



Reconceptualising adaptation to climate change as part of pathways of change and response[☆]



R.M. Wise^{a,*}, I. Fazey^b, M. Stafford Smith^c, S.E. Park^d, H.C. Eakin^e,
E.R.M. Archer Van Garderen^{f,g}, B. Campbell^h

^a CSIRO Ecosystem Sciences, Black Mountain, Canberra, Australia

^b School of Environment, Centre for Environmental Change and Human Resilience, University of Dundee, Perth Road, Dundee DD1 4HN, UK

^c CSIRO Climate Adaptation Flagship, Canberra, Australia

^d WorldFish Centre, CGIAR, Malaysia

^e School of Sustainability, Arizona State University, USA

^f CSIR, Natural Resources and Environment Division, Johannesburg, South Africa

^g School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, South Africa

^h International Center for Tropical Agriculture (CIAT), c/o Department of Agriculture and Ecology, University of Copenhagen, Denmark

ARTICLE INFO

Article history:

Received 2 April 2013

Received in revised form 24 November 2013

Accepted 2 December 2013

Available online 11 January 2014

Keywords:

Climate change adaptation

Pathways

Transformation

Framing

Uncertainty

ABSTRACT

The need to adapt to climate change is now widely recognised as evidence of its impacts on social and natural systems grows and greenhouse gas emissions continue unabated. Yet efforts to adapt to climate change, as reported in the literature over the last decade and in selected case studies, have not led to substantial rates of implementation of adaptation actions despite substantial investments in adaptation science. Moreover, implemented actions have been mostly incremental and focused on proximate causes; there are far fewer reports of more systemic or transformative actions. We found that the nature and effectiveness of responses was strongly influenced by framing. Recent decision-oriented approaches that aim to overcome this situation are framed within a “pathways” metaphor to emphasise the need for robust decision making within adaptive processes in the face of uncertainty and inter-temporal complexity. However, to date, such “adaptation pathways” approaches have mostly focused on contexts with clearly identified decision-makers and unambiguous goals; as a result, they generally assume prevailing governance regimes are conducive for adaptation and hence constrain responses to proximate causes of vulnerability. In this paper, we explore a broader conceptualisation of “adaptation pathways” that draws on ‘pathways thinking’ in the sustainable development domain to consider the implications of path dependency, interactions between adaptation plans, vested interests and global change, and situations where values, interests, or institutions constrain societal responses to change. This reconceptualisation of adaptation pathways aims to inform decision makers about integrating incremental actions on proximate causes with the transformative aspects of societal change. Case studies illustrate what this might entail. The paper ends with a call for further exploration of theory, methods and procedures to operationalise this broader conceptualisation of adaptation.

© 2013 The Authors. Published by Elsevier Ltd. All rights reserved.

1. Introduction

Over recent decades, the climate adaptation community has made important contributions to improving understanding and awareness of climate-change related problems. These efforts have focused on: quantifying climate change (Hansen et al., 2006) and the biophysical, social and economic consequences of climate hazards (Stern, 2006; Tol, 2010), developing and applying methods for assessing the vulnerability of communities and ecosystems (Turner et al., 2003; Eakin and Luers, 2006; Adger et al., 2007; Fussler, 2007), providing general principles and broad strategies for adaptation (Fankhauser et al., 1999; Hallegatte, 2009), and identifying opportunities for and barriers to adaptation (Burch, 2010; Moser and Ekstrom, 2010).

[☆] This is an open-access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike License, which permits non-commercial use, distribution, and reproduction in any medium, provided the original author and source are credited.

* Corresponding author. Tel.: +61 26246 4374; fax: +61 26246 4202; mobile: +61 457 839323.

E-mail addresses: Russell.Wise@csiro.au, rusty.wise@gmail.com (R.M. Wise), i.fazey@dundee.ac.uk (I. Fazey), Mark.StaffordSmith@csiro.au (M. Stafford Smith), S.Park@cgiar.org (S.E. Park), hallie.eakin@asu.edu (H.C. Eakin), earcher@csir.co.za (E.R.M. Archer Van Garderen), b.campbell@cgiar.org (B. Campbell).

A growing intensity of calls for more decision-oriented research has been evident in recent years, as priorities have moved from estimating impacts and vulnerabilities in order to make the case for mitigation, to adaptation planning and action in a world that is looking less and less likely to stay within 2 °C of global warming (e.g., World Bank, 2012). Such calls emphasise the need to focus on enabling decision makers to make the difficult and urgent choices between a range of alternative policy and management options in interconnected social and natural systems (Sarewitz et al., 2003; Pielke, 2007; Eakin and Patt, 2011). The factors behind these calls are varied. They include perceptions of the limited usefulness of many assessments of impact, vulnerability and adaptive capacity for informing choices between adaptation options (Hinkel, 2011; Downing, 2012), as well as concerns that adaptation plans often seem to lack the links to implementation due to a diversity of limitations and barriers relating to human behaviour and governance (O'Brien and Wolf, 2010; Pelling, 2011). In addition, decision-oriented approaches are seen as more able to tackle difficulties in planning for future uncertain consequences of changing and unpredictable values, preferences and vulnerabilities of at-risk populations (Fazey et al., 2010b; O'Brien and Wolf, 2010), and the challenges of accommodating many confounding issues such as cross-scale effects over space and time and multiple forms of uncertainty (Dessai et al., 2007; Stafford Smith et al., 2011).

A critical consequence of such challenges is that the resulting loose coalition of research and practice that represents 'adaptation science' has to date had a modest impact on the number of

effective adaptation decisions influenced in policy, planning and management (Tompkins et al., 2010; Berrang-Ford et al., 2011; Ford et al., 2011). Additionally, and despite long-standing calls for a focus on decision making (Willows and Connell, 2003), the adaptation actions that have been implemented have tended to be mostly incremental and focused on proximate causes, with limited reports of transitions and transformational change (cf. Park et al., 2012).

More recent efforts to address this situation have used "route maps" or "pathways" as a metaphor for helping visualise a decision-centred approach to adaptation, as classically represented in the Thames barrier study (Reeder and Ranger, 2011). The concept of pathways focuses more on the processes of decision making, rather than the outcome; emphasising the adaptive nature of the decision process itself in the face of high uncertainty and inter-temporal complexity. Fig. 1 (Andy Reisinger, pers. comm.) illustrates this 'classic' adaptation pathways metaphor for exploring and sequencing a set of possible actions based on alternative external, uncertain developments over time. This visualisation of the concept is complemented by Haasnoot et al. (2013) who instantiate the pathways metaphor with a proposal for a rigorous syntax for illustrating the implementation of adaptation plans and policy. Both of these efforts focus on the individual decision-making actor and climate change with the intended outcome comprising more and improved decisions. Where the goals of adaptation are not ambivalent and the decision maker is in the 'adaptive space' (white area, Fig. 1) with the power and agency to

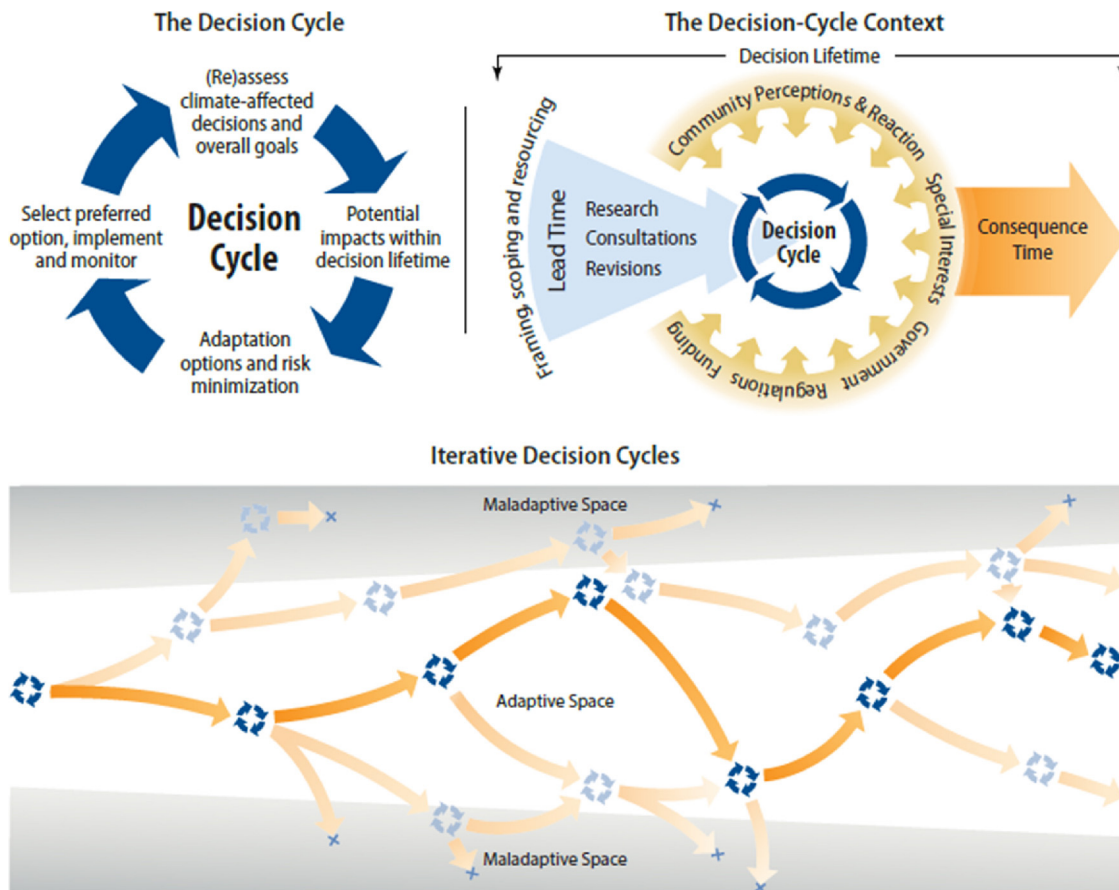


Fig. 1. The current 'classic' conceptualisation of adaptation pathways – as a series of adaptive learning decision cycles over time (top left, cf. Willows and Connell, 2003; Haasnoot et al., 2013) with their decision lifetimes (top right – the sum of lead and consequence times, cf. Stafford Smith et al., 2011), where some chains of decisions lead to maladaptive outcomes over time, but there may be other alternatives that are adaptive (bottom, cf. Reeder and Ranger, 2011; Haasnoot et al., 2013). From the perspective of the current decision point at the left, a currently satisfactory pathway can be plotted through the future (strongest colour), but this must be re-visited at each decision point (Figure developed by Andy Reisinger, pers. comm.).

make decisions, these approaches are powerful tools for supporting decision makers explore and sequence a set of possible specific actions under deep uncertainty about the future.

