1

Introduction

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1.1 The Rationale for This Book

Every year extreme events occur which are costly in terms of human life and damage to infrastructure. Even in a stable climate, these events will occur as the tails of the normal distribution of events which characterise the climate of a place – climate variability. People and ecosystems will be partially adapted to such events but, especially in the case of severe events of great rarity, damage will ensue. The extent of this damage is a measure of the extent to which adaptation, whether planned or autonomous, has been successfully undertaken. Following the event, there will generally be an appraisal of the impact, the success or otherwise of the emergency management and the relative costs and benefits of additional adaptation measures. Where the conclusion is that the level of damage has been unacceptably high, it is likely that action will be taken to enhance coping capacity and resilience, especially when the costs are not prohibitive.

Extreme events, their impacts and the adaptations undertaken to protect ecosystems, human activities and human welfare contain instructive lessons for adaptation to climate change. First, understanding where, when and how action is taken to address vulnerabilities to extreme events is informative of the enabling factors needed to translate knowledge of climate change into adaptation. Second, understanding the reasons why some interventions designed to enhance adaptation to these extreme events succeed while others fail can help us to understand how to design effective adaptations to climate change. Finally, in many situations, the impacts of climate change will be felt principally through an increased frequency/severity of climate extremes. It is through adapting to this changed climatology of extremes that many adaptation actions to address climate change will take place.

This book explores climate extremes which have occurred in the recent past, in different geographical contexts, in the developed and developing world. By comparing the impacts, it seeks to identify what moves people to adapt, which adaptive activities succeed and which fail (and the underlying reasons for success or failure) and the factors that determine when adaptation is indicated and when bearing the impact is a more appropriate response.

This book intends to inform about adaptation practice – what works, what does not, and why. Much has been written about the theory of adaptation, and high-level, especially international, policy responses to climate change. Although the literature on the practicalities of adaptation is, by comparison, remarkably small, there is a great need for such studies to inform our thinking. By presenting a set of case studies on adaptive responses to climate extremes, together with chapters which attempt to synthesise generally applicable conclusions from the outcomes of these case studies, this book begins to address this imbalance.

1.2 The Structure of This Book

The book is divided into six parts. The introductory part consists of this chapter and a discussion of disaster risk management and the interface with adaptation by Madeleine Thomson. The next four parts consist of case studies from North America, Australia, Europe and the Developing World respectively, and exploring extremes of droughts, floods, heatwaves and windstorms. These case studies examine the vulnerability and resilience of people, ecosystems and places prior to the event, disaster preparedness, emergency management responses during the event and responses after the event – the lessons learned, the barriers to adaptation and the characteristics of successful adaptation policies and activities. They use their findings to explore the implications for a world in which these events may become more frequent or intense.

Part I, covering North America, begins with a chapter by Andrew Garcia, looking at the impact of hurricane Katrina on New Orleans, and taking a primarily engineering perspective. It identifies the event as a case of clear forecasting success but social failure in responding. Sadly, Andrew passed away shortly after writing this chapter. We are deeply grateful to Kathleen White from the US Army Corps of Engineers for kindly helping us to proceed with the chapter. Chapter 4 is an examination of the history of flooding in the Mississippi River Basin by Timothy Kusky, leading to a discussion on the effectiveness of flood control measures in constricted rivers and urbanised floodplains. Jon Keeley, Alexandra Syphard and C.J. Fotheringham in Chapter 5 examine wildfires in Southern California and the vulnerability of human settlements located in and around fire-prone wildland vegetation. David Mills and William Snook close out Part I by exploring, in Chapter 6, the evolution of the extreme heat program established in Kansas City, Missouri, in 1980 in response to a severe heatwave in that year, and the lessons to be learned from the revision and accrued experience of that program.

Part II contains case studies from Australia, a country where the climate has been described as ‘boom or bust’. In Chapter 7, Linda Botterill and Stephen Dovers examine the process of drought policy change and issues of water allocation in the

Murray-Darling Basin under conditions of water scarcity and climate variability. It explores the move from disaster-focused responsive policy-making to long-term planning and building resilience. In Chapter 8, Joshua Whittaker, John Handmer and David Karoly explore the environmental context and human dimensions of the 2009 'Black Saturday' bushfire disaster in south-east Australia. They outline the findings of the Royal Commission set up to enquire into the fires, the resulting policy and management changes and the community response. In Chapter 9, Matthew Mason, Katharine Haynes and George Walker look at the steps taken to revise building regulations and construction practices following cyclone Tracy, which struck Darwin in 1974. With 60 per cent of homes destroyed by the cyclone, the goal was to ensure that such levels of damage could never be repeated in Australia, and this chapter considers the long-term success of the ensuing changes to building regulations. David King, Armando Apan, Diane Keogh and Melanie Thomas in Chapter 10 use questionnaire surveys to understand how communities and businesses in a small inland outback town and a medium-sized coastal city of Queensland coped with the 2008 floods, and what measures they took to lessen the impact of future events.

