FRAMING COMMUNITY DISASTER RESILIENCE

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Framing Community Disaster Resilience

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Resources, Capacities, Learning, and Action

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Introduction

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'Natural' disasters are not natural. This has been stated by many researchers and practitioners from as early as the eighteenth century onwards (O'Keefe et al. 1976; Blaikie et al. 1994; Kelman 2010; Paravicini and Wiesmann 2016). The key aspects influencing the extent of disastrous losses or damages depend to a large degree on power and access to resources as well as on human behaviour – individual and collective. They are strongly connected to societal norms and values and were characterised as 'social calculus' by Smith (2005). This social calculus comprises underlying causes for vulnerabilities, the capacities to prevent and to prepare ahead of hazardous events, the susceptibilities during crisis or the capability to recover in a timely way in their aftermath (Blaikie et al. 1994). During the last decade, the recognition of these facts has found its way into disaster literature. However, activities and measures aiming to reduce disaster impacts often still have natural and environmental processes as their primary focus. To complement this, efforts aiming to build social resilience are now considered relevant to reduce disaster risk and are consequently at the core of Priority 3 of the disaster risk reduction (DRR) focused Sendai Framework 2015–2030 (UNISDR 2015).

The term *resilience* has a long tradition in engineering and construction but also in art, law, literature and psychology (Alexander 2013). Although it had been introduced as an applied concept in systems ecology by Holling in 1973, it was not until the early years of the twenty-first century that the concept of resilience became a buzzword in both academic and more policy-oriented contexts. As part of these attitudinal shifts, we saw the term *vulnerability* (perhaps *the* catchword of the later years of the twentieth century), with its sometimes negative connotations, replaced by the word 'resilience', seen by many as a more solution-oriented approach. This almost ubiquitous capture is not without its critics, many of whom see its ascendant position as a depoliticisation project (Cannon and Müller-Mahn 2010). The term *resilience* is now on everyone's lips, whether in ecology or economy, in science or policy, in disaster risk reduction or climate change adaptation.

In disaster and climate adaptation research, the resilience concept has given a strong impetus to bridging theory and practice, and emphasising the importance of social and societal aspects in explanation and reduction of negative consequences. However, due to

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its continuously increasing contexts and purposes, the term has lost sharpness or precision. The number of circumstances in which resilience is used is almost proportional to the number of ways in which it is interpreted (Brand and Jax 2007). Consequently, the concept of resilience has been criticised for being fuzzy and even counterproductive by allowing dominant power structures to allocate liabilities and the burden to deal with vulnerabilities to less powerful communities (see for example Tanner et al. 2017).

This book is about *community resilience* and tackles the question of how community resilience can be described, explained, assessed and strengthened within the context of natural hazard events and processes. The book can help to (re-)focus the lens of resilience applications on the essentials required for an in-depth understanding of underlying causes of harm and pressures aggravating successful resilience building. It places particular emphasis on the significance of community-related aspects of resilience such as the sense of belonging and commitment, social networks, the sharing of perspectives and mutual actions in geographical locations. However, this, almost universally positive, reading of the 'community' concept must also be balanced by the need to avoid homogenising communities, recognising that their inherent social diversity leads inevitably to inequalities of experience and access to resources.

We very much hope that this book contributes to both a better understanding of the theoretical background of community resilience and to the awareness of the need to empower and strengthen communities in their effort to deal with natural events. Except for the chapters dealing with the theoretical concept, the contributions of this book have been achieved together with communities and are strongly based on their participation and input.

1.1 Book Content

The content of this book draws strongly on the activities and achievements of the project emBRACE – Building Resilience Amongst Communities in Europe. emBRACE was a European Commission-funded Research Project that ran from 2011 to 2015. Its consortium members are placed in six different European countries and cover various academic disciplines from medical science and psychology via social and economic geography to risk research and emergency management. The emBRACE project aimed to build resilience to disasters amongst communities in Europe. Its work was based on the awareness that for the achievement of this objective, it is vital to merge forces in research knowledge, networking and practices. emBRACE tasks therefore covered both academic aspects, such as: framework development and the identification of key dimensions of resilience across a range of disciplines and domains; the operationalisation of theoretical concepts by means of indicators; and the analysis of community characteristics, networks, behaviour and practices in specific test cases.

