because of its abstract nature and the challenges in operationalizing the concept, planning for resilience is a significant challenge for decision-makers. In the building sector, researchers have suggested the need for resilience metrics and guidance to inform building stakeholders including building owners, managers, residents, architects, engineers, community organizations, and policymakers.

In his 2008 book, Bosher states that a resilient built environment, "should be designed, located, built, operated and maintained in a way that maximizes the ability of built assets, associated support systems (physical and institutional) and the people that reside or work

within the built assets, to withstand, recover from, and mitigate for, the impacts of extreme natural hazards and human induced threats" [25]. Indeed, the use of resilience as a concept for buildings has been rapidly growing. Much work has been directed towards examining the climate resilience of cities and communities, or urban resilience (see for example [26,27,28,29,30]). However, understanding how resilience is conceptualized within the building sector and how it is translated into practice by building professionals remains unclear and therefore is the focus of this paper.

1.3. Objective of Paper

Approaches to climate change resiliency are varied and grounded in multiple academic domains. For example, in their examination of community resilience definitions, the Community and Regional Resilience Institute listed 46 definitions of resilience [31]. Meerow et al. found 25 definitions for urban resilience [32], while Manyena found 12 definitions of resilience [33]. The variability in definitions is a reflection of current literature on resilience that argues its malleable nature as a concept challenges the development of coherent, consistent, and holistic definitions [4].

However, to date, there have been few efforts to examine how the building sector approaches climate change resiliency. To address this gap, this paper examines eighteen climate change resilience documents providing guidance to the building sector. The primary objective is to better understand the current approaches and limitations to climate change resiliency efforts in the building sector.

Accordingly, we compare conceptualization of resilience in the building sector through a content analysis of recent resilience documents for the building sector in the United States. Specifically, the paper addresses the following research questions:

(1) How do existing resilience guidance documents in the building sector address and incorporate different academic domains of resilience?
(2) Does the building sector employ a bouncing-back or bouncing-forward approach to climate change resilience?

Based on the literature review, we hypothesized that the majority of resilience efforts in the building sector are shaped by the engineering and disaster risk reduction academic domains, thus employing a bouncing-back approach to climate change resilience.

2. MATERIALS & METHODS

To examine how the building sector conceptualizes resilience we analyzed climate change resilience documents developed for building professionals in the United States. To identify relevant documents, we screened resilience initiatives, programs and frameworks that directly addressed the resilience of buildings. These included general guidance documents, resilience standards, and building design and construction strategies that could be utilized by stakeholders within the building sector such as architects, building managers and operators, homeowners, building users, and neighborhoods and community organizations. A total of eighteen resilience documents for buildings were identified. Table 1 provides a brief description of each tool.

Table 1. Description of climate change resilience documents for building professionals.

Document	Description
LEED [Resilient Design Pilot Credits]	Developed by the U.S. Green Building Council (USGBC), the Leadership in Energy and Environmental Design, or LEED, rating system is one of the most popular green building rating systems in the world. In 2015, the LEED pilot credits on resilient design were adopted. Three pilot credits were incorporated in the LEED rating system and fall into the Integrative Process category of LEED. The three pilot credits are: (1) assessment and planning for resilience (climate change assessment or emergency planning); (2) design for enhanced resilience (design for top three hazards); and (3) design for passive survivability (choose two of thermal resilience, back-up power, and access to water).
PEER [Performance Excellence in Electricity Renewal]	Administered by Green Business Certification Inc. (GBCI) (Washington, DC, USA), the PEER standards evaluate the performance of power systems in seven categories: reliability and resilience; operations, management and safety; energy efficiency and environment; grid services; innovation and exemplary performance; regional priority; and education. There are four levels of certification including certified, silver, gold, and platinum certification. PEER standards aim at integrating buildings with the energy and power industry by improving the efficiency, reliability, and resiliency of power systems in campuses, critical infrastructural, transit, and utilities and cities. A total of 39 credits were examined.
RELi [Resilience Action List and Credit Catalog]	Developed by the RELi Resilience Collaborative (Perkins and Will, U.S. Green Building Council, AREA Research, C3 Living Design, The Capital Markets Partnership's National Safety and Resiliency Committee, AIA Minnesota, and the University of Minnesota School of Architecture), RELi is a resilient rating system providing certification for buildings, neighborhoods, homes, and infrastructure. The RELi action list is divided into four main categories including: panoramic approach; risk adaptation and mitigation for acute events; comprehensive adaptation and mitigation for a resilience present and future; and applied creativity and contextual factors for resiliency. A total of 62 requisites, policy-requisites, policy-credits, and credits were examined (including sub-credits, the credit catalog consists of over 190 credits).
ENVISION	Developed and administered by the Institute for Sustainable Infrastructure, the ENVISION rating system is a framework of sustainability criteria, or credits, for infrastructure projects. The objective of ENVISION is to improve the performance and resiliency of physical infrastructure. Credits are divided into five overarching categories: quality of life; leadership; resource allocation; natural world; and climate and risk. A total of 60 credits were examined.
B-READY	Developed by DNV-GL (Oslo, Norway), the B-READY building resilience assessment tool incorporates an assessment of local climatic hazards and a building's vulnerability and resilience to provide a resiliency index (based on a 0–100 scale). The assessment tool also provides recommendations for resilience measures based on best-practices in the industry. The resilience measures cover twelve building systems including envelope and structure; mechanical systems and controls; electrical and lighting; communication and security; interior, equipment, and furnishing; energy generation and storage; fire suppression; plumbing; site; conveying equipment; and operations, and community. A total of 130 resilience measures were examined.

Table 1. *Cont.*

Document	Description
BRLA [Building Resilience Los Angeles]	Developed by the USGBC Los Angeles chapter, the BRLA primer for facilities offers guidance for organizations and buildings to become more resilient. It provides a framework for developing an effective resilience building process at the building and campus level. The primer includes multiple regional, national, and international case studies and sample resilience strategies divided into six categories including shelter, water, energy, food, natural and outdoor spaces, and communication. A total of 94 sample strategies were examined.
ENTERPRISE [Strategies for Multifamily Building Resilience]	Developed by Enterprise Community Partners, Inc. (New York, NY, USA), the Strategies for Multifamily Buildings Resilience provides guidance for existing multifamily buildings through several retrofit and mitigation strategies. The manual includes guidance on identifying a building's exposure to hazards, assessing risks, and determining resilience strategies. The proposed strategies are grouped into four categories including protection, adaptation, backup, and community. A total of 19 resilience strategies were explored.
USGBC [Green Building and Climate Resilience]	This guidance report titled "Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions" was developed by the USGBC and the University of Michigan. The report highlights research on the projected impacts of climate change by region, and explores design, construction, and operation strategies that improve a building's resilience. The strategies include no-regrets and resilience strategies which are divided into six categories including envelope; siting and landscape; heating, cooling, lighting; water and waste; equipment; and process and operations. A total of 81 strategies were examined.
NIST [Community Resilience Planning Guide]	Developed by the National Institute of Standards and Technology, the Community Resilience Planning Guide for Buildings and Infrastructure Systems consists of two volumes. The first volume illustrates a six-step process for planning for resilience, while the second volume provides tools to characterize the social and built community and identify dependencies, and highlights examples of community resilience metrics. Unlike other documents, this guide addresses climate change resilience at the community level and identifies strategies for different sectors, including buildings, transportation, energy, communication, and water and wastewater. Strategies that explore the resilience of buildings were examined. This included references to existing best practices for wind and flood resistant design and construction and solutions for future and existing construction. While the NIST guide incorporates a vulnerability assessment to identify potential climate change impacts, the building strategies included only address flooding, wind, and rain hazards. 16 strategies were examined.
NYSERDA [Climate Change Impacts on New York's Building Sector]	Developed by the University at Buffalo for the New York State Energy Research and Development Authority, this document provides guidance to owners and operators, policymakers and planners, and architects and engineers on how to prepare buildings for the expected impacts of climate change in New York State. The document features 25 strategies that were examined.
BOSTON [Enhancing Resilience in Boston]	Developed by A Better City (ABC), this guide for large buildings and institutions examined the resilience of commercial buildings. The report illustrates climate-related risks and identifies resilience actions, or strategies, for buildings inside and outside of projected floodplains in Boston. The strategies are group into three main categories including permeable pavement, dry floodproofing, and permanent flood barriers. A total of 32 strategies were examined.

Table 1. *Cont.*

Document	Description
New York City [Preliminary Climate Resiliency Design Guidelines]	Develop by the New York City (NYC) Mayor's Office of Recovery and Resiliency, the goal of the guidelines is to incorporate forward-looking climate data in the design of infrastructure and buildings. The guidelines are grouped to address three main hazards including increasing heat, increasing precipitation, and sea level rise. A total of 16 guidelines were examined.
FORTIFIED COMMERCIAL [Hail and High Wind]	The Insurance Institute for Business and Home Safety's (IBHS) FORTIFIED programs provide recommendations for reducing damage caused by specific natural hazards for existing and new buildings (programs are designated for either commercial buildings or homes). The program offers three levels of FORTIFIED designations, bronze, silver, and gold based on the intended resilience goals. A total of 13 guidelines for reducing hail and high wind damage to commercial buildings were examined.
FORTIFIED COMMERCIAL [Hurricane]	(see FORTIFIED COMMERCIAL for Hail and High Wind above). A total of 14 guidelines for reducing hurricane damage to commercial buildings were examined.
FORTIFIED HOME [Hail and High Wind]	(see FORTIFIED COMMERCIAL for Hail and High Wind above). A total of 16 guidelines for reducing hail and high wind damage to homes were examined.
FORTIFIED HOME [High Wind]	(see FORTIFIED COMMERCIAL for Hail and High Wind above). A total of 16 guidelines for reducing high wind damage to homes were examined.
FORTIFIED HOME [Hurricanes]	(see FORTIFIED COMMERCIAL for Hail and High Wind above). A total of 22 guidelines for reducing hurricane damage to homes were examined.
REDi [Resilience-based Earthquake Design Initiative]	A three-level resilience rating system with silver, gold, and platinum ratings. The rating system, developed by Arup (London, UK), is based on four overarching guidelines and criteria: organizational resilience, building resilience, ambient resilience, and loss assessment. A total of 65 resilience criteria were examined.

Ten of the resilience documents were developed for specific building typologies, mainly residential (three single family and two multifamily housing) and commercial (four). PEER and ENVISION tools addressed resiliency of infrastructures, campuses, and capital projects, while the remaining tools were not specific to any building typology.

For the LEED and RELi tools, resilience strategies that respond to the specific requirements of a building typology were considered a part of the overall resilience process. Generally, all tools recommend that stakeholders examine the needs and vulnerability of their buildings by incorporating typology considerations such as building functions, occupants, operations, and business continuity. Table 2 also illustrates who controls the implementation or operation of the resilience strategies.

Data Analysis

A content analysis was performed on the eighteen building resilience documents and the strategies proposed. The analysis consisted of coding the text and strategies based on the research objectives including climate change hazards addressed (resilience to what?) and the resilience academic domain adopted within each tool (ecology, engineering, disaster risk reduction, and social sciences). Examining the

Table 2. Characteristics of climate change resilience tools for buildings.

RESILIENCE TOOLS	Type		Building Typology								Control of Strategy			
	Rating/Standard	Guidance doc.	Residential [1]		Commercial	Campuses	Infrastructure	General	New Buildings	Existing Structures	Owner	Occupant	O&M	Passive
			S	M										
LEED [Resiliency Design Pilot Credits]	●	○	○	○	○	○	○	●	●	○	●	●	●	●
PEER [Performance Excellence in Electricity Renewal]	●	○	○	○	○	●	●	○	○	●	●	●	●	●
RELi [Resilience Action List + Credit Catalog]	●	○	○	○	○	○	○	●	●	○	●	●	●	●
ENVISION	●	○	○	○	○	○	●	○	●	○	○	●	●	●
B-READY	●	○	○	●	●	○	○	○	○	●	○	●	●	●
BRLA [Building Resilience Los Angeles]	○	●	○	○	○	○	○	●	○	●	●	●	●	●
ENTERPRISE [Strategies for Multifamily Building Resilience]	○	●	○	●	○	○	○	○	○	●	○	●	●	●
USGBC [Green Building & Climate Resilience]	○	●	○	○	○	○	○	●	●	●	●	●	●	●
NIST [Community Resilience Planning Guide]	○	●	○	○	○	○	○	●	●	●	○	○	○	●
NYSERDA [Climate Change Impacts on NY's Building Sector]	○	●	○	○	○	○	○	●	●	●	●	●	●	●
BOSTON [Enhancing Resilience in Boston]	○	●	○	○	●	○	○	○	●	●	○	●	●	●
NYC [Climate Resiliency Design Guidelines]	○	●	○	○	○	○	○	●	●	●	○	○	●	●
FORTIFIED COMMERCIAL [Hail & High Wind]	●	○	○	○	●	○	○	○	●	●	○	○	●	●
FORTIFIED COMMERCIAL [Hurricane]	●	○	○	○	●	○	○	○	●	●	○	○	●	●
FORTIFIED HOME [Hail & High Wind]	●	○	●	○	○	○	○	○	●	●	○	○	●	●
FORTIFIED HOME [High Wind]	●	○	●	○	○	○	○	○	●	●	○	○	●	●
FORTIFIED HOME [Hurricanes]	●	○	●	○	○	○	○	○	●	●	○	○	●	●
REDi [Resilience-based Earthquake Design Initiative]	●	○	○	○	○	○	○	●	●	○	○	○	●	●

[1] Residential building typologies were categorized into single family (S) and multifamily homes (M).

variety of climate change hazards addressed provides a better understanding of the scope of hazards that are prioritized by the building sector. This theme builds on research that argues hazards which have resulted in visible physical and fiscal damage are prioritized in climate change responses [34].

The resilience academic domains adopted are examined to gain a better understanding of how resilience is shaped within the building sector. This was conducted by coding all building strategies proposed based on the intended outcome of that strategy. For example, resilience strategies that addressed social cohesion and community empowerment were coded as social sciences resilience and as bouncing-forward resilience, while strategies for bracing reinforcements and roof strengthening were coded as engineering resilience and bouncing-back resilience. The tools were thus categorized according to the four academic domains identified in the literature section, engineering, ecology, disaster risk reduction, and social sciences.

3. RESULTS

3.1. Resilience to What?

A total of 724 resilience strategies were identified from eighteen building climate change resilience tools. To examine the climate change hazards addressed, strategies were grouped into 12 hazard categories based on the coding results (Table 3). The documents ranged from being hazard specific (developed to address one or two types of hazards) to having an all-hazard approach in which a vulnerability assessment was part of the resilience building process. Only three documents were developed to address a specific context including BOSTON (Boston), NYSERDA (New York State), and BRLA (Los Angeles). This means that the resilience strategies proposed within those documents were developed to address the climate change hazards specific to a region.

Five resilience documents (LEED, PEER, RELi, ENVISION, and B-READY) address climate change hazards as part of a vulnerability assessment, or all-hazards approach. The documents provide guidelines on the process of conducting a vulnerability assessment to inform the development of appropriate resilience strategies. Resilience strategies in these tools were considered as pathways that support a building's resilience regardless of the projected hazards or expected risks. For example, strategies such as maintaining backup

power to critical systems, building community ties, providing areas of refuge, developing emergency management plans, planning for long-term monitoring and maintenance, and system redundancy are not hazard-specific and can be applied to improve the overall resilience of a building.

Table 3. Hazards addressed in climate change resilience documents for buildings.

	Resilience To	Water Quali	Air Qualit	Seismic Acti	Drought	Wildfires	Pest Infestat	Rising Sea Le	Flooding	Hurricane	Sever Storn	Winter Storn	Heatwave
All-Hazards	LEED	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
	PEER	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
	RELi	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
	ENVISION	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
	B-READY	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙
Multiple Hazards	BRLA	◎	◎	●	●	●	○	◎	●	●	●	●	●
	ENTERPRISE	○	○	○	○	◎	◎	◎	●	◎	●	●	●
	USGBC	○	◎	○	●	●	◎	◎	●	●	●	●	●
	NIST	○	○	●	○	○	○	◎	●	◎	●	●	○
	NYSERDA	●	●	○	◎	◎	●	●	●	●	●	●	●
Hazard Specific	BOSTON	○	○	○	○	○	○	●	●	○	○	●	●
	NYC	○	○	○	○	○	○	●	●	○	○	○	●
	FORTIFIED COMMERCIAL (High Wind & Hail)	○	○	○	○	○	○	○	○	○	●	●	○
	FORTIFIED COMMERCIAL (Hurricanes)	○	○	○	○	○	○	○	○	●	○	○	○
	FORTIFIED HOME (High Wind)	○	○	○	○	○	○	○	○	○	●	●	○
	FORTIFIED HOME (High Wind & Hail)	○	○	○	○	○	○	○	○	○	●	○	○
	FORTIFIED HOME (Hurricanes)	○	○	○	○	○	○	○	○	●	○	○	○
	REDi	○	○	●	○	○	○	○	○	○	○	○	○

Key: ●: Document directly addresses hazard. ⊙: Document addresses hazard as part of an all-hazard approach/ vulnerability assessment. ◎: Document indirectly addresses hazard. ○: Document does not address hazard.

Eight tools (BOSTON, NYC, FORTIFIED COMMERCIAL, FORTIFIED HOME, and REDi) were identified as hazard specific. Building strategies were developed to improve a building's resilience to a defined hazard including seismic activity, rising sea levels, flooding, hurricanes, severe storms, winter storms, and heatwaves. The remaining documents were general resilience guidance documents that incorporated strategies to address a range of climate change hazards either directly or indirectly.

Table 3 above illustrates that flooding, heatwaves, severe storms, and hurricanes encompassed the focus of most climate change resilience tool in the building sector. Other hazards such as air and water quality, drought, wildfires, and pest infestation were not as extensively covered. This pattern is consistent with literature in which current climate change efforts are concentrated on visible hazards or hazards that have resulted in extensive physical and economical damage [34].

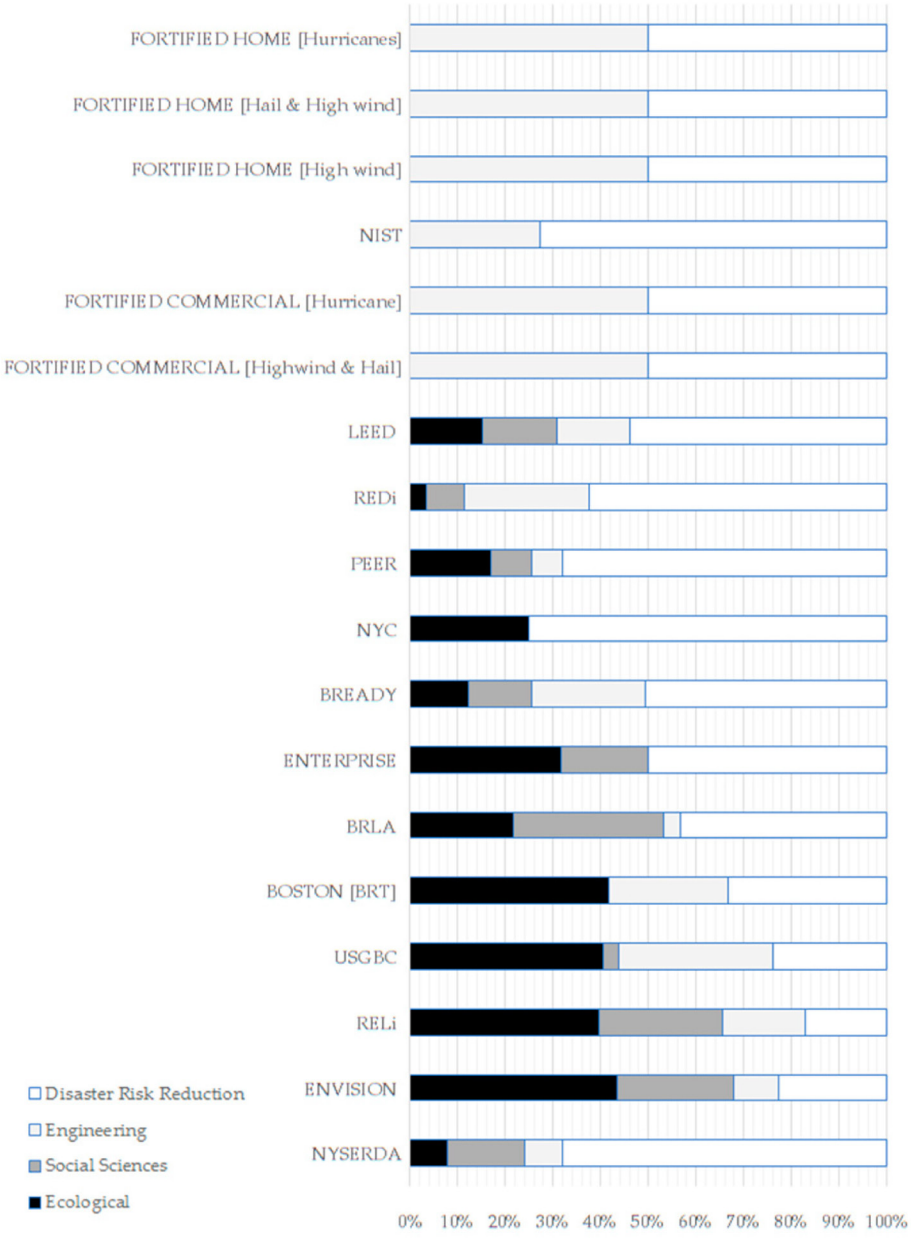
3.2. Resilience Approach

To examine the resilience academic domains adopted within each tool, a total of 724 resilience strategies for the building sector were coded based on the intended outcome of that strategy as explained in the previous section. All documents were also coded based on the overall approach to climate change resilience they described. It is important to note that some resilience strategies may fall under more than one resilience academic domain. For example, elevating a building on piles can be considered as an engineering and disaster risk reduction approach to resilience. Similarly, extreme heat awareness can be categorized as a disaster risk reduction and social sciences approach.

Based on the coding results, Figure 1 illustrates the variability of resilience approaches. The figure highlights the representation of the four academic domains of climate change resilience. While some of the documents may have addressed the importance of a conducting

vulnerability assessment to identify the appropriate resilience pathways for buildings, most strategies introduced represented narrow conceptualizations of climate change resilience. Specifically, engineering resilience and disaster risk resilience were represented in all documents. Accordingly, the majority of strategies reinforced bouncing-back and robustness after a disturbance or shock. This finding aligns with current resilience literature that states the predominance of engineering resilience in current climate change policy, programs, and initiatives [2,23].

Figure 1. Framing of resilience across the eighteen resilience documents.



Ecological resilience was adopted in eleven resilience documents but not as extensively as engineering and disaster risk resilience. Ecological resilience strategies addressed adaptation to change and uncertainty and the need for transformation in current practices mainly through passive design approaches.

The social sciences resilience was the least represented resilience approach. Resilience strategies within this approach support social cohesion, community ties, information flow, and the empowerment of individuals and communities. Strategies included extreme heat

awareness, fostering collaboration and teamwork, and providing bilingual communication.

4. DISCUSSION

While this analysis does not explore how professionals themselves define resilience, the findings provide crucial insights on the applications and definitions of climate change resilience being used by guidance documents for the building sector. Based on the findings above, resilience practice in the building sector is driven by engineering-related resilience. Consequently, the focus on the ability of buildings to bounce-back after a disaster to an equilibrium state has reduced resilience building efforts to the development of emergency responses, or disaster risk reduction.

In addition, the building sector emphasizes strategies that reduce the time scale of recovery after a disaster or shock. Specifically, resilience strategies on the ground and at the local level represent strategies that reinforce building stability and emergency responses. Current resilience tools reflect a focus on the physical resilience of buildings with minimal attention to underlying inequities facing building users and community residents. This finding aligns with current literature on the predominance of engineering resilience in practice [2,23], and the need to explore the factors that shape how individuals and communities respond to climate change hazards and risks [19].

In addition to its narrow implementation, resilience is often employed to address specified hazards, leaving the responsibility to address other hazards to other disciplines. However, increasing the resilience of one component of a system to one specific shock may leave it vulnerable to other types of disturbances. As such, resilience efforts must recognize the importance of addressing the interrelation of all system components and they system's response to varying climate change impacts.

Generally, the buildings' resilience tools draw on no clear empirical evidence to efficiently validate the development of climate change resilience strategies. While some employ case studies, community knowledge through participatory techniques, and/or stakeholder consultation, discussions on the theoretical background of resilience in the built environment were not evident.

In response to current limitations, we find that new alliances and fields have emerged that provide more holistic framing of resilience. The Resilience Alliance was established to provide an interdisciplinary "Resilience Thinking" framework for understanding transformation in socio-ecological systems. The Resilience Engineering Association has introduced a subspecialty of engineering, resilience engineering, as a new way of thinking about safety. Additionally, the American Society of Adaptation Professionals was recently established to support and connect climate adaptation professionals working to improve the climate change adaptation and resilience of cities and communities across the country. These new fields reflect an increasing awareness of the challenges professionals faces in conceptualizing and implementing climate change resilience in the built environment.

Diversity is a key theme in resilience; diversity of impacts, of system components, of measurement, and as explored in this paper, of definitions and applications. As a multifaceted concept, current discourse on climate change resilience in the building sector requires more critical and constructive action. Having insights on the different conceptualizations of resilience and the associated building strategies helps stakeholders select appropriate approaches and make informed decisions. Specifically, stakeholders can identify the limitations and opportunities provided within different conceptualizations of resilience and develop context- and system-sensitive climate change resilience strategies for their own buildings.

5. CONCLUSIONS

The goal of this paper was to examine how resilience is translated into practice within the building sector by examining existing climate change resilience tools for buildings. The findings highlight the need for new approaches that addresses the variability of resilience definitions. While each academic domain brings unique contributions to the practice of resilience in the building sector, it is important to acknowledge that each body of literature alone cannot comprehensively address all aspects of resilience. As a complex challenge for the building sector, addressing climate change and resilience will require integrative and transdisciplinary efforts.

This may be achieved by providing platforms for authentic dialogue and stakeholder engagement to build a deep understanding of impacts, hazards and risks across sectors, and facilitating cross-disciplinary collaboration and co-development of new resilience guidance, strategies, and standards. Further research on the barriers to collaboration among domains and professionals, and how resilience is approached on individual projects is a critical next step.

Finally, this research also shows that adopting climate change resilience strategies is not as simple as selecting an existing resilience guidance document produced by others. At this early stage of climate resilience practice, building professionals must acknowledge the limitations of existing literature, guidance, codes, and standards to avoid maladaptation and undermining of long-term climate-related resilience.

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Comparing Conceptualizations of Urban Climate Resilience in Theory and Practice

by Sara Meerow & Melissa Stults

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ABSTRACT

Abstract: In the face of climate change, scholars and policymakers are increasingly concerned with fostering "urban resilience". This paper seeks to contribute towards a better understanding of synergies and differences in how academics and local decision-makers think about resilience in the context of climate change. We compare definitions and characteristics of urban climate resilience in the academic literature with a survey of 134 local government representatives from across the U.S. Our analysis shows discrepancies in how academics and practitioners define and characterize urban climate resilience, most notably in their focus on either "bouncing back" or "bouncing forward" after a disturbance. Practitioners have diverse understandings of the concept, but tend to favor potentially problematic "bouncing back" or engineering-based definitions of resilience. While local government respondents confirm the importance of all 16 resilience characteristics we identified in the academic literature, coding practitioners' free response definitions reveals that they rarely mention qualities commonly associated with resilience in the scholarly literature such as diversity, flexibility, and redundancy. These inconsistencies need to be resolved to ensure both the usability of climate resilience research and the effectiveness of resilience policy.

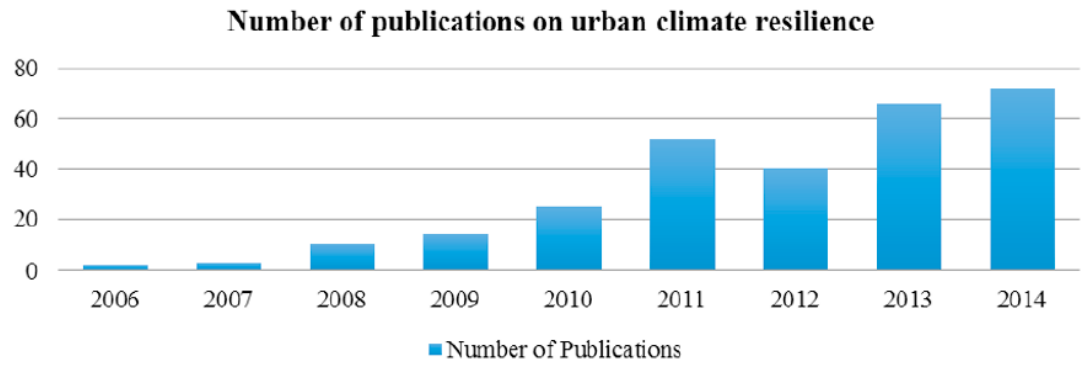
Keywords: climate change; resilience; urban resilience; resilient city; climate resilience; adaptation

1. INTRODUCTION

There is a critical relationship between cities and climate change. On the one hand, urban areas are major contributors to climate change, being responsible for the majority of global energy consumption and greenhouse gas emissions. On the other hand, densely populated urban areas are particularly vulnerable to climate change impacts including sea-level rise, storm surge, heat waves, droughts, and shifting diseases, with vulnerable populations in cities likely to be disproportionately impacted [1,2]. Moreover, due to the heat island effect, urban areas are already experiencing amplified warming effects [3], which will probably continue as the climate warms [4]. In short, climate change is likely to exacerbate existing urban problems and vulnerabilities, placing additional pressure on already strained municipal capacities [5,6].

Confronted with these challenges, cities cannot simply sustain the status quo [7]. This realization has led academics and policymakers to look for new ways to frame development and operations in a manner that helps cities build the capacities needed to effectively and efficiently prepare for climate change impacts [8]. Increasingly, these conversations are turning to the concept of resilience [9]. This 'resilience turn' in urban policy is evident in both the academic literature (Figure 1) and in major policy initiatives like the Rockefeller Foundation's "100 Resilient Cities".

Figure 1. The rise of resilience in climate change research: graph shows the number of citations in Web of Science for each year with the terms "urban resilience" and "climate change" in the title, keywords, or abstract.



The concept of resilience is not new. It has a long history of use in engineering, psychology, and ecology [10]. The urban climate change literature draws heavily on ecological resilience theory originally developed by Holling [11]. In his conceptualization, resilience refers to an ecosystem's ability to "persist" in the face of a disturbance or change, but this persistence does not necessarily mean that the system remains static [11]. Holling and colleagues used this dynamic ecological resilience concept as the foundation for broader theories of change for social-ecological systems [12].

The explosion in popularity of the term "resilience" has been accompanied by an equally remarkable proliferation of definitions of resilience. Some argue that the concept's very popularity is owed at least in part to the fact that the meaning of resilience is "infinitely malleable" [13]. Yet scholars have expressed concern that as resilience becomes ubiquitous, the term may lose any real meaning or cause confusion [14]. In this regard, resilience may be comparable to other increasingly ambiguous yet fashionable concepts like sustainability [15]. Undoubtedly, one of the strengths of resilience theory is its applicability across disciplines and ability to serve as a boundary object [16]. This malleability can be a barrier to interdisciplinary collaboration, however, if every discipline has its own idea of what resilience means [17]. The absence of an accepted definition has not stopped researchers from proposing various process- and outcome-focused system characteristics that supposedly enhance climate resilience [9]. However, the lack of a unified understanding of resilience has made it difficult to operationalize the concept or to develop metrics for resilient systems [9,15].

Prior studies have reviewed the academic literature on urban resilience [7,9,18], but it is unclear how scholarly definitions and characteristics compare with those of practitioners. In this paper we attempt to address this gap and advance our knowledge of how climate resilience is understood in both theory and practice. We compare definitions and characteristics of urban climate resilience from a recent review of the academic literature and a survey of local government practitioners from across the U.S. Our analysis reveals some important inconsistencies in how the scholarly literature defines and characterizes urban climate resilience as opposed to how practitioners view the topic, particularly as it relates to recovering and "bouncing back" versus transformation and "bouncing forward". In addition, practitioner survey responses show a much wider range of interpretations of what resilience means in practice than what is commonly discussed in the scholarly literature. Collectively, the practitioners seem to favor "bouncing back" or engineering definitions of resilience, which we argue could be problematic. Survey results also suggest that practitioners see all sixteen characteristics of resilient systems that we identified in the literature as important, but we find considerable variation in the extent to which practitioners include these characteristics in their own definitions of urban resilience. Ultimately, understanding these synergies and differences in how academics and practitioners are thinking about climate resilience can lay the foundation for more usable resilience research, which is crucial given the scope of the urban climate change challenge.

2. MATERIALS AND METHODS

To examine how practitioners and academics conceptualize resilience, we combined an extensive literature review with the results of a 2014 survey of U.S. local government officials. For the literature review, we drew from a broader review of the urban resilience literature [18], which looked at 172 articles from 1973 to 2013 with the terms "urban resilience" and "resilient cities" in the title, abstract, or keywords in order to identify how resilience was conceptualized across the literature. We reviewed these articles, as well as the studies they frequently cited, to identify a list of potential characteristics of resilient urban systems. We then developed a survey instrument to gauge how urban climate change resilience is defined and characterized by practitioners and how this compares to definitions and characteristics in the literature. It should be acknowledged that since urban resilience research and practice is rapidly evolving, new definitions have likely emerged since the research was completed.

The survey of local practitioners was conducted as part of a larger project funded by The Kresge Foundation to assess the range of climate adaptation resources and services available to support local climate adaptation (for more information see Nordgren et al. [19]). The online survey was developed and administered by the researchers in collaboration with three nonprofit organizations: ICLEI-Local Governments for Sustainability USA (ICLEI), the Urban Sustainability Directors Network (USDN) and the National League of Cities (NLC). The survey instrument, which was built using Qualtrics software, was reviewed by members of the Kresge Foundation, the project's expert advisory committee, and survey experts at the University of Michigan's Institute for Social Research. The survey was also piloted with students at the University of Michigan and local government staff members from three communities around the U.S. The final survey was distributed by ICLEI, NLC, and USDN through their membership lists, and ran from 27 March 2014 to 6 May 2014.

We are unable to calculate exactly how many individuals received the survey, since membership in the three organizations administering the survey overlap. However, we estimate that around 1200 distinct individuals working for local governments received the survey. A total of 446 began taking the survey and 291 completed more than three-quarters of the questions. A total of 134 completed the final two questions on resilience that are pertinent to this analysis. Importantly, the survey sample is not representative of the population of cities in the U.S., since communities elect to be members of each of these three organizations. Nevertheless, the survey as a whole did succeed in capturing a wide range of communities: respondents represented 41 states and were well distributed in terms of local jurisdiction size and geographic features. Respondents' roles in their communities also varied with the largest group (30 percent) working in the energy or environment field (i.e., energy, environmental services, parks, or sustainability staff), followed by 24 percent that serve as elected officials, and 12 percent that work in local government administration.

The survey included a total of 24 questions, but for the purposes of this study, we were primarily interested in the two questions that focus on conceptualizations of resilience. The first of these was a free response question asking respondents, "What do you think it would mean for your local jurisdiction to be resilient to climate change?" A total of 134 respondents provided a response to this question. The second question asked, "In your opinion, how important are each of the following characteristics in making your local jurisdiction more resilient" and then asked respondents to rate the importance of 16 different characteristics on a five-point scale (1—unimportant, 2—slightly important, 3—important, 4—very important, 5—critical). A total of 199 respondents filled out this question. The characteristics were drawn from and defined based on the literature review and chosen because of their common association with resilience. Respondents were also given the opportunity to fill in and rate a self-determined "other" characteristic.

We coded all responses to the question where respondents were asked to define resilience (question one), looking for the presence of the 16 resilience-based characteristics identified in the literature. We also coded the definitions for whether they focused on "bouncing back" or "bouncing forward", explained in Section 3.1. All responses were coded independently by two researchers (inter-coder agreement was 94.27%; the inter-coder reliability percentage includes all instances where both researchers agreed that a characteristic was either present or absent in the definition), after which the discrepancies were discussed and reconciled.

3. RESULTS: DEFINITIONS OF A CLIMATE RESILIENT CITY

Definitions of urban climate resilience in the scholarly literature differ, but they do have some commonalities. All definitions identified in our analysis (Table 1) are broad, defining resilience in terms of a generic capacity to deal with climate impacts and disturbances. One key distinguishing factor is the extent to which the definitions incorporate change, as opposed to resistance or recovery. This tension is also evident in the definitions provided by practitioners in the survey. Overall, we find much more variation in the practitioners' definitions of resilience than what exists in the scholarly literature.

Table 1. Definitions of urban climate resilience from the academic literature (Definitions taken from review conducted by Meerow et al. (2016) [18]).

Authors	Definition
Brown et al. (2012) [20]	"The capacity of an individual, community or institution to dynamically and effectively respond to shifting climate circumstances while continuing to function at an acceptable level. This definition includes the ability to resist or withstand impacts, as well as the ability to recover and re-organize in order to establish the necessary functionality to prevent catastrophic failure at a minimum and the ability to thrive at best. Resilience is thus a spectrum, ranging from avoidance of breakdown to a state where transformational change is possible." (p. 534)
Henstra (2012) [21]	"A climate-resilient city . . . has the capacity to withstand climate change stresses, to respond effectively to climate-related hazards, and to recover quickly from residual negative impacts" (p. 178).
Leichenko (2011) [9]	"The ability of a city or urban system to withstand a wide array of shocks and stresses" (p. 164)
Lu and Stead (2013) [22]	"the ability of a city to absorb disturbance while maintaining its functions and structures" (p. 200).
Thornbush et al. (2013) [23]	"a general quality of the city's social, economic, and natural systems to be sufficiently future-proof" (p. 2).
Tyler and Moench (2012) [6]	"In the case of urban climate adaptation, an approach based on resilience encourages practitioners to consider innovation and change to aid recovery from stresses and shocks that may or may not be predictable...three generalizable elements of urban resilience: systems, agents and institutions." (p. 312)
Wamsler et al. (2013) [8]	"A disaster resilient city can be understood as a city that has managed . . . to: (a) reduce or avoid current and future hazards; (b) reduce current and future susceptibility to hazards; (c) establish functioning mechanisms and structures for disaster response; and (d) establish functioning mechanisms and structures for disaster recovery" (p. 71).
Wardekker et al., (2010) [24]	"A resilience approach makes the system less prone to disturbances, enables quick and flexible responses, and is better capable of dealing with surprises than traditional predictive approaches . . . a 'bottom-up' way of thinking about adaptation that aims to promote a system's capability of coping with disturbances and surprises" (p. 988)

3.1. "Bouncing back" or "Bouncing forward"?

The academic literature makes a major distinction between "engineering resilience", which is about resisting change and returning to a prior state of equilibrium following a disturbance, and "ecological resilience", which focuses on maintaining key functions while accepting that it is not always possible or desirable to return to previous conditions [25,26]. This division is also framed as "bouncing back" versus "bouncing forward" [27]. Prominent resilience scholars, such as the leaders of the international Resilience Alliance, advocate for the latter conceptualization. They argue that the concept of resilience, particularly ecological resilience, is better suited for complex systems that are in a constant state of flux, and must therefore adapt to change and uncertainty. Cities are certainly complex and dynamic systems [28], and indeed, Meerow et al.'s [18] review found that the majority of urban resilience definitions are more closely aligned with ecological resilience. Despite this recognition, engineering resilience continues to persist in many fields, including disaster management, economics, and public policy [29].

That said, there still seems to be some disagreement within the urban climate resilience literature as to whether resilience is about resisting impacts and change or embracing them. Looking at the definitions identified in the literature (Table 1), Henstra's [21] seems more aligned with engineering resilience since it emphasizes the capacity to "withstand" and "recover". In contrast, Brown et al. [20] include reorganization and even "transformational change" as part of their definition of resilience, which is more consistent with 'bounce forward' or ecological resilience.

This divide is also evident in the different definitions of resilience provided by survey respondents, with engineering, equilibrium perspectives predominating. According to our coding, 35 definitions suggested that resilience was about bouncing back, 15 indicated that it could be about improving and bouncing forward, and seven indicated that both could be important. In the remaining definitions it was impossible to determine the respondent's position. Five respondents specifically mentioned "bouncing back", another emphasized a "return to normalcy", two equated resilience to stability, and several others highlighted minimal disruption or "community changes" as being key to a resilient urban system.

Of the 15 that provided definitions related to bouncing forward or improving, two explicitly mentioned the ability to "bounce forward" and several others saw resilience not just in terms of persisting under changing climate conditions, but actually adapting, improving and thriving. These definitions are more closely aligned with resilience as defined in the social-ecological systems literature.

3.2. Unpacking Practitioners' Definitions of Urban Resilience

One of the most striking results of the survey was the variation in the responses practitioners provided when asked what resilience would mean in their local jurisdiction (Table 2). While academics see resilience as omnipresent [30], several practitioners claimed not to know what it means, others noted that it was not acknowledged in their community, and one even dismissed it as "meaningless jargon". In contrast, other respondents called resilience "critical" and "absolutely imperative". Some definitions focused on very specific threats or sectors, like "heavy rain", "hurricanes", or "public transportation", whereas in other cases resilience was more generic, such as "improvement in quality of life." In fact, livability or quality of life was mentioned in almost 10 percent of responses. For more than 20 percent of respondents, resilience had an economic component, whether in terms of general economic prosperity or specifically in terms of reducing the cost of climate impacts. Other common themes (found in at least 5 percent of responses) were health, education and learning, sustainability, self-sufficiency, advanced planning, and the importance of assisting vulnerable populations.

4. RESULTS: CHARACTERISTICS OF A CLIMATE RESILIENT CITY

In our review of the academic literature we identified 16 characteristics of urban systems and processes that supposedly foster resilience (Table 3). Hypothesized characteristics of resilient processes include: inclusivity, transparency, and equity in stakeholder engagement approaches [9,31,32], as well as processes that are flexible, forward looking, and iterative [6,33,34,35]. Resilience processes are also valued for being knowledge or information driven, meaning that they integrate traditional, as well as scientific knowledge into their frameworks and approaches and provide equitable access to information for all parties interested [36,37,38]. Research in the climate, urban, and resilience fields has postulated that there may be general characteristics of resilience, as well as generic/general forms of adaptive capacity that promote resilient systems [39,40,41,42,43]. Examples of general resilience characteristics include: diversity, iterative/feedback mechanisms, transparency, collaboration and integration, social-ecological integration (also coined environmental focus), efficiency, and adaptive capacity enhancement [42,44,45]. There is also a series of characteristics that are believed to be important for assessing specific resilience to unique climate impacts. Examples include redundancy in the case of drought, robustness in the case of hurricanes and extreme winds, and decentralization in the case of flooding [46,47,48].

Table 2. Illustrative a definitions of urban climate resilience from local practitioner survey.

"To be able to bounce back—with seemingly little or no negative effect—from heavy rains and flooding. To have our city infrastructure built and ready to take on heavy rains and drastically fluctuating temperatures, with little or no impact."
"Achieving the goal of climate change resilience will mean the city can reduce the sensitivity of vulnerable communities to extreme weather events while increasing their capacity to bounce back from such an event. In the long term, this is made possible when city departments will work together to develop a City Climate Resiliency Plan with specific goals and actions. This will have to include the coordination and communication with regional partners."
"Have the ability to bounce forward from climate change impacts to create a more sustainable community."
"Our community could become one that reflects a quality of life that includes the well-being of human and other species. It means a commitment to collaboration, learning new skills and recognition that we are far better together."
"To not suffer economic damage every time a severe weather event hits our city. That we are able to lessen the costs of repairs and shrink the time needed to make those repairs. And to help our residents recover more quickly or suffer less impact from storms."
"It would mean that we are better prepared to respond to the extreme weather events and their consequences that will occur as a result of climate change in all areas of municipal infrastructure and operations, including but not limited to water/wastewater/stormwater, emergency management, public health, public works, urban forestry, parks and recreation, and facility management. It would also mean we are incorporating reasonably foreseeable weather scenarios into our planning and budgeting processes. It would also mean we are better prepared to help our citizens respond to the impacts of climate change, especially those least able to take action on their own, e.g., low-income households, the elderly, the young, those with respiratory and other health problems."
"Be more attractive to certain kinds of businesses. Hopefully prevent poor decisions on location of development for the future."
"We don't even know what you mean by resiliency—sounds like meaningless jargon to us. We have real issues to pursue like public safety and economic development—things that matter now to our residents. Even given unlikely worse case scenarios, our need to react is limited, and not cost effective at this time."

[a] These eight definitions were chosen from the 134 different responses provided by survey respondents to highlight their variation, and do not represent all conceptualizations.

When asked to rate the importance of these 16 characteristics (Table 3), survey respondents collectively indicated that they were all important. The mean score for all 16 was high (Figure 2), with very few respondents indicating that any of the characteristics were "1—unimportant" or only "2—slightly important" (Figure 3). Additionally, only five respondents listed an "other" characteristic, which could suggest that they were satisfied with the list. There is, however, some variation in the perceived importance of the characteristics. For example, robustness had the highest average rating, over 4 (very important), and the largest number of respondents who rated it 5 (critical). In contrast, decentralization had the lowest average ranking, although the mean score is still above 3 "important).

A careful review of survey respondents' collective rating of the 16 characteristics (Figure 2 and Figure 3) combined with those included in their free responses (Figure 4) points to key differences in what practitioners and the scholarly literature view as resilience. For example, some of the most commonly cited characteristics in the academic literature, such as diversity, redundancy, flexibility, decentralization, and adaptive capacity, were not among the highest rated by local government respondents. Conversely, practitioners emphasized the importance of robustness, yet there is debate in the literature about the universal desirability of this attribute. There were other characteristics commonly mentioned in the literature that practitioners simply did not focus on, including being predictable or safe-to-fail, iterative, having good systems for feedback, and transparency. Where scholars and local government respondents did seem to agree was on the importance of supporting environmental systems, equity, and integration.

4.1. Tensions between Resilience Characteristics in Theory and Practice

In the urban resilience literature, robustness is about a system's ability to resist change or disturbance: it is essentially about "strength" [22]. In the survey, the characteristic robustness was defined as "ensuring municipal-wide infrastructure and organizations can withstand external shocks and quickly return to the previous operational state". Robustness is very similar to the notion of engineering resilience. If robustness is seen as a desirable characteristic of a system, it implies a wish to maintain the status quo. This is not controversial when thinking about certain scales or engineered systems; no one wants a building to collapse in a hurricane. But there are many other more problematic, but nonetheless robust, aspects of modern cities (i.e., inequality or the reliance on fossil fuels). Many

Table 3. Sixteen Resilience Characteristics from the literature.

Characteristic	Definition	Illustrative [a] Sources
Robustness	Ensuring municipal-wide infrastructure and organizations can withstand external shocks and quickly return to the previous operational state	[49,50]
Redundancy	Having back-up systems, infrastructure, institutions, and agents	[20,49,51–54]
Diversity	Ensuring a diverse economy, infrastructure, and resource base (e.g., not relying on single mode of operation, solution, or agent/institution)	[6,22,49,51–53,55]
Integration	Making sure that plans and actions are integrated across multiple departments and external organizations	[6,56,57]
Inclusivity	Ensuring that all residents have access to municipal infrastructure and services, including providing an opportunity for all people to participate in decision-making processes	[6,57,58]
Equity	Ensuring that the benefits and impacts associated with actions are felt equitably throughout the municipality	[49,59]
Iterative Process	Creating a process whereby feedback and lessons learned are continually used to inform future actions	[6,20]
Decentralization	Decentralizing services, resources, and governance (e.g., solar or wind energy; stronger local governance)	[51,58,60]
Feedback	Building mechanisms so that information is rapidly fed back to decision-makers or system operators	[51,53]
Environmental	Protecting natural systems and assets	[20,49]
Transparency	Ensuring that all municipal processes and operations are open and transparent	[6,58]
Flexibility	Making municipal operations and plans flexible and open to change when needed	[51,58,59]
Forward- Thinking	Integrating information about future conditions (i.e., population, economy, weather) into community planning and decision-making	[6,24]
Adaptive Capacity	Ensuring that all residents have the capacity to adapt to climate change	[24,61]
Predictable	Ensuring that systems are designed to fail in predictable, safe ways	[6,51]
Efficiency	Enhancing the efficiency of government and external operations	[49,50]

[a] References are meant to be illustrative, and do not represent an exhaustive list of studies that mention these characteristics.

Figure 2. Mean resilience characteristic importance rating.

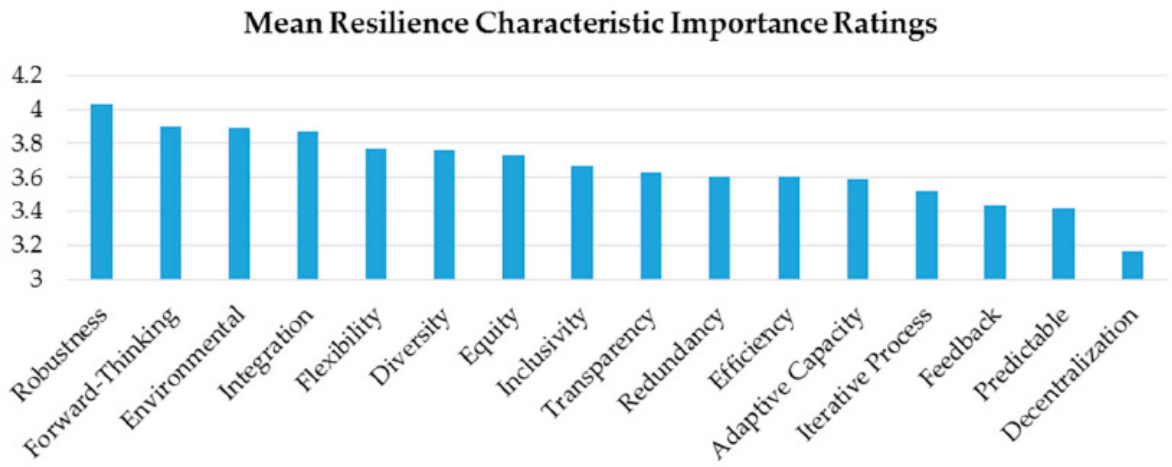


Figure 3. Distribution of resilience characteristic importance ratings.

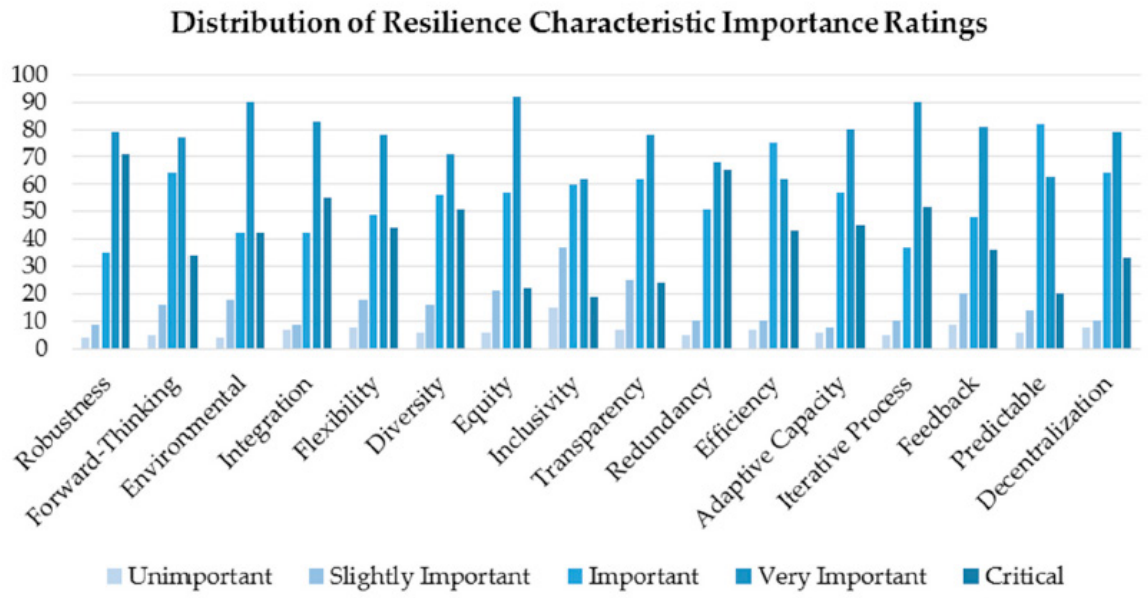
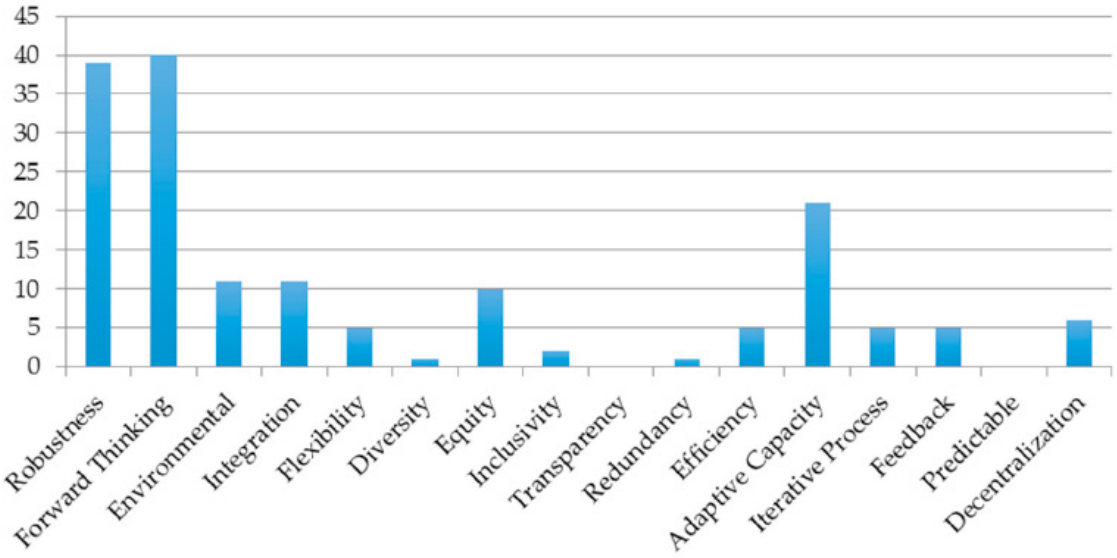


Figure 4. Number of practitioner definitions referencing resilience characteristics based on coding.



critics of resilience discourse and policy argue that resilience, particularly when applied to social systems, is inherently conservative and often employed to prevent positive transformations [62,63,64]. In response to these criticisms, some resilience scholars have incorporated transformation into their conceptualizations of resilience [65]. In academic theory, the trend seems to be away from static, engineering resilience with its emphasis on robust systems [6] towards these more flexible and adaptive forms of resilience. However, the high importance ascribed to robustness by survey respondents, as well as the numerous references in the definitions to "bouncing back", suggest that it persists as a dominant line of thinking in 'on-the-ground' urban resilience activities.

According to the local practitioners surveyed, the characteristic forward-thinking was second only to robustness in terms of average importance. For the purposes of the survey, forward-thinking was defined as "Integrating information about future conditions (i.e.,

population, economy, weather) into community planning and decision-making." In the definitions written by practitioners, almost one in ten specifically mentioned the future, and nearly 15 percent of responses suggested the need for advanced planning. For example, one respondent defined resilience as "No surprises for changing landscape. Advanced planning to make us better prepared". Another wrote "… as change occurs, it has been anticipated and planned for such that no or minimal disruption occurs."

While the academic literature also emphasizes preparing for future changes, some resilience scholars caution against too much emphasis on prediction or the use of single scenarios to understand future threats. Instead, focus is placed on techniques such as scenario planning [7] and the selection of actions that will perform well under a wide array of potential future conditions (known as robust actions in the scholarly literature) [66]. This assessment did not evaluate the types of tools or techniques that local practitioners are using as part of their advanced planning, but we would argue that it is important to provide practitioners with appropriate tools and the support needed to effectively utilize them.

Another area of discrepancy relates to the relative importance of adaptive capacity. In the urban climate resilience literature, building resilience is often equated with enhancing adaptive capacity [9]. However, survey respondents did not rate adaptive capacity among the most important characteristics. Furthermore, the term adaptive capacity was not explicitly used in any respondents' definitions; however, 21 respondents did allude to it.

In the academic literature, flexibility is one of the most commonly cited resilience characteristics [9]. Flexibility means that a system can function under different circumstances and absorb change [6]. In the survey, flexibility was defined as "making municipal operations and plans flexible and open to change when needed". Unfortunately, efficient adaptation and robustness against certain threats may come at the expense of the flexibility to deal with unexpected future changes [35]. If practitioners are primarily focused on robustness, as the survey results suggest, urban systems may not be sufficiently flexible to deal with unexpected climate impacts or other stressors. There were two respondents who explicitly called out flexibility: One noted that moving towards climate resilience would mean "increasing flexibility" and another stated that resilient jurisdictions should "exhibit nimble behavior". Overall, however, flexibility was not highlighted in the practitioners' definition of resilience. This seems logical given that local institutional structures and decision-making processes are rigid, making it difficult to create flexible, adaptive systems capable of integrating emerging information and changing as needed. Going forward, devising solutions to build more flexible systems will likely remain an important area of research.

Like flexibility, diversity is frequently cited in the literature as a key characteristic of resilience. This relates back to ecological theory, which suggests that biodiversity enhances the ability of an ecosystem to withstand change [51]. Looking specifically at the urban climate change context, Tyler and Moench [6] differentiate between "spatial diversity", meaning system components are widely distributed to reduce the likelihood that the whole system is impacted by a single disruption, and "functional diversity", where there are multiple avenues for meeting critical needs. Diversity can also be applied to governance systems, with the idea being that polycentric systems that engage a wide array of stakeholders are more resilient [9]. For the purposes of the survey, diversity was defined more broadly as "Ensuring a diverse economy, infrastructure, and resource base (e.g., not relying on single mode of operation, solution, or agent/institution)." Given the emphasis on diversity in the resilience literature, it was surprising that more respondents did not rate it as important, and only one explicitly mentioned diversity in their definition.

Related to the concept of spatial diversity, scholars have argued that decentralized systems are more resilient than centralized ones because when something disrupts a central unit, the entire system is jeopardized, whereas in a decentralized system it only impacts a small portion. In the literature, arguments are made for decentralization in both physical systems (like electricity generation) and governance [35,67]. Admittedly, some resilience scholars caution that decentralized governance may not be universally preferable [14,68,69]. Survey respondents clearly rated decentralization, defined in terms of "decentralizing services, resources, and governance, e.g., solar or wind energy; stronger local governance", as less critical for resilience than all the other 15 criteria. Similarly, none of their definitions mentioned decentralization.

For most resilience scholars, a certain level of functional redundancy is thought to enhance resilience; the argument being that when you have units with overlapping functions, if one falters, it can be easily substituted [24]. The definition provided for redundancy in the survey was "having back-up systems, infrastructure, institutions, and agents". Like diversity, redundancy is a characteristic that can be applied to both technical systems, like electricity infrastructure, and social networks. Only one respondent mentioned redundancy in their definition, and then only in the context of "water and power systems".

This mismatch between theory and practice with respect to redundancy could stem from the fact that redundancy has a somewhat negative connotation, and supporting it may seem to conflict with cost or even eco-efficiency [20,49]. In fact, scholars have cautioned that efficiency may be at odds with redundancy [70] and that "efficiency, as traditionally conceived, does not necessarily promote resilience" [71]. Yet efficiency still tends to have a positive connotation in popular discourse, and is sometimes cited in the literature as a characteristic of resilient urban systems [22].

Some urban resilience scholars such as Ahern [51] have argued that resilient systems should be "safe-to-fail" as opposed to "fail-safe". In the survey, this was represented by the characteristic predictable, defined as "ensuring that systems are designed to fail in predictable, safe ways". Looking specifically at urban climate resilience, Tyler and Moench [6] define "safe failure" as "the ability to

absorb sudden shocks (including those that exceed design thresholds) or the cumulative effects of slow-onset stress in ways that avoid catastrophic failure. Safe failure also refers to the interdependence of various systems, which support each other; failures in one structure or linkage being unlikely to result in cascading impacts across other systems." Practitioners did not seem to consider this characteristic to be important, and "predictability" or "safe-to-fail" was not mentioned in any of the resilience definitions. In fact, one respondent even commented "why would anyone design a system to fail", indicating the mismatch between what theoretically is conceived of as being important to resilient systems and what is achievable in practice.

According to the literature, efforts to build resilience should be conducted iteratively, providing opportunities for participants to take stock of what has been learned and apply that knowledge to the next step [6,20]. As defined in the survey, an iterative process is "one whereby feedback and lessons learned are continually used to inform future actions". This characteristic emphasizes the importance of learning, which "includes not only the mobilization and sharing of knowledge but also such factors as basic literacy and access to education. These kinds of factors have been identified empirically as contributing to community resilience to disasters" [6]. Iterative learning is also an important part of the popular adaptive management approach, which is closely tied to resilience theory [59]. While the iterative process characteristic was not rated as important, on average, as other characteristics, the terms "understanding", "education" or "learning" did appear in almost 10 percent of respondents' definitions. For example, one respondent wrote that resilience means "a commitment to … learning new skills", another "an educated community", and still others noted that residents need to be educated on climate change.

Implementing tight feedbacks—or as defined in the survey: "building mechanisms so that information is rapidly fed back to decision-makers or system operators"—can support the iterative process, learning, and ultimately, the resilience of urban systems [24,70]. As previously noted, a number of practitioners referred to education or learning in their conceptualizations of resilience, but none of them mentioned feedback directly. On average, respondents also rated this characteristic relatively low in importance.

Transparency and inclusivity are also both process- or governance-related characteristics. The meaning of transparency as described in the survey is "ensuring that all municipal processes and operations are open and transparent". Survey respondents were prompted to think of inclusivity as "Ensuring that all residents have access to municipal infrastructure and services, including providing an opportunity for all people to participate in decision-making processes". While transparency and inclusivity are not as commonly associated with resilience theory as other characteristics such as diversity and flexibility, both are mentioned in the literature as being important for continued engagement and good governance. For example, Tanner et al. [58] note that a "delivery of climate resilient urban development relies on a municipal system that maintains a relationship of accountability to its citizens, and is open in terms of financial management, information on the use of funds and adherence to legal and administrative policies." Researchers also emphasize the importance of inclusive, participatory decision-making processes that engage those groups most heavily impacted [6]. This emphasis was not mirrored in practitioners' definitions of resilience; neither transparency nor inclusivity were mentioned in any of the survey responses.

4.2. Synergies between Theory and Practice

While we do see a number of inconsistencies and unresolved issues with respect to resilience characteristics in the academic literature and amongst the surveyed practitioners, there are some promising areas of agreement. Within the urban climate change literature, the concept of resilience is most often traced back to the field of ecology, and therefore the relationship between humans and the environment are often central to definitions of resilience. The survey results reveal that practitioners also consider being environmental, defined as "protecting natural systems and assets", as quite important for resilience. It was, on average, the third highest rated characteristic. Moreover, several respondents specifically mentioned "ecosystem health", "ecosystem integrity", "ecosystem services", "natural resources", and "biodiversity" in their definitions of resilience.

While resilience theory is often praised for its focus on the interconnections between social and ecological systems, a common critique leveled against resilience theory generally, and urban climate resilience more specifically, is that it fails to address issues of equity [72,73]. These scholars critically ask "resilience for whom?" and argue that because resilience theory traditionally uses a systems approach, it ignores inequalities and trade-offs within the system boundaries [74]. It is therefore interesting that practitioners rated the importance of equity, defined in terms of "ensuring that the benefits and impacts associated with actions are felt equitably throughout the municipality", fairly high. While the word equity was not used in any of the respondents' definitions, a number of them did specifically mention assisting vulnerable or less powerful groups within their communities. For example, one respondent wrote that resilience "would also mean we are better prepared to help our citizens respond to the impacts of climate change, especially those least able to take action on their own, e.g., low-income households, the elderly, the young, those with respiratory & other health problems." Another respondent noted, "our priority is to build resilience in our institutions, systems, infrastructure, and communities [that] must protect the poor, elderly, young and ill against hazards and shocks."