Part III looks at case studies of windstorm, heatwave and flood events in Europe. Uwe Ulbrich, Gregor Leckebusch and Markus Donat begin in Chapter 11 by reviewing windstorms as one of the most common and most costly natural disasters affecting Europe. They note that part of the required knowledge of windstorm risk is based on proprietary risk models, available to insurance brokers on a commercial basis from companies specialising in these services. This market-driven 'vulnerability' has potentially negative implications for timely adaptation. In Chapter 12, Mathilde Pascal, Alain Le Tertre and Karine Laaidi take a public health perspective on adaptation to heatwaves, drawing on the lessons learned in France from the 2003 heatwave. They highlight the need for both long-term adaptation through changing behaviours, climate-sensitive housing design and reducing urban heat islands in cities, and immediate responses based on heat warning systems and government-developed and legislatively-enforced heat prevention plans. The two chapters that follow discuss lessons learned about flood management based, respectively, on the 1997, 2002 and 2010 floods in Central Europe (Zbigniew Kundzewicz, Chapter 13) and on the 1953 North Sea storm in the Netherlands (Pier Vellinga and Jeroen Aerts, Chapter 14). The first study highlights socio-economic factors leading to increased vulnerability including development, urbanisation and political transition. The latter provides an example of strong political and community will to prevent the repeat of a catastrophic disaster through large-scale economic investment supported by pragmatic cost-benefit analysis and the adoption of a future-forward acceptable risk baseline.

Part IV looks at case studies of extreme events in the developing countries of Africa, Asia and Central America. In Chapter 15, Simon Batterbury and Michael Mortimore explore adaptive measures taken by Sahelian people to minimise the risk of lost food production during severe droughts, and argue that social and community-driven change represents these communities' successful adaptation to changing climate conditions. In Chapter 16, the only one on a non-climatic event, but still informative for thinking around climate change adaptation, Sam Hettiarachchi and Priyan Dias explore the effects of the 2004 Indian Ocean tsunami on Sri Lanka. They highlight the importance of geographically distributing assets and infrastructure, and the need for combined approaches (e.g. early warning systems together with engineered protection) to reduce vulnerability. In Chapter 17, Bimal Paul and Munshi Rahman look at recovery from the impacts of the 2007 cyclone Sidr in Bangladesh, focusing specifically on progress made to date on housing reconstruction. The case study highlights the challenges of disaster recovery in developing nations and explores the concept of a 'build back better' approach to aid recovery and address development needs. Hallie Eakin, Helda Morales, Edwin Castellanos, Gustavo Cruz-Bello and Juan Barrera (Chapter 18) take a socio-ecological approach to exploring adaptation to tropical storms by coffee producers in Guatemala and Mexico. They highlight the importance of empowering local communities to act on their existing knowledge and experience, and of building on local social institutions to enhance local risk management capacity. In Chapter 19, Marisa Goulden and Declan Conway look at responses to the 1997–1998 floods in the Upper White Nile, linking strategies for disaster risk reduction and climate change adaptation. The concluding chapter of this part, by Zbigniew Kundzewicz, Jiang Tong and Su Buda, discusses both structural and non-structural (e.g. forecasting and modelling) flood control measures taken following several floods in the Yangtze River, China, and a growing awareness of increasing flood risk.