The most relevant findings of this work – particularly those concerning the generation of new scientific knowledge as well as experience and guidance for assessing and building community resilience in practice – are reported in this book. The applied methodology of the various contributions range from targeted data analysis of the impacts of past hazardous events and resilience indicators to agent-based modelling and social network analysis. The context for resilience analysis was provided by means of five test cases whose communities are facing impacts triggered by different hazards,

namely: river floods in Central Europe (Germany), earthquake in Turkey, landslides in South Tyrol (Italy), heatwaves in London (UK) and combined fluvial and pluvial floods in Northern England (UK).

The book is divided into three main parts. The first part covers the conceptual and theoretical background required to fully understand the complexity of community resilience to hazardous events or disasters. The second part tackles the issue of data and indicators to report on past events, assess current situations and tackle the dynamics of community resilience. The third part focuses on empirical analysis to back the resilience concept and to test the usage of indicators for describing community resilience. Within this part, the contributions reflect the experience of the pilot case work. These three main scientific parts are followed by concluding remarks which reflect upon the emBRACE project journey and the rationale for our approach.

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Section I

Conceptual and Theoretical Underpinnings to Community Disaster Resilience

The resilience concept – is it a paradigm or science, or is it just a tool to guide the design of disaster risk reduction intervention objectives and intentions? Given the term's ubiquity, it is perhaps surprising that this important distinction has not been resolved. However, its very indeterminacy is arguably a benefit for a boundary concept such as resilience which embraces many disciplinary fields, approaches and philosophies, and typifies so-called 'wicked problems'. The next section comprises four chapters which underpin the emBRACE project team's approach to community disaster resilience and discusses some of the core debates in this diverse field; the theoretical and conceptual exposition is entwined with the methodological.

The emBRACE project team set out to develop an approach which addressed some of the limitations of the dominant framing of resilience (the social ecological systems (SES) approach), including a lack (at the time) of empirical evidence, and to build a framework of sufficient sophistication to incorporate explanatory power and yet sufficiently accessible for practical application by non-academics.

Is resilience an outcome or a process? The literature abounds with descriptive/technical approaches over critical/social ones, with a concomitant absence of power analyses and the politics of resilience. The lack of engagement with critical social theory produces resilience as resistance and an equilibrium model or approach, with a static perspective. The benefit of this approach is that it does allow easier definition of quantifiable boundaries and thresholds. However, the emBRACE team was keen to find ways to capture a more dynamic, process-oriented conceptualisation to highlight reorganisation, transformation and learning.

Resilience is now recognised as a boundary term or object which brings together normally separate perspectives, people, professions and practices and creates a space for dialogue. It promises integrative power, reflecting the interdependence of social, economic and environmental systems. Furthermore, in some readings, it offers transformative potential in social systems to address some of the root causes of disaster risk.

On the other hand, it carries with it widespread charges of conceptual vagueness; this is especially the case in its transition from ecological and engineering approaches to critical social sciences. It still faces a dearth of data and appropriate indicators for

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modelling and the early absence of empirical data weakened support for its application. However, its main challenge is to make something meaningful out of its evolution from a static equilibrium concept to a heuristic for social change. How to measure something in flux which undergoes constant change and transformation?

The emBRACE team faced this challenge of dealing with the complexity inhered within the resilience concept. The sustainable livelihoods approach (SLA), while less familiar to those outside the development field and working within the European context, offers an established (although not uncontested) framework that has also been applied to the disaster context. The fundamental elements of a livelihoods approach include people-centred, multilevel, multisectoral, and locally embedded conceptions and practices. Thus, it offers a radical alternative to top-down, expert systems perspectives. At the simplest level, it presents a checklist of key components necessary to comprehend people's experience and the context in which they face, cope with or adapt to hazards, shocks, and disasters. These are variously characterised as human, social, natural, financial, and physical 'capitals' or 'assets' or, in the emBRACE case, 'resources and capacities'. The additions of 'political' and 'cultural' are later refinements that are also sometimes present. The general structure of SLA is now applied quite widely to resilience thinking but without acknowledgement of its theoretical roots.