The characteristic integration, as defined in the survey, requires "making sure that plans and actions are integrated across multiple departments and external organizations." Jabareen [7,75] argues that dealing with the uncertainties and complexities of climate change necessitates an "integrative approach", one that fosters collaboration across a multitude of public and private stakeholders, agencies, and organizations. Additionally, adaptation planning may be more effective if it is integrated into other local plans, with plans at the state or federal level, or combined with efforts of surrounding municipalities [21,76]. A number of the survey respondents specifically

mentioned integration in their definitions. For example, one noted that resilience suggests an approach "to foster integrative—cross sector, cross discipline—solutions." Another definition did not use the term integration but noted that to be resilient they would need to "include climate adaptation in all of our future planning functions—capital plans, resource allocation, stormwater, etc." Similarly, another respondent highlighted the importance of "regular communications between all sectors and with and among the community". Overall, scholars and practitioners seem to agree on the importance of supporting ecological systems, equity, and integrated planning for urban resilience, so there is some common ground for collaboration or knowledge exchange. However, there are a number of other theorized characteristics that practitioners see as relatively less important, or that have been called into question by other scholars. In particular, practitioners' emphasis on robustness, which is associated with an engineering or "bounce back" conceptualization of resilience, may be problematic.

5. CONCLUSIONS

Academic researchers and policymakers are increasingly focused on the concept of urban resilience. Arguably, resilience now rivals sustainability as a major organizing principle or "buzzword" for urban research and policy [76]. Resilience is especially predominant in the climate change discourse, since it is fundamentally about coping with disturbances and change [9]. The challenge is that resilience, like sustainability, is a "fuzzy concept" that is not easily defined or measured [77]. Indeed, it is clear from our comparative analysis of the literature on urban climate resilience and the results of a survey of U.S. local government respondents that academics and practitioners define and characterize urban climate resilience quite differently (Table 4). This points to a disconnect between academic theory and practice. Although local government decision-makers generally confirmed the importance of the 16 resilience characteristics commonly discussed in the academic literature (and did not suggest many others), when prompted to define resilience, they did not incorporate most of these characteristics into their definitions. Furthermore, the characteristics that were rated most important on average did not necessarily match those that are cited most frequently in the practitioners' definitions of resilience or those frequently discussed in the academic literature. For example, diversity, flexibility, and redundancy are considered fundamental to resilience in the scholarly literature, yet they are rarely mentioned in practitioners' definitions. Conversely, robustness, which is more controversial in the resilience literature, was rated as the most important characteristic in the survey. It is also interesting that many practitioners still use a more engineering, or "bounce back" conceptualization of resilience, while the scholarly literature seems to be moving towards a "bouncing forward" conceptualization. This is consistent with the findings of other studies [29], and bolsters criticisms that resilience policy and discourse is overly focused on maintaining the status quo and therefore inherently conservative [63,78,79]. This is particularly disheartening for those who do not think our cities are currently sustainable and would like to see transformative urban change.

Table 4. Some key differences in how academics and practitioners conceptualize urban resilience.

	Academic Literature	Local Government Practitioners
Resilience as "bouncing forward" vs. "bouncing back"	Majority "bouncing forward"	Majority "bouncing back"
Definition consistency	Some differences, but share a broad focus on coping with climate and disturbances	Huge variation in meaning, perceived importance, scope, and specificity
Commonly cited characteristics	Diversity, flexibility, redundancy, adaptive capacity, integration, inclusivity, equity, iterative process, decentralization, feedback, environmental, transparency, forward-thinking, predictable	Robustness, forward-thinking, environmental, integration, equity
Less frequently cited or contested characteristics	Robustness, efficiency	Decentralization, predictable, redundancy, feedback, iterative process, transparency

These findings highlight several avenues for future research. First, it would be interesting to survey urban climate resilience scholars and ask them to rate the importance of the sixteen characteristics, to allow for more direct comparison between results presented in this paper and the thinking of leading resilience scholars. It would also be useful to conduct a more representative sample of local practitioners in the U.S. and to survey practitioners in other countries to see how their definitions and characteristic ratings compare. This latter point seems logical since many of the academics whose work we reviewed are not from the U.S. Given the recent explosion in resilience research and policy, it would also be useful to rerun the survey and update the literature review to see whether understandings of resilience have changed in the last couple years. Moving beyond this study, there is a clear need to explore why scholars and practitioners have different conceptualizations of resilience and to empirically examine and test resilience characteristics in different urban contexts to see what types of plans and policies are being implemented at the local level to build more resilient communities, how these activities relate to what is known about fostering resilience, and whether they lead to improved outcomes.

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SECTION III:
IDENTIFYING & EVALUATING RESILIENCE

Methods/frameworks for measuring
& assessing resilience
Case studies using different approaches
to identify indicators

Identifying & Evaluating Resilience

Considering the difficulty in pinning down an agreeable interpretation of resilience, choosing the best metrics for evaluating it can also pose a challenge. After all, how can you evaluate the state of something when you are not completely sure what you are looking for? Still, it is often important to measure (quantitatively) or assess (qualitatively) resilience in order to justify a particular plan of action, or to determine the effects of a past effort. There are no universal indicators of resilience - that is, the specific system features targeted for evaluation. They are chosen ad hoc by the researcher, based on the research question/project at hand, and often have to do with his/her theoretical or disciplinary leanings. For example, an ecologist may judge the resilience of an urban wetland system by its function and presence of biodiversity; an urban planner may consider flooding and infrastructure damage within the same system. Similarly, an engineer may consider a city resilient to extreme heat if roads can withstand high temperatures; a public health official may emphasize access to air conditioned space for vulnerable populations. Depending on one's perspective and interests, framing and methods will vary.

This section provides multiple case studies in which researchers sought to frame, identify (via a series of chosen indicators), and assess or measure resilience. Methods range from quantitative to qualitative; indicators from general to local. The cases come from both the global north and south, address numerous climate-related hazards, and frame resilience in terms of economic prosperity, food security, vulnerability, adaptation, and more. The purpose is not to advance one methodological framework for identifying and evaluating resilience - all have their advantages and disadvantages - but to offer some potential avenues that you might take. Remember, resilience is a flexible concept, and different situations may call for different approaches to evaluating it. However, it is always helpful to clarify the following details before undertaking an evaluation:

I want to evaluate the resilience of _____ to _____.

READINGS INCLUDED

[Open access articles; Full text included]

Kruse, S., Abeling, T., Deeming, H., Fordham, M., Forrester, J., Jülich, S., … Schneiderbauer, S. (2017). Conceptualizing community resilience to natural hazards – the emBRACE framework. Natural Hazards and Earth System Sciences, 17(12), 2321–2333. https://doi.org/10.5194/nhess-17-2321-2017

Feldmeyer, D., Wilden, D., Kind, C., Kaiser, T., Goldschmidt, R., Diller, C., & Birkmann, J. (2019). Indicators for monitoring urban climate change resilience and adaptation. Sustainability, 11(10), 2931. https://doi.org/10.3390/su11102931

Jones, L., Samman, E., & Vinck, P. (2018). Subjective measures of household resilience to climate variability and change: Insights from a nationally representative survey of Tanzania. Ecology and Society, 23(1), art9. https://doi.org/10.5751/ES-09840-230109

Nguyen, K. V., & James, H. (2013). Measuring household resilience to floods: A case study in the Vietnamese Mekong River Delta. Ecology and Society, 18(3), art13. https://doi.org/10.5751/ES-05427-180313

Voelkel, J., Hellman, D., Sakuma, R., & Shandas, V. (2018). Assessing Vulnerability to Urban Heat: A Study of Disproportionate Heat Exposure and Access to Refuge by Socio-Demographic Status in Portland, Oregon. International Journal of Environmental Research and Public Health, 15(4), 640. https://doi.org/10.3390/ijerph15040640

ALTERNATIVE SELECTIONS

[Full text not included; May be accessible through your university library or elsewhere]

Brunetta, G., & Salata, S. (2019). Mapping urban resilience for spatial planning—A first attempt to measure the vulnerability of the system. Sustainbility, 11(8), 2331.

DasGupta, R., & Shaw, R. (2015). An indicator based approach to assess coastal communities' resilience against climate related disasters in Indian Sundarbans. Journal of Coastal Conservation, 19(1), 85–101.

Linstädter, A., Kuhn, A., Naumann, C., Rasch, S., Sandhage-Hofmann, A., Amelung, W., … Bollig, M. (2016). Assessing the resilience of a real-world social-ecological system: lessons from a multidisciplinary evaluation of a South African pastoral system. Ecology and Society, 21(3).

Quinlan, A. E., Berbés-Blázquez, M., Haider, L. J., & Peterson, G. D. (2016). Measuring and assessing resilience: Broadening understanding through multiple disciplinary perspectives. Journal of Applied Ecology, 53(3), 677–687.

Shandas, V., van Diepen, A., Voelkel, J., & Rao, M. (2017). Chapter 5: Coproducing resilience through understanding vulnerability. In K.N. Ninan & M. Inoue (Eds.), Building a climate resilient economy and society (pp. 78-95). Northampton, MA: Edward Elgar Publishing.

STUDENT EXERCISES

[To be completed after assigned reading]

(1) Select a climate-relevant podcast (60 minutes or less) and listen to an episode of your choice.
[Some relevant podcasts you might explore: Climate One; America Adapts; Climatecast; Climate Connections]

(2) Now, consider what you have read and heard. As a practitioner attempting to identify or evaluate climate resilience, what approach might you use and why? You can choose from approaches presented in readings and/or podcasts, or propose your own.

(3) What do you think is the relationship between RESILIENCE and VULNERABILITY? Is evaluating VULNERABILITY equivalent to evaluating RESILIENCE?

Tip for instructors: We suggest that students be given the opportunity to read each other's responses prior to class. This will alleviate the need for students to summarize for each other what they have written, and leave more class time for deeper, exploratory discussions.

FOR INSTRUCTORS: CLASSROOM ACTIVITIES

(1) Provide a fictional or real world climate change scenario; include location, key actors, concerns, outcomes, and other relevant details.

Discussion Prompt:
Within the context of this scenario, what would you identify as resilience INDICATORS? How would you go about assessing (qualitative) or measuring (quantitative) resilience in this case? Why?

Conceptualizing Community Resilience to Natural Hazards –the emBRACE Framework

by Sylvia Kruse, Thomas Abeling, Hugh Deeming, Maureen Fordham, John Forrester, Sebastian Jülich, A. Nuray Karanci, Christian Kuhlicke, Mark Pelling, Lydia Pedoth and Stefan Schneiderbauer

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ABSTRACT

The level of community is considered to be vital for building disaster resilience. Yet, community resilience as a scientific concept often remains vaguely defined and lacks the guiding characteristics necessary for analysing and enhancing resilience on the ground. The emBRACE framework of community resilience presented in this paper provides a heuristic analytical tool for understanding, explaining and measuring community resilience to natural hazards. It was developed in an iterative process building on existing scholarly debates, on empirical case study work in five countries and on participatory consultation with community stakeholders where the framework was applied and ground-tested in different contexts and for different hazard types. The framework conceptualizes resilience across three core domains: (i) resources and capacities, (ii) actions and (iii) learning. These three domains are conceptualized as intrinsically conjoined within a whole. Community resilience is influenced by these integral elements as well as by extra-community forces comprising disaster risk governance and thus laws, policies and responsibilities on the one hand and on the other, the general societal context, natural and human-made disturbances and system change over time. The framework is a graphically rendered heuristic, which through application can assist in guiding the assessment of community resilience in a systematic way and identifying key drivers and barriers of resilience that affect any particular hazard-exposed community.

1. INTRODUCTION

Community resilience has become an important concept for characterizing and measuring the abilities of populations to anticipate, absorb, accommodate or recover from the effects of a hazardous event in a timely and efficient manner (Patel et al., 2017; Almedom, 2013; Berkes and Ross, 2013; Deeming et al., 2014; Walker and Westley, 2011). This goes beyond a purely social–ecological systems understanding of resilience (e.g. Armitage et al., 2012:9) by incorporating social subjective factors, e.g. perceptions and beliefs as well as the wider institutional environment and governance settings that shape the capacities of communities to build resilience (Ensor and Harvey, 2015; Paton, 2005; Tobin, 1999). Many conceptual and empirical studies have shown that the community level is an important scale on which to build resilience that can enhance both the individual/household and wider population level outcomes (Berkes et al., 1998; Cote and Nightingale, 2012; Nelson et al., 2007; Ross and Berkes, 2014).

Yet, the community remains poorly theorized with little guidance on how to measure resilience building processes and outcomes. Both terms – resilience and community – incorporate an inherent vagueness combined with a positive linguistic bias and are used with increasing frequency both on their own as well as in combination (Patel et al., 2017; Mulligan et al., 2016; Brand and Jax, 2007; Strunz, 2012; Fekete et al., 2014). Both terms raise, as Norris et al. (2008) put it, the same concerns with variations in meaning.

In resilience research we can detect a disparity whereby the focus of research has often lain at either the larger geographical scales (e.g. regions) or, as in psychological research, at the level of the individual, extending to households (Ross and Berkes, 2014; Paton, 2005). Across these scales and sites of interest, resilience is consistently understood as relational. It is an ever-emergent property of social–ecological and technological systems co-produced with individuals and their imaginations. As a relational feature, resilience is both held in and produced through social interactions. Arguably, the most intense interactions that are of direct relevance to those at risk are at the local level, including the influence of non-local actors and institutions. It is in this space that the community becomes integral to resilience and a crucial level of analysis for resilience research (Cutter et al., 2008; Walker and Westley, 2011; Schneiderbauer and Ehrlich, 2006).

The idea of community comprises groups of actors (e.g. individuals, organizations, businesses) which share a common identity or interest. Communities can have a spatial expression with geographic boundaries and a common identity or shared fate (Norris et al., 2008:128). Following the approach of Mulligan et al. (2016) we propose to apply a dynamic and multi-layered understanding of community, including community as a place-based concept (e.g. inhabitants of a flooded neighbourhood), as a virtual and communicative community within a spatially extended network (e.g. members of crisis management in a region) and/or as an imagined community of individuals who may never have contact with each other but who share an identity or interest.

Considering the conceptual vagueness and variations of community and resilience, only a few approaches have tried to characterize and measure community resilience comprehensively (Cutter et al., 2014; Sherrieb et al., 2010; Mulligan et al., 2016). Thus, the aim of this paper is to further fill this gap and elaborate a coherent conceptual framework for the characterization and evaluation of community resilience to natural hazards by building both on a top-down systems understanding of resilience and on an empirical, bottom-up perspective specifically including the subjective variables and how they link to broader governance settings. The framework has been developed within the European research project emBRACE in an iterative process building on existing scholarly debates and on empirical case study research in five countries (Germany, Great Britain, Italy, Switzerland, Turkey) using participatory consultation with community stakeholders, where the framework was applied and ground-tested in different regional and cultural contexts and for different hazard types. Further the framework served as a basis for guiding the assessment of community resilience on the ground.

The paper is structured as follows: the next section provides an overview of key themes and characteristics of conceptual frameworks on community resilience and identifies gaps and open questions in the current conceptual framings in the context of natural hazards. In Sect. 3 we present the methodology for the development of the emBRACE framework of community resilience. In Sect. 4 the emBRACE framework is introduced along its central elements and characteristics and illustrated by examples from the case study research. Section 5 discusses the interlinkages between the framework elements as well as the application and operationalization of the framework and reflects on the results, methodology and further research.

2. CONCEPTUAL TENSIONS OF COMMUNITY RESILIENCE IN DISASTER RESEARCH AND POLICY

Both the concept of community and resilience are contested and this in different fields of research and policy. This chapter therefore does not aim at providing a comprehensive overview of different strands of research (for more details see Abeling et al., 2018); the ambition is rather to present a heuristic framework for understanding, explaining and assessing community resilience to natural hazards. Therefore, we present here central strands of research that influenced the development of the emBRACE framework of community resilience.

Alexander's etymological resilience journey (2013) shows that the word looks back on a "long history of multiple, interconnected meanings in art, literature, law, science and engineering. Some of the uses invoked a positive outcome or state of being, while others invoked a negative one. In synthesis, before the 20th century, the core meaning was `to bounce back"' (ibid., 2710). However, since Holling's influential publication (1973) on "Resilience and Stability of Ecological Systems" the idea of restricting resilience above all to the ability of ecosystems to bounce back to a pre-disturbance state and, by implication, assume a more or less stable environment, came under increasing pressure. Therefore, another of the tensions surrounding the concept of resilience in the context of disaster risk reduction concerns its relation to social change and transformation. A divide is emerging between those that propose resilience as an opportunity for social reform and transformation in the context of uncertainty (Bahadur and Tanner, 2014; Brown, 2014; Olsson et al., 2014; MacKinnon and Derickson, 2013; Sudmeier-Rieux, 2014; Weichselgartner and Kelman, 2015; Kelman et al., 2016), and those that argue for a restriction of the term to functional resistance and stability (Smith and Stirling, 2010; Klein et al., 2003). Limiting resilience to narrow interpretations of robust infrastructure would promote local disaster risk reduction that fails to address the need for social change and learning. Frameworks of disaster resilience need to account for multiple entwined pressures, (e.g. development processes, DRR and climate change; see Kelman et al., 2015) to learn and adapt and to innovate existing risk management regimes on the community level.

At the heart of this divide is the gradual translation of resilience from its firm base in the natural sciences to the social sciences, which brings with it a set of inherent ontological and epistemological challenges that become particularly prominent in discussions of community resilience. Rooted in ecology, resilience through the lens of Holling (1973, 1996) emphasized the concept of (multiple) equilibriums of systems in the face of "disturbances". This focus on returning to or progressing towards stability domains laid the foundation for the "bouncing back" narrative that continues to shape resilience policy and discourses, particularly in the area of disaster risk management and emergency planning. When discussing resilience in the context of community, however, a range of questions arise that shed light on the difficulties of translating ideas from the natural to the social sciences. These concern, amongst others, the character of disturbances in social systems (e.g. who gets disturbed by what or by whom?), the intentionality of human action (e.g. what role for purposeful interventions?), the overarching goals of resilience (e.g. what is desirable?), challenges with system boundaries (e.g. who is part of a social system?) and the role of power (e.g. who is empowered to act, participate, transform).

Besides the differences in scope of the definition between bouncing back and societal change, there is another tension about whether resilience is a normative, an analytical or a more descriptive concept (Fekete et al., 2014; Mulligan et al., 2016). While, early on, resilience was employed as a descriptive concept in ecology that attempted to integrate different notions of stability (i.e. withstanding, recovering and persisting), its thematic expansion to the analysis of socio-ecological systems goes hand in hand with a strong normative orientation or even prescriptive elements of how resilience ought to be organized (Brand and Jax, 2007), which is also increasingly applied as a policy goal to promote disaster risk reduction at all scales (United Nations Office for Disaster Risk Reduction, 2015, 2007). The notion of resilience is meanwhile an integral element at the international policy level to both the Hyogo Framework for Action and the Sendai Framework for Disaster Risk Reduction (United Nations Office for Disaster Risk Reduction, 2015, 2007) as well as to national and local

discourses on disaster risk reduction, e.g. in the UK National Community Resilience Programme (National Acadamies, 2012) or on the level of local authorities in the UK (Jacobs and Malpas, 2017; Shaw, 2012).

However, simply transplanting a descriptive concept established in ecology to a normative idea of how societies should be governed through resilience is not necessarily a step forward since there is the risk that "the role of physical shocks" is overemphasized and the relevance of "political economic factors" undertheorized (Cote and Nightingale, 2012:478). Even if the social–ecological systems approaches take into account political or economic factors, they tend to do this with a focus on functions and structures of institutions and tend to neglect the wider "political, historical and cultural meaning." (ibid). As an implication, as Lewis and Kelman argue (2012), attempts to make communities more resilient can actually result in a contrary situation, as they put them in a less tenable situation. This arises because resilience-based governance approaches have a tendency to be neglectful of social conflicts, inequalities and power (Fainstein, 2015:160; Jerneck and Olsson, 2008; Davoudi, 2012; MacKinnon and Derickson, 2013; Olsson et al., 2014), underestimate the relevance of social institutions and political struggle (Hayward, 2013; Sjöstedt, 2015) or be unheeding of the challenges associated with the idea of community participation (Bahadur and Tanner, 2014; Bahadur et al., 2013).

In addition to underestimating the relevance of socio-economic–political and interpretational aspects, resilience itself is shaping the way disaster risk reduction is organised and how responsibilities between public and private actors are distributed. In the UK, for example, resilience is part of a responsibilization agenda in which responsibility for disaster risk reduction is intentionally devolved from the national to the local level (Department for Environment, Food and Rural Affairs, 2011; Deeming et al., 2018a). This creates opportunities but is also contested and can provoke resistance by activists (Begg et al., 2016). Despite this increasing critical engagement with resilience, the notion is "here to stay" (Norris et al., 2008:128) for the conceivable future, not only as a theoretical concept but also as a policy tool for promoting disaster risk reduction. As such, it will have direct implications for hazard-prone communities.

Based on these arguments, we identify three gaps that characterize existing resilience frameworks and are related to conceptual challenges for a comprehensive community resilience framework. First, there seems to be insufficient consideration and reflection on the role of power, governance and political interests in resilience research. Secondly, many resilience frameworks still seem to fall short of exploring how resilience is shaped by the interaction of resources, actions and learning. Due to the conceptual influence of the Sustainable Livelihood Framework (SLF) of some approaches (Chambers and Conway, 1992; Scoones, 1998; Ashley and Carney, 1999; Baumann and Sinha, 2001), resilience concepts tend to be focused on resources but fail to systematically explore the interaction of resources with actions and learning and how understanding these variables might then usefully illustrate disparities in how social equity, capacity and sustainability (i.e. key considerations of the SLF approach; see Chambers and Conway, 1992) manifest. Third, an explicit description of learning and change is largely absent in the literature that characterizes community resilience. So far, resilience as a theory of social change seems to remain rather vaguely specified (Cote and Nightingale, 2012).

A resilience framework which accounts for these conceptual challenges is necessarily focused on the prospects of social reform and incorporates many "soft" elements that are notoriously difficult to measure. We thus agree with the need to operationalize resilience frameworks (Carpenter et al., 2001) but argue that existing framework measurements (e.g. Cutter et al., 2008) often fail to systematically include those challenges that we consider of critical importance for community resilience.

3. FRAMEWORK DEVELOPMENT AND METHODS USED

Developing an interdisciplinary, multi-level and multi-hazard framework for characterizing and measuring the resilience of European communities calls for the application of a multifaceted approach that adopts interdisciplinary methodological processes. Therefore, we applied a complementary research strategy with the purpose of investigating resilience on different scales, from different perspectives and by applying different research methods as well as integrating the viewpoints of distinct actors. The research team came from different disciplinary backgrounds and it was the intention that no single disciplinary approach would dominate. Rather, a democratic process of consensus building was employed to arrive at methods and outputs acceptable to all.

A first strand of this research strategy included intensive structured literature reviews. The first sketch of the community resilience framework was informed by the early review systematizing the different disciplinary discussions on resilience into thematic areas. As the project continued, specialized literature reviews complemented this first review by focusing on different aspects of the emerging framework and considering more recent publications. Throughout the project, developments in the literature were closely monitored and literature reviews were continuously updated (Abeling et al., 2018).

A second strand involved empirical case study research in five European countries investigating community resilience related to different hazard types on different scales. The five case studies comprised multiple Alpine hazards in South Tyrol, Italy and Grisons, Switzerland; earthquakes in Turkey; river floods in central Europe; combined fluvial and pluvial floods in northern England; and heatwaves in London. A number of qualitative and quantitative methodologies were adopted in the case study research in order to develop the final community resilience framework. The outcomes of this research have been used to inform the conceptual framework at different stages of the development process and helped to illustrate how the framework can be applied and adapted to different hazard types, scales and socio-economic and political contexts (Kuhlicke et al., 2016; Doğulu et al., 2016; Ikizer et al., 2015; Ikizer, 2014; Abeling, 2015a, b; Taylor

et al., 2014; Deeming et al., 2018a; Jülich, 2017, 2018).

A third strand saw three participatory workshops with stakeholders in case studies in Cumbria, England; Van, Turkey; and Saxony, Germany in order to add the perspectives of different community stakeholders on the local and regional scales to the framework development. The aim of the participatory assessment workshops was to collect, validate and assess the local appropriateness and relevance of different dimensions of community resilience and indicators to measure them. With the selection of case studies in different countries and different types of communities, we took into account that different cultures and communities conceptualize and articulate resilience differently. The workshops allowed discussion with local and regional stakeholders about how resilience can be assessed. This was both a presentation and revalidation of the first results of the case study and involved working together with the stakeholders. It was also a starting point for further development of the framework.

A fourth strand involved internal review processes with project partners as well as external experts on community resilience.

4. THE emBRACE FRAMEWORK FOR CHARACTERIZING COMMUNITY RESILIENCE

The emBRACE framework conceptualizes community resilience as a set of intertwined components in a three-layer framework. First, the core of community resilience comprises three interrelated domains that shape resilience within the community: resources and capacities, actions and learning (see Sect. 4.1). These three domains are intrinsically conjoined. Further, these domains are embedded in two layers of extra-community processes and structures (see Sect. 4.2): first, in disaster risk governance which refers to laws, policies and responsibilities of different actors on multiple governance levels beyond the community level. It enables and supports regional, national and international civil protection practices and disaster risk management organizations. The second layer of extra-community processes and structures is influenced by broader social, economic, political and environmental context factors, by rapid or incremental socio-economic changes of these factors over time and by disturbance. Together, the three-layers constitute the heuristic framework of community resilience (see Fig. 1), which through application can assist in defining the key drivers and barriers of resilience that affect any particular community within a hazard-exposed population.

Figure 1. The emBRACE framework for community resilience to natural hazards (source: own illustration).

4.1 Intra-community domains of resilience: resources and capacities, action and learning

4.1.1 Resources and capacities

The capacities and resources of the community and its members constitute the first domain of the core of resilience within the community. Informed by the Sustainable Livelihoods Approach (SLA) and its iterations (Chambers and Conway, 1992; Scoones, 1998; Ashley and Carney, 1999; Baumann and Sinha, 2001) as well as the concept of adaptive capacities (Pelling, 2011), we differentiate five types of capacities and resources. This approach also addresses in parallel the need identified by Armitage et al. (2012) for material, relational and subjective variables as well as the social subjective dimension of resilience (see Sect. 1).

Natural and place-based capacities and resources relate to the protection and development of ecosystem services. This includes but is not limited to the role of land, water, forests and fisheries, both in terms of their availability for exploitation as well as more indirectly for personal well-being of community members. Place-based resources can also refer to cultural and/or heritage resources, to local public services, amenities and to the availability of access to jobs and markets.
Socio-political capacities and resources account for the importance of political, social and power dynamics and the capacity of community members to influence political decision-making. Here, institutions such as the rule of law, political participation and accountability of government actors are of critical importance. Participation in governance can be both formal, for example through elections and interest representation, and informal, for example through empowerment and resistance in political decision-making. Therefore, power dynamics in community resilience include both empowerment and resistance as well as cooperation and learning (related to the differentiation between "power to" and" power with"; see Partzsch, 2016; Allen, 1998). Therefore, structural social resources are also inherent within the structural and cognitive components of social capital (Moser and McIlwaine, 2001), i.e. networks and trust. Social capital refers to lateral relationships between family, friends and informal networks but also to more formal membership in groups, which may involve aspects of institutionalization and hierarchy. Cognitively defined trust relationships can assist in collective action and knowledge-sharing and thus seem integral for the development and maintenance of community resilience (Longstaff and Yang, 2008). Operating within the framework's disaster risk governance domain, however, it should be acknowledged that mutual social–trust relations – as might be expressed between community members – can be differentiated from trust in authority wherein hierarchical power differentials introduce an element of dependency to the relationship (Szerszynski, 1999).

Financial capacities and resources refer to monetary aspects of disaster resilience. This includes earned income, pensions, savings, credit facilities, benefits and importantly access to insurance. The role of financial capacities raises questions about availability of and access to individual and public assets and about the distribution of wealth across social collectives. The causal relationships that underpin the role of financial resources for community resources are not linear. Increases in available financial resources are not necessarily beneficial for community resilience, for example if income inequality is high and financial resources are concentrated in a very small and particular segment of society.

Physical capacities and resources for community resilience include adequate housing, roads, water and sanitation systems, effective transport, communications and other infrastructure systems. This can also refer to the availability of and the access to premises and equipment for employment and for structural hazard mitigation (i.e. both at household and community scales).

Finally, human capacities and resources focus at the individual level, integrating considerations such as gender, health and well-being, education and skills and other factors affecting subjectivities. Psychological factors are also accounted for here, including self-efficacy, belonging, previous hazard experience, coping capacities and awareness. These factors together can be understood to impact on individuals' perceptions of risk and resilience but also as enablers of the community-based leadership that drives collective action.

From the case study in Turkey, socio-political (having good governance, specific disaster legislation, supervision of the implementation of legislation, coordination and cooperation, being a civic society, having mutual trust, having moral and cultural traditional values, etc.) and human (e.g. gender, income, education, personality characteristics) resources and capacities were the most pronounced (Karanci et al., 2018).

In one of the participatory workshops an earlier version of the framework was discussed with local stakeholders regarding the case study on flooding in northern England. It revealed that for the participants, social–political and human capacities and resources were most important for characterizing their community resilience. Indicators measuring, for example, out-migration and in-migration as well as willingness to stay in the region and engage in associational activities were proposed to describe the degree of community spirit and solidarity that was considered to be crucial for their community resilience in a region that is threatened by population loss and demographic change.

4.1.2 Actions

Within the emBRACE framework, community resilience comprises two types of actions: civil protection and social protection. The civil protection actions refer broadly to the phases of the disaster management cycle, i.e. preparedness, response, recovery and mitigation

(Alexander, 2005) which, despite longstanding academic critique (McEntire et al., 2002; Neal, 1997), are persistent in practice. Resilience actions undertaken by the community can be related to these phases (e.g. weather forecasting and warning as preparedness action). Accordingly, civil protection is focusing on hazard specific actions. We add to this social protection considerations, which include hazard independent resilience actions, e.g. measures of vulnerability reduction and building social safety nets (see Fig. 1). Social protection action includes diverse types of actions intended to provide community members with the resources necessary to improve their living standards to a point at which they are no longer dependent upon external sources of assistance (Davies et al., 2008). Social protection has been included as a main component because many resilience building actions cannot be directly attributed to civil protection action but are instead concerned with the more general pursuit of well-being and sustainability (Davies et al., 2013; Heltberg et al., 2009). For example, the presence of an active community-based voluntary and/or charity sector capable of providing social support (e.g. food banks) and funding for participatory community endeavours (e.g. a community fund) and which could be extended or expanded in times of acute, disaster-induced, community need were found to be factors that provide a certain level of security for all those affected by hazards, either directly or indirectly (Dynes, 2005).

Such social protection measures are not, however, delivered solely by the community and voluntary sector alone, so it is important to understand that these elements also relate to the much broader provision of welfare services (health, education, housing, etc.), which are ultimately the responsibility of national and local government. The inclusion of social protection as a main component of this domain therefore represents an important progression over some other frameworks, because it explicitly includes the consideration of how communities manifest resilience through their capacity to deal with and adapt to natural hazards but also their capacity to contribute equitably to reducing the wider livelihood-based risks faced by some, if not all, of their membership.

In a case study in northern England, social support mechanisms were particularly important across multiple communities (from hill farmers to town dwellers) in the aftermath of a flood event (Deeming et al., 2018a). Key considerations were that, despite evidence of learning and adaption that had occurred between two floods in 2005 and 2009, the sheer magnitude of the latter event effectively discounted the effects of any physical mitigation and civil protection measures that had been introduced. Where non-structural measures, such as community emergency planning, had been adopted there were significant improvements in the levels and successes of response activity. However, while these actions reduced some damage (e.g. fewer vehicles flooded), where properties were inundated significant damage still resulted. Accordingly, community champions emerged who were capable of advocating community outcomes and the need for community spaces (e.g. groups or buildings) where those affected could learn by sharing experiences and deliberating plans. They proved to be key in driving the recovery as well as the concurrently occurring future mitigation efforts. Much of the support in the aftermath of the flood events was coordinated by particular officers from the statutory authorities, whose "normal" roles and skills were social rather than civil protection orientated. This emphasised the importance of understanding resilience in framework terms as a practice-encompassing process rather than as a simple measure of hazard response capability.

4.1.3 Learning

Learning is the third integral domain that shapes intra-community resilience in the emBRACE framework. We attempt to provide a detailed conceptualization of learning in the context of community resilience. We follow the notion of social learning that may lead to a number of social outcomes, acquired skills and knowledge building via collective and communicative learning (Muro and Jeffrey, 2008). It occurs formally and informally, often in natural and unforced settings via conversation and mutual interest. Further, social learning is said to be most successful when the practice is spread from person to person (Reed et al., 2010) and embedded in social networks (McCarthy et al., 2011). In this understanding, social learning is an ongoing, adaptive process of knowledge creation that is scaled-up from individuals through social interactions fostered by critical reflection and the synthesis of a variety of knowledge types that result in changes to social structures (e.g. organizational mandates, policies, social norms) (Matyas and Pelling, 2015). Based on this understanding we conceptualise social learning as consisting of different elements from the perception of risks or losses, its problematization, to the critical reflection and testing/experimentation in order to derive new knowledge which can be disseminated throughout and beyond the community, enabling resilience at a range of societal levels (see Fig. 1). The first element, risk and loss perception, is the ability of any actor, organization or institution to have awareness of future disaster risk or to feel the impact of a current or past hazard event. Awareness can be derived from scientific or other forms of knowledge.

Second, the ability to problematize risk and loss arises once a threshold of risk tolerance has passed. A problematization of risk manifests itself as the perception of an actor that potential or actual disaster losses or the current achieved benefit-to-cost ratio of risk management are inappropriate. This includes procedural and distributional justice concerns and has the potential to generate momentum for change. Third, critical reflection on the appropriateness of technology, values and governance frames can lead to a questioning of the risk-related social contract of the community. Critical reflection is proposed as a mechanism through which to make sense of what is being learned before applying it to thinking or actions.

Fourth, experimentation and innovation refers to testing multiple approaches to solve a risk management problem in the knowledge that they will have variable individual levels of success. This can shift risk management to a new efficiency mode where experimentation is part of the short-term cost of resilience and of long-term risk reduction. In this context, innovation can be conceptualised as processes that derive an original proposition for a risk management intervention. This can include importing knowledge from other places or policy areas as well as advances based on new information and knowledge generation.

Fifth, dissemination is integral for spreading ideas, practices, tools, techniques and values that have proven to meet risk management objectives across social and policy communities. Sixth and finally, monitoring and review refers to the existence of processes and capacity that can monitor the appropriateness of existing risk management regimes in anticipation of changing social and technological, environmental, policy and hazard and risk perception contexts. The Turkish case study on earthquakes revealed that an earthquake experience in one region of the country led to learning, mostly by the state, to changes and to the adoption of new legislation and new organization for disaster management. This experience seemed to have very robust effects on attitudes towards disasters, changing the focus from disaster management to disaster risk management (Balamir, 2002). The same change process seemed to apply to individuals as well but to a smaller extent, in that an earthquake experience led to an increase in hazard awareness and preparedness (as would be predicted based on classical hazards theory; Kates, 1971).

The Italian case study in the Alpine village of Badia focuses on the perception of risks and losses as one element of resilience learning. The findings reveal that, even though people living in Badia have high risk awareness, many did not expect or prepare for an event. The interpretation of the different risk behaviour profiles shows that people who perceived themselves to be under risk of future landslide events had either personally experienced a landslide event in the past or participated in the clean-up work after the landslide event in 2012. Results from comparing the two groups of inhabitants affected by the landslide event 2012 and not affected in 2012 point in the same direction, showing that personal experience, not only recent but also past experience, together with active involvement in the response phase, lead to a higher risk perception especially when thinking about the future (Pedoth et al., 2018).

4.2 Extra-community framing of community resilience

4.2.1 Disaster risk governance

In the proposed characterization of community resilience with respect to natural hazards, the three core domains – resources and capacities, actions and learning – are embedded in two extra-community frames. The first frame is that of formal and informal disaster risk governance, which comprises laws, policies and responsibilities of disaster risk management at the local, regional, national and supra-national levels. From the case study research it became clear that community resilience and its constituent resources and capacities, action and learning processes are strongly interacting with existing formal and informal laws, policies and responsibilities of civil protection and risk management more generally (e.g. flood mapping as per the German National Water Act and the EU Flood Directive). Responsibilities relate to the actors and stakeholders involved in disaster risk management.

The wider ideas of risk governance to the specific context of a community involves focus on the interaction between communities' resources and capacities and actions as well as their learning processes. This is related to the specific framework by which responsibilities, modes of interaction and ways to participate in decision-making processes in disaster risk management are spelt out. The responsibilization agendas in the two case studies in Cumbria, England and Saxony, Germany may serve as an example. In both case studies community actions are being influenced by the downward-pressing responsibilization agenda, which is encompassed, for example, within Defra's "Making Space for Water" strategy for Great Britain and Saxony's water law in Germany, the latter of which obliges citizens to implement mitigation measures. This explicitly parallels Walker and Westley's call to "push power down to the local community level where sense-making, self-organization and leadership in the face of disaster were more likely to occur if local governments felt accountable for their own responses" (2011:4). The case study work showed that this not only relates to local governments (Begg et al., 2015; Kuhlicke et al., 2016) but also to the individual citizens potentially affected by natural hazards (Begg et al., 2016). More specifically, Begg et al. (2016) found that if the physical and psychological consequences are perceived as being low with regard to their most recent flood experiences, then respondents tend to accept the attribution of responsibility towards individual citizens and also report higher response efficacy (i.e. the respondents have the feeling they can reduce flood risk through their own actions) if they have taken personal mitigation measures prior to the flood event. In addition, respondents who have taken personal mitigation measures are more likely to report higher response efficacy than those who have not taken such actions and also agree with the responsibility attributed to them. In other words, if respondents took personal mitigation measures before the flood and did not experience severe consequences as a result of the flood, they are likely to agree with statements which support citizen responsibility and report high response efficacy. This shows that resilience action and learning processes are always embedded in the broader formal and informal risk governance settings.

4.2.2 Indirect hazard-related context, social–ecological change and disturbances

As a second extra-community framing we consider three dimensions as influential boundary conditions for community resilience: first the social, economic, political and environmental context; second, social, economic, political and environmental change over time; and third diverse types of disturbances.

The first dimension of indirect hazard-related boundary conditions for community resilience is the social, economic, political and environmental/bio-physical context. This includes contextual factors and conditions around the community itself, requiring the expansion of the analysis of community resilience to take into account the wider political and economic factors that directly or indirectly influence the resilience of the community. In different concepts and theories these contextual factors have been addressed, e.g. in

institutional analysis (Whaley and Weatherhead, 2014; Ostrom, 2005), common pool resource research (Edwards and Steins, 1999) or socio-ecological systems research (Orach and Schlüter, 2016).

The analysis of contextual factors can also expand backward in time and include an analysis of change over time. Therefore, apart from the more or less stable context factors we include social, economic, political and environmental change over time as an influencing force of extra-community framing of community resilience. Disaster risk and hazard research scholars (Birkmann et al., 2010) as well as policy change scholars (Orach and Schlüter, 2016) have identified different dynamics and types of change from gradual, slow-onset change to rapid and abrupt transformation and from iterative to fundamental changes. This can include social change, economic change and policy change as well as changes in the natural environment, e.g. connected to climate change and land degradation.

Considering the third boundary condition, a broad variety of disturbances can influence the community and its resilience is partly closely interlinked with the perceived or experienced changes and the specific context factors. As already noted by Wilson (2013), disturbances can have both endogenous (i.e. from within communities, e.g. local pollution event) and exogenous causes (i.e. outside communities, e.g. hurricanes, wars) and include both sudden catastrophic disturbances (e.g. earthquakes) as well as slow-onset disturbances such as droughts or shifts in global trade (for a typology of anthropogenic and natural disturbances affecting community resilience; see Wilson, 2013). In line with Wilson we conclude that communities are never "stable" but are continuously and simultaneously affected and react to disturbances, change processes and various context factors. Therefore, disturbances can not only have severe negative impacts on a community but also trigger change and transformation that might not have activated otherwise. As a result, in empirical applications a clear-cut differentiation between contextual change over time and slow-onset disturbances or disturbances that trigger change is not always possible.

5. DISCUSSION AND CONCLUSIONS

5.1 Interlinkages between the domains and extra-community framing

Considering the intertwined components of the proposed framework, research can be guided by acknowledging the complexity of the possible interactions between the resources and capacities, learning and actions domains in shaping community resilience. Therefore, efforts that evaluate these multiple levels; their interactions; and how they operate in different contexts for different hazards can provide an enriching evaluation of community resilience.

An example of how the emBRACE framework of community resilience helped to reveal the interrelatedness of socio-political and human resources in the civil protection actions and the importance of social solidarity and trust as important contextual factor is delivered in the case study work in the city of Van, Turkey. Here the exploration of individual resilience after a severe earthquake proved how influential the contextual factors are. The results indicated that the political context played an important role in shaping survivors' perceptions of their own resilience. Doğulu et al. (2016) shows that community resilience is facilitated when provision of post-quake aid and services is based on equality and trust (and not nepotism and corruption) and not hindered by discrepancy of political views among government bodies, community members and NGOs.

Further, the analysis revealed that the earthquake experience in the Marmara region of Turkey in 1999, 12 years earlier influenced the resilience of the community following the Van earthquake, based on learning processes that resulted, for example, in a change in the public disaster management by state organizations as well as the adoption of new legislation. Thus, especially for the state institutions, the impact of a past disturbance may lead to significant changes in disaster risk management, which in turn are likely to contribute to fostering community resilience in Van and beyond (Karanci et al., 2018). This example shows how the framework provides an understanding of the interrelatedness of the three domains and the importance of their interactions in shaping community resilience. Yet, the specific types of relations and interlinkages are case specific, i.e. influenced by various external variables. How to specify these and develop typologies of linkages and relations will need to be investigated in further research.

5.2 Application and operationalization of the framework in indicator-based assessments

The emBRACE framework for community resilience was iteratively developed and refined based on the empirical research of the specific local-level systems within the five case studies of emBRACE; thus it is strongly supported by local research findings on community resilience. It was mainly developed to characterize community resilience in a coherent and integrative way. Nonetheless, it was also developed for measuring resilience and is thus a heuristic to be operationalized in the form of an indicator-based assessment. Thus, the framework provides one possible – but empirically legitimized – structure and route with which to select and conceptually locate indicators of community resilience.

Within the emBRACE project we derived case-study-specific community resilience indicators as well as a set of more concise, substantial indicators that are generalizable across the case studies (Becker et al., 2018). The generalizable key indicators include a wider range of indicators from more quantitative indicators, like the presence of an active third-sector emergency coordination body or the percentage of households in the community that subscribed to an early-warning system, operationalizing the domain of civil protection action, up

to more qualitative indicators such as social/mutual trust and the sense of belonging to a community, applying the domain of human and social resources and capacities.

Besides identifying and selecting suitable indicators, it is crucial to understand how to develop, integrate, interpret and apply indicators (Jülich, 2018; Bahadur and Tanner, 2014). Concrete instructions are needed to provide a useful source of information for proper indicator application in practice and we recommend using some form of guideline for community resilience indicator development (see for example Becker et al., 2015). In particular, the possible methods of data collection for the constituent parts of this framework require attention, since they affect not only the methods adopted to parameterise the indicators but also the scale of application.

5.3 Reflections on the results and emBRACE methodology and limits of the findings

The term "resilience" is both ubiquitous and indeterminate. Similarly, "community" is equally pervasive and prone to common sense understandings which appear to obviate critical discursive engagement. Together, the two concepts represent both a challenge and an opportunity to influence the shape of effective and inclusive disaster risk reduction. The frequently simplistic and bounded uses of "community resilience" (across a range of sectors but most particularly in the civil protection and emergency management fields) limit the reach of risk reduction endeavours through a narrow focus on technical interventions at the expense of recognizing and enabling social transformations. The proposed three-layered framework for characterizing community resilience was developed deductively by considering theoretical approaches of resilience from various disciplinary backgrounds and state-of-the-art research, and it was also developed inductively based on empirical insights from our case study work. The result is a theory-informed heuristic that has the potential to guide empirical research as well as disaster management and community development in a more inclusive and expansive way.

Research and practice rarely include all elements we have identified but often focus on some specific domains and their interaction in more detail. When guiding disaster management and community development the framework helps to highlight the importance of the multiple factors that are related to community resilience. Whether the framework is to inform scientific or more practical applications, in most cases it will be necessary to adapt the framework to the specific context in which it is applied, e.g. cultural background, hazard types or the socio-political context. This framework was developed in a European context, and while the research team has drawn upon their wider research knowledge and experience it was not tested outside that geographic boundary.

The emBRACE framework was developed as a heuristic device, i.e. a strategy based on experience and as an aid to communication and understanding, but it is not guaranteed to be optimal or perfect. The framework should be subject to further research both for further conceptualizing community resilience and applying and specifying the framework in various contexts of community resilience.

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Indicators for Monitoring Urban Climate Change Resilience and Adaptation

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ABSTRACT

In the face of accelerating climate change, urbanization and the need to adapt to these changes, the concept of resilience as an interdisciplinary and positive approach has gained increasing attention over the last decade. However, measuring resilience and monitoring adaptation efforts have received only limited attention from science and practice so far. Thus, this paper aims to provide an indicator set to measure urban climate resilience and monitor adaptation activities. In order to develop this indicator set, a four-step mixed method approach was implemented: (1) based on a literature review, relevant resilience indicators were selected, (2) researchers, consultants and city representatives were then invited to evaluate those indicators in an online survey before the remaining indicator candidates were validated in a workshop (3) and finally reviewed by sector experts (4). This thorough process resulted in 24 indicators distributed over 24 action fields based on secondary data. The participatory approach allowed the research team to take into account the complexity and interdisciplinarity nature of the topic, as well as place- and context-specific parameters. However, it also showed that in order to conduct a holistic assessment of urban climate resilience, a purely quantitative, indicator-based approach is not sufficient, and additional qualitative information is needed.

Keywords: resilience; indicator; monitoring; climate change; climate adaptation

1. INTRODUCTION

Our society is facing multitudinous different challenges—in this paper we are focusing on two main challenges: climate change and urbanization. In 2015, 3.9 billion people were living in cities. By 2050, the population in cities is projected to reach up to 6.7 billion people [1]. Urban agglomerations will continue to grow and are increasingly threatened by the high uncertainty of climate change impacts [2]. In response to these impacts, cities are already implementing climate change adaptation measures in order to prepare for uncertain future changes. Adaptation to climate change and climate variability is not a new phenomenon [3]. However, steadily rising temperatures, increasing magnitude and frequencies of climate-induced extreme events, such as droughts, floods, storms or intense rainfall, as well as the growth of the global human population pose new adaptation challenges to humankind [3]. In our research, we use the term adaptation as defined by the United Nations Climate Change [4]: "Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change". Furthermore, the ability of adaptation is understood as part of resilience, as described by Folke et al. [5]. The concept of resilience can be attributed to Holling [6] and originates from ecology. He described resilience as the "measure of persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationship between population or state variables" [6]. The original concept of resilience gained increased importance in other disciplines, whereby the definitions of resilience were steadily differentiated, broadened and deepened. There are three main understandings of the character of resilience: "bounce back" which refers to the fast return to an equilibrium state of a system after a shock event, "bounce forward" which focuses on a system which should have capacities to be adapted to uncertainty and "both" which addresses the co-occurrence of the capacities for "bounce back" and "bounce forward" [7]. Meerow et al. [2] analysed 57 academic definitions of urban resilience, with particular regard to these fundamental understandings of urban resilience. The analysis showed that 35 definitions focus on "bouncing back", 15 on "bouncing forward" and only seven see both capacities as elementary for resilience. Figueiredo et al. [8] pointed out that the definitions shifted from an equilibrium-centred understanding of resilience towards an evolutionary/transformational understanding of resilience. Four main approaches to resilience can be identified: disaster risk reduction [9], socio-ecological [10], sustainable livelihoods [11] and the community-oriented approach [12]. Resilience can also be discussed on different scales (county, region, urban area, city, community and household) [8]. Even though it is important to take action on all scales, in this work we are focusing on cities—particularly in Germany—and are using the socio-ecological approach. Besides the definitions and understandings of resilience in academia, it is very important to also consider how practitioners interpret resilience. Practitioners and policy makers are a central part of the resilience-transformation process. Therefore, it is remarkable that the term resilience is interpreted in a much wider range of ways by practitioners than by academia [13].

Adaptation measures are implemented in different sectors of the city system. Since cities are complex and multifaceted systems,

which in turn contain other systems, measuring the success of resilience-increasing activities poses a particular challenge. However, measurement is of great importance in order to be able to govern and steer the adaptation and transformation process. Every city has its specific context and needs, and its exposure to risk and vulnerability is dynamic and changes over time [8].

However, it is important to develop measurable indicators for different reasons. Indicators enable monitoring of the resilience-building process, as they provide regular and impartial feedback. They build an evidence base and make resilience more tangible for decision and policy makers as well as society at large. Furthermore, indicators can help to govern and steer the transformation process because they help to structure the new field of urban climate resilience. Clear indicators are not only important for the general measurement of resilience, but also for the analysis of whether adaptation measures were effective and whether the expected results were achieved [14]. Indicators also contribute to the credibility, transparency and accountability of the measures implemented. This in turn is very important for local policy makers to support further adaptation measures.

However, the development of indicators in this context poses particular challenges. In addition to the conceptual challenges of urban climate resilience, context specificity represents another challenge for the development of resilience indicators. Consequently, it is very important to consider how to include context specificity in the indicator set. Another fundamental consideration is in regard to the context-specific, dynamic and ever-changing nature of risk and vulnerability [8].

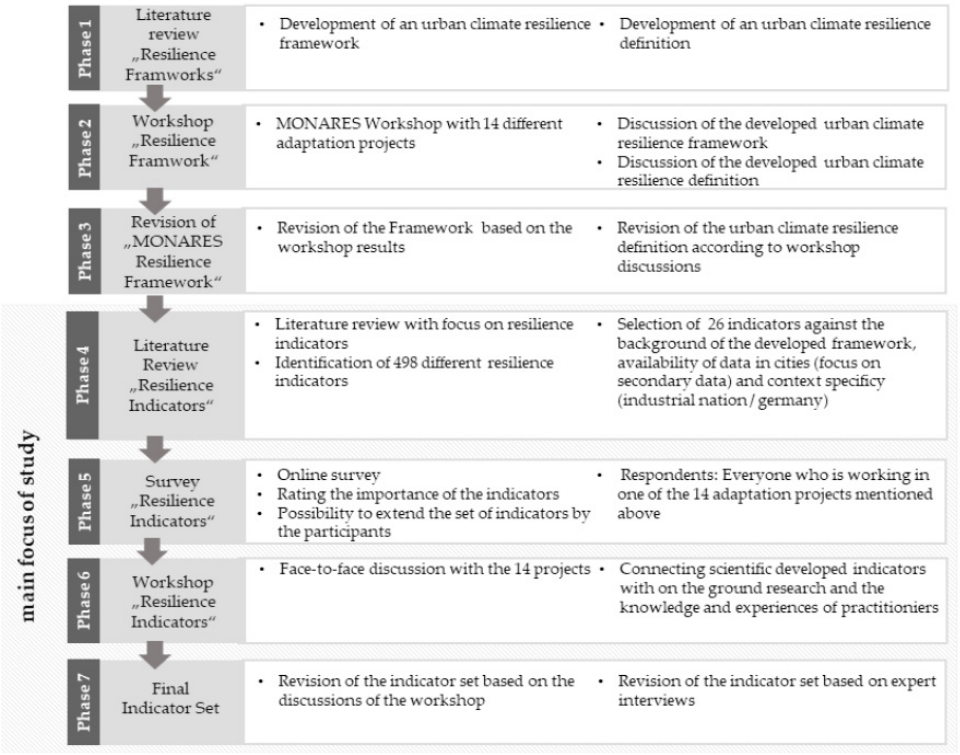
MONARES (monitoring of adaptation measures and climate resilience in cities), a project funded by the German Federal Ministry of Education and Research (BMBF), was initiated in order to address the main challenges of (1) developing a consistent understanding of resilience for both practitioners and academia, (2) shaping the adaptation and transformation process into a transparent process of governing and steering and (3) the use of resilience and adaptation measurements. The aim of MONARES is to create application-oriented methodologies for monitoring and evaluating local adaptation measures. As we are focusing on the special needs for cities in Germany, we are working together with 14 other projects of the funding initiative "Climate resilience through action in cities and regions" of the BMBF, who are focusing on climate change adaptation measures and urban resilience, as well as doing on-the-ground research in municipalities across Germany. These projects and cities differ considerably concerning scale (street, district, city, suburbs and region), inhabitants and type of adaptation measure (e.g., planning, physical infrastructure, capacity building or greening). Important commonalities of the projects are their interdisciplinary approach, the aim to enhance urban climate resilience and that they conduct on-the-ground research. However, the projects test many different pathways to improve resilience, and MONARES is focusing on how to measure the success and impact of these different projects and activities with a common set of indicators. In order to ensure applicability, we began to involve the projects at an early stage of our research. The first key step (Figure 1 Phase 1) before developing the indicators was to develop a framework [15] to describe urban resilience. Based on 19 frameworks described in the literature [16, 17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34], our first draft was developed, which then was modified together with the projects. This process was indispensable as it resulted in a definition of urban resilience that is suitable for all projects so that there was agreement on common basic principles.

Based on steps 1 to 3 as shown in Figure 1, the final definition of urban resilience in MONARES is as follows:

The climate resilience of a city depends on the ability of its sub-systems to anticipate the consequences of extreme weather and climate change, to resist the negative consequences of these events and to recover essential functions after disturbance quickly, as well as to learn from these events and to adapt to the consequences of climate change in the short and medium term, and transform in the long term. The more pronounced these abilities are, the more resilient a city is to the consequences of climate change. All abilities are important.

Based on this preliminary work, a four-step mixed-method approach (Figure 1 Phases 4–7) was designed to develop the indicators for urban climate resilience on which this paper focuses.

Figure 1. MONARES—research process.



2. MATERIALS AND METHODS

The exponential growth of literature concerning urban resilience contains a multitude of approaches, indicators and methods stressing the resistance of an urban system. The development of the method of this paper was guided by the questions: resilience for whom, for what and where [35]. A reflexive approach of input and feedback loops was developed in order to adapt and validate international indicators. A main challenge was to adapt the indicators to the specific context of German communities in the face of climate change.

2.1. Literature Review: “Resilience Indicators”

The selected frameworks (see Figure 1 Phase 1) were identified through an extensive literature review using the key search terms “resilience”, “urban resilience”, “climate resilience”, “adaptive capacity + urban/city”, “resistibility + urban” and “learning capacity + urban/city” (in German and English). Based on these frameworks and their operationalisation of resilience, an extensive list of indicators was deduced. These indicators were matched with the MONARES framework, developed in steps 1–3, which consists of dimensions and action fields (see Table 1).

Table 1. Dimensions and action field of the resilience framework.

Dimension	Action Field
Environment	Soil and green spaces
	Water bodies
	Biodiversity
	Air
Infrastructure	Settlement structure
	Energy
	Telecommunication
	Traffic
	Drinking and wastewater
Economy	Innovation
	Business
	Economic structure
Society	Research
	Knowledge and risk competence
	Healthcare
	Socio-demographic structure
	Civil society
	Civil protection
Governance	Participation
	Municipal budget
	Strategy, plans and environment

As we have the aim to develop a user-friendly, applicable and transparent indicator set, we firstly reduced the indicators to two indicators per action-field. The two most important selection criteria were (1) context specificity of industrial nations, especially Germany, and (2) data availability. Context specificity is important because many of the indicators in the literature are suitable for the context of the Global South but not for the Global North, and even indicators that might be suitable for the Global North might not be suitable in the German context. The second criteria—data availability—is therefore important because municipalities have, on the one hand, good access to a lot of data but have, on the other hand, resource problems regarding time, finances and human resources. Action fields without literature-based indicators required the development of new ideas within the project. Given the available data, some action fields were difficult to measure without significantly neglecting the complexity of the action field.

2.2. Survey to Assimilate the Indicators for Context Specificity

Based on the literature review (see Figure 1 Phase 4) and the described selection process, an online-survey was developed (see Figure 1 Phase 5). The survey was used because, given that the indicators should be transparent and user-friendly, not only the scientific background is important, but a clear understanding of the indicators in the broad community is important also. The survey was sent to all persons who are working in one of the 14 projects mentioned above. 39 people answered the survey.

The main aim of the survey was to measure how participants assess the different indicators. They were requested to rate the importance of every indicator regarding urban climate resilience on a scale from one (low importance) to five (high importance). Each action field was represented by at least one indicator (Table 1). Besides the rating of indicators, the survey consisted of four chapters: First, some general background; Second, the context of urban climate resilience; Thirdly, the indicators; Fourthly, the possibility of extending the set of indicators by indicators without existing data sources, and some final remarks.

2.3. Workshop Following the Survey

As mentioned previously, the explanatory power of an indicator set of urban climate resilience is hugely dependent on the context, and therefore we discussed the results of the survey again with the 14 projects (see. Figure 1 Phase 6). Moreover, this feedback loop increases the transparency of the process and the robustness of the results. The workshop started with presenting the survey results and then the participants were split into two groups in order to create two independent feedback loops and cross-validation of the indicator set. For each group, a poster was prepared, listing all indicators included in the survey. The indicators that were ranked lower in the survey were written on the poster in light grey (compared to black), for an improved visualization of the survey results. Hence, both groups had the visual results to discuss and were asked to compare each pair in detail and find explanations for the survey results. In addition, the overall set remained visible, which allowed participants to keep the important question of the overall themes in mind. Therefore, indicators could be moved across the set or could become more important if they were deemed a missing piece in the mosaic. The guiding questions for this phase of the workshop were: (1) Are there enough indicators? (2) How many indicators are needed and sufficient? (3) Are the selected indicators the right ones or should they be changed? And (4) are there important gaps in the set that are yet to be filled?

2.4. Finalizing the Indicators Set

In Step 7 (see Figure 1) we analyzed the results of the workshop. Furthermore, expert interviews with practitioners were conducted with the aim to develop indicators in action fields where neither the literature review nor survey and workshop produced results. On this basis, we finalized the urban resilience indicator set.

3. RESULTS

In our review of the academic literature, 19 indicator-based resilience frameworks were analyzed. Based on the indicators of these frameworks a list of 498 indicators (including duplicates) was generated. The indicator list was used as an important starting point for developing the MONARES Indicator Set (MIS). After screening the indicators through the lens of the MONARES-framework, some action fields remained empty and were filled by proposed indicators of the MONARES project-team. One to four indicators were selected per action field in order to cover all topics and include sufficient redundancy. Table 2 shows the selected and proposed indicators.
Table 2. Delineated indicators and action fields.

3.1. Survey about Resilience Indicators

The survey was structured based on the results of Phase 4. The survey (Figure 1 Phase 5) was filled out by 39 respondents within the funding initiative “Climate resilience through action in cities and regions” of the BMBF. The overall mean perceived importance of the indicators was 3.63 within the complete range from one to five. Considering the complexity of the urban system and the interdisciplinary character of the indicator set, this rating was regarded as high. The median of four was also high. The standard deviation of 1.17 together with the entire evaluation range reflected the diversity of interpretations. Nevertheless, despite this diversity, these core numbers show that the indicators were overall judged as important. Splitting the indicators into the five main dimensions (Figure 2), the median shows that only the indicators within the dimension of economy were rated less important, they are rated in the middle of the range, which might indicate a slight indecisiveness.

Table 2. Delineated indicators and action fields.

Dimension	Action Field	Indicator	Code	Literature
Environment	Soil and green spaces	Degree of soil sealing	A_a_1	[31]
		Land consumption	A_a_2	[21]
		Recreational area	A_a_3	[21]
	Water bodies	Share of water bodies	A_b_1	[36]
		State of water bodies	A_b_2	[23]
	Biodiversity	Share of nature conservation and protection areas	A_c_1	[23]
		Wetlands and retention areas	A_c_2	[36]
	Air	Cold air parcels	A_d_1	[23]
Infrastructure	Settlement structure	Density of buildings	B_a_1	[37]
		Accessibility of green spaces	B_a_2	[38]
	Energy	Share renewable energy	B_b_1	[18]
		Diversity renewable energy	B_b_2	[18]
	Telecommunication	Broadband access	B_c_1	[37]
	Traffic	Concept for sustainable traffic	B_d_1	[21]
	Drinking and wastewater	Number of springs	B_e_1	[8]
Economy	Innovation	Innovation index	C_a_1	[37]
	Business	Ratio of insolvencies to start-ups	C_b_1	[22]
	Economic structure	Share of employees in largest sector	C_c_1	[39]
		Employees in research intensive companies	C_c_2	[40]
Society	Research	Number of research projects	D_a_1	[18]
	Knowledge and risk competence	Citizen information about heat, heavy rain and flooding	D_b_1	[37]
		Experience with extreme events in last five years	D_b_2	[37]
	Health care	Accessibility of hospitals	D_c_1	[41]
		Doctors per 10,000 citizens	D_c_2	[40]
	Socio-demographic structure	Share of citizens ABV6/U65	D_d_1	[42]
		Share of employees	D_d_2	[30]
	Civil society	Voter turnout	D_e_1	[42]
		Number of associations	D_e_2	[42]
	Civil protection	Fire brigade	D_f_1	[37]
		Citizens in honorary positions	D_f_2	[31]
Governance	Participation	Number of participation processes	E_a_1	[37]
		Contact point for participation	E_a_2	[37]
	Municipal budget	Depth per citizen	E_b_1	[21]
		Tax income	E_b_2	[21]
	Strategy, plans and environment	Risk and vulnerability analysis	E_c_1	[26]
		Strategies against heavy rain and heat in plans	E_c_2	[26]
		Landscape plan legally binding	E_c_3	[37]
		Climate change adaptation part of urban development plan	E_c_4	[30]
	Administration	Inter-office working group regarding risk, climate change and resilience	E_d_1	[37]
		Climate manager	E_d_2	[37]

Several reasons could explain this, such as that the indicators selected were not covering the dimension in a satisfactory manner or that the dimension is perceived as unrelated to urban climate resilience. Those questions were discussed in the workshop (Figure 1 Phase 6) in detail.

All top five ranked indicators had a median rating of 5. The mean values ranged from 4.4 to 4.6. Only two respectively three respondents did not rate the indicators, showing the general agreement regarding the importance. Nevertheless, regarding the minimum values, all had a large range from 2 to 5.

The set of five indicators in Table 3 shows that the three dimensions environment, governance and society were seen as particular important. The indicator rated as the most important was the environment indicator cold air parcels. Second and fourth ranked were governance indicators, namely inter-offices working groups regarding risk, climate change and resilience and strategies against heavy rain and heat in plans. Third and fifth ranked were two indicators from the dimension society. The respondents saw the importance of experience with extreme events in the last five years and citizen information about heat, heavy rain and flooding as particularly crucial for building urban resilience.

Figure 2. Median importance of indicators grouped into five dimensions.

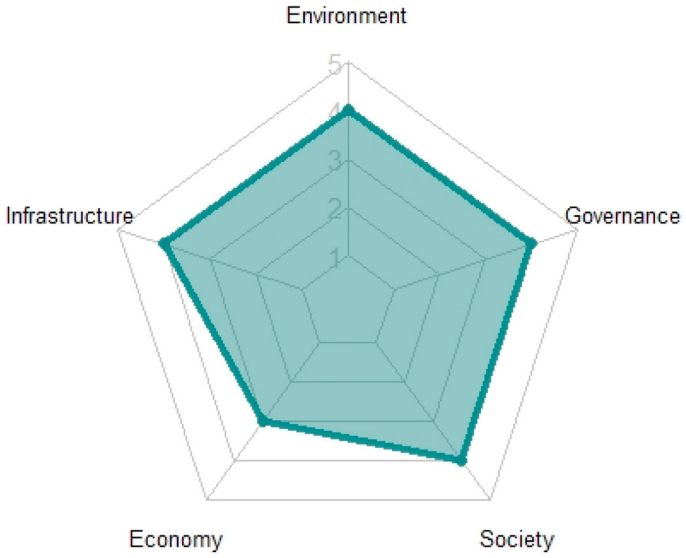


Table 3. The five indicators rated as most important in the survey.