Together, these case studies explore in depth our knowledge of present-day vulnerabilities, adaptation and resilience to climate variability. In the concluding Part V, the lessons from these case studies are drawn together in a set of synthesising chapters to address the overarching goal of informing our thinking about adaptation to future climate change. In Chapter 21, Jessica Ayers, Saleemul Huq and Sarah Boulter examine the interrelationships between development, vulnerability and adaptive capacity, considering how these have influenced disaster responses in developed and developing countries. They highlight that, even though there is strong evidence that low development frequently determines vulnerability to hazards, it also creates entry points for development-based and participatory disaster responses that are often missed in high-income contexts. This is followed by Karen O'Brien and Thomas Downing in Chapter 22 looking at how climate change has affected, and will affect, vulnerabilities to disasters and disaster risk management. They argue that climate change is a 'game changer' that requires new ways of thinking about managing extreme events. They conclude that climate change calls for more than taking into account the lessons learned from vulnerabilities and responses to past events and applying these to future scenarios; rather, it calls for transformative approaches to reducing risk in a changing climate. In Chapter 23, Jon Barnett, Colette Mortreux and Neil Adger draw insights from the case studies to illuminate their thinking about the limits and barriers to climate change adaptation, and the risk of maladaptation. In Chapter 24, Sarah Boulter, Jean Palutikof and David Karoly consider the commonalities and points of difference among the case studies and synthesising chapters to consider what lessons emerge from the book for climate change adaptation.

The book is completed by an afterword on what happens when multiple natural disasters affect the same location in a short period of time (David Karoly and Sarah Boulter, Chapter 25). It takes the case of the Australian experience in 2010–2011, when wildfires, heatwaves, flooding, cyclones and insect plagues challenged almost the entire continent across a summer period. This multiplicity of events may be one of the greatest risks we face from future climate change. At the present time, such occurrences are rare, yet when they do occur they offer one of the few opportunities we have to empirically explore what it may be like to live with climate change.

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2

Climate Change and Disaster Risk Management: Challenges and Opportunities

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An increase in extreme weather and climate events (e.g. floods, droughts, heatwaves, windstorms, etc.) is widely understood as one of the expected outcomes of global climate change (IPCC, 2012). Over the last forty years the disaster response community have increasingly focused on prevention and preparedness for such natural (hydrometeorological) disasters, moving from disaster response to disaster risk management and towards disaster risk reduction (UNISDR, 2011), and are increasingly engaged in the discourse on climate change adaptation (see Figure 2.1).

Recent developments in climate science, climate services, geo-referenced data assimilation, management, analysis and dissemination tools and communication technologies have dramatically improved the opportunity for increasing resilience of communities to weather- and climate-related disasters. Here the challenges posed by gaps in our understanding of climate change and disaster risk in terms of space and time scales, evidence-based action and regulations and policies are discussed alongside new knowledge, technologies and policy frameworks that may help to overcome these gaps and make a difference on the ground.

2.1 Challenges of Climate Change and Disaster Risk: Space and Time Scales

Attributing disasters associated with extreme weather events to anthropogenic changes in the climate system remains a major challenge, although there is increasing interest in making progress in this area. It has commonly been stated that no individual extreme event can be attributed to climate change, but increasingly the probability that global climate change has influenced individual events (or not) is a subject for scientific discussion (Peterson et al., 2012). In the language of the Intergovernmental Panel on Climate Change (IPCC, 2012), ‘it is likely that anthropogenic influences have led to warming of extreme daily minimum and maximum temperatures at the global scale’ and that ‘there is medium confidence that anthropogenic influences have contributed to intensification of extreme precipitation at the global scale’.