The emBRACE approach aimed to go beyond the pervasive definition of resilience as 'bouncing back' post disaster because this suggests a limiting response mode which does little to transform people's conditions of risk or their capacity for adaptive change. This raises a question concerning how (or if) people translate experience or knowledge to action and what is the role of learning, in particular social learning which goes beyond the individual and is embedded within social networks. Social learning is not a passive absorption of information based on the contested deficit model but active in its demands for critical reflection. The emBRACE project's approach to social learning for community resilience is via co-produced and shared learning experiences through social networks to enable behavioural change. These knowledge exchange and support networks work with both informal and formal mechanisms.

Social learning is one of the strategies or mechanisms which create the potential for communities to 'bounce forwards'. This is most clearly achieved through a process of transformative learning which signals a change in the worldview or frame of reference of an individual or a group with a concomitant change in adaptive behaviour and to social structures.

The philosophy behind emBRACE was to employ the widest possible participatory approaches and not follow 'business as usual' pathways. This inevitably introduces complexity yet we regarded the underestimation of the social and overestimation of the technical/ecological within the SES approach and its lack of social transformative capacity as fundamental flaws. We aimed for a real level of transdisciplinarity, going beyond the dominance position of environmental change professionals, and based on better integration and also greater participation. It is self-organising and self-governing within communities which create the conditions for resilience – as an emergent property of the community – not something created by outsiders and external experts.

The emBRACE approach seeks to unite social and behavioural resilience research with technical and engineering dimensions through a biophysical modelling approach. It aims to do that with a nuanced understanding and explicit conceptualisation of community (although *community* is a contested term in much community resilience work, and

definitions are generally absent). Our aim is to integrate different types of knowledge (technical, traditional, and local) and generate shared understanding and co-learning. The complexity of the resilience concept and the transdisciplinarity of our interpretation demand multiple methods and a melding of theoretical and scientific concepts with practitioners' and community members' accessibility. We hope our emBRACE Resilience Framework (see Chapter 6) is a useful heuristic.

Chapter Descriptions

Chapter 2 sets out the theoretical, conceptual, methodological, and measurement challenges presented by community disaster resilience. It outlines the dissatisfaction with descriptive concepts which lack power analyses and the emBRACE team's search for a normative interpretation encompassing social transition, learning, and innovation. This includes consideration of the implications of a transition from the natural to the social sciences and the ability of the resilience concept to represent complex, dynamic processes.

Chapter 3 addresses livelihoods approaches in contemporary resilience frameworks. It examines the understanding of how communities can best mobilise resources and capacities to prepare, plan, and adapt to risks. This chapter examines the underpinnings of the SLA, drawing out key criticisms and linkages between livelihoods thinking and resilience, and discusses opportunities for resilience to progress the livelihoods agenda and vice versa.

Chapter 4 sets out what is meant by social learning in the context of European DRR and how we have interpreted and applied it in emBRACE. This analysis discounts knowledge deficit models in favour of social learning which has the potential to be socially transformative; no longer just 'bouncing back' but 'bouncing forwards'. The chapter includes references to the emBRACE empirical studies from the UK and Turkey which are presented in greater detail below.

Chapter 5 spans the social-natural-technical-policy frameworks within which the emBRACE project work can be considered and presents its philosophical position. This is characterised as a structured, multisectoral, multimethod, and multilevel approach which was piloted in the emBRACE empirical case studies.

2

Understanding Disaster Resilience

The emBRACE Approach

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2.1 Introduction

This chapter discusses literature that justifies the emBRACE approach to community resilience. It does not present a comprehensive and broad literature review on community resilience, but rather reviews literature from different disciplines associated with the concept of resilience that informed the emBRACE project. The focus is on resilience concepts in general, rather than on community resilience specifically. The chapter thus provides an overview about concepts, methods, and indicators that paved the way towards the conceptual development of the emBRACE framework on community resilience. It takes the shape of an overview discussion, highlighting studies that present conceptual frameworks, theories and heuristics of resilience, and methodology as well as indicator-based approaches for measuring resilience. The aim of this chapter is to highlight those gaps and challenges of selected resilience literature that provide grounds for the emBRACE framework of resilience. It does so by synthesising key themes across academic disciplines and shedding light on prevalent weaknesses and 'blind spots'. The text of this chapter draws from Deliverables in Work Package (WP) 1 of the emBRACE project.