Dimension	Action field	Indicator	Min.	1st Quartile	Median	Mean	3rd Quartile	Max	N/A
Environment	Air	Cold air parcels	2	4	5	4.6	5	5	3
Governance	Administration	Inter-offices working group regarding risk, climate change and resilience	2	4	5	4.5	5	5	2
Society	Knowledge and competence	Experience with extreme events in last five years	3	4	5	4.5	5	5	3
Governance	Strategy, planned and environment	Strategies against heavy rain and heat in plans	2	4	5	4.5	5	5	3
Society	Knowledge and competence	Citizen information about heat, heavy rain and flooding	2	4	5	4.4	5	5	2

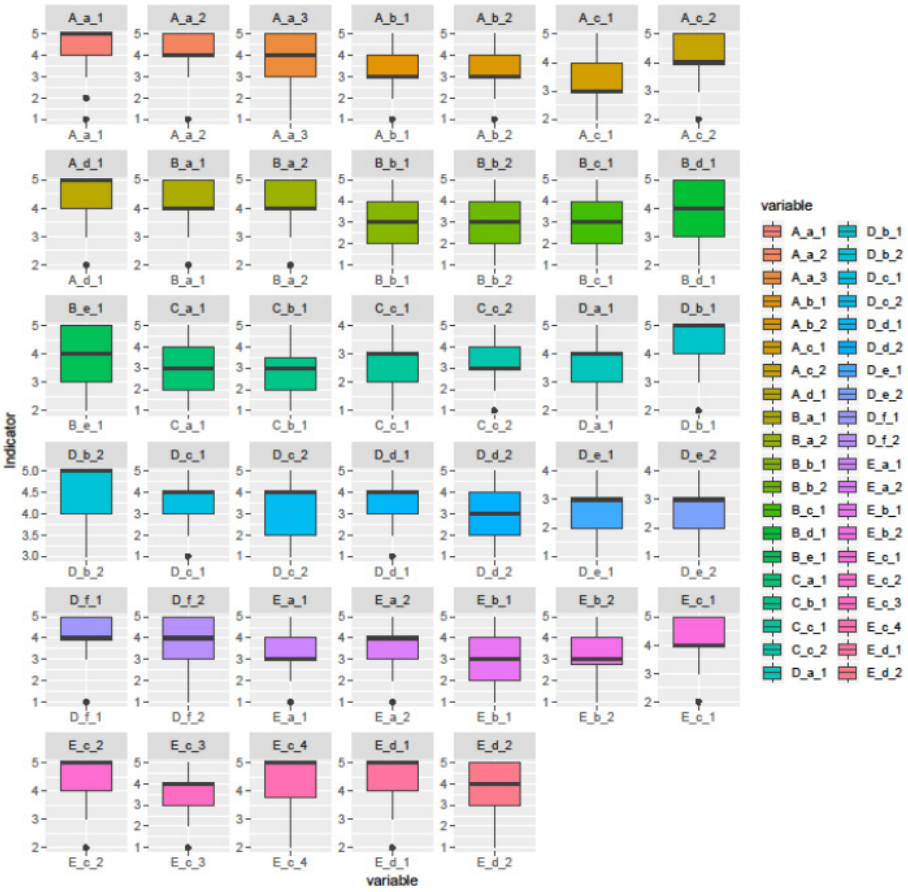
Table 4 displays the five lowest ranked indicators in context of their relevance related to urban climate resilience. The overall lowest rated indicators were both from the society dimension, namely voter turnout and number of associations. The respondents did not think that they were relevant for measuring and monitoring urban resilience. The third lowest indicator was the infrastructure indicator broadband access. Fourth and fifth were two economic indicators measuring ratio insolvencies to start-ups and share employees in largest sector.

Table 4. Five lowest rated indicators.

Dimension	Action field	Indicator	Min.	1st Quartile	Median	Mean	3rd Quartile	Max	N/A
Society	Civil society	Voter turnout	1	2	3	2.4	3	4	1
Society	Civil society	Number of associations	1	2	3	2.6	3	4	2
Infrastructur	Telecommunicatior	Broadband access	1	2	3	2.8	4	5	3
Economy	Business	Ration insolvencies to start-ups	1	2	3	2.8	3.5	5	4
Economy	Economic structure	Share Employees in largest sector	1	2	3	2.8	3	4	6

Figure 3 displays boxplots of all indicators. The main tendency has already been shown in a more condensed form previously in Figure 2. Share of nature conservation and protection areas (A_c_1) was the lowest ranking in the dimension environment. The second indicator of the action field biodiversity, however, received high approval, which emphasised the perceived importance of biodiversity considerations for climate resilience in the urban context. Settlement structure (B_a_1&2) was seen as vital for structural climate change adaptation, similar to the first action fields of soil and green spaces (A_a_1-3).

Figure 3. Box-plots of all indicators included in the survey (see Table 2 for indicator codes). Energy (B_b_1&2) indicators, in contrast, not only ranged from a rating of one to five, but the quartiles of the boxplot also show a comparably high range around the middle of the scale.



3.2. General Workshop Results Regarding the MIS

The discussion of the indicators during two discussion groups yielded important feedback on the overarching attributes and requirements of the MIS. They were mentioned several times from different persons and related to different indicators. Firstly, one important aspect

was the size of the municipality and hence the scaling of the indicator. No universal scaling was found appropriate, since the different units and scales required indicator-specific scaling. Nevertheless, the scaling was seen as an important factor in order to reach the goal of acquiring indicators for municipalities and therefore an interpretable result on this level of administrative organization.

The overall discussion about applicability and feasibility was touched on in many ways from different angles, most prominently regarding data availability, numbers of indicators and total effort needed. The balancing of the loss of information related to simpler indicators or vice versa with more complex indicators with higher explanatory power but with an infeasibility to be handled by the target group was seen as a key challenge. Therefore, the participants agreed that the indicators should be based solely on existing data, thereby reducing the overall effort and simplifying the calculations and data management.

The idea of detailed factsheets describing the data source and calculation of the indicator and helping with the interpretation of the result was raised by participants and received wide support. Factsheets also help to communicate the meaning of an indicator to uninitiated persons, which was also mentioned as a crucial aspect.

The total number of indicators to be feasible was seen at around 25. Certain gaps were identified during the workshop due to the fact that specific expertise related to certain action fields was missing in the room, specifically regarding the action fields energy, wastewater and civil protection. Here, single expert interviews were carried out after the workshop to fill in the gaps.

3.3. Indicator Specific Workshop Results

Table 5 summarizes the process of indicator development during the three phases of the survey, the workshop and ending in the final set of indicators. The indicators highlighted in grey are those of the initial indicator set that were seen as important by survey respondents and therefore stayed on the list. The indicators highlighted in orange were updated or modified as a result of the survey and/or workshop. The yellow indicators were moved from one action field to another. The indicator degree of soil sealing was inverted to degree of unsealed ground, as sealing is not per se negative, even may even be desirable or unavoidable in urban areas. The cold air parcels was seen as an important factor of resilience but should be updated, adding cold air streams to the indicators. Biodiversity was discussed in contradictory ways, as it was not clear to the participants how it is related to climate hazards. Hence, the workshop resulted in representing urban biodiversity with the indicator wetland and retention areas in order to include flood protection arguments into the indicator of biodiversity.

Infrastructure was seen undoubtedly as a key area for achieving urban climate resilience, but also related to secondary data and its inherent complexity most difficult to quantify currently. Accessibility of green spaces was rather seen as an indicator of social justice and less as a settlement structural indicator and hence the second indicator building density, slightly lower ranked in the survey, was included instead. The share of renewable energy indicator focused strongly on climate protection and less on resilience factors, such as robustness and redundancy. These factors were seen to be better covered by the diversity of renewable energy sources. However, it was also argued that even conventional energy should be included in the indicator. This observation was followed by the consideration that no climate resilience can be achieved without climate protection in the long term. Therefore conventional energy sources cannot be regarded as a positive contribution to climate resilience in the long term. The action field of telecommunication was deleted in accordance with the participants' perception of this as being less important than the other action fields, lacking data and having low to no influence of the municipality. Instead, the action field wastewater treatment was included, as there was agreement on its importance additionally to the supply side. No specific indicator was defined in the workshop due to missing competence in this regard. Transportation was discussed as an important action field for municipalities, but participants agreed that its complexity cannot be covered by one indicator. Therefore, the action field remained as an action field of the framework, reminding of the importance of the topic and urging municipalities to consider and discuss it qualitatively.

The discussion around the economic dimension reflected the lower ranking of its indicators in the survey. The dimensions environment and infrastructure were seen to be more naturally linked to resilience than the economic dimension. Nevertheless, discussing the importance of a resilient economy for an urban system generated acceptance for the dimension and its components. This example illustrates one very important lesson of the workshop: the need for explanation and building a common understanding. Innovation was seen to be covered best by the number of employees in research intensive companies not by the innovation index. The tax income from companies was considered an important resource for the financial ability of the municipality to adapt. This indicator was part of the action field municipal budget in the survey and has since been moved to business. Similar to energy, a diverse economy was considered more robust, flexible and redundant when facing uncertainty of climate impacts. It was also discussed whether there might be sectors with crucial or higher relevance than others, but the group agreed that no single sector could be selected.

There was a general agreement on the importance and contribution of society to urban climate resilience, but less agreement on how to measure it quantitatively. Literature shows that the experience with extreme events contributes positively to citizens' resilience. In addition, citizen information about heat, heavy rain and flooding (Table 3) was amongst the top five rated indicators. However, regarding the spatial scale of municipalities, it was argued that information is not only provided by the local authority and therefore the indicator was not further considered. Civil society started an intense discussion on how to measure it and if the proposed indicators were adequate. In contrast to the survey, where the indicator voter turnout ranked higher, the workshop participants disliked this

indicator, arguing that voter turnout nowadays cannot be seen as a proxy indicator for solidarity and community in Germany. The indicator associations was also critically reflected upon as being unable to capture civil society entirely. Still, the participants were in favour of the imperfect indicator associations instead of deleting the action field. In the survey, the dimension governance and its indicators were ranked high, and this result was confirmed in the workshop. Only one change was decided: replacing the contact point for participation processes with the number of conducted participation processes. Both were ranked very close in the survey with a mean of 3.3 and 3.4, respectively.

Table 5. Indicator set after the survey, workshop and final set.

ıension	Action Field	Survey Result	Workshop	MIS
	Soil and green spaces	Degree of unsealed ground	Degree of unsealed ground	Degree of unsealed ground
ronment	Water bodies	State of water bodies	State of water bodies	State of water bodies
	Biodiversity	Wetlands and retention areas	Wetlands and retention areas	Nature conservation and protection areas
	Air	Cold air parcels	Cold air parcels and flows	Ventilation status
	Settlement structure	Accessibility of green spaces	Building density	Building density
structure	Energy	Share renewable energy	Diversity of renewable energy	Diversity of renewable energy
			Per capita energy consumption	Per capita energy consumption
	Water supply and wastewater treatment	Number of springs	Number of springs	Number of springs
			(Including wastewater indicator)	Adapted sewer system
	Innovation	Innovation index	Employees in research intensive companies	Employees in research intensive companies
ɔnomy	Business	Ration insolvencies to start-ups	Commercial tax per capita	Commercial tax per capita
	Economic structure	Employees in research intensive companies	Diversity of business	Diversity of business
	Research	Number of research projects	Number of research projects	Number of research projects
ɔciety	Knowledge and risk competence	History with extreme events	History with extreme events	History with extreme events
	Health care	Accessibility of hospitals	Accessibility of hospitals	Number of doctors
	Sociodemographic structure	Share of citizens ABV6/U65	Share of citizens ABV6/U65	Share of citizens ABV6/U65
	Civil society	Voter turnout	Associations per 10000 capita	Associations per 10000 capita
	Civil protection	Fire brigade	Fire brigade	Fire brigade volunteers
	Participation	Contact point for participation	Number of participation processes	Number of participation processes
ernance	Municipal budget	Depth per citizen	Depth per citizen	Depth per citizen
	Strategy, plans and environment	Risk and vulnerability analsysis	Risk and vulnerability analsysis	Risk and vulnerability analsysis
		Strategies against heavy rain and heat in plans	Strategies against heavy rain and heat in plans	Strategies against heavy rain and heat in plans
	Administration	Inter-offices working group regarding risk, climate change and resilience	Inter-offices working group regarding risk, climate change and resilience	Inter-offices working group regarding risk, climate change and resilience
		updated	switched action field	no change

3.4. Urban Climate Resilience Indicator Set

Since even the diverse group of participants of the workshop did not cover all topics of the indicator set, experts were interviewed. Furthermore, the results of the survey and the results of the workshop were summarized and merged.

The final set of indicators is shown in Table 5 in the column MIS. Compared with the workshop set, the action field of biodiversity was seen crucial in its own right and better approximated by the indicator nature conservation and protection areas. Moreover, wetlands and retention areas were already covered by the state of the water bodies in line with the European Water Framework Directive regarding good ecological and chemical status. Hence, in order to create a balanced set of indicators, it was seen that the latter indicator added thematically more information and another aspect to the overall set. Secondly, the air action field was further developed, as cold air parcels and flows was difficult to interpret. The simple number or share of cold air parcels and streams were not clearly related to resulting air status. The ventilation status including the effects of air streams and cold air production parcels was therefore selected. For the wastewater action field introduced by the workshop, an expert interview recommended the indicator share of adopted sewer system. Another interview was conducted with the lower civil protection agency. The interviewee stressed the importance of

volunteers across organizations, but as no data were gathered assessing the total numbers of volunteers, the most important one of the fire brigade was considered. Moreover, the municipality may have to consider this important topic even more in the future, as the principle of volunteers may be endangered due to demographic development. Finally, yet importantly, the accessibility of hospitals was interchanged with the density of doctors.

4. DISCUSSION

The results from the work on indicators for monitoring urban climate resilience presented above yields a number of important insights and implications—with respect to previous studies but also for future research and for practitioners in this field.

Existing indicator sets are a good starting point, but adapting and extending them for the context at hand is crucial. There are numerous indicator sets for urban resilience; these provided a good basis from which the MONARES indicator set could be developed. However, many of the indicators analysed in the literature review were aimed at the context of developing countries. To adapt indicators identified in the review for the German context, four steps were important: (A) Disregarding indicators that do not allow sufficient distinction between cities, e.g., literacy rate is favoured as an indicator in many sources, but in Germany the literacy rate is rather high and differences between cities are marginal. (B) Disregarding indicators for which the data availability was rather limited in Germany. (C) Adding new indicators for action fields that are deemed important in the context of MONARES but which were not touched upon in the literature. (D) Focusing on municipalities as the key player for climate change adaptation. These level of municipalities require the set to be manageable in terms of data availability as well as size and complexity of the calculations.

Step A did not pose any major difficulties. Further, step B based on research concerning data availability did not cause problems. However, step C and D need to be examined in more detail.

First, the workshop clearly stated here the conflicting goals when discussing single action fields. It was felt that one indicator does not reflect the entirety of the topic, but at the same time all action fields were considered important and the total number of indicators should not exceed around 20, in order to stay manageable, which is far less than the proposed 52 indicators by the City Resilience Index (CRI) [22] and comparable to the core of 14 by the project Building Resilience Amongst Communities in Europe (embrace) [37] or Cutter's [43] core of 22. Since researchers, as well as practitioners, participated in our workshop, we had the impression that researchers tended to prefer larger, encompassing indicator sets. Compared with the scientists, practitioners were more in favour of concise and compact sets. The discussions in the workshop showed that persons with a research background had numerous ideas for new indicators for all dimensions, and advocated for their inclusion. During the workshop and its aftermath, practitioners working in municipalities displayed a different tendency—their perspective tended to focus more on how to handle the indicators in practice. Hence, what some researchers considered a concise indicator set was perceived by practitioners as overwhelming and too extensive. In order to find an adequate balance between a broad coverage and good usability in practice, it is important to involve both researchers and practitioners in the development of an indicator set. This finding is consistent with the literature and is one strength of the current study. Meerow and Stults [13], for example, stress the need for including practitioners in the process. Consequently, the trade-off between practicability and completeness had to be balanced, leading to the fact that some indicators that were considered important were still sorted out in order to cover all action fields and still achieve a manageable amount of indicators.

Second, it was mentioned that the indicators just by title were not clear in terms of their effect on and relation to urban climate resilience, and were consequently rated around the middle. This fact was considered while developing the survey, but an in-depth explanation of indicators was removed from the survey in favour of including more indicators covering all action fields and in consideration of the time needed to fill out the survey. However, this lack of explanations meant that the disciplinary background of respondents affected the ratings.

Third, indicators from the dimension environment were met with relatively high consensus while indicators from the dimension economy were faced with more diverging opinions. The indicator selection was dependent on the conceptualization of urban resilience and the urban context. The results contribute to the gap between the understanding of urban resilience by scholars and practitioners [13]. This became apparent both in the survey and the workshop and shows that more research is warranted on what characterizes a climate resilience urban economy. Supporting evidence for this can be taken from the fact that much more has been published on climate resilience and environmental issues than on climate resilience and economic issues. Moreover, this discussion displayed the importance of a negotiation-focused approach for defining place-specific attributes of urban resilience and its measures [44].

Fourth, secondary data was seen as crucial for monitoring purposes in order to reduce resource expenditure by the administration. In other words, "The best indicator is inoperable if there is no feasible way to obtain the required data." [37]. Moreover, there was a strong request from the local administrations for more provision of data from the higher administrations. They argued that data handling, data collection and finances for these activities are lacking. They stressed the need for data provision to be handled at the higher level of administration to avoid scaling and data comparability issues. Hence, data availability for indicators on a municipal level is a strong limiting factor, especially when it comes to indicators concerning infrastructure and social aspects [45]. Parts of the infrastructure related to energy, transport and communication are owned or organized by entities on a higher administrative level, such as the national

government or by private entities. This tends to lead to limited data availability when it comes to data with a sufficient resolution on a municipal level. Here it would be favourable if entities in charge of the respective infrastructure made access to data easier and provided data with a resolution that is suitable for analyses on a municipal level. Moreover, the discussion centred around technical measures and physical impacts and less about social drivers and demographic changes. The latter are seen as core aspects of the community's ability to resist unforeseen threats. Nevertheless, the intense discussion around the proxies suggested by literature displayed vividly the intricacy of social dynamics. New data and methods from the higher administration or crowd-sourced databases are needed to better understand and monitor the indicators [43].

Fifth, it is important to mention that a conflict of goals among indicators can arise and can lead to a competition for the scarce resources. These reciprocal processes cannot be completely avoided. For example: impervious surfaces are seen negative regarding heavy rain, fresh air and heat island effects, but they are necessary for a redundant infrastructure and other urban functions. Another example is provided by Meerow and Newell [35] who analysed the negative correlation of park access and stormwater management goals, concluding that resilience measures create winners and losers. This also requires transparency of the data and the method of the indicator definition to understand the root causes of the conflicting goals and find adequate solutions. Here the Rockefeller [22] approach seems like a black box because it is difficult to deduce what adaptation measures are used as a data basis, and indicator calculations are unclear. During the workshop, several practitioners mentioned consequently the necessity of transparency and the need for precise communication and non-scientific language.

Sixth, following the previous point, many indicator approaches are used to build a composite index for resilience [19,22,45,46,47], vulnerability [18,48,49,50,51,52] or risk [53,54,55]. Specifically, at the scale of urban resilience, indexing across the multitude of action fields was discussed critically. The different scales, topics and units appeared to not be logically linkable. Moreover, a combined index value was seen to not tell much about the level of resilience. It was seen as more important to see the contribution of each action field to the overall resilience. Also, considering the next step of adaptation measures, it is more relevant to have a resilience profile displaying specific topics to be addressed in the municipal context.

Working at the science-policy interface was challenging for all sides. The mixed method approach proved invaluable in finding a common language, tolerance and understanding. This created an environment that allowed for constructive criticism, which is indispensable for finding a compromise.

5. CONCLUSIONS

In this study, we developed an indicator set to measure and monitor urban climate resilience for municipalities, thereby assessing the requirements of indicators and implementing a method for adapting global approaches to the local context.

The mixed method approach proved to be essential for the process of indicator development. It provided an adequate frame and time to develop a mutual understanding across disciplines, researchers and practitioners, which is needed in order to select indicators or accept indicators from different fields of expertise. Transparency in the process and the inclusion of feedback builds acceptance and trust. The concept of resilience provided the required assembly hall and saw climate change as the imperative. Even the often-criticized ambiguity of the resilience concept was helpful as it created room for discussion. The number of 24 indicators based on secondary data balanced as well as possible the diverging interests. Amongst the indicators, conflict of goals is unavoidable. Making the conflicts visible is a helpful basis for making informed decisions, which is a strength of this indicator set. In general, the softer and more qualitative aspects of resilience are challenging. They were seen as crucial but very hard to assess by quantitative proxies based on secondary data. Still, representative surveys to cover them in more detail on a regular basis were rejected by municipalities as too expensive and labour-intensive.

Developing an indicator set tends to be easier than assessing the significance or validity of an indicator over time and it requires an extended period of observations to be able to make statements about the significance of a certain indicator. Nevertheless, in order to advance this field of research, it is necessary to pursue this path and start inquiries into the significance or validity of the numerous indicators that are permeating the ongoing discussions. In further research, the indicators need to be tested in reality, and there needs to be more research that addresses the validation of the indicators.

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Subjective Measures of Household Resilience to Climate Variability and Change: Insights from a Nationally Representative Survey of Tanzania

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ABSTRACT

Promoting household resilience to climate extremes has emerged as a key development priority. Yet tracking and evaluating resilience at this level remains a critical challenge. Most quantitative approaches rely on objective indicators and assessment frameworks, but these are not fully satisfactory. Much of the difficulty arises from a combination of conceptual ambiguities, challenges in selecting appropriate indicators, and in measuring the many intangible aspects that contribute to household resilience. More recently, subjective measures of resilience have been advocated in helping to overcome some of the limitations of traditional objective characterizations. However, few large-scale studies of quantitative subjective approaches to resilience measurement have been conducted.

In this study, we address this gap by exploring perceived levels of household resilience to climate extremes in Tanzania and the utility of standardized subjective methods for its assessment. A nationally representative cross-sectional survey involving 1294 individuals was carried out by mobile phone in June 2015 among randomly selected adult respondents aged 18 and above. Factors that are most associated with resilience-related capacities are having had advance knowledge of a previous flood, and to a lesser extent, believing flooding to be a serious community problem. Somewhat surprisingly, though a small number of weak relationships are apparent, most socio-demographic variables do not exhibit statistically significant differences with regards to perceived resilience-related capacities. These findings may challenge traditional assumptions about what factors characterize household resilience, offering a motivation for studying both subjective and objective perspectives, and understanding better their relationship to one another. If further validated, subjective measures may offer potential as both a complement and alternative to traditional objective methods of resilience measurement, each with their own merits and limitations.

Keywords: measurement; perceptions; resilience; subjective

INTRODUCTION

Resilience measurement has soared to the top of the development agenda (Frankenberger et al. 2014). As a result, researchers have proposed many frameworks and methods seeking to quantify the resilience of different social systems, whether at household, community, or national levels (Elasha et al. 2005, Twigg 2009, USAID 2009, Constas and Barrett 2013, Nguyen and James 2013, D'Errico and Giuseppe 2014). To date, most of these methods have focused on objective indicators and approaches, often centered on observing key socioeconomic variables and other types of capital that support people's livelihoods (Bahadur and Pichon 2017). More recently, the advantages of subjective approaches to measuring social systems have been advocated (Marshall and Marshall 2007, Jones and Tanner 2015, Lockwood et al. 2015, Maxwell et al. 2015, Béné et al. 2016a,b). These methods may offer the opportunity to address many weaknesses that beset traditional objective approaches, such as difficulties with indicator selection, a lack of attention to context specificity, and an inability to take people's knowledge of their own resilience into account.

However, few quantitative standardized assessments of subjective resilience have taken place (Marshall 2010). As such, little is known about their feasibility as a resilience measurement tool and how they compare with traditional objective methods, particularly when applied at scale. Accordingly, in this study, we propose a simple tool that seeks to measure 'subjective resilience' at a household level alongside numerous characteristics that often form part of objective assessments of resilience. We subsequently apply this tool to investigate the following research question: Is subjective resilience connected to particular socio-demographic characteristics of households, and if so, which ones?

In doing so, we seek to analyze the relationship between objective indicators generally used to signal resilience (or a lack thereof) and subjective assessments. If the relationship is weak, this has several potential implications. It could suggest that a more comprehensive assessment of resilience requires accounting for a broader range of objective characteristics, which may in turn suggest additional policy levers that could enhance resilience. Alternatively, it could suggest that intangible characteristics that are difficult to quantify shape resilience-related perceptions or indeed that subjective measures may not reflect overall resilience well. If the relationship is strong, then this could indicate that subjective measures, which require far fewer resources to administer, could be a useful proxy for

(or used alongside) objective measures, for example, between rounds of an extended household survey; and that information about the relative influence of the objective measures on subjective resilience could enhance objective approaches, for example, by suggesting 'weights' that could be used in multidimensional indices.

To address the research question, we present results from a nationally representative survey focused on the subjective resilience of households to flood risk in Tanzania. To our knowledge, this is the first time that such a tool has been applied nationally. We propose survey questions to explore key resilience-related capacities, namely the capacities to prepare for, cope with, and adapt to future flood risk. We then assess how these capacities vary across socioeconomic characteristics to understand how subjective resilience is manifest across different household profiles. The choice of methods and wording of questions used in this study leans on earlier theoretical work by Jones and Tanner (2017), who explore the merits and limitations of assessing subjective resilience at the household level. It also draws on related methodological insights from earlier work by Marshall and Marshall (2007) and Maxwell et al. (2015) that use similar survey-based approaches to examine subjective resilience: the former proposes a method of subjectively measuring 'social resilience' in coastal communities in Australia, while the latter sets out principles and guidelines for the subjective measurement of resilience. Based on these exercises, we provide insights into the factors that are associated with subjective assessments of household resilience in Tanzania and compare these with traditional assumptions, those based largely on objective markers. Last, we present future avenues for the methodological refinement and testing of subjective approaches to household resilience.

BACKGROUND AND CONTEXT

Resilience has its roots in several different disciplinary fields, ranging from mechanics to ecology and psychology (see Alexander 2013 for a comprehensive historical overview). However, the term's more recent adoption across the sustainability sciences has bolstered its popularity amongst academic and policy communities alike. Indeed, resilience now forms a central pillar in many key international policy frameworks such as the United Nations' Agenda 2030, Sendai Framework for Disaster Risk Reduction, and Paris Agreement (United Nations 2015a,b,c). Though the utility of a broad resilience framing has brought many benefits, it has also contributed to definitional and conceptual inconsistencies in its use (Olsson et al 2015). For example, early framings of resilience in describing social systems leant heavily on ecologic frameworks and revolved around the capacity to absorb change and disturbance in order to maintain core functions (Holling 1973, Walker et al. 1981, Odum 1985). Subsequent thinking within the field of social-ecological systems has challenged these frames when applying resilience to understand human responses to climate risk, encouraging greater recognition of the ability of social groups to adapt and change their core structure and functions (Berkes et al. 2002, Walker et al. 2004, 2006, Folke 2006, Bollettino et al. 2017). In some cases, it is argued that the complete transformation of a system may be a necessary component of a resilience process (Kates et al. 2012, Aldunce et al. 2015).

Nevertheless, there is broad agreement across disciplines that resilience comprises a range of evolving capacities and processes rather than constituting a static state (Maguire and Cartwright 2008). For example, in the context of community resilience to disaster risk, Norris et al. (2008) propose that resilience can be broken down into three core capacities: robustness (the strength of a system's resources); redundancy (the extent to which elements are substitutable in the event of disruption or degradation); and rapidity (how quickly the resource can be accessed and used). Béné et al. (2012) propose a framework consisting of the capacities to absorb, adapt, and transform. Many other such frameworks exist. However, agreement over the exact characterization of resilience is missing amongst the wider literature. These conceptual distinctions matter not only because the capacities needed to support them are different, but because they present a fundamentally different conceptualization of what a resilient system constitutes: "Such wide meanings may end up being contradictory as in the notion of 'restoring equilibrium and getting away from it by moving to a new state'" (Alexander 2013, as cited in Olsson et al. 2015:22).

As such, properties such as coping, adaptive and transformative capacities are often used in different ways and in different combinations when framing resilience (Bahadur and Pichon 2017). Indeed, they are frequently used interchangeably with resilience itself (Olsson et al. 2015). This lack of definitional and conceptual agreement presents challenges when seeking to track and measure resilience, but these difficulties notwithstanding, a wide range of measurement toolkits have emerged in recent years (Constas and Barrett 2013, FAO 2016, Frankenberger et al. 2014, Béné et al. 2016a).

Most efforts to measure climate resilience use objective criteria, socioeconomic indicators and processes that are considered to support a household's ability to deal with risk (Schipper and Langston 2015). "Objective," in this context, tends to denote framings of resilience that are based on external judgement and verification (Maxwell et al. 2015). Such approaches tend to be guided by an overarching conceptual framework, usually designed by technical experts or those external to the individual or household themselves, though sometimes these draw on qualitative inputs from intended communities or the piloting of survey instruments (Jones and Tanner 2017). Yet there is no universal acceptance on how resilience can and should be measured and hence a plethora of different objective frameworks and indicator lists exist, some contrasting markedly (Constas et al. 2016).

One widely used example is the United Nation's Food and Agriculture Organization (FAO) Resilience Index Measurement and Analysis model (RIMA), which combines socioeconomic variables from five dimensions: access to basic services; assets; adaptive capacity; social safety nets; and sensitivity to shock. These are then further broken down into dozens of individual indicators (D'Errico and Giuseppe

2014). Given that RIMA is centered around a predefined framework primarily based on wider resilience literature, has a list of expert-derived indicators for each characteristic, and relies on extensive surveys to collect externally verified information on household socioeconomic conditions (FAO 2016), the approach can be readily classified within the objective camp of measurement tools.

Objective measurement approaches such as RIMA have many strengths, including the ability to generate composite scores of resilience that can be readily compared across households. However, they also present several clear limitations. Most notably, they rely heavily on predefined resilience characteristics and standardized indicators. This renders it challenging to capture the context-specific nature of resilience: factors that make a coastal fisher in coastal Kenya resilient are unlikely to be the same as those for a pastoralist in the northeastern drylands of Kenya. In addition, objective approaches operate on the basis that resilience can be externally determined. Such approaches favor structural determinants at the expense of those based on human agency, which may be harder to understand and measure (Tanner et al. 2015). Crucially, they do not take into account people's knowledge of their own resilience and how they evaluate their lives. Thus, objective evaluations often require value judgements in generalizing the factors that are assumed to make others resilient and simplifying the complex nature of resilience across differing contexts. Ironically, these value judgements mean that many so-called "objective" approaches to resilience fall short on their own terms. Despite the limitations, objective approaches to resilience measurement remain the norm and dictate to a large degree our understanding of resilience processes at all scales.

Though yet to be fully explored in both conceptual and practical terms, subjective methods may offer an alternative and complementary approach to objective assessments of resilience (Marshall and Marshall 2007, Nguyen and James 2013, Jones and Tanner 2015, Maxwell et al. 2015, Béné et al. 2016a,b, Seara et al. 2016). Subjective evaluations are often used to gain bottom up and grounded insights into people's own understandings of resilience and its components. A significant body of literature has sought to understand subjective elements of household resilience (Twigg 2009, Buikstra et al. 2010, Gaillard 2010, Miller et al. 2010). The vast majority of this work is based on qualitative assessments, typically based on ethnographic case studies, interviews, and focus groups or participatory rural appraisals (PRA). Although these approaches provide tremendous value, particularly in allowing for depth and nuance, they are difficult to use as a basis for measuring resilience at scale or across contexts. We are concerned with a branch of subjective resilience consisting of standardized and quantifiable methods for evaluating perceived resilience.

At its simplest, subjective household resilience relates to an individual's cognitive and affective self-evaluation of the capabilities and capacities of their household, community, or any other social system to respond to risk (Jones and Tanner 2015). If care is taken to design suitable methodologies and survey questions, then a household's subjective resilience can, in theory, be readily quantified. Standardized subjective indicators can be measured in many ways. Perhaps the most evident and practical way of collecting standardized data is through large household surveys. Although open-ended questions might provide rich qualitative detail, closed-ended questions are more likely to enable the aggregation of scorings of resilience capacities and to facilitate comparison across social groups or time (OECD 2013). Indeed, insights and research from related fields, such as subjective well-being, risk perception, and psychological resilience suggest that that standardized subjective evaluations may help to capture many "softer" elements of resilience-related capacities; allow comparison across different contexts; and permit individuals' knowledge of the factors that contribute to their own resilience to be incorporated (Jones and Tanner 2015).

Despite its clear potential, relatively little is known about how people evaluate their own resilience using standardized subjective measures, nor whether factors traditionally associated with objective household resilience match those from subjective self-evaluations when assessed at scale. For this reason, in this article we seek insights into these research gaps.

We focus on a subset of resilience: household resilience to climate extremes. Multiple epistemological entry points for climate resilience exist, though most objective measurement frameworks break the concept down into a common series of distinct yet interrelated characteristics (Schipper and Langston 2015). Properties such as the capacity of a household to prepare for and reduce the impact of climate extremes (Bahadur et al. 2015); absorb and cope with disturbances; and modify and adapt structures in accordance with changing climatic stimuli (Jones et al. 2010) each commonly feature within the literature. However, myriad other properties and combinations thereof surface in each framework, and each also relies on different interpretations of resilience and its constituent processes and indicators (Schipper and Langston 2015). Identifying a common set of observable indicators that relate to a household's capacity to recover from climate extremes, or their ability to adapt to ever-increasing climate risk has so far proven difficult (Cutter et al. 2008). This is not least because many factors that contribute to resilience-related capacities are process driven and relatively intangible (Jones et al. 2010). For example, self-efficacy, social networks and cohesion, power and marginalization, and risk tolerance each help to determine a household's resilience (Adger et al. 2013, Béné et al. 2016b). For this reason, we believe that a subjective approach may have value in assessing resilience in this specific context.

METHODOLOGY

Conceptual approach

To explore the feasibility of assessing subjective resilience quantitatively and its links to objective characteristics that often feature in resilience measurement, we added a module of close-ended questions to a nationally representative longitudinal telephone survey in

Tanzania. To narrow the focus, we concentrated our survey questions on household-level disaster resilience, more specifically, resilience to flood risk.[1] Our survey was based on a standardized and widely used framing of climate resilience (Aldunce et al. 2015, Bahadur et al. 2015), comprising of three core capacities.

The first capacity used in our subjective framework relates to a household's ability to prepare, more specifically, to anticipate and reduce the impact of climate variability and extremes through preparedness and planning, often by making use of relevant information and early warning (Bahadur et al. 2015). The second capacity relates to a household's ability to recover. This is primarily associated with its ability to absorb and cope with the impacts of climate variability and extremes, often through maintaining core functions or livelihood activities (Sundres and Birnbaum 2003, Folke et al. 2010). The third capacity relates to a household's ability to adapt, more specifically, to adjust, modify, or change its characteristics or actions to moderate potential damage or take advantage of new opportunities that arise (Jones et al. 2010).

We administered a single question to address each of these three capacities (Table 1). The three items are conceptually distinct, well understood by respondents, easy to use and, as we show below, were found to be relatively independent of one another. Each capacity question used a standardized unipolar Likert scale with four response alternatives. The approach builds on methods used to assess social resilience in individual communities (see Marshall and Marshall 2007, Nguyen and James 2013, Seara et al. 2016), as well as similar approaches used to evaluate subjective capacities in related fields such as subjective well-being (OECD 2013), risk perception (Mills et al. 2016), and psychological resilience (Connor and Davidson 2003).

Table 1. Resilience-related questions administered through the national survey.

Component of interest	Survey question	Response items
Enumerator introduction: "First we would like to ask you about what would happen if an extreme flood affected your community in the near future. By extreme flood, I mean one that is likely to affect your household, or harm your dwelling, fields, or resources."		
Capacity to prepare	If an extreme flood occurred, how likely is it that your household would be well prepared in advance?	4-point scale: (1) Extremely likely; (2) Very likely; (3) Not very likely; (4) Not at all likely.
Capacity to recovery	If an extreme flood occurred, how likely is it that your household could recover fully within 6 months?	4-point scale: (1) Extremely likely; (2) Very likely; (3) Not very likely; (4) Not at all likely.
Capacity to adapt	If extreme flooding were to become more frequent, how likely is it that your household could change its source of income and/or livelihood, if needed?	4-point scale: (1) Extremely likely; (2) Very likely; (3) Not very likely; (4) Not at all likely.
Enumerator introduction: "Finally, I'm going to ask you about your household's experience of flooding over the last two years."		
Severity	In the last two years, how serious a problem has flooding been to your household?	4-point scale: (1) The most serious problem; (2) One of the serious problems of many; (3) A minor problem; (4) Not at all a problem
	In the last two years, how serious a problem has flooding been to your community?	4-point scale: (1) The most serious problem; (2) One of the serious problems of many; (3) A minor problem; (4) Not at all a problem
Early warning	Please think about the last extreme flood that affected your household. Did you know about it in advance?	3-point scale: (1) No; (2) Yes; (3) Household not affected by a flood in the last two years

Although each capacity question is administered via a single-item, as per the approach adopted by Béné et al. (2016a,b)[2], we see resilience as multidimensional; therefore it is not amenable to being measured via a stand-alone question. It is important to underscore that none of the three capacity questions should be interpreted as representing resilience overall; it is for this reason that we refer to them as "resilience-related capacities" throughout. Instead they should be considered to represent several core functions deemed necessary to support household resilience.

This study is primarily exploratory. Although we seek to test a research question, given this is a novel area of academic interest with few other studies applied at the national level, we are primarily interested in understanding the dynamics of subjective resilience and working toward further validation and refinement of the tools applied. We hope that future work can build on these research insights and seek more confirmatory and experimental approaches, including the use of scales with numerous, replicative items (see Jones 2017).

Survey instrument

The questions were administered via a nationally representative survey in Tanzania, namely the Sauti za Wananchi (Voices of Citizens) longitudinal survey managed by the Tanzanian nongovernmental organization Twaweza and surveying company Ipsos Synovate. The survey is composed of two phases. First, a baseline survey was carried out through traditional face-to-face interviews using a multistage stratified sampling approach (Twaweza 2013). A sample of 2000 households in 200 enumeration areas were surveyed in October 2012, using a sampling frame designed to be representative of the Tanzanian population aged 18 years and older based on the 2012 Tanzania Population and Housing Census (NBS 2013). At this point, all households were given a mobile phone and solar charger. The second phase consists of a series of mobile telephone surveys with the same sampled households as in the baseline (Details of

surveys to date and the datasets are available at http://www.twaweza.org/go/sauti-za-wananchi-english).

In the round associated with this paper's results, the survey focused on assessments of political leadership. Resilience-related questions were included in an add-on module.[3] Respondents were contacted in July 2015 to take part in the survey through a computer aided telephonic interview (CATI) operated via an Ipsos Synovate managed call center in Dar es Salaam. A total of 1335 respondents out of the potential 2000 from the initial baseline completed this wave of the survey.[4] Questions were administered in Swahili and English, with a small financial incentive provided to respondents for their participation (US$0.5 mobile airtime credit). For full details of the sampling procedure, weighting, and data collection see (Twaweza [date unknown]). For 1334 of the respondents, a wide array of socio-demographic data from the 2012 baseline are available, as well as responses to the resilience questions listed above.[5] We removed an additional 40 of these respondents from the dataset because it was not certain that the same person replied as in the baseline, leaving 1294 matched observations.[6]

In the analysis, we describe the characteristics of our sample and then present descriptive statistics on their reported resilience-related capacities, followed by multivariate analysis. Because the ordinal variables measuring resilience-related capacities are not normally distributed, we test the equality of proportions rather than means.[7] In the multivariate analysis, we used ordinal logistic models in which we regressed resilience-related scores—the extent to which respondents reported it was likely they could prepare for, adapt to, or transform their livelihoods in the event of severe flooding—on a range of objective controls to test whether these individual variables were independently able to predict levels of perceived household resilience. Independent variables included the age, gender, education, and household size of respondents, whether they were occupied in farming and whether they lived in an urban or rural area;[8] the wealth quintile of the household (using an asset index); and whether the household had previous experience of a flood, believed flooding to be a serious problem for their community, and whether they had known about the last flood that affected them (within the previous two years) in advance.[9] Given the regressors are the same across these models, we use a seemingly unrelated estimation technique to account for the correlation in the error terms (Weesie 1999, StataCorp 2013).

Sample characteristics

Our respondents to the survey were primarily household heads (98%), the majority of whom were male (57%).[10] They were primarily rural (65%) and occupied in farming (also 65%). We defined household wealth status according to an asset index that places households into quintiles.[11] Some 93% of households in the poorest asset quintile were in rural areas compared with about 16% of households in the richest asset quintile. Most respondents had a completed primary education (61%) whereas around 13% had at least some secondary education, 3% had a higher education, and just under 10% had no formal education. The mean age of respondents in our sample was 40 years, 37 for females and 42 for men, with a range of between 18 and 89 years old.

RESULTS

Experience of floods and perception of risk

Respondents were asked to report their previous experience of extreme flooding (see Table A1.1.[12]). Overall, 32% reported having experienced at least one such event in the past two years. Among respondents with recent experience of severe flooding, 26% reported having had advance warning before the flood. Respondents were also asked how serious a problem extreme flooding was, independently of whether they had recently experienced a flood. Most did not report flooding as a serious concern either for their households (86%) or for their communities (71%; Fig. A1.1). However, respondents from households that had experienced a flood in the previous two years were far more likely to perceive flooding as problematic; close to 40% of the exposed population reported flooding as a serious problem or the most serious problem for their household and over half (54%) reported it as serious or most serious for their community, compared with 2% and 17% of those who had not been exposed to a recent flood, respectively. This is in line with previous studies finding experience of past flooding as a strong contributing factor to risk perception (Mills et al. 2016). There were no other socio-demographic cleavages, except that respondents from asset poor households were more likely to believe flooding was serious for their communities.

Among respondents with recent flood exposure, those who had early warning of that flood were more likely to perceive it as a serious problem, both for their households and their communities, than those who had not (Fig. A1.2). Some 57% and 67% of the population who had received advance warning of a previous flood perceived flooding to be a serious threat to their households and communities respectively, compared with 33% and 49% of those that did not have an early warning.

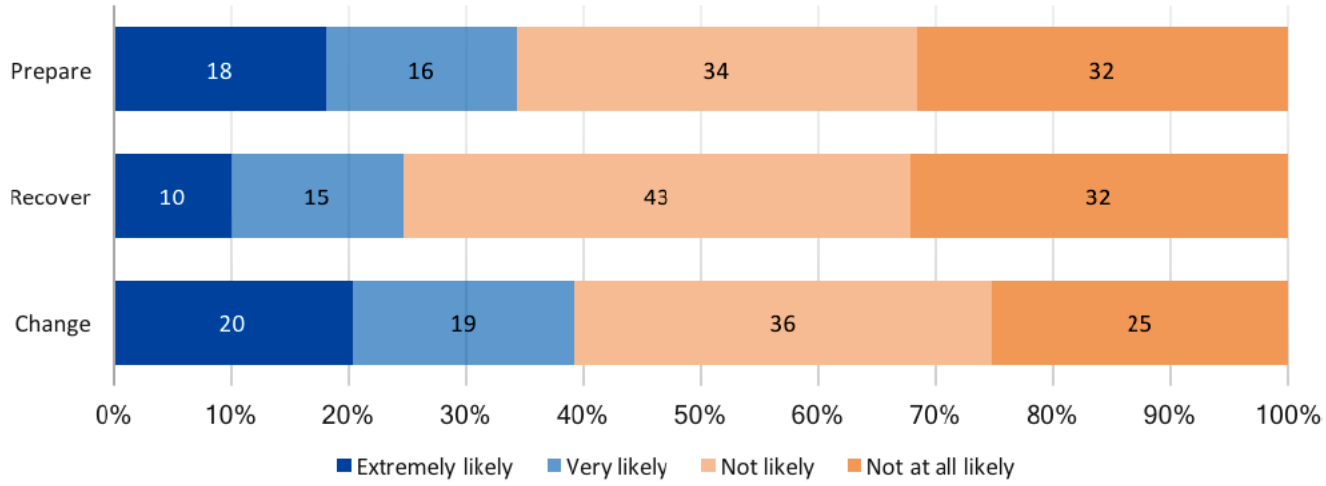
Perceptions of resilience and association with experience and perception of risk

Respondents assessed their perceived capacities to prepare for, recover from, and change their livelihood strategy in response to an extreme flood event. Most respondents reported a low perceived ability to prepare, recover, or change. Just one-third of the population reported that their households would be prepared in the event of a flood, one-quarter felt their households were capable of recovering fully within a six-month period, and 4 in 10 people felt their households could change their source of income/livelihood, if needed (Fig. 1).

Association between dimensions of resilience-related capacities

Examination of the relationship between the three capacities reveals that they are only moderately associated. For example, 53% of respondents who said they were likely to be prepared also said they were likely to recover, compared to just 10% of those who were unlikely to be prepared. Odd ratios show that respondents who were likely to prepare were five times more likely to recover compared to respondents unlikely to prepare (Fig. A1.3). Nevertheless, when using the four-point Likert scale, the rank order correlations among

Fig. 1. Subjective self-evaluations of resilience-related capacities to extreme flooding in Tanzania.



these three types of capacity were all less than 0.5 (Fig. A1.4). The highest correlation (0.45) is between reporting being able to prepare for a flood and to recover from it; while the lowest (0.25) is between being able to recover from a flood and to change one's way of life in response to it. We also constructed binary variables (likely/unlikely) and found very similar correlations.

We examined whether these items could be combined to form an index of a latent construct of resilience. The three items did not meet the established threshold for internal consistency (Cronbach's alpha is 0.62, below the commonly accepted threshold of 0.7). However, item selection was also tested by principal components analysis that showed that the three items loaded strongly onto one variable with an eigenvalue higher than 1 (the threshold recommended by Kaiser's rule; Fig. A1.5). This gives some support for constructing an index of perceptions of resilience; however, in this paper we focus on analysis of the three components individually to obtain more insights into factors that are associated (or not) with each. We defer discussion of the value of a composite index for future work.

Factors associated with perceptions of resilience

We analyzed the three resilience-related capacities across a range of variables of interest (Figs. 2 and 3, Tables A1.1–A1.6). Male and female respondents provide very similar responses across the board, though this may not be surprising given that the survey deliberately asks respondents to rate household-level capacities, not individual ones. Fewer farmers than nonfarmers (and people in rural versus urban areas) report an ability to recover fully from an extreme flood event within six months. Responses are very similar across occupations and rural/urban zone with respect to the perceived capacity to prepare for and adapt, though a lower share of farmers and rural residents report that it is "extremely likely" that they would adapt to an extreme flood.

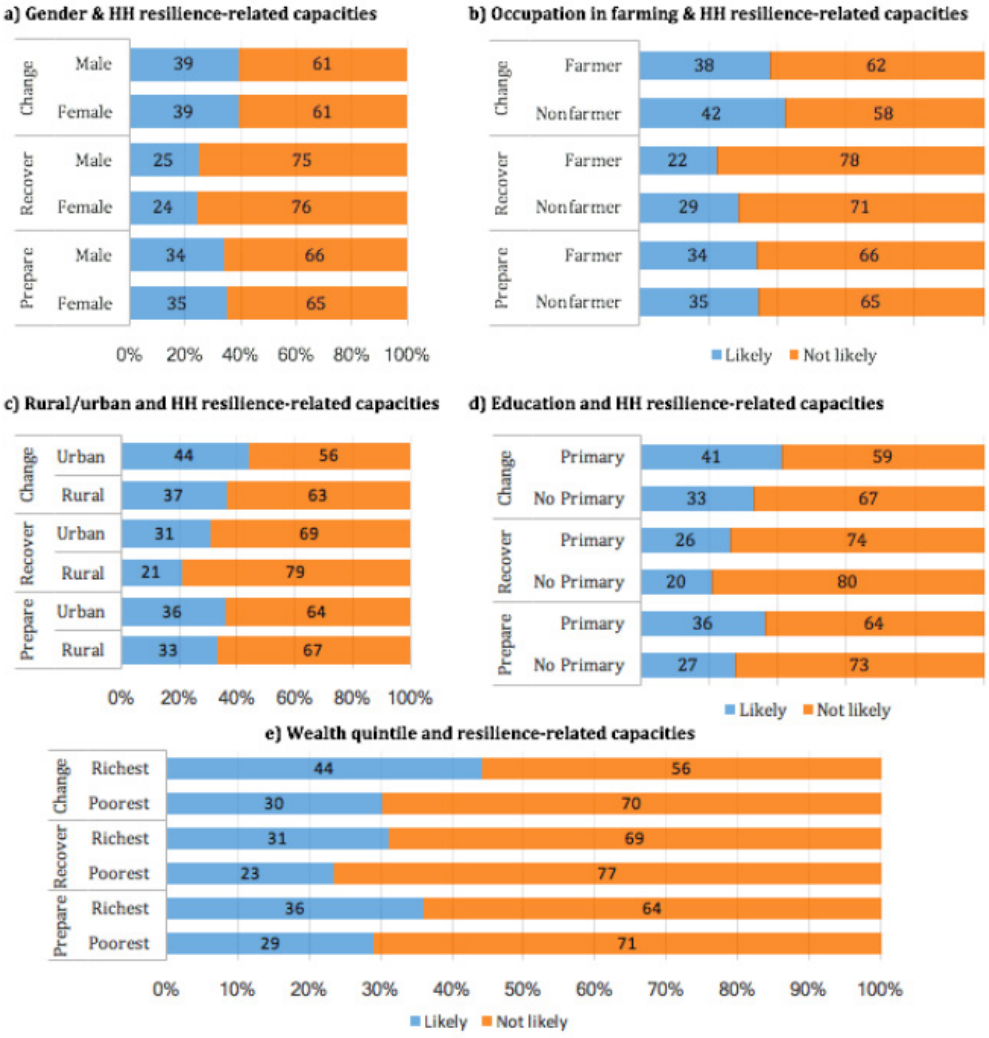
Education is positively associated with the perceived capacity to recover from a flood but not with the capacity to be prepared or to adapt on average. However, far fewer respondents with a higher education believe it is "not at all likely" they would be prepared for or able to adapt to an extreme flood, relative to those with less education. Wealth quintile is not linked with perceived preparedness but a higher share of respondents in wealthier quintiles report that they could recover and change their livelihoods in response to an extreme flood event (Fig. 3).

Self-reported capacities differ more markedly in line with the recent experience of flooding. Indeed, a higher share of those who had an experience of extreme flooding in the two years prior to the survey reported that they would be likely or very likely to prepare and to recover (but not to change their livelihood). For example, one-quarter of the population with recent flood exposure reported it was "not at all likely" they would be prepared for or recover fully from extreme flooding within a six-month period, compared with over one-third (35–36%) of those who had not experienced a flood. This suggests either that perceptions are influenced by experience of flooding,

which in turn builds confidence in their ability to deal with flood risk, or that floods have been experienced in areas where households have higher resilience-related capacities.

Perhaps of most interest, having had early warning is consistently and strongly associated with all three capacities (Fig. 3). For example, 45% of those with early warning of a previous flood reported it unlikely that they would be prepared for extreme flooding, compared with 70% of those who had not had such a warning. For the capacity to recover, the figures were 57% and 79%, respectively, while for the capacity to adapt, they were 40% and 64%. In other words, the differences associated with early warning ranged between 22 and 25 percentage points. The most common source of early warning is through local and national radio (75%) with television (18%) and newspapers (3%) being far less common. It could be that respondents in more resilient households are more likely to obtain information regarding upcoming extreme weather events, or conversely, that the receipt of such information improves household resilience (indeed both mechanisms could be in play, or an unobserved trait could influence both aspects). But given that the provision of early warning information is such an important policy lever, greater exploration of the hypothesis that making information about flooding available improves resilience-related capacities is warranted, in line with similar research on risk perceptions of flooding (Miceli et al. 2008).

Fig. 2. Relationships between resilience-related capacities and socioeconomic variables.



Multivariate analysis

To understand better factors associated with the perceived capacity to be prepared for, to recover from, and to adapt to extreme flooding, and how they relate to one another, we conducted seemingly unrelated regressions using ordinal logistic models with the capacity variables as the dependent variables. Across all the models, it is immediately apparent that the regressors have negligible explanatory power, explaining at most 2% of variation in these capacities.[13] Very few variables display a statistically significant

association with any of the capacities (Table A1.7).

Across all the regressions, the only consistent explanator was not having known about the previous flood; in all cases, this was associated with lower reported capacities and the coefficients were strongly statistically significant. Examination of the marginal effects reveals the extent of these gaps (Fig. 4). Interestingly, in all cases, predicted probabilities for respondents who had not experienced a flood or had experienced a flood but did not know about it in advance were very similar (the differences were not statistically significant). Meanwhile respondents who had had advance knowledge of a previous flood were more likely to report preparedness and the capacities to recover and adapt.

Fig. 3. Relationships between early warning and resilience-related capacities.

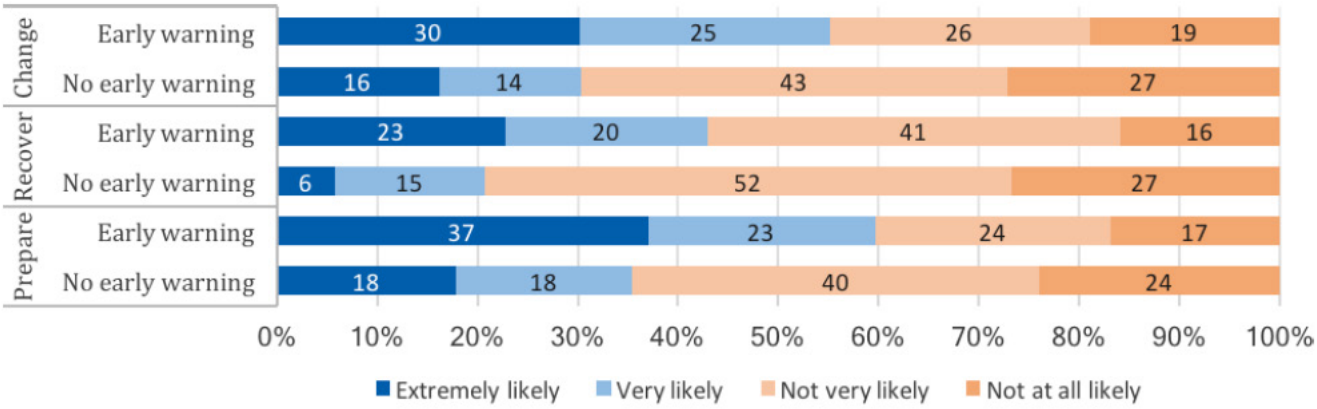
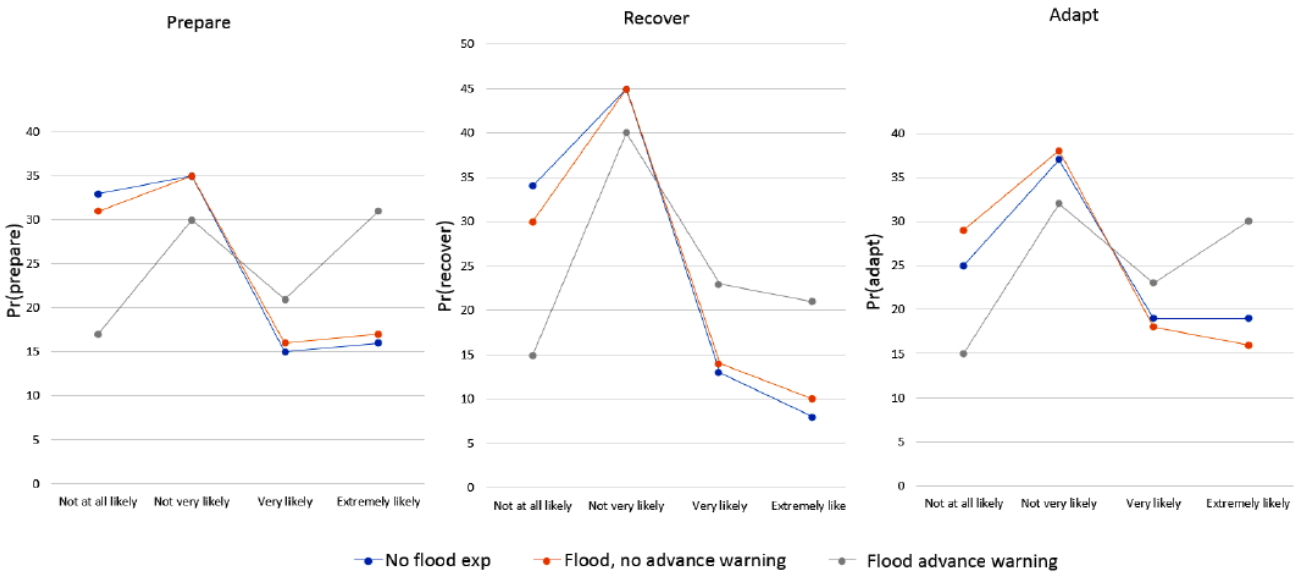


Fig. 4. Predicted probability of capacity to prepare, recover, and adapt to an extreme flood event, based on early warning of that event. Marginal effects computed on the basis of the separate ordinal logistic regressions.



Other positive (and statistically significant) relationships were found between having a higher education and both preparedness and the capacity to recover; between household size and the capacity to recover; and between wealth quintile and the capacity to adapt (Table A1.7). The effect of age is negatively associated with reporting preparedness until the age of 35 and positive thereafter. None of the covariates variables had an equivalent effect to having known about a previous flood, with the sole exception of being in the top wealth quintile on the perceived capacity to adapt.

DISCUSSION

We have proposed a tool to explore perceived levels of household resilience to climate extremes in Tanzania, and how objective characteristics map onto these assessments. We seek to contribute to a nascent body of literature on the measurement of resilience-related capacities. The results of the nationally representative survey point to a logical association between the previous experience of flooding and perceived severe risk associated with flooding at the household and community levels. Respondents who had received advanced warning of flooding in the past were more likely to perceive it as a serious problem, both for their households and their communities, than those who had not. This association could be a function of the severity of the previous flood—more efforts are likely to be taken to warn people of more extreme events in areas where floods are more severe—but it could also reflect that people who believe flooding is serious are more likely to seek out advance warning.

The survey results also suggest that low resilience-related capacities appear to be a concern in Tanzania where most households reported limited capacities to be prepared for, respond to, or change their livelihood strategies in response to an extreme flood. The scores across the three capacities were fairly similar; around one-third of respondents felt they were likely to be prepared in the event of a flood, one-quarter felt they could recover fully within six months, and 4 in 10 felt they could change their livelihood if needed. It is intriguing, however, that a greater proportion of respondents felt able to change their livelihood strategies than to prepare for, and to a much greater extent, cope with, an extreme flood. This may suggest that perceived levels of adaptive capacity are higher relative to the other two resilience capacities. The share is somewhat lower among people with less education and fewer assets (though only the wealth differences are statistically significant); however, fully 30% of respondents without education and one-third of those from households in the poorest asset quintile felt that they would be able to adapt. The results could, in part, be explained by increasing levels of livelihood diversity and flexibility with regards to sources of income and livelihood among Tanzanians (Hedges et al. 2016). In future work, it would be advisable to probe understandings of the adaptive capacity-related question, including whether people associate it with longer term change rather than short-term coping strategies, and the sorts of livelihood strategies people feel they can adopt.

The correlations among responses to the three questions were positive but lower than expected (less than 0.5), reflecting considerable diversity among households with respect to the three capacities. These moderate correlations (and the relatively low Cronbach's alpha of 0.62) also point to a lack of internal consistency, though principal components analysis showed that they loaded strongly onto a single factor. To better understand these three components, we treat them separately and defer the question of whether an index of resilience-related capacities could be useful to follow-up research.

What is perhaps most interesting is that though a small number of weak relationships are apparent, most socio-demographic variables do not exhibit statistically significant differences with regards to perceived resilience-related capacities, e.g., age, education, occupation, wealth status, and place of residence. This is important given that these factors feature in objective assessments and are typically assumed to be strongly associated with household resilience (see FAO 2016). In this, our findings align with those of Béné et al. (2016b) who find that among coastal fishing communities in Ghana, Fiji, Vietnam, and Sri Lanka, none of the demographic characteristics that they analyzed apart from assets had a demonstrable impact on subjective resilience, which they characterize as "individual perception and self-confidence about their own ability to handle future events" (Béné et al. 2016b:21). It is perhaps notable that the strongest relationship we find among the demographic variables is between belonging to the upper wealth quintile and the perceived capacity to adapt. Moreover, our data show that relationships between socioeconomic variables and perceived resilience-related capacities are broadly similar among respondents who had recently experienced a flood, i.e., in the previous two years, and those that had not.

Several areas are worth considering. On the one hand, these results could indicate that traditionally measured objective characteristics do not have a strong influence on individual perceptions of a household's ability to prepare, recover from, and adapt to climate risk. If replicated in other areas and through different means, this could in turn cast doubt on the suitability of objective characteristics as effective measures of household resilience overall (Levine 2014). On the other hand, a subjective approach to assessing household resilience may be a poor reflection of overall resilience: those with a low resilience may perceive themselves to be more resilient than they are, and vice versa.

Part of the difficulty in establishing which of these two positions is applicable is that there is no present means of validating one or the other. Both objective and subjective measures are approximations of a somewhat intangible, contextual, and evolving concept. This is similar in many ways to difficulties faced in defining and measuring concepts such as well-being, risk perception, and happiness (Deeming 2013). More needs to be done to examine the effects of different characterizations and framings of resilience within subjective survey modules so as to establish the robustness of comparative subjective scores. Additional considerations relate to the validity of the survey questions themselves, response structures, or the means of administering the survey by telephone (see Leo et al. 2015). Each may have affected the results of the survey and explain several of the counterintuitive findings. In addition, several of the variables focus on individual characteristics such as gender and education, making it difficult to differentiate between personal and household-level dynamics. To confront this subjective-objective mismatch, further qualitative work is recommended, to seek to establish which factors are more closely associated with community-wide assessments of preparation, recovery, and adaptation. Ultimately a long-term cohort study and natural experiment may be needed to effectively assess how well proposed measures of resilience, objective and subjective, measure actual resilience as demonstrated in the face of natural disasters.

It is striking, however, that this study finds that the strongest and most consistent relationship is with having had advance knowledge (presumably through some form of early warning system) of a flood's occurrence. The mechanisms are unclear and will warrant further exploration, but these variables suggest potentially valuable policy levers to enhance resilience through the provision of early warning and (to a lesser extent) by raising awareness about the potential severity of extreme flooding. Most importantly, the results provide some confidence to the considerable investments that have gone into early warning systems (EWS) as a means of supporting disaster risk reduction and resilience regionally and globally (Sorensen 2000, Basher 2006, Miceli et al. 2008). In particular, our findings underscore the centrality of radio in sharing weather-related information and warnings among East African communities.

We believe that our study also demonstrates the ability to use subjective measures of household resilience at scale, i.e., in a national survey, and to administer them using mobile phone technology, which confers notable advantages in terms of cost, frequency, and accessibility. The latter characteristic could be especially useful following a severe climatic shock.

It remains to be seen whether standardized scaled-up subjective approaches to resilience measurement can be used for cross-temporal and cross-cultural comparison. Although the former may be relatively straightforward, particularly if panel data are in use, the latter may require considerable thought and validation, both empirical and qualitative, to assess whether internalized notions of resilience mean the same thing across contexts, and if data collected at such scales are meaningful. However, in related work on subjective well-being, there is some, albeit mixed, evidence that cross-cultural measures are meaningful and valid (Jorn and Ryan 2014). If this holds for resilience, then subjective tools may offer some promise in tracing progress in resilience-building over time and across contexts at local, national, and international levels.

CONCLUSION

The research presented in this paper represents one of the first efforts to collect nationally representative data on subjective aspects of resilience, namely perceptions of the capacity to prepare for, to recover from, and to adapt to an extreme flooding event. We also explore the potential for collecting such data via a mobile phone survey, taking advantage of an ongoing panel survey in Tanzania.

We find that while some factors traditionally associated with household resilience such as asset wealth are strongly associated with subjective assessments, others like levels of education, livelihood types, and degree of urbanization have weak and in some cases nonexistent statistical relationships to subjective resilience. However, receipt of advance knowledge of flood risk appears to be one of the strongest predictors of a household's perceived ability to deal with risk, with notable policy relevance. Above all, the research underlines the need for greater recognition of subjective elements of resilience, not only with regard to how psychological and socio-cultural factors may contribute to a household's ability to deal with climate risk, but also factoring in people's knowledge of their own resilience.

While the work we have presented suggests the approach we adopt is potentially useful, it is necessarily far from indicative or comprehensive at this stage. Further testing of this instrument and of other efforts to measure perceptions of resilience, alongside objective indicators, is warranted. This includes examining the implications of different definitions and framings of resilience on subjective scores; exploring different multi-item scales to measure subjective resilience; assessing how subjective resilience changes over time and across contexts; and establishing the effects of various cognitive biases. This research also draws attention to a more acute issue facing the study of resilience and resilience-related capacities, namely the lack of a gold standard of what constitutes resilience against which attempts at its measurement could be triangulated. That such a standard might itself be context specific adds yet an additional layer of complexity to this multilayered, yet vitally important, concept.