There is, however, a need to make explicit the tensions between adaptation policies and actions aimed at proximate causes of vulnerability (i.e., supporting decision making within prevailing governance arrangements), and those seeking broader and systemic change to social and political regimes – in other words, transformation (Pahl-Wostl, 2009; Pelling, 2011; O'Brien, 2012). The growing likelihood of a >2 °C warmer world will require proactive adaptation that continually cycles between incremental and transformative actions (Park et al., 2012). Attention therefore now needs to be given to better understanding and informing the “when”, “where” and “how” of complementing incremental actions on proximate causes with the more challenging and long-lead time transformative aspects of societal change (Nelson, 2009; O'Brien et al., 2009; Pelling, 2011).

In this regard (Dovers and Hezri, 2010: 220), emphasise the potential value of drawing upon decades of efforts in “cognate sectors (i.e., emergency management, integrated natural resources management, and water resource policy) and sustainable development”. Pertinent examples in the sustainable development domain are the contributions made by the STEPS (Social, Technological and Environmental Pathways to Sustainability) Centre – which they term ‘the pathways approach’ (Leach et al., 2010a) – as well as work on socio-technical transitions (Geels and Schot, 2007) and steering for sustainability (Newig et al., 2007). These efforts all emphasise the need to transform the social and political conditions that produce vulnerability and the challenges of dealing with the complex dynamics of social and ecological processes, and the high degrees of uncertainty in planning for sustainability in the current era. Leach et al. (2010a), for example, argue that in the face of significant change and uncertainty, the tendency has often been to “close down” too rapidly to a small set of decision alternatives by reconfiguring uncertainty into more manageable, but inappropriately narrow, calculations of risk and cost-benefit equations. The STEPS centre advocates “opening up” policy processes to wider participation, thus increasing the diversity of values and ideas, as well as equity in decision-making (Stirling, 2006). In this approach, development *pathways* are defined as the “alternative possible trajectories for knowledge, intervention and change, which prioritise different goals, values and functions” (Leach et al., 2010a: p. 5).

The concept of “pathways” has clearly gained traction in a variety of discourses and policy domains. The purpose of this paper is to propose a broader conceptualisation of the adaptation pathways perspective that allows decision makers to explore the need for and the implications of societal transitions and transformation. In particular, this broadened pathways perspective provides insights and guidance on diagnosing whether systemic change is needed and the role of incremental adaptation in achieving this; and raising awareness and understanding of the interplay between knowledge, values, power and agency to inform responses to change, particularly in dynamic, complex and contested contexts.

In broadening this conceptualisation we first canvassed the status and effectiveness of adaptation research and practice as documented in the literature over the past few years (Section 2). This review revealed key insights into the factors contributing to the limited on-ground adaptation and the predominance of incremental over transformational change. The role that framing plays in influencing the nature and effectiveness of adaptation was identified as critical and is discussed in Section 3. Section 3 also provides the justification for a broadening of the prevailing IPCC vulnerability-impacts framing which is largely based on predict-and-provide approaches (e.g., Adger et al., 2007) by drawing upon

lessons from sustainable development. The Section justifies the need for further developing decision-oriented approaches to adaptation. Our re-conceptualisation emphasises the perspective of adaptation as part of pathways of change and response, where the intent and outcome of adaptation are not risk reduction per se but rather addressing the systemic drivers of vulnerability in dynamic systems. Section 4 provides and discusses detailed examples to explain and justify why this pathways approach is a more productive and effective approach for facilitating adaptation. The paper concludes (Section 5) with a call for further exploration of this conceptualisation of adaptation and, importantly, some initial considerations for its application to the task of enhancing ongoing and dynamic adaptation action, noting the contribution of other papers in this special issue.

2. The status of adaptation research and practice

To understand the current status of adaptation, we reviewed a selection of international literature that directly and indirectly assessed the status, barriers and opportunities to adaptation practice, those that reported empirical studies of adaptation decisions and on-ground actions, and those specifically with “pathways” in the content. This literature was a small subset (about 10%) of the 1423 articles found published over the last decade with the term ‘climate change adaptation’ in the topic using Web of Knowledge. The purpose of this review was therefore to be more indicative of trends in the literature, rather than an exhaustive systematic evaluation. To provide further in-depth analysis, this review was supplemented with four case studies of adaptation experiences (Table 1). The case studies draw on the practical experiences of the authors and case-specific literature; they were chosen to represent a diversity of adaptation contexts that: (a) cover developing and developed country contexts; (b) focus on different levels of decision-making, i.e. community adaptation to climate change (Solomon Islands), local government experiences (Australia and United States of America), national decision making (national adaptation plans in developing countries, and biodiversity planning in South Africa), and (c) cover a diversity of sectors/zones (biodiversity, agriculture, coastal zones). Finally, important and impactful contributions in the sustainable development literature, specifically focused on “pathways” perspectives to understand and inform societal responses to novel global changes, were also reviewed.

2.1. The status of adaptation practice

Three broad types of studies on adaptation practice are evident. First, there have been recent direct assessments of adaptation practice, with a primary focus on adaptation initiatives in developed countries (Berrang-Ford et al., 2011; Ford et al., 2011). These found that, whilst there were considerable efforts and studies to assess vulnerability, there was limited evidence of actual adaptation action. Where adaptation action had occurred, this was typically in sectors sensitive or considered to be sensitive to climate impacts (e.g., coastal zones, utilities, infrastructure and transport) and action had most often been implemented at the local scale and facilitated by federal governments. Climate change was rarely the sole or primary motivator, and extreme events tended to be important catalysts for many adaptation actions. The primary “adaptation mechanisms” were institutional (i.e., guidelines and policies) and financial (e.g., providing financial support) and there was limited reporting of adaptation efforts taking advantage of climate change or focusing on marginalised groups, such as women, the elderly, or children (Berrang-Ford et al., 2011; Ford et al., 2011). A more recent analysis of “the adaptation concept in the climate change literature” by Bassett and Fogelman

Table 1
Summary of the adaptation context, status of adaptation practice and key issues for five case studies, done by the authors drawing on their knowledge and experiences in these contexts.

Case study	Adaptation context	Status of adaptation practice to date	Key issues
Local governments in the US	<ul style="list-style-type: none"> •Lack of national leadership and policy framework to provide institutional coordination across sectors. Limited stakeholder participation. Absence of effective financing mechanisms (Poyar and Beller-Simms, 2010; Carmin et al., 2012) 	<ul style="list-style-type: none"> •Cities and local governments are emerging as centres of action for climate change planning (Carmin et al., 2012) •Currently in the domain of “early adopters” (Poyar and Beller-Simms, 2010) •Local champions, extreme events and participation in national and international networks of organisations are promoting action (Anguelovski and Carmin, 2011) 	<ul style="list-style-type: none"> •Little evidence of reform of social issues relating to resource access and opportunity •Broader structural concerns associated with urban design addressed in local planning
Coastal local governments in Australia	<ul style="list-style-type: none"> •Coastal ecosystems and built infrastructure are at increasing threat of inundation due to sea level rise, storm surge and flooding •Capacity- and budget-constrained local Governments are responsible for making choices between protection and retreat of private assets and ecosystems •Higher levels of government are providing little leadership 	<ul style="list-style-type: none"> •Many Councils have undertaken vulnerability assessments and evaluated adaptation options •A few councils have taken action using land-use planning systems (Gibbs and Hill, 2011); largely to limit legal liability (Baker and MacKenzie, 2011) and protect public assets •Responses have been incremental and focused on proximate causes (Herriman et al., 2012; Webb et al., under review) 	<ul style="list-style-type: none"> •Adaptation action is limited and hampered by the non-binding nature of state-wide policies (Gibbs and Hill, 2011) which are ambiguous in their intent and provide little guidance for determining ‘coastal hazard zones’, weighting climatic and non-climatic risks, clarifying liability and compensation issues, and defining roles and responsibilities
Least-developing-country (LDC) National Adaptation Programmes of Action (NAPA)	<ul style="list-style-type: none"> •As of June 2012, 47 NAPAs had been completed by LDCs and lodged with the UNFCCC secretariat (http://unfccc.int/resource/docs/2012/sbi/eng/15.pdf) •Despite a GEF-managed LDC Fund being established in 2002 to finance NAPAs, there remains a lack of clarity regarding who and how they will be implemented (Huq and Khan, 2006; Paavola and Adger, 2006; Saito, 2012) 	<ul style="list-style-type: none"> •NAPAs have involved the synthesis of information, participatory assessments of vulnerability, and evaluation and prioritisation of activities •Methods and processes have been systems-based, participatory and multi-disciplinary •Few NAPAs have been implemented, but successes are due to effective inter-Ministerial mainstreaming of adaptation into development planning (Kalame et al., 2011) 	<ul style="list-style-type: none"> •Urgency for adaptation has been balanced against the urgency of actions in many other areas •Many NAPA processes were overly narrowly focused. Marginalised and more vulnerable groups (e.g. women) often excluded from participatory processes (Huq and Khan, 2006) •Progress hindered by failure to build in-country capacity to plan & implement integrated measures (Huq and Khan, 2006)
Adaptation in the Solomon Islands	<ul style="list-style-type: none"> •Major challenges to governance exist due to: limited capacity (i.e., chronic lack of infrastructure and financial capital) and a culturally and linguistically diverse population (Connell, 2010) •National departments on disaster risk management and climate change to be amalgamated and climate change mainstreamed (MECDM, 2012) •Civil society organisations are building capacity to support communities adapt to climate change (MECDM, 2012) •Rural communities depend on natural resources (Allen et al., 2006) which are being compromised due to increasing population and resource use •Loss of social cohesion, increasing rates of alcoholism, disputes, and emphasis on cash crops are reducing adaptive capacity and increasing vulnerability (Fazey et al., 2011) 	<ul style="list-style-type: none"> •The NAPA (completed in 2008) involved a broad assessment of climate change vulnerability at the national level and of the marine sector. (MECMH, 2008). More specific vulnerable locations were identified in the 2nd National Communication to UNFCCC •Community-based adaptation has been identified as a national strategy to improve food security and well-being, and build adaptive capacity to climate change in the context of other pressures •There is evidence of some effective community-based adaptation in the Solomon Islands (Schwarz et al., 2011) but in general subsequent implementation of NAPAs has been limited 	<ul style="list-style-type: none"> •Current multiple trajectories of change (e.g. erosion of social cohesion, climate and natural disasters) and response are often not addressing underlying causes of vulnerability (Fazey et al., 2011) •While there may be greater recognition in government of the importance of adaptation measures actual on ground adaptation initiatives remain incremental, and the capacities to do anything significant are limited •Current increasing population pressures and their impacts on food security and health are more urgent issues than climate change
Adaptation planning in the biodiversity sector in South Africa	<ul style="list-style-type: none"> •Adaptation efforts have focused on biodiversity (e.g., National Biodiversity Assessment (Driver et al., 2012)) and future direction is provided in the Climate Change Response White Paper (Department of Environmental Affairs, 2011) •Ecosystem-based adaptation (EBA) is being promoted as the best way to conserve biodiversity and ecosystems, adapt to climate change, and generate socio-economic benefits 	<ul style="list-style-type: none"> •Some longstanding experiences in EBA exist: vulnerability assessment processes informed a pilot EBA project in the Namakwa region; and in the Suid Bokkeveld area, civil society worked with local farmers to adapt to climate change and promote sustainable livelihoods, in situ conservation and ecosystem restoration (Archer et al., 2008) •Successful adaptation initiatives have had local support from civil society and government 	<ul style="list-style-type: none"> •Key weaknesses in support for adaptation exist at local and provincial government levels (on occasion, a support then provided by stakeholders such as civil society) •Significant, as yet inadequately realised opportunities exist to scale up successful approaches to provincial, national and regional concrete planning levels