2.2 Resilience: Concept

The prospects and limits of resilience as a concept in research on disaster risk reduction are discussed differently by Alexander (2013), and Keck and Sakdapolrak (2013). In his review of the etymological development of resilience, Alexander (2013) expresses concerns over attempts to develop resilience as a research paradigm or science, suggesting that the strength of the concept lies in its ability to describe objectives and intentions of disaster risk reduction. Keck and Sakdapolrak (2013) seem to be more optimistic about

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the prospects of resilience to innovate research on risk reduction. In particular, their study points to the opportunities for strengthening the social and political dimensions of resilience research, which so far have often depoliticised social structures, according to the authors. For this, the local scale, and the community in particular, emerges as the central unit of analysis, and this speaks to the relevance of the emBRACE approach.

Increasing attention is paid in resilience research to social, in contrast to merely technical or environmental, dimensions of the concept. This is reflected, for example, in critiques of socioecological resilience literature as putting too much focus on the ecological (natural hazards and risk) (Cote and Nightingale 2012), rather than the social dimensions of resilience. Based on contributions that condense the evolution of resilience research (e.g. Alexander 2013), questions arise as to what steps can be taken to further develop the resilience concept, how this is best done, and what the goals of this process are (e.g. communication to policy makers, analytical value, etc.). These questions suggest struggles within the literature on resilience to understand how exactly the resilience concept can be conceptualised to include social dimensions, and how this can be applied through methods such as agent-based modelling (Saqalli et al. 2010).

2.2.1 Resilience in the Social Domain

The conceptualisation of resilience in the social domain, on both a collective and an individual level, seemed to be a challenge emerging from a shift in focus from technical (engineering resilience) to social characteristics of resilience. Both levels are addressed through interdisciplinary research within emBRACE. Case study work on psychological dimensions of resilience in Van, Turkey (Chapter 15), for example, offers insights into sociopsychological resilience at an individual level. Reflections on conceptualising resilience in the social domain also emerge from the London case study (Chapter 14) and its focus on social networks and capital during heat events. In particular, Klinenberg (1999) demonstrates how a social reading of heatwaves that goes beyond biophysical and epidemiological aspects can contribute to more nuanced explorations of urban heat risk. Klinenberg's foundational work has indeed informed the set-up of the London case study in emBRACE (Chapter 14), which attempts to combine research on biophysical aspects of urban heat stress with behavioural and decision-making analysis. Insights into how social capital shapes individual resilience to heat stress in the UK are also offered by Wolf et al. (2010), who suggest a complex, rather than linearly positive relationship between social capital and resilience to heat stress. According to the study, strong bonding networks might enhance, rather than reduce, vulnerability to heat stress, if they perpetuate misperceptions about heat stress among the elderly.

Studies that highlight the depoliticised nature of current discourses on resilience provide grounds for the approach taken in emBRACE, which in many ways focuses on the social and political dimensions of community resilience. Indeed, the emBRACE framework should be read as an explicit attempt to substantiate resilience research that often seems to be decoupled from the ambiguities of social practice. A particular focus on the social dimensions, at both a collective and individual level, is thus a contribution of emBRACE, and this resonates with literature that suggests this is important (Walker and Westley 2011; Keck and Sakdapolrak 2013; Welsh 2014). The politics of resilience are the focus of a contribution from Welsh (2014), for example, who reflects on how a focus of resilience in response to events or shocks might undermine desirable transformations and changes, reinforcing rather than changing dominant system configurations.

Walker and Westley (2011) make a similar argument by pointing to the role of governance in resilience. Their study suggests that vertical power relationships between different administrative scales (national, regional, local) can shape community resilience if they provide room for critical reflection and innovation at the local level, potentially suspending rules to make room for self-organisation and leadership.