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[1] Flood risk was chosen specifically given that it is a rapid onset shock that is easily communicable and defined in a survey context. In addition, flooding is a hazard that affects large areas of Tanzania with recovery typically occurring immediately after the cessation of a flood. It is worth noting that extensive flooding had occurred two weeks prior to the survey (May 2015) affecting areas of Dar es Salaam, Arusha, Kilimanjaro, Tanga, and Kagera.
[2] Indeed, Béné et al. (2016a,b) apply a single-item question to represent household resilience in its entirety. Here we choose to disaggregate further by examining distinct resilience-related capacities.
[3] Financial support was provided by the Global Resilience Partnership.
[4] The individuals and households who participated in this round were assigned "weights" to adjust for nonresponse and design error (Twaweza [date unknown]). The resulting data are intended to be representative of the adult population of mainland Tanzania not including Zanzibar (Twaweza 2013).
[5] For one respondent, baseline information was not available and so the corresponding data were removed.
[6] Because the Sauti za Wanachi survey is administered by phone, each time it is conducted, the respondent is asked to give their name. In this round, 8 respondents gave a different name than in the baseline and 32 respondents did not provide a name. We removed all 40 responses.

[7] The Wilcoxon-Mann Whitney statistic (for two groups) and the Kruskal-Wallis test (for more than two groups) were selected as the nonparametric test best suited to ordinal responses (following Marusteri and Bacarea 2010), although it does not permit incorporating the complex stratified survey design. Nonparametric tests do not make assumptions about the underlying distribution of a variable but are less powerful than parametric tests.
[8] The sample size is not large enough to permit analysis by subregion apart from by urban-rural zone (Sana Jaffers, personal communication).
[9] The belief that flooding posed a problem to the community and the household were highly correlated; we chose to include the former because the bivariate analysis revealed stronger relationships with the resilience-related capacities. We restricted the focus to flooding occurring in the last two years to ensure a relatively recent and consistent frame of reference.
[10] Because almost all respondents were household heads, we focused our analysis on the gender of the respondent rather than female versus male headship.
[11] The wealth index was generated by principal components analysis using the following household assets: radio, mobile phone, fridge, TV, sofa set, electric/gas cooker, motor vehicle, livestock, and water pump (Twaweza, personal communication).
[12] The statistics presented here are for the population, i.e., they incorporate the complex sampling design, while Appendix 1 presents the unweighted data and test statistics for these data. In practice, the differences between the averages derived from weighted and unweighted data are very slight.
[13] It is not feasible to compute a measure of goodness of fit for the ordinal logit that takes into account complex sampling design in STATA. To give an indication of the fit, we computed the Pseudo R2 for unweighted specifications of these regression, which yields values of about 2%.

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Measuring Household Resilience to Floods: a Case Study in the Vietnamese Mekong River Delta

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ABSTRACT

The flood is a well-known phenomenon in the Vietnamese Mekong River Delta (MRD). Although people have experienced the impact of floods for years, some adapt well, but others are vulnerable to floods. Resilience to floods is a useful concept to study the capacity of rural households to cope with, adapt to, and benefit from floods. Knowledge of the resilience of households to floods can help disaster risk managers to design policies for living with floods. Most researchers attempt to define the concept of resilience; very little research operationalizes it in the real context of "living with floods". We employ a subjective well-being approach to measure households' resilience to floods. Items that related to households' capacity to cope with, adapt to, and benefit from floods were developed using both a five-point Likert scale and dichotomous responses. A factor analysis using a standardized form of data was employed to identify underlying factors that explain different properties of households' resilience to floods. Three properties of households' resilience to floods were found: (1) households' confidence in securing food, income, health, and evacuation during floods and recovery after floods; (2) households' confidence in securing their homes not being affected by a large flood event such as the 2000 flood; (3) households' interests in learning and practicing new flood-based farming practices that are fully adapted to floods for improving household income during the flood season. The findings assist in designing adaptive measures to cope with future flooding in the MRD.

Keywords: impacts; floods; Mekong River Delta; resilience; vulnerability; well-being

INTRODUCTION

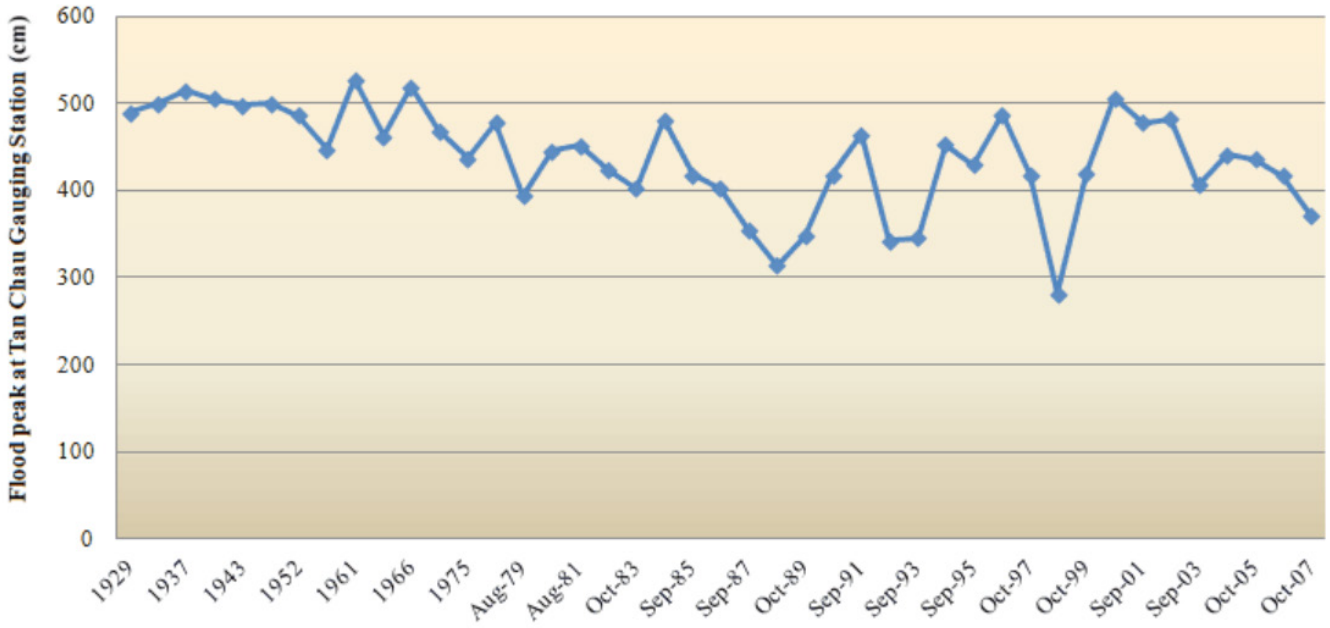
Floods are a familiar and frequent feature of life in the Vietnamese Mekong River Delta (MRD) (Socialist Republic of Vietnam 2004). Among disaster events, flood frequency, damage and mortality were ranked as the second most severe after the impacts of typhoons in Vietnam (Imamura and To 1997). Half of the MRD's total area (about 2.0 million ha) is annually flooded (Tuan et al. 2007). Floods bring fish, wash farm residuals, deposit silt sediment, purify water, kill pests, and wash alum, which makes the soil of the delta fertile (Tien 2001b; Tran et al. 2008). It is estimated that the average fish capture in the delta is about 500 kg per household per year, providing a significant protein source for local people (Mekong River Commission (MRC) 2002, Nguyen and Binh 2004). Every year, the flood deposits around 150 million tonnes of fertile sediment on paddy fields, so rice farmers achieve good yields after every flood season thanks to water and sediment brought by the flooding (Tien 2001b). Traditionally, people relied on floods for building their livelihoods in the flood prone region of the delta (Biggs et al. 2009). More recently, farmers can develop flood-based livelihoods to improve household income during several flood months (Nguyen 2008). However, some people are vulnerable, while some are resilient to flood events (Lebel et al. 2006).

The flood can be seen as an "external shock", if the flood is either too "big' or too "small", it exceeds the coping capacity of households. Local people distinguish between flooding that is "large", "moderate" and "small" (Tien 2001b). The flooding of 1998 was thought to have been the smallest flood in the past 80 years (Figure 1). A small flood often does not cause damage to property, houses, crops and other livelihood activities and assets, but it affects rural livelihoods in different ways. Poor people are more likely to lose their income from fishing activities as they cannot catch many fish due to low water. The large floods occurred in 1850, 1937, 1961, 1966, 1978, 1984, 1994, 1995, 1996, 2000, 2001, and 2002 (Can Tho University 1995, Socialist Republic of Vietnam 2004). The worst flood, in 2000, affected 11 million people living in 610 flooded communes, of which 4.5 million people lived in the 77 most affected subdistricts (communes) where flood levels exceeded more than 3 meters (Nguyen et al. 2003). In addition, more than 800,000 houses were inundated; 50,000 households had to be evacuated; 500,000 households needed emergency support; and 800,000 high school students had to stop their studies (Tien 2001a). About 55,123 ha of rice crop were completely destroyed and an additional 159,260 ha of rice were inundated and so had to be harvested immediately (Tinh and Hang 2003). The total direct economic cost of the 2000 flood was estimated at USD 289.8 million (1$~VND 13,800 in 2000).

There is additional evidence that a rise in sea level due to climate change will increase the risk of flooding in the MRD, which will affect the livelihoods of millions of people (Wassmann et al. 2004, Dasgupta et al. 2007, Eastham et al. 2008, Reid 2008). Sea level is expected to increase by 75 cm by the end of the 21st century in Vietnam's Mekong Delta (Ministry of Natural Resources and Environment 2009).

Consequently, the livelihoods of people in the MRD will be vulnerable if measures are not undertaken to cope with and adapt to future flooding.

Fig. 1. The highest water levels during different flood years in the MRD (1929-2007). Source: Tuan et al. 2007.



Resilience has become a useful concept in the study of environmental hazards. The term "resilience" first originated from the ecological discipline. Holling (1973:17) defines resilience as "a measure of the ability of these systems to absorb change of state variables, driving variables and parameters and still persist". This concept focuses on the capacity of an ecological system to absorb changes but still maintain its core function. Flood risk managers define resilience as "the ability of the system to recover from floods" (Bruijn 2004:199). In a social system, Adger et al. (2002:358) define social resilience as "the ability of a system to absorb external changes and stress, while maintaining the sustainability of their livelihoods". A system in this context may be a region, a community, a household, an economic sector, a business, a population group, or an ecological system (Brooks 2003). Buckle (2006:91) refers to resilience as the "capacity to withstand loss". Norris et al. (2008:130) define resilience as "a process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation after a disturbance". Recently, the concept of resilience has been seen in a linked social and ecological system (Folke et al. 1998, Adger 2000, Folke 2006). The resilience concept is concerned with the capacity for renewal, reorganization and development (Folke 2006); creativity (Adger 2000, Maguire and Hagan 2007), and transformation in a social-ecological system (Walker et al. 2004) and capacity to maintain its identity (Cumming et al. 2005).

Although there are various definitions of resilience from different disciplines, three common properties of resilience dominate in resilience literature (Carpenter et al. 2001). The first property is about the speed of recovery at which a system can recover after disturbance. So natural hazard researchers attempt to observe the speed of recovery after disasters as a measure of resilience (Bruijn 2004). The second is the magnitude of a disturbance relative to a threshold that can be absorbed before a system changes its structure by changing the processes and variables that control it (Colding et al. 2003). The final property is about the capacity to learn from and to create new things from disturbance, and to transform (Folke et al. 2002, Berkes and Seixas 2005). Therefore, the conventional approach to measure resilience as the speed of recovery may not capture its full dimensions.

Resilience of the system is dependent on several factors such as demographic, social, cultural, economic, political, type of natural hazards, and geographical setting of the place (Gaillard 2007). However, these factors may vary at different levels of analysis (Buckle 2006). At the household level, access to agricultural land, diversity of income sources, and good housing quality create essential resources for households to cope with annual flood events in Bangladesh and climate change in the coastal province of Vietnam (Adger 1999, Brouwer et al. 2007). Learning to live with change and uncertainty, nurturing learning and adapting, and creating opportunities for self-organization were found as the important factors for enhancing household resilience in the Cambodian context (Marschke and Berkes 2006). Marshall and Marshall (2007) identified four perceived factors that contribute to conceptualizing resilience at the individual level: (1) perception of risk associated with change, (2) perception of ability to learn, plan and self-organize, (3) perception of the ability to cope, and (4) level of interest in changes in an Australian context.

At the community level, Norris et al. (2008) identified four primary sets of capacities that enhance community resilience, including economic development, social capital, information and communication, and community competence. Economic development refers to economic growth, stability of livelihoods, and equal distribution of resources within the population (Adger 1999). Social capital refers to networks of social supports, bonding within community, bridging between communities, and networking between communities and government bodies (Adger 2003, Pelling and High 2005, Mathbor 2007). Information and communication refer to the system and infrastructure for informing the public because people need accurate information about danger and behavioral options for them to act quickly. Community competence is about the capacity of the community to learn, work together flexibly, and solve problems creatively. These contributing factors should be measurable in the practical context.

Most researchers attempt to define the concept of resilience; very little research operationalizes it in practice. Cumming et al. (2005) note that resilience is a multidimensional concept, so it is difficult to operationalize in practice. Coping with this problem, they develop a "surrogate approach" as an indirect way of measuring resilience (Carpenter et al. 2005: 967). Marschke and Berkes (2006) adopted the surrogate approach to operationalize resilience from livelihood perspectives in rural Cambodian villages using a subjective well-being approach. However, Marschke and Berkes (2006) only explore the well-being of households and communities in a qualitative manner; they do not attempt to quantify resilience indicators at a household level. It is argued that well-being is what people think and feel about their life or subjective well-being (Copestake and Camfield 2009). The subjective well-being approach was widely accepted in poverty and livelihood studies in developing countries (Narayan et al. 2000). However, little is known about different dimensions of households' resilience to floods in a real "living with floods" context. Knowledge of the ability of households to cope with, adapt to, and benefit from floods reflects their resilience, but there is no study that operationalizes the concept in the MRD.

METHODS

Three communes (Phu Duc, Thanh My Tay, and Trung An) were selected for this study to represent different flood and socioeconomic conditions of the MRD (Figure 2). The socioeconomic conditions and livelihood activities of the three locations are represented in Table 1.

Fig. 2. The Mekong River Delta and location of the study sites. Source: Quang (editor) 2012.

The study employed both qualitative and quantitative research approaches to conceptualize household resilience to floods. The three key qualitative data collection approaches for this study included in-depth interviews with key informants, focus group discussions (FGDs), and field observations. Four FGDs and some 10 in-depth interviews were carried out in each commune, each covering a range of social classes and gender. Information from the qualitative research was used for designing the structured questionnaires for the household survey in August 2010.

Table 1. Socioeconomic conditions and livelihood activities in the three study sites

Socioeconomic, demographic and flood conditions	Selected sub-districts		
	Phu Duc commune (site1)	Thanh My Tay commune (site2)	Trung An commune (site3)
Population (number of people)	6,940	25,100	13,606
Population density (persons per sq km)	212	637	194
Households	1,586	5,141	2,362
Land area (ha)	5,170	3,656	1,197
Poverty (%)	11.4	11.5	12.0
Flood depth	>2.5 m (over 5 months)	1.5-2.5 m (4-5 months)	<1.5 m (<3 months)

The study used a multiple items approach using both Likert scales and a dichotomous response to design questionnaires for measuring household resilience. As noted by de Vaus (2002) it is beneficial to use multiple indicators to measure the complexity of a concept. Multiple items also help to increase reliability and precision of the measure. The multiple item approach using Likert scales was widely accepted in measuring individual resilience to stresses in psychological disciplines (Wagnild and Young 1993, Connor and Davidson 2003, Yu and Zhang 2007, Baek et al. 2010, Wang et al. 2010), and individual resilience to institutional changes (Marshall and Marshall 2007). As rural households in the MRD have experienced the impacts of annual flood events for years, we argue that using a "subjective well-being approach" helps to identify the ability of households to cope with, adapt to, and benefit from floods.

Ten statements that reflect subjective well-being of rural households were developed to construct households' resilience to floods in the MRD. As reviewed in the introduction section, resilience is referred as the capacity of a system to cope with and recover from an external shock or stress. Some people may argue that flood events in the MRD are not external shocks because people have experienced the floods every year. However, we argue that large flood events such as the historic flood in 2000 can be seen as "external shocks" because they exceed the coping capacity of many people. Some people could cope well with the event, but many people were vulnerable to that flood. Therefore, the statements used in this approach to measure households' resilience to floods are related to their coping capacities in the 2000 flood event. The statements related to confidence in securing food, income, and health of family members during historic flood events (the 2000 flood), and safe evacuation in future extreme flood events due to climate change or rising sea levels, and recovery after the flood if they are affected; confidence in securing homes in a large flood event such as the 2000 historic flood, and their interest in learning and implementing new ways of living with floods (flood-based livelihoods). In this analysis, most of the items are more likely to focus on experiences or perceptions of households in coping with floods in the past rather than the capacity to cope with future flood events in the context of local climate change scenarios. Therefore, further studies should be carried out to incorporate possible changes in the flood regimes into measures of resilience.

The respondents, who represent their households, were asked to rate their agreement with 10 statements. The responses on the first nine items were provided using a five-point Likert scale, while a dichotomous response was applied for the last item (Table 2). The response rate was 100%.

The stratified sampling approach was used to divide the total population of the delta into sub-populations of "three communes", based on the existing socioeconomic and natural flood characteristics of the delta. The samples were chosen on the basis of social groups: poor, medium-income and better-off households. This approach has been widely used in rural development and natural hazard studies in developing countries (Smith et al. 2001, Tran et al. 2008). Within each stratum, five hamlets were randomly chosen and 30 households were randomly selected from the wealth ranking of households in each hamlet. In the case of Phu Duc commune, 50 samples were collected as there are only three hamlets in this commune. The total sample size in each case study was 150. The exception was Thanh My Tay commune, for which there were 159 samples.

The average age of respondents was 52 years old. The proportion of male respondents was higher than that of female respondents. This may cause biases in terms of differences in perceptions between males and females toward floods. The education level of respondents and their family members was generally low. The average household size was 4.7. The gender ratio of households was

equally distributed. Most respondents followed Hoa Hao Buddhism, while very few respondents belonged to the Cao Dai or Catholic religion. Poor households account for 39.4% of the sample, followed by well-off households (31.8%) and medium-income households (28.8%). Average household income was $2,918.0 per year ($1 or approx. VND 20,830.0 in 2010). However, the average income of poor households was $763 per year. For medium-income households it was $2,553.0 per year, while better-off households had an average income of $5,909.0 per year. The per capita income of each person was an average of $600.0 per year. Per capita income in poor households was $168.0 per year. In medium-income households, per capita income was $576.0, and it was $1,161.0 in better-off households.

Table 2. Statements for measuring household resilience to floods in the MRD

Items	Statements (N=459)	Mean	Strongly Disagree	Disagree	Do not know	Agree	Strongly Agree
					%		
1	I can replace my house quickly when it is affected by floods[†].	3.42	8.50	28.10	3.70	32.46	27.23
2	I am confident that my house will not be submerged by the highest floods in the last 20 years[†].	3.54	8.06	23.53	4.79	31.37	32.24
3	I am confident that my house will not collapse or be swept away by the highest floods in the last 20 years[†].	3.31	11.55	25.93	4.79	32.68	25.05
4	I am confident that my household has enough rice to eat during the flood season[†].	3.56	9.15	25.93	15.25	37.04	12.64
5	I am confident that my household will not need to borrow rice or money from informal sources during the flood season[†].	3.41	1.53	6.97	10.68	48.15	32.68
6	I am confident that my household can find a safe place to evacuate to if there is an extreme flood event in the future[†].	3.18	1.74	12.20	13.73	54.03	18.30
7	I am confident that children and elderly people are safe during extreme floods[†].	4.03	10.46	24.40	4.36	22.22	38.56
8	I am confident that the health of my family members will not be negatively affected by floods[†].	3.75	13.51	25.93	6.75	23.53	30.28
9	I want to learn new farming practices to cope with floods, such as fishing, prawn farming[†].	2.94	13.07	40.74	1.09	29.41	15.69
10	I have used new farming practices to cope with floods such as fishing and vegetables or prawn farming[‡].	0.23	Agree			Disagree	
				27.7		77.3	

[†]Statements were measured using a 5-point scale for the first nine items: 1-strongly disagree, 2-disagree, 3- neither agree nor disagree, 4- agree, 5- strongly agree. [‡]Statement was measured according to the binary response (0- No; 1-Yes) for the ten items.

A factor analysis was used for combining related variables into "composite" variables for conceptualizing components of household resilience to floods. Factor analysis helps us to identify patterns in responses to a set of questions (de Vaus 2002). The purpose of this technique is to reduce the large amount of variables to a smaller set of underlying variables by creating factors (Kim and Mueller 1978). The principal component factor method is used in this analysis. There are a number of methods involving rotation variables including the quartimax method, the equamax method, and the varimax method (Kim and Mueller 1978). One of the most frequently used methods is the varimax method, which aims to minimize the number of variables that have a high loading on a factor. This approach was widely used when identifying the factors of the vulnerability analysis (Cutter et al. 2003, Fekete 2009). Because binary variables were not suitable for a factor analysis, each item response was standardized (z-score) before conducting a factor analysis using SPSS software. This method was used by identifying underlying factors in measuring social vulnerability to natural hazards (Cutter et al. 2003). Factors will be selected if they have an Eigenvalue greater than one. The results of factor analysis from SPSS were also triangulated by using MPLUS software with the original nonstandardized data.

RESULTS

Definition of resilience to floods

Results from factor analysis indicate that nine of ten statements reliably contribute to the scale, and formed the basis for measuring household resilience to floods (Table 3). The factor analysis in SPSS shows that the responses to the statements were best described by three factors that represent three components of resilience. The finding from the factor analysis conducted in MPLUS showed similar results, including three factors comprising nine items. These total factors in SPSS represented 68.0% of the variance. The first component represents 37.1% of the variance, including five statements (1, 4, 5, 6, 8) relating to securing food, income, health, safe evacuation during the flood season, and recovery after floods. The second component, representing 17.5% of the variance, consisted of two statements (2 and 3) related to the level of confidence of households that their houses will not be affected (submerged or collapsed) by future floods as large as the threshold flood of 2000. The third component representing 13.3% of variance was comprised of two statements (9 and 10) related to the level of interest in learning and conducting new flood-based farming practices for living with floods. Reliability analysis shows that Cronbach's alpha coefficient of factor one is 0.77; factor two is 0.89; and factor three is 0.67.

Table 3. Factor matrix of household resilience, Mekong River Delta, Vietnam, 2010 (nine standardized items)

Items	Statements	Factor loadings			Communality
		Factor 1	Factor 2	Factor 3	
1	I can replace my house quickly when it is affected by floods†.	0.71			0.58
4	I am confident that my household has enough rice to eat during the flood season†.	0.90			0.83
5	I am confident that my household will not need to borrow rice or money from informal sources during the flood season†.	0.88			0.80
6	I am confident that my household can find a safe place to evacuate to if there is an extreme flood event in the future†.	0.41			0.22
8	I am confident that the health of my family members will not be negatively affected by floods†.	0.59			0.39
2	I am confident that my house will not be submerged by the highest floods in the last 20 years†.		0.92		0.90
3	I am confident that my house will not collapse or be swept away by the highest floods in the last 20 years†.		0.92		0.89
9	I want to learn new farming practices to cope with floods, such as fishing, prawn farming†.			0.86	0.75
10	I have used new farming practices to cope with floods, such as fishing, prawn farming‡.			0.84	0.71
	Eigenvalues	3.34	1.58	1.19	6.12
	% of variance	37.14	17.55	13.32	68.01

†Statements were measured using a 5-point scale for the first nine items: 1-strongly disagree, 2-disagree, 3- neither agree nor disagree, 4- agree, 5- strongly agree. ‡Statements were measured on a binary scale (0-No, 1-Yes). All items were standardized into z-scores (0,1). Selected factors have Eigenvalues greater than 1. Selected variables have factor loadings greater than 0.3 Total variance is 68.

Interpretation of resilience components

Confidence to secure food, income, safe evacuation during flooding, and recovery after floods

Results from Focus Group Discussions (FGDs) and in-depth interviews reveal that participants are concerned with several issues for maintaining livelihoods during and after floods. These include: (1) capacity to secure food, (2) income, (3) health of family members during the floods, (4) capacity to find a safe place if evacuated during floods, and (5) capacity to recover if houses are affected.

Firstly, floods occur for two to six months per year, so they often disrupt the income sources of some social groups. Poor people's livelihoods rely heavily on collecting fish and aquatic resources, and agricultural wage labor during the flood season. When a large flood event occurs, there are strong winds and giant waves that disrupt daily livelihood activities. So, if households are not confident that they will have sufficient food and income to survive during flooding, they feel that they are vulnerable to floods. Medium and better-off households reported that they are less vulnerable to floods as they have sufficient savings to use during the flood period.

A poor woman, aged 26, living in K9 hamlet, Phu Duc commune, Tam Nong district, Dong Thap province, and a second poor woman, aged 33, said that poor people worried seven to eight times more during flooding, while better-off households only worried two to three times more. They are concerned about a shortage of income for purchasing rice (FGD 01PD January 2010).

However, if they can access resources from family members, neighbors, and social networks, they may be confident of securing food and income during the flood season. For example, seasonal migration may provide remittances to send to their family members to help them survive during the flood season.

The president of the Thanh My Tay commune reported that there were about 5,000 seasonal migrants in this commune in 2009. Some poor migrants go to Ho Chi Minh (HCM) City to work in the construction sector, such as builders, to avoid the floods and come back to do agricultural labor in the dry season. Other migrants stay permanently in HCM city, if they find a good job. There seem to be two types of migration: push and pull. Some successful migrants send remittances to their family. For example, one man has two sons working in HCM City; they send him a remittance each month. He can live well with the floods now. However, migration is not stable for some social groups (in-depth interview on 15th September 2010).

A poor women, aged 32, living in Phu Duc commune, said that her husband works for a construction company in HCM city as a builder. Income from laboring in HCM is more stable than working in this Phu Duc commune. Some days are off, but some days we work. The job is not secure here (in-depth interview on 11th September 2010).

In contrast, seasonal migration provides an important opportunity for coping with floods, but it is also a challenge for some people. Some people cannot save money or even go into debt because they do not find a good job in HCM city.

A poor woman, aged 35, living in Phu Duc commune, said that during the flood season, most people in her places [residential clusters] [1] close their houses and go to Ho Chi Minh city to work in the construction sector and work in garment factories. She indicated that: Working in HCM city is for survival during the flood season. My husband and I went to HMC and returned to do agricultural labor in the dry season. Life in HCM is also very hard. We returned without any money. We lost networks in the village. We feel life is more difficult than before [in-depth interview on 12th September 2010].

Child deaths during the flood season were cited as the key concerns of most participants in twelve FGDs. Children were recognized as the most vulnerable group, especially during large flood events. Deaths of children were not directly caused by flood-related disease, but related to drowning due to lack of supervision from caregivers. Many examples show that children drowned while their parents were doing housework, sleeping at night, and fishing on the floodplain. Children's deaths were mostly reported in the highest and moderate flood prone regions, while very few cases were mentioned in the low flood region. Importantly, most people said that child deaths were more likely to happen in households who settled in the paddy fields. Poor households, who went fishing during the floods, had to leave their children at home alone or with their brothers and sisters or relatives. Lack of supervision resulted in vulnerability to floods.

A primary teacher in Phu Duc commune, aged 41, recalled that his house floor was submerged in the 2000 flood. He had to remove the wooden floor[2] to keep the house from being swept away by the floodwater. His family (himself, wife and little son) had to survive in the only bed for several days. They cooked, ate and slept, toileted .... on the bed. Suddenly, his son fell into the floodwater underneath the floor. Luckily he grabbed him in time. If he had not grabbed him, his son would have been swept away by the strong waves (FGD PD02).

Evacuation during floods is one of the most important indicators of living with floods at the household level. If the flood submerges homes, having a safe place to which to evacuate provides confidence to cope with floods. In the flood of 2000, many people could not move out of their homes for several days. They had to stay on the roofs of their houses when the water was rising. Their lives were at risk all the time during the flood.

A poor woman in Phu Duc commune, aged 35, said that her house was deeply submerged in the 2000 flood; all clothes were wet, while there was no rice to eat. No family members could sleep and they lost weight. Her house was located along the canal banks and was cut off by floodwaters. It was very difficult to find a safe place to evacuate to (FGD 02PD January 2010).

Recovery after floods was considered another important indicator of coping with floods. Evidence shows that the flood in 2000 destroyed and submerged thousands of homes in the MRD. If someone could recover more quickly they would be more resilient to the impact of the flood. Poor people lived in unsafe conditions (in simple houses without protective materials inside the flooded fields), which were easily destroyed by flooding and during storms.

Confidence to secure homes that would not be affected by floods such as the 2000 flood

As reported by most participants in FGDs, the flood in 2000 can be seen as the historical flood. In flood years, many homes were submerged or destroyed by flooding. The flood level in 2000 was considered as the threshold for designing housing structures by most rural households. Through field observation and FGDs with participants in three study sites, it was found that both richer households and poorer ones that resided in residential clusters were more likely to be confident that their houses would not be submerged or destroyed by a flood as large as the 2000 flood. This indicator reflects the threshold that rural households can cope with floods in terms of the housing sector. Two items (items 2 and 3) which formed the factor explaining the threshold were included (Table 3).

Interest in learning and implementing flood-based livelihoods during floods

As noted by Paul (1984, 1995, 1997) and Shaw (1989) floods are hazards as well as resources for development. Some people may see floods as disasters, but others consider floods as benefits (Lebel et al. 2006). The large flood event in the MRD led to significant costs to households and communities, but farmers can also benefit from the resources that the floods give to people. In particular, such floods bring abundance of aquatic resources such as fish, crabs, and snails. Many farmers rely on income from collecting fish, crabs, and snails during the flood season for maintaining livelihoods. However, poor people may not have enough financial resources to buy fishing tools (a small boat, nets, or traps), which may make them more vulnerable to food insecurity during the flood season. In some cases, they borrow informal credit for purchasing a boat and nets. However, they may incur debt during large floods that may sweep away their nets. The following in-depth interview illustrates the ways that people completely adapt to the flood season in the highest flood prone region.

A rice farmer in K9 hamlet, aged 45, Phu Duc commune, has one hectare of rice land. He traps fish during the flood season. He loves the flood season very much because he can earn an extra VND 200,000-300,000 per day from this off-farm activity (in-depth interview on 15th September 2010).

Interestingly, rural people have adapted to floods using an innovative way for improving their household income in the moderate flood prone region. The golden snails have been seen as pests for rice farmers in the MRD. However, they become resources for people who can collect golden snails for maintaining livelihoods during flooding. Most poor and medium income households engage in these livelihood activities because they require less capital investment as well as labor. In particular, young couples who are poor and landless are more likely to participate in this activity for survival, while medium-income households are more likely to accumulate capital by conducting this business.

The household income of a medium-income farmer in TMT commune, aged 45, relies on rice farming (two crops) and collecting golden snails during the flood season. He said that local people are very interested in livelihood activities during the flood season. He uses a small motorboat to travel to many places in An Giang, Dong Thap, and Kien Giang provinces to collect snails. He can earn a net income of around VND 300,000 (~USD 15) per day. He can save at least VND 10.0 mil (USD 480) in a flood season, which equals the net income from 2.0 ha of rice. Mr. Luoc realized that the water season is a wonderful income season for his family and his neighbors. Fish, prawn, and duck farmers can buy low-priced snails, a cheap source of protein to feed their stock. Children and old people in his neighborhood can earn about VND 50,000 (~USD 3.5) a day to take off the snail shells for him [in-depth interview on 5th January 2010].

Local people not only benefit from exploiting the natural fish, crabs or snails from the floodplain, but also they create new farming activities that are totally adapted to floodwaters. For example, medium and better-off farmers who have paddy land are more likely to grow Neptunia prostrate (a type of aquatic vegetable), integrate duck and fish farming systems, and cultivate prawns during the flood season. These farming activities were introduced by farmers in 2001. The activities were first tested on an individual basis and expanded to the community level. The stories that follow show that farmers are more resilient to floods by transforming flooded fields into flood-based farming practices.

A 61-year old man, living in Trung An commune, owns 3 ha of rice land. He grows two rice crops in the dry season and uses an integrated farming system during the water season. In particular, Mr. Sau raises ducks and fish in the flooded paddy fields using net fences to keep ducks and fish inside. He started to implement this system five years ago and the system is quite sustainable. He said that after harvesting the summer rice crop, he put nursery fish into the paddy fields. Fish eat rice straws, worms, and falling rice husk. Additionally, he adds ducklings and ducks into the paddy fields. Ducks also eat the remaining falling rice husk. After four months, he harvests fish, ducks, and eggs. The net benefit of these resources is much greater than the net benefit of the main rice crop. The fish and ducks make the paddy soil more fertile, so rice farmers apply less fertilizer in the next crop. This system is more resilient to the water season. Farmers can gain double benefits from the system. However, the system is not suitable for the landless and poor. It requires land and capital for investment, which the poor cannot afford (in-depth interview on January 15th 2010).

Another man, aged 40, with nine years of schooling, lives in Bo Dau hamlet, TMT commune and owns 0.7 ha of rice land. He grows two rice crops in the dry season and raises prawn in the paddy-flooded fields in the flood season. He has adopted new flood-based prawn farming since 2007. He uses bamboo fences and nets to keep the prawn inside the fences and uses floodwater for farming prawn. He said that the water season is good for prawn farmers like him. Although the system is very risky with the market as well as water

environment, it brings enormous benefit. Compared to two rice crops, this farming practice generates greater benefits. In 2007, he earned a net benefit of VND 70 million ($3,500) from prawn (in-depth interview on January 06th 2010).

DISCUSSION AND CONCLUSION

This study has identified the key characteristics of households that determine the capacity of households to cope with, adapt to, and benefit from floods. As discussed by de Vaus (2002) it is better to use multiple items to measure a multidimensional concept. Although resilience is a multidimensional concept, it can be grouped into three different components in the context of living with floods in the MRD. Three factors found by this study include: (1) the capacity of households to secure food, income, health of their family members during the flood season, safe evacuation during future extreme flood events, and recovery after extreme floods if they are affected, (2) the capacity of households to secure their homes during large floods such as the historic flood of 2000, (3) the level of interest in learning and carrying out new flood-based livelihoods during the flood season to improve their livelihood security. These three factors are consistent with general resilience theory and practices. A novel point of this study is to identify the capacity to learn from disturbance for genuine adaptation to floods. The ways that farmers use floodwater for growing prawns, fish, eels, and vegetables are very innovative and transformative.

The first factor of resilience in this study related to the degree to which households are capable of self-organization. This characteristic has been mostly accepted by resilience researchers (Klein et al. 2003, Carpenter et al. 2001, Folke 2006). However, it is difficult to translate the term "capacity for self-organization" into the real context of living with floods in the MRD. In particular, the capacity for self-organization comprises several dimensions of livelihoods with people being mostly concerned about the impacts of previous flood events. These dimensions are confidence that they have sufficient food to eat during the flood season, confidence that they do not need to borrow informal credit during the flood season and can find a safe place to evacuate to during future extreme flood events; and confidence that the health of their family members is secured.

Because the flood season often disrupts income streams of some socioeconomic groups, borrowing money from local informal credit is the common way of coping with six months of flooding. Accessing informal credit with high interest rates is the fear of most poor households during the flood season. Landless households are the most vulnerable groups from being in chronic debt with informal credit providers because they do not have land title to borrow against for formal credit to survive during the flood season. However, if households are confident that they will not borrow this type of credit, they may be able to borrow from their relatives, family members, and the banks with low interest. These sources of support are important for them to maintain their livelihoods during the flood season. Health of family members, especially children, is the most serious concern during floods. Many children died because of drowning. If households are confident that they can keep their children secure in the face of flooding, they are more likely to be resilient.

In particular, rice is the most important staple food for rural households in the MRD. If the households do not have enough rice to eat, they feel very anxious about coping with the flood season. In the developing country context, especially Southeast Asia, food sources are often at the backdoor in nearby ponds and with close neighbors and do not require access to highly developed Western-style transport and communications systems.

A medium well-off woman, aged 44, living in Phu Duc commune, said that a good neighbor used his small ferry to evacuate people, animals, and supply food to people when the large flood of 2000 submerged most houses in the village. He mobilized local resources (food and clothes) from the less affected villages to help them. She said that transportation by boat is the most effective means during the large flood season.

Rural-urban remittances may help some people to maintain their income during the flood season. But in some cases, migration does not necessarily help some households to improve their income because the living cost in Binh Duong or Ho Chi Minh City is relatively high. So, many migrants reported that they return homes without money and sometimes are in debt. As a result, they become more vulnerable to future flood events.

A poor woman in Phu Duc commune, aged 38, with nine years of schooling, said that she has lived in this village for 30 years. She originated from Cao Lanh district of Dong Thap province. She used to live by an internal canal subjected to annual flooding. Her income is mainly from fishing and collecting. However, the floods have been small in the past several years and she could not catch much fish. She decided to go to Binh Duong to work in a factory. However, the salary was not sufficient for her family to survive. She decided to return homes and her livelihood is difficult now.

The second characteristic of resilience is related to the amount of disturbance that a system can cope with, while still maintaining its function in terms of the housing sector. This characteristic has been widely accepted in recent natural hazards literature. In this study, the amount of disturbance is seen as the amount or magnitude of flood events in the MRD. The historic flood of 2000 was perceived as the most serious, destructive flood of the last century in the MRD. Thousands of homes were submerged, damaged, and swept away by the flood. Since that event, local people upgraded their house floors or raised the house foundation above the flood level. However, not all households can adjust their home to a certain level of stability because of financial barriers. The capacity to secure their homes

so that they would not be affected by floods like the 2000 flood is determined by their well-being or capacity to cope with floods. Those who can upgrade their house are more resilient to the impacts of floods.

The third characteristic of household resilience is about their interest in learning and doing new creative things. This is consistent with the third property of resilience, namely, the capacity to transform and innovate (Folke et al. 2002, Walker et al. 2004, Marschke and Berkes 2006, Marshall and Marshall 2007). However, what are the new creative things in this context? Many farmers developed an innovative way of living with floods by exploiting the flood benefits as well as carrying out flood-based farming activities. These farming practices allow them to improve their household income and create jobs for local laborers to maintain their livelihoods during flood months. These emerging flood-based farming practices not only provide income and food security for rural households, but also help to maintain agricultural sustainability. The perception of floods transformed them from natural disasters into beneficial resources for livelihood development.

The subjective well-being approach of measuring households' resilience is used to reflect the actual capacity of households to cope with flood events. Because resilience is a multidimensional concept, the use of multiple items can help to capture a wide range of factors that contribute to households' resilience in a specific context. The use of standardized data yielded better underlying factors than the nonstandardized data in this context. While the former approach captured nine items forming three factors, the latter approach only obtained five items forming three factors (Appendix A 1). A standard factor analysis cannot deal with dichotomous variables, but the standardized data approach allowed a factor analysis to be carried out with dichotomous responses. This approach was well validated by using both SPSS and MPLUS software (Appendix A 2). By combining qualitative and quantitative analytical methods, new aspects of resilience among farmers in the MRD have been highlighted. The responses and adaptive behaviors enable some of these farmers to sustain their livelihoods during floods and recover quickly afterward.

However, the use of the subjective well-being approach to obtain the perceived capacity at the household level to cope with historical flood events may be prone to some limitations in explaining the resilience of households to future large flood events in the context of climate change. Although item 6 in Table 2 reflects the capacity to evacuate in a future extreme flood event, it does not capture all the dimensions of resilience in future large flood events. For example, with regard to the level of interest in learning and carrying out new flood-based livelihoods, this measure does not take into account future large flood events or very small flood events that may occur due to climate change, which may exceed the capacity of households. This is a key limitation of this research. Therefore, it is important for future research to integrate climate change scenarios into the questionnaires for assessing the resilience of households in the MRD.

It is also argued that the determinants of resilience may include demographic, social capital, cultural, economic, and political, aspects of the natural hazards, information, and the geographic setting of places (Gaillard 2007, Norris et al. 2008). For example, information and social networks are very vital for people in disaster prone areas to make behavioral decisions. But these factors may be variable at different scales of analysis. The social capital of households is important for accessing resources to cope with annual flood events. However, some of these factors are not included in the current measures of households' resilience to floods within the scope of this research. The current measures of households' resilience were more likely to focus on conceptualizing the concept of resilience in the real context of "living with floods" in the MRD. Some factors such as social capital are often treated as exogenous variables (Narayan and Pritchett 1997). The resilience properties obtained from the factor analysis from this research will be used as latent variables to investigate their relationships with social capital and socioeconomic variables of households in further analysis. At present, the current measures focus on the experience or perceptions of households in coping with past flood events, but do not permit interpretation of the results in the context of climate change. Further study should be carried out to improve the current measures of resilience in future flooding under predicted climate change scenarios.

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Assessing Vulnerability to Urban Heat: A Study of Disproportionate Heat Exposure and Access to Refuge by Socio-Demographic Status in Portland, Oregon

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ABSTRACT

Extreme urban heat is a powerful environmental stressor which poses a significant threat to human health and well-being. Exacerbated by the urban heat island phenomenon, heat events are expected to become more intense and frequent as climate change progresses, though we have limited understanding of the impact of such events on vulnerable populations at a neighborhood or census block group level. Focusing on the City of Portland, Oregon, this study aimed to determine which socio-demographic populations experience disproportionate exposure to extreme heat, as well as the level of access to refuge in the form of public cooling centers or residential central air conditioning. During a 2014 heat wave, temperature data were recorded using a vehicle-traverse collection method, then extrapolated to determine average temperature at the census block group level. Socio-demographic factors including income, race, education, age, and English speaking ability were tested using statistical assessments to identify significant relationships with heat exposure and access to refuge from extreme heat. Results indicate that groups with limited adaptive capacity, including those in poverty and non-white populations, are at higher risk for heat exposure, suggesting an emerging concern of environmental justice as it relates to climate change. The paper concludes by emphasizing the importance of cultural sensitivity and inclusion, in combination with effectively distributing cooling centers in areas where the greatest burden befalls vulnerable populations.

Keywords: urban heat; vulnerability; environmental justice; heat exposure; resilience

1. INTRODUCTION

Extreme heat poses a growing threat to human populations, with numerous implications for public health, economic stability, and quality of life [1,2,3]. Past heat waves have had devastating, deadly outcomes worldwide [4,5,6], and such events are expected to increase in intensity, frequency, and duration as climate change progresses [7,8]. Although human settlements of any type may experience the negative effects of extreme heat, these are and will continue to be most pronounced in urban areas, the development practices of which are highly correlated with rising temperatures [9,10,11]. Currently, more than 50% of the world's population is located in urban areas, and that figure is expected to reach over 66% by 2050 [12]; with so many people potentially at risk of exposure, it is imperative that local governments and planning practitioners recognize varying degrees of vulnerability among urban residents.

Urban heat events—defined as those above the 90th percentile of historic temperatures [13]—are an environmental stressor, placing economic, infrastructure, and human health burdens on society [14,15,16]. As a stressor, urban heat can create vulnerabilities, which may be understood as a combination of three factors [17]: exposure, sensitivity, and adaptive capacity. Exposure refers to an individual's contact with a stressor, either from living, working, or spending time in an affected location. Sensitivity is the point at which exposure becomes dangerous to an individual's health [18]. Finally, adaptive capacity refers to one's ability to change exposure or sensitivity, or to cope with an extreme event. Regarding urban heat, indicators believed to enhance adaptive capacity include high income, social cohesion, and knowledge of hazardous environments [19,20]. Given these conditions, it may be reasonable to categorize extreme heat exposure as an environmental justice issue.

The phenomenon central to this study is the urban heat island (UHI) effect, which has been known to researchers since the mid-19th century, and indicates a strong correlation between urban environments and high temperatures [21,22]. Impervious surfaces and anthropogenic activity within cities portend rising temperatures, as does the relative scarcity of heat-ameliorating elements such as trees and grasses [23,24,25]. A higher frequency of regional extreme heat events, as such, will amplify temperatures [8], and generate UHI in areas that have greater amounts of heat absorbing surfaces. While early studies focused on the comparative temperatures between urban and non-urban regions, the emergence of mobile sensors, highly accurate global positioning systems, and computational software allows for the comparison of intra-urban spaces, measuring variation in temperature distribution across a single city [26,27]. Past research has utilized infrared satellite data for this purpose [10,28,29], though vehicle-based traverse measurements (used in this

study) can provide a detailed representation of heat exposure at a smaller scale [30,31,32,33].

From an environmental justice point of view, the existing research emphasizes point source pollution [34,35,36], though it has become clear that climate change affects communities differentially and creates novel impacts never before witnessed in traditional environmental research. As such, we argue that climate change is catalyst for injustice. While some of the effects can be easily observed at the national level, particularly in the world's poorest countries [37,38], there is relatively little understanding of the impact at a more granular scale. Needed are approaches—methodological, conceptual, and pragmatic—that help us to identify those communities disproportionately affected by UHI, and strategies that can help to reduce vulnerabilities. This study provides new evidence of disproportionate exposure to climate change at a local level, as well as access to refuge, an understudied facet of adaptive capacity.

Previous studies indicate a relationship between socio-demographic factors and heat-related morbidity/mortality [39,40]. Income is quite predictive of vulnerability (inverse relationship) [41,42,43], though it is possible that other indicators also play a role. If so, urban heat exposure may be framed as an environmental justice or 'climate justice' [44] issue, disproportionately affecting marginalized socio-demographic groups with limited adaptive capacity. This study aims to identify such populations in Portland, Oregon by assessing (1) disproportionate heat exposure among socio-demographic groups; and (2) disproportionate access to refuge (either public refuge facilities or residential central air conditioning), resulting in heightened or lowered adaptive capacity. An in-depth statistical and spatial analysis will reveal significant, inequitable relationships, validating the application of an environmental justice lens in addressing urban heat resilience.

2. MATERIALS AND METHODS

2.1. Study Area

Our assessment occurs in a Pacific Northwest city of the United States. The City of Portland, Oregon is located at approximately 45.5° North, 122.6° West, at the confluence of the Willamette and Columbia Rivers. The city covers approximately 345 square kilometers, with of a population of nearly 640,000 as of 2016 [45]. The City of Maywood Park, Oregon is located within northeast Portland and, though an enclave of the City of Portland, has been excluded from the study. Due to the fact that summer temperatures have an average monthly highs of 22.7 °C, 26.4 °C, and 26.7 °C for June, July, and August, respectively [46], Portland offers several advantages to conducting an assessment of disproportionate effects of urban heat. First, historical high temperatures have rarely exceeded 35 °C, which reduces public concern for heat related illnesses. Second, as of 2013, fewer than 35% of households had air conditioning [47], and communities may not have immediately available private residences to consider refuge from heat waves. Finally, Portland Climate Action Plan (2015) explicitly addresses the importance of reducing disproportionate exposure to urban heat waves, yet few actions have materialized.

2.2. Data

Three main data types were used in this study, all at the U.S. census block group level: socio-demographic indicators, distribution of ambient temperatures in the study location, and refuge availability. Socio-demographic data used include: income (percent of the population below 50% of the poverty line); race (percent of the population who do not self-identify as white); education (percent of the population over 25 years old without a high school degree or equivalent); age (percent of the population over 65 years old that lives alone); and English speaking ability (percent of the population that claims to have poor or no English skills). Obtained from the U.S. Census Bureau's American Community Survey 5-year estimates, 2009–2013 [47], these data reflect categories into which individuals have self-identified. Another, non-census piece of data used to highlight socio-demographic status is presence of affordable housing, obtained from Oregon Metro's Regional Land Information System [47]. In order to differentiate "low" and "high" categories used in the analysis, a model-based clustering algorithm was used to split each variable [48].

Following an established protocol [13], we collected approximately 60,000 temperature readings during one day of an extreme heat event on 25 August 2014, in Portland, Oregon, when the average temperature during the hottest hour of the day was in the 90th percentile of 30-year historic daily temperatures for the study region. We sampled temperatures for one hour at 3 times during the day (6 a.m., 3 p.m., and 7 p.m.) using vehicle traverses (cars with a mounted temperature sensor and global positioning system (GPS)) in six predetermined sections of the city. The temperature sensor consisted of a type T-fine (30 gauge) thermocouple in a plastic shade tube (12 cm in length and 2.5 cm in diameter) mounted on the passenger-side window approximately 25 cm above the roof of each of 5 vehicles deployed. Each temperature sensor was connected to a data-logging device with an estimated system accuracy of ±0.5 °C and a 90% response time of less than 60 s in 1 m/s airflow. A GPS unit on each vehicle paired temperature measurement and location. Based on the results from the temperature collection and subsequent modeling, we created three separate heat surfaces, which are continuous descriptions of temperature variation across the study region, corresponding to the three time periods. The resulting maps consisted of a 32-bit floating point 1-meter raster format and contain 449,359,188 pixels for each of the three time periods [13,49]. These three urban heat models were created using random forest machine learning on temperature data collected using vehicle-based traverse measurements. Multiple land uses are included in the model (e.g., tree cover, building volume), and the temperatures derived are representative of the underlying urban form. Earlier research suggests that evening temperatures can have the greatest impact on

human health, in part due to the exposure overnight, when physiological responses [50,51,52] can be acute among those with pre-existing health conditions. As a result, this study utilizes the evening temperature model in an attempt to identify areas with prolonged exposure to high temperatures. The 7 pm model has an R2 of 0.9715 and an RMSE of 0.2078. Using "zonal statistics" in ArcGIS (ESRI, Redlands, CA, USA), average UHI temperature was calculated for each census block, ranging from 26.4 to 30.1 °C. This aggregation method simplifies the UHI dataset, however this alteration of the raw data is deemed worthwhile in order to assess relationships with demographic data. Additionally, this is a common practice in geographic analysis [15,53,54].

In the context of this study, "refuge" refers either to public cooling facilities, or availability of central air conditioning in one's home; in other words, the availability of coping mechanisms. Public heat refuge data were obtained from the Multnomah County Office of Aging, Disability and Veterans Services [55]. These include three County cooling centers; 33 places to play in the water; 59 libraries; and 73 community centers. The heat refuges were geocoded using Google Earth. Nine out of 33 places to play in the water are not free for personal use, but are treated as such for the purpose of this study. Residential Central Air Conditioning (CAC) data were obtained from the Multnomah County Assessment Office [55].

2.3. Analysis

This study assessed multiple facets of vulnerability through the use of mixed spatial and statistical methods, with the aim of identifying not only those hottest areas of the city, but also trends of socio-demographic disparity. Elements considered include exposure of sensitive populations, as well as their ability to cope with heat by accessing refuge.

First, heat exposure was determined by mapping UHI data at the census block group (CBG) level. Using the "raster" package in R statistical software, the mean of all pixels falling geographically within an individual CBG polygon was appended onto that polygon's data table, resulting in a visual representation of spatial temperature distribution. This indicated areas of the city most exposed to extreme heat.

Second, the relationship between various socio-demographic groups and high-exposure areas was assessed using the Student's t-test method, where = 0.05 for all tests. This method reveals which sensitive groups, if any, are disproportionately exposed to extreme heat conditions. In each case, two groups are compared: those with low adaptive capacity characteristics, and those with high adaptive capacity characteristics. Indicators included in this analysis, bifurcations of each, and hypotheses tested are as follows.

H0: Average of low income population – Average of high income population = 0
H1: Average of low income population – Average of high income population > 0
where:
Average of low income population = Mean temperature of low income block group
Average of high income population = Mean temperature of high income block group

H0: Average of non-white population – Average of white population = 0
H1: Average of non-white population – Average of white population > 0
where:
Average of non-white population = Mean temperature of block groups with large non-white population
Average of non-white population = Mean temperature of block groups with small non-white population

H0: Average of low education population – Average of high education population = 0
H1: Average of low education population – Average of high education population > 0
where:
Average of low education population = Mean temperature of block groups with large population with less education
Average of low education population = Mean temperature of block groups with small population with less education

H0: Average of isolated elderly population – Average of accompanied elderly population = 0
H1: Average of isolated elderly population – Average of accompanied elderly population > 0
where:
Average of isolated elderly population = Mean temperature of block groups with large population of isolated elderly
Average of isolated elderly population = Mean temperature of block groups with small population of isolated elderly

H0: Average of low English proficiency population – Average of English proficiency = 0
H1: Average of low English proficiency population – Average of high English proficiency population > 0
where:
Average of low English proficiency population = Mean temperature of block groups with large population low English proficiency
Average of low English proficiency population = Mean temperature of block groups with small population with low English proficiency

H0: Average of population in affordable housing – Average of population in non-affordable housing = 0

H1: Average of population in affordable housing – Average of population in non-affordable housing > 0
where:
Average of population in affordable housing = Mean temperature within 100 m of affordable housing
Average of population in non-affordable housing = Mean temperature within 100 m of non-affordable housing

Third, this study examined the accessibility of refuge for various populations, broken out into specific racial categories, as well as elderly (over 65 years) and young children (under 5 years) age groups. The race groups included in the analysis are white; black or African American; American Indian or Alaskan Native (AIAN); Asian; Native Hawaiian and other Pacific Islander (NHPI); and Hispanic or Latino. Access to public heat refuges was calculated for walking speeds of slow, normal, and fast. Maximum acceptable walking time was set at 15 min, and analyzed based on average walking speeds for sedentary elderly (1.4 km/h), average elderly (3.5 km/h), and active adults (5.6 km/h) [56]. These distances (0.35, 0.875, and 1.4 km, respectively) were applied using "network distance analysis" in ArcGIS to establish heat refuge catchment areas.

Additionally, differences in walking access to refuges, temperature exposure, and access to residential central air conditioning (CAC) were assessed for the aforementioned groups using covariance analysis. Using GeoDa's "scatter plot" function, percentages of residents with specific characteristics were used as X variables, and the accessibility of heat refuges, UHI, and the prevalence of CAC were used as Y variables (Table 1).

Table 1. Variables used in covariance analysis. Socio-demographic factors represented as X variables (independent); Heat refuge factors represented as Y variables (dependent).

	Variables
First Variable (X)	• % of White • % of Black or African American • % of American Indian and Alaskan Native (AIAN) • % of Asian • % of Native Hawaiian and Other Pacific Islander (NHPI) • % of Hispanic or Latino • % of residents under age 5 (young children) • % of residents over age 65 (elderly)
Second Variable (Y)	• Urban Heat Index (UHI) • Central air-conditioning units (CAC)/km^2 • Accessibility to public heat refuges (fast, average, and slow walking speeds)

3. RESULTS

Results have been divided into three sections. We begin by providing background on the UHI and its integration with the CBG data. We follow with outputs from statistical analyses, which identify relationships between heat exposure and specific socio-demographic groups. Finally, we identify the accessibility of heat refuge options (public cooling centers or central air conditioning) to those who have a low level of adaptive capacity.

3.1. Ambient Temperature Distribution

The UHI model employed shows a concentration of high-heat areas to the east side of the city, while the west side of the city is relatively cool (Figure 1). Also, we note two implications of converting heat data to CBG. First, the block groups are not coterminous with the UHI data; the boundaries do not exactly overlap, which means that each block group draws from the nearest temperature. Second, since the UHI map is at 1 m resolution and the block groups are much larger, all temperature values within a CBG were averaged. Although these limitations may reduce the overall accuracy of the precise temperature in each CBG, our purpose is to evaluate broad relationships between socio-demographics and UHI, rather than a precise household-scale assessment.

3.2. Heat Exposure by Socio-Demographic Group

The results of statistical t-tests (Table 2) reveal significant relationships between heat exposure and populations that are low-income, non-white, minimally-educated, or poor English speakers; all of these socio-demographic groups, as well as those living in affordable housing, experience higher temperatures than their wealthy, white, educated, English-speaking counterparts. Isolated elderly is the only tested indicator that did not significantly correlate with higher temperatures.

3.3. Exposure and Access to Refuge

The network distance analysis of public refuge access shows that 3.4–32.7% of the city's population can access a refuge on foot, depending upon walking speed (Table 3, Figure 2). These cooling centers are most numerous in North and Northeast Portland, while the farthest eastern and western regions of the city offer fewer options for public refuge.

Figure 1. Comparison of the original raster format of the distribution of ambient urban heat (left) and the transformed block group-based urban heat dataset (right).

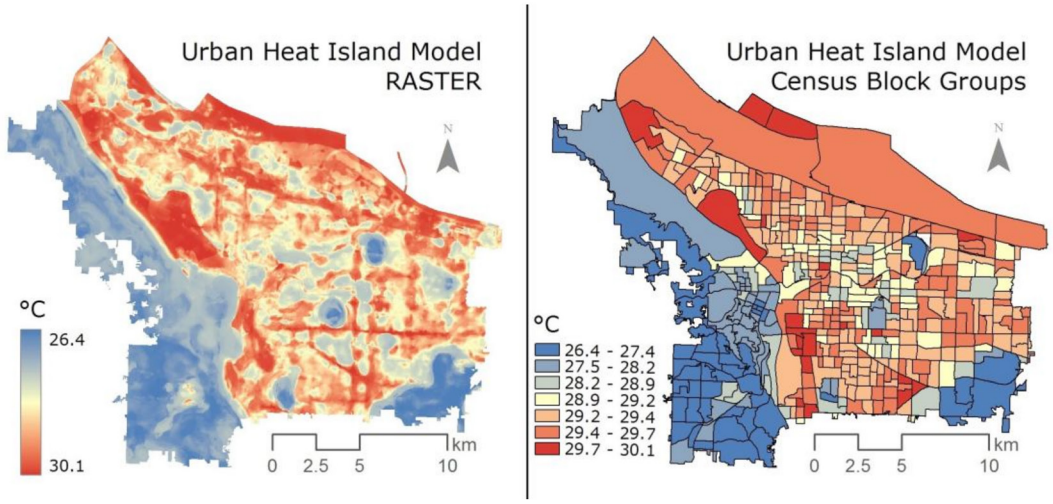

Table 2. Results of Student's t-tests: Statistical significances. Tests which have a p-value greater than 0.05 are considered to have failed to reject H0.

Variable	Description	*t*-Statistic	*p*-Value	95% Interval—Low	95% Interval—High	Conclusion
Extreme Poverty	Percent of population below 50% of the poverty line	2.0848	0.0378	0.009 °C	0.317 °C	Reject H_0
High Racial Diversity	Percent of population who do not identify as 'white'	5.7579	1.565×10^{-8}	0.274 °C	0.558 °C	Reject H_0
Low Education	Percent of population without a high school diploma or equivalent	7.8371	3.359×10^{-14}	0.402 °C	0.672 °C	Reject H_0
Isolated Elderly	Percent of population who are 65+ years old and live alone	−0.0709	0.994	−0.221 °C	0.206 °C	Fail to Reject H_0
Poor English Skills	Percent of population with poor English speaking abilities	6.0897	2.446×10^{-9}	0.297 °C	0.580 °C	Reject H_0

Figure 2. Catchment areas of public heat refuge access for slow, average, and fast speeds.

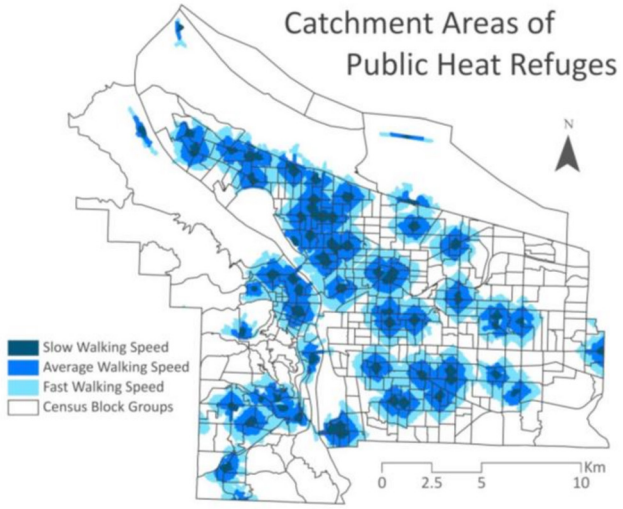

Table 3. Percentage of the city having access to one or more public heat refuges (cooling centers).

	Slow Walking Speed	Average Walking Speed	Fast Walking Speed
Access to Public Refuges	3.4%	16.9%	32.7%

Based on the results of covariance analyses, distinct inconsistencies emerge and define disproportionate exposure to high temperatures, and accessibility to CAC and public refuges (Table 4). The figures in this table represent expected changes in the dependent variable for a single-unit increase of the independent variable in question. For example, the –1.515 value between "White" and "UHI" indicates that for a 100% increase in white population, a 1.515 degree Celsius decrease in temperature would be expected.

Table 4. Results of covariance analysis: relationship between socio-demographic factors (independent variable), heat exposure, and refuge (dependent variables).

	Socio-Demographic Indicators							
	White	Black	AIAN	Asian	NHPI	Hispanic	Children	Elderly
Expected Temperature Change (C)—for single unit increase of socio-demo indicators	−1.515 **	1.949 **	3.089	1.008	3.471 **	2.010 **	4.620 **	−2.114 **
Central Air Conditioning (CAC units)	96.196 **	−90.034	−552.782	−45.506	−339.324	−111.992	−305.086 *	58.325
Refuge:								
Fast Speed	−1.290 *	5.917 **	6.104	−4.839 **	1.146	−0.767	1.125	−4.103 **
Average Speed	−0.365	2.175 **	2.779	−2.043 **	0.293	−0.492	0.666	−1.764 **
Slow Speed	−0.004	0.293 *	0.280	−0.370 **	−0.056	−0.069	0.144	−0.390 **

Note: * ($p < 0.05$); ** ($p < 0.01$).

3.3.1. Exposure to Urban Heat

The white and elderly populations have a negative relationship with UHI (–1.515 and –2.114, respectively), which is statistically significant. This means that census blocks with a higher number of white residents and older adults as a percentage of the total census block population are more likely to have lower temperatures during an urban heat event. For example, for every 10% increase in the white population, temperatures are lower by 0.1515 °C on average during a heat event. By contrast, a larger black/African American population, along with NHPI, Hispanics, and young children all have a positive linear relationship with UHI. For example, the coefficient for NHPI is 3.471, meaning that for every 10% increase in NHPI, of the total census block population, temperatures are higher by 0.3471 °C on average. The share of AIAN and Asians do not have a statistically significant relationship. This analysis is based solely on demographic characteristics as they relate to temperature and does not explicitly account for the presence of buildings, trees, or other factors which influence urban heat. However, it may be inferred that those groups experiencing the highest temperatures are located in areas which lack heat-ameliorating infrastructure, or possess built urban features that exacerbate heat [21,22].

3.3.2. Central Air Conditioning (CAC) Units per Area

Only the white population has a significant positive relationship with CAC per area (km2). On the other hand, only young children have a negative linear relationship with CAC, which is statistically significant. For every 10% increase in white population, of the total census block population, CAC units are likely to be higher by 9.6 units per square km, and for every 10% increase in young children, CAC units are likely to be less by 30.5 units on average. The share of black/African American residents, AIAN, Asians, NHPI, Hispanics, and the elderly do not have a statistically significant coefficient.

3.3.3. Public Cooling Centers

When assuming the average walking speed, only the black/African American population has a positive relationship with accessibility to public heat refuges. On the other hand, Asians and the elderly have a negative linear relationship with public heat refuges in the city. For every 10% increase in black/African American population of the total census block population, the residents have more access by 0.22 public heat refuges on average, and for every 10% increase in Asians, the residents have less access by 0.20 public heat refuges. Other tested socio-demographic characteristics do not have statistically significant relationships with the accessibility to public heat refuges.

4. DISCUSSION

This study examined socio-demographic factors in relation to the distribution of urban heat in an attempt to better understand vulnerability based on (1) disproportionate heat exposure among socio-demographic groups; and (2) disproportionate access to refuge (either public cooling facilities or residential central air conditioning), resulting in heightened or lowered adaptive capacity. Overall, results indicate that populations with low adaptive capacity characteristics also experience high exposure, and that access to refuge is significantly influenced by socio-demographic status.

A series of Student's t-tests were performed to test the hypotheses that the difference between "high" and "low" adaptive capacity groups were significantly greater than 0. The results of the study, with the exception of the variable isolated elderly, allow rejection of the null hypothesis, and indicate that populations with characteristics of low adaptive capacity do experience higher temperatures than those with high adaptive capacity within the study area. Additionally, the analysis showed significantly higher temperatures in the area directly surrounding affordable housing when compared to a random sample of non-affordable (i.e., regular) housing from similar block groups.