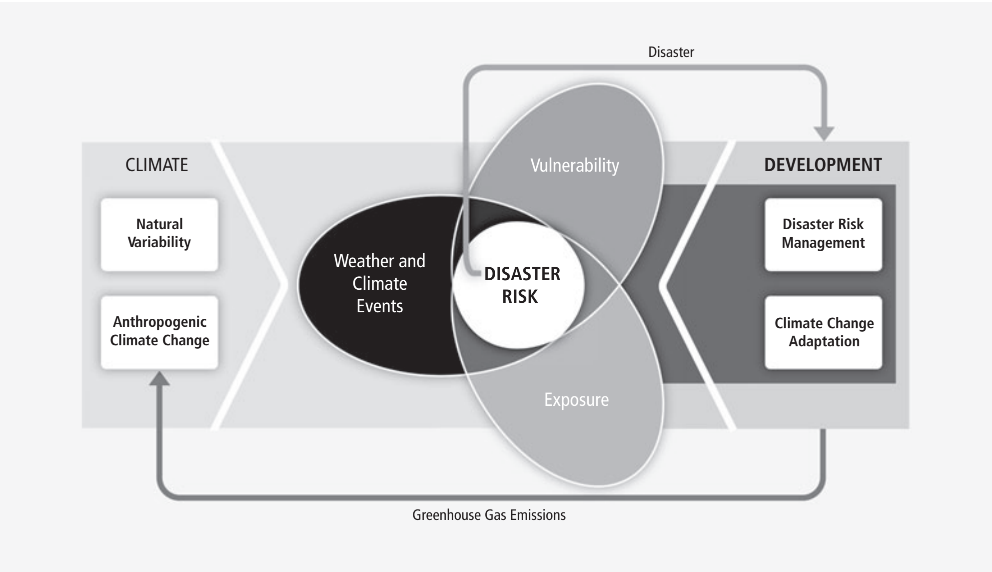

Figure 2.1 Illustration of the core concepts 'Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation' (IPCC, 2012, figure SPM1). Human-induced climate change and natural climate variability interacts with socio-economic development (via vulnerability and exposure) and the responses from the disaster risk management and climate change adaptation communities to influence disaster risk.

A key challenge is the fact that climate change is best observed at the global and regional scales but population vulnerabilities and many significant climate/weather phenomena occur at sub-regional, national or sub-national scales. Thus the disaster risk community is faced with a need to reconcile the interaction of a global-scale phenomenon with local-scale challenges. We illustrate this issue of scale with the example of the global and local impact of the El Niño–Southern Oscillation (ENSO) phenomenon.

Much of the evidence for climate change occurring over century-long time scales comes from large-scale increases in upper-ocean temperatures that are evident in observational records (Gleckler et al., 2012). At shorter (one year or two) time scales, the most significant natural global climatic driver is the ENSO phenomenon. This is a periodic warming or cooling of sea surface temperatures (SSTs) in the eastern and central equatorial Pacific, which generates a significant proportion of short-term climate variations. Since ENSO (El Niño for warming SSTs and La Niña for cooling SSTs) and its climate impacts were first documented in the 1980s (Ropelewski and Halpert, 1987), the prevailing assumption has been that more severe and widespread climate anomalies – and, therefore, greater climate-related socioeconomic losses – should be expected during ENSO extremes (Gueri et al., 1986; Bouma, 1997). Contrary to expectations, a global-scale study indicated that disaster losses are not necessarily higher at the global level during ENSO extremes when compared with neutral periods (Goddard and Dilley, 2005). Furthermore, ENSO events lead to greater predictability of the climate (Cane et al., 1986) and, potentially, better socio-economic outcomes (Buizer et al., 2000). From their study, Goddard and Dilley (2005: 651) concluded, 'Thus, the prudent use of climate forecasts could mitigate adverse impacts and lead instead to increased beneficial impacts, which could transform years of ENSO extremes into the least costly to life and property'.

However, at the regional or sub-regional scale, ENSO years may yet be indicative of disaster years. Thomson et al. (2003) obtained the number of years (1980–2001) in which drought disasters were recorded for every country in southern Africa (Botswana, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe) from the Centre for Research on the Epidemiology of Disasters (CRED) Emergency Events Database (EMDAT) (global disaster history database; see following paragraphs). With a logistic regression model, they explored the likelihood of drought disaster occurrence during the late rainy season (January–March) the year after an El Niño event when ENSO impacts are known to occur in Southern Africa. They recorded a 120 per cent increase in probability of drought disaster in the year after El Niño onset ($p = 0.0005$) when compared with other times.

Given the difficulties in attribution and the uncertainties in predicting changes in future risks at regional or local scales, the disaster risk management community must take a highly pragmatic approach to reducing disaster risk associated with hydro-meteorological events in a changing climate.

To date the most widely used global resource that provides a routinely updated assessment of the impact of natural disasters on societies around the world comes from CRED,[1] based at the Catholic University of Louvain, Brussels. CRED manages a routinely updated disaster database which records disaster losses in terms of economic costs, number of deaths and numbers of persons affected, by type of disaster. The CRED disaster database has been instrumental in providing data to support the current consensus that the economic impacts of hydro-meteorological disasters are increasing (IPCC, 2012). What is not so clear, however, is whether the higher impacts stem from an increase in weather and climate extremes or an increase in exposure, as populations continue to rise and economic growth inflates figures for economic damage during any given disaster (UNISDR, 2011). Noteworthy is that a high proportion of disasters in the CRED database (and other more detailed national databases such as DesInventar,[2] developed for Latin American countries) are not necessarily associated with extreme events per se but rather with the interaction between climate and environmental changes and high levels of societal vulnerability. Thankfully the CRED database also

[1] http://www.cred.be/ [2] http://online.desinventar.org/desinventar/

indicates that the loss of life per disaster is decreasing – the fact which may be attributed, in part, to improved early warning and response systems (Golnaraghi, 2012).