(2013) report that most (70%) of the 558 articles they surveyed across four journals adopted “adjustment [incremental] adaptation approaches, which view climate impacts as the main source of vulnerability”, only 3% “focus on the social roots of vulnerability and the necessity for political–economic change to achieve ‘transformative’ adaptation”, and 27% ‘located’ “risk in both society and the biophysical hazard” which subsequently promoted “reformist adaptation”.

Second, there are numerous studies that characterise the limits and barriers to, and opportunities from adaptation (e.g., Adger et al., 2009; Burch, 2010; Moser and Ekstrom, 2010; Nielsen and Reenberg, 2010; Sietz et al., 2011; Marshall et al., 2012). These, and others listed below, seek to develop the conceptual, theoretical and knowledge foundations for understanding adaptation, assessing the vulnerability of social and ecological systems to projected climate changes, and developing and implementing adaptation strategies. Many comment on how useful these efforts have been for building understanding and awareness, measuring vulnerability and adaptive capacity, identifying adaptation options, and, in certain circumstances, creating opportunities for adaptation (Burch, 2010; Eakin and Patt, 2011). Many also report that thorough and reliable evaluations of adaptation options have been undertaken and plans developed. However, actual on-ground implementations are reported in very few of these papers. The detailed case studies presented in Table 1, for example, describe the status of adaptation practice to date to be limited or ‘in progress’, with few examples of what might be considered fully fledged implementation. These examples also clearly show limited scope and planning for transformational change. In the cases of the U.S. and Australian local governments, for example, the authors observe limited real reform. In the case of Least Developed Country National Adaptation Plans of Action (NAPAs), translation to in-country planning and action remains limited, and NAPAs are arguably not being written in ways that readily translate to real action. Some successes in incremental adaptation actions are evident, and provide lessons and potential options for future direction.

Literature that characterises barriers and opportunities also explores the reasons for the limited conversion of assessments and plans into action. These include behavioural and cognitive aspects (O’Brien and Wolf, 2010; Nelson, 2011), uncondusive governance arrangements (Amundsen et al., 2010; Storbjörk, 2010), lack of or self-interested leadership (Anguelovski and Carmin, 2011; Moser et al., 2012), competing planning agendas and lack of institutional coordination (Moser and Ekstrom, 2010), insufficient financial and human capital and mechanisms for enabling these (Bryan et al., 2009; Kabubo-Mariara, 2009), lack of information and data (Deressa et al., 2009; Hammill and Tanner, 2011), historical determinacy and path-dependency (Chhetri et al., 2010; Abel et al., 2011), incorrect or incomplete diagnosis of problems (Gorddard et al., 2012), the widening science–policy gap associated with wicked problems (Moser, 2010), and uncertainty and ambiguity (Sarewitz, 2004; Dessai et al., 2007). While identifying potential problems is important, shopping lists are not helpful: a key challenge for adaptation research is to identify which barriers are likely to arise in which kinds of contexts to inform how to address them.

Third, there is a body of literature that reports actual and ongoing on-ground adaptation practices. The vast majority of these studies are in agricultural contexts and in community- or ecosystem-based initiatives in rural, resource-dependent communities of developing countries (WRI, 2011; Park et al., 2012; Rodima-Taylor et al., 2012). In the case of adaptation in agricultural settings, the actions reported are mostly either addressing proximate causes of problems through incremental, no-regrets actions, or building the resilience of desired system functions by

facilitating social organisation and technological applications. Some of the latter are building the potential to transition prevailing rules and decision processes. Examples include the provisioning of information services (e.g., facilitating information flows such as seasonal forecasting to farmers and improved monitoring and feedback mechanisms); livelihoods management; trialling and replicating technical solutions (e.g., shifting to multi-species cropping, agroforestry systems, farming to deliver ecosystem services, conservation agriculture, water-use efficiency, and genetic research); promoting financial approaches (e.g., weather derivatives, micro-finance); land-use zoning; and changing organisational structures and the rules governing decision making processes (e.g., water markets, boundary organisations to provide extension services and disseminating information, creating community networks, and supporting the role of communities within public institutions) (Atwell et al., 2008; Rickards and Howden, 2012).

Most of the ecosystem- and community-based adaptation examples have focused on rapidly realising improvements in quality of life of resource-dependent communities through changes to livelihoods and natural-resource management strategies (e.g., Acosta-Michlik et al., 2008; World Bank, 2010; WRI, 2011). In essence, all of these are focused on building the specific resilience (as opposed to general resilience, cf. Folke et al., 2010) of existing urban or rural ecosystems and the capacity of communities to cope, acclimate and adapt through strategies that ensure the prevailing suite of ecosystem goods and services are sustained (Jones et al., 2012). There is often little recognition and acknowledgement that some of these ecosystems may transition to entirely different states providing different goods and services as a result of climate change, and that adaptation will increasingly be needed to facilitate transitions of governance arrangements and transformations of societal processes, norms and values.

2.2. Recent developments in adaptation research

There are growing efforts by the research community to better understand and develop methods and processes to support and inform adaptation research and decision-making. These efforts have focused on developing techniques and tools for dealing with uncertainty, long time horizons, distributed decision making, diverse knowledge types and contested values. Willows and Connell (2003), Dessai and van der Sluijs (2007), Ranger et al. (2010) and Weaver et al. (2013) have strongly argued for and developed decision-centred approaches that provide comprehensive and pragmatic guidance on scoping problems in complex settings, identifying relevant information, interpreting uncertain projections and selecting decision-making methods that are appropriate to the nature and level of uncertainty. Importantly, they also provide practical tools and procedures for incorporating adaptation principles and heuristics developed by Fankhauser et al. (1999), Hallegatte (2009) and others when developing context-sensitive, ‘no regrets’, robust and flexible adaptation strategies.

The above decision-centred approaches have inspired the recent developments in adaptation planning and decision support mentioned earlier, which use ‘pathways’ as a metaphor to help visualise what adaptation is about (i.e., Stafford Smith et al., 2011; Haasnoot et al., 2013; Fig. 1), and provide an analytical approach for exploring and sequencing a set of possible actions based on alternative external changes over time. These developments build on earlier contributions and experiences such as the application of the pathways approach to adaptation planning in New York and London (Yohe and Leichenko, 2010; Reeder and Ranger, 2011; Rosenzweig and Solecki, 2013), and an extensive engineering project management literature in other contexts (e.g., Wade,

1968). These initiatives provide a powerful and flexible analytical approach for decision makers in relatively closed, high-reliability systems that are (largely) amenable to technical solutions (e.g., the Thames barrier: Reeder and Ranger, 2011). A key strength of this approach for adaptation is that it explicitly considers the interdependencies between the uncertain timing and magnitude of climate-change impacts and the characteristics of responses in terms of their costs, lead and lag times, and reversibility. In this regard, the tool emphasises the need for flexibility and iterative management of immediate decisions, informed by a strategic vision of the future and a framework to inform future actions based on decision triggers and monitoring (Haasnoot et al., 2013).