We focused on isolated elderly specifically because they have historically been disproportionately impacted by heat waves in other parts of the U.S. [39,40], though similar patterns are not statistically significant in the City of Portland. In fact, the observed non-significance of the isolated elderly (percent of the population 65+ years old and who live alone) could be related to the spatial nature of the census block group geographies. A test for spatial autocorrelation conducted using Moran's I [56] showed that, while census block groups with a high percent of isolated elderly have statistically significant clustering (z-score = 2.921, where 0 is random; p-value = 0.0035), they are far more random in spatial distribution than the variables for extreme poverty (z-score = 6.411; p-value ≈ 0), high racial diversity (z-score = 15.475; p-value ≈ 0), poor English skills (z-score = 15.673; p-value ≈ 0), and low education (z-score = 17.787; p-value ≈ 0). This notable difference in spatial autocorrelation shows that block groups with high levels of isolated elderly populations are more randomly distributed than the other socio-demographic variables, thus increasing the chances that they will have a more randomized exposure to extreme heat and a less significant Student's t-test result.

The accessibility analysis revealed that walking speeds, as they relate to the distribution of cooling centers, greatly affect the percentage of areas in the city having access to heat refuge. At the slower walking speed (1.4 km per hour), only 3.4% of residents have access; at the average speed (3.5 km per hour), the percentage increases to 16.9%; and at the fast speed (5.6 km per hour), it increases to 32.7%. This finding reveals that even in the best case scenario (fast speed), less than one third of the population can access a public heat refuge. This may be especially meaningful for individuals with mobility challenges, such as those using wheelchairs, those with pre-existing

health conditions, and bedridden patients, though such groups have not been included in this study.

The covariance analysis found racial and age-related disparities in distribution of UHI, CAC, and walkable access to heat refuges. Risk factors concentrate on some socio-demographic groups, especially young children. They are more likely to live in census blocks which are hotter during urban heat events, and with a smaller number of CAC units. In contrast, white populations tend to live in census blocks with less UHI effect, and more CAC units. Black/African American populations tend to have better accessibility to public heat refuges, which may prove helpful if they are concentrated in high-heat census block groups. While analyses focusing on environmental justice have found that non-white communities are disproportionately living near point sources, urban heat and the access to refuge arguably represent novel concern that may further deepen the inequities in society.

This study does not offer a complete exploration of the factors which determine why certain socio-demographic groups cluster in areas experiencing higher temperatures. This is a complex question that would require a complete study of its own, though some of the likely contributing factors are known to researchers. Urban development patterns often feature lower rents in areas near large roads and buildings [57], both of which can amplify urban heat effects. Assuming individuals with limited financial means seek out lower rent, this increases their likelihood of locating in areas with higher heat stress. A second possible factor relates to socialization and, in some cases, spatial isolation of minority communities. Such groups have a history of building social capital by co-locating in neighborhoods, as well as being coercively isolated in specific locations [58,59,60]; this could result in apparently heightened heat exposure for such groups, simply due to their proximity. In the case of Portland, local development practices have typically placed large trees and other heat-ameliorating features in higher-income neighborhoods [61], exacerbating heat exposure of low-income and minority communities who have historically been excluded from these areas. These are multifaceted relationships that differ across cities, and are outside the purview of this study. However, it is useful to consider the underlying causes of physical clustering and resulting exposure.

One major drawback to the analyses in this study is the geographic format of the data. The irregular polygon geometry of the census block group data relies on areal aggregation to protect the anonymity of individuals; this aggregation of population and heat data into enumeration units can 'smooth' the dataset, eliminating extreme highs and lows in the process of representing the data with a single mean value. This complication is difficult to avoid, as the block group geometries employed in this study are the highest resolution datasets available with the required socio-demographic information. Additionally, the Modifiable Areal Unit Problem (MAUP) may introduce error when using enumeration units such as census block groups [62]. A potential alternative to this census-based study would be to create an entirely new survey of randomly sampled households in the region. This potential new study could allow for a building-level analysis similar the one performed here for affordable housing, but for all socio-demographic variables. A survey with a sample size high enough for statistically sound inference and analysis would be time consuming and costly, however it could potentially reveal more accurate or meaningful results.

This study is also lacking in a key piece of information which would provide a more complete understanding of vulnerability; though exposure and adaptive capacity have been well explored, sensitivity has not, mainly because reliable data on health, genetics, and lifestyle choices are difficult to obtain. For this reason, the definition of vulnerable populations may not be fully accurate because we do not accurately know whether individuals do not, in fact, have access to other forms of refuge (e.g., ductless heat pump, swimming pool, alternative residences, etc.). At the same time, at the population level, the present study finds significant associations between high exposure and low adaptive capacity, which provide meaningful direction for decision makers to prioritize those areas and groups that are likely to be at high risk.

Next Steps for Practitioners

The results of this study may serve as a guide for practitioners in Portland, Oregon, directing attention to those areas of the city most at risk of extreme heat exposure. However, socio-demographic indicators can only reveal general characteristics of a population; as such, community engagement in these priority areas will be a key strategy moving forward. These results suggest that practitioners will need to meet with community members directly to better understand what they experience during a heat wave, how they adapt, and what they perceive their needs and strengths to be. Rather than offering strictly external monetary or technological support, sustainable solutions may be reached by working with local organizations and individuals to build internal capacity.

Given the diverse nature of marginalized groups exposed to extreme heat, it will be helpful for the City of Portland and Multnomah County to release heat-related materials for such an audience. Information regarding public refuges and heat safety, as well as heat wave warnings should be issued in multiple languages and formats (print, online). Messaging tailored to specific groups may also be helpful. It is further recommended that government agencies work with community organizations to disseminate information and provide refuge, as marginalized populations may be wary of government programs. Although this particular study pertains to Portland, the development of inclusive materials and interventions is a best practice for all cities.

5. CONCLUSIONS

This study provides compelling evidence that extreme heat exposure is an environmental justice issue. Exposure and adaptive

capacity are clearly associated with socio-demographic differences, and many marginalized, low adaptive capacity groups experience disproportionately high temperatures. As low-income populations and non-white populations are presumably most vulnerable to heat-related malady, it is imperative that local governments and practitioners recognize and address social disparities in heat resilience efforts. A detailed local survey process is recommended to overcome limitations of available demographic data, though this study should provide a strong basis for program planning and outreach. Though these results are specific to Portland, Oregon, such relationships likely exist elsewhere, and it is suggested that an environmental justice lens be applied to future study of heat resilience.

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SECTION IV:
RESILIENCE IN PRACTICE

Existing climate adaptation and/or
resilience plans
Practical applications of resilience thinking
to climate planning

Resilience in Practice

As previously noted, a goal of resilience has become ubiquitous across planning and policy documents, organizational mission statements, natural resource management strategies, and conversations about climate change. At times, resilience is barely interpreted by those who call for it; it is offered only as a nebulous antidote to human and ecological suffering. When clearly defined but in a way that is too discipline-specific, the invocation of resilience may alienate outsiders and limit practical partnerships. In other cases, city bureaus and community groups may be participating in work that very much aligns with resilience thinking, but are not using the normative language and thus go unrecognized.

Part of engaging with climate change adaptation and resilience solutions is taking stock of what is out there: how cities have previously presented or framed resilience (or not) in practice; what kinds of solutions or partnerships have been attempted; and what lessons have been learned. While theory provides us a view of the ideal scenario, only practice can teach us what works, what does not, and what we might do differently within real-world constraints.

In this section, you will review existing urban and/or climate adaptation plans that address the need for resilience, either explicitly or implicitly. This should reveal the extent to which some of the major theoretical concepts and evaluative indicators have been taken up in practice. Furthermore, some practical interventions and outcomes are explored through case study research. Finally, an article by Douglas Glandon [1] calls for a common language of resilience to facilitate collaboration between researchers and practitioners. While not directly addressing climate change issues, this sentiment has meaningful implications for resilience advocates broadly.

READINGS INCLUDED

[Open access articles; Full text included]

Your city's climate action plan or equivalent, if available. If your city has no such plan, or if you are teaching within Portland, Oregon, we suggest: City of Portland, Climate Action Plan (2015). https://www.portlandoregon.gov/bps/article/531984

Glandon, D. M. (2015). Measuring resilience is not enough; we must apply the research. Researchers and practitioners need a common language to make this happen. Ecology and Society, 20(2), 27.

van Niekerk, W. (2013). Translating disaster resilience into spatial planning practice in South Africa: Challenges and champions. Jàmbá : Journal of Disaster Risk Studies, 5(1), e1-e6.

Jacobs, B., Boronyak-Vasco, L., Moyle, K., & Leith, P. (2016). Ensuring resilience of natural resources under exposure to extreme climate events. Resources, 5(2), 20.

ALTERNATIVE SELECTIONS

[Full text not included; May be accessible through your university library or elsewhere]

Adger, W. N., Brown, K., Nelson, D. R., Berkes, F., Eakin, H., Folke, C., … Tompkins, E. L. (2011). Resilience implications of policy responses to climate change: Resilience implications of policy responses to climate change. Wiley Interdisciplinary Reviews: Climate Change, 2(5), 757–766.

Hughes, S. (2015). A meta-analysis of urban climate change adaptation planning in the U.S. Urban Climate, 14(1), 17–29.

Wamsler, C., Brink, E., & Rivera, C. (2013). Planning for climate change in urban areas: from theory to practice. Journal of Cleaner Production, 50(1), 68–81.

STUDENT EXERCISES

(1) Choose an existing municipal or regional climate resilience plan (or adaptation plan). Read through and look for:

- explicit references to "resilience"
- focal areas of risk, exposure, or vulnerability
- proposed solutions to climate-related problems

(2) Prepare a 10 minute presentation answering the following questions:

- How does this plan refer to and identify resilience?
- For whom or what is resilience prioritized?
- Does this plan seem to view resilience and vulnerability through an engineering, ecological, social-ecological, ecosystem services, or other lens?
- How, from your perspective, does the plan operationalize resilience?
- What would you change in the plan? What is missing (if anything)?

FOR INSTRUCTORS: CLASSROOM ACTIVITIES

(1) If possible, we suggest that you extend this section over multiple weeks and invite local practitioners to speak to the class about their work.

(2) Ask students to write a short (1 paragraph) reflective exercise after each guest speaker presentation, explaining how theoretical concepts from resilience literature might be relevant to the speaker's practical work.

Measuring Resilience is Not Enough; We Must Apply the Research. Researchers and Practitioners Need a Common Language to Make This Happen

by Douglas M. Glandon

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ABSTRACT

This article is contributed by a practitioner in the area of country-level health systems strengthening who also has a background in resilience research. The intent of the article is to offer constructive reflection on the disconnect between the insights of resilience research and the application of those insights through development assistance. The primary reason for the existence of this communication block is that resilience research findings are not often translated in a format that is useful to those implementing resilience promotion projects. As a result, implementers do not usually review relevant research to guide their interventions. Resilience researchers and practitioners need a common language, one that arises from effective community engagement.

Keywords: community resilience; development assistance; research to action

RESILIENCE IS EXPERIENCED AS A SOCIAL NARRATIVE, NOT AS A SET OF NUMBERS

Although details vary from place to place, wherever you travel in the world, sooner or later you are likely to hear a story about resilience. Whether it is "bouncing back" from adversity or "bouncing forward" to a new normal that is enhanced in some way relative to the time before a traumatic event, examples of resilience can be found everywhere, from individuals and households to communities, organizations, and governments.

Some researchers have characterized resilience by focusing on the absence of a particular pathology, such as post-traumatic stress disorder, as noted by Almedom and Glandon (2007). Other researchers have explored resilience as a personality trait, or as a quantified adjustment in a group of people after a "potentially traumatic event". The adjustment would usually be compared to that of another group that experienced the same event exposure but had a different "adjustment" score (Bonanno 2012).

It is worth noting that many definitions of resilience, such as those listed above, are closely linked to a specific research methodology. This is convenient from a research perspective but may limit understanding of the particular resilience characteristics of the communities being studied. A broader, more holistic definition of resilience—and the one adopted for this article—is proposed by Almedom and Tumwine (2008):

. . . resilience is defined as the capacity of individuals, families, communities, systems, and institutions to anticipate, withstand and/or judiciously engage with catastrophic events and/or experiences; actively making meaning with the goal of maintaining normal function without fundamental loss of identity.
This definition emphasizes the need to understand the catastrophic event from the perspective of members of the affected community, especially in terms of people's experiences relating to meaning and identity. This information is likely to come in the form of a story or narrative that has meaning to the community rather than through a specific analytical or conceptual lens.

Following are several examples of community resilience that were verbally relayed to me as part of my work in providing technical assistance for global development projects. These case examples were not investigated within any specific analytical framework. The point here is that they are all conceptually consistent with the definition of resilience offered by Almedom and Tumwine—that is, each describes experiences of a community that actively responded to an adverse event, and essentially maintained normal functioning and, ostensibly, their collective identity.

Benin

To avoid being captured and sold into slavery by the Fon ethnic group of the Dahomey Kingdom in the 17th century, the Tofinu tribe literally moved their entire village into a lake. According to the guide who poled our pirogue through the village, the Tofinu knew that the Fon belief system prevented them from attacking them in a body of water so they begin building their homes, and eventually stores, schools, clinics, a church, etc., in Lake Nokoué. In other words, their thoughtful reflection on the threat facing them and their

collective willingness to adapt to a totally different way of life is what allowed them to survive. The village, which still exists today and is on the tentative list for UNESCO World Heritage Sites, was named Ganvié, which in the Tofinu language roughly translates to "saved community".

Senegal

The population in the southern region of Senegal known as the Casamance has been living through a low-level civil war for three decades, experiencing periodic bursts of violence from the ongoing conflict between the local separatist movement and the national government in Dakar. Yet while the media tend to fixate on the turmoil and unrest, when I visited the Casamance shortly after the breakdown of negotiations with the Senegalese government in early 2005 I saw armed soldiers smiling and joking with each other amidst an otherwise typical backdrop of Senegalese village and town life. A local man from the Diola ethnic group of the Casamance explained that while the people of the region had suffered, the conflict actually reinforced their cultural identity as a distinct group with an egalitarian structure and a sense of pride in resisting centralized authority, which is a narrative extending back to the time of French colonial rule.

Tanzania

Once having spanned most of the Great Rift Valley in East Africa, the pastoralist Maasai are now having to adapt to decreasing access to land due to environmental preservation, tourism, or other pressures, leading to frequent characterizations of the Maasai as a dying culture or as a tribe struggling to survive. Yet, while working on a research project in Dar es Salaam from June to August 2006, I also saw another side of the story, in the forms of traditionally dressed Maasai men with machetes and cattle-herding staffs amidst the rush-hour pedestrian traffic of jeans, t-shirts, business suits, and briefcases—walking to work. The Maasai seem to have gained an impressive market share in the security guard business, leveraging their historical reputation as skilled warriors. While it is certainly no justification for forced migration, the ability of the Maasai to adapt to an urban livelihood while retaining their distinctive identity also makes it difficult to fully justify the "dying culture" narrative.

Haiti

Traditional religious beliefs were suppressed when Haiti became a French slave colony in the 18th century and Haitians were forced to convert to Christianity. In response, many Haitians nominally accepted the new faith to avoid persecution, simultaneously renaming traditional deities as Christian figures, including God and the saints. In 2007 I had the opportunity to see the modern-day expression of this religious syncretism while visiting Plaine du Nord with an undergraduate student research team during the Catholic celebration in honor of St. Jacques—who also happens to symbolize the voodoo spirit Ogoun. Inside the church a wall-to-wall crowd sang hymns and listened to passages from the Bible during Mass. At the same time, just outside the church doors and extending through the streets was a crowd of voodoo adherents with thousands of lit candles, chanting, drumming, dancing, and performing various rituals including animal sacrifices and bathing in a mud pool in the center of town. The Catholic practices and icons that were once imposed upon the country have now become a source of prayer and celebration for those still adhering to their traditional beliefs.

Fiji

To deal with and prevent shortages of fish as a food source, chiefs in Fijian coastal villages traditionally established periodic "taboos", or bans, on fishing in certain areas to replenish the fisheries. Several local fishermen explained to me that this approach worked well in the past when the fishing vessels were small, stayed closer to shore, and were piloted by other islanders. With the advent of modern commercial fishing, often done in deeper waters by foreign vessels, the traditional taboos became markedly less effective and now the only feasible means of regulating fishing is through maritime policing by the national government. However, rather than managing this effort independently, the national government chose to integrate the traditional practice of taboo into the effort, thereby gaining widespread support and collaboration from communities across the country. While fish shortages are an ongoing challenge in Fiji, this method has already shown positive results in some parts of the country (Corcoran and Hughes 2012).

RESEARCH SHOULD HELP TRANSLATE COMMUNITY NARRATIVES INTO INSIGHTS

Human resilience is intrinsically linked to the social, natural, and built environments in which people live. Narratives provide a contextual richness that is critical for investigating the phenomenon. A clear analytical framework can sort through the details of these stories to derive insights that may help promote resilience, whether within the same community or elsewhere.

For instance, if we refer to a community's resilience, are we talking about its ability to maintain certain attributes during times of adversity, such as a sense of cultural identity, psychosocial wellbeing, access to food, or something else? Or are we referring to its ability to modify some characteristics in order to adapt to a changing environment or circumstances, such as moving to a new location or reinventing a belief system?

Due to the wide variety of interpretations of resilience, the appropriate analytical framework should clarify what is actually meant by "resilience"—including resilience by whom or of what—and how it may be enhanced. The framework has value when it helps break down and analyze a social narrative of resilience, much as a literary critic might assess the key elements of a novel. In the context of human resilience, if an adverse event is the conflict, a useful analytical framework helps us investigate the factors that influence the characters' abilities to cope or adapt.

While some resilience-promoting or "salutogenic" traits or characteristics (Antonovsky 1996), such as genetic traits, are more or less fixed and cannot be changed, others, such as child-rearing practices, social support, cognitive interventions, coping self-efficacy (Southwick 2012), and social cohesion or connection (Zraly and Nyirazinyoye 2010), may have prescriptive value for shaping interventions and possibly public education.

It is this latter category, of what could be termed malleable or transferable factors, that captures the interest of practitioners in the health and development community. By understanding salient factors that promote resilience in a particular context, we gain ideas about which ones might help promote resilience in other groups, locations, circumstances, or adversities. If, for instance, we want to examine the examples of community resilience narratives mentioned above to find insights that might be relevant elsewhere, selecting a suitable analytical framework is a critical first step.

One useful construct is the notion of "resilience pivots" that was introduced by Rotarangi and Stephenson (2014) to highlight elements of a particular community or group that remain constant through an adverse event. If we were to apply this lens to the Senegal example, we could investigate whether the continuity, and perhaps even reinforcement, of the Diola cultural identity as an independent, egalitarian community in the Casamance region helped that population cope with the long-term separatist conflict. Similarly, the resilience pivot concept may also help describe how the incorporation of the traditional cultural practice of taboo in temporarily banning fishing in certain areas of Fiji is currently helping the country respond to and prevent the depletion of its marine resources from overfishing.

Folke et al. (2010) articulated how "transformational change" at a local or specific level can contribute to resilience at a larger scale or in a broader context. Looking at the resilience narrative from Benin, this view might support the idea that the decision of the Tofinu to move their home into a lake was a transformational change that ultimately allowed them to survive as a group. Similarly the Haitians completely redefined their religious icons during the French colonial period in order to retain their ability to openly practice their faith, while an increasing number of Maasai pastoralists reinvented their livelihood from herding livestock in the countryside to guarding homes and offices in a major urban center in order to continue to survive and provide for their families in a changing environment.

In each example we see a glimpse of how the right analytical framework and research questions may help guide practitioners in building resilience, especially when preparing for similar types of adverse events. The question is whether the insights from this type of analytical research can be effectively applied to strengthen resilience in individuals, communities, and populations. If so, the magnitude of the potential benefits creates an ethical imperative to do so. In this respect a quote from Leonardo DaVinci is fitting: "I have been impressed with the urgency of doing. Knowing is not enough; we must apply. Being willing is not enough; we must do" (Suh 2005).

OPPORTUNITIES TO APPLY ANALYTICAL RESILIENCE RESEARCH ARE GROWING GLOBALLY

It is encouraging to see that many governments and organizations have taken such an interest in resilience in recent years and have raised its priority on the social agenda, both in terms of domestic efforts and development aid for other countries.

This increased focus on resilience is especially visible in initiatives to help communities prepare for natural disasters and climate change. A Google search in August 2014 with depersonalized results for the words "resilience" plus the name of each of the countries listed above—one at a time—yielded references to climate- or disaster-related initiatives in at least eight out of the top ten search results for each country. For Senegal and Fiji, it was all of the top ten search results.

In monetary terms, climate-change-related initiatives in these same five countries account for nearly US$300 million in approved development assistance funds since 2003. This is according to the database compiled by Climate Funds Update (http://www.climatefundsupdate.org), a joint initiative of the Overseas Development Institute and the Heinrich Böll Foundation, two independent think tanks based in the UK and Germany, respectively. Of note, all of the associated funding sources list resilience promotion as a key objective or priority on their respective websites.

According to the same database, the top ten country funding sources have collectively invested nearly US$31 billion on climate change worldwide through development assistance initiatives since 2003—and again, each one of the listed funding sources includes explicit references to resilience promotion on their websites.

Although these projects and investments represent only a subset of the myriad initiatives worldwide for promoting resilience as part of efforts to help communities and societies adapt to climate change, there are several valuable takeaway points, including: (1) climate

change adaptation is a priority for many government and health and social development organizations; (2) resilience is increasingly seen as part and parcel of climate change adaptation efforts; and (3) lots of time, money, and labor are being invested in promoting resilience globally.

Furthermore, the general consensus among the scientific community that there will be a long-term gradual increase in at least some types of extreme weather events (Alley et al. 2007) is a strong indication that these types of resilience promotion efforts will continue and possibly increase into the foreseeable future.

BOTH RESEARCHERS AND PRACTITIONERS HAVE ROLES TO PLAY IN BRIDGING THE GAP BETWEEN THEORY AND PRACTICE

Given the substantial financial outlays represented by many of these efforts to strengthen resilience, naturally the funding institutions and agencies will invest considerable time and energy into careful, thoughtful planning and into developing appropriate mechanisms to monitor implementation progress. Implementers of resilience-promotion projects and programs will pay close attention to the level of quality and completion of planned infrastructure, the average increases in income among local poor, and the square kilometers of restored mangroves, and other key performance indicators, as they should. Some initiatives may even estimate the expected benefits in terms of helping communities cope with severe weather events or other effects of climate change. Whether or not these are appropriate or meaningful measures of resilience is less clear.

This is where analytical resilience research has a key role to play. To start, a review of relevant research articles and case studies may help practitioners who implement resilience programs to clarify their own definition of resilience and to identify examples of factors that have been demonstrated to promote resilience in similar communities or circumstances. Even taking the first step of translating resilience as an abstract concept into a specific, measurable framework with concrete examples may yield valuable insights for designing and implementing a project or program. Similarly, practitioners may benefit from existing evidence-based tools, such as those listed on the Resilience Alliance website (http://www.resalliance.org), when thinking about how to practically assess the resilience of social-ecological systems and develop strategies to enhance it.

Thoughtful community engagement is also critical to ensuring that the planned resilience initiatives complement and do not undermine pre-existing preferences, norms, and behaviors. Local residents understand how their neighbors think and behave in a way that could potentially take outsiders years to learn. Accessing that knowledge and enlisting the support of key community stakeholders is especially important for initiatives addressing climate change, since the proposed changes are often immediate while the anticipated consequences may be far into the future. Also, communities may have different views about which factors will be most important for strengthening their own resilience. In some cases, they may agree that what is needed most are more retaining walls or restoration of coastal mangroves, but in other cases it might be something completely different.

Yet despite the potential value of drawing from the available research and resources and seeking substantive input from communities to design and implement these initiatives, these steps seem to be frequently omitted, or addressed only perfunctorily. Because a large portion of development assistance funding is delivered through 2-to-5-year projects with predetermined objectives and deliverables, there may be insufficient time or insufficient contract flexibility for implementing agencies to work with communities to develop a shared framework for assessing and building resilience. Although "local stakeholder engagement" or the equivalent is almost guaranteed to be included as a contract requirement for many of these projects, the timelines and pressure to commence implementation as soon as possible mean that the de facto intent of this step is often to get endorsement or "buy-in" from the appropriate local leaders. Hiring local staff to lead or guide project implementation can ameliorate, but not eliminate, these limitations.

The major risk of this type of superficial embrace of resilience as a concept is that we may end up with well-funded and well-intentioned initiatives that ultimately miss their mark because they lack a coherent, evidence-based design or are out of step with local customs and context. As Strauch et al. (2008) note, for instance, one critical limitation of many initiatives to enhance resilience in sub-Saharan Africa through water-related infrastructure is that they tend to focus on large-scale, one-off projects that fail to take into account the key "drivers of change" in social-ecological systems, including the ecosystem, people and technology, local knowledge, and property rights.

INCREASING THE PRACTICAL IMPACTS OF RESILIENCE RESEARCH DOES NOT NEED TO BE COMPLICATED

The key question is how we can translate insights from resilience research into proactive efforts led by communities to enhance resilience-promoting factors or characteristics. There will likely never be a single, sure-fire approach, but acknowledging that this is important would be a start. There is room for improvement within both the researcher and practitioner communities.

Although some researchers' primary objective may be to contribute to the academic body of knowledge on resilience, a worthy secondary objective would be to help guide efforts to translate that knowledge into actions that improve people's lives. If practitioners without a research background are to draw meaningful insights from academic articles about resilience, researchers may want to

comment briefly on some of the potential implications of their findings in terms of how they might be applied in human communities. A good example of this is the work done by Brian Walker and David Salt in their books Resilience Thinking (2006) and Resilience Practice (2012), which provide practical guidance on how to understand and apply concepts of social-ecological resilience in real-world settings. It would also be useful to apply this type of approach to human resilience, using examples like the study by Almedom et al. (2007, as cited in Walker and Salt 2012) on the psychosocial transition in post-war Eritrea, which is briefly referenced in the latter book.

On the implementation side, funders of development projects have a key role to play. Beginning with the initial design, development assistance contracts that seek to enhance human resilience could recommend or require the implementer to review the relevant resilience literature or resources and identify any analytical frameworks or findings that may be useful. For example, a project team focusing on natural disaster resilience in the South Pacific may, as a result of reviewing the case study compiled by Rumbach and Foley (2014) about the 2009 tsunami in American Samoa, think more carefully about how to most effectively engage indigenous institutions through a national emergency response plan. The Workbook for Practitioners prepared by the Gunderson et al. (2010), while not designed for disaster preparedness per se, provides an easy-to-use worksheet for stakeholder mapping of local formal and informal institutions.

Relatedly, funders of resilience projects would do well to allow for an emergent contract design in which some of the specific objectives and approaches are initially kept broad so they can be refined through consultation with the relevant communities. While the funder will often pay for monitoring and evaluation personnel to track implementation progress and estimate the impact attributable specifically to the project investment, this information may be of little value to the local community and will quickly lose relevance once the project has been completed. There is also a need for projects to invest time, money, and personnel into engaging with relevant local institutions, such as ministries of health, universities, or other organizations, to develop monitoring and evaluation mechanisms that are meaningful and useful for them. As Walker and Salt point out (2012:53), "resilience practice is not so much about producing a single 'best' system description as it is about creating a process whereby the system description is constantly revisited, reiterated, and fed into adaptive management."

THE NEED FOR APPLIED RESILIENCE RESEARCH WILL CONTINUE TO GROW

As global interest in resilience continues to grow, whether related to climate change adaptation or other events, there will be increasing demand to translate what we know about resilience into practical action in order to strengthen it. Disaster relief and humanitarian response efforts will continue to include more language about resilience; in some cases, project funding proposals may even require it. As this happens, it will be important for practitioners to make sure "resilience" is not just a buzzword referenced in purpose statements and project plans, but a holistic view of how communities respond to adversity. Some interventions designed to enhance communities' ability to cope with extreme weather events may involve changes that are easy to observe, but the psychosocial and social-ecological factors should not be overlooked. The only way to make sure this happens is to actively engage local communities, not just through perfunctory consultations or buy-in from key leaders at the beginning, but throughout planning, implementation, and assessment. Insights from the literature on community resilience and available resources, such as those compiled by the Resilience Alliance, can help practitioners think critically and strategically about how to do this. Although these changes may in some cases require more time, effort, and flexibility in development assistance contracts, it is the only way to ensure that these resilience-promotion efforts actually benefit the communities they affect and that those benefits last beyond the duration of the initiative. A project may last 2 to 5 years; all signs point to climate change lasting much longer.

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Translating Disaster Resilience into Spatial Planning Practice in South Africa: Challenges and Champions

by Willemien van Niekerk

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ABSTRACT

It is highly likely that hazards and extreme climatic events will occur more frequently in the future and will become more severe – increasing the vulnerability and risk of millions of poor urbanites in developing countries. Disaster resilience aims to reduce disaster losses by equipping cities to withstand, absorb, adapt to or recover from external shocks. This paper questions whether disaster resilience is likely to be taken up in spatial planning practices in South Africa, given its immediate developmental priorities and challenges. In South Africa, issues of development take precedence over issues of sustainability, environmental management and disaster reduction. This is illustrated by the priority given to 'servicing' settlements compared to the opportunities offered by 'transforming' spaces through post-apartheid spatial planning. The City of Durban's quest in adapting to climate change demonstrates hypothetically that if disaster resilience were to be presented as an issue distinct from what urban planners are already doing, then planners would see it as insignificant as compared to addressing the many developmental backlogs and challenges. If, however, it is regarded as a means to secure a city's development path whilst simultaneously addressing sustainability, then disaster resilience is more likely to be translated into spatial planning practices in South Africa.

INTRODUCTION

According to the International Federation of Red Cross and Red Crescent Societies (IFRC), well-run cities can be amongst the safest places in the world from the impact of natural hazards if basic services, food security, policing, running water and sewerage are guaranteed, and building codes are respected. However, in reality, many cities in the world are the most dangerous places on earth. 'The signs of our vulnerability to urban risk are everywhere' (IFRC 2010:8): earthquakes bringing critical urban infrastructure and assets down with tragic consequences (for example, the earthquakes in Haiti and Chile in 2010, and Japan in 2011); a volcanic eruption in one country throwing city airports across the world into chaos (for example, the volcanic eruptions in Iceland in 2010 and Chile in 2011); the drug trade turning inner cities into war zones; epidemics turning into pandemics in the developing world; and streets in the slums of developing cities turning into open sewers during seasonal flooding.

Over the past 40 years, 80 000 people have been killed on average each year and 200 million people have been affected by natural disasters (UNISDR 2010b; World Bank & United Nations 2010:23). Of greater concern than the current trends, is the increasingly clear prognosis from the United Nations International Strategy for Disaster Reduction (UNISDR) and the Intergovernmental Panel on Climate Change (IPCC) that hazards and extreme climatic events will occur more frequently in the future and will become more severe (IPCC 2007; UNISDR 2010a). Many international development organisations (IFRC 2010; IPCC 2007; UN-Habitat 2010; UNISDR 2010a; World Bank 2008) and several researchers (Wisner & Pelling 2009; Puppim de Oliveira 2009; Pelling 2003) warn us that as urbanisation and other global processes continue, a 'strange new urban world' (IFRC 2010:8) is developing – one that is increasingly at risk of experiencing natural, social and/or industrial disasters beyond many urban authorities' experience and ability to manage (ICLEI 2010). The consequences are bigger losses more often, but also long-term implications for human settlements – settlements, particularly in the developing world, that are already challenged by a range of socio-economic development stresses (Parnell, Simon & Vogel 2007:359).

'An emphasis on resilience, rather than just disaster response and recovery has become a mainstream idea in disaster reduction' (Collins 2009:103). Whereas disaster reduction seeks to identify and reduce vulnerabilities and risks, resilience (defined below) is also partly defensive, but more creative in implying coping and adaptation. Planning for resilient cities thus involves more than merely being occupied with minimum standards or widely-accepted spatial designs, it involves accommodation of and adaptation to changing conditions over the long-term (Collins 2009:104).

This article questions whether disaster resilience is likely to be translated into spatial planning practice in South Africa, given its immediate developmental priorities and challenges. The article starts by considering what risk, vulnerability and resilience mean conceptually; then discusses the planning context and spatial planning practices in post-apartheid South Africa; and concludes with a case study on the City of Durban to demonstrate how a 'new' policy paradigm has recently been mainstreamed into local planning

practices, in spite of developmental and intergovernmental challenges.

CONCEPTUAL FRAMEWORK

Urban disaster risk and vulnerability

The vulnerability of people to disasters is increasing progressively, and, if left unchecked, will augment the local disaster risk burden of the world's urban poor (Laukkonen et al. 2009). An urban risk divide is developing in cities as they become increasingly unjust, polarised, divided and fragmented: the well-connected elite barricade themselves in well-serviced and regulated high-security villages (Todes 2011:116; Watson 2005:286), whilst some communities struggle to survive along the fault lines of urban risk (IFRC 2010:8). The poor are largely 'priced out' of safe areas and are concentrated in severely vulnerable and unsafe spaces – most often in informal settlements that are low-lying or steeply-sloping, flood-prone, close to pollution sources, often at highest risk of fire and disease, cauldrons of social tension and crime, with inadequate or non-existent services, and lack of protection from extreme climatic events (Parnell et al. 2007; Pelling & Wisner 2009). Hazards interact with each other to produce compound hybrid hazards, and as everyday disaster risk grows, it undermines the coping capacities of communities. Each succeeding event erodes the resources of a household to cope with and recover in time for the next shock, resulting in a 'ratchet effect' of vulnerability (Faling 2012; Freeman et al. 2002:5; Laukkonen et al. 2009:287; Parnell et al. 2007:357, 361; Pelling 2003:16; Pelling & Wisner 2009:4).

It is clear that addressing urban disaster risk and vulnerability is critical in protecting the lives and livelihoods of people, as well as the infrastructure and development gain. Resilience offers a perspective on reducing disasters and everyday risks, as well as making people and places more robust and adaptable to changes and shocks.

Resilient cities

'Cities are among humankind's most durable artefacts' (Vale & Campanella 2005a:5). Resilience is perhaps a new metaphor to many disciplines, being used to describe and frame a counter-response to threat, but resilience has always preoccupied the inhabitants of cities as they sought to defend and secure their interests. The rise of resilience is ascribed to a growth in political action against a number of perceived threats and events such as climate change-related events, disease pandemics and global terrorism (Coaffee, Wood & Rogers 2009:1; Todes, 2011:118).

C.S. Hollings introduced the term 'resilience' for the first time in 1973 as applied to the analysis of ecosystems. It emerged as a concept in ecosystems theory to explain how ecological systems cope with external shocks, or how to interpret their stability (Coaffee 2009:85; Ernstson 2008:17). Ecological resilience was defined as 'the amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures' (Coaffee et al. 2009:112). The range of application of the term resilience has since then broadened in both theory and research. In recent years resilience has become a transdisciplinary concept that integrates socio-political and physical aspects (Coaffee 2009:87) and is becoming a common frame for the policy goals of socio-ecological systems – such as cities (Coaffee et al. 2009:114; Hamin & Guran 2009:239). Resilience as a concept has its critics though: it is seen by some as merely aspiring to return to the situation before the shock, with no aspirations for transforming society, and therefore only benefitting some and not those most at risk (Pelling 2011).

Resilience is popularly understood as the capacity to accommodate, absorb, bounce back from, or adapt to some kind of perturbation (Hamin & Guran 2009:239; Vale & Campanella 2005b:335; World Bank 2008:32). If resilient, a system has a degree of elasticity, allowing it to withstand a shock and reorganise itself when necessary (World Bank 2008:32) and is thus forgiving of external shocks (Hamin & Guran 2009:239). Resilience is indicated by the continuation of particular functions at an acceptable level (Pelling 2011:42). Moreover, it includes the ability to learn by continuously adapting to the constantly changing risks and vulnerabilities (Collins 2009:106; Hamin & Guran 2009:239).

The goals of a disaster-resilient city need to be built into the everyday practices of urban planning (Coaffee 2009:87). However, urban planning, particularly in the developing world, has so far played a limited role in consciously reducing vulnerability to disasters or everyday risks; and disaster resilience is little understood (Biesbroek, Swart & Van der Knaap 2009). The International Council for Local Environmental Initiatives (ICLEI) sums up the reason for the lack of action:

'[W]hile the changing nature of disaster risk is well analyzed and increasingly addressed at international and national levels of debate and decision-making, efforts to provide direct and practical guidance to local government policy-makers and planners on how to reduce exposure and increase resilience to disasters have been few'. (ICLEI 2010:1)

Because disaster resilience is not made practical, planning practices are often unsustainable – in fact, our everyday decisions could even increase people's exposure to risks and hazards, as opposed to building resilience (Pelling 2003).

Most planners would agree that building disaster-resilient cities is of great consequence, but many countries in the developing world,

including South Africa, have major immediate development challenges – compared to which the pursuit of resilience seems like a 'nice to have'. The next section considers whether disaster resilience is likely to be translated into spatial planning practice in South Africa.

CONTEXTUAL FRAMEWORK

The South African planning context

Pre-1994, apartheid had purposefully and systematically restricted black South Africans from meaningful participation in the economy. The assets of the majority of people were directly and indirectly destroyed and access to skills and self-employment was racially restricted (The Presidency 2009; Todes 2011). Despite solid and consistent economic growth for most of the past 18 years, and numerous policy and legislation changes, the present resilience of urban settlements in South Africa is endangered by spatial inequalities, fragmentation, urban sprawl, inequalities between rich and poor that are deepening, the overload on basic infrastructure and services, congestion on roads, social exclusion, increased crime, and pressure on ecosystem services (Biermann 2011:14). Despite having one of the largest public housing projects in the world, decent shelter near employment opportunities remains elusive for most people – many do not have access to housing or security of tenure, quality social services, public facilities and amenities, economic opportunities and livelihoods, and/or basic services. Moreover, the South African space economy is characterised by the coexistence of formal and informal economic activities, housing and transportation systems, and a dualism in quality of all aspects of life (Biermann 2011:14, 16; Oranje 2010:59; World Bank Institute 2012). The stark inequalities in the country threaten the fragile social cohesion, and have given rise to an increasing number of violent service delivery protests and xenophobic attacks. There are, furthermore, huge territorial disparities between rural and urban areas (Van Huyssteen et al. 2010:24–25, 35).

Planning in South Africa

With the rise of democracy in South Africa, expectations of the eradication of socio-economic imbalances, including equitable development and access to basic services, were high (Carmin, Anguelovski & Roberts 2012:21). A new path of reconstruction and development was cut out for a post-apartheid South Africa in the form of numerous green and white policy papers, Acts and regulations. Simultaneously, a new intergovernmental system was established with a strong focus on the process of inclusive planning rather than planning products (Biermann 2011; Oranje & Van Huyssteen 2011:8), thus Integrated Development Plans (IDPs), which promote the developmental government paradigm (including disaster management), became the dominant planning instrument in post-apartheid South Africa. These plans focus on stakeholder processes and institutional coordination but neglect the notion of using space to restructure settlements. Watson calls this preoccupation with intergovernmental coordination at the expense of transforming previously disadvantaged settlements the 'marginalization of the spatial' (in Biermann 2011:12).

Oranje and Van Huyssteen (2011:6–7) describe post-1994 development planning in South Africa as being characterised by a conflict in intent, action and outcome between service delivery and transformation. 'Servicing' is ensuring a rapid response to a lack of housing and basic services. As such, it has a 'very near-future perspective', concerned with the number of houses completed and services delivered – often in areas where people should not even be living. Oranje and Van Huyssteen (2011:6) argue that the outcome has not necessarily transformed the post-apartheid space economy, but only addressed the symptoms. 'Transformation', on the other hand, is concerned with the restructuring of the entire space economy 'through the pursuit of shared, sustainable, equitable and inclusive growth'. However, much more emphasis has been placed on servicing, which means that many communities may have houses and basic services, but the expansion of the economy into these 'serviced' areas has been minimal and people remain far from social and economic opportunities; for it is often assumed by planners and politicians that it is possible to change the spatial pattern of economic growth and development through state intervention. Municipalities, furthermore, face a number of challenges in overcoming the apartheid spatial legacy: lack of funds; lack of technical, managerial, financial and planning skills and capacity to take up the developmental role; institutional transformation issues because of the amalgamation of municipalities; economic woes inherited from apartheid; huge service delivery backlogs; and intergovernmental misalignment and complexity (Oranje & Van Huyssteen 2011:8; Van Huyssteen et al. 2010:27). Thus the short-term focus on attaining 'servicing' targets (which are immediate and bottomless) often comes at the expense of long-term and transformative planning (Oranje & Van Huyssteen 2011) such as planning for disaster resilience.

Translating disaster resilience into spatial planning practice in South Africa

Before 1994, environmental management, disaster reduction and sustainability, amongst other concerns, received very little attention in South African policy. This changed after 1994 as the process of democratisation resulted in a revised development agenda (Roberts 2008:521). But the simultaneous, parallel development of many policies resulted in duplicated development application processes, competing bureaucracies, interests and agendas, and differences in training, discourse and practice (Todes 2011:123). There was also a growing tension between the need to expedite development to address inequalities, and the need to introduce sustainability concerns such as environmental management and disaster reduction into planning. As described above, development won out as the priority, so that long-term issues were of less immediate concern. There are exceptions, but for the most part this tension has still not been resolved, but has, in many cases, intensified due to the range of immediate and severe development challenges (Roberts 2008:523). For example, the author has found that planning for everyday disaster resilience is not a priority amongst planners in some municipalities

in South Africa due to the pressure of providing for immediate development needs, so that they do not even deem reducing the risk of natural disasters to be part of the planning process, but rather as part of what the 'environmental people' do (Faling, Tempelhoff & Van Niekerk 2012).

What follows is a case study of the City of Durban in South Africa – a metropolitan city facing typical development challenges – and how they have started to mainstream climate change adaptation into their everyday planning. This serves as a hypothetical demonstration that the mainstreaming of disaster resilience in spatial planning can be accomplished if approached in such a way that it is seen as part of the immediate development agenda and integrated into existing planning strategies and everyday planning practices.

CASE STUDY: CLIMATE CHANGE ADAPTATION IN DURBAN

Durban is a coastal city with the largest port on the east coast of Africa. The eThekwini Municipality manages the 2300 square kilometre municipal area that hosts a population of 3.5 million people and is South Africa's third biggest urban economy (Carmin et al. 2012:20; Roberts 2008:521; SACN 2012:37).

The City of Durban faces typical post-apartheid challenges as described above. It also experiences severe weather events such as flooding, storms, droughts and tornadoes. To this extent, a report commissioned by the Municipality on climate change suggests that over time Durban would experience minimum and maximum temperature increases; and rainfall would become more infrequent, but more severe – causing flooding and high tide levels. The report also indicates that the sea level is rising by 2.7 cm per decade. These changes in the climate and sea level will affect numerous sectors in the city such as food security, health, infrastructure, water security, biodiversity and the economy, and many people will become more vulnerable to disaster risks (Carmin et al. 2012:18–21; Roberts 2008:528). At that time, few strategies in eThekwini engaged proactively with each other to reduce the risk for disasters due to extreme weather events. Moreover, the disaster management sector was mostly responsive to emergencies, not focusing on proactively planning to minimise exposure and susceptibility, relocating people and infrastructure away from high risk areas, or on developing early warning systems. As severe weather events started to cause more damage to the city during the last decade – notably the severe flooding in 2007 and coastal erosion that caused significant damage to the coastline around Durban – the Municipality started to wake up to the consequences of these events, and realised that many of the post-apartheid development gains are already being undermined or lost, and will be exacerbated further by climate change. Climate change adaptation, or resilience-focused interventions, started to achieve prominence in Durban for the potential it offers for 'development-linked co-benefits that are responsive to a context of poverty and underdevelopment' (Carmin et al. 2012; Roberts 2008:532, 2010:398–399).

It still took some time, and trial and error, for Durban to be recognised today as one of the leaders in climate change adaptation. To start with, the Environmental Management Department commissioned the development of an adaptation strategy, published in 2006, which summarised general adaptation actions that could be taken by sector departments. It was an important document to further the debate on climate change in the city, but it did not act as a catalyst for action – in part because it did not specify goals and actions for specific departments, and partly because many departments were dealing with work backlogs and overloads, as well as a lack of funding and capacity (Roberts 2010: 401). In 2008, the Environmental Management Department, whose name changed to the Environmental Planning and Climate Protection Department (EPCPD) – to indicate the priority given to climate change in the city – realised that to gain widespread support for an adaptation plan, they had to shift the emphasis from the threats climate change presented to presenting adaptation as a means to realise immediate development priorities. Work was started on individual plans for specific sector departments by embedding adaptation planning into existing business plans and development objectives. These plans formulated measures and protocols to maintain or improve the functioning of municipal systems, services and infrastructure given the projected impacts of climate change. 'Essentially, the goal was to build increased resilience one adaptation intervention at a time' (Roberts 2010:401). Climate change considerations were also factored into the overall long-term plans and budgets of the municipality (Carmin et al. 2012:21–23; Roberts 2008:533, 2010:401).

Notwithstanding exogenous factors such as the growing demand from global and local civil society to address climate-related issues, or international treaties, three endogenous factors seem initially to have driven the adaptation initiatives in Durban. One is the efforts by a champion who pushed the adaptation agenda and creatively navigated the minefield that is local government. Two, the city came under the impression of the gravity of climate change impacts and the danger their residents were in if it became more severe. Three, the municipality realised that climate change adaptation was a means to secure the city's development path whilst simultaneously addressing sustainability and resilience (Carmin et al. 2012:28). eThekwini found ways to link adaptation to existing policies and plans to 'demonstrate that this is not an unfamiliar or inconsequential issue but one that was already part of current citywide priorities and initiatives' (Carmin et al. 2012:29). Adaptation came to be seen as integral to the ongoing work of municipal departments and is starting to influence planning practices in the city.

If the City of Durban managed to integrate climate change consideration into their various sector plans which are starting to have an impact on the way the city is planned, then surely other South African cities can attempt to mainstream disaster resilience (including climate change adaptation) into their spatial planning practices?

CONCLUSION

It is very likely that losses to lives, livelihoods, assets and infrastructure will increase in the future as more people migrate to cities and as the effects of global processes such as climate change increase communities' vulnerability and disaster risk. Many of the implications will be beyond the capacity and experience of local governments to address, wiping out development gain and diverting scarce funds toward disaster relief and reconstruction. Developing countries will suffer most from these impacts, increasing the risk divide within and between nations.

Disaster resilience attempts to reduce these losses by mainstreaming physical, social, economic and environmental measures into planning practices to allow urban systems to accommodate, absorb, adapt to or bounce back from shocks to the urban system. Spatial planning is critical in building this resilience. By managing growth and change in cities, spatial planning can promote liveability, sustainability and inclusion (Todes 2011:128). By mainstreaming disaster resilience (including climate change adaptation) into spatial planning practices, these development endeavours can be protected from future losses.

Post-apartheid spatial planning has had 'far more of a life on paper than in practice' due to various fears and concerns and inabilities concerning implementation (Oranje 2010:66). Planning in South Africa is burdened with addressing housing and service backlogs; fragmented and sprawled spatial patterns and inefficient transportation systems that result in unequal access to urban functions and the economy; challenges of intergovernmental coordination; and so forth. To add another distinct burden – that of building disaster resilient cities – would be met with contempt or despair. The Durban experience shows how planners and officials can be entrepreneurial and innovative in seeking to promote an emerging policy domain. What can be learnt from this ongoing initiative that is slowly starting to influence the way Durban is being planned and managed, is that by presenting disaster resilience as a means to realise a city's immediate development priorities whilst protecting the development gain, it is more likely that resilience would be translated into spatial planning practice in South Africa than if it were presented as a policy paradigm inconsequential from what planners are already doing.

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Ensuring Resilience of Natural Resources under Exposure to Extreme Climate Events

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ABSTRACT

Natural resources directly support rural livelihoods and underpin much of the wealth of rural and regional Australia. Climate change manifesting as increasing frequency and or severity of extreme weather events poses a threat to sustainable management of natural resources because the recurrence of events may exceed the resilience of natural systems or the coping capacity of social systems. We report the findings of a series of participatory workshops with communities in eight discrete landscapes in South East New South Wales, Australia. The workshops focused on how natural resource management (NRM) is considered in the Prevent-Prepare-Respond-Recover emergency management cycle. We found that NRM is generally considered only in relation to the protection of life and property and not for the intrinsic value of ecosystem services that support communities. We make three recommendations to improve NRM under extreme climate events. Firstly, the support to communities offered by emergency management agencies could be bolstered by guidance material co-produced with government NR agencies. Secondly, financial assistance from government should specifically target the restoration and maintenance of green infrastructure to avoid loss of social-ecological resilience. Thirdly, action by natural resource dependent communities should be encouraged and supported to better protect ecosystem services in preparation for future extreme events.

Keywords: natural resource management; extreme climate events; emergency management

1. INTRODUCTION

Natural resources directly support the livelihoods of rural society and underpin much of the economic activity of rural and regional areas globally [1,2,3]. Australia's natural resource base is in decline and climate change poses an additional threat to the sustainable management of land, water and biodiversity [4]. The impact of extreme climate events such as bushfire, floods and drought in rural and regional areas can be devastating and disruptive to social and economic activity [5]. If the events result in a step-change in the supply of ecosystem services through, for example, top-soil erosion, surface water pollution or local plant and animal extinctions, the consequences for rural and regional communities can be a permanent loss of natural capital and flow on impacts to social cohesion and accelerated rural decline [6].

Projections of future climate suggest that changes to the frequency and/or severity of extreme climate events are likely to occur [7]. Attempts to define extreme events can be made difficult because of a shifting baseline. Taleb's discussion of Black Swan events emphasises society's blindness with respect to randomness, particularly in relation to large deviations [8]. Easterling et al. categorise climate extremes into two broad groups: (i) those based on simple climate statistics, which include extremes such as heavy daily or monthly rainfall volumes or very low or very high daily temperatures, that occur annually; and (ii) more complex event-driven extremes, examples of which include severe drought, storms and floods, which do not necessarily occur every year at a given location [9]. Smith defines an extreme event for ecological systems as "an occurrence in which a statistically rare or unusual climate period alters ecosystem structure and or function well outside the bounds of what is considered typical or normal variability" [10] (p. 658). She suggests that in response to an extreme climate event, ecosystems surpass an extreme response threshold with two possible outcomes. Either, an ecosystem over time will recover its "normal" function, or it can undergo a change of state likely accompanied by species loss and invasion [9]. Under climate change, the severity and frequency of events will likely combine to determine the interval required for recovery of social-ecological systems. If the frequency of recurrence is greater than the rate at which the system recovers its pre-event level of function then the socio-ecological system can be pushed beyond certain thresholds (leading to a potential state change), most likely resulting in a loss of resilience in the natural system and/or the coping capacity of the social system [5]. While the potential exists for an extreme climate event that causes local ecosystems to change state, the consequences of such an occurrence would be highly unpredictable and likely beyond the coping capacity of local emergency services and NR managers with lasting consequences for the environment and ecosystem services. Instead, in this paper we consider the case of an event of lesser intensity where the social system responds effectively through management intervention to avoid thresholds, enhance recovery of ecosystems and increase resilience to repeat events [11].

Many local, state and national governments have developed comprehensive disaster management plans that encompass extreme climate events (e.g., State of New York [12], Public Safety Canada [13], Sahin et al. [14]). In Australia, the State Government of New South Wales has well-developed emergency service capability for natural disasters and has implemented a State Emergency Management Plan [15]. It is based on an adaptive management system (learning from past events) and supported by local social capital (through community volunteer services). The Plan uses a 4-phase framework of prevent, prepare, respond and recover (PPRR). In the event of a natural disaster this framework is applied to inform government and its combat and support agencies of the appropriate administrative and operational responses throughout the duration of the event. While the Plan recognises the importance of reducing the level of risk to communities during the prevent and prepare phases, and the restoration of the environment during recover, in practice it focuses primarily, and necessarily, on saving lives and protecting property before, during and after an extreme event. Under climate change, a shift of focus may be required to better address the protection of natural resources from extreme events.

This paper seeks to examine key questions in relation to the protection of natural resources from extreme climate events:

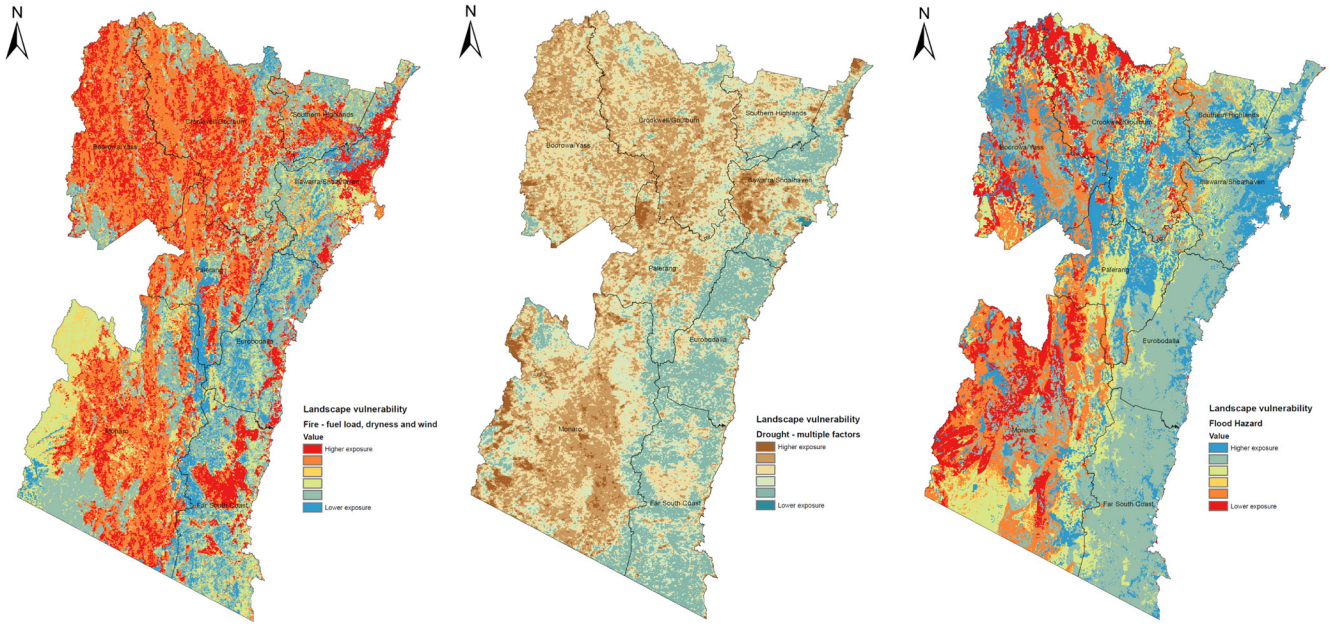
Is the PPRR emergency management cycle useful for the range of events experienced by rural and regional communities?
How does Government's view of a community's progress through the PPRR cycle accord with the lived experience of that community?
In practice, how are natural resources currently considered in the management of extreme climate events?
How can natural resource management be improved to ensure the prosperity and viability of rural and regional communities for an uncertain future?

2. RESULTS

2.1. Extreme Event Exposure

The community's perception of exposure in any particular landscape accorded closely with the mapped exposure levels shown in Figure 1 for each event type. Bushfire exposure was discussed in four regions: Palerang, Eurobodalla, Southern Highlands and the Far South Coast of NSW. Hazard mapping Figure 1 indicates that these regions all have large areas of the landscape that are exposed to bushfire; this is often co-located with human settlements, although the areas differ in the reasons for the high level of exposure. For the inland regions, grass fires, were identified as the major cause of exposure to bushfire for agricultural landholders. For coastal regions high levels of bushfire exposure are due to the extent and density of reserve areas (State Forests and National Parks). Exposure to bushfires in coastal areas is heightened by seasonal tourism. The peak tourist period (summer school holidays) coincides with peak fire danger, resulting in an influx of people relatively unconnected to local communication channels and with limited local knowledge of bushfire.

Figure 1. Extreme event exposure to (L to R) bushfire, drought and flood for South East NSW.



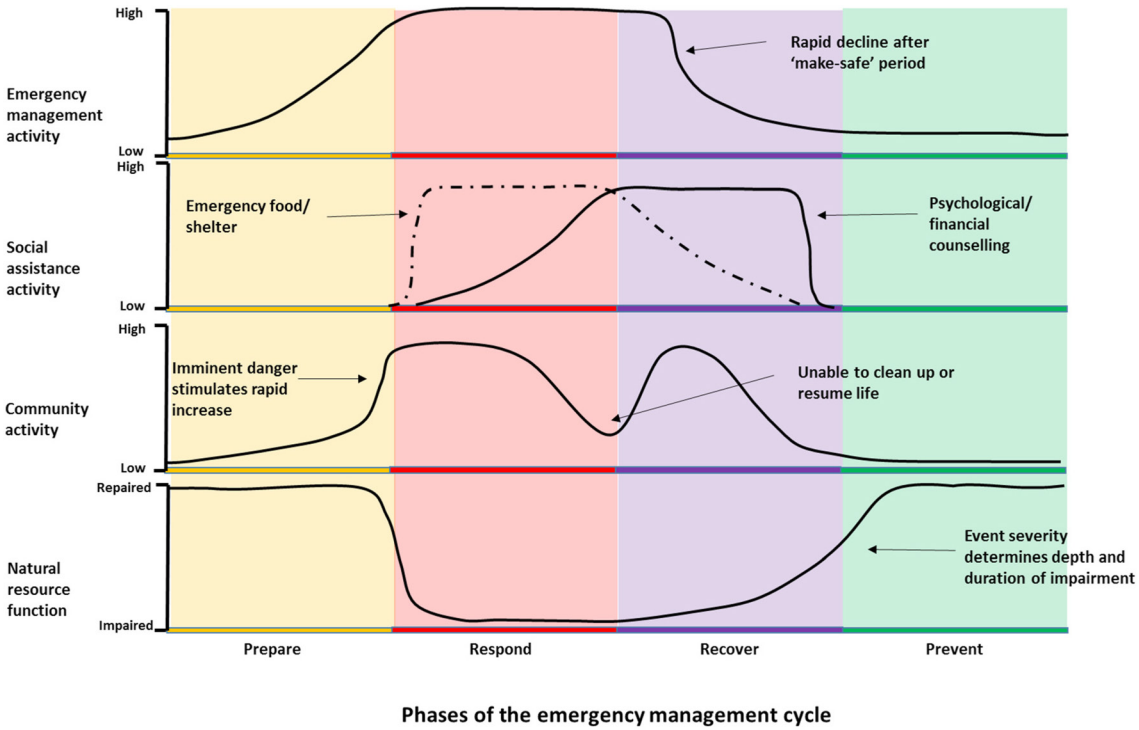
The impacts of drought on the community and NRM were discussed in three regions: Boorowa-Yass and Crookwell-Goulburn and Cooma-Monaro. The hazard map Figure 1 indicates that exposure to drought is high throughout these regions and very high in selected areas. These regions suffer from a combination of relatively variable and unpredictable rainfall patterns and large areas of shallow, sedimentary soils predisposing them to drought. The largely agriculture-based economy in these towns means that the community is greatly impacted by this type of extreme event.

Storms and flooding were discussed at one workshop in the Illawarra-Shoalhaven landscape. Storms resulting from the formation of intense East Coast Low (ECL) pressure systems are one of the most damaging weather events for the entire South East coast of NSW [16]. ECL often intensify rapidly overnight and their relatively weak pattern of occurrence, primarily in autumn and winter, means that coastal residents receive little warning. The hazard map Figure 1 indicates that susceptibility to flooding occurs in discrete locations that coincide with coastal river catchments (and urban settlements). A combination of a narrow coastal plain and many small river catchments amplifies on human populations and high value infrastructure the impacts of sea level rise, storm surges, flooding and subsidence. In addition, the SE Region has numerous shallow coastal lakes and estuaries (including swamps and salt marshes) that are officially recognized as important threatened ecosystems. The lakes are exposed to the risk of marine sediment deposition which limits flushing and replenishment leading to stagnation and eutrophication.

2.2. An Extreme Event Timeline

To frame a discussion of extreme events in the context of improved protection of natural resources that span multiple types of events in multiple regions by multiple actors we propose a theoretical extreme event time line (Figure 2). The timeline illustrates the level of activity that occurs in each phase of the PPRR cycle throughout the duration of an extreme event. It draws on general information elicited through the workshop process and seeks to show how the different types of extreme events can vary from the theoretical, and where the current short comings in the use of the PPRR cycle lie from the dual perspectives of the community and of natural resource management.

Figure 2. Theoretical extreme event timeline to illustrate levels of emergency management activity, social assistance activity, community activity and natural resource function in each phase of the emergency management cycle.



The actions of diverse emergency response actors have been grouped into 3 separate timelines: EM service agencies under emergency management activity, NGOs involved in community support under social assistance activity; and, community members not directly involved in volunteer EM services under community activity. An additional timeline seeks to illustrate the impact of an extreme event

on ecosystem service provision under natural resource function. Activity ranges across a generic scale from low to high for social actors and from impaired to repaired for NR function.

For emergency service actors, activity increases throughout Prepare, plateaus at a high level during Response and remains high through the "make-safe" period early in Recover. Activity then declines through the remainder of Recover to stabilise at a lower level throughout Prevent. For social assistance actors, activity increases rapidly during early Respond stimulated by the availability of government disaster funding to provide emergency food, clothing and shelter for evacuees. This type of social assistance remains high throughout Respond and declines during Recover as people are able to return to their homes after the "make-safe" period. A second type of social assistance that provides financial and psychological counselling for disaster victims (and emergency service volunteers) increases during Respond and peaks during Recover. These services decline sharply as government funding is withdrawn at the end of Recover. For the community, activity rises sharply in response to imminent danger and marks the change from Prepare to Respond. It then remains relatively high except for a hiatus in activity at the change from Respond to Recover as evacuees are unable to begin clean-up activities while emergency service personnel operate in the "make-safe" period. Community activity then declines through Recover as "normal" life is resumed and stays at a relatively low level during Prevent. Natural resource function declines sharply with the onset of the extreme event, remains impaired during Respond and may rise with the re-establishment of ecosystem services during Recover. The severity of the event determines the depth and duration of impairment. Ideally the level of emergency management and community activities in Prevent and Prepare would be sufficient to ensure protection of the natural resource base during the event and complete repair of natural resource function during Recover. It should be noted that none of the event types examined in workshops conforms perfectly to the theoretical timeline.

2.3. Activity in the Extreme Event Management Cycle

2.3.1. Prepare

Bushfire

The threat of bushfire is seasonal and there is a well-organised bushfire awareness-raising program delivered by emergency services that targets the community—especially in the lead up to the bushfire season. Despite this program, most of the community rarely focuses on bushfire until late in the preparation phase when fire risk is already "Extreme". Action in this phase by rural landholders was likely to be anticipatory and driven by local knowledge of the significance of weather patterns—prolonged hot, dry and windy conditions coupled with official weather forecasts, particularly of lightning strikes, and public hazard signs. Participants reported looking for signs in the landscape, such as bushland that is low in moisture, or the build-up of fuel in natural areas. NRM action reported to take place in preparation and prevention phases is similar and is largely centered on removing native vegetation such as Eucalyptus from around dwellings, or replacing native trees with non-natives such as deciduous trees. Where possible, rural landholders reported attempting to mitigate risk by: incorporating fire and wind breaks into native plantings, using grazing management or slashing (contentious due to the risk of sparks) to reduce the threat of grass fires; and, clearing understory vegetation to reduce fuel loads in selected areas.

In the Prepare and Prevent phases emergency management agencies and Local Councils engage in fuel reduction activities such as prescribed burning, mechanical clearing/slashing, trimming trees, maintaining fire trails and Asset Protection Zones (APZ's). However, these activities can have negative consequences for NRM and are reportedly increasingly contentious among communities. Some coastal residents felt that "hazard burning, reducing canopy cover and loss of moisture increases vulnerability".

2.3.2. Response

The transition from the Prepare phase into the Respond phase occurs when a warning is communicated via the local radio, television or through RFS website or text messaging. In this phase people will smell and/or see smoke or may be subject to ember attack on their properties. However there is often confusion over the exact location of a fire and its direction of movement.

The primary focus in the Respond phase is protecting lives and property, yet this often comes at the expense of natural resources. Landholders open gates and cut fences to allow livestock to roam free, and firebreaks and fire trails are created with bulldozers—which can inadvertently damage sensitive ecological communities (EECs or riparian zones) and may require extensive rehabilitation once the fire has passed. Phosphate-based chemical suppressants may be used to fight fires in remote areas, in spite of the fact that native vegetation is known to be sensitive to phosphate levels and the impact of fire suppressants is largely unknown. One RFS volunteer explained that the local RFS "try to protect trees with hollows for nesting sites by wetting them down". The use of Remote Area Fire Teams (RAFT) to quickly extinguish fires in inaccessible areas as a result of lightning strikes drew some criticism because it was seen as interrupting the natural hazard reduction processes that occur through regular burning and increased the likelihood of future catastrophic fires.