2.2.2 Resilience: An Outcome or a Process?

A central theme in resilience research is the question of whether resilience is best understood as something to be built (e.g. by individuals, communities, etc.) or whether the value of resilience thinking lies in its ability to provoke discussions and thoughts about issues in governance of disaster risk reduction in the context of climate change. Grey literature, in particular, seems to conceptualise resilience more as an outcome than a process, suggesting frameworks and assessment tools to conceptualise and measure resilience. Prominent examples in this respect are contributions from the Rockefeller Foundation and Arup (2014), and the UNISDR self-assessment tool and score card for resilience assessments by local governments. Academic contributions seem to be more reserved about conceptualising resilience as something 'fixed' to be attained. Almedom (2013), for example, suggests that resilience cannot be built by outside experts, but acknowledges that external interventions can stimulate the development of conditions that are conducive to resilience building through self-organisation and local governance. The authors highlight, however, that resilience itself is an adaptive and ongoing process. As pointed out above, other studies see the integrative power of the resilience concept as its key contribution, highlighting the way in which it facilitates discussions and reflections by stakeholders involved in disaster risk reduction (Brand and Jax 2007; Vogel et al. 2007; Strunz 2012).

2.2.3 Resilience on Individual and Collective Levels

The identification of specific components of community resilience seems to be the focus of research that centres on a collective, rather than individual level. At the heart of literature in this domain remains the question of what community resilience is, and how it can best be conceptualised. Norris et al. (2008) suggest that a focus on well-being, rather than civil protection, can be a meaningful way of advancing knowledge on resilience. The authors place their focus on how communities can make use of dynamic resources to mitigate adverse effects of hazards, and how these community capacities can be beneficial for community resilience. Well-being is also at the heart of the contribution by Armitage et al. (2012), who use this concept to draw out the interdependence of social, ecological, and environmental systems. The systems perspective allows the authors to reflect on and identify a range of 'control variables' that shape the interaction of nested adaptive cycles. Among others, identity, perceptions and aspirations, beliefs, values and norms, and satisfaction are identified as control variables that shape resilience from a systems perspective. These control variables are valuable for emBRACE as they offer conceptual clarity for the resilience concept while providing grounds for the integration of both individual and collective accounts of resilience.

Studies focusing on psychological aspects of resilience on an individual level suggest that there are opportunities to link, conceptually, individual with collective perspectives on resilience. Research on individual resilience places focus on discussions of whether resilience is best seen as an outcome or a process – a discussion that equally relates to

research on community resilience. Mancini and Bonnano (2009) define resilience as an outcome, and suggest that it can be conceptualised and measured in terms of psychological adjustment after traumatic events. A contribution of Paton et al. (2010) points to cultural aspects that shape individual resilience, and thus provides an interesting link to reflections within emBRACE on how to account for cultural aspects of community resilience in the framework. Focusing on community earthquake preparedness in two cities in Japan and New Zealand, the study finds that culturally specific determinants add to more cross-cultural aspects of hazard beliefs and social characteristics in predicting earthquake preparedness. Links to the emBRACE framework are also recognisable in an early study of Paton and Johnston (2001) in which a resilience model is developed and tested in different contexts. Here, the authors suggest conceptualising communities as agents capable of activating and utilising internal resources and capacities. This focus on resources and capacities seems to relate to the emphasis on community resources in other case studies within emBRACE, and points to possibilities of bridging individual and psychological perspectives with collective and socially focused perspectives within resilience research.

Research on psychological aspects of individual resilience might offer more robust concepts and methodologies than studies that focus on resilience of social structures on a collective level. Research on social-psychological resilience has developed comprehensive models and frameworks on resilience (e.g. Freedy et al. 1992; Paton and Johnston 2001) that facilitate empirical investigations of resilience that so far seem to prove challenging on a community level. This raises questions on whether lessons can be learned from social-psychological research on resilience that can stimulate innovation in other domains of (community) resilience research. Of particular concern, in this respect, might be potential negatives of resilience, relating to fear, stress, depression, and psychosis, for example, which can be highly resilient, yet undesirable phenomena. Considering such potential negative aspects of resilience can facilitate a more comprehensive and differentiated discourse on resilience, beyond the mostly positively connotated buzzword.