These approaches, however, only partially consider (if at all) the dynamic interactions between values, knowledge cultures, and institutions that enable and constrain all research and decision-making processes (Pahl-Wostl, 2009; Pelling, 2011; O'Brien, 2012). These underpinning elements of societal decision-making are highly evolved, dynamic, interdependent and complex, and difficult to change, yet in the context of climate and global change may rapidly become anachronistic. The task of enabling decision-making and adaptation thus requires understanding the interdependencies between institutions, values and knowledge and how to change these (Stern et al., 1999; Head, 2010; Gorrdard et al., 2012). There are consequently a growing number of studies attempting to better understand and address these systemic causes of vulnerability. These studies report on the specific approaches, difficulties and experiences involved in recognising, understanding and informing changes to the institutions and values that underpin research and decision processes. Important but not exhaustive contributions here include: efforts focused on the wider societal processes and institutions that govern the interplay between actors and decision processes (van der Brugge et al., 2005; Downing, 2012; Gorrdard et al., 2012; Rodima-Taylor et al., 2012); shifting the focus of adaptation from viewing climate change risks as exogenous threats to development to accepting them as both products and drivers of development in an iterative manner (Fazey et al., 2010a); viewing climate adaptation “as a dynamic in social-ecological co-evolution” where processes of social learning and self organisation are key (Ensor and Berger, 2009; Pelling, 2011: 169); and improved understanding and development of approaches to bridge knowledge types and decision hierarchies, particularly deliberative participatory learning by stakeholders (e.g., Reid et al., 2006; van Aalst et al., 2008; Huntjens et al., 2012). These insights highlight the significant impact that values and rules have on current framings of

adaptation in both social and analytical senses. From an actor-oriented perspective, Haasnoot et al. (2013) explore how social groupings with different values or worldviews may choose different decision pathways from the set of available options. Leach et al. (2010a) complement such analyses by offering specific methodologies for eliciting the overarching framing and associated narratives that structure sustainability decision-making. A focus on social framing – which Leach et al. (2010a) define as “particular contextual assumptions, methods, forms of interpretation and values that different groups might bring to a problem, shaping how it is bounded and understood” – is central to thinking through adaptation pathways.

3. Current framings of adaptation and how these influence action

A key challenge to achieving greater implementation of adaptation initiatives, especially in ways that are likely to address the more systemic causes of vulnerability, relates to how adaptation is framed analytically. UNEP (2012) demonstrates the potential range in perspectives on adaptation by identifying seven different framings (Table 2). These reflect the diversity of contexts in which adaptation is required and the different world views, value systems, interests, and perspectives of adaptation researchers and decision makers (Juhola et al., 2011). Of particular relevance is how these actors, consciously or implicitly, view and define the relationships between humans and nature, the goals of adaptation, and the role of knowledge in decision-making.

An important component of the adaptation framing, related to whether responses should be directed at proximate or root causes of problems, is the degree of contextual complexity. The contexts within which adaptation is required are extremely diverse (Section 2). Voß et al. (2007) presents a typology of contexts along a gradient of increasing complexity based on different combinations of the degrees of uncertainty in knowledge, ambivalence in goals and distribution of power. The simplest of these contexts is where knowledge of system functioning is relatively certain, a central decision maker exists and is easily identifiable, and goals are clearly defined and uncontested. Problems in these contexts are ‘tame’ problems and are well-suited to the rationalist reductionist approach to decision making (Rittel and Webber, 1973; Stirling and Scoones, 2009). Equally, in relatively closed systems with a central locus of power and unambiguous goals (e.g., high reliability urban water supply systems) the problem is largely a ‘knowledge problem’ and can be tackled through capability building and tools

Table 2
Summary of seven analytical framings of adaptation (UNEP, 2012).

Framing	Focus and emphasis
Livelihoods-based	This approach emphasises the importance of existing social conditions, individual perceptions, local experiences and informal institutions as critical aspects for determining how communities cope with current climate conditions as a starting point for developing appropriate adaptation responses
Impact-analytical	This approach of the IPCC views adaptation as a single (or few) decision(s) that is (are) taken on the basis of projected future impacts, where it is assumed impacts and decisions can be singled out and formally quantified and evaluated using multi-criteria, cost-effectiveness or cost-benefit analyses
Institution-analytical	This framing emphasises the need for horizontal integration of policy to mainstream climate change adaptation considerations into existing policy processes
Decision making under uncertainty	In this framing, the analysis starts with a concrete decision (e.g., raise dikes) based upon all information on the range of possible impacts, rather than with climate scenarios and projections of impacts
Social & institutional process	This framing emphasises how in linked social-ecological systems the outcomes of actions can usually not be predicted as they depend on actions of many agents as well as the social, cultural and natural context. The focal points of analyses thus are institutions (formal and informal rules) that shape the interplay between the actors
Multi-level governance	This framing emphasises how the cross-scale and systemic nature of climate impacts requires understanding and creating multi-level institutions and organisations that promote vertical and horizontal integration
Social learning & adaptive management	In this framing, the complexity and non-determinism of many resource management situations is recognised and adaptive processes of improving management goals, policies and practices through learning are adopted to help bridge the science-policy gap

for decision making under uncertainty (Ranger et al., 2010). However, under climate change, many contexts have high degrees of uncertainty in knowledge, distribution of power or ambivalence in goals. In such systems (e.g., coastal communities along beach-dune systems and rural resource-dependent communities in developing countries) problems are best diagnosed and solutions proposed through legitimate and fair processes of communication, engagement, deliberation and negotiation (Stirling, 2006). A variety of approaches to facilitating learning, participatory dialogue and action across decision levels and knowledge cultures have been proposed. These include creating networks across levels of formal and informal governance (Ostrom, 2010), scenario planning and visioning (Enfors et al., 2008), multi-criteria mapping (Stirling, 2006), and conceptual mapping and soft modelling (Checkland and Poulter, 2006; Cundill et al., 2012). It is through processes such as these that dominant narratives, which are based on mechanistic modes to research and decision making and which promote responses to control and 'stabilise' the status quo, can be challenged (Leach et al., 2010a: Fig. 3.7, p. 59). For the sake of balancing investment efficiency and effectiveness with fairness and legitimacy, it is essential to recognise contexts in which simpler, cheaper approaches are sufficient, as opposed to when these are likely to fail so that more complex approaches are required.

Most adaptation efforts to date have, to varying degrees, adopted the IPCC's predict-and-provide or impact-analytical approaches to the design and implementation of adaptation (Downing, 2012; UNEP, 2012; Bassett and Fogelman, 2013). These are largely based on a rationalist and linear approach to science-policy which focuses on the *specific* risks identified as 'additional' in the climate change context (and thus "close down" the problem definition, *sensu* (Leach et al., 2010a)), rather than the *generic*, *complex* risks that characterise real-world decision-making. The latter risks are characterised by high uncertainty, ambiguity or ignorance (also referred to as deep, severe, radical or fundamental uncertainty) in which knowledge about the likelihood of impacts

and outcomes are problematic (Lempert et al., 2003; Stirling and Scoones, 2009). By assuming adaptation decisions can be managed in a traditional risk framework, adaptation efforts have tended to be problem-oriented and reductionist in approach. Additionally, in many cases and particularly in developed-country contexts, research and planning efforts to support adaptation have adopted approaches based on the assumption that a clearly identifiable rational decision maker exists with the mandate to make decisions. The level of active participation of researchers and policy-makers in learning has varied depending on the framing; with the least participation in the 'impact-analytical' and 'decision-making under uncertainty' framings, increasing for the institutionally oriented framings, and being prevalent in the 'social process' framings. The often problematic implications of such approaches to adaptation are listed in Table 3. Collectively, these favour adaptation responses that are more incremental than transformational in nature.

Despite their limitations, adaptation initiatives have helped build the awareness and understanding of adaptation researchers and decision makers of climate change, vulnerability, adaptive capacity and the barriers to making decisions in uncertain and complex contexts. However, such initiatives tend to be ill-equipped to deal with multiple and deep uncertainties, dynamic and inter-dependent values and institutions, a diversity of perceptions and tolerances for global-change risks, positive feedbacks and path-dependency across space and time, and high levels of distributed power and decision making (Funtowicz and Ravetz, 1993; Voß et al., 2007). Proactive preparation for futures in a >2 °C world will require responses that continually cycle between incremental and transformative actions (Park et al., 2012). Attention now needs to turn from incremental actions on proximate causes, to more challenging and long-lead time transformative aspects (Nelson, 2009; O'Brien et al., 2009; Pelling, 2011). This requires the social processes, institutions, organisations, skills and capabilities necessary to guide, facilitate, and manage the "when", "where" and "how" of adaptation for building

Table 3

Implications and consequences of the prevailing rationalist predict-provide and impact-analytical approaches to adaptation.

Implications and consequences	References
Considerable time and effort invested into explaining and justifying problem definitions in contexts where complexity, uncertainty or ambiguous goals make polarised world views legitimate and largely unavoidable. Leads to science being inappropriately used to try resolving contested problem definitions and solutions	(Sarewitz, 2004)
The solution space being constrained to addressing symptoms and proximate causes (e.g. infrastructure planning, livelihoods management, legal liability) thus largely unsuited to informing and initiating innovative transformational changes to address root causes of problems	(Pelling, 2011)
Focuses attention to static measures of vulnerability and adaptive capacity and on impacts at particular future dates, which has promoted once-off actions without due consideration for the temporal interdependencies between these variables and the general current and historical context in which adaptation is occurring	(Fazey et al., 2011; Hinkel, 2011)
Research, decision-making and values-deliberation processes being undertaken in relatively discrete stages of adaptation planning leading to limited opportunities for triple-loop learning by all stakeholders, which are a prerequisite to transformation	(Gorrdard et al., 2012)
Emphasis on adaptation being about managing specific quantifiable or observable risks through increased control of the environment (i.e. assumed impacts and adaptation decisions can be singled out and formally quantified and evaluated using multi-criteria, cost-effectiveness or cost-benefit analyses). Results in lack of consideration of the wider social, political and normative elements of adaptation	(Carter et al., 2007)
Adaptation being promoted as a single or a few decisions to be made by the end of a project and largely unable to account for issues that play out over the long term such as cultural, institutional, political, technological and economic path-dependencies	(Abel et al., 2011)
Expectations and beliefs being created or reinforced that more research will reduce uncertainty and make choices easier leading to funds being allocated uncritically to scientific pursuits to 'reduce uncertainty'	(Dessai et al., 2009)
Insufficient integration of climatic drivers of change with other drivers of change and within broader development initiatives, particularly in developed nations	(Fazey et al., 2010a)
Tried-and-tested solutions (measured as the absence of the problem) are fitted to the status quo rather than novel solutions being generated to create desired conditions that may question or challenge the status quo	(Swenson and Anstett, 1997)
Governments contributing as independent providers of information, capacity and funding without sufficiently exploring their own institutional limitations and partnering in learning and innovation	(Gorrdard et al., 2012)
Focus on scientists as the key producers of knowledge with the learning being framed by and associated with external researchers rather than those who are supposed to be implementing adaptation or are supposed to benefit from it	(Fazey et al., 2010b)

the resilience of desirable system functions and for transforming values, decision-making processes and governance arrangements. Achieving this thus requires a paradigm shift in the framing of adaptation research and practice.