The key combat agency in managing bushfire response generally views protection of natural assets as a low priority. In a field operation, decision-making is necessarily rapid, and reactive to local conditions. Allocation of resources is prioritized for the protection of life and property (often the lives of the fire crews themselves are in serious jeopardy). Under such circumstances, particularly in intense, large-

scale fires, there is little opportunity to implement any plans for the protection of natural assets that might have been formulated in prevention and preparation phases.

There are a limited number of NRM-focused activities that landholders engage in during the Respond phase due to the brief period between a warning and the arrival of an event. Landholders reported making small sources of water available for wildlife during hot weather and fires. However, personal household and rural property fire plans are not currently required to focus on aspects of natural resource management.

2.3.3. Recovery

The Recover phase attracts considerable external resources and mobilises support within the affected area, which can be local or regional in scale. After a bushfire, NGOs provide initial support with government funding, as well as the immediate physical needs (such as food, emergency shelter, and clothing) and social needs (such as psychological and financial counselling) of the community. Funding is channeled toward replacement of essential public assets, and reconstruction of private assets, such as housing, using insurance payouts where available. Government funding is generally withdrawn before the recovery phase is complete. This is critical for natural resource-dependent businesses. Agricultural landholders in particular are often socially isolated and have slower rates of economic recovery than urban communities because rural livelihoods are closely tied to rates of recovery in the landscape.

The demarcation of the Respond and Recover phases is blurred. Participants, particularly those involved in the RFS, generally acknowledged that there can be an extended "make-safe" period after a fire-front has passed. During this time, the risks of fires may continue for long periods (up to weeks) resulting in a need for on-going vigilance placing a heavy physical and psychological burden on communities. When people return to their properties, lives can still be significantly at risk due to falling trees and unsafe buildings.
For landholders, natural resource-based livelihoods damaged by fire can take an extended time to recover. Natural resources identified as being degraded by fire include: soil health, water quality, vegetation cover (including sown pasture) and native animal populations. Efforts in the recovery phase focus on the need to rehabilitate areas "opened up" by fire and attempts to control it (such as fire breaks), which involve re-establishment of vegetation and control of erosion. The success of these actions is often dependent upon prevailing weather conditions that can limit plant growth (heat, lack of soil moisture) or exacerbate soil loss and weed invasion (rainfall). Other recovery efforts focus on managing water quality, weeds and attending to injured animals.

Loss of livestock has a direct economic impact on agricultural industries, and this is often exacerbated by a lack of adequate insurance cover. Native animals that survive fires can become disoriented; they may have difficulty finding habitat and food, and may be exposed to predators or struck by cars in attempting to relocate to unburnt areas. Communities often need to rehabilitate or euthanise animals (native fauna, livestock and domestic pets) burnt or injured by fire with assistance from wildlife recovery groups and local vets, which adds to the psychological burden of adjusting to the aftermath of disaster. All of these actions incur a cost to the community and the burden often falls inequitably on rural landholders because there is a lack of specific funding for remediation. Concerns were expressed by these communities that an increase in fire frequency and intensity may result in permanent changes to ecosystems, exacerbate the loss of biodiversity and fundamentally change communities in these regions.

2.3.4. Prevent

Because bushfires rely on a combination of specific weather conditions and fuel load, a fire event generally lowers the risk of a subsequent event, providing a period of respite in which prevention measures can be implemented. However, severe fires that cause major socio-economic disruption to communities can result in significant delay and "blurring" in the transition from Respond to Prevent. Individual social groups, businesses (particularly natural resource dependent-businesses) and aspects of community well-being (such as mental health) may recover at vastly slower rates. These factors are currently unaccounted for during the Prevent phase, which is defined as a return to "normal" following an event.

El Nino forecasts were identified as one trigger for action in the prevention phase because they raise expectations of warmer and drier weather periods. However, some rural landholders disagreed, suggesting that they paid little attention to these types of announcements as "they make that prediction every year".

Participants outlined a number of preventative actions that can reduce their exposure to bushfire risk whilst contributing to NRM such as soil, water and vegetation management and planting layout. In common with the Prepare phase, some actions are contentious within the community such as hazard reduction burning and clearing native vegetation from around properties. NRM activities that are more sensitive to the local environment were identified as planting less-flammable native species (e.g., Allocasuarina verticillata was suggested) in clumps, in a line or to create a wind-break to interrupt the path of the fire. In addition, removal of fuel such as fire prone invasive grasses (e.g., Eragrostis curvula, African lovegrass) was seen as a priority. The management of water focused on the collection, storage and pumping of water close to dwellings for firefighting, as well as encouraging moisture retention generally in the landscape and reducing evaporation.

The prevention phase is most important for NRM but much of the community is disengaged from the awareness-raising efforts of

emergency services. Disengagement was attributed to two main factors:

Coastal communities with little recent experience of a major fire. The previous large fire on the Far South Coast was 20 years ago (1994). Population growth and turnover has reportedly contributed to a loss of local knowledge and a breakdown of community networks through urbanisation and rural land-use change.

The seasonal nature of fire risk leads to community complacency and a disinterest in preventative action when fire events fail to materialise. While the community routinely identified the RFS as a trusted source of information and assistance, they were often at a loss to describe what other social and information networks or services they might draw upon in the event of a fire.

Landuse planning decisions, in relation to new residential developments that fail to take into account current and future fire risks (which are likely to increase in frequency and intensity) were linked to adverse impacts upon NRM, often requiring risk-mitigation activities that are damaging to sensitive coastal ecosystems.

2.4. Drought

2.4.1. Prepare

The Prepare phase for drought was likened to "a train crash you see coming for a period before it hits". Landholders in all three areas reported monitoring the Bureau of Meteorology (BOM) forecasts of the Southern Oscillation Index and El Nino warnings. However, as with bushfire, they felt that the value of the warnings was diminished by their inaccuracy. Instead landholders monitor subtle signs within the local landscape such as feed levels, pasture and plant growth and water levels in creeks and dams. For larger-scale commercial farms, landholders reported using a general heuristic for drought preparation, with failed autumn rain as the initial warning, followed by failed spring rain, which indicates the onset of drought: "When the spring rains failed last year, farmers started preparing for drought". (Drought workshop—Crookwell-Goulburn landscape)

Participants agreed that "you have to be prepared at all times to respond to drought", and that there is "nothing lost" in undertaking preparations. Drought preparations were considered good management practice in an "unpredictable climate". Preparation activities focus on the capture, retention and distribution of water in the landscape via landscape-based water harvesting, dam and weir maintenance, reticulating and recycling (particularly on smaller-scale properties) water to draw on during drought. Monitoring and maintaining groundcover is seen as critically important to prevent erosion. Landholders plant perennial grasses, swales and deep-rooted trees to improve retention and access to soil moisture.

2.4.2. Respond

Unlike bushfire, there is often little clear distinction between Prepare and Respond phases for drought. The slow but progressive onset of drought makes it difficult for people to realise they are in the Respond phase: "By the time you realise, you are already in a drought". (Drought workshop—Boorowa-Yass landscape)

The Respond phase is evidenced by ongoing deficit of rainfall, particularly during periods of high evaporative demand, loss of surface water, lack of pasture growth, and vegetation die back. The adaptive responses are highly localised as landholders review their situation in terms of water reserves, livestock numbers, availability and cost of feed and their financial situation. Drought has a severe impact upon animals through reduced access to pastures, loss of condition and increased likelihood of disease. Landholders weigh up the potential damage of stock management actions on natural resources such as the pasture base and soil condition. Landholders reported the widespread adoption of practices such as "sacrificial paddocks" (paddocks reserved for high-intensity grazing) and drought feed lots, as well as constant adjustment of stock numbers using computer software-based management tools, if available. They also use drought as an opportunity to remove accumulated sediment from dams to increase their capacity while they are dry, and to repair fencing. Drought also affects biodiversity through reduced habitat availability and quality e.g., paddock trees often have hollows for arboreal animals but these trees are susceptible to die back during drought. Erosion and dust storms can also reduce water quality and low water levels negatively impact on aquatic biodiversity.

Unlike other extreme climate events, drought fails to attract an emergency management response. This is most likely because of the spatial variation in onset, the slow progression from Prepare to Respond and the often vast scale of the disaster. Community-based NRM groups (e.g., Landcare) can act to mobilise volunteers for NRM; however, landholders reported a decline in Landcare membership during drought because people become more focused on the management of their own property rather than undertaking NRM action on public land (particularly smaller-scale landholders). Would-be volunteers become short of time because of the additional burdens of hand-feeding stock (larger-scale landholders), stock transport and sales. Hand feeding is increasingly difficult for an ageing farm population, often comprising single owner-managers on large properties. Long-term droughts can contribute to the erosion of local NRM skills and knowledge, which would normally be mediated through social networks. Government agriculture and NRM agencies were identified as contributing to community cohesion and resilience in some areas. While Government may declare an area as drought affected this may not trigger support, as the duration of the response phase is unpredictable.

The decline in social networks during drought can exacerbate feelings of isolation for people on rural properties. As a consequence landholders socialise less frequently as the drought progresses—often at a time when they are most in need of support. Landholders reported that those most in need were often likely to be isolated before the drought, and therefore even less likely to seek any social assistance or counselling services. Unlike bushfire, where communities come together to "fight" and organisations such as the RFS provide a social focus around action, drought erodes family and community structures. Drought-induced suicides among landholders are disproportionately common, having a huge impact on both families and the wider community. Communities do attempt to alleviate the isolation through social events such as drought buster parties ("a reason to have a drink when there's no reason", Monaro landscape). Participants emphasised the need to have healthy and alert farmers able to act on signs of recovery. Community mental health was considered a largely hidden aspect of extreme droughts and a depressed community was thought to be much slower to act and less innovative in response and recovery.

Extensive grazing is the major agricultural activity in the Southern Tablelands and Alpine regions of the South East. Declining terms of trade have severely eroded the profitability of grazing enterprises, particularly on more marginal land. One Alpine (Monaro region) grazier explained: "I'm running out of corners to cut". Drought further reduces landholders' financial reserves and can leave them with a burden of debt that remains long after the drought has ended. This in turn means that landholders are unable to afford to finance prevention measures. There is reportedly a lack of funding for NRM activities for limiting the impact of drought and when drought assistance is provided it is often "too little too late". Where funding is available, applications have to be very detailed in order to justify a grant, requiring extensive administration, monitoring and very-technical reporting. This is often beyond the capabilities of volunteer organisations or single landholders already experiencing stress, and many are discouraged by the conditions or lack the time or expertise to submit a funding application.

2.4.3. Recover

As with bushfire, the biophysical, financial and psychological aspects of communities recover at different rates. Some participants noted that recovery starts when you "get good pasture growth, not just good rain" (biophysical) but others said that recovery does not begin until stock levels have returned (financial) and the communities have recovered from the shock (psychological). Depending on the extent of the drought, recovery can proceed for several years rather than months, and some communities undergo permanent changes from which they never "recover". In some landscapes graziers believed that they did not recover fully from a drought in 1982, because it marked a step-decline in rainfall that permanently lowered productivity. While returning stock to paddocks is a matter of urgency for financial recovery this is often difficult because stock prices are high during recovery. Landholders believed that the South East's unpredictable climate means that there is not really a well-defined recovery phase: "It's more of a respite from the next drought than a recovery. You cannot be confident you are in a recovery phase". (Drought workshop—Boorowa-Yass landscape)

A bank of moisture in the soil can provide some confidence that the drought is ending but loss of vegetation cover results in poor rainfall retention, lower infiltration and high levels of run-off. Erosion is a problem in the Recover phase and is worsened by past clearing of native vegetation, poor agricultural management practices unsuited to the region's soils and overstocking. Invasion by new species of weeds can be problematic as the lack of ground cover provides little competition for species introduced through imported feed or purchased replacement stock.

Smaller landholders reported maintenance of ground-cover through composting, re-seeding paddocks with legumes, encouragement of native perennial grasses and planting fodder such as lucerne. Both large and small-scale landholders reduce erosion through improved grazing management and fencing of riparian and woodland zones from livestock. They recognised the importance of allowing bare soil to re-cover, providing protection from wind and rain.

Recurring drought is reportedly influencing the range of some native animal species. For example, landholders reported higher numbers of wombats in areas not previously observed. Workshop participants feared permanent changes to the region's ecosystems as a result of frequent drought and agreed on the need for a more holistic view of landscape management that considers native flora and fauna.

2.4.4. Prevent

As with bushfire, the activities undertaken to protect NRM in the Prepare and Prevent phases are similar. Landholders focus on trying to "drought proof" properties by planting trees to form windbreaks, and block plantings of native drought resistant species and deep-rooted perennials. Some landholders have trialed plantings of tree-fodder species (such as Tagasaste or "tree Lucerne") but were unable as yet to report on its efficacy as drought fodder (however, one grazier emphasised that "you would need a lot of tree lucerne to provide anything more than a minor supplement to forage supply in a drought" (Boorowa-Yass landscape).

Retaining water in the landscape is an important way to reduce exposure to the impacts of drought. Participants noted that direct drilling technology can improve the condition of soils and reduce land degradation by avoiding the compaction associated with repeated passes of heavy machinery. Soil condition and ground cover can be maintained also by sound rotational grazing management, although in some areas changes in property ownership, an influx of absentee landholders and smaller-scale holdings often see farms over-

stocked by inexperienced landholders. Fencing sensitive areas such as gullies and creeks to prevent disturbance by cattle was also seen as an important way to protect riparian zones. Most landholders adopted reticulation and troughs to supply water to livestock, but agreed that this environmental improvement came at the cost of extra infrastructure, monitoring and maintenance of water points. Landholders also reported controlling willows and planting natives such as Eucalyptus viminalis (manna gum) along river banks.

2.5. Storms and Flood

In contrast with drought but in common with bushfire, storm and flood events have well defined stages. Storms generally have a very rapid onset (i.e., short preparation phase) followed by a relatively short duration (or response phase) due to the relatively rapid rise and fall of flood waters in short coastal catchments. However, as with the other extreme climate events the damage caused can result in a prolonged recovery phase. The State Emergency Service (SES) is the combat agency tasked with coordinating the response to storms and flood.

2.5.1. Prepare

Of the three types of events examined in workshops storms appear to have the least well-developed Prepare phase. In general, little action is undertaken by the community in the Prepare phase to reduce threats of storms because of the unpredictable nature of ECLs with very short (often only hours) advanced warning and, unlike bushfire, the lack of a defined "storm season". As a result, the community is frequently unprepared. At the time of the workshops there was no institutionally-supported planning process in place to deal with East Cost Lows in same way as the RFS supports household fire plans for bushfire events. Lack of preparation has consequences for protecting life and property and for the management of natural resources.

Given the limited potential for action in the Prepare phase, awareness-raising to promote "storm readiness" needs to shift to prevention throughout the year—not just when the threat of storm or flood is imminent. Workshop participants agreed on the need for a "household storm plan" (similar to a fire plan) that outlines how to mitigate risks for personal safety and assets to reduce damage to life and property as well as natural resources. For example, during storms unsecured gas bottles (from caravan parks), chemical drums (from rural properties) and other buoyant debris are dislodged and move with the flow of flood water. These materials end up in waterways and are often deposited in inaccessible areas of estuaries, wetlands and swamps where they become a long-term litter problem adding to pollution. Planning for "storm readiness" should encourage behavior in the community that prevents these potentially hazardous materials from entering the environment. Participants referred to "tree hysteria" among local residents following wind events, which results in widespread calls for trees to be cut down with little or no thought to tree preservation or environmental impact. The localised nature of storms can result in long intervals between major flood events, which present a challenge to overcoming inertia and loss of knowledge in the community.

2.5.2. Respond

As with other extreme events there is inadequate consideration of NRM in the Respond phase for storms and flood. The focus of emergency services includes coordinating other combat and support agencies, sandbagging to control inundation, securing storm damaged properties, keeping evacuation routes open and assisting in the evacuation of the community. Workshop participants agreed that natural resource management is rarely considered during the response phase and that actions to manage the event can cause unintended consequences for the environment. For example, riparian areas subject to inundation are often managed with heavy earth moving machinery such as bulldozers to control bank stability. Little consideration is given in these operations to their impact on river and lake water quality and loss of top-soil and seed banks. Beaches are routinely used to collect and fill sand bags for flood control. There is some uncertainty around the legality of this action and there is currently no guidance for emergency workers on the most appropriate location for sand collection.

The severity of the storm event reportedly modifies the ability of the emergency services to respond. Very severe storms can make it unsafe for the SES to send out emergency response crews, leaving the community particularly exposed to the likelihood of disruption of essential services such as power, water and telecommunications. Participants identified a lack of clarity around the processes of communication during storm events. Calls to local council regarding problems with trees are reportedly transferred to council's tree management office. Unlike the SES, these staff may not be trained in dealing with emergency management situations.

2.5.3. Recover

In common with other types of extreme events, recovery for the community can be slow and support is often withdrawn before economic and social recovery is complete. Flood waters can remain in low lying areas for long periods. There can be an extended period of "make-safe" where flooded properties require inspection to ensure electrical hazards have been addressed before residents are allowed to return to begin the clean-up process.

For NRM, much of the work undertaken by community-based NRM groups with government grant funding can be damaged or lost during floods. Despite the high risk of loss of restoration works in riparian areas, there is no provision of funding to replace riparian

remediation works following a flood event. NRM volunteers at the workshop indicated that replacement of storm-damaged NRM works would require a new funding application, with no guarantee of success, which can be disheartening for NRM workers. In addition, action to clear waterways and coastal lakes of sediments involving dredging can impact the fragile estuary environments.

2.5.4. Prevent

Workshop participants recognised that flood prevention was a whole-of-catchment issue. Land use change in the upper catchment affects flood risk in the lower catchment. Some locations have a limited floodplain and the cumulative impact of urban development increases impervious areas with dramatic effects on the volume and velocity of surface runoff, exposing areas to the risk of erosion and flash flooding. For coastal areas subject to beach erosion and storm surges, participants feared that the natural coastal protection features, such as dune systems and the vegetation they support are being damaged through residential development. Aside from the significant loss of these endangered ecosystems, the damage to "bio-protection" buffering increases the exposure of beach-side dwellings to storm impacts. There is a need to spatially identify areas exposed to the impact of storms and flooding to ensure that future developments consider the increased risk of extreme ECL events.

Riparian restoration is a focus of NRM actions in coastal catchments to prevent stream bank erosion. However, workshop participants identified some NRM actions in riparian zones as producing downstream consequences in floods. In particular, the materials such as weed matting or bamboo canes used to assist re-vegetation efforts are often washed downstream during a flood, adding to pollution in estuaries.

Participants felt that planning for storms in coastal catchments must become a more integral part of community preparedness for extreme events. In particular, the community needs to become much more aware of the role of ecosystem services in coastal protection. The current mindset appears to allow degradation to occur, then replace green infrastructure with inadequate (non-adaptive) engineered structures, which are prone to failure and can be more costly than green infrastructure.

3. DISCUSSION

Four questions were posed in the introduction to this paper in relation to the protection of natural resources from extreme climate events. The narrative constructed in the results about each type of event will be interrogated to discuss these questions.

3.1. Is the PPRR Emergency Management Cycle Useful for the Range of Events Experienced by Rural and Regional Communities?

The PPRR emergency management cycle is a useful concept to engage rural and regional communities in the generic responses to extreme climate events including the roles of government combat and support agencies and NGO social services [17,18]. It also helps to identify the responsibilities of local communities for ensuring their own readiness for extreme events. However, it has limitations. For example, in practice, variations among the types of extreme events, the hazards within specific landscapes and the capacity of discrete communities within the South East region [19,20] most often means that the PPRR cycle does not accord with the lived experience of a community. Participants generally agreed that there was considerable blurring of the demarcation between prevent and prepare phases, particularly where the former may be abruptly truncated (as is the case with coastal storms).

3.2. How Does Government's View of a Community's Progress through the PPRR Cycle Accord with the Lived Experience of that Community?

The question of divergence among government and community perceptions of the PPRR cycle is important because the cycle is embedded in central government's emergency management policy, which in turn determines the broader governance of an event. The duration of each phase of the cycle from the community's perspective will depend on the type of extreme event. For drought the Prepare phase progresses slowly merging into Respond and results in a gradual deterioration of natural resource function that underpins economic activity, with flow on effects to community social cohesion as the drought continues [21]. For bushfire the threat is regular and seasonal but the high risk period is being extended by changing climate so that Prepare and Prevent phases are becoming less well defined. Community interest tends to wane through the need for a constant state of readiness [18]. Storms are unpredictable and of limited duration so Prepare and Respond phases are correspondingly short allowing little opportunity for community action.

Recovery, or the ability to bounce back from shocks, is central to theories of social ecological resilience [22]. However, the recovery phase of the PPRR cycle is the most complex, hardest to manage and, in many ways, the most critical phase of the cycle. The often protracted nature of recovery and its reliance on local context make it difficult for centralised responses from government. The speed of recovery varies across economic, social and environmental components of social-ecological systems. While economic recovery can be slow, it is supported through rebuilding of private assets with insurance payouts, and essential public infrastructure through government disaster funding. Social impacts of extreme events, particularly those on mental health, are becoming recognised as increasingly important if not always fully addressed [23]. Recovery from bush fires generates high public interest and is often a focus of media attention because they are of relatively short duration and provide moving images (e.g., media coverage of the anniversary of the 2013 Blue Mountains

fire event). While drought generates sympathy in urban communities, its longer duration can result in media fatigue and waning public interest [24]. It was clear from workshops that community workers believed that government social assistance for extreme events is withdrawn well before many members of the community recover.

The combined duration of Recover, Prevent and Prepare phases is equivalent to the interval between single events. This interval varies with the type of event and, for some events, is also influenced by natural resource function. For example the incidence of major bushfires is dependent on weather conditions and fuel load. Fuel load is removed by fire (either an event or a hazard reduction burn) providing a period of respite between events while vegetation recovers. Droughts often occur as clusters of dry spells following ocean temperature cycles (measured by the Southern Oscillation Index) punctuated with periods of wetter conditions [25]. Storm events, which can lead to flooding, however, could occur in close succession. There is also the increasing potential for multiple events to occur consecutively: drought leading to higher incidence of bushfires followed by intense rain and flooding, which further blurs the phases of the EM cycle.
The concept of "normalization" to climate change and extreme events to build community resilience and self-reliance is becoming central to government disaster planning [26]. Extreme events often accelerate autonomous adjustment processes that are ongoing in regional areas. However, long term or catastrophic events can overwhelm a community's coping ability leaving it unable to recover without external assistance. Various alternative models of government support under drought have been proposed (e.g., [27,28]). Landholders that participated in the drought workshops understood and accepted short-term dry periods (1–2 years) as part of the agricultural production environment. They generally agreed that land managers should be expected to plan for such regular events. However, their ability to set aside sufficient reserves to manage for severe droughts (such as the Millennium Drought from 2002 to 2007 [29]) appears beyond their capability. There is evidence in the high incidence of rural family breakdown, farmer suicides and rapid demographic/land-use change in rural Australia that coping strategies are being already overwhelmed. The wisdom of a government policy stance for extreme events in rural and regional communities that relies heavily on building and maintaining local community resilience is questionable in the knowledge community coping will be exceeded in the future. It may be necessary to facilitate local transformation in order to preserve regional resilience [30,31,32].

Rates of recovery also depend on the re-establishment of ecosystem service provision particularly for natural resource dependent livelihoods (such as agriculture and tourism). For the SE Region, grazing enterprises, which are the dominant form of agricultural production, are particularly hard hit because recovery depends not only on plant growth rates (pasture availability) but also on having sufficient stock numbers to harvest available pasture mass. Stock numbers depend in turn on breeding rates and or ability to purchase suitable animals (usually unavailable because of high prices following widespread drought). There is already considerable autonomous adaptation occurring in response to a range of drivers including variable rainfall. These adaptations include changed practices (drought feedlots, adaptively managed stocking rates), changed land-use (both fragmentation of "unviable" farms and consolidation of agriculture on land of higher capability) and a shift to other livelihood options (reliance on off-farm employment, non-resident ownership) [30,31]. Further change along some of these pathways may be limited. For example amalgamation of properties to achieve economies of scale at low stocking rates is limited by labour availability. It is likely that socioeconomic tipping points will be exceeded with only small future changes to production environments (such as further declining terms-of-trade) coupled with increased intensity or frequency of extreme climate events [33].

In light of our discussions with a broad range of local communities we suggest that the uniform application of the PPRR cycle in all landscapes and for all types of extreme climate events often fails to account for the needs of the local communities it is intended to support.

3.3. In Practice, How Are Natural Resources Currently Considered in the Management of Extreme Climate Events?

This research suggests that despite the intrinsic value of natural resources in supporting rural and regional communities, they are seldom explicitly considered in the management of extreme events. Actions to better protect the natural resource base are unlikely to occur during the response phase, where protection of lives and property will remain the priority and under the control of emergency management combat agencies, especially for large scale events. Instead, protection of natural resources from extreme events should focus more attention in the Prevent phase. Our greatest concern is that unlike infrastructure assets, which often incorporate adaptive improvements during rebuilding [34], natural assets are largely expected to recover autonomously. Where the frequency or severity of events does not allow time for recovery of ecosystem function before a succeeding event, ecosystems may decline, ultimately losing resilience and transforming into undesirable states [20] that fail to provide essential ecosystem services for natural resource dependent communities (Figure 3).

3.4. How Can Natural Resource Management be Improved to Ensure the Prosperity and Viability of Rural and Regional Communities for an Uncertain Future?

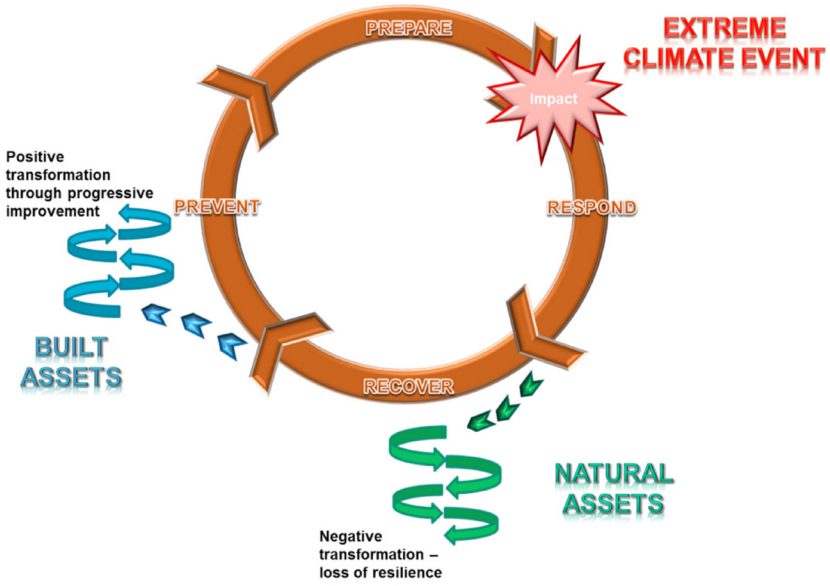
In conclusion, we propose some changes to the hypothetical extreme event time line (Figure 2) to improve the management of natural resources. These following three changes are a synthesis of information from all of the workshops and do not relate specifically to one type of event or individual landscape:

Increased activity by emergency management combat agencies to advise and support communities, particularly rural landholders, to

sensibly manage vegetation on private land so that over-clearing and "tree hysteria" is limited. The information required to undertake such additional activity may require greater co-operation among combat and natural resource support agencies to formulate local guidance material.

Increased social assistance from government that specifically-targets the restoration and maintenance of living green infrastructure, particularly where it has been damaged by recent extreme events and is essential to the ongoing protection of communities (such as dune systems in coastal regions) in order to reduce the potential for loss of resilience (Figure 3).

Figure 3. Conceptualization of the potential changes in state of built and natural assets through repeated emergency management cycles.



Increased community activity to protect natural resource-dependent livelihoods, which includes action on both public and private land. The availability of social assistance funding for natural resource restoration could be used as a catalyst for this activity, which would not only protect ecosystem services but raise awareness in the community of extreme event preparedness in both Prevent and Prepare phases.

These three changes should reduce the level of impairment of natural resource function during the response phase. The form that these additional activities should take needs to be negotiated at landscape scale and be informed by local understanding of the most significant extreme event hazard (e.g., [35] for bush fire).

4. MATERIALS AND METHODS

4.1. Place-Based Participatory Workshops

This paper provides a synthesis of the findings from a series of place-based participatory workshops that focused on the management of natural resources for extreme weather events across 8 sub regions of South East NSW, Australia (Figure 4).

The workshops were conducted in 2014 with approximately 100 (in total) community members representing farmers, landholders, emergency service volunteers, local and state government, business owners, Indigenous peoples, financial institutions and Non-Government Organisations (Table 1). Participation was through invitation (by the regional NRM agency) and self-selection, provided two basic criteria were met: (1) participants lived in the landscape under discussion (but not necessarily at the workshop location); and, (2) they were widely networked and able to reflect on issues relating to NRM, extreme event management or the community in general. Meeting these criteria offset the limitations imposed by low numbers of participants at some workshops. In addition, because the same type of extreme event was discussed at different locations (with the exception of storm events) there was considerable redundancy in the data with most themes recurring at multiple workshops. Some workshop participants represented a number of different groups, for example, farmers that are also part of community-based NRM groups or that volunteer with the rural fire management service.

Government representatives were also considered as representing their community because they lived and worked in the landscape under discussion. Our approach represents an often necessary compromise in consultation with small rural communities between scientific rigor and the need for relevance to stakeholder concerns; establishment of clear links between activity and impact; ability to capture spatial and temporal context; and resonance with the public to represent society's concerns and aspirations [36].

The workshops were designed to enable a clearer understanding of the South East region's vulnerability to climate change and to inform the development of strategies that support the community to build landscape and community resilience to extreme climatic events.

Workshop Process:

Qualitative data were collected during facilitated workshop sessions. Two key activities were conducted during each workshop. The first activity was undertaken as an open plenary discussion that utilised the emergency management cycle—Prevent, Prepare, Respond and Recover (PPRR) to frame participant consideration of the most important local hazards—bushfires, drought, storms and flooding under current climate projections (Figure 5). In particular we sought information about the local, lived experience [37] of extreme climate events throughout the emergency management cycle. This discussion was captured directly into a spreadsheet template and the information projected onto a screen to enable real-time clarification by participants.

Figure 4. Location of the South East region in Australia and the locations of workshops in eight regional landscapes.

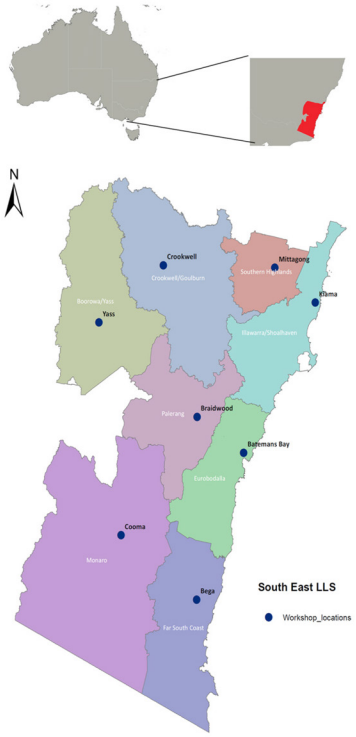


Table 1. Community representation at the extreme events workshops.

Community Representatives	Number
Community-based NRM—local environmental groups and conservation volunteers	36
Farmers and agricultural representatives	25
State Government (environment, agriculture and regional development agencies) and Local Government staff working in emergency or risk management roles	22
Emergency Management—paid staff and volunteers	10
Property owners not engaged in farming	8
Local business owners	7
NGO's-welfare groups, Indigenous representatives	4
Education (Secondary and Tertiary)	4

Figure 5. Emergency management cycle (PPRR) and definition of the phases as used in the workshops [17].

Key questions for participants at each workshop included:

How much time is spent in each phase of the EM cycle?
When do the EM cycle phases begin and end?
What is most at risk in this landscape?
What actions are undertaken by the community (not necessarily NRM focused) during these phases?

The second activity was designed to specifically address the actions taken to manage natural resources and aspects of community capacity to undertake management actions in each phase of the PPRR cycle.

Participants were divided into four groups corresponding to one phase of the cycle. Where possible the expertise of individuals was matched to particular phases of the cycle. For example, rural counsellors and community finance representatives were often assigned to the recovery phase. Within each group a facilitator led an in-depth discussion of current actions to manage natural resources for extreme events, and views on the aspects of the natural environment and local livelihoods and lifestyles that may be lost to the community if extreme events become more frequent or intense. Finally improvements to the management of extreme events throughout the PPRR cycle to better protect the natural resource base were discussed.

These data were recorded in printed A3-sized templates by a facilitator assigned to each discussion group. The qualitative information collected about each stage of the emergency management cycle was coded for workshop location and extreme event type. This information was subjected to qualitative meta-synthesis [38] to identify emergent themes and provide deeper insights than might be possible from studies of a single location or event type [39].

4.2. South East NSW Climate Drivers

To inform the workshops an analysis of the climate drivers and potential hazards faced by communities in the South East was conducted. Information was drawn from historical climate analyses (Australian Bureau of Meteorology) of temperature trends, rainfall trends, anomalies and seasonality, and the occurrence of severe low-pressure systems; and, a climate summary for SE NSW prepared for the SE Integrated Regional Vulnerability Assessment [40] (Table 2).

Table 2. A summary of the major climate impacts for the South East NSW.

Hotter
Rainfall shift: likely increase in summer and decrease in winter
Snowfall: likely decrease
Run-off and stream flow: likely decrease in spring & winter, particularly in the west, and an increase during summer
Sea level: virtually certain to continue to rise
Erosion: likely increase on some soils
Coastal agricultural soils: increase in inundation and acidification
Sea Level Rise with increased flooding leading to risk to property and infrastructure on the coast
Changes to natural ecosystems (alpine, low-lying coastal and fire sensitive).
Changes in flora and fauna—possible increased incidence of invasive and pest species

Source: OEH NSW Climate Profile [41].

4.3. Regional Hazard Mapping

A series of maps were developed, using existing state-wide land, soil vegetation and land use data to identify areas that are vulnerable to the impacts of extreme climatic events (Figure 1). Details of the preparation of the maps are provided in Chapman and Barrett [42]. The bushfire hazard map accounted for topographic wind exposure and relative fuel load according to native vegetation formation. The flood hazard map identified flat areas that pool water, soil drainage, rainfall, topographic slope, position and propensity for water logging. The drought map combined dryness/moisture loss with bare soil vulnerability. Bare soil vulnerability was determined as the highest level of bare soil recorded from annual satellite imagery for the 2000–2012 period. This level was used as an indicator of ground cover which would be experienced during an extreme drought under modelled conditions. These maps were then used to initiate discussions with communities, based upon the event or events (drought, bushfire and flooding) that were most likely to affect them.

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SECTION V:
FUTURE DIRECTIONS

Critiques & novel frameworks
Practical directions
Resilience & justice

Future Directions

At this point, you have read a variety of articles on resilience in general, and urban resilience to climate change in particular. You have perhaps developed an idea of how to characterize it, identify it, study it, and plan for it, based on past and current work in the field. You have likely also noticed some discrepancies between scholars and practitioners; competing themes and goals; and critiques of the resilience concept, all of which are shaping future directions in resilience studies and practice.

Critiques & Limitations

Despite its popularity among planners, policymakers, and some theorists, the notion of resilience is not above criticism. Many scholars and practitioners - particularly those with an interest in social justice - have noted that resilience goals too often prioritize an economic, ecological, or infrastructural status quo. If social systems are taken into account at all, the emphasis tends toward maintaining an existing regime, rather than improving it; on surviving rather than thriving, in other words. More radical thinkers argue that the ultimate goal should not be about maintaining, but about transforming institutions [1,2]. This is a call to address social justice issues as a key component of broader socio-ecological resilience, including such issues as social vulnerability, demographic inequity, and quality of life. While this mentality is gaining ground in academic circles, the practical reality of achieving transformation may be quite a challenge. However, practitioners can champion incremental changes from within, and urban climate plans increasingly make reference to equity and justice as critical components of a resilient city [see for example 3-5].

Only fairly recently have researchers come to appreciate the unstable nature of social-ecological systems. While planning for resilience has typically been about stability, mitigating risk and avoiding change, we are now somewhat more comfortable with the notion that change is inevitable. This has led to a gradual shift in resilience thinking away from rigidity, toward adaptation; the idea that we must be flexible and willing to adjust our practices, cities, and attitudes as needed. Again, this is easier said than done, but progressive cities have already begun putting this idea into practice, and adaptability will be a key metric of future climate resilience. In this same vein, there is an apparent need for resilience-oriented research and planning methods to acknowledge and account for the uncertainty inherent to climate change. Models and forecasts tell us what we might expect and plan for based on past trends, but future planning efforts are encouraged to explore alternative avenues for data gathering [6].

In this section, you will be presented with several articles on future directions for researchers and planning practitioners; progressive approaches to framing and pursuing resilience; and case studies which illustrate real-world intersections of resilience and social justice. Moving forward, it will be important for you to understand that resilience - how it is defined, framed, and applied - is a concept laden with power and normativity. Often the concept is wielded to maintain a status quo, achieve hegemonic short-term goals, and exclude marginalized populations; though it may just as readily be used in service of environmental justice, equity, and social transformation in the future.

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READINGS INCLUDED

[Open access articles; Full text included]

Hill, K. (2016). Climate change: Implications for the assumptions, goals and methods of urban environmental planning. Urban Planning, 1(4), 103.

Hart, A., Gagnon, E., Eryigit-Madzwamuse, S., Cameron, J., Aranda, K., Rathbone, A., & Heaver, B. (2016). Uniting resilience research and practice with an inequalities approach. SAGE Open, 6(4), 215824401668247.

Hughes, S. (2013). Justice in urban climate change adaptation: Criteria and application to Delhi. Ecology and Society, 18(4), 48.

Benzie, M. (2014). Social justice and adaptation in the UK. Ecology and Society, 19(1), art39. https://doi.org/10.5751/ES-06252-190139

ALTERNATIVE SELECTIONS

[Full text not included; May be accessible through your university library or elsewhere]

DeVerteuil, G., & Golubchikov, O. (2016). Can resilience be redeemed?: Resilience as a metaphor for change, not against change. City, 20(1), 143–151.

Fainstein, S. (2015). Resilience and justice: Debates and developments. International Journal of Urban and Regional Research, 39(1), 157–167.

Ziervogel, G., Pelling, M., Cartwright, A., Chu, E., Deshpande, T., Harris, L., … Zweig, P. (2017). Inserting rights and justice into urban resilience: a focus on everyday risk. Environment and Urbanization, 29(1), 123–138.

STUDENT EXERCISES

[To be completed after assigned reading]

(1) Reflect on the relationship between RESILIENCE and JUSTICE. Come to class prepared to discuss your perspectives based on the week's readings. You may consider:

- The relationship between racial equity, social justice, and climate resilience
- The relationship between general resilience and climate-specific resilience
- Which social, political or economic systems limit opportunities for resilience

Tip for instructors: We suggest that students be given the opportunity to read each other's responses prior to class. This will alleviate the need for students to summarize for each other what they have written, and leave more class time for deeper, exploratory discussions.

FOR INSTRUCTORS: CLASSROOM ACTIVITIES

(1) Identify some of the pervasive social, political or economic systems that limit opportunities for resilience, increase vulnerability, produce an uneven distribution of climate-related risk, or breed environmental injustice. These may be introduced by the instructor, or drawn from students' written exercises.

(2) Discussion prompt:
As a planner working within existing institutional constraints, what actions could you take to overcome some of the negative or inequitable outcomes associated with these systems?

Now, try to think more transformatively. What drastic changes would propose to address environmental injustice? (You may make suggestions that seem radical or unrealistic, but use resilience theory to support your position.)

Climate Change: Implications for the Assumptions, Goals and Methods of Urban Environmental Planning

by Kristina Hill

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ABSTRACT

As a result of increasing awareness of the implications of global climate change, shifts are becoming necessary and apparent in the assumptions, concepts, goals and methods of urban environmental planning. This review will present the argument that these changes represent a genuine paradigm shift in urban environmental planning. Reflection and action to develop this paradigm shift is critical now and in the next decades, because environmental planning for cities will only become more urgent as we enter a new climate period. The concepts, methods and assumptions that urban environmental planners have relied on in previous decades to protect people, ecosystems and physical structures are inadequate if they do not explicitly account for a rapidly changing regional climate context, specifically from a hydrological and ecological perspective. The over-arching concept of spatial suitability that guided planning in most of the 20th century has already given way to concepts that address sustainability, recognizing the importance of temporality. Quite rapidly, the concept of sustainability has been replaced in many planning contexts by the priority of establishing resilience in the face of extreme disturbance events. Now even this concept of resilience is being incorporated into a novel concept of urban planning as a process of adaptation to permanent, incremental environmental changes. This adaptation concept recognizes the necessity for continued resilience to extreme events, while acknowledging that permanent changes are also occurring as a result of trends that have a clear direction over time, such as rising sea levels. Similarly, the methods of urban environmental planning have relied on statistical data about hydrological and ecological systems that will not adequately describe these systems under a new climate regime. These methods are beginning to be replaced by methods that make use of early warning systems for regime shifts, and process-based quantitative models of regional system behavior that may soon be used to determine acceptable land uses. Finally, the philosophical assumptions that underlie urban environmental planning are changing to address new epistemological, ontological and ethical assumptions that support new methods and goals. The inability to use the past as a guide to the future, new prioritizations of values for adaptation, and renewed efforts to focus on intergenerational justice are provided as examples. In order to represent a genuine paradigm shift, this review argues that changes must begin to be evident across the underlying assumptions, conceptual frameworks, and methods of urban environmental planning, and be attributable to the same root cause. The examples presented here represent the early stages of a change in the overall paradigm of the discipline.

Keywords: climate change; ecological planning; planning theory; sea level rise; urban environments

1. INTRODUCTION

Anthropogenic climate change is already causing measurable effects in regional and local environments (Boon & Mitchell, 2015; DeConto & Pollard, 2016; Hannaford, 2015; Kelley, Mohtadi, Cane, Seager, & Kushnir, 2015). There is increasing evidence that these changes are forcing urban environmental planners to gradually alter their epistemological assumptions, conceptual frameworks, goals, and methods. A paradigm shift in an applied discipline such as planning involves precisely these types of changes, in everything from philosophical assumptions to applied methods. This paper will use examples to argue that the phenomenon of entering a new climate era is producing a paradigm shift in urban environmental planning. However, like climate change itself, this shift is still in its early stages.

In this review, I argue that the goals and concepts, methods, and philosophical underpinnings of urban environmental planning are beginning to shift. A broad literature of examples is available, many of which have emerged from the demands of current practice rather than from a theoretical position. An emerging literature proposes new frameworks and methods for urban planning generally to respond to the implications of climate change (Hodson & Marvin, 2009; Jabareen, 2015; Stone, 2012). Like these authors, I contend that the implications of climate change require us to shift some of the fundamental assumptions of planning. However, while they address more general planning practices, I will focus specifically on theories and plans that address the biophysical conditions of the city and its region. I intend for this review to serve as an original contribution by categorizing and synthesizing emerging patterns in theory and practice. Its focus on examples from North American cases and literature in urban environmental planning allows my claim of an emerging paradigm shift to remain grounded in a network of academics and practitioners who are aware of and influenced by each other's work. Throughout, I will argue that a coherent paradigm shift can only be said to exist if changes are occurring simultaneously in the key assumptions, conceptual frameworks, and methods of a discipline, and that these changes must be driven by the same root

cause.

2. URBAN ENVIRONMENTAL PLANNING AND BIODIVERSITY: THE U.S. CONTEXT

My observations of a paradigm shift in environmental planning are rooted in novel planning efforts over the last fifteen years that were intended to protect biodiversity from urbanization, as well as planning efforts that originate in a desire to establish resilience to flooding events, or—more recently—to adapt to permanent trends such as rising sea levels. For that reason, it is important to briefly note two key U.S. Federal laws, the expansion and enforcement of which led U.S. urban environmental planning to change under different conditions and with different timing than in Europe and Asia.

Since the late 1960s, urban environmental planning in western North America has paid increasing attention to biodiversity (Thomas, 2003). Like South America, Australia, India and Africa, western North America was industrialized relatively late, developing cities in the modern sense only after 1850 (Otterstrom, 2004). Large wild animals with strong cultural associations continue to exist within many urban ecosystems—not just in rural areas. Cities across the North American west include small but visible populations of mountain lions (Puma concolor), black bears (Ursus americanus), bald eagles (Haliaeetus leucocephalus), and Chinook salmon (Oncorhynchus tshawytscha), among other species (Beatley, 2000). The US Endangered Species Act (ESA) of 1973 was initially focused on conserving populations of species, rather than on maintaining a network of protected habitats, as in the European Union's Natura 2000 legislation (Verschuuren, 2004). Large animals with extensive ranges often pass through urban and suburban areas during migrations or in search of resources, and the US Endangered Species Act protects these species even from the indirect effects of urbanization, such as pollution in stormwater runoff. For these reasons, urban environmental planning in the United States, particularly the western U.S., has been challenged to plan and design urban areas to accommodate large wildlife species whose populations are in decline, such as the Chinook salmon (Simenstad, Tanner, Crandell, White, & Cordell, 2005), which was listed as threatened under Federal law in the Puget Sound region of Washington State in 1999 (National Oceanic and Atmospheric Administration, 1999).

Similarly, the U.S. Clean Water Act of 1972 now strictly regulates pollution loads in urban stormwater runoff that originate in dispersed, non-point sources such as motorized vehicle traffic (Craig, 2005). Cities must not exceed established maximum loads, or they face penalties. This extension of the Clean Water Act to set standards for urban runoff prompted widespread experimentation with landscape-based methods for detaining runoff and filtering pollutants, significantly expanding the technical role of urban environmental planners. Together, these two Federal laws led to significant changes in urban infrastructure design and urban environmental planning since the 1990s, particularly in regions that discharge urban runoff to ecosystems with high biodiversity, such as the Puget Sound in the Pacific Northwest (Feist, Buhle, Arnold, Davis, & Scholz, 2011; Simenstad et al., 2005), and the Chesapeake Bay in the mid-Atlantic region.

It would be impossible to describe the recent trend towards a paradigm shift in North American urban environmental planning without noting these regulations. The efforts of urban planners to optimize the pattern and performance of cities to support aquatic habitat and higher levels of water quality are important points of origin for the paradigm shifts we confront today in relation to climate change (Ward, Anderson, Beechie, Pess, & Ford, 2015).

In the first section of this paper, I will present changes in the conceptual frameworks of urban environmental planning as a result of extreme weather events and climate trends. The second section of this paper will contain a review of key methods that are changing as a result of the same phenomena. The third and final section will suggest changes that are beginning to occur in the philosophical assumptions that underlie urban environmental planning, which I argue is the final component necessary to identify a coherent paradigm shift.

3. CHANGING CONCEPTS: FROM "SUITABILITY" TO "SUSTAINABLE DEVELOPMENT" TO "RESILIENCE" TO "ADAPTATION"

Over the last thirty years, the stated goals and associated conceptual frameworks of urban environmental planning in the U.S. have changed, and these changes have occurred with increasing speed. Before the 1980s, the dominant framework was driven by the search for "suitability," defined as a good match between the physical characteristics of a location and its land use, or the type of design that is used (Hills, 1974; McHarg, 1969; Steinitz, 1990). Since that time, the broad goal of urban environmental planning has shifted to an effort to manage "sustainable development" (World Commission on Environment and Development, 1987), which recognized that there are limits to development that involve temporal patterns of resource use and availability, as well as spatial patterns. More recently, the goal of many cities and regions has been to achieve "resilience," or, an ability to recover quickly from disasters such as earthquakes, hurricanes, river flooding, fires, and terrorist attacks (Chelleri, Waters, Olazabal, & Minucci, 2015). Barely a decade old, the concept of "resilience" to temporary events has already begun to be subsumed under the need to engage in permanent adaptation to climate trends. The concept of "adaptation" refers to reducing the vulnerability of an area to permanent, incremental trends such as higher sea levels, reduced regional rainfall or snowfall, new geographic patterns of disease transmission as a result of warming winters, and extended heat waves—along with the secondary and tertiary effects of these trends on urban regions (Hill, 2015).

These changes in the rationales and concepts of planning represent underlying changes in our understanding of the complexity of

interrelated environmental patterns in space and time. They also represent shifts in the goals and rationales for planning. Ian McHarg's lectures and writing in the 1970s strongly emphasized the need to restrict negative human impacts on the environment (see for example his lecture titled, Man, Planetary Disease, [McHarg, 1971]). In contrast, the Brundtland Report emphasized the potential for human cities and expanding resource uses to be successfully integrated into the natural systems of the planet (World Commission on Environment and Development, 1987). Shortly after, symposia were held that recognized global climate trends as a challenge to sustainable resource use, although optimism was still high that global climate change could be avoided through careful planning (DeFries & Malone, 1989).

Since the late 1980s, the concept of sustainable development has been used widely in urban environmental planning (Wheeler & Beatley, 2014). In North America, it has often been applied by adopting the goal of sustaining pre-development processes (particularly hydrological flow regimes and species movement patterns) and the biodiversity that is characteristic of a geographic region (Bixler et al., 2016). This overall goal of sustaining pre-development processes and biodiversity led to the development of a set of concepts and methods within the patchwork of local land-use and infrastructure authorities that limit the scope of U.S. urban planning. Together, the goal itself and the concepts and methods associated with it might be called the "sustainable development conceptual framework" in American urban environmental planning.

As it developed in the U. S., sustainable development relied on the ability of planners and ecologists to describe historical ecological relationships, inferred from soil patterns and other markers of past processes, and track the effects of contemporary resource uses on the health of those historical relationships (Kerans & Karr, 1994; Rapport et al., 1998). Similarly, the concept of a "native species" in North America relies on a determination that a species has been present in a region over thousands of years, and implies an assumption of relative stability in species distributions (Goodenough, 2010). The concept of "native" is fundamentally historical and ignores the scientific knowledge that species have moved as climates have changed throughout the Holocene. The concept doesn't consider whether or not a species is well suited to a particular region as its climate changes. This makes the central concept of "native species" vulnerable to becoming completely outdated in the next few decades (Baker et al., 2013; Sorte, 2013). It also points out limitations in the way that the concept of sustainable development has been applied in U.S. urban environments, because of its conceptual dependency on the idea of sustaining pre-development processes (Hobbs et al., 2014; Palmer & Ruhl, 2015). The concepts of a "reference condition" and a "native species" both need significant re-consideration, along with the assumption that the scale of processes that underlie both biodiversity patterns and cultural landscapes, such as hydrologic flows, will continue to resemble the patterns of the last 1,000–3,000 years (Rockström et al., 2014). To the extentthat the concept of sustainable development in North American urban regions became synonymous with the goals of sustaining native species and pre-development hydrologic processes, the concept is not robust in an era of rapid climate change.

The newer term that has already replaced "sustainable development" as a goal and framework in North American cities, particularly coastal cities, is "resilience" (Coaffee & Lee, 2016). This goal refers to the ability of a system to recover its functions quickly after a major disturbance. The very frequent use of this term in the last decade reflects a heightened awareness of the potential for extreme weather to produce destructive events in North American cities. Hurricane Katrina in New Orleans (2005) and Superstorm Sandy in the New York region (2012) were important events that drove the adoption of resilience as the highest-priority goal of these coastal cities (Weisz, Blumberg, & Keenan, 2015).

In post-hurricane New Orleans, a series of workshops sponsored by the Dutch Embassy brought Dutch engineers and urban planners to the U.S., working alongside American planners and engineers (Waggonner & Meyer, 2010). These workshops eventually led to the development of a new water management strategy for the New Orleans region (Waggonner and Ball Architects, 2013) which emphasizes strategies for managing stormwater runoff from an extreme rainfall event. In New York, federal agencies sponsored a design/planning competition called "Rebuild by Design" that emphasized strategies for that region to recover from the types of storm surges and extreme rainfall related to large hurricane events (Hurricane Sandy Rebuilding Task Force, 2013). "Resilience" was used frequently to describe the desired capacity to recover more quickly from a disastrous event.

Yet it is important to note that the shift in goals and framework from "sustainable development" to "resilience" occurred because of a focus on disastrous single events, not on the incremental trends (such as higher sea levels) that are expected as a result of climate change (Shi, Chu, & Debats, 2015). Initially, the use of the term "resilience" could be seen as an extension of the sustainable development framework, because it marks planners' recognition that sustaining cities requires that those cities must be prepared for major disaster events—from hurricanes to terrorist attacks. But as media news sources, academics and professional planners in some regions of the United States have converged on a general level of acceptance that climate change is happening, the term "sustainable" has frequently been replaced by the term "resilience" as public agencies present their planning goals. This represents a significant shift, and often implies an unstated recognition that some of the land and infrastructure cities administer today may not be sustained into the future (Wang, Tang, & Wang, 2014). The poignancy of this reality is palpable in urban neighborhoods that are unlikely to ever fully recover from an extreme storm, such as the still largely depopulated Lower Ninth Ward of New Orleans (Landphair, 2007).

Even more recently, a framework is emerging that recognizes the goal of incremental, permanent environmental change in urban planning. This became evident in 2009, when one of the leading public agencies of the San Francisco Bay area sponsored a design competition called "Rising Tides" (King, 2009). In this competition, the San Francisco Bay Conservation and Development Commission (BCDC) called for urban and environmental planning strategies to address the permanent sea level rise associated with climate change.

The competition was followed by a planning program that is working county-by-county to identify needs for adaptation in public infrastructure, called "Adapting to Rising Tides" (http://www.adaptingtorisingtides.org). The concept of using adaptation to adjust to permanent changes while building in resilience to extreme events is now embedded in planning conversations in the San Francisco Bay Area. In other parts of the U.S., political affiliation seems to affect the perceived need for adaptation in addition to resilience (Botzen, Michel-Kerjan, Kunreuther, de Moel, & Aerts, 2016). Terms like "recurrent flooding" are used instead of referring to adaptation to sea level rise in regions where climate change is not an acknowledged phenomenon (Huler, 2012). But this is a special case of language being limited by regional politics, not by the knowledge or goals of the planning discipline.

My argument that a paradigm shift is occurring in urban environmental planning relies on the conclusion that these changes in terminology for goals and conceptual frames are more than just semantic. The change from "sustainability" to "resilience" to "adaptability" reflects changes in the underlying goals of urban environmental planning, driven by a growing comprehension of the types of significant changes cities are experiencing. Pursuing the goal of "resilience" operates as a kind of halfstep between the paradigms of sustainability and adaptation, since resilience to extreme events will be needed in the future as much as it is needed today. In that sense, the change in conceptual frames is really a change from the "sustainability framework" to the "adaptation framework," while retaining the goal of resilience (meaning, the ability to recovery quickly from a disaster event) into the new climate future.

4. CHANGES IN METHODS FOR URBAN ENVIRONMENTAL PLANNING

If a paradigm shift is indeed occurring in urban environmental planning in response to our awareness of global climate change, this shift should be evident in the methods of planning as well as in its goals and conceptual frameworks. In fact, some methods are changing. This is evident in several areas of planning work, from physical and social vulnerability assessments to typological design methods and statistically-based methods of sizing systems for flood protection. This section will present examples of these methodological changes.

The first area of methods that are changing might be referred to broadly as vulnerability assessments (Füssel & Klein, 2006). Many communities in the United States are engaged in what is currently a somewhat chaotic effort to define the appropriate scope and analytical methods for vulnerability studies (Berke et al., 2015), sometimes assisted by guidance from state and county jurisdictions (see for example, California Coastal Commission, 2015). These may be studies of vulnerability to physical phenomena such as sea level rise and freshwater flooding, earthquake liquefaction, fire, or drought, as well as new public health hazards or social inequality drivers. Terms such as exposure, risk, vulnerability, and hazard are not standardized, nor are the timeframes that should be used in order for the assessments to reflect future conditions. Generally, only primary exposures are studied, which excludes the study of secondary network impacts such as traffic congestion caused by fire or flooding effects on roadways (Biging, Radke, & Lee, 2012). Potential changes in ecological conditions that might be considered tertiary exposures are also rarely considered in vulnerability plans, such as harmful algal blooms driven by nutrient inputs and warming temperatures that affect the use and value of coastal property, along with human health (Glibert et al., 2014).

Moreover, there are new questions about the methods that are appropriate for assessing social vulnerability in vulnerability plans. The index of social vulnerability was developed in relation to events, not long-term permanent adaptation processes (Cutter, Boruff, & Shirley, 2003). This index includes variables such as income, family size, languages spoken, and race, which have been correlated with vulnerability in emergency events in the US southeast. But the current need is for methods that will allow us to predict the ability of different adaptation proposals to increase social equity, rather than maintain the status quo. The term "vulnerable" itself is becoming contested in new ways, as communities that are relatively wealthy but physically vulnerable use the term to justify new funding that could help them adapt to changes such as sea level rise (see for example the vulnerability study for affluent coastal communities that serve as vacation rental properties most of each year, in Marin, California—Marin County Community Development Agency, 2015).

The second category of changing methods is the statistical methods that are deeply embedded in the epistemological assumptions of environmental planning and risk management, such as calculating the statistical recurrence interval of rainfall, flood or fire events. These methods rely on the concept of stationarity, which assumes that variability in natural systems occurs within a consistent envelope or range of values over long periods of time. As one author in the recent method debates has noted, "In view of the magnitude and ubiquity of the hydroclimatic change apparently now under way, however, we assert that stationarity is dead and should no longer serve as a central, default assumption in waterresource risk assessment and planning. Finding a suitable successor is crucial for human adaptation to changing climate," (Milly et al., 2008). While there is currently an active debate about what methods can be used to compensate for climate change, it is clear that methods will need to change, particularly as the statistical signal of climate change becomes stronger (Milly et al., 2015; Stedinger & Griffis, 2011; Stroup, 2011). If stationarity is "dead," the loss of its associated methodological assumptions represents a very significant shift from past methods in urban environmental planning as well as ecosystem management, water resources and civil engineering.

The third area of change is in the development of socalled "early warning systems." New methods are emerging that attempt to track the statistical dynamics of system behavior in order to identify and eventually to predict abrupt changes in state. Some researchers are looking for so-called regime shifts using moving-window calculations as an analytical tool with large datasets, tracking the range of variability in those data over time, among other variables (Dakos, Carpenter, van Nes, & Scheffer, 2014). These new methods are

being used to forecast changes in the ecosystem or population-level status of conditions in lakes, wetlands, housing markets, and human biomedical assays associated with epileptic seizures. The difficulty is in identifying the right variables to track, according to some authors (Pace, Carpenter, & Cole, 2015). The intention of these new methods is to allow managers and planners to make adjustments in systems before they shift to a less-desirable state, as in a lake that becomes eutrophic or filled with toxic algae, or a tidal wetland that collapses to a mudflat because of repeated storm surge events. One of the most interesting theoretical observations that has come out of these new methods with respect to urban environmental planning is the observation that habitat connectivity may be less desirable in a changing climate (Scheffer et al., 2012). Redundancy may preserve more biodiversity under conditions of stress than connectivity. This research on regime shifts is in early stages as it relates to urban planning, but it is likely to generate a suite of new methods associated with the adaptation framework in planning.

Fourth, there is also a need for generative methods that help planners identify appropriate spatial strategies for coastal protection and urban district design. It seems likely that new typologies will be needed that serve to organize the range of possible physical strategies (Hill, 2011, 2015). These can allow planners to assess current conditions and gain new insights about the spatial variability of vulnerability and change. For example, it is likely that logical pairings of urban district types with shoreline types will be needed, such as pairing floodable urban districts with wetland and beach/dune systems, rather than selecting a shoreline strategy independently. Typologies can also help to assess whether suitable strategies are being overlooked, perhaps unintentionally (Hill, 2015).

Finally, the use of an "adaptation conceptual framework" in urban environmental planning is prompting new uses of regional process models. Whether planners are using two-dimensional models of change in wetland response or sediment erosion, or more complex models of hydrodynamics and flooding (P. L. Barnard, Jaffe, & Schoellhamer, 2013; Holleman & Stacey, 2014), the change is in how the models are used. In a sustainability framework, the models would be used to optimize spatial configurations. In an adaptation framework, they are more likely to be used iteratively to gain successive approximations of what adaptations are likely to work well or cause problems. For example, the US Geological Survey has developed a hydrodynamic model of the San Francisco Bay that allows planners to estimate tidal flooding depths at different locations around the shoreline (P. Barnard, 2015). Early studies using similar models have shown that in some parts of the San Francisco Bay, building walls on shorelines as an adaptation measure will increase the depth of flooding in nearby areas (Holleman & Stacey, 2014). In only a few years, planners will be able to insert proposals for coastal adaptation into the model and predict whether those adaptation projects will make another property owner's situation worse. They could use that information to alter the design and re-test it, or to allow or deny a permit. As adaptation changes occur, they will have to be recorded in the physical descriptions within the model so that new predictions would continue to reflect current conditions.

5. CHANGES IN PHILOSOPHICAL ASSUMPTIONS: EPISTEMOLOGY, ONTOLOGY, AND ETHICS IN ENVIRONMENTAL PLANNING

One of the key assumptions that underlies urban environmental planning is an epistemological assumption that the processes and patterns of the past can serve as a guide to the future. We have been able to know what is "good" and therefore in need of conservation by comparing our present conditions to the conditions of the past (Steinitz, 2012). The past has been, in a philosophical sense, a source of authority for environmental planning (Spirn, 1984, 2002). We have treated the relatively new practices of industrial agriculture and urbanization as destabilizing forces which must be countered by planning. The goal was to retain and protect elements of an earlier landscape. Our assumption has been that biodiversity, ecosystems, air and water quality, and human health can all be protected most effectively if we retain the framework of a long-standing landscape mosaic (Forman, 1997; Forman & Godron, 1986; Marsh, 1991).

In an effort to define and mimic a stable set of fundamental processes within urban regions, urban environmental planners have tended to represent the past as relatively stable. Yet studies from the 1960s demonstrated that American plants and animals experienced dramatic changes in range as a result of the last glaciation of North America, and that they returned individualistically to their current communities—not in the associations we have seen them occupy in over the last hundred years and more (Terasmae, 1970). In spite of that evidence, most environmental planners still tend to think and speak of these plant and animal communities as if they have been stable, and can be maintained as stable units of ecosystems. Given certain temporal scale assumptions, this was reasonable. But given current predictions for rapid climatic change, it is now necessary to let go of this epistemological assumption that the past should be our primary source of authority on how to prioritize the components of present and the future ecosystems (Davis & Shaw, 2001). Presumably, it should be replaced with a heavier reliance on predictive models that represent the dynamics of systems, in spite of their uncertainties.

The second philosophical issue raised by global climate change is ontological, or related to how we conceptualize our larger world and its interactions. Scholars and planners have come to recognize that local regions are deeply affected by global trade and financial investment patterns (Harvey, 2000; Sassen, 2014), but nevertheless, professional planners are often put in the position of working as if their jurisdictions are coherent regions with development trajectories independent of global systems. This is an ontological assumption in the sense that policy makers and citizens may think the degree to which we live in a globalized system can be reduced, using new laws, policies and/or physical border walls (Porter, 2016). But in fact, we live in an unprecedented situation of simultaneous environmental and economic changes that continue to occur and produce cascading effects on a global scale.

A third philosophical issue involves the ethical assumptions that influence environmental planning. It has been accepted as reasonable

in the United States for each generation to conserve some land from development, and pass this legacy on to future generations as a form of inter-generational inheritance; a legacy of natural resources that are represented by the proxy of geographic space (see for example, the dedication of a very large marine reserve by President Obama off the coastline of the US State of Hawai'i in September of 2016 [Hirschfeld Davis, 2016]). This act of reserving large areas of land has been the primary way in which American environmental planners fulfill their perceived obligations to future generations. For example, a renowned American biologist has recently called to set aside half of the earth to sustain biodiversity (Wilson, 2016). Other forms of contemporary resource use, such as fossil fuel use, have received less attention in an inter-generational context because the assumption is that technology will change and allow future humans to use other energy sources (Nicholson, 2015).

But climate change is forcing new, uncomfortable reflections on the scale and cost burden of the structural adaptation projects current generations should assume (Moellendorf, 2009; Moellendorf & Schaffer, 2016). Should the generations that enjoyed the use of fossil fuels invest more of their resources to prepare for the future dynamics of flooding, drought, and fire that are the consequences of their unrestricted use of carbonbased fuels? In other words, should we build big adaptation projects now, before the seas rise much more rapidly, or should we defer that cost to future generations who will do it when it is needed (Grasso, 2010)?