More systematic approaches of conceptualising and assessing resilience on a collective level and in the social domain seem to be emerging (Tyler and Moench 2012), and might be able to catalyse further efforts in this direction.

The diversity of contributions that reflect on the concept of resilience discussed in this section speaks to the conceptual vagueness that continues to characterise literature on the subject. This ambiguity, in itself, can be read as a strength or as a weakness of resilience research. The following sections will discuss methodologies and indicators of resilience, and both constitute important vehicles for grounding conceptual discussions of resilience in empirical research.

2.3 Resilience: Methodology

2.3.1 Social/Political Resilience

Grasping resilience empirically is one of the challenges that arises from the conceptual ambiguity of the concept, and the emerging focus on social and political dimensions of resilience, in particular. Work in emBRACE is informed by different approaches

relating to the measurement of resilience, both from an indicator (discussed below) and methodological point of view. Methodological approaches to community resilience can be considered as a step towards more comprehensive applications of the resilience concept in the social domain.

The focus on social dimensions of community resilience within emBRACE is related to methodological studies that discuss social network analysis and agent-based modelling (ABM), in particular. Research by Burt et al. (2013) points to the importance of focusing on attributes, roles, and fit of agents in social network analysis, and thus suggests that other resilience measures such as network centrality or betweenness fall short of grasping the complexities of social networks in resilience research. The authors explore the role of structural holes in social networks, which are conceptualised as empty spaces between clusters of people that share information and knowledge, and which can shape resilience through the information that they convey or block. This conceptualisation seems to relate to Wenger's (1998) communities of practice, and points to the importance of connectedness for the dissemination of information and knowledge. The value of this study seems to lie, in particular, in its strategic approach to network governance, which allows the identification of critical points in networks that shape resilience.

Social methods for the assessment of community resilience were discussed in some of the papers annotated by project partners in emBRACE. Social methods refer to conceptual frameworks, developed in both academic and grey literature, which aim at guiding resilience assessments by experts and practitioners alike. A valuable contribution in this domain comes from Tyler and Moench (2012), who develop a framework for urban climate resilience. Their framework builds on systems, agents, and institutions as fundamental elements of resilience, and allows for stakeholders to operationalise these concepts as appropriate in their local context. A similar methodology for the assessment of resilience was developed by the Rockefeller Foundation and Arup International (2014). Their city resilience framework distinguishes between four categories of resilience (health and well-being of individuals, urban systems and services, economy and society, leadership and strategy) that reflect a focus on people, place, organisation, and knowledge. For each category, the framework suggests a set of performance indicators, which assess the outcome of resilience-building actions, rather than the actions themselves. Indicators are supplemented by a set of 'resilience qualities' which characterise a resilient city, according to the framework. The frameworks of Tyler and Moench (2012) and Rockefeller Foundation and Arup (2014) both suggest that social methods for the assessment of community resilience seem to be focused on urban rather than rural areas. This can be associated with a particular interest in urban areas as domains of resilience, but might also relate to challenges in data availability, which might be stronger in rural areas.

The need for selecting, applying, and possibly advancing agent-based modelling methods is the focus of several papers that proved to be of relevance for emBRACE. The methodological ambitions of emBRACE to go beyond highly localised and specialised accounts of resilience become apparent through a critical reading of Barrios (2014). The study offers an anthropological reading of community resilience, which can be appreciated for its conceptual clarity but falls short of moving its focus from qualitative to semi-quantitative and structured methods like network modelling. Methods of social network mapping applied in the emBRACE Tyrol case study (Chapter 13) provide an opportunity to capture the development of resilience over time, through relationships and in locations.