Recognition that different ways of understanding adaptation are needed is steadily entering science and practice discourses (Fazey et al., 2010a, 2011; Pelling, 2011; Downing, 2012; Gorrdard et al., 2012; O'Brien, 2012). Such an evolution provides opportunities for a new coalescence of adaptation science and practice that is more effective and influential in helping decision-making and in guiding complex social-ecological systems.

4. Discussion – towards a new framing of adaptation as part of pathways of change and response

We suggest that the paradigmatic shift required in adaptation science and practice involves conceptualising adaptation as an element of pathways of interacting global changes and societal responses. This broadens the existing conceptualisation and instantiation of adaptation pathways documented by Fig. 1 and Haasnoot et al. (2013), discussed in Section 2, to emphasise the societal change aspects of adaptation. This broader conceptualisation of 'adaptation pathways' particularly emphasises five critical dimensions to the adaptation challenge that are currently poorly integrated in research and practice. The first is acknowledging that climate adaptation is not separable from the cultural, political, economic, environmental and developmental contexts in which it occurs and is therefore only part of a range of societal responses to change. Second, and related, is the prevalence of changes and responses that cross spatial scales, sectors and jurisdictional boundaries, which can lead to threshold effects and can be exacerbated if responses are not coordinated. A third dimension is the inter-temporal aspects due to positive feedback loops and system inertia. These intrinsic processes express themselves as historical determinism, path-dependency, and lock-in; they mean future pathways are contingent on historical pathways and difficult to change. A fourth dimension relates to the difficulty of determining (i.e., measuring and monitoring) and understanding where the system is, on what trajectory, due to the many emergent properties of social-ecological systems as they adaptively respond to change. The final dimension, which is related to those above, is that societal processes are enabled or constrained by the prevailing rules, values and knowledge cultures, and their interdependencies, making it important to recognise and understand the influences of these interdependencies and how to change them to better enable adaptation research and practice. This final dimension is particularly important in evaluating the potential for adaptation to transform the wellbeing of disadvantaged and politically marginalised populations whose vulnerability may be perpetuated by existing power relations, norms and institutions (Leach et al., 2010a; Pelling, 2011; Maru et al., 2014).

We return to more detail on these below, but their collective effect is to force researchers and decision makers to approach the adaptation challenge at two levels. The first of these involves continuing existing predominantly incremental actions (within prevailing governance arrangements) that address proximate causes of vulnerability or developmental needs but modifying these to ensure that they are informed by and inform systemic change. The second and more systemic level involves taking note of the intentions and outcomes of societal change; this level must put a particular focus on understanding the influence of existing rules and values on framing and decision making, and on how to change these to better enable society to anticipate and proactively guide systems on to more desirable pathways in the context of global change. As others have noted (e.g., Leach et al., 2010a; Pelling, 2011), existing rules and values can translate into differential

vulnerability outcomes within society: defining what is "more desirable" and ultimately, more just and fair, thus requires new approaches to governance, and the use of specific tools in planning. Importantly, the perspective of adaptation as part of pathways of change and response emphasises that both levels are required; they are not mutually exclusive, and in fact need to be complementary and mutually informative. Making explicit this distinction in the levels of responses to change is important because each level implies different intentions, outcomes, and planning horizons and therefore requires different capabilities, tools, and processes for its design and implementation.

Fig. 2 seeks to represent a broader conceptualisation of adaptation pathways as part of global change and response, by accommodating these complicating societal dimensions, with the goal of allowing their implications for adaptation research and practice to be more intuitively and explicitly considered. The relevant changes from Fig. 1 conceptualisation add to the 'classic' view of adaptation pathways (Box A in Fig. 2), with an expanded, dynamic, and non-linear decision space, as well as adaptation contexts where the causes of vulnerability are systemic in nature (Boxes B, C, and D in Fig. 2). Each of these is explored below, drawing on case-study examples from this special edition, Table 1, and the broader literature.

The 'classic' view on adaptation pathways (Fig. 1, and Box A in Fig. 2) is clearly a limited and partial conceptualisation of the adaptation challenge. In particular it deals rather peripherally with the risk that a series of relatively incremental steps, whether well intentioned or motivated by narrow political and economic vested interests, may ultimately lead to maladaptation at some level of society as a whole (e.g., Barnett and O'Neill, 2010; Fazey et al., 2011). This may result because of: the adaptive landscape drifting away from current conditions due to climate change, other global drivers of change, and the decisions of many distributed actors; the misdiagnosis of the location of the system within the 'adaptive space' or its proximity to thresholds; or the capturing and closing down of the framing of the issues by powerful actors and institutions to maintain the status quo. The possible implications of these issues are visualised and explored in Box B of Fig. 2. For example, a series of incremental decisions along 'pathway 1' in Fig. 2 seems adaptive but ceases to be so due to a changing adaptive landscape, such that by point e, a cycle of transformative change is needed to recover (pathway 7). However, through the application of various tools, this might be identified earlier (e.g. at decision point d or even c), thus necessitating less rapid and more thorough and considered re-direction. Such tools include deliberative, participatory, long-term visioning and scenario-planning (e.g., Butler et al., 2014; Vervoort et al., 2013), consideration of transformative cycles (Park et al., 2012), clear consideration and balancing of responses that adaptively and reflexively promote stability, resilience, durability or robustness as appropriate to the nature of the dynamics (Leach et al., 2010a; Fig. 3.8; Maru et al., 2014), and decision-making forums that reveal and challenge dominant marginal-change narratives that lock decision-making into reductionist modes that lead to maladaptation (Leach et al., 2010b). This broader perspective lends itself to a wider consideration of the consequences of all responses to change (i.e., not only adaptation actions), particularly those with an insidious nature; this can create awareness both of the various sources of decision uncertainty and how to contextualise and manage these (Stafford Smith et al., 2011), and of opportunities for more explicitly integrating adaptation with mitigation and development (Eriksen et al., 2011; van Vuuren et al., 2011).

The 'classic' view on pathways also does not represent the decision contexts where the current status of the system and its future trajectory are heavily influenced by the past. The broader conceptualisation of pathways presented here acknowledges

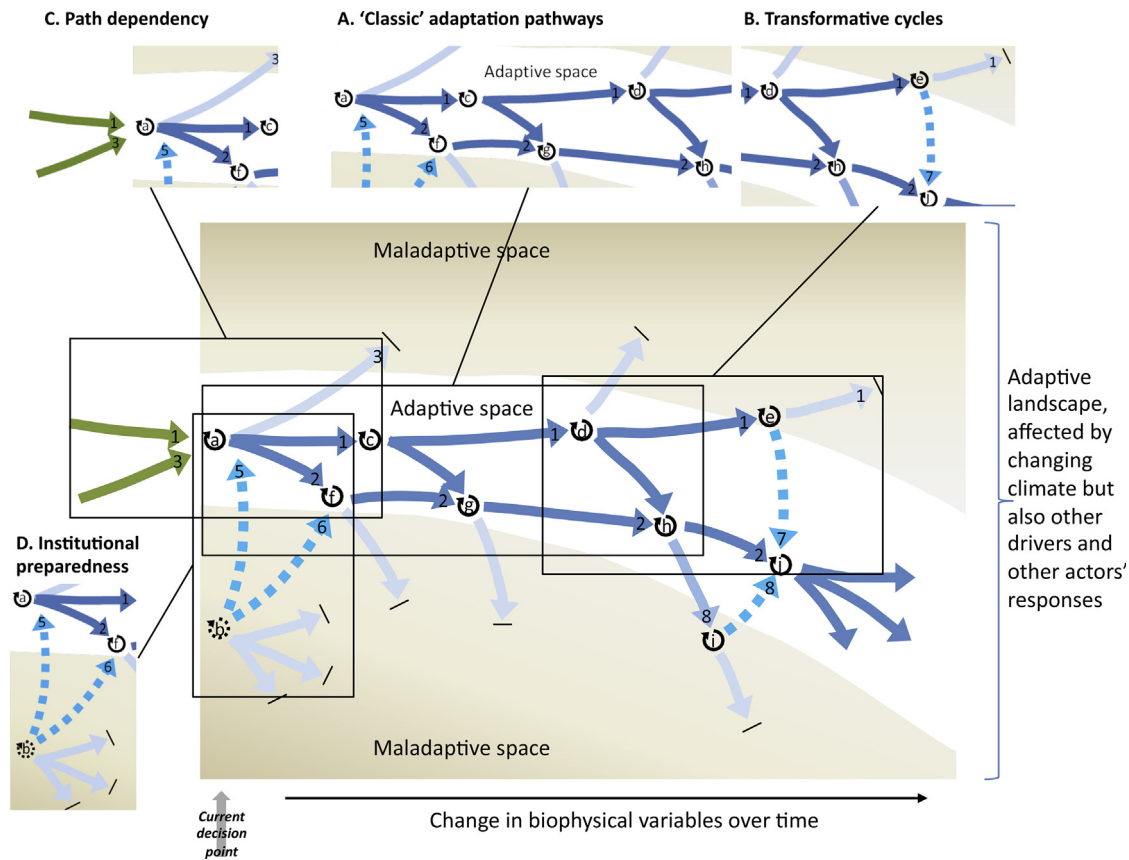


Fig. 2. One decision-making actor's adaptation pathways through an adaptive landscape, building on the metaphor of Fig. 1, where the boundaries between adaptive and maladaptive responses are changing over time, due to biophysical changes, but also due to changes in social and institutional context, including the actions of other decision-makers who may perceive different adaptation pathways. Circle arrows represent decision points, dark blue arrows represent pathways that are contemporaneously adaptive, grey arrows lead to maladaptive dead-ends; dashed blue arrows represent more-or-less transformative pathway segments, and the green arrows show antecedent pathways prior to the current decision cycle (a) faced by the decision-maker of concern. Boxes A–D highlight differences from Fig. 1 that are discussed in the text.

historical determinism and path-dependency (Abel et al., 2011; Peters et al., 2012) and allows users to visualise and consider the implications for adaptation planning (Box C in Fig. 2). Here, although pathways 1, 2, and 3 all seem open at decision point *a*, path contingencies may mean that antecedent pathway 3 is more likely to result in the maladaptive decisions whereas antecedent pathway 1 may pre-adapt decision making better for adaptive pathways 1 and 2. It is thus critical to recognise the importance of historical context (i.e., the positive feedbacks associated with social and cultural practices, technologies, and institutional arrangements (Dobusch and Schüßler, 2012)), and to have a reasonable idea of which pathway a social-ecological system is on, to understand existing vulnerabilities and capacities to adapt and to inform future planning and responses (e.g., the Solomon Islands case study, Table 1).