Most planners, scientists and geographers who reflect on the onset of an Anthropocene era focus on defining the threshold at which that new era has begun or will begin (Braje, 2016; Waters et al., 2016). But from an ethical reasoning perspective, we could also interpret our current era as the last few stable decades of an 8,000–10,000 year period (the Holocene). What is an ethically appropriate use of the last few decades of a long, stable period? Should we continue to optimize our investments to a lowest-cost, least-disruption adaptation pathway in the near future (Reeder & Ranger, 2011) or are we ethically bound to do all we can for future generations, given that they will bear most of the costs of our past use of cheap fossil fuels (Grasso, 2010)? Seen in that light, the transition to the Anthropocene creates an urgent need to re-evaluate the goals of urban environmental planning projects, even if the effects of trends such as sea level rise may not be acute until after 2050. As a result, a wide range of new ethical questions are starting to be asked during discussions of appropriate goals and methods of planning for the Anthropocene (Graham & Roelvink, 2010).

In summary, my argument in this section has been that three key philosophical assumptions are changing that underlie urban environmental planning: the epistemological assumption that the past is the key to knowledge about the future, the ontological assumption that regions can choose to become more independent from global systems; and the ethical assumption that we can defer the costs of urban adaptation to a changed climate to future generations.

6. CONCLUSIONS

The examples presented here provide evidence that pressures are mounting to drive a genuine shift in the concepts, methods and underlying assumptions of urban environmental planning in the United States, and more broadly in North America. Table 1 summarizes the examples presented under each category of praxis. This summary demonstrates that a series of changes have occurred in the concepts and goals of environmental planning over the last 30 years. My argument is that it is the rapid turnover from sustainability to resilience to adaptation during the last 25 years, coupled with changes in methods and philosophical assumptions, which provides the evidence for a genuine paradigm shift.

Perhaps the greatest change as a result of climate trends is occurring in the rationale for urban environmental planning itself. The need to make strategic plans immediately to guide the interactions of communities with their environments—in the context of ethical arguments, contested financial investments, and predicted environmental changes—is more urgent than ever. If we accept the scientific evidence that we are currently enjoying the last stable decades of an 8,000–10,000 year period, 20–30 years from now we can expect to be in a state of perpetually responding to extreme conditions. Urban environmental planning has never been more urgently needed as a strategic planning approach, anticipating future change, rather than as a rear-guard effort to protect resources from development. We urgently need to expand and strengthen the concepts, methods and assumptions of urban environmental planning to incorporate predictions of rapid, permanent environmental change and prepare cities for the immediate future.

Table 1. Summary of a paradigm shift: how is our encounter with climate change beginning to change planning?

	A *Paradigm Shift* involves changes to:
Philosophical Assumptions	**Epistemology**—How do we know what sources of knowledge will be sufficient, given our uncertainty about the magnitude and complexity of future change? We are coping with the loss of the past as a guide to what is good or sufficient.
	Ontology—How can we conceive of our new inter-scalar relationships? What is local and global, when simultaneous changes in global processes are expressed locally, and local changes impact regional dynamics? We need to re-define the dependence/independence of local and regional choices, in both environmental and economic contexts.
	Ethics—How much should we do now, and for whom/where?
Goals/Conceptual Frameworks	**Suitability**—Goal was to put things in the right place, given long-term historical conditions.
	Sustainability—Goal was to keep what we have, while mitigating/reducing carbon emissions.
	Resilience—Goal is to recover more quickly and with fewer losses after disaster events.
	Adaptation—If we can't sustain some things in a new world ("native" species example), then the new goal is to accept new forms for cities and new characteristics of ecosystems that are adapted to new conditions, that are resilient to extreme events, and that reduce carbon emissions.
Methods	**Vulnerability Assessments**—Problematic to determine how to do this, when there are so many inter-related variables and processes, many changing simultaneously (uncertainties and scale interactions). Also problematic to do them in a way that defines/identifies particularly vulnerable communities, in an unequal social context (ethics).
	End of Stationarity—We can no longer rely on statistical methods of the past. We need new ways of estimating sufficiency in plans, particularly regarding acceptable levels of risk.
	Early Warning—We need to anticipate regime shifts. New statistical methods and interpretations seem to be emerging but are still unreliable.
	Building Urban Districts—We can't use traditional types in traditional locations, and markets seem unlikely to supply the solution quickly. Typological approaches to search "solution spaces" may be most useful now.
	Managing Complex Models—Regulators need to model and predict new regional dynamics, not just rely on patterns of the past. For coastal areas, new methods are available for quantitative regional models to support the regulatory process, but using them will also change that regulatory process.

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Uniting Resilience Research and Practice With an Inequalities Approach

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ABSTRACT

The concept of resilience has evolved, from an individual-level characteristic to a wider ecological notion that takes into account broader person–environment interactions, generating an increased interest in health and well-being research, practice and policy. At the same time, the research and policy-based attempts to build resilience are increasingly under attack for responsibilizing individuals and maintaining, rather than challenging, the inequitable structure of society. When adversities faced by children and young people result from embedded inequality and social disadvantage, resilience-based knowledge has the potential to influence the wider adversity context. Therefore, it is vital that conceptualizations of resilience encompass this potential for marginalized people to challenge and transform aspects of their adversity, without holding them responsible for the barriers they face. This article outlines and provides examples from an approach that we are taking in our research and practice, which we have called Boingboing resilience. We argue that it is possible to bring resilience research and practice together with a social justice approach, giving equal and simultaneous attention to individuals and to the wider system. To achieve this goal, we suggest future research should have a co-produced and inclusive research design that overcomes the dilemma of agency and responsibility, contains a socially transformative element, and has the potential to empower children, young people, and families.

Keywords: resilience research, resilience practice, adversity, inequalities, social justice, Boingboing resilience

INTRODUCTION

In this article, we explore definitions and criticisms of the concept of resilience within government policy, social justice perspectives, and the resilience research literature that are said to shape the field today. We then introduce our own approach and describe how Boingboing, our community of practice and social enterprise, supports the development of resilience research and practice that includes a strong inequalities dimension (www.boingboing.org.uk). This includes conducting academic research that advocates for people facing embedded societal inequalities, and is more focused on challenging inequitable policy agendas; engaging in co-produced research containing socially transformative rather than solely personally transformative elements; facilitating supported agency, and co-identifying and co-delivering responses to adversities (these may be addressing societal inequalities but may more realistically include tackling prejudice, discrimination, stigma, and stereotyping); and encouraging the research community to be open to and prepared to undertake co-produced research with groups that are perceived to be more challenging to work with, and so are underrepresented in the literature, but whose voices are equally or more important as a result. We outline some examples and steps that we are taking toward our goal of consolidating resilience research and practice with a social justice approach in the support of children, young people, and families.

Resilience Research

Initially spurred by observation of children who performed unexpectedly well in unfavorable circumstances, the first wave of resilience research sought to identify correlates of resilience with a focus on the unique qualities possessed by the person or child (Masten, 2007). With resilience perceived as purely internal it is the individual who becomes tasked with compensating for their disadvantaged circumstances. The second wave of research was interested in associations between correlates of resilience. Identification of risk and protective factors as moderators and mediators of desirable outcomes expanded from the micro level of the individual to incorporate meso-level structures such as the family, school, and local community. The disadvantaged child is, from this perspective, no longer left wholly responsible for their outcomes. In addition to their own attributes, caregivers, schools, neighborhoods, and other community organizations are all seen to play a part in influencing children's resilience. Putting the findings of the first two waves into practice, the third wave of research focused on developing and testing interventions. By endeavoring to improve outcomes for people facing adversity, valuable learning around effectiveness and the role of context brought to attention both the dynamic nature of resilience processes, and the importance of culture in defining meaningful outcomes (Ungar, 2004). Applying what is defined as a positive outcome within mainstream contexts to disadvantaged and marginalized groups may be inappropriate, and may lead to further exclusion. A focus on wider context and culture encourages a more systemic understanding of resilience in which the individual and his or her environment interact to produce, and construct, outcomes.

Presently, the fourth wave is said to be in ascendance, as the discoveries of the first three waves become assimilated with more sophisticated methods of investigation to develop a richer understanding of the multilevel, contextualized, and dynamic nature of resilience (e.g., Kassis, Artz, Moldenhauer, Geczey, & Rossiter, 2015). Using Bronfenbrenner's (1977) human ecology theory, an ecological understanding of resilience places both the individual and the adversity within a dynamic multilevel context, where the impact of higher level factors (e.g., social, economic, cultural) on factors proximal to children is emphasized (Cassen, Feinstein, & Graham, 2009).

Resilience itself is not a unified concept, and a long history of controversy means that there is little consensus on its precise meaning. The only feature common to most definitions used by academic authors (see Table 1) is that resilience assumes adversity and is relative to it (Noltemeyer & Bush, 2013). Exactly how resilience relates to adversity is conceptualized in a variety of ways, including helping people and communities adapt to adversity, interact with it, or transform aspects of it. A further complication is that the understanding of resilience and how it relates to adversity also depend upon the nature of adversity (whether defined explicitly or implicitly), which may or may not be related to social disadvantage.

Table 1. Definitions of Resilience in Research-Based Resilience Literature.

Authors	Definitions of resilience
Alvord and Grados (2005, p. 238)	. . . skills, attributes, and abilities that enable individuals to adapt to hardships, difficulties and challenges.
Connor and Davidson (2003, p. 76)	. . . personal qualities that enables one to thrive in the face of adversity.
Donnon and Hammond (2007, p. 965)	. . . capacity of children and adolescents to adapt successfully in the face of high stress or adversarial conditions.
Edwards (2007, p. 256)	. . . capacity for adaptation along appropriate developmental pathways, despite disruptions such as family breakdowns.
Hart, Blincow and Thomas (2007, p. 10)	. . . people with persistently few assets and resources, and major vulnerabilities . . . have better outcomes than we might expect given their circumstances, and in comparison to what we know happens with other children in their contexts.
Hart, Gagnon, et al. (2013)	. . . overcoming adversity, whilst also potentially changing, or even dramatically transforming, (aspects of) that adversity.
Lee and Cranford (2008, p. 213)	. . . capacity of individuals to cope successfully with significant change, adversity or risk.
Leipold and Greve (2009, p. 41)	. . . individual's stability or quick recovery (or even growth) under significant adverse conditions.
Lerner (2006, p. 40)	. . . person←→context exchanges that are mutually beneficial for the individual and his or her setting . . . Resilience involves mutually beneficial reciprocally influential relations between a person and his or her context.
Luthar, Cicchetti, and Becker (2000, p. 543)	. . . dynamic process encompassing positive adaptation within the context of significant adversity.
Masten (2011, p. 494)	. . . capacity of a dynamic system to withstand and recover from significant challenges that threaten its stability, viability, or development.
Masten, Best, and Garmezy (1990, p. 426)	. . . process of, capacity for, or outcome of successful adaptation despite challenging or threatening circumstances.
Masten and Powell (2003, p. 4)	. . . patterns of positive adaptation in the context of significant risk or adversity.
Roisman, Padrón, Sroufe, and Egeland (2002, p. 1216)	. . . emergent property of a hierarchically organised set of protective systems that cumulatively buffer the effects of adversity and can therefore rarely, if ever, be regarded as an intrinsic property of individuals.
Rutter (2012, p. 336)	. . . reduced vulnerability to environmental risk experiences, the overcoming of a stress or adversity, or a relatively good outcome despite risk experiences.
Ungar (2008, p. 225)	. . . resilience is both the capacity of individuals to navigate their way to the psychological, social, cultural, and physical resources that sustain their well-being, and their capacity individually and collectively to negotiate for these resources to be provided and experienced in culturally meaningful ways.
Zolkoski and Bullock (2012, p. 2296)	. . . achieving positive outcomes despite challenging or threatening circumstances, coping successfully with traumatic experiences, and avoiding negative paths linked with risks.

As shown in Table 1, there are 17 subtly distinct conceptualizations of resilience that we have counted in use by academic authors. Only three of these definitions include any potential to alter aspects of the wider adversity context, which are those of Hart, Gagnon, Aumann, and Heaver (2013); Lerner (2006); and Ungar (2008). For instance, the notions of "navigating" and "negotiating" hold the potential to have some influence over the availability of resources for others (Ungar, 2008, p. 225). Similarly, the notion of "reciprocally influential relations between a person" and his or her environment (Lerner, 2006, p. 40) captures at least some potential for the environmental context itself to be altered. However, presenting such exchanges as mutually beneficial fails to acknowledge the extent to which structural power imbalances consistently undermine the efforts of those facing the most profound disadvantage.

For the majority of definitions, resilience is anchored within an individual perspective, as it is the outcome which is most often of interest. However, mechanisms that enhance resilience can be portrayed as residing both internally and externally across the different levels of the system. This breadth has important implications for assumptions about the range of resources available when making resilient moves—small changes that can be made quickly and which acknowledge where the young person is starting from. While definitions which conceive of resilience as internal draw largely upon a person's psychological resources, more ecological approaches which encompass wider social factors also place responsibility upon institutions and society. The different understandings of resilience can be viewed within the context of how resilience research has developed in the "four waves" said to have shaped the field today (see Masten, 2007).

Health Inequality and Resilience

Following international recognition of the impacts of myriad social inequalities on health (e.g., Black, Morris, Smith, & Townsend, 1980; Lawn et al., 2008) the ethical obligation to tackle health inequalities has been steadily gaining influence as a political issue (Crombie, Irvine, Elliott, & Wallace, 2005; Marmot & Bell, 2012). Health inequalities are defined as "disparities in health (and in its key determinants) that are systematically associated with social advantage/disadvantage" (Braveman & Gruskin, 2003, p. 256). It is not possible to talk meaningfully about health inequalities without talking about ethics and social change. With health and well-being now recognized as social phenomena, questions about how to tackle health inequalities become reframed as questions of how to transform the social structures and systems which produce inequality (Commission on Social Determinants of Health, 2008; Wilson & Pickett, 2009).

The reduction of health inequalities is now a key strategic priority both in the United Kingdom (Public Health England, 2013) and internationally (World Health Organization, 2014). Within this context, building people's resilience through an individual focus is increasingly being presented within government policy and supplementary papers as a viable mechanism for the reduction of health challenges (Children and Young People's Health Outcomes Forum, 2012a, 2012b; Department of Health, 2010a; Public Health England, 2014). In government explanations that privilege lifestyle choice and a person's internal capacities and abilities, it is the individual who bears the brunt of responsibility for reducing health inequalities (Department of Health, 2010b), for example, pressure on individuals to reduce their alcohol consumption within a society that encourages excessive drinking with extended liquor licenses, "happy hours", and cheap supermarket offers.

Criticisms of Resilience

From a social justice perspective, however, responsibility lies to a larger extent with governments, and global decision makers, in their power to determine the economic, social, and health policies that shape the wider socioeconomic conditions. Taking a capabilities perspective, individuals also have agency to affect their own trajectories and those of others (Nussbaum, 2003; Sen, 1999). It is from within the shifting of responsibility for health outcomes from governing institutions onto individuals, and vice versa, that critique of resilience arises. Reacting to the tendency for neoliberal practices and policies to emphasize personal responsibility, while reducing levels of state services, cultural theorists, and social critics consistently warn against an emphasis on promoting resilience (Bottrell, 2013; de Lint & Chazal, 2013; Friedli, 2012, 2013; Harrison, 2012). They identify the concept of resilience as a vehicle for the responsibilization of individuals in place of social structures and governing institutions (e.g., Bottrell, 2013; de Lint & Chazal, 2013; Harrison, 2012; Schmidt, 2015; see Table 2). Little attempt has been made within the resilience literature to offer a response to this critique despite many resilience frameworks working from a risk/adversity perspective (Noltemeyer & Bush, 2013), which may naturally be assumed to capture inequality issues.

Political and economic influences may become concealed when higher level structural factors are assumed to be only as influential as more intermediary influences, such as the personal capacities and behavior of individuals. Structural determinants are no longer seen as "the causes of the causes" (Marmot, 2005) when they are being given equal status. This paves the way for internalized explanations to proliferate when lifestyle factors of behavioral origin appear to exert the greatest influence over health and well-being outcomes (Department of Health, 2010b) and a focus on the level of the individual and on higher level structural factors is presented as mutually exclusive. Responsibilization of individuals then occurs when structural accountability is denied and health inequalities come to be understood wholly as the result of these individual choices and internal capacities.

To critics, a focus on resilience is seen as synonymous with accepting this internalized explanatory model for health inequalities. Many resilience practitioners' and researchers' own understandings and experiences of processes of inequality and disadvantage are not congruent with this model. Particularly for those who identify as members of, or who are working alongside, marginalized and disadvantaged groups, the power of conditions of injustice to constantly undermine caring work does not go unnoticed (Prilleltensky & Prilleltensky, 2005). And in our own projects the impact of structural challenges such as poor housing, transport, and income is often highlighted in the "basics" category of our resilience framework (Hart, Blincow, & Thomas, 2007).

By contrast, abstracted from context, resilience takes on the appearance of an independent variable separable from higher level political and economic factors, and structural accountability becomes deniable, or at least ignorable. It is important to note that decontextualization of resilience also fundamentally ignores findings in resilience research, where context is cardinal for adaptive development (Ungar, 2012). As the internalized resilience presented in policy bears little resemblance to the contextualized ecological

models common today, many resilience researchers and practitioners may feel such critique is simply not relevant to their work, even though they may also not feel empowered to influence or challenge policy. Nevertheless, the problem of conflating explanatory levels continues to be an issue.

Table 2. Criticisms of Resilience.

Authors	Criticisms of resilience
Bottrell (2013)	As the individualised "can do" notion of resilience, twinned with the privatisation of responsibilities, circulates in and flows from policy texts, it obscures historical and more recent structural inequalities that are fundamental barriers to the wellbeing of the poor and blames and penalises them for what are intertextually deemed to be their failings, deficits and unhealthy dependencies.
Friedli (2012, p. 1)	. . . cannot adequately explain inequalities in mental health and wellbeing and may serve to disguise or distract from analysis of social structures that result in and maintain inequalities in power, wealth and privilege and the impact of these inequalities on population mental health.
Garrett (2015, p. 3)	. . . problematic operational consequences of "resilience"-driven policy for children's services; "resilience" discourse is permeated with frequently unacknowledged, value judgements and unquestioned assumptions; excessive emphasis placed on individuals at the expense of social structure and social forces; apparent affinity between "resilience" and key neo-liberal tenets.
Harrison (2012, p. 99)	A focus on resilience lends itself to overemphasis on the ability of those at the sharp end of economic downturn to "bounce back": such a focus may be at the cost of understanding the nature of structural factors that mean that "bouncing back" erodes resilient capability in the long term. . . . it depoliticizes and shifts responsibility for dealing with crisis away from those in power.
Harrison (2012, p. 99)	In focusing on apparent resilience, the costs of this resilience maybe rendered invisible and compounded over time.
Harrison (2012, p. 109)	. . . often focuses on psychological dispositions and personality traits as "protective factors" to the exclusion of analysis of the ways in which these are influenced by wider structural considerations.
Harrison (2012, p. 110)	. . . tends to characterise as individual that which should be understood to be the result of collective effort.
Joseph (2013, p. 40)	. . . urges us to turn from a concern with the outside world to a concern with our own subjectivity, our adaptability, our reflexive understanding, our own risk assessments, our knowledge acquisition and, above all else, our responsible decision making. . . . the way resilience works, certainly in Anglo-Saxon approaches, is to move fairly swiftly from thinking about the dynamics of systems to emphasising individual responsibility, adaptability and preparedness.
Joseph (2013, p. 40)	. . . fits with a neoliberal mode of governmentality . . . the term lacks any proper philosophical meaning . . . To develop a philosophical account of resilience would be to give this discourse a credibility it does not deserve and to ultimately legitimate a set of practices of governance . . . It has been plucked from the ecology literature and used in a fairly instrumental way to justify particular forms of governance which emphasis responsible conduct.
de Lint and Chazal (2013, p. 157)	. . . involves discounting a longer view that challenges the dominant social institutions and orders of neoliberalism.
de Lint and Chazal (2013, p. 158)	. . . prohibits challenges to the systems and institutions in which the individual is located.
de Lint and Chazal (2013, p. 161)	Although studies of resilience consider the individual relatively holistically and locate them contextually within broader environments and social structures, they nevertheless direct interventions towards the individual rather than seeking structural reforms.
de Lint and Chazal (2013, p. 172)	. . . designed to maximise alignment with neoliberal ordering and burden the individual with the responsibility to adapt to status quo actor-network associations.

To overcome these difficulties, Harrison (2012) argues that resilience might be best replaced with the concept of vulnerability. She suggests that while references to resilience emphasize individual responsibility, the term vulnerability suggests moral obligation for those in positions of power toward those who are less powerful. Despite noting that vulnerability can imply people lack agency or are "helpless victims" (p. 99), she proposes that nevertheless the term is preferable, as, in contrast to resilience, vulnerability can be reduced by intervening in the political and economic allocation of resources. To resilience researchers and practitioners working with disadvantaged and marginalized individuals and communities, a focus on vulnerability in place of resilience is neither constructive nor ethical. For marginalized populations, left abandoned to their own fate, the only persons available to act upon their interests may well be themselves and those in close proximity. Relying solely upon appeals to those in power to take on moral responsibility for outcomes antithetical to their own interests remains an insufficient course of action. Furthermore, such an approach risks further marginalizing the most excluded groups in society who are already poorly represented in research. And finally, by replacing the concept of resilience with vulnerability, we risk missing the ways in which some people can display vulnerability, and at the same time strengths and capability (Zautra, Hall, & Murray, 2010). To illustrate the point from one of our own resilience-building research projects, a young woman who consistently displayed considerable signs of distress and vulnerability, often needing to leave meetings, also revealed that she was a prominent and successful campaigner for mental health justice with a leading young people's mental health charity, simultaneously showing strength and capability.

We propose that approaches should address both individual and structural elements that could make a difference, while acknowledging that the range of individual strategies available may be largely determined by higher level political and economic factors (e.g., healthy eating may not be possible for someone on a low income due to the often higher price of "healthy" foods than "junk" foods, and is not necessarily about their individual conscious unwillingness to adopt a diet that the government tells them will be better for their health).

Resilience and Social Justice

The need for resilience research and practice development to engage with inequalities issues, and consequently the accompanying critique, is becoming increasingly urgent (Ungar, Ghazinour, & Richter, 2013). We propose that it is time for resilience to go beyond understanding how individuals cope with adversity, to challenge the structures that create disadvantages in the first place, and contribute to the development of a new wave of research that unites resilience research and practice development with social justice and activism. This process should invite the relocation of community members, researchers, and policy makers in dynamic, multilevel processes. They can then seek to challenge the contributory practices that conflate higher level causes with proximal determinants.

Recognizing that an unjust system unavoidably demands resilience because it relates to adversity, we suggest, as does Bottrell (2009), that we begin by asking, (a) to what extent adversity will be tolerated, on the assumption that resilient individuals can and do cope; and (b) how much adversity resilient individuals should endure before social arrangements, rather than individuals, are targeted for intervention. However, we propose it is then necessary to consider broader shifts that might emerge from resilient moves at the individual/micro level, where there is potential for knowledge and practice to travel and spread and in the process target social determinants (Aranda & Hart, 2014). For instance, in our mental health–related projects we identify stigma and discrimination as key adversities faced by people with mental health problems, including people in our research team. Our work involves considering ways to challenge that adversity in our daily lives, in our local communities, and at a national level by media campaigns and lobbying.

In addition, we notice that while a social justice–oriented understanding of resilience has been emphasized in adult populations (Brown, Payne, Dressner, & Green, 2010; Irizarry, 2008; Maxwell, Locke, & Scheurich, 2014), remarkably few resilience authors or researchers explicitly attempt to incorporate inequalities perspective when working with children and young people (Hart, Blincow, & Thomas, 2007; Prilleltensky & Prilleltensky, 2005; Ungar, 2015), and therefore there is a clear literature gap in addressing this in younger populations, for whom adults may assume they know best.

At Boingboing, we use a strategic resilience-focused methodology to support disadvantaged children, young people (up to age 25 years), and their families in overcoming the adversity they face in their lives (Hart, Blincow, & Thomas, 2007), attempting to address this literature gap in practice. Our work has always been informed by an inequalities awareness and we have developed and applied the concept of an "inequalities imagination" (Hart, Blincow, & Thomas, 2007; Hall & Hart, 2004; Hart, Hall, & Henwood, 2003). We define adversity in relation to social disadvantage, and building on more recent and socio-ecologically contextualized definitions (e.g., Lerner, 2006; Ungar, 2008), we construct resilience as, "overcoming adversity, whilst also potentially subtly changing, or even dramatically transforming, (aspects of) that adversity" (Hart, Gagnon, et al., 2013). This creates the possibility for resilience-based interventions to have an emancipatory function (i.e., potential to overcome adversity and oppression) and contribute toward systemic change, for example by changing school policy to cultivate a more supportive and positive school culture that discourages discrimination, alongside targeted work to build resilience strategies in pupils to deal with stigma and bullying. Current resilience interventions based on an ecological understanding (e.g., Daniel & Wassell, 2002; Kourkoutas & Xavier, 2010) have the potential to target a number of dynamic processes at a range of levels and to overcome inequalities. Within the systemic approach, resilience researchers should introduce specific directions for interventions and social policies, through identifying processes that significantly mitigate the effects of adverse life conditions (Luthar & Brown, 2007). In most instances, however, practicalities of implementation result in interventions predominantly targeting factors proximal to the individual, while acknowledgment of more distal processes remains fairly cursory. For example, many practitioners feel comfortable with and skilled in helping people to make micro "resilient moves" in their lives but feel less empowered and knowledgeable about influencing or challenging policies.

Boingboing supports the development of resilience research and practice that includes a strong inequalities dimension, underpinned by a co-production framework. According to the Social Care Institute for Excellence (2015), co-production is key in developing public services; the advantages include cost-effective services, integration, improved user and carer experiences of services, and increased community capacity. At Boingboing, our co-production work is carried out both with and as disadvantaged communities; most of the team working on our research themselves experience additional challenges and/or social exclusion. We focus on trying to include those of us who might be perceived as highly disadvantaged and marginalized in all stages of our research and knowledge transfer activities, amplifying the voices of others who experience social disadvantage, mental health problems, disability, and other vulnerabilities at different stages in life. We carry out co-productive resilience research and practice in our various identities as affiliates to the community of practice Boingboing.

From this perspective, we have witnessed firsthand how the concept of resilience generates interest and momentum because it inspires (e.g., Big Lottery Fund UK, who award grants to good causes, made a £75 million investment in HeadStart programs in schools in England with much of the funding going to resilience-based initiatives; Big Lottery, 2013; KidsMatter primary school mental health initiative in Australia; KidsMatter, n.d.); therefore, there is a clear imperative to continue resilience research and practice to strengthen

children and young people and enable them to deal with adversities they may face. With the support of concrete examples from a range of our completed and ongoing research, we outline ways in which others can incorporate resilience theory, interventions, and continuing research practice, into an overarching critical approach which privileges knowledge co-produced by researchers and communities (Hart, Maddison, & Wolff, 2007).

Knowledge Co-Production

Traditional forms of knowledge production and transfer, such as the objective measurement of outcomes, are unable to sufficiently capture the multifaceted impacts of health inequalities within a dynamic system. This is partly due to insensitivity to the perspectives of communities. Not only does academic knowledge (Gibbons et al., 1994) have a strong tendency to decontextualize people and communities, but it is also associated with elitism and status inequality (Hart & Aumann, 2007). We suggest that new forms of contextualized, egalitarian knowledge production and exchange are more appropriate for understanding the multifaceted dynamic nature of adversity, resilience, inequalities, and transformational change. We advocate a peer-reviewed, applied, heterogeneous, problem-centered, trans-disciplinary and change-orientated mode of knowledge, with a critical dimension of being "co-produced by the university and community" (Hart, Maddison, & Wolff, 2007, p. 6). Developed in the context of University–Community partnerships, co-produced knowledge develops richer understandings of resilience, captures its costs, and detects hidden resilience, while also empowering people and communities with the tools and voice to challenge processes of injustice (Bolzan & Gale, 2012). An example from Boingboing concerns a group of young adults with learning disabilities. They are working with PhD student, Anne Rathbone, one of the co-authors of this paper, on a co-productive project that enables them to understand and document their own struggles and capacities in relation to the concept of resilience. They have been highly motivated to develop data collection tools. These include a resilience game that when played, helps the group to order their research data in a way that enables the cognitive functioning of the group to be accommodated. The young people have also been highly motivated to support other young people to develop resilience through making their game available more widely (Hart, 2016a). Finally, they have challenged wider inequalities in access to transport through lobbying Members of Parliament (MP) and transport providers (Hart, 2016a).

Looking at resilience through a social justice lens, the synergy between resilience and adversity continually positions researchers and practitioners as the natural advocates for marginalized, excluded, and disadvantaged children and young people, and supporters of their capacities and opportunities for self-advocacy. Co-produced research is necessary to capture the complexities of these groups by enabling a holistic approach. For instance, in our work in schools, we work across the school system in collaboration with all staff groups and levels, as well as students, to understand the resilience mechanisms of students, especially those who are disadvantaged, and to improve their resilience outcomes. In one of our Imagine projects in Greece, undertaken by Elias Kourkoutas and colleagues (Kourkoutas, Georgiadi, & Plexousakis, 2016), school staff, university students, child development center staff, and academics joined with parents of children with complex needs in a resilience-building Community of Practice (CoP). Applying lessons from the resilience research field to their own contexts, including our resilience framework, was the CoP's focus. This local practice has now influenced the work of other academics in Crete and has also impacted the way that some local councils deliver mental health support. In particular, it has led to more community-based resilience-building practices being adopted and the sharing of expertise between parents, schools staff, local councils, students, and academics becoming routine. University teaching curricula have also been adapted to support trainee teachers to learn about and embed resilience-building approaches through this sharing of expertise.

Transformative Practice

We propose that resilience work should encompass a "basics" dimension designed specifically to tackle deprivation and associated health inequalities (Hart, Blincow, & Thomas, 2007). At a broader level, the Prilleltenskys' concepts of epistemic and transformational psychopolitical validity (Prilleltensky, 2003; Prilleltensky & Prilleltensky, 2005; Prilleltensky, Prilleltensky, & Voorhees, 2008) provide a constructive framework for uniting micro- and macro-level factors, through combining understanding of psychological and political influences. Epistemic psychopolitical validity refers to using psychology and politics in understanding social phenomena. Resilience researchers can use this to consider how their understanding of adversity and resilience relates to individual and higher level structural influences, such as asking whether their work includes an understanding of (a) the impact of global, political, and economic forces on the issue at hand; (b) how global, political, and economic forces, as well as social norms, influence the perceptions and experiences of affected individuals and groups; and (c) how the cognitions, behaviors, experiences, feelings, and perceptions of individuals, groups, and entire communities perpetuate or transform the relevant forces and dynamics. They should also consider whether they appreciate how political and psychological powers interact at the personal, relational, and collective levels, affecting the issue at hand.

We argue that resilience research and practice has the potential to use psychopolitical validity as a guide toward liberation at the personal, interpersonal, and structural domains. To challenge our own practice and those of others, we might ask questions such as whether interventions (a) promote psychopolitical literacy; (b) educate participants on the timing, components, targets, and dynamics of strategies to overcome oppression; (c) empower participants to take action to address political inequities and social injustice within their relationships, settings, communities, or even internationally; (d) promote solidarity and strategic alliances and coalitions with groups facing similar issues; and (e) account for the subjectivity and psychological limitations of agents of change.

In our ongoing work, we have made modest steps in these directions. For example, all 16 individual projects of an overall program,

on which we are working, involve some form of activity designed to challenge adversity conditions. We described above how a group of young adults with learning disabilities are tackling inequalities in transport provision. Emerging findings from other projects suggest that through lived experience, practitioner and academic partners can work together with an inequalities-focused approach to resilience-building. For example, in the building resilience for well-being and recovery course, we developed a session focused on "changing the odds" in which learners shared experiences of challenging adversity and developed action plans. One participant highlighted discriminatory attitudes toward people with mental health problems in her church, and with the support of the learning group developed an action plan involving challenging church authorities to take the issue seriously and to circulate educational material.

To overcome the dilemma of agency and responsibility, one possibility is to move away from modernist notions of agency, which privilege voluntary, deliberate, or conscious efforts (Shove, Pantzar, & Watson, 2012), toward a focus on actions as practices (Aranda & Hart, 2014). In terms of health inequalities, resilience, and ecology, this means moving away from focusing on individuals as sources of action, or on structures as external forces. Instead, accounts of resilience, capacities, or capabilities are intimately entwined with norms, practices, and institutions, which in turn are shaped and modified by those enactments. Practices, rather than individuals, become the unit of analysis.

A practice lens therefore suggests that no one, single factor controls change, including practitioners themselves who do not exist in isolation (and in this theoretical sense of the term "practitioner", we mean anyone). Yet opportunities for intervention or change remain possible; practitioners can operate in a number of ways to influence elements of practice (Shove et al., 2012). This entails exploring how practices spread through research, intervention, or organization. Any attempt to understand resilient moves must acknowledge that these attempts are set within a nexus of global health practices seeking to address or tackle inequalities. Research should pay attention to the materiality of policies, reports, public health documents, and strategies; for instance, here in England that would include the recent government reforms now influencing the National Health Service (NHS), and reconfigurations of informal and formal health and social care services. It is worth holding in mind that, as we argued earlier, responsibilization of individuals occurs when structural accountability is denied, and health inequalities come to be understood wholly as the result of individual lifestyle choices and capacities.

Participation

Co-production of knowledge means committing to work with and alongside individuals and communities to better understand their adversity context, including the impacts of inequality, and resilience-building as an ecological process. Particular attention should be paid to issues of power and power relations, how power imbalances manifest and how they can be challenged in resilience research and practice development. The relationship between power and knowledge and the existence of different types of knowledge and competing perspectives should be acknowledged. We should be sensitive to how various types of knowledge are valued and constructed and for what purpose; and how they are used, exchanged, and managed (Hart, Davies, et al., 2013). We acknowledge that fully engaging people and communities in research requires resources, effort, time, and management, and often the practicalities are challenging, but we urge researchers to consider the value that co-produced knowledge adds to understandings of resilience. The simple but powerful way we incorporate this into our research agenda is through inviting study participants to become co-researchers and take an active role in the whole research process, in a way that is appropriate to their needs. In this we are not denying the complex power issues (and indeed practicalities) involved in making this happen. However, as a group we are committed to co-productive research and are constantly striving to improve our practice in terms of shared ownership and accountability.

Empowerment

Working with and alongside people and communities not only involves an undertaking to celebrate capability and build capacity as we share knowledge and practice but also provides potential to empower people and groups to challenge their adversity context. However, we must be especially careful around the meaning and use of empowerment. Within government policy, empowerment is presented as "empowering individuals to make healthier choices" (Department of Health, 2010b, p. 2). However, when we refer to empowerment we are interested in the emancipatory potential. In the context of resilience and inequalities, this means supporting individuals, groups, and communities to increase their control over the events that determine their health and well-being in the first place (World Health Organization, 2014). We also see ways in which more collective community-based understandings of empowerment, represented by the disability rights slogan of "nothing about us without us," has been reinvented into the more individual "no decision about me without me" (Department of Health, 2010c, p. 13), reflecting the need for involvement rather than protection. For example, another PhD student in our group, Stephanie Coombe, supported the development of a resilience-building approach involving the whole-school community, including children (Hart, 2016b). Changes were made to the school day that meant children from disadvantaged backgrounds were able to make choices that increased their chances of going on to further studies or gaining employment. They could choose and/or be paid to develop clubs for hobbies and work experience placements, activities that the school did not previously provide, but which, as reported in the literature, are readily available to more advantaged school children (Broh, 2002; Farb & Matjasko, 2012; Stewart, Sun, Patterson, Lemerle, & Hardie, 2004).

Inclusion

Many of our team of resilience researchers and practitioners are drawn to the field precisely because of our own challenging backgrounds.

Particular attention should be paid to explicit inclusion of marginalized people in resilience research and practice, including involvement in the more technical aspects of data collection. Current research practices routinely encourage underrepresentation of those termed hardest to reach and most in need. In our own exploration of the resilience literature, we found that children and young people with complex needs are unjustly underrepresented in study samples (Hart & Heaver, 2013; Hart et al., 2014). As discussed elsewhere (Hart & Heaver, 2013; Hart et al., 2014) the political economy of research, that is, academic capitalism (Barry, 2011), creates conditions which encourage researchers to focus on tame populations, people who will sit quietly and complete pen and paper or computer-based measures, with minimal supervision and in the fastest time.

We know that competition between researchers to present the best value for money to funders is an issue here, having large sample sizes and including people with learning disabilities are not usually congruous, as we have found in our own projects. Furthermore, academic journals often expect similarly large sample sizes, so there is clearly some work to do for both funders and journal boards in encouraging more appropriate research participation.

Resilience researchers and practitioners should be especially concerned about underrepresentation, as it is the people who are in most need of resilience-based interventions who are in danger of being systematically left out of the knowledge base because they may need additional support to participate. Challenging this state of affairs requires commitment from individual researchers and academic institutions to make emancipatory, resilient moves within research itself. Although we urge researchers to strive toward the inclusion of easy to ignore groups, and those who need additional support, there are steps that can be taken in the meantime to create pressure for change within research contexts. We can stop underrepresentation being a hidden problem, and improve the validity of the information we do have, by routinely including detailed demographic information about participants in our research. And, by justifying the use of unrepresentative samples, we can explicitly state decision-making processes, allowing these processes to be more carefully considered (Thimasarn-Anwar, Sanders, Munford, Jones, & Liebenberg, 2014). In our own research, young people with disabilities (physical, mental health, and learning) are integral members of our community of practice and work as Boingboing co-researchers (Hart, Griffiths, & Mena-Cormenzana, 2015).

Measures

The use of representative samples should be especially considered in the development of adversity and resilience measures. If disadvantaged groups are not included when measures are developed, this further perpetuates their exclusion from studies (Hart et al., 2014) and reduces validity. Making measures more accessible (e.g., easy read, symbol, or pictorial format), and ensuring they acquire information from children and young people who have difficulty compiling forms (e.g., read aloud or proxy completion), will aid inclusion.

Resilience-focused items should extend beyond the individual to aspects of the person's ecology, such as the social (e.g., family), institutional (e.g., school), and cultural and community contexts in which they live. Adversity measures should include questions designed to capture the types of inequalities that the person is facing. Resilience measures should attempt to capture emancipatory elements such as activism and advocacy, both in relation to self and others. We appreciate that this is hard in some contexts, but examples include whether participants take part in political activities, for example, voting, lobbying around inequalities, community advocacy; or whether the resilience program they attended had wider effects for their community, for example, raising awareness of mental health. Finally, cost-free, easily obtainable resilience measures are of the greatest benefit in more disadvantaged contexts, potentially increasing inclusion of disadvantaged people and communities.

CONCLUSION

Wider structural factors, such as political and economic dynamics, are largely neglected in the current models, research and practices of resilience-building for children and young people. This is partly due to the assumption that a focus on the individual and these wider levels is mutually exclusive. We challenge this assumption by uniting resilience research and practice development with a social justice approach. It is essential for the advancement of the field that researchers and practitioners acknowledge the wider political and economic context in which both the resilience models and resulting research and practice sit. Through a social justice lens, engagement with this wider context demands that those of us who don't self-identify as disadvantaged take up our role as advocates and/or promote self-advocacy alongside disadvantaged, marginalized, and excluded children, young people, and families.

It is essential that the resilience literature shifts debate on to look beyond the individual. We urge scholars to work with an inclusive and robust conceptualization of resilience that pays attention to the individual, societal, and environmental interactions simultaneously. We also ask researchers and practitioners to consider how they can make resilient moves within their own work which contribute toward systemic transformation and the reduction of inequalities. Moreover, working with and alongside individuals and groups facing disadvantage will deepen researchers' and practitioners' understanding of their needs, those that can be met and those that cannot. Resilience research and practice has the potential to affect the wider adversity, and therefore inequalities, context with small resilient moves that set in motion chains of events. This not only raises the profile of and strengthens day-to-day research and practice, but it also encourages academics, practitioners, and policy makers to tackle systemic inequalities (Aranda & Hart, 2014). Key here are the strategic plans and daily practices of research funders. Boingboing has been active in trying to shape these in a context where research

funding in the United Kingdom is being increasingly given over to work on big data, with quantitative research, particularly randomized controlled trials, held up as the gold standard against which all other methods are judged.

However, despite this larger picture, there is some room for optimism. For instance, even the National Institute for Health Research, which lauds randomized controlled trials, has a powerful Patient and Public Involvement Agenda, which at least in theory enables service users to lead research projects drawing on expertise gained through their service user identity. Elsewhere in the United Kingdom, co-productive research has been animated by the Arts and Humanities Research Council's Connected Communities Programme. We are involved in this through our own co-productive research project, Imagine, and by contributing to the Connected Communities' wider community of co-researchers, which sees us meet regularly to share ideas and develop collaborative practices (http://www.boingboing.org.uk). The Economic and Social Research Council also takes the involvement of people with lived experience seriously with, for example, new initiatives being developed with recourse to service users' experiences.

Of course there are many miles to go with this agenda, and we constantly challenge our own practices. Furthermore, many aspects of the wider policy context are not favorable to such initiatives at present. However, as we have argued above and elsewhere, there are always practices to be found that start in one arena and get shifted to others, including government policy agendas. The Boingboing community of practice approach is one such grassroots initiative that has traveled beyond its local context and which hopes to sustain itself for the future. Some of the practical steps we attempt to live by are outlined below. Uniting resilience research with an inequalities agenda is where we see our community developing and we hope that others will join us.

Practical moves that can be made in current research practice include

- increasing transparency of research, including a clear conceptualization of resilience;

- conducting academic research that advocates for people facing embedded societal inequalities and is focused on challenging inequitable policy agendas;

- including detailed demographic information about research participants in resilience-based initiatives;

- justifying the use of non-representative populations;

- encouraging the research community to undertake co-produced research with underrepresented groups that are more challenging to work with;

- increasing availability and accessibility of resilience measures;

- developing co-produced research and practice designs, with clear skills development pathways for all co-researchers;

- engaging in co-produced research containing socially transformative rather than solely personally transformative elements;

- initiating research that shares research goals, processes, publications, and financial resources between academic and community partners;

- facilitating supported agency, and co-identifying and co-delivering responses to adversities (to address societal inequalities, or tackle prejudice, discrimination, and stereotyping);

- investigating the impact of inequalities/social disadvantage at multiple levels on processes of resilience-building, remembering that resilience is concerned with overcoming adversity, while also potentially changing or even dramatically transforming (aspects of) that adversity;

- drawing on existing research in allied disciplines (e.g., policy, health disparities, inequalities) when designing resilience research programs to inform the wider socio-ecological context; and

- taking every opportunity to influence research policy makers and help them understand the relationship between inequalities and resilience.

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Justice in Urban Climate Change Adaptation: Criteria and Application to Delhi

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ABSTRACT

Cities around the world are increasingly developing plans to adapt to the consequences of climate change. These plans will have important consequences for urban populations because they are likely to reshape and reconfigure urban infrastructures, services, and decision making processes. It is critical that these adaptation plans are developed in a way that is just. Criteria was developed that can be used to assess justice in adaptation so that the processes, priorities, and impacts address the needs of the most vulnerable urban populations. Further, mechanisms are outlined that have been proposed as responsible for producing urban injustice. The justice criteria are applied to the case of adaptation planning in Delhi and the extent to which poor and informal populations are included and affected by this planning. The analysis shows that adaptation planning in Delhi does not meet the justice criteria in part because of a lack of capacity and the political economy of poverty in the city. The criteria for justice and mechanisms of injustice offer an important step toward developing a greater understanding of not only whether city-level adaptation planning is just, but also why it is or is not.

Keywords: adaptation; cities and climate change; equity; justice; planning

INTRODUCTION

Climate change is, and will continue to be, a policy and planning concern for cities around the world. Given the variability in existing capacities, exposures, and development priorities in cities, urban adaptation planning will be a particularly challenging task (de Sherbinin et al. 2007). One important challenge will be ensuring that the processes and outcomes of climate change adaptation are just and that the introduction of adaptation planning does not serve to reinforce or exacerbate existing vulnerabilities in the city (Bulkeley 2010). A first step in achieving this goal is developing clear criteria to use in identifying justice in urban climate change adaptation. In addition, a better understanding of the mechanisms through which policy and planning contribute to urban injustice will help identify entry points for enhancing justice in adaptation.

Criteria for justice in urban climate change adaptation, drawing on classical texts as well as more recent applications related to cities and climate change, contribute to adaptation research and the themes of this special issue. However, it is not enough to simply know whether the adaptation is just; we must also understand why it came to be that way. Four possible mechanisms of injustice are examined: the political economy of poverty, thick injustice, technocratic governance, and institutional capacities, along with the role they may play in urban climate change adaptation. Finally, the case of climate change planning in Delhi is used as an empirical application of the criteria and an examination of the mechanisms of injustice. The criteria, mechanisms, and case study forward our ability to not only evaluate the outcomes of urban climate change adaptation, but also to improve our understanding of why the outcomes occur and how they can be improved. Promoting justice in adaptation is a critical issue for urban residents and communities and one to which the urban politics community can contribute substantial insights.

CITIES AND CLIMATE CHANGE ADAPTATION

Climate change adaptation can be a direct response to perceived or expected climatic changes, i.e., "clearly identified as being triggered by climate change" (Adger et al. 2005:78), or the result of other, nonclimate related factors such as economic changes. These actions are at times purposefully directed toward addressing climate change and at other times are designed with other, or additional, policy goals in mind (Aall et al. 2007). Adaptation has been defined by the Intergovernmental Panel on Climate Change (IPCC) as "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities" (Field et al. 2012:36). Drawn from this definition, those adaptation actions conceived of and implemented by city governments explicitly as a response to climate change are of concern to this research.

Cities face significant adaptation challenges. They are sites of climate change impacts such as floods, heat waves, and heat islands (Grimmond 2007, Gasper et al. 2011). Sea level rise will especially affect coastal cities. For example, in the city of Rio de Janeiro sea level rise is predicted to affect 400,000 people (Young 2011), and coastal flooding is predicted in Dar es Salaam (Kebede and Nicholls 2012). Many inland cities, such as Mexico City, are predicted to experience floods that will be more severe and will inflict greater damage

with climate change (Baker 2012). In some cases, ongoing urbanization will exacerbate the effects of climate change by increasing temperatures through heat island effects and boosting energy demands (Timmerman and White 1997).

The vulnerability, i.e., the "propensity or predisposition to be adversely affected" (Field et al. 2012:32), of urban populations to the effects of climate change will vary within a given city. People's income and assets are the most consistent indicators of their vulnerability and are used as the two factors characterizing vulnerable and disadvantaged groups. Most disaster-related injuries and deaths in cities occur among low-income groups (Moser and Satterthwaite 2008, United Nations Habitat 2011). Poverty places populations in a position of greater risk, with fewer resources and options to draw on (Hardoy and Pandiella 2009). Climate change will exacerbate the existing vulnerabilities of the urban poor and create new risks as more areas in a city are exposed to climate related hazards. Inequities in the provision of services and access to resources can hinder the ability of cities to effectively adapt to climate change (Romero Lankao 2010).

Cities around the world are developing plans to adapt to climate change, and these plans will have consequences for the availability and distribution of resources and opportunities. Urban adaptation can result in changes to the built environment, land use patterns, decision making processes, development planning, exposure to hazards, and access to services (Carmin et al. 2009, Ford et al. 2011). For example, cities can incentivize water conservation, fund energy efficient transportation, and improve flood mitigation structures. Although many of these actions intersect with mitigation efforts, e.g., increasing energy-use efficiency, adaptation also requires reducing people's exposure and vulnerability and increasing people's resilience to extreme events (Field et al. 2012). The infrastructure investments required can create spaces of inaccessibility in a city by excluding certain groups and connecting select urban places (Graham and Marvin 2001). Adaptation plans and programs are also likely to be embedded within existing decision making frameworks, priorities, and processes that determine a city's broader socioeconomic development trends. Adaptation, therefore, has the potential to contribute to the reproduction of inequalities and differential environmental burdens in cities and to include or exclude the needs of the most vulnerable, that is, those urban populations that lack wealth and assets.

Adaptation actions should therefore be evaluated, at least in part, based on justice criteria to ensure decision making processes and the distribution of costs and benefits include and benefit urban populations that lack wealth and assets. However, a recent review has shown that our understanding of the consequences of urban climate change governance for justice concerns is lacking (Bulkeley 2010), and most cities do not include justice criteria in their climate change planning efforts (Zeemering 2009, Finn and McCormick 2011). This gap is hindering efforts to improve the environmental performance of cities because "the greatest challenge...is not necessarily the lack of environmental services and infrastructure, but the societal structures reproducing unequal distribution and malfunctioning of these services" (Myllylä and Kuvaja 2005:224).

Previous studies of urban climate change policy have focused on the motivations behind planning processes and their outcomes, primarily in developed countries (Robinson and Gore 2005, Engel and Orbach 2008, Zahran et al. 2008, Amundsen et al. 2010, Ford et al. 2011, Krause 2011, Sharp et al. 2011). Climate change justice research has largely focused on rural areas and resource dependent communities, or conflicts in the global arena (Brown 2003, Adger et al. 2006, Dellink et al. 2009, Füssel 2010, Okereke and Dooley 2010, Marino and Ribot 2012, Yates 2012). The use of participation and collaboration processes in cities, and the political struggles these processes necessarily engage, are only starting to be considered by the IPCC and the broader urban climate change community (Few et al. 2007, van Aalst et al. 2008, Aylett 2010). A more holistic and empirical approach to evaluating justice in urban climate change planning, and, more specifically, plans for adaptation, is a necessary next step.

WHAT IS JUSTICE IN URBAN ADAPTATION?

Identifying justice in urban adaptation requires clear criteria for evaluating decision making processes and outcomes; at the same time, justice is a contested and normative concept. John Rawls, a prominent political philosopher, saw justice as fairness, meaning that the terms of allocating benefits and burdens are such that a reasonable person would accept them and expect others to do the same (Rawls 1971). He argued that even if all people were given equal liberties and opportunities at birth, differences in position and power would still arise. These social and economic inequalities are just, Rawls claims, only if they work to the greatest benefit of the least-advantaged members of society, what is referred to as the "maximin" criterion (Cohen 1989, Rawls 2001). Rawls' definition is commonly used to evaluate existing institutional arrangements against the ideal system that is able to allocate opportunities and burdens fairly, or what is commonly referred to as a means-based approach to justice.

Nobel Prize winner Amartya Sen later shifted discussions of justice away from Rawls's interest in designing just institutions to an approach that relies on identifying outcomes or options that are more just than the status quo. Sen referred to his approach as "focusing more on the extents of freedoms, rather than on the means " (Sen 1992:xi, emphasis in original), which is often considered an ends-based approach to justice. He argued that policy options that produce enhanced basic freedoms and opportunities for well-being are more just than the status quo (Sen 2009). Although Sen did not specify what freedoms should be enhanced by these just alternatives, Martha Nussbaum proposed the following: life, bodily health, bodily integrity, senses imagination and thought, emotions, practical reason, affiliation, other species, play, and control over one's environment (Nussbaum 2003). This approach to justice is often referred to as the capability approach because "in contrast with the utility-based or resource-based lines of thinking, individual advantage is

judged in the capability approach by a person's capability to do things he or she has reason to value" (Sen 2009:231) as the result of a policy or development intervention. Capability, therefore, becomes the metric with which policies, and society more broadly, are judged.

Applying these concepts of justice empirically to urban policy and planning can be difficult, but researchers have found various ways of translating broader concepts of justice, such as those proposed by Rawls and Sen, into evaluative criteria for cities. Some have built on Sen's emphasis on ends-based justice to promote climate change adaptations in cities that benefit vulnerable groups. For example, Moser and Satterthwaite have proposed an asset-based framework for "pro poor adaptation" in which investments in the assets, intellectual and physical, of vulnerable and poor communities are used to reduce vulnerability and improve capacity (Moser and Satterthwaite 2008, 2010, Moser 2011). Hastings (2007) has proposed a "territorial justice" of service provision in which the level of provision always meets the level of need.

However, there is a growing emphasis within the urban environmental justice community to include both means-based and ends-based justice criteria in evaluations. Although too much emphasis on process and institutions can shift focus away from people's lived experiences, which is Sen's central argument, ignoring these factors "does not permit an assessment of procedural injustice" (Boone 2008:150, emphasis in original) and discounts the "social structure and institutional context that often help determine distributive patterns" (Young 1990:15). Again highlighting the importance of including both means- and ends-based criteria, Jekwu Ikeme (2003) distinguishes justice from equity by defining environmental justice as encompassing both procedural and distributive justice, although equity is often only interested in the distributive outcomes. Agyeman and Evans (2003) argue that the meaningful involvement of all people in decision making and implementation, as well as the equitable distribution of benefits and burdens, are the necessary components of environmental justice in cities, a definition that encompasses both procedural and substantive outcomes. Likewise, Susan Fainstein (2010) has proposed that democracy, diversity, and equity are the basic elements of a just city. Within the climate change justice community, focused at the global scale, there is also an emphasis on both procedural and distributional justice (Adger et al. 2006). Understanding the justice dimensions of both the way in which decisions are made and the outcomes of these decisions therefore becomes a powerful tool for evaluating the justice of a new policy or program, such as adaptation planning.

Despite the growing body of work surrounding urban environmental justice, there is a need to better understand what climate change adaptation in cities will or could mean for vulnerable populations and how to evaluate the process and outcomes of adaptation using justice as a criterion. The growing emphasis on both means- and ends-based, or procedural and distributive, criteria reflects Harvey's description of justice as "a just distribution justly achieved" (Harvey 1973:116). Drawing on this idea, and the work of environmental justice scholars, justice in urban climate change adaptation is defined as 'just adaptation justly achieved.' The criteria for meeting this definition are: (1) inclusiveness, i.e., representation of vulnerable groups in adaptation planning processes for the city; (2) prioritization, i.e., priority setting and framing that recognize the adaptation needs of the vulnerable groups in the city; and (3) impacts, i.e., impacts of adaptation that enhance the freedoms and assets of vulnerable groups in the city (Table 1).

These criteria reflect both the means- and ends-based approaches to evaluating justice and also account for the distinction typically made in evaluations of the effectiveness of public policies between outputs, outcomes, and impacts. Representation of vulnerable groups meets the process criteria for justice and enhances people's ability to affect change in their city through open and democratic decision making processes. Explicit prioritizing of vulnerable groups and framing adaptation as, in part, a tool with which to reduce their vulnerability ensures that planning documents and institutions that develop around adaptation, i.e., outputs and outcomes, reflect equity and fairness concerns. Finally, the tangible results of adaptation planning, i.e., impacts, should meet the criteria of enhancing the freedoms and assets of the city's most vulnerable groups.

THE MECHANISMS OF INJUSTICE

Although identifying injustice in urban adaptation is important, it is equally important to understand why injustices occur so that strategies for improving the processes and outcomes of urban adaptation are developed. Research in urban politics and planning has shown that there are a variety of mechanisms that have the potential to contribute to continuing injustice in cities. These mechanisms, although not necessarily exclusive or independent, can be categorized as: the political economy of poverty, thick injustice, technocratic governance, and institutional capacities. The extent to which any given mechanism contributes to injustice varies between cities and between policy issues.

Thick injustice

Contemporary injustices may be the result of past decisions and resource allocations, thus making it difficult to track the source of the injustices to a particular event or institution. This is referred to as thick injustice or "unjust power relations that are deep and densely concentrated, as well as opaque and relatively intractable" (Hayward and Swanstrom 2011:4). Thick injustice is rooted in the historical patterns of a city's governance and infrastructure in a way that makes it difficult to identify and change. From this perspective, injustice in the distribution of burdens and benefits in cities is rooted in historical processes and is a legacy of past policies that continue to affect the participation opportunities, engagement, and outcomes of decisions surrounding land use planning and public services. Past programs for economic restructuring and suburbanization can foster a spatial mismatch between where people can live, where people

can work, and their subsequent contemporary access to decision making processes and outcomes (Morello-Frosch 2002). Access to property or green space in the city can be limited for certain racial or ethnic groups because of past decisions that have led to differential housing densities (Heynen et al. 2006).

Table 1. Summary of major contributions to the examination and definition of justice relevant to urban climate change adaptation and proposed criteria for justice in urban adaptation.

Author	Topic	Key Argument	Representative Publication
John Rawls	Just Institutions	Justice as fairness: terms of allocating benefits and burdens are acceptable to all; inequities work to benefit of disadvantaged	*A Theory of Justice*. 1971. Harvard University Press
Amartya Sen	Capability Approach	Outcomes that increase people's basic capabilities and opportunities are more just than outcomes that do not	*The Idea of Justice*. 2009. Harvard University Press
Catherine Moser and David Satterthwaite	Pro-Poor Adaptation	Adaptation actions should seek to increase and rebuild the assets of the urban poor	*Towards Pro-Poor Adaptation to Climate Change in the Urban Centres of Low- and Middle-Income Countries*. 2008. IIED Human Settlements Discussion Paper
Neil Adger	Climate Change Justice	Fairness in adaptation responses requires both procedural and distributional justice	*Fairness in Adaptation to Climate Change*. (with colleagues). 2006. MIT Press
Susan Fainstein	Just Cities	Just cities are democratic, diverse, and equitable	*The Just City*. 2010. Cornell University Press
Julian Agyeman; Christopher Boone	Environmental Justice	Justice requires meaningful involvement of all people in decision making and implementation together with the equitable distribution of outcomes	Agyeman. "Toward Just Sustainability in Urban Communities: Building Equity Rights with Sustainable Solutions." 2003. *Annals of the American Academy of Political and Social Science*
Proposed	Justice in Urban Climate Change Adaptation	(1) Inclusiveness: representation of vulnerable groups in adaptation planning processes for the city (2) Prioritization: priority setting and framing that recognize the adaptation needs of the vulnerable groups in the city (3) Impacts: impacts of adaptation enhance the freedoms and assets of vulnerable groups in the city	

Thick injustice proposes that injustice is the outcome of historical processes and patterns of allocating resources and access to spaces within the city. This approach has also been called the structural-historical perspective, which is concerned with "the extent to which present-day injustices are the outcome of historical development paths, as opposed to contemporary development policy" (Pelling 2003:168). Pelling (2003) argued that it is important to know the difference if we are to know the degree to which contemporary policy interventions can promote justice. For example, Boone et al. (2009) demonstrated that the current disproportionate exposure of white communities to toxic chemicals in Baltimore was the result of zoning decisions made in the 1920s and 1930s rather than recent decisions made by industry to locate in particular areas.

From a thick injustice perspective, whether or not the outcomes of urban climate change adaptation are just will be determined by past decisions and resource allocations. For example, an adaptation strategy centered on enhancing existing flood protection barriers will provide little benefit in areas that don't have flood protection barriers to begin with or whose flood protection barriers have been poorly maintained for the last 50 years. These deeply rooted and place-based inequalities may work to obscure the source of urban injustices and require interventions that are able to rectify the legacy outcomes of past decisions.

Political economy of poverty

In addition to historical or 'thick' mechanisms of injustice, contemporary political-economic conditions in cities, particularly political representation and access to decision making, have been consistently identified as drivers and maintainers of urban poverty and exclusion. The political economy approach emphasizes the politics of democracy and citizenship in urban decision making processes, and the "rights of the citizen as an urban dweller, or citadin, and user of multiple services " (Lefebvre 1996:34). Although local government is often the most representative scale of government, and this is true in India (Kaviraj 1991), political economy of poverty research has shown that the urban poor are still likely to have fewer opportunities than other groups to influence policy making processes in a meaningful way or help set spending priorities; consequently, the decisions made by municipalities are unlikely to benefit these groups. This dynamic creates a positive feedback loop and a type of poverty trap (Bowles et al. 2006). For example, although in Delhi poorer people are more likely to be politically active, this does not translate into political power because of the prevalence of middle class interests in civil society and newly developed channels of participation and state access that prioritize land ownership (Harriss 2005, Ghertner 2011). As people's access to decision making and investment in the political economy of the city are diminished, so are the benefits they are likely to receive from this system.

In many cases adaptation planning is embedded in existing policy and planning processes (Anguelovski and Carmin 2011), which will further tie adaptation decisions and outcomes to the political economy of urban poverty. Drawing on this approach, we would predict that the inability of vulnerable groups to currently participate in, influence, and be prioritized by the policy process will inhibit just outcomes in urban climate change adaptation. Conversely, from a political economy of poverty perspective, we would expect that cities whose political and institutional arrangements allow for equal access to and influence upon decision making would develop more just adaptation strategies.

Technocratic governance

Technical information can often be an important input to urban environmental policy and climate change adaptation decisions. A dominance of technical information in policy making can marginalize groups that are not using, familiar with, or included by this information (Fischer 2005, Jasanoff 2007). Particular epistemologies can become institutionalized such that the way information is produced and used results in decisions that do not account for goals or processes that lie outside the dominant way of thinking. For example, Eden and Tunstall (2006) found that ecological restoration projects that rely solely on environmental data and do not account for the needs and motivations of the community are unsuccessful and controversial. Even the tools used to analyze policies, e.g., cost-benefit analyses and efficiency metrics, can lead us to different conclusions about the equity of their distribution of costs and benefits (Hajer and Wagenaar 2003). Government agencies are asked to undertake ever more complex analyses of the risks and benefits of regulation and elite advisory committees are often used as advisers (Jasanoff 1990). The type of information that is used in decision making and the way this information is generated and evaluated can help to determine the accessibility of decision making and its distribution of costs and benefits.

Adaptation is often informed by large-scale climate models and aggregate statistics that underlie temperature and precipitation scenarios for the future. Adaptation, therefore, has the potential to be seen as a purely technical enterprise with justice concerns considerably marginalized (Finn and McCormick 2011). From a technocratic governance perspective, adaptation planning processes that rely heavily on experts and technical information and do not include local knowledge and participation in decision making are less likely to meet the justice criteria. Climate adaptation planning processes should ensure that technical materials are accessible even to those with minimal technical skills and understanding, and more diverse sources of information should be included.

Institutional capacities

Institutions underlying policy processes can play an important role in determining their outcomes (March and Olsen 1989, Polski and Ostrom 1999). Research has shown that local governmental institutions often lack the administrative, financial, or technical capacity to successfully develop and implement new policies and programs. Because of rapid growth and relatively weak accompanying governance structures, cities in low and middle income countries may particularly lack the qualities of good urban governance: decentralization and autonomy, transparency and accountability, and responsiveness and flexibility (Pelling 2003, Dodman and Satterthwaite 2008, Kraas 2008, Parnell and Walawege 2011). In some cases, a municipality may not have the authority it needs to reach its climate goals because of complex institutional networks and jurisdictions, such as in the case of Mexico City (Romero Lankao 2007). Policy efforts that seek to alleviate urban poverty often have very different approaches and priorities, and any given department is likely to have an incomplete understanding of the problem. Cities may also lack the necessary financial resources caused by an inability to generate and collect adequate tax revenue. Municipal governments in highly centralized countries may have limited control over their financial resources. Further, decision makers may lack the technical capacity and training necessary to address the needs of the vulnerable. Cities may lack the institutional capacity to address the needs of vulnerable groups, despite any good intentions.

From this perspective, institutional capacity will play a role in determining whether and to what extent urban climate change adaptation is just. The greater the institutional capacity, e.g., authority, financial resources, and expertise, the more likely a city will be able to develop climate change adaptation strategies that are just.

EMPIRICAL APPLICATION: DELHI

The city of Delhi is used as a case study for applying the justice criteria and identifying the mechanisms of injustice at play in climate change adaptation planning. Delhi is a useful case for applying the proposed criteria for justice in adaptation planning because it is part of a broader trend: cities in developing and newly industrializing countries taking action on climate change (Betsill and Bulkeley 2007). Although these efforts are still relatively new in Delhi, the city was one of the first major cities in the world to initiate a climate change action plan and is continuing to update its approach to addressing and adapting to climate change. It is a growing city with major deficits in services and a vibrant middle class.

Between April and May 2012, 21 interviews were conducted with people working on climate change issues in the central government, Delhi government, academia, and NGOs. Interviewees were first chosen using a strategic sampling method targeting individuals from government, NGOs, and academia involved in, interested in, or contributing to city-scale planning for climate change, environment, energy, water, or land use. This resulted in an initial set of 15 interviews. A snowball sampling method (Noy 2008) was then used to identify and interview an additional six people that participants thought would be valuable sources of information for the research. The final set of 21 interviews included 8 people from city government, 1 person from subcity government, i.e., the Municipal Corporation of Delhi, 4 people from central government, 6 people from NGOs, and 2 academics.