Challenges for ABM methods arising from weak empirical data are the focus of Smith (2014), who argues that insufficient data often undermines an effective use of otherwise well-specified models. The study thus reflects some of the key challenges of using ABM methods in resilience research, and its consideration by the consortium speaks to how these challenges concern the emBRACE project, too. Difficulties of specifying and collecting data on resilience are closely linked to the conceptual ambiguities that continue to characterise the resilience concept. This is also illustrated in the study of Saqalli et al. (2010), which critique an overrepresentation of environmental factors in many models. The authors relate this overrepresentation to the difficulty of collecting data on social and human aspects, especially in rural contexts of developing countries. Their study points to the need to draw on many empirical sources of data, and underlines that a lack of data for modelling is a challenge not unique to the emBRACE project. Opportunities to improve data availability for ABM methods are highlighted by Edmonds (2014), who suggests ways to include narrative data in ABMs. Bastian et al. (2009) discuss the Gephi software as an open source opportunity for social network modelling, and thus inform the methodology of modelling work in emBRACE.

2.3.2 Linking Biophysical and Social Resilience

Model and data challenges are also the focus of work that informs emBRACE contributions on the biophysical aspects of resilience. These are more specific to the case study context that they are applied to (see Chapter 14), but point to the common challenges of empiricising resilience in various dimensions. The biophysical modelling exercise in the London case study links social and behavioural resilience research in emBRACE to the technical and engineering dimensions of resilience. A study by Järvi et al. (2011) provides insights into the specification and application of biophysical models by applying the surface urban energy and water balance scheme model (SUEWS) to Los Angeles and Vancouver. The model includes on-site meteorological data and was thus informative for the emBRACE approach of linking local biophysical data with behavioural decisions of elderly people in London.

The evaluation of biophysical models applied in the London case study is also informed by two studies that develop an approach to evaluation that builds on a comparison of estimated and observed energy balance components (Kotthaus and Grimmond 2014a,b). Both papers build on observations collected in London over three years, providing an extensive dataset against which model predictions in the emBRACE case study can be evaluated. Observations that inform model evaluation in emBRACE also stem from a study by Ward et al. (2014), which extended the SUEWS model to a suburban area outside London.

Further specifications for the biophysical model in the emBRACE case study stem from studies that offer ways to account for the impact of building structures on urban microclimates. Lindberg and Grimmond (2011) evaluate the effect of shadow patterns from buildings and urban green space on mean radiant temperatures, and find that vegetation, in particular, can help to reduce urban heat stress. A similar conclusion is offered by Grossman-Clarke et al. (2010) who found that urban development and land use cover shaped temperature extremes during four heat events in Phoenix, Arizona. The study informs emBRACE case study work through its application of the weather research and forecasting model (WRF), which facilitates the use of scenarios in urban climate modelling.

2.4 Resilience: Indicators

Can resilience be measured? Despite its popularity in political and policy cycles, the concept of resilience remains ambiguous. Its analytical usefulness often suffers from the terminological ambiguity that characterises its application in different contexts. Approaches to conceptualise resilience differ in particular with regard to their stated goals, their defined system of interest, the scale of analysis, the hazards or phenomena identified as triggering events, as well as to their proposed mechanisms to identify resilience (emBRACE 2012a,b). What does this conceptual vagueness mean for the application of resilience in practical terms? Is resilience a concept with empirical identity? If so, how is it operationalised and measured? And what can we learn from the applications that exist?

The notion of measuring resilience is contested. Due to its ambiguous character, many studies ascertain resilience by proxy properties that represent the processes and properties of the concept. This effort is complicated by the ambiguity that surrounds resilience research, which poses a series of challenges that make the concept particularly difficult to grasp empirically. The following section outlines some of these challenges.

The ability to measure resilience critically depends on the underlying conceptualisation and the epistemological background that guides the analysis. One of the most fundamental challenges in measuring resilience thus arises from the significant evolution of the concept. Current understandings of resilience focus on reorganisation and learning and are much more dynamic than traditional, ecology-based approaches that merely consider the ability to withstand shocks. Perceiving resilience as a process rather than an outcome provides new opportunities for expanding from an overly reductionist approach focusing on outcomes to a more comprehensive process approach.