Furthermore, we may not even be in the adaptive part of the decision space today. Governance arrangements and cultural values and practices evolve over time in response to the prevailing and predominant forces and dynamics of socio-economic, technological, biophysical, ecological and climatic conditions (Young et al., 2008). In the context of climate and global change, however, the inertia in institutions and values means these can become anachronistic and fail to serve their purpose of enabling societal processes (such as research and decision-making) for realising fair, legitimate, and effective allocations and uses of resources. The broadened conceptualisation of adaptation proposed here allows for the implications of this to be visualised and explored (Box D in Fig. 2). If decision-makers are not even currently in the adaptive

space (e.g., coastal local councils in Australia and the USA; Table 1), as at decision point *b*, then all pathways may be maladaptive. In this case, transformations of the institutional arrangements or cultural values are needed, either through dramatic intervention (pathway 5) or through strongly directed incremental change (pathway 6) (Gorddard et al., 2012; Butler et al., 2014). In both cases intervention from higher levels of governance is likely to be needed, but is often only forthcoming in response to disasters or catastrophic events due to vested interests in the status quo (Pelling, 2011).

There are numerous additional implications of this broader conceptualisation for adaptation research and practice, many of which are explored in the papers in this special section. For example, this broader framing ensures decision makers more readily recognise that various desirable and undesirable pathways can emerge from an intervention and that adopting a narrow focus on simple cause-effect relationships, as when adapting to proximate causes of vulnerability, can lead to unintended or mal-adaptive consequences (Sterner et al., 2006). An often cited example of this is the response of building more flood defences which can affect perceptions of risk and lead to greater problems, or can reinforce existing tendencies for people to look towards external agencies for solutions, thereby reducing some opportunities for more transformative changes (Newell and Wasson, 2002). Instead, by allowing both the root and proximate causes to be simultaneously considered, as this broader conceptualisation of adaptation pathways does, decision-makers can be open to direct and indirect pathways for

achieving desirable outcomes (e.g., Butler et al., 2014; Maru et al., 2014).

The pathways perspective implies an iterative and ongoing approach, informed by a strategic vision, that enables experimentation and learning so that choices along pathways can be altered in response to predefined triggers (Rosenzweig and Solecki, 2013). This conceptualisation also implies a deeper consideration of how adaptation can potentially reduce flexibility or limit opportunities (e.g., by further commitment to a specific infrastructure design, power relations or distribution of rights, rather than complete reconsideration of it) and potentially lead to rigidity. It further implies the need for a shift to longer-term programmes of integrated research and practice (which existing institutions and organisations are not particularly well designed to do) that are solution oriented and comprise multiple complementary projects better designed to embed in the context and do the necessary monitoring and reflection (e.g., Future Earth, 2013). Key to delivery of such programmes is carefully designed processes of knowledge exchange, participation and negotiation that enhance ownership, fairness and responsibility while empowering participants to take action (Stringer et al., 2006). Such approaches are particularly relevant for helping address the ‘key issues’ listed for the case studies in Table 1 (column 4).

Coupled with the analysis presented here, the framing of Fig. 2 highlights some key foci for adaptation research and practice efforts (Leach et al., 2010a; Smith and Stirling, 2010; Pelling, 2011; Fischer et al., 2012): building the capacity for critical consciousness and actor reflection (i.e., “reflexivity”) on established institutions and power distributions; creating space and opportunities for new collaborations in innovation and experimentation of alternative values, ideas and practices within protected niches; providing legitimate, transparent and fair forums where actors with different levels of power and agency can actively negotiate changes to prevailing distributions of resources, rights and responsibilities; and supporting the creation of shadow networks of individuals and organisations in order to disseminate, popularise and mainstream successes from these niches.

5. Conclusion

As the world seems increasingly likely to face a future with more than 2 °C warming, it becomes increasingly important to move beyond impacts and vulnerabilities to adaptation action. Yet the uncertain and complex nature of future change poses significant challenges. We thus call for further exploration of the theoretical, methodological and procedural underpinnings of our proposed broader conceptualisation of adaptation, with an eye to more in-depth and previously ‘non-traditional’ considerations of adaptation’s complex role. For many of us working in the adaptation field, such approaches are likely to take us well out of our comfort zones; but further towards truly effective and meaningful intervention and change. The case studies in Table 1 exemplify what this might entail. For example, the US and Australian local government case studies illustrate how path-dependencies and powerful vested interests hamper urgent transformational responses. Here our proposed pathways approach could provide a heuristic and the necessary guidance for the opening up of the policy processes through participatory deliberation and negotiation; this could trigger the creation of mechanisms for funding and protecting small-scale trials of innovative policy alternatives in order to build the evidence base for novel effective transformative responses, and supporting self organisation and social networks so communities can exploit extreme events as triggers of transformational change. Comparably, the approach would help explore a more integrated approach in the NAPAs, South African and Solomon Islands case studies. The rest of this special edition comprises contributions spanning some areas of

the required theory, as well as lessons from other case study experiences.

The capacities required to develop and implement this broader conceptualisation of adaptation pathways will be heavily influenced by the extent to which stakeholders can learn from the experimentation of others via social and organisational networks. Hence, we also reiterate the calls of Fischer et al. (2012) and Nelson (2011) not only to consider the ‘technical fix’ type solutions for responding to social and environmental change, but also to conceptualise and use exposure and responses of people to the current impacts of climate change as a way to reflect on and reconsider the social norms and societal values that underlie existing problems. This should encourage greater responsiveness and reorganisation of institutional structures that are likely to lead to more sustainable trajectories. As Fischer et al. (2012) point out, focusing on such underlying issues is challenging and difficult and requires all sectors of society to reflect on their behaviours and practices, including the research community. Reconceptualising adaptation as part of pathways of change and response increases emphasis on such vital underlying issues.

Acknowledgements

Thanks to Andy Reisinger for discussions around Fig. 1. We are grateful for valuable comments by an anonymous reviewer. Funding was provided by the CSIRO Climate Adaptation Flagship under the Enabling Adaptation Pathways project.

References

- Abel, N., Gorddard, R., Harman, B., Leitch, A., Langridge, J., Ryan, A., Heyenga, S., 2011. Sea level rise, coastal development and planned retreat: analytical framework, governance principles and an Australian case study. *Environmental Science & Policy* 14, 279–288.
- Acosta-Michlik, L., Kelkar, U., Sharma, U., 2008. A critical overview: local evidence on vulnerabilities and adaptations to global environmental change in developing countries. *Global Environmental Change* 18 (4) 539–542.
- Adger, W., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D., Naess, L., Wolf, J., Wreford, A., 2009. Are there social limits to adaptation to climate change? *Climatic Change* 93 (3) 335–354.
- Adger, W.N., Agrawala, S., Mirza, M.M.Q., Conde, C., O’Brien, K., Pulhin, J., Pulwarty, R., Smit, B., Takahashi, K., 2007. Assessment of adaptation practices, options, constraints and capacity. *Climate change 2007: impacts, adaptation and vulnerability*. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (Eds.), *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, pp. 717–743.
- Allen, M.G., Bourke, R.M., Evans, B.R., Iramu, E., Maemouri, R.K., Mullen, B.F., Pollard, A.A., Wairiu, M., Watoto, C., Zotalis, S., 2006. *Solomon Islands Smallholder Agriculture Study: vol. 4, Provincial Reports* AusAid Australian Government, Canberra.
- Amundsen, H., Berglund, F., Westskog, H., 2010. Overcoming barriers to climate change adaptation – a question of multilevel governance? *Environment and Planning C: Government and Policy* 28 (2) 276–289.
- Anguelovski, I., Carmin, J., 2011. Something borrowed, everything new: innovation and institutionalization in urban climate governance. *Current Opinion in Environmental Sustainability* 3 (3) 169–175.
- Archer, E.R.M., Oettlé, N.M., Louw, R., Tadross, M.A., 2008. ‘Farming on the edge’ in arid Western South Africa: adapting to climate change in marginal environments. *Geography* 93 (2) 98–107.
- Atwell, R.C., Schulte, L.A., Westphal, L.M., 2008. Linking resilience theory and diffusion of innovations theory to understand the potential for perennials in the U.S. *Corn Belt. Ecology and Society* 14 (1) 30., <http://www.ecologyandsociety.org/vol14/iss1/art30/>.
- Baker, MacKenzie, 2011. *Local council risk of liability in the face of climate change – resolving uncertainties*. In: *A Report for the Australian Local Government Association*. Baker & Mackenzie.
- Barnett, J., O’Neill, S., 2010. Maladaptation. *Global Environmental Change* 20, 211–213.
- Bassett, T.J., Fogelman, C., 2013. Déjà vu or something new? The adaptation concept in the climate change literature. *Geoforum* 48 (0) 42–53.
- Berrang-Ford, L., Ford, J.D., Paterson, J., 2011. Are we adapting to climate change? *Global Environmental Change* 21 (1) 25–33.
- Bryan, E., Deressa, T.T., Gbetibouo, G.A., Ringler, C., 2009. Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science & Policy* 12 (4) 413–426.