Without indicators that can correctly attribute the drivers of disaster increases, the past is not a particularly reliable guide to understanding potential losses (i.e. economic, lives) from hydro-meteorological disasters in the future. This is particularly so because climate change may have tertiary impacts on vulnerability such as, for example, disruption of global or local economies or food supply systems and the risk of infectious diseases. Additionally, the relationship of vulnerability and the impact of hydro-meteorological events may be highly non-linear. Given the uncertainty, a priority must be given to the development of a 'climate-smart' disaster community – one that is conversant with a basic knowledge of the climate system and an understanding of how the climate's natural variability on multiple time scales interacts with global environmental change and societal vulnerabilities to produce devastating societal impacts. It is particularly important to focus on the utility of information coming from the climate community in solving practical problems. Short-term weather forecasts for extreme events are proving astonishingly accurate when available. However, in many developing countries weather forecasts rarely extend beyond one to two days, and access to the information by the population at large is often limited. Seasonal climate forecasts are still underutilised, and little is known about the potential predictability of extreme events, although there are indications that such intra-seasonal information may become available in some regions (Robertson et al., 2009). Many decision makers would like to incorporate climate change information into their decision process, but the century-long span of typical climate change projections does not fit with their operational outlook that often spans only a few years. For those planning infrastructure developments the operational focus may extend to a few decades, but demand for climate information at the decadal time scale may well be running ahead of supply. This is because, while decadal predictions are high on the climate science research agenda (Meehl et al., 2011), there is considerable uncertainty as to whether the practical requirements for this type of information can be met anytime soon – if at all (Cane, 2010).

While it is increasingly understood that effective early warning must explicitly address the spatio-temporal dimensions and estimations of uncertainty of the climate and weather drivers of disasters, to date this knowledge is rarely translated into practical methodologies for operational use. The 'translation of the best science on climate change into practical action' is now an urgent priority (M. Wahlström,[3] personal communication, 2011).

[3] UN Secretary-General's special representative for disaster reduction and head of the UN International Strategy for Disaster Reduction (UNISDR) when speaking at the 'high-level dialogue and adaptation roundtable: global sustainability in a changing climate'.

For instance, over the last decade the Horn of Africa has experienced an increasing frequency of drought events, particularly during the 'long rains' which typically runs from March to May (Lyon and DeWitt, 2012). The most recent of these events, in 2010–2011, was associated with La Niña and considered the most severe in sixty years (Williams and Funk, 2011). Of importance is the fact that the observed drying differs from climate change projections, which suggest that the climate of East Africa will become wetter by the end of the current century (IPCC, 2007). The apparent discrepancy between recent drying and projections for a wetter future raises some fundamental questions to climate scientists and poses particular problems for regional policymakers who must make strategic decisions for many millions of people with conflicting information. Should they prepare societies for floods or droughts? Furthermore, if climate change scenarios are of too long a time scale for practical use, decadal climate forecasts are still on the research bench, and seasonal forecasts still underexplored, what should practitioners expect from the climate community to help to manage climate-related disaster risks?

2.2 Knowledge for Action

Following the devastating Sahelian droughts of the 1970s and 1980s, the disaster response community sought to prioritise prevention over more traditional response capacities and to identify disaster risk management (including preparedness and early warning systems) as key to economic and social development (Blench and Marriage, 1999). It soon became clear that technological capabilities for famine early warning alone cannot guarantee a timely response, either by international donors or national governments. It is critical to know who 'owns' early warning information and how the information is used in order to understand whether or not the information could result in an appropriate and timely response (Buchanan-Smith and Davies, 1995). In recent years, early warning systems for natural disasters that are tied to response capability have emerged as a priority for the disaster and development communities (IFRC, 2009). The incorporation of climate change into a disaster response portfolio of risk management has further reinforced the need for better data, methodologies and tools as well as policies and practices. In particular, the potential for climate change to increase the likelihood of extreme events has resulted in a renewed focus on early warning for adaptation. The idea is that better preparation for climatic shocks today will build capacities to better manage an increasingly extreme climate in the future (Hellmuth et al., 2011).

The recent occurrence of hurricane/tropical storm Sandy, which hammered the eastern seaboard of the United States in October 2012, illustrates the impact of an extreme weather disaster in a highly developed urban environment. The hurricane forecasts provided by global centres, particularly the European Centre for Medium Range Weather Forecasting (Hewson, 2012), proved highly informative and were