One of the most influential attempts to introduce a methodology for giving resilience an empirical identity is based on an outcome-focused understanding of resilience. The study of Carpenter et al. (2001) develops an approach that aims to define the system state of interest (resilience of what?) and the perturbations against which this system state might be resilient (resilience to what?). The focus on ecosystems allows for a rather accurate approximation of the resilience state and the stressor of interest and for a quantification of these. Drawing on this data, the authors demonstrate that it is possible to determine thresholds of different system states (e.g. clear water versus turbid water state for agricultural lake systems) and to measure resilience as the distance between two attractor states. The cornerstone of this conceptualisation is a static perspective that defines resilience as the ability to resist shocks and remain in the same state. This facilitates attempts to measure resilience, as it allows the researcher to focus on a clearly definable system with quantifiable boundaries and thresholds.

The picture becomes more complicated when resilience is not primarily conceptualised as an outcome or characteristic, for example in the sense of a system's ability to absorb shocks without fundamentally changing state. As shown above, resilience theory is increasingly focusing on more dynamic conceptualisations of the concept, which highlight reorganisation and learning in response to feedbacks as crucial elements of a resilient system. Heuristic tools such as the adaptive cycle, but also the notions of adaptive capacity and panarchy demonstrate the increasing process orientation of resilience thinking. This has fundamental consequences for operationalising the concept and giving it empirical identity. When resilience is primarily about change and transformation, then new challenges arise for assessing it. How can we measure and quantify change in

systems if these systems are flexible and constantly reshaped? Are transformations which affect resilience always observable?

When dealing with social systems, such as communities, measuring resilience faces additional difficulties. Here, systems and system state often cannot be clearly identified. Even if this is possible, the approximation of resilience in social terms appears to be a very challenging task, with data availability being only one out of many problems. What constitutes a social system and on what grounds is it defined? What subsystems are crucial elements of the social system? How do these subsystems affect the resilience of the overall system? What does it mean if we make the preanalytical decision to define society as a system and not as a group of actors sharing the same understanding of reality? Answering these questions is a challenging task and a prerequisite for assessing societal resilience.

Moreover, when attempting to assess resilience, questions of temporal and spatial scale arise. When resilience is perceived as a process of change and transformation, it becomes apparent that the concept cannot be assessed at a certain point in time. Measuring resilience thus requires longitudinal data over a period of time. This challenges the researcher to define and justify timeframes in which the transformations of interests can be appropriately captured. The same holds for scalar analysis. If it is indeed possible to observe resilience, at what scale can we do so? Here, the interaction of subsystems across time and scales plays an important role. It has been shown that increasing the resilience of some parts of a system at a certain scale can reduce adaptive capacity at others. These scalar and temporal linkages are just some of the complexities that need to be considered when attempting to assess resilience.

Finally, a fundamental challenge of assessing resilience is to answer the question why this is intended in the first place. Assessing resilience can be motivated by academic as well as normative purposes, for example. Depending on these, different approaches to the development and specification of indicators might be taken. For analytical reasons, researchers might be interested in gaining a better understanding of how different actors (e.g. individuals, organisations, communities) frame, understand, and define resilience. The motivation for such an approach could stem from the assumption that gaining answers to these questions allows for a more comprehensive assessment of the system of interest. For drawing causally valid inferences, this specific research interest would require robust and measurable indicators. However, if the interest in measuring resilience stems from normative reasons, qualitative indicators or even narratives might be more appropriate to assess resilience. These narratives could, for example, identify groups that are less resilient than desired by the subjective perception of the (activist) researcher, helping him/her to make the case for stronger support for them. Being explicit about the motivations for, and objectives of, measuring resilience is critically important for a scientifically valid approach.

Grey literature can add considerably to efforts to develop, identify, and evaluate resilience indicators (OECD 2008; Mitchell 2013; Rockefeller Foundation and Arup 2014). This suggests that practice-oriented research on resilience might be ahead of academia in identifying indicators of resilience, and that academic literature continues to struggle with the development of resilience indicators. The *OECD Handbook on Constructing Composite Indicators* (OECD 2008), for example, informed the development of indicators in the emBRACE Alpine case study (Chapter 13). The compilation