- Burch, S., 2010. Transforming barriers into enablers of action on climate change: insights from three municipal case studies in British Columbia, Canada. *Global Environmental Change* 20 (2) 287–297.
- Butler, J.R.A., Suadnya, W., Puspadi, K., Sutaryono, Y., Wise, R.M., Skewes, T., Kirono, D., Bohensky, E., Handayani, T., Habibi, P., Kisman, M., Suharto, I., Hanartani, Supartarningsih, S., Fachry, A., Duggan, K., 2014. Framing the application of adaptation pathways for rural livelihoods and global change in eastern Indonesian islands. *Global Environmental Change* 28, 368–382.
- Carmin, J., Anguelovski, I., Roberts, D., 2012. Urban climate adaptation in the global South: planning in an emerging policy domain. *Journal of Planning Education and Research* 32 (1) 18–32.
- Carter, T.R., Jones, R.N., Lu, X., Bhadwal, S., Conde, C., Mearns, L.O., O'Neill, B.C., Rounsevell, M.D.A., Zurek, M.B., 2007. New assessment methods and the characterisation of future conditions. *Climate change 2007: impacts, adaptation and vulnerability*. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (Eds.), *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, pp. 133–171.
- Checkland, P., Poulter, J., 2006. *Learning for Action: A Short Definitive Account of Soft Systems Methodology and Its Use for Practitioners, Teachers and Students*. Wiley and Son, West Sussex.
- Chhetri, N.B., Easterling, W.E., Terando, A., Mearns, L., 2010. Modeling path dependence in agricultural adaptation to climate variability and change. *Annals of the Association of American Geographers* 100 (4) 894–907.
- Connell, J., 2010. Pacific islands in the global economy: paradoxes of migration and culture. *Singapore Journal of Tropical Geography* 31, 115–129.
- Cundill, G., Cumming, G.S., Biggs, D., Fabricius, C., 2012. Soft systems thinking and social learning for adaptive management. *Conservation Biology* 26, 13–20.
- Dessai, S., Hulme, M., Lempert, R., Pielke, R.J., 2009. Do we need better predictions to adapt to a changing climate? *EOS* 90 (13) 111–112.
- Deressa, T.T., Hassan, R.M., Ringer, C., Alemu, T., Yesuf, M., 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change* 19 (2) 248–255.
- Dessai, S., O'Brien, K., Hulme, M., 2007. Editorial: on uncertainty and climate change. *Global Environmental Change* 17 (1) 1–3.
- Dessai, S., van der Sluijs, J., 2007. *Uncertainty and Climate Change Adaptation: A Scoping Study*. Report prepared for the Netherlands Environmental Assessment Agency Copernicus Institute for Sustainable Development and Innovation, Utrecht University, Utrecht, The Netherlands.
- Driver, A., Sink, K.J., Nel, J.N., Holness, S., Van Niekerk, L., Daniels, F., Jonas, Z., Majied, P.A., Harris, L., Maze, K., 2012. *National biodiversity assessment 2011: an assessment of South Africa's biodiversity and ecosystems*. In: *Synthesis Report*. South African National Biodiversity Institute and Department of Environmental Affairs, Pretoria.
- Dobusch, L., Schüßler, E., 2012. Theorizing path dependence: a review of positive feedback mechanisms in technology markets, regional clusters, and organizations. *Industrial and Corporate Change* 22 (3) 617–647.
- Dovers, S.R., Hezri, A.A., 2010. Institutions and policy processes: the means to the ends of adaptation. *Wiley Interdisciplinary Reviews: Climate Change* 1 (2) 212–231.
- Downing, T.E., 2012. Views of the frontiers in climate change adaptation economics. *WIREs Climate Change* 3, 161–170. <http://dx.doi.org/10.1002/wcc.157>.
- Eakin, H., Luers, A.L., 2006. Assessing the vulnerability of social–environmental systems. *Annual Review of Environment and Resources* 31 (1) 365–394.
- Eakin, H.C., Patt, A.G., 2011. Are adaptation studies effective, and what can enhance their practical impact? *Wiley Interdisciplinary Reviews: Climate Change* 2 (2) 141–153.
- Enfors, E.I., Gordon, L.J., Peterson, G.D., Bossio, D., 2008. Making investments in dryland development work: participatory scenario planning in the Makanya Catchment, Tanzania. *Ecology and Society* 13.
- Ensor, J., Berger, R., 2009. *Understanding Climate Change Adaptation: Lessons from Community-Based Approaches*. Practical Action ISBN-10:1853396834.
- Eriksen, S., Aldunce, P., Bahinipati, C.S., Martins, R.D., Molefe, J.I., Nhemachena, C., O'Brien, K., Olorunfemi, F., Park, J., Sugna, L., Ulsrud, K., 2011. When not every response to climate change is a good one: identifying principles for sustainable adaptation. *Climate and Development* 3, 7–20.
- Fankhauser, S., Smith, J.B., Tol, R.S.J., 1999. Weathering climate change: some simple rules to guide adaptation decisions. *Ecological Economics* 30, 67–78.
- Fazey, I., Gamarra, J.G.P., Fischer, J., Reed, M.S., Stringer, L.C., Christie, M., 2010a. Adaptation strategies for reducing vulnerability to future environmental change. *Frontiers in Ecology and the Environment* 8 (8) 414–422.
- Fazey, I., Kesby, M., Evelyn, A., Latham, I., Wagatora, D., Hagasua, J.-E., Reed, M.S., Christie, M., 2010b. A three-tiered approach to participatory vulnerability assessment in the Solomon Islands. *Global Environmental Change* 20 (4) 713–728.
- Fazey, I., Pettorelli, N., Kenter, J., Wagatora, D., Schuett, D., 2011. Maladaptive trajectories of change in Makira, Solomon Islands. *Global Environmental Change* 21 (4) 1275–1289.
- Fischer, J., Dyball, R., Fazey, I., Gross, C., Dovers, S., Ehrlich, P.R., Brulle, R.J., Christensen, C., Borden, R.J., 2012. Human behavior and sustainability. *Frontiers in Ecology and the Environment* 10 (3) 153–160.
- 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) 20. <http://www.ecologyandsociety.org/vol15/iss4/art20/>.
- Ford, J.D., Berrang-Ford, L., Paterson, J., 2011. A systematic review of observed climate change adaptation in developed nations. *Climate Change* 106, 327–336.
- Funtowicz, S.O., Ravetz, J.R., 1993. Science for the post-normal age. *Futures* 25 (7) 739–755.
- Füssel, H.M., 2007. *Vulnerability: a generally applicable conceptual framework for climate change research*. *Global Environmental Change* 17 (2) 155–167.
- Future Earth, 2013. *Future Earth Initial Design, Future Earth Interim Secretariat*. ICSU, Paris. http://www.icsu.org/future-earth/media-centre/relevant_publications/future-earth-initial-design-report.
- Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. *Research Policy* 36, 399–417.
- Gibbs, M., Hill, T., 2011. *Coastal climate change risk – legal and policy responses in Australia*. In: Report Prepared by Blake Dawson for the Commonwealth of Australia. Department of Climate Change and Energy Efficiency.
- Gorddard, R., Wise, R.M., Alexander, K., Langston, A., Leitch, A., Dunlop, M., Ryan, A., Langridge, J., 2012. *Striking the balance: Coastal development and ecosystem values*. Report prepared for the Australian Department of Climate Change and Energy Efficiency and the CSIRO Climate Adaptation National Research Flagship CSIRO ISBN: 978-1-922003-38-6.
- Haasnoot, M., Kwakkel, J.H., Walker, W.E., ter Maat, J., 2013. Dynamic adaptive policy pathways: a method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change* 23 (2) 485–498.
- Hallegatte, S., 2009. Strategies to adapt to an uncertain climate change. *Global Environmental Change* 19, 240–247.
- Hammill, A., Tanner, T., 2011. *Harmonizing Climate Risk Management: Adaptation Screening and Assessment Tools for Development*. IISD Publications Centre.
- Hansen, J., Sato, M., Ruedy, R., Lo, K., Lea, D.W., Medina-Elizade, M., 2006. *Global Temperature Change*. Proceedings of the National Academy of Sciences 103, 29.
- Head, B., 2010. Three lenses of evidence-based policy. *The Australian Journal of Public Administration* 67 (1) 1–11.
- Herriman, J., Kuruppu, N., Gero, A., Mukheibir, P., 2012. *Cross-scale barriers to climate change adaptation in local government, Australia*. In: Workshop Two Report prepared for the National Climate Change Adaptation Research Facility. Institute for Sustainable Futures, University of Technology, Sydney.
- Hinkel, J., 2011. "Indicators of vulnerability and adaptive capacity": towards a clarification of the science–policy interface. *Global Environmental Change* 21, 198–208.
- Huntjens, P., Lebel, L., Pahl-Wostl, C., Camkin, J., Schulze, R., Kranz, N., 2012. Institutional design propositions for the governance of adaptation to climate change in the water sector. *Global Environmental Change* 22 (1) 67–81.
- Huq, S., Khan, M.R., 2006. *Equity in National Adaptation Programs of Action (NAPAs): the case of Bangladesh*. In: Adger, W.N., Paavola, J., Huq, S., Mace, M.J. (Eds.), *Fairness in Adaptation to Climate Change*. MIT Press, Cambridge, Massachusetts, pp. 131–153.
- Jones, H.P., Hole, D.G., Zavaleta, E.S., 2012. *Harnessing nature to help people adapt to climate change*. *Nature Climate Change* 2 (7) 504–509.
- Juhola, S., Keskkitalo, E.C.H., Westerhoff, L., 2011. Understanding the framings of climate change adaptation across multiple scales of governance in Europe. *Environmental Politics* 20 (4) 445–463.
- Kabubo-Mariara, J., 2009. *Global warming and livestock husbandry in Kenya: impacts and adaptations*. *Ecological Economics* 68 (7) 1915–1924.
- Kalame, F., Kudejira, D., Nkem, J., 2011. *Assessing the process and options for implementing National Adaptation Programmes of Action (NAPA): a case study from Burkina Faso*. *Mitigation and Adaptation Strategies for Global Change* 16, 535–553.
- Leach, M., Scoones, I., Stirling, A., 2010a. *Dynamic Sustainabilities*. Technology, Environment, Social Justice Earthscan, London.
- Leach, M., Scoones, I., Stirling, A., 2010b. *Governing epidemics in an age of complexity: narratives, politics and pathways to sustainability*. *Global Environmental Change* 20 (3) 369–377.
- Lempert, R.J., Popper, S.W., Bankes, S.C., 2003. *Shaping the Next One Hundred Years: New Methods for Quantitative, Long-Term Policy Analysis*. Report prepared for the RAND Pardee Centre, Santa Monica RAND. http://www.rand.org/pubs/monograph_reports/2007/MR1626.pdf.
- Marshall, N.A., Park, S.E., Adger, W.N., Brown, K., Howden, S.M., 2012. Transformational capacity and the influence of place and identity. *Environmental Research Letters* 7 (3) 034022.
- Maru, Y.T., Stafford Smith, M., Sparrow, A., Pinhoc, P.F., Dube, O.P., 2014. *A linked resilience and vulnerability framework for adaptation pathways in remote disadvantaged communities*. *Global Environmental Change* 28, 337–350.
- MECDM, 2012. *Solomon Islands national climate change policy: 2012–2017*. In: Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM). Solomon Islands Government, Honiara. http://www.gcca.eu/sites/default/files/catherine.paul/si_climate_change_policy.pdf.
- MECMH, 2008. *Solomon Islands National Adaptation Programmes of Action*. In: Ministry of Environment, Conservation and Meteorology. Solomon Islands Government, Honiara.
- Moser, S.C., 2010. *Now more than ever: the need for more societally relevant research on vulnerability and adaptation to climate change*. *Applied Geography* 30 (4) 464–474.
- Moser, S.C., Ekstrom, J.A., 2010. *A framework to diagnose barriers to climate change adaptation*. *Proceedings of the National Academy of Sciences* 107, 22026–22031.
- Moser, S.C., Jeffress Williams, S., Boesch, D.F., 2012. *Wicked challenges at land's end: managing coastal vulnerability under climate change*. *Annual Review of Environment and Resources* 37 (1) 51–78.

- Nelson, D.R., 2009. Conclusions: transforming the world. In: Adger, W.N., Lorenzoni, I., O'Brien, K.L. (Eds.), *Adapting to Climate Change: Thresholds, Values, Governance*. Cambridge University Press, Cambridge, pp. 491–500.
- Nelson, J.A., 2011. Ethics and the economist: what climate change demands of us. *Ecological Economics* 85, 145–154.
- Newell, B., Wasson, R., 2002. Social system vs solar system: why policy makers need history. In: Castelein, S., Otte, A. (Eds.), *Conflict and Cooperation Related to International Water Resources: Historical Perspectives*. UNESCO, Grenoble, pp. 3–17.
- Newig, J., Voß, J.-P., Monstadt, J., 2007. Editorial. Governance for sustainable development in the face of ambivalence, uncertainty and distributed power: an introduction. *Journal of Environmental Policy and Planning* 9 (3) 185–192.
- Nielsen, J.Ø., Reenberg, A., 2010. Cultural barriers to climate change adaptation: a case study from Northern Burkina Faso. *Global Environmental Change* 20 (1) 142–152.
- O'Brien, K., 2012. Global environmental change II: from adaptation to deliberate transformation. *Progress in Human Geography* 36 (5) 667–676.
- O'Brien, K., Hayward, B., Berkes, F., 2009. Rethinking social contracts: building resilience in a changing climate. *Ecology and Society* 14 (2) 12.
- O'Brien, K.L., Wolf, J., 2010. A values-based approach to vulnerability and adaptation to climate change. *Wiley Interdisciplinary Reviews: Climate Change* 1 (2) 232–242.
- Ostrom, E., 2010. A multi-scale approach to coping with climate change and other collective action problems. *The Solutions Journal* 1 (2) 27–36.
- Pahl-Wostl, C., 2009. A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change* 19 (3) 354–365.
- Park, S.E., Marshall, N.A., Jakku, E., Dowd, A.M., Howden, S.M., Mendham, E., Fleming, A., 2012. Informing adaptation responses to climate change through theories of transformation. *Global Environmental Change* 22 (1) 115–126.
- Paavola, J., Adger, W.N., 2006. Fair adaptation to climate change. *Ecological Economics* 56 (4) 594–609.
- Pelling, M., 2011. *Adaptation to Climate Change: From Resilience to Transformation*. Routledge, London.
- Peters, I., Christophos, I., Funder, M., Friis-Hansen, E., Pain, A., 2012. *Understanding institutional change: A review of selected literature for the Climate Change and Rural Institutions Research Programme*. DIIS DIIS Working Paper 2012:12.
- Pielke, R.J., 2007. *The Honest Broker: Making Sense of Science in Policy and Politics*. Cambridge University Press.
- Poyar, K.A., Beller-Simms, N., 2010. Early responses to climate change: an analysis of seven U.S. state and local climate adaptation planning initiatives. *Weather, Climate, and Society* 2 (3) 237–248.
- Ranger, N., Millner, A., Dietz, S., Fankhauser, S., Lopez, A., Ruta, G., 2010. *Adaptation in the UK: A decision-making process*. Policy Brief Grantham Research Institute on Climate Change and the Environment/the Centre for Climate Change Economics and Policy.
- Reeder, T., Ranger, N., 2011. How do you adapt in an uncertain world? Lessons from the Thames Estuary 2100 project. World Resources Report. World Resources, Washington, DC. , <http://www.worldresourcesreport.org>.
- Reid, W.V., Berkes, F., Wilbanks, T., Capistrano, D. (Eds.), 2006. *Bridging Scales and Knowledge Systems Concepts and Applications in Ecosystem Assessment*. Island Press, London. ISBN 1-59726-037-1 <http://www.millenniumassessment.org/en/Bridging.html>.
- Rickards, L., Howden, S.M., 2012. Transformational adaptation: agriculture and climate change. *Crop and Pasture Science* 63 (3) 240–250.
- Rittel, H.W.J., Webber, M.M., 1973. Dilemmas in a general theory of planning. *Policy Sciences* 4 (2) 155–169.
- Rodima-Taylor, D., Olwig, M.F., Chhetri, N., 2012. Adaptation as innovation, innovation as adaptation: an institutional approach to climate change. *Applied Geography* 33 (0) 107–111.
- Rosenzweig, C., Solecki, W.D., 2013. Hurricane Sandy and adaptation pathways in New York: lessons from a First-Responder City. *Global Environmental Change*.
- Saito, N., 2012. Mainstreaming climate change adaptation in least developed countries in South and Southeast Asia. *Mitigation and Adaptation Strategies for Global Change* 18 (6) 825–849.
- Sarewitz, D., 2004. How science makes environmental controversies worse. *Environmental Science and Policy* 7 (5) 385–403.
- Sarewitz, D., Pielke, R.J., Keykhah, M., 2003. Vulnerability and risk: some thoughts from a political and policy perspective. *Risk Analysis* 23 (4) 805–810.
- Schwarz, A.-M., Béné, C., Bennett, G., Boso, D., Hilly, Z., Paul, C., Posala, R., Sibiti, S., Andrew, N., 2011. Vulnerability and resilience of remote rural communities to shocks and global changes: empirical analysis from Solomon Islands. *Global Environmental Change* 21 (3) 1128–1140.
- Sietz, D., Boschütz, M., Klein, R.J.T., 2011. Mainstreaming climate adaptation into development assistance: rationale, institutional barriers and opportunities in Mozambique. *Environmental Science & Policy* 14 (4) 493–502.
- Smith, A., Stirling, A., 2010. The politics of social-ecological resilience and sustainable sociotechnical transitions. *Ecology and Society* 15 (1) 11.
- Stafford Smith, M., Horrocks, L., Harvey, A., Hamilton, C., 2011. Rethinking adaptation for a 4C World. *Philosophical Transactions of the Royal Society A* 369, 196–216.
- Stern, N., 2006. Stern review on the economics of climate change. HM Treasury. http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm.
- Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A., Kalof, L., 1999. A value-belief-norm theory of support for social movements: the case of environmentalism. *Research in Human Ecology* 6 (2) 81–97.
- Sterner, T., Troell, M., Vincent, J., Aniyar, S., Barrett, S., Brock, W., Carpenter, S., Chopra, K., Ehrlich, P., Hoel, M., Levin, S., Maler, K.G., Norberg, J., Pihl, L., Soderqvist, T., Wilen, J., Xepapadeas, A., 2006. Quick fixes for the environment: part of the solution or part of the problem. *Environment* 48, 20–27.
- Stirling, A., 2006. Analysis, participation and power: justification and closure in participatory multi-criteria analysis. *Land Use Policy* 23 (1) 95–107.
- Stirling, A.C., Scoones, I., 2009. From risk assessment to knowledge mapping: science, precaution and participation in disease ecology. *Ecology and Society* 14 (2) 14. , <http://www.ecologyandsociety.org/vol14/iss2/art14/>.
- Storbjörk, S., 2010. 'It takes more to get a ship to change course': barriers for organizational learning and local Climate adaptation in Sweden. *Journal of Environmental Policy & Planning* 12 (3) 235–254.
- Stringer, L.C., Dougill, A.J., Fraser, E., Hubacek, K., Prell, C., Reed, M.S., 2006. Unpacking "participation" in the adaptive management of social-ecological systems: a critical review. *Ecology and Society* 11 (2) 39.
- Swenson, D.X., Anstett, D.N., 1997. Solution-Focused Problem Solving: Finding Exceptions That Work. <http://faculty.css.edu/dswenson/web/Solfocus.htm>.
- Tol, R.S.J., 2010. The economic impact of climate change. *Perspektiven der Wirtschaftspolitik* 11, 13–37.
- Tompkins, E.L., Adger, W.N., Boyd, E., Nicholson-Cole, S., Weatherhead, K., Arnell, N., 2010. Observed adaptation to climate change: UK evidence of transition to a well-adapting society. *Global Environmental Change* 20 (4) 627–635.
- Turner, B.L., Kasperson, R.E., Matsone, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luerse, A., Martellog, M.L., Polsky, C., Pulsipher, A., Schiller, A., 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences* 100 (14) 8074–8079.
- UNEP, 2012