The interviews were semistructured and included questions on how climate change planning takes place and what it consists of, how vulnerable groups are included, what information was used in the process, and plans for the future (Appendix 1). Because the climate change agenda does not distinguish between mitigation and adaptation aims, participants were asked about climate change actions broadly, and the answers were interpreted and analyzed as they pertained to adaptation. The interviews were transcribed and coded using a deductive coding scheme reflective of the three justice criteria and the four potential mechanisms of injustice. The results from these interviews, together with other literature and government reports, were used to identify the city's climate change challenges, apply the three criteria for justice in adaptation, and determine what mechanisms are at play in producing injustices in adaptation. The analysis, therefore, was largely based on the perceptions and responses of the interviewees as measured against the criteria for justice and potential mechanisms of injustice described in the literature and presented above (Smith and Wiek 2012).

Climate change adaptation and Delhi

Nearly 17 million people live in the National Capital Territory of Delhi, referred to here as Delhi, and the population has been expanding rapidly, growing by 47% between 1991 and 2001 and by 20% from 2001 to 2011 (Census of India 2011). Delhi is predicted to experience increased temperatures and extremes in precipitation in response to climate change (IITM 2005). The city lies on the banks of the Yamuna River, and increases in extreme precipitation events combined with accelerated glacial melt are likely to increase the chance of major floods (Revi 2008). Increased temperatures may also lead to increased urban heat islands, particularly in high density housing neighborhoods. More intense droughts are also predicted for the city and the regions it depends upon for resources. Delhi already struggles to meet the water supply, sanitation, and water quality needs of its residents (Centre for Science and Environment 2012), and climatic changes will exacerbate these challenges.

The city supports a growing middle class that has benefitted greatly, both politically and economically, from globalization and India's subsequent economic growth. The city has also been undergoing significant changes because of its drive to become a world-class, or global, city (Dupont 2011). However, this growth in prominence and wealth has also served to further marginalize the urban poor and working classes (Fernandes 2004, Ghertner 2012). In addition, large portions of the city's residents live in informal settlements that receive little or no city services and are exposed to flooding hazards and air pollution. These groups, the poor and the informal, are the most vulnerable in the city and are the target population for evaluating justice in adaptation in Delhi.

In 2008 the city released its climate change plan, called the Climate Change Agenda for Delhi 2009-2012. The plan contains 65 action points, 1 for every year of India's independence, that include both mitigation and adaptation activities. The plan did not come with explicit budgets but did allocate responsibility for implementation to existing groups and government agencies within the city (former Delhi Department of Environment employee, 30 April 2012, personal communication). These assignments were therefore essentially unfunded and in many cases built on or incorporated existing programs within the agencies. Then in August of 2010, the national government initiated a collaborative effort with states to develop a common framework for implementing national climate change objectives. As a union territory, Delhi is currently developing a state level action plan under this framework, which will replace the Climate Change Agenda for Delhi 2009-2012 when it is completed. Funding for the state level action plans is predicted to come from federal ministries as well as from internal, bilateral, multilateral, and private funding sources (United Nations Development Programme (UNDP) representative, 3 May 2012, personal communication). The state action plans are expected to focus more on adaptation and, according to a representative from the national Ministry of Environment and Forests, on 23 May 2012, they hope to get mitigation benefits through adaptation measures and avoid setting explicit emissions targets. Delhi's efforts at climate change adaptation planning are still relatively young: the climate change agenda has only been in place since 2009 and the state level action plan is still being developed. However, Delhi remains one of the early actors in developing a climate change plan, particularly among low and middle income countries, and learning from these experiences can have value not only for the city itself as it moves forward, but also for other cities with similar ambitions.

Justice criterion 1: representation of vulnerable groups in adaptation planning processes

The planning process for the Climate Change Agenda for Delhi 2009-2012 did not include mechanisms for vulnerable groups to participate or be represented. In 2008, the Chief Secretary of Delhi decided to work on a climate change plan for the city of Delhi beginning with an evaluation of the climate change plans of other global cities, including London. On 8 May 2012, he said: "I started, I must tell you, by searching the net on a number of American cities which have come out with climate change protocols of their own." After drawing on these plans for the conceptual approach, he began collecting data for a plan for Delhi. His methods for collecting data largely followed the central government's methods, "because I saw that that framework would be good for our department too." Finally, he identified 20 government departments in Delhi that should be involved and worked with them to develop 65 action points for the city to tackle between 2009 and 2012. Updates and monitoring took place through weekly conference calls between the Chief Secretary of Delhi and the heads of the government departments.

The process of developing the new state action plan for Delhi may have been more inclusive. This was, in part, because of the involvement of the UNDP who, in collaboration with the central and state governments, helped to develop a common framework for climate change planning at the subnational level in India that included stakeholder workshops. The workshops were intended to target, in part, marginalized communities, civil society, and activists (UNDP representative, 3 May 2012, personal communication). Indeed, a key tenet of the new framework is "that process is important" (UNDP representative, 3 May 2012, personal communication), and indeed partnership and coordination are listed as the first stage of the new framework. However, the framework is voluntary and because Delhi already had a climate change plan in place, it is unclear how closely it will follow the proposed common framework. The Mahatma Gandhi Institute for Combating Climate Change, a quasi-governmental strategic research institute, has been tasked with launching an educational campaign about the Delhi government's targets for the state action plan by targeting communities, NGOs, schools, and colleges. However, there are not similar plans to involve these groups in the construction of the goals themselves.

One way vulnerable groups could be better represented in adaptation planning is through an expansion of the city's Bhagidari System, an initiative of Chief Minister Sheila Dikshit. According to the Chief Minister, she realized there was a need to increase citizen involvement in government beyond voting every few years because "decision making should be participatory all the way through" (Chief Minister Sheila Dikshit, 18 May 2012, personal communication). Bhagidari means 'partnership,' and the program empowers and provides venues for residential welfare associations (RWAs) throughout the city to set priorities for their neighborhood and communicate these to the Delhi government. The Bhagidari System has received international recognition for its innovative approach to metropolitan governance, including a Public Service Award from the United Nations. As mentioned previously, the system currently favors property owners by relying on RWAs, which are themselves "groups of private property owners organized at the neighborhoods level" (Ghertner 2011:505). According to the Chief Minister's office there are 1229 unauthorized colony RWAs that have been provisionally registered with the government (Chief Minister of Delhi, 18 May 2012, personal communication), but these need to be made official if the most vulnerable populations are to be represented. The Bhagidari System has been a conduit for greater public input in the more recent climate change planning process. The leaders of the Bhagidari System have provided input to the state action plan (Chief Minister of Delhi, 18 May 2012, personal communication), and RWAs are seen as important players in implementation (Parks and Gardens Society, 9 May 2012, personal communication). However, despite this progress, there remains no explicit mechanism through which the most vulnerable populations in Delhi can participate specifically in the city's adaptation planning.

Previous research, focused on the procedural or means-based dimensions of justice, has shown that meeting justice criterion 1 requires vulnerable groups to be represented in adaptation planning processes. Based on the evidence presented here, Delhi's process does not meet this criterion: decision making about the climate change agenda was highly centralized and lacked transparency, and the current configuration of the Bhagidari System is not inclusive of the city's vulnerable groups. The workshop-based process proposed for the state level action plan and the outreach programs of the Mahatma Gandhi Institute for Combating Climate Change have greater potential to meet this criterion.

Justice criterion 2: priority setting and framing that recognize the adaptation needs of the vulnerable groups in the city

Evaluating the Climate Change Agenda for Delhi 2009-2012 and the programs and priorities it lays out, i.e., the policy outputs and outcomes, revealed that there were two passages that recognized the needs of vulnerable groups. In the introduction, the agenda reads: "climate change is a global challenge and needs a positive development policy response to ensure that the objectives of growth with equity are achieved while at the same time to ensure long term sustainability of the environment" (GNCTD 2009). However, the agenda does not specify how this is to be achieved, except in the case of water supply, which is the second place where the needs of vulnerable groups are recognized. Overall, the agenda places an emphasis on the need to improve public services and specific objectives are developed for water. The agenda motivates changes in water management by recognizing that current service patterns are inequitable: "Today whether it is the rich or poor all pay the same cost and while the distribution system in rich areas is better and hence the availability, the same is not true of poorer areas of the city" (GNCTD 2009). One way the agenda proposes to remedy this is by providing sewage connections to all villages and unauthorized colonies, a responsibility given to the Delhi Jal Board. This board is using the climate change agenda as a starting point for their own strategic planning and priority setting with a plan set to be released in 2012 (senior official at the Delhi Jal Board, 25 May 2012, personal communication).

Beyond these explicit references, many of the city's adaptation goals are strategically bundled with the city's broader development goals (Aggarwal 2013). For example, when describing the urgency of acting to address climate change, the introduction to the climate change agenda reads, in part: "This means putting in place small efforts which are encapsulated in a framework which makes it possible for each Delhiite to become a part of the process of change. This document sets forth the ways in which Delhi's Development Agenda can be marshaled to meet the objective of preserving our planet" (GNCTD 2009). The aim then seems to be to develop a program that builds on existing development aims. However, the plan does not contain specific strategies by which Delhi's development agenda will be leveraged for climate change benefits, and although there are many components of Delhi's development agenda that target the needs of vulnerable groups, as a whole it does not prioritize the needs of these groups (Ghertner 2010). According to an NGO representative in Delhi: "Currently they are planning for the middle class but climate change requires that they plan for the most poor, the people who are vulnerable. The people who they are planning for, they are more resilient. They are not vulnerable. The communities, the poor communities, are the people who are more vulnerable. But there's no plan that says each person should have access to a minimum number of liters (of water)" (NGO representative in Delhi, 2 May 2012, personal communication).

An important improvement in the forthcoming state action plan is the use of a vulnerability assessment, as recommended in the common framework. The city has commissioned academics from the Indian Institute of Technology to conduct quantitative vulnerability assessments for the city based on potential climate impacts. In theory, the use of a vulnerability assessment should help the city identify and target vulnerable groups. However, it is still not clear how the vulnerability assessment will be conducted and the extent to which it will be used in setting adaptation priorities.

Meeting justice criterion 2 requires that the outputs and outcomes of the policy process recognize and prioritize the adaptation needs of the vulnerable groups in the city. Although vulnerable groups are mentioned in the climate change agenda, particularly in reference to the provision of sewage connections in all villages and unauthorized colonies, the needs of vulnerable groups in Delhi extend well beyond sewage connections. In addition, the climate change agenda is explicitly linked to the broader development goals of Delhi's development agenda, a program that has been criticized for prioritizing the middle class. For these reasons, climate change adaptation planning in Delhi does not meet the second justice criterion.

Justice criterion 3: outcomes and impacts of adaptation enhance the freedoms and assets of vulnerable groups in the city

Evaluating the outcomes and impacts of the climate change agenda is challenging for at least two reasons. First, the outcomes and impacts of the climate change agenda are in many ways conflated with the outcomes and impacts of existing programs in the city, such as Delhi's development agenda and the tree planting program of the Parks and Gardens Society, as well as national programs, such as Mission for a Green India and the National Solar Initiative, that have been explicit motivators of some of the targets in the Climate Change Agenda for Delhi 2009-2012. For example, Delhi's tree planting program has successfully partnered with RWAs to revitalize parks and green spaces throughout the city (Parks and Gardens Society, 9 May 2012, personal communication). However, the conflation among the climate change agenda, the existing tree planting program of the Parks and Gardens Society, and the national Mission for a Green India makes it difficult to attribute the success of tree planting efforts to the climate change agenda itself.

Second, the city itself has not systematically tracked progress in meeting the goals of the climate change agenda, and many key individuals who were involved with the agenda are now working in very different parts of the government or in the central government. The tracking that has been done largely focused on documenting the introduction of city-level policy measures that are aligned with the six national missions addressed in the climate change agenda, e.g., solar tariffs and mandatory use of CFL light bulbs. Detailed information about where and to what extent these measures have been implemented is not publicly available.

Although attributing outcomes and impacts directly to the climate change agenda is challenging, there is little indirect evidence that the freedoms and assets of vulnerable groups have been enhanced by this program or by the development agenda. Forty-five percent of the city remains unconnected to the sewer network, and 25% of the city is not connected to the water supply network (senior official at the Delhi Jal Board, 25 May 2012, personal communication). There are ongoing conflicts between the city's river restoration goals, included in the climate change agenda and the development plan, and informal settlements: technically the city is not allowed to relocate people for the purpose of restoration (Delhi Development Authority, 24 May 2012, personal communication), but in some cases court rulings prioritizing Delhi's efforts to become a world-class city have led to the destruction of homes for the purpose of riverbank restoration (Bhan 2009), whereas other projects, such as the Akshardham Temple, have been allowed to take place on the floodplain (Ghertner 2010). The broader environmental agenda has not been conducive to meeting the needs of the most disadvantaged in the city either. Some actions against the interests of the poor and informal in Delhi are the result of public interest litigation brought to the courts by environmentalists, leading to the claim that "bourgeois environmentalism has emerged as an organized force in Delhi" (Baviskar 2003:90).

The perceptions of interviewees mirror these findings. One NGO representative says, "in terms of action...there's nothing unconventional or new being done from the climate change point of view, not much at all" (NGO representative, 2 May 2012, personal communication). There were no accountability mechanisms in place to ensure that the various departments were implementing their assigned actions. According to a former city government employee, although the departments were asked to report what they were doing, they were

never asked why they weren't doing more or completing their tasks (former Delhi Department of Environment employee, 30 April 2012, personal communication). According to this same person, development issues are more important to the city than climate change and so climate change actions are not prioritized. Another NGO representative said "climate change is an add-on in agencies' plans, the city is not serious about it" (NGO representative, 20 May 2012, personal communication) and sees the government's plans to address climate change as a way of placating an increasingly environmentally aware middle class with negative consequences for the poor.

Meeting justice criterion 3 requires that observed impacts of adaptation enhance the freedoms and assets of vulnerable groups in the city. Because of the difficulty of the conflation of the aims and implementation of the climate change agenda with other programs and plans, the fact that the city has not undertaken a targeted assessment of its own, and the lack of evidence that the assets of vulnerable groups in Delhi have significantly increased during this time period, the impacts of adaptation in Delhi do not meet the third justice criterion.

Mechanisms underlying adaptation injustices in Delhi

The analysis shows that in applying the criteria for justice in adaptation, the process, priorities, and impacts in Delhi do not meet these criteria. Based on the same interview results, there are at least two mechanisms of injustice at play in the city that are contributing to these outcomes: a lack of institutional capacity and the political economy of poverty.

The issue of capacity is evidenced by the shifts in planning process and priorities that have come with the involvement of the UNDP and the development of a common framework for climate change planning at the state level in India. The common framework has introduced the notion of stakeholder workshops, vulnerability assessments, and outreach, all of which have the potential to increase justice in adaptation in Delhi. The Climate Change Agenda for Delhi 2009-2012 was the result of entrepreneurial but isolated work on the part of the Delhi government. With additional resources and guidance from the UNDP and the national government it is the possible to improve the city's capacity to undertake just adaptation planning that includes vulnerable populations in the process, prioritizes their needs, and ultimately enhances their freedoms and assets in ways that reduce their vulnerability.

Additional capacity issues remain, however. Funding for climate change adaptation is extremely limited. There are currently no dedicated funding streams for climate change at the city level. Funding from the national level will depend on the extent to which the state action plan aligns with national priorities. Funding through the Clean Development Mechanism (CDM) tends to favor very large projects that may not address the needs of poor and marginalized communities. There is also a lack of technical capacity in the city. All of the assessment components of the state action plan have been contracted to outside entities, including the vulnerability assessment, emissions inventory, and climate projections and scenario development (Local Governments for Sustainability representative, 9 May 2012, personal communication). Finally, there is a lack of institutional capacity. There is no dedicated office for climate change in the city and currently very little invested leadership in developing a robust and just state action plan. Further investment in capacity from within the city will be necessary for just adaptation in Delhi.

A second mechanism of injustice in adaptation for Delhi is the political economy of poverty. The poor and informal populations of the city have very limited venues for accessing decision making, government programs, and public services in Delhi. This is evidenced in part by the provisional status of unauthorized settlements in the Bhagidari System to form RWAs and in the lack of services in these areas because the city is not required to provide water and sanitation to unauthorized colonies (NGO representative, 2 May 2012, personal communication). As the middle class has expanded, poor areas have become increasingly marginalized (Ghertner 2012). According to a representative from an NGO in Delhi, "the government doesn't feel a moral commitment to the poor" because "it is too captivated by the rising power phenomenon" (Delhi NGO representative, 25 May 2012, personal communication). Development goals, then, tend to reflect these ambitions rather than the needs of the most vulnerable groups. In addition, the political dynamics in the city are such that the poor are often marginalized or discounted in decisions about new infrastructure. One NGO representative describes the decision making process surrounding Delhi's metro system built in 2002: "Even for the Metro, the original plan was to go through poor localities to provide public transport. But the real estate mafia re-drew the Metro routes to go through their middle class housing areas and home values went up even higher" (NGO representative, 25 May 2012, personal communication).

If climate change continues to be tied to development goals, it will be subject to the same political economic dynamics. There are signs of this changing. The most recent national five-year plan, entitled Faster, Sustainable and More Inclusive Growth, highlights the need to include all Indian citizens in the country's development (representative from the India Planning Commission, 21 May 2012, personal communication). Because state action plans will be tied explicitly to national priorities, this could serve to circumvent city-level mechanisms of injustice.

DISCUSSION AND CONCLUSION

My aim was to develop criteria that can be used to evaluate whether urban adaptation is just, to identify the mechanisms that may underlie injustice in urban adaptation, and to use these criteria and mechanisms to evaluate the case of Delhi. By reviewing the classic literature on justice as well as more modern urban interpretations, three criteria for justice in urban adaptation were proposed: (1)

representation of vulnerable groups in adaptation planning processes for the city, (2) priority setting and framing that recognize the adaptation needs of the vulnerable groups in the city, and (3) outcomes and impacts of adaptation that enhance the freedoms and assets of vulnerable groups in the city. In addition, four potential mechanisms of injustice were identified: the political economy of poverty, thick injustice, technocratic governance, and institutional capacities. These criteria and mechanisms provide a starting point for an urban adaptation research agenda able to more explicitly account for the political forces that underlie decision making about climate change.

Applying these ideas to the case of Delhi showed that the city did not meet the three criteria for justice in urban adaptation. However, the analysis provided insights into how justice may be improved given existing processes and priorities. For example, the Bhagidari System could be further developed for poor populations and informal settlements and could be better integrated into the climate change planning process. The vulnerability assessment that is being conducted as part of the state action plan should be conducted in a way that recognizes the sources of vulnerability people face, should be fully integrated into the planning process, and used for priority setting. Finally, the city should evaluate its progress in meeting its climate change goals. Although coordinating climate change and development goals is useful in many ways, it makes it more difficult to know how well the climate change program itself is doing. Therefore, an additional capacity for the city to develop would-be-tools for tracking and monitoring progress in adapting to climate change is needed.

The analysis also revealed that at least two mechanisms are responsible for the lack of justice in adaptation in Delhi: a lack of capacity and the political economy of poverty. In identifying these mechanisms, we also identified leverage points for change. Efforts to develop the city's capacity further should be a priority. There is already some evidence from the involvement of the UNDP that this can be a successful endeavor. In addition, it will be important to find ways to overcome the political and economic barriers to include vulnerable communities and their needs in climate change adaptation. Such efforts will need to account for the broader development dynamics in the city and the ways that climate change adaptation planning intersects and interacts with current practices and priorities. Although this is perhaps a daunting task, there are already tools in place that could be used as starting points, such as the Bhagidari System.

This special issue examines the governance of climate change adaptation and encourages decision makers and scholars to reflect on the implications of action taken at different levels. Because cities play an increasingly important role in developing and implementing adaptation actions, it is critical that we develop a greater understanding not only of whether urban adaptation is just, but also why it is or is not. Although we know that in many cases cities have a poor track record of addressing the needs of the vulnerable, their decision to take on the relatively new policy area of climate change is an opportunity for learning. Research can contribute to this learning by uncovering the mechanisms of injustice in urban climate change adaptation, the obstacles and opportunities for greater justice in different contexts, and, more generally, the relationship between where and how climate planning occurs and the benefits that are experienced.

Future research should expand on these criteria and findings. Are some mechanisms of injustice more prevalent than others in adaptation? How and when do actors overcome barriers to just adaptation? We can also move beyond descriptive explorations of the mechanisms of injustice to examine how, when, and why these mechanisms of injustice are likely to be at play in adaptation. In addition, adaptation planning requires dealing with greater levels of uncertainty and new types of data and information. Future climate scenarios and their impacts are uncertain, particularly at the city scale (Satterthwaite et al. 2007). To what extent does this uncertainty inhibit justice in adaptation planning? The institutional context in which urban climate change adaptation takes place may also help to determine the extent to which the various mechanisms of injustice influence decision making. One unique feature of urban climate change planning is that it is inherently multilevel (Betsill and Bulkeley 2006, Ebi and Semenza 2008, Corfee-Morlot et al. 2009). As a result, the relative authority of municipal, state, and national governments over key planning resources may help determine the extent to which the mechanisms of injustice are able to influence outcomes.

One important requirement for furthering our understanding of justice in urban climate change adaptation is improving our understanding of who the vulnerable and vulnerable groups are in a city, their sources of vulnerability, and the barriers they face to building greater levels of capacity. As my analysis and the Delhi case shows, justice in urban climate change adaptation is fundamentally tied to broader issues of accessibility and participation. Existing research on urban injustice, the right to the city, and urban informality, although not explicitly addressing issues of climate change adaptation, therefore has much to contribute to this understanding. Future investments in climate change policy and planning should focus on leveraging and further developing this type of knowledge in a transparent and inclusive way.

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Social Justice and Adaptation in the UK

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ABSTRACT

Adaptation strategies and policies are normally based on climate impact assessments that fail to take account of the social nature and distribution of vulnerability to climate change. This is largely a product of the dominant assessment techniques that are used to inform such strategies and the limits of existing evidence. In this paper I contribute to filling gaps in the current adaptation literature by exploring the social nature of vulnerability and the potential for socially just adaptation. It does so by reviewing studies from the UK, in particular those under the Joseph Rowntree Foundation's Climate Change and Social Justice programme. It finds that vulnerability to high temperatures and fluvial and coastal flooding, in terms of sensitivity, exposure, and the capacity to anticipate, respond, and recover, is concentrated in certain disadvantaged and socially marginalized groups, including those on low incomes. It also finds that both autonomous and planned adaptation may fail to protect the most vulnerable individuals and groups, and may even reinforce existing patterns of vulnerability in some cases, i.e., mal-adaptation, especially where they rely on unmediated market forces or where they fail to explicitly recognize aspects of social vulnerability in their design and implementation. I argue that social justice should be an explicit objective of adaptation strategy.

Keywords: adaptation; social justice; vulnerability

INTRODUCTION

In recent years research and policy have begun to focus on the need to adapt to inevitable climate change. This requires decision makers at a range of scales, global to local, sectoral, etc., to assess the likely impacts of climate change to identify priorities for adaptation (Brown et al. 2011). To date, few adaptation assessments have considered the uneven distribution of climate impacts and vulnerability across groups and individuals within society. This is partly a result of the tools and methods that are used to inform adaptation policy. Another reason is that the task of assessing individuals' and groups' vulnerability to future change is highly complex, given large uncertainties about the direction and pace of future socioeconomic and climatic trends and events. This makes it difficult to say with certainty which groups or individuals are most vulnerable. Here, vulnerability to climate change, climate variability, and extreme events are defined as a function of exposure to climate impacts, sensitivity to those impacts, and the adaptive capacity of the people or systems impacted (following Blaikie et al. 1994, IPCC 2007).

In this paper I take as a premise that society should and does care about social justice as a core value[1]. I also take the perspective that when assessing the impacts of climate change, the focus should be on who suffers, how much, when and how, and that adaptation should aim to be equitable as well as effective, efficient, and legitimate (after Adger et al. 2005). Adaptation should therefore strive to be socially just and to protect those who are most vulnerable to climate impacts.

Adaptation research and methods

Adaptation outcomes will only be as good as the methods and evidence used to inform adaptation decisions. Adaptation decision support methods include climate science, risk assessment, economic analyses, and vulnerability assessment.

Climate science

Decision makers take adaptation seriously because of the messages provided by climate science. Various general circulation models are used to project scenarios of future climate, which can be downscaled to model local-level impacts, e.g., precipitation, run-off, flooding, etc. Information of this type can be used to assess the likelihood and severity of future changes in climate and thereby identify priorities for adaptation. Methodologies based on this kind of top-down approach can loosely be termed "impacts-based" (see Brown et al. 2011).

Impacts-based approaches tend to focus on physical and natural systems rather than social systems. This is because the drivers and mechanics of these systems are better known and already modeled to some extent in most cases. Models of the impacts of climate change on hydrology, including flooding, and coastal change are therefore fairly common (HR Wallingford 2012); new models of physical systems, e.g., urban heat islands, are emerging (e.g., Hoffmann et al. 2012).

Social systems are highly complex and are rarely modeled as such. Human actors respond to a range of stimuli in often irrational and highly context-specific ways, which makes it difficult to simulate human decisions at the societal scale in models (Goldspink 2000). For example, it is more difficult to model how an individual will respond to a flood than it is to model how a river system will respond to heavy rain. The result is that science-led, impacts-based approaches fail to represent the social nature of climate impacts.

Risk assessment

Climate science and impacts model results can be used in a variety of ways to support actual decisions. One of the most commonly advocated methods to support adaptation is to follow a risk management framework (Willows and Connell 2003, Jones and Preston 2011). Risk management is particularly appropriate because of the pervasive uncertainty involved with adaptation decisions.

One way to undertake a climate risk assessment is to identify a long list of potential impacts and then to scientifically assess their likelihood and magnitude to identify a level of risk (Brown et al. 2011). This sort of risk assessment can be seen as a continuation of an impacts-based approach to adaptation decision making. It implies that there is a value-neutral or scientific measurement of risk.

An alternative approach is objective-based risk identification (Institute of Risk Management 2002). This involves the assessment of a number of possible "risk drivers" on the cost or potential for achieving an explicit set of objectives. This sort of approach is more common in project or corporate risk assessment. It is equally applicable to policy-based organizations or governments, however. It requires decision makers to be explicit about their objectives, which often involves making normative choices of about what is most important, or what should be achieved. The civil servants and advisors who often undertake climate risk assessments aim to appear neutral in terms of future policy choices and are therefore often reluctant to specify strategic objectives. It is sometimes considered safer not to state normative preferences and base adaptation decision making on some value-free, scientific (impacts-based) approach.

However, Bradbury (1989) argues that risk management is better when it is based on openly subjective preferences about what is important to society. If policy makers can be explicit about their objective to, for example, improve the quality of life for all citizens, or to reduce social inequalities, then objective-based risk assessments hold significant potential for capturing the social nature of climate impacts, risks, and vulnerability.

Economic analyses

Adaptation decisions can also be supported by economic analyses, including social or project cost benefit analysis (CBA) and, at the global scale, integrated assessment modeling (IAM). The objective of these tools is to identify efficient or optimal policy choices, not to consider equity as a priority criterion.

Information on the costs of climate impacts and the benefits of adaptation are limited for most impacts and in most sectors (Watkiss 2011). However, investment decisions need to be informed by analysis of available options and in some instances, where investment costs and the value of avoided damages can be relatively well understood, e.g., for physical flood defences, CBA is an important and effective decision support tool. Social CBA seeks to maximize welfare from a utilitarian perspective, meaning that there might be winners and losers from an investment, but it will remain attractive as long as the winners are able to compensate the losers and still be better off. However, the distribution of the costs and (dis)benefits from social CBA for adaptation rarely receive much attention, and some argue that the treatment of time preference in CBA via discount rates also raises questions of intergenerational justice (e.g., Ackerman 2009). Similarly, the use of IAMs to inform decisions on adaptation policy design fails to shed light on social inequality or justice issues and may overestimate society's ability to adapt because of the crude representation of adaptation decisions in such models (see Patt et al. 2009, Stanton et al. 2009). Economic analyses, although important in many respects, therefore fail to adequately account for the distribution of climate impacts across society.

The use of impacts-based approaches can be generally characterized as "top-down" (Dessai and Hulme 2004). Top-down approaches, because they are based on climate scenarios, focus on exposure to harm and tend to see vulnerability as an "end-point" (Kelly and Adger 2000) or an "outcome" (O'Brien et al. 2007) and therefore static, as opposed to part of a social process. Top-down approaches, including relatively high-resolution maps or indicators, can also imply that vulnerability is heterogeneous across groups or places, which may be inaccurate and stigmatize certain people or places as being "high risk" (Benzie et al. 2011). An advantage of top-down assessments, however, is that they can generally be carried out for a large geographical area, for example across a country, or indeed globally.

Vulnerability assessment

Bottom-up approaches, also known as vulnerability-based assessments, on the other hand, tend to focus on the impacts of current climate variability and the underlying causes and processes that cause some people to be more vulnerable than others to those impacts (an example is Brown and Walker 2008). In this way, they place a greater emphasis on adaptive capacity rather than exposure in assessing vulnerability and try to avoid seeing vulnerability as an inevitable effect of certain socioeconomic characteristics (Spiers 2000). Bottom-up approaches are more likely to incorporate people's own perception of vulnerability and attitudes toward risk, which

may ultimately be more important than exposure in determining who adapts and who suffers during climate events. A disadvantage of bottom-up assessments is that they are resource-intensive and generally only apply to specific local areas. A number of qualitative, mostly bottom-up, studies on the social nature of vulnerability to climate change are referred to below.

The UK Climate Change Risk Assessment

The UK has generally been considered a forerunner in adaptation. For example, it has initiated various state-of-the-art processes and projects in relation to climate science, including the production of UK Climate Projections User Interface (http://ukclimateprojections.metoffice.gov.uk/) and the establishment of the UK Climate Impacts Programme in 1997 to support stakeholders and decision makers in using climate science to achieve adaptation. In 2008 the UK parliament passed the Climate Change Act, which, among other things, created a duty to conduct a Climate Change Risk Assessment (CCRA) every five years. The first CCRA was laid before Parliament in January 2012, with an accompanying report on the economics of climate resilience (ECR) completed in 2013. The reports will play an important role in influencing the UK National Adaptation Programme 2013 and its implementation.

The CCRA includes features of both a top-down, impacts-based assessment and an objective-based one. It takes as its starting point a list of over 700 impacts, identified after considering climate projections, reviewing existing evidence, and consulting with stakeholders. This long list of impacts was reduced to around 100 key risks, using a methodology that considered the magnitude of the impact and the level of confidence associated with the evidence (HR Wallingford 2010). The CCRA aims to identify all climate risks to the UK, but also considers risks in light of key government objectives, not least as the result of risk identification processes that consider Departmental Adaptation Plans, which themselves look at key departmental policies when identifying climate risks (HR Wallingford 2010).

The CCRA is based on a series of 12 sectoral assessments, each of which is led by a separate sector expert and team. The sectors covered by the CCRA include: agriculture, biodiversity and ecosystem services, built environment, business, industry and services, energy, floods and coastal erosion, forestry, health, marine and fisheries, transport, and water. This has implications for the way in which social issues are captured – or missed – in the assessment. Many if not all of these 12 sectors can be relevant to social justice and inequality in some way; built environment, floods and coastal erosion, health, and water are perhaps most relevant. However, by taking a sector approach, there is a danger that impacts are considered in terms of their effect on the functioning of the sectoral system and not on the lives of people affected by that system, e.g., focus on the number of people suffering from heat stress, rather than which people in society are likely to suffer harm as a result of heat stress.

Another key feature of the CCRA, and the ECR report, is that they are both based on existing evidence. The majority of climate change research, particularly quantitative analyses, has taken place within the fields of physical and natural science. CCRA and ECR results are therefore likely to be skewed by the available evidence (Prof. Martin Parry, CCRA Synthesis Report Peer Review, unpublished manuscript) and may underestimate the social nature of vulnerability and risk.

As well as underestimating the social nature of risk, the scope of the CCRA was limited to impacts within the UK, although as recent evidence suggests, indirect impacts on the UK resulting from climate change elsewhere in the world may be as significant, if not more so, than direct impacts at home (Foresight 2011). In particular, of the indirect impacts identified in the Foresight report, health, security and migration impacts may affect some groups in society more than others.

The CCRA is the first national assessment of its kind and embodies the proactive approach to adaptation policy being taken in the UK. However, for various methodological reasons, not least the reliance on existing evidence, the first iteration of the CCRA may undervalue the social nature of climate impacts, risks, and vulnerability. The resulting policies may thus also fail to protect the most vulnerable members of UK society.

Social justice and climate change

Recognizing this possibility, the Joseph Rowntree Foundation (JRF), a social policy research and development charity in the UK, initiated a research program on Climate Change and Social Justice (http://www.jrf.org.uk/work/workarea/climate-change-and-social-justice). The JRF program has funded various projects to improve the evidence base on the links between social justice and climate change mitigation and adaptation. I briefly review the results of a selection of projects from the first phase of that program. Three of the key research questions posed by these projects are: Who emits the most? Who is most vulnerable to climate impacts? Does adaptation protect the most vulnerable?

Who emits the most?

There is a strong correlation between household income and household emissions. A quantitative study by Fahmy et al. (2011) explored the nature of this link by compiling a new dataset that combines information on household income, consumption of household fuels, private road travel, public transport use, and domestic and international aviation. The report provides new insights into who is responsible for emitting how much carbon dioxide and identifies the relative contributions of different aspects of consumption to household carbon emissions (Fahmy et al. 2011). The relationship between emissions and income is clear. Higher income households

generally emit more; lower income groups emit the least[2]. This observation may imply a level of injustice, if it is the case that lower emitting groups are also more vulnerable to the climate impacts caused by greenhouse gas emissions. Fahmy et al. go on to use the database of household emissions to analyze the social impacts of mitigation policies, which in some cases have important negative implications for social justice (see also Speck 1999).

Who is most vulnerable?

Climate impacts will vary between climatic zones and local areas in the UK (HR Wallingford 2012). However, the harm, or opportunities, that will result from these changes in climate will also vary between social groups within and across different localities. Furthermore, different climate impacts will affect groups differently.

The current evidence base on the social distribution of climate impacts and vulnerability is generally poor. Studies have looked at the relationship between impacts such as heat and mortality (e.g., Basu and Samet 2002, Mirabelli and Richardson 2005, Hajat et al. 2007), sometimes with a social analysis of the results. Literature from the U.S., drawing on the rich tradition of environmental justice research in that country, has analyzed the impact of extreme weather such as heat waves from a social perspective, for example to analyze the distribution of harm, again, usually mortality, across different ethnic groups (e.g., Klinenburg 2002, O'Neill et al. 2005, Morello-Frosch et al. 2009), as well as other social effects associated with heat waves, including stress, social disruption, violence, and increased crime levels (Simister and Cooper 2005). Recently, similarly social-based analyses of heat have begun to emerge in the UK (e.g., Brown and Walker 2008, Wolf et al. 2010).

Following the environmental justice angle, in the UK, where flooding has been a more traditional impact, a small number of studies have looked explicitly at flood vulnerability and environmental inequalities (e.g., Tapsell et al. 2002, Fielding et al. 2005, Thrush et al. 2005, Walker et al. 2006) with a specific Environment Agency research programme focusing on the social aspects of flood management published in 2005 (EA 2005). This literature did not explicitly focus on flooding in the context of climate change or changes in future risk, however.

More specific research on the social processes that drive vulnerability is not yet widespread. A Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) report in 2009 gave an overview of many of the social issues that are relevant to climate change and identified gaps in research (CAG Consultants 2009). The JRF Climate Change and Social Justice program represents the first effort since this SNIFFER report to strategically improve the evidence base and communicate issues directly to policy makers and wider stakeholders.

Below, three recent studies from the JRF program are reviewed, each looking at different but overlapping aspects of social vulnerability to climate change, namely: Zsamboky et al. (2011) on the impacts of climate change on disadvantaged coastal communities, Benzie et al. (2011) on vulnerability to heat waves and drought, and Lindley et al. (2011) on climate change, justice, and vulnerability. Table 1 provides an overview of the socially contextual factors that determine vulnerability to climate change, based on an interpretation by the author, drawing on these three projects. In it, I reinterpret the analysis in the original sources, which use slightly different framings to describe socially contextual factors to the ones summarized in this table.

Coastal vulnerability

Zsamboky et al. (2011) look at the impacts of climate change on disadvantaged coastal communities. They found a strong social dimension to the exposure of people to coastal flood risk, but also a number of links between deprivation and the ability of households and communities to respond to flood events and adapt to future threats.

Coastal communities in the UK tend to be characterized by high levels of youth out-migration and a corresponding in-migration and concentration of older people, as well as transient groups, including tourists, who are identified as being most sensitive to climate impacts. Coastal communities are particularly vulnerable because of their high reliance on coastal infrastructure, ecosystems, and communications, which are especially susceptible to damage and disruption from climate impacts, namely sea-level rise, storm-related damage, coastal erosion, and flooding.

A high economic reliance on seasonal employment related to tourism also heightens the sensitivity of coastal communities to extreme weather events and possibly long-term climate change, although climate change may present opportunities for tourism-related employment as well. Local health, social, and emergency services are also put under pressure during the tourism season, reducing the capacity of these services to support local populations in the event of extreme events such as heat waves or floods, and rendering tourists themselves at higher risk.

The physical isolation of some coastal communities, particularly those on islands and remote coastlines, adds to their vulnerability, as do the generally old and poor-quality housing stock and below-average income levels associated with deprived coastal communities. Zsamboky et al. (2011) highlights the risk that certain coastal towns and villages become "blighted" by the perception of high risks from coastal change and therefore suffer from falling property values, lost job opportunities, and lower investment, and possibly even less flood defence protection from central government, leading to further social deterioration and increased vulnerability.

Vulnerability to high temperatures

Benzie et al. (2011) examine the concepts of vulnerability and resilience as they are used by the climate change community and relate these to the concept of social justice. They find that there is likely to be a strong social dimension to climate change vulnerability in the UK. The report focuses on the complexity of social vulnerability to high temperatures.

Table 1. Overview of socially contextual factors that determine vulnerability to climate change.

Study	Zsamboky et al. (2011)	Benzie et al. (2011)	Lindley et al. (2011)
Impacts considered	Coastal flooding, heatwave	Heatwave, drought	Fluvial and coastal flooding, heatwave
Methods	Community-level focus groups, literature review	Literature review, stakeholder interviews	Extensive literature review
Determinants of vulnerability	Age Existing health conditions Self-perceptions of vulnerability Household resources (poverty) Livelihoods, particularly where related directly to the coast Reliance on coastal infrastructure Housing quality Geographical isolation, e.g., island communities "Blighted" neighborhoods, e.g., stigma or crash in property values related to perceived climate risks Community deprivation, including capacity of local authorities Access to affordable insurance	Exposure Housing quality Occupation Physical neighborhood characteristics including urban heat island, green spaces, etc. Geographical location, e.g., in drought zone or urban/rural Sensitivity Age Health and disability, including mental and physical health conditions Lifestyle, including drug use, outdoor activities, etc. Adaptive Capacity Education Access to information and knowledge Tenure Transience Perception Household size Household use of resources, e.g., water use Income Lifestyle flexibility, including alternative employment and leisure options Social capital and community cohesion Access to social networks Access to political power and representation Institutional jurisdiction, e.g., quality of local health services, local authorities, water companies, etc.	Personal factors Age Health Education, knowledge, and awareness Family size Gender, ethnicity Mobility Housing tenure Occupation Transience, including tourists, travelers, homeless Access to decision making Income Insurance Environment factors Physical attributes of neighborhood, including green space, urban heat island, overcrowding Building characteristics, including elevation and access to air conditioning Social factors Social networks Social characteristics of neighborhood, including isolation, fear of crime, public cool spaces, inequality, trust, unemployment, population turnover Institutional regimes, e.g., nursing homes, loss of individual autonomy Local authority resources Experience of previous extreme weather event(s) Access to social/ health services

In the UK, vulnerability to high temperatures has previously been understood as a function of health and a matter for the health service (DoH 2010). Although accurate, this physiological focus on sensitivity fails to account for the social processes and social context that determine who is able to anticipate, cope with, and adapt in order to avoid harm during heat waves.

There are spatial patterns to the distribution of vulnerability to high temperatures; for example, urban residents are more exposed (Hajat et al. 2007) and within towns and cities it is often deprived areas that are most likely to be located within the center of urban heat islands (UHIs). Deprived inner-city communities are also less likely to have close access to cool spaces such as green parks, gardens, or woodlands. Social factors are also important determinants of vulnerability, although research in this area is generally lacking.

Social cohesion at the community level, including ethnic or faith-based communities that span different urban neighborhoods, can help to identify vulnerable people and offer support during heat waves; such informal networks often replace official medical or social services, particularly where population turnover is high and trust between social groups and official services is low, as in some deprived urban neighborhoods (Brent Council 2009). In this respect, the presence of strong communities and high social capital may sometimes be higher in some deprived neighborhoods than in some higher income neighborhoods, e.g., suburban commuter districts.

Some studies indicate a link between social isolation and mortality during heat waves (e.g., Klinenberg 2002), whereas others identify stronger links between mortality and residency in care homes (e.g., Brown and Walker 2008). Welfare losses from heat, as opposed to

mortality, including discomfort, distress, morbidity, violence, and social unrest, have received much less attention in the literature, but may also be concentrated in deprived inner-city areas (Benzie et al. 2011). Studies have found links between ethnicity and vulnerability to heat (e.g., Basu and Samet 2002, Morello-Frosch et al. 2009), depending on nonphysiological factors such as employment (Mirabelli and Richardson 2005), education, and levels of air conditioning (O'Neill et al. 2005).

Many studies find a link between age and vulnerability to high temperatures (e.g., Fouillet et al. 2006), but it is also important to note the role of risk perception among all groups (Grothman and Patt 2005). Various studies show that people who do not perceive themselves to be at risk are less likely to take measures to prevent the effects of heat stress, even when they are in fact at high risk (Abrahamson et al. 2009, Wolf et al. 2010). One study looked at the links between employment and climate change vulnerability, uncovering an additional social layer of vulnerability whereby people's occupation exposes them to a greater level of climate risk, for example lower-paid, unskilled jobs, e.g., outdoor manual laborers, train drivers, or factory workers, are higher risk than higher paid, high-skill jobs, e.g., those in air-conditioned offices (TUC 2009). One key finding of this literature is that vulnerability to climate events is highly dependent on local context, and that a better account of individuals' and groups' adaptive capacity is needed to understand the social nature of vulnerability in each case (e.g., Brown and Walker 2008).

A socio-spatial index of vulnerability

Lindley et al. (2011) identify the determinants of vulnerability to heat waves and floods and use these to develop a spatially explicit index of vulnerability that accounts for the social nature of sensitivity, exposure, and adaptive capacity. The results constitute the first quantitative representation of the potential for future losses in well-being that take explicit account of the social nature of vulnerability. In total 8% of English neighborhoods are estimated to have extremely high flood-related social vulnerability, with a strong concentration of vulnerability in deprived urban and coastal areas (38% of the areas are within 2 km of the coast). These areas are represented as having low capacities to prepare, respond, and recover from flood events, according to the index. The specific variables that influence the distribution of social flood vulnerability include: lack of gardens and green space, which help to regulate run-off flows; a proxy measure of insurance availability, based on current flood probabilities; low income; poor knowledge; and low mobility.

Lindley et al. (2011) also produced a similar index for social vulnerability to heat. A similar proportion of neighborhoods are estimated to have extremely high social vulnerability to heat as to flooding: 9% in this case. Again, there is a strong urban dimension to the results, particularly in London, which has three times the mean level of heat vulnerability compared with other regions and 40% of all of the extremely vulnerable neighborhoods in England. Interesting detail emerges in the disaggregated results, which show, for example, a low capacity to respond to high temperature events in remote rural areas that are isolated from medical services, even though exposure is not particularly high in rural areas. There is also a strong coastal component, which is influenced by the adaptive capacity indicators rather than the signal of increased exposure from higher temperatures, underlying the dominantly social nature of vulnerability to climate change.

Taken together, the two aggregate indices of social vulnerability show the significant overlap between vulnerable neighborhoods to multiple climate impacts; fully 64% of the extremely socially vulnerable neighborhoods to flooding are also classified as extremely vulnerable to heat. This has significant implications for the design of adaptation strategies: If the same social groups tend to be vulnerable to multiple climate impacts, then a key element of adaptation strategy should be to protect and build resilience among, and to consult with, these most vulnerable groups.

Does adaptation protect the most vulnerable?

Adaptation implementation is in its early phases in the UK. Despite a growing body of research and an improved level of awareness among decision makers of the need to adapt, specific adaptation actions are few and difficult to identify (ASC 2011). Nevertheless, the JRF program has undertaken some case studies to assess emerging lessons on whether adaptation offers protection to the most vulnerable.

Planned vs. autonomous adaptation

Adaptation can either be planned, usually by a national or local government, or autonomous, i.e., undertaken by private actors in response to their own calculation of costs and benefits (Smit and Pilifosova 2001). Planned adaptation should be carefully considered; the scope for considering social justice issues should be high. Autonomous adaptation may occur within narrower contexts, and the potential for maladaptation may be higher. Maladaptation is generally understood as those actions taken ostensibly to avoid or reduce vulnerability to climate change that impact adversely on, or even increase the vulnerability of, other systems, sectors, or social groups (Barnett and O'Neill 2010).

Improving water efficiency in response to drought risk

The southwest of England is projected to become much drier as a result of climate change, particularly in the summer, with the upper end of climate projections (at the 10% probability level) for summer precipitation showing reductions of up to 50-70% under a high

emissions scenario (UK Climate Projections 2009). This region also happens to have the fastest-growing population in the UK (ONS 2003) with the number of households projected to increase by 36% by 2030 (DCLG 2009). The southwest is also one of the most popular tourism destinations in England, with over 21 million visits per year, a figure that is also projected to rise because of changing patterns in the tourism industry and also because of climate change impacts elsewhere in Europe (EEA 2008). Improving water efficiency is therefore a priority for South West Water, the utility company that manages and delivers water services in the region.

However, water affordability is already a serious issue in the southwest, where prices are around 40% higher than in other regions of the UK, because of a mixture of legacy, infrastructure, and tourism factors. Delivering affordable water efficiency is therefore the additional challenge.

Benzie et al. (2011) examined a pilot project by South West Water to introduce a Rising Block Tariff for water customers. In theory, this tariff structure incentivizes water efficiency while delivering affordable water to all. It offers three differently priced "blocks" of water use: Block 1: "essential use" at 73% of the standard unit price; Block 2: standard price (a buffer); Block 3: "premium use" at 181% of the standard unit price.

The theory is that users who reduce their use are rewarded with cheaper water, and those who chose to use more pay a premium for doing so. The system relies on there being a free and equal choice between households on how much water they use. However, Benzie et al. (2011) show that water use requirements differ between households; some are less able to reduce their water use, as a result of household size, certain medical requirements, or even as a result of tenure and inflexibility to fit water-saving devices or inability to purchase water-efficient technologies, e.g., new washing machines. Such households, if on low incomes, may be unfairly penalized by the introduction of a Rising Block Tariff system, raising the prospect that water efficiency schemes could push more households into a situation of "water poverty," defined as spending more than 3% of disposable income on water bills (Fitch and Price 2002).

The case study also revealed the role of support schemes that protect low-income households from water poverty where metering and new tariff structures are in place. In the southwest, the WaterSure scheme caps bills for qualifying households, i.e., those on low incomes or with defined medical requirements, and the WaterCare scheme aims to improve water efficiency and provide support to households in debt with water companies. Thus, efficiency incentive schemes, including water metering and new tariff structures, are not inherently regressive and do provide the potential to address climate risks, i.e., drought, in socially just ways, provided that they are always implemented in tandem with support schemes for vulnerable households.

Benzie et al. (2011) and the independent Walker Review of affordability and water charging (Walker 2009) identify various features of the water sector that are important for maintaining affordability and make various recommendations to ensure that water poverty is avoided as a consequence of maladaptation to climate change. In this case, autonomous adaptation, i.e., using pricing mechanisms to address resource scarcity and reduce risks, only avoids being unjust because consumer rights are well represented in the heavily regulated water sector.

Future flood insurance

Flood insurance in the UK is currently governed by an agreement between the state and the insurance sector, known, in its most recent incarnation, as the "Statement of Principles." In short, the state commits to provide flood defences and prevent development in very high-risk areas, in return for a commitment from insurers to provide insurance cover to all households and most small businesses (see Crichton 2002). This agreement is due to expire in 2013, stimulating a lively debate between insurers, the government, and various stakeholders on what should replace it. The JRF recently published a "viewpoint" report that addresses the social justice aspects of this debate (O'Neill and O'Neill 2012).

One in six homes in England is currently at risk from flooding (EA 2009), and low-income households are the likeliest to be uninsured and the least able to recover from the financial impacts of flooding (Pitt 2008). Flood risk is increasing in the UK as a result of increased development, i.e., more and higher value homes, and climate change, including changing precipitation patterns and sea level rise. Looking into the future, there is a tension between creating disincentives to live and develop in flood zones and penalizing people who already live there. If the insurance market were left to adapt autonomously by simply pricing the actual risk for each household, insurance rates would drive demand for housing in low-risk zones, and therefore raise property values, while high-risk areas would become cheap, attracting low-income households, blighted and potentially uninsured or uninsurable, creating significant inequalities and social injustice (O'Neill and O'Neill 2012).

Alternative, nonmarket, insurance models exist and are common in other European countries, where the state often plays a larger role. O'Neill and O'Neill (2012) explain how different concepts of fairness imply different insurance models and argue strongly for a more solidaristic flood insurance regime in the UK. The case of flood insurance, as an example of autonomous adaptation where risk is priced, shows the inability of some forms of adaptation to protect the most vulnerable and a much more worrying possibility that maladaptation may significantly increase the vulnerability of some groups to climate change.

The Heatwave Plan

Temperatures in the south of England are projected to increase significantly over coming decades, with extreme heat wave events in particular likely to cause significant harm and economic damage (Stott et al. 2004, Metroeconomica 2006). Demographic trends in parts of England, particularly the southwest, are likely to increase the population's vulnerability to high temperatures, largely as a result of increases in the number of older people, the proportion of whom is projected to rise from 22.5%, already above average, to 29% by 2031, and increased numbers of tourists.

The only current strategy for explicitly managing risks relating to high temperatures in the UK is the Heatwave Plan for England and Wales, led by the Department of Health. The existence of the strategy is in part a reaction to the unforeseen impacts of the 2003 heat wave in Europe, which led to the premature deaths of around 2000 people in the UK (Metroeconomica 2006) in addition to 30,000 deaths and billions of Euros' worth of damage across mainland Europe (De Bono et al. 2004).

The Heatwave Plan relies on various tiers of governance to "cascade" down responsibilities during heat wave events. Different levels of alert are defined within the plan and are triggered once weather forecasts exceed certain thresholds (see DoH 2010, 2011 for details).

Benzie et al. (2011) interviewed various "responsible authorities" under the Heatwave Plan and other relevant stakeholders to examine their understanding of "vulnerability to high temperatures" and to see how the concept of vulnerability was operationalized in practice. Unsurprisingly, given the complexity and lack of an evidence base identifying vulnerable people, there is some confusion and an oversimplification of vulnerability in practice, which tends to revert to health-based definitions of vulnerability. This tends to ignore the social processes that determine vulnerability and therefore misses opportunities to build resilience to high temperatures, rather than merely to respond during emergency situations. In many cases it is unlikely that the most vulnerable people will receive support during heat wave events, largely because health services are not able to identify who is most vulnerable.

The case study found that resources for implementing the Heat wave Plan were severely limited, and responsibility to implement the plan fell mostly on emergency planning departments within local government and health care professionals. This precludes the potentially crucial role of local stakeholders who benefit from a more detailed understanding of vulnerability and climate change, including social services, climate change partnerships, researchers, and, in particular, community groups.

The role of stakeholders with the ability to help build resilience to high temperatures, for example spatial planners and educators, is not yet a feature of Heatwave Plan implementation, according to Benzie et al. (2011). However, a key recommendation in the report is to go beyond the Heatwave Plan, which is understandably focused mostly on health and emergency response, given its remit, and to take a much more proactive and integrated approach to build resilience to high temperatures in the UK in ways that explicitly promote social justice and equity.

Quadruple injustice

These cases highlight the social nature of vulnerability and the uneven distribution of vulnerability to climate change. They also highlight the potential for maladaptation to increase certain groups' vulnerability, especially autonomous maladaptation, and the uneven and uncertain benefits that adaptation might bring to certain social groups in the UK.

In conclusion, it is possible to identify a "quadruple injustice" to climate change within the UK. Certain disadvantaged groups, including those on low incomes, the socially marginalized, and older people: emit the least; may be negatively impacted by mitigation policies; are most vulnerable to climate impacts; and, may be negatively impacted by adaptation policies. However, these groups are diverse and there is not always a uniform correlation between social disadvantage and emissions or vulnerability. Sometimes the reverse is true and there will be various exceptions. Identifying the quadruple injustice is not intended to imply a determinist view of vulnerability to climate change. Instead it aims to highlight the social nature of climate change causes and consequences, with a view to influencing policy responses.

This presents a particular set of challenges to adaptation decision makers. First, it raises questions of procedural justice. How can the voices of the most vulnerable be heard in the design and implementation of adaptation policies? It has been shown that the implementation of the Heatwave Plan in England and Wales has so far failed to involve vulnerable groups, or organizations that represent vulnerable groups, in the process of identifying who is vulnerable or in delivering emergency response services during heat wave events. However, the involvement of the Consumer Council for Water in the Rising Block Tariff trial in the southwest of England is evidence of a more participatory decision-making process, which also happens to result in a more just outcome (Benzie et al. 2011). Given the complexities involved in adaptation policy design, including the treatment of complex and uncertain science and the normative choices relating to risks that characterize adaptation, it is both difficult and yet essential that vulnerable groups be brought into adaptation decision making.

Second, questions of substantive justice have been raised, particularly with respect to autonomous adaptation and, most of all, where unmediated market forces are employed to deliver efficient adaptation outcomes, whether these are in the pricing of risk (via free

market insurance models) or via scarcity and price signals (via water metering).

Third, there is the potential for adaptation to enhance social justice, although this has not been the focus of this paper. Adaptation measures, for example the creation of sustainable urban landscapes that offer free, cool public spaces and reduce flood risks, could improve the quality of life for residents and facilitate more cohesive community living spaces.

DISCUSSION

Methods

This paper began with a brief review of methodologies used to inform adaptation decision making. This analysis has implications for the governance of adaptation. On one level, over-reliance on top-down assessment techniques may tend to hide the social nature of vulnerability and lead to adaptation strategies that fail to protect the most vulnerable. This would be the consequence of focusing on the size of a risk, or its aggregate costs, rather than on the social nature of the risk: who will suffer harm as a result of that risk.

As has been seen from the case studies, vulnerability to multiple climate impacts tends to overlap for certain social groups, namely those with low adaptive capacity, who now tend to be marginalized and disadvantaged in society. The implications of this for adaptation governance are that more bottom-up analyses should be used to inform adaptation policy, incorporating procedural elements, such as more consultation with vulnerable groups, as well as methodological elements that base climate risk assessment more on current climate vulnerability and that focus more on identifying cross-cutting issues from different sectors.

The UK Climate Change Risk Assessment provides an interesting case. Although initially designed as an impacts-based risk assessment, the CCRA methodology was modified to better account for the social aspects of risks, perhaps partly in response to the evidence generated and put forward by the Joseph Rowntree Foundation. The CCRA methodology now includes a stage (step 5) to explicitly consider equity issues and social vulnerability. Within this stage, broad clusters of risks have been assessed using a Social Vulnerability Checklist (HR Wallingford 2010). An evidence review report on social vulnerability to climate change impacts (Collingwood Environmental Planning, unpublished manuscript) was also prepared as part of the CCRA process to inform decision makers, though this has not yet been made public. Step 7 of the CCRA methodology, which develops risk metrics for each risk, also provides the opportunity to develop social metrics that can be used to measure changes in risks relevant to social justice, e.g., changes in the number of deprived households at risk from flooding (see HR Wallingford 2010).

In these ways, the social nature of vulnerability is recognized in the CCRA, and attempts have been made to update the methodology to better account for social vulnerability. Top-down assessments can therefore be carried out in ways that do draw attention to the social nature of vulnerability and risk, although current evidence gaps make this difficult in practice.

Governance

The quadruple injustice of climate change challenges adaptation governance to become more just and to deliver more just outcomes. I introduce the concept of a new policy concept to transfer funds between high emitters and the vulnerable, based on the logic of the quadruple injustice.

Public attitudes to fairness represent a barrier but also an opportunity for designing new, socially accepted climate change policies. Another report from the JRF Climate Change and Social Justice programme (Horton and Doran 2011) used focus groups to look at people's sense of fairness in relation to behaviors and rules governing climate change. For example, they looked at collective antipathy toward "freeriding" behavior and public support for rules to prevent excessive consumption, specifically in situations of resource scarcity, such as climate change[3]). The report concludes that climate change regulations do not need to appeal solely to self-interest and to cost-saving opportunities, as many regulations and policy initiatives currently attempt to. Instead, regulations may be more successful if they appeal to people's sense of fairness, based on the link between excessive consumption, i.e., emissions, and climate change (Horton and Doran 2011). Although the focus groups did not explicitly ask people about their sense of fairness in relation to adaptation, the results present an interesting question: could people's sense of fairness be harnessed to address the quadruple injustice of climate change by transferring resources from high emitters to the most vulnerable?

The logic behind this question is that a scientifically robust causal link can be established between excessive consumption, e.g., driving a high-emitting SUV or frequent flying, physical climate change, and impacts on vulnerable people, e.g., flooding a family living on low income. Although it is unlikely that an acceptable scheme could be designed for direct payments between emitters and vulnerable groups, there may be public support for policies that use revenues from taxes on high-emitting behavior to compensate or protect vulnerable groups, or preferably to invest in building resilience among vulnerable people. This, after all, is the logic applied to global negotiations on climate change, in which developed countries have agreed to provide significant financing to help the most vulnerable countries adapt, via mechanisms such as the Green Climate Fund and the Adaptation Fund, in recognition of their historical emissions and greater financial capacity[4]. Public awareness of climate change, vulnerability, and adaptation would need to improve significantly

before the fairness aspects of such a policy could be widely understood and accepted, but perhaps in future, similar mechanisms could be applied within countries to fund investment in socially just adaptation.

CONCLUSION

In this paper I have reviewed the first wave of projects in the UK that address the social nature of vulnerability to climate change. At the time of their instigation, these projects were addressing relatively new territory in terms of adaptation research in European countries. The findings therefore represent a tentative and initial exploration of the nature of vulnerability. Further examination of the issues raised, including additional case studies from other countries and ex-post analyses of the impact of climate-related events on different social groups will be helpful. In particular, more insights are needed on the scope for adaptation interventions to reduce, or indeed to exacerbate and reinforce, patterns of social vulnerability.

Although equity and justice are well-established concepts in global climate change governance (Paavola and Adger 2002), they have traditionally received much less attention at the national and subnational levels (Thomas and Twyman 2005). However, the results highlighted by this paper are broadly supported by emerging examples from other places, especially in the U.S., for example, the state of California (Cooley et al. 2012), and the cities of Phoenix and Philadelphia (Uejio et al. 2011) and New York (see Bardy 2010), where the tradition of environmental justice research and activism has evolved to consider the explicit social nature of vulnerability to climate.

The existence of a strong social dynamic in climate vulnerability raises issues for the governance of adaptation. The social distribution of vulnerability should influence the way in which policy makers interpret and use climate vulnerability indicators. There is a significant and growing interest in such indicators as a tool to support adaptation decision making, for example by identifying hotspots of vulnerability at the local level and to inform climate risk assessment and adaptation planning (Füssel 2009, EEA 2012).

The complex nature of social vulnerability raises two issues. First, the socio-spatial detail of indicators should be improved to better reflect layers of social vulnerability. Second, top-down assessments, such as indicator based assessments, should be complemented by bottom-up assessments with input from a variety of stakeholders, including those that are well placed to identify vulnerable groups and individuals, such as community groups and social services. Responding to these issues requires improved socioeconomic data for inclusion in vulnerability indicators and an open-minded approach to adaptation governance, in terms of who is involved in defining and assessing vulnerability, climate risk, and in the design and implementation of adaptation strategies and policies.

At least in the European context, social justice has so far not been a key organizing principal or an explicit objective of national or local adaptation, despite the progress that many European countries have made in adaptation planning. Given the explicitly social nature of vulnerability to climate change, as explored above, a clearer focus on justice is warranted. Adaptation strategies should not be afraid to state their normative objectives. Achieving social justice and building the resilience of the most vulnerable individuals and groups in society should be one of the core objectives of adaptation.

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SECTION VI:
CONCLUSIONS

Summary of all material in the volume
Suggestions for further reading
Sample final project

Conclusions

In this volume, we have covered the basics of climate change science and related threats; the theoretical underpinnings of modern resilience thinking; various frameworks and methods for identifying and evaluating resilience; practical applications of these concepts; and opportunities for future transformation. By now, you should recognize that resilience is a challenging concept, open to a variety of interpretations and applications. However, you will also hopefully have developed your own ideas around this concept, including advantages, shortcomings, and future possibilities. If you are an aspiring planner or practitioner, perhaps you have begun to consider how you might approach resilience in your career: institutional limitations or attitudes you might face, and ways that you could push those boundaries. If you are a researcher or scholar, perhaps you have come to see some of the nuanced facets that comprise this complex concept. In any case, there is much more to be learned about resilience should you wish to explore it further.

Suggestions for further reading

Refer back to the READINGS INCLUDED and ALTERNATIVE SELECTIONS lists in all previous sections for articles and book chapters that were not assigned for your course.

Books:

Biggs, R., Schlüter, M., & Schoon, M. L. (Eds.). (2015). Principles for building resilience: Sustaining ecosystem services in social-ecological systems. Cambridge: Cambridge University Press.

Walker, B. H., & Salt, D. (2006). Resilience thinking: Sustaining ecosystems and people in a changing world. Washington, DC: Island Press.

Wallace-Wells, D. (2019). The uninhabitable earth: Life after warming (First edition). New York: Tim Duggan Books.

Pelling, M. (2011). Adaptation to climate change: From resilience to transformation. London ; New York: Routledge.

Zolnikov, T. R. (2019). Global adaptation and resilience to climate change. Cham, Switzerland: Palgrave.

STUDENT EXERCISES

(1) Based on your current understanding of the concept, define "resilience." You may use diagrams, words, or sentences to describe your understanding.

(2) Look back at your response to EXERCISE 1.1. How has your understanding of resilience changed (or not) after completing this course?

(3) What questions or curiosities do you still have about this topic? What have we missed?

FOR INSTRUCTORS: SAMPLE FINAL PROJECT

This project will allow students to apply the ideas they have developed during the course to a real-world problem context, similar to what they may encounter as practicing planners. Furthermore, in PART 2, they are encouraged to go beyond their comfort zones, and think about solutions that are creative and transformative:

INSTRUCTIONS:
Choose a specific site that does not have a climate adaptation or resilience plan - rather than a whole city, you may select something at a smaller scale (e.g., neighborhood; reservation; rural town; beach community). Identify climate-related threats and likely indicators of resilience (e.g., economy; housing; health; culture; ecosystem services) for this location.

PART 1: CONVENTIONAL PLAN
Working within realistic parameters of how our society understands resilience, responds to climate threats, and operates within a neoliberal, bureaucratic system, craft a plan to address the issues you have identified. This plan should be feasible given current political, economic, social, institutional constraints. You may refer to existing plans for guidance on style and structure.
[up to 15 pages including maps, models, and other visuals]

PART 2: IMAGINATIVE PLAN
Now, assume that those parameters are flexible, and that transformative action is possible. Use your imagination and expand upon your initial plan to push those boundaries. This imaginative component should serve as a supplement to your original plan. Without political or financial constraints, what could a truly transformative, equitable plan for this site look like? Have fun with this!
[up to 5 additional pages including maps, models, and other visuals]
Tips for supplementing your conventional plan: Revise existing sections or add new sections; Expand outreach, assessments, indicators, partnerships; Offer creative or "extreme" solutions (action items); Focus on 2-3 areas within your conventional plan that are of particular personal interest, and expand upon those

Structural Components that you may include in your plan(s):
- Vision statement - Current or future climate threats, or drivers of climate-related risk - Entities likely to be affected
- Areas of known geographic or social vulnerability - Governance structure - Potential partnerships
- Operationalizing resilience: goals, priorities, action items and/or proposed solutions
- Community engagement strategy (who & how) - Indicators of resilience and/or vulnerability
- Metrics for measuring or assessing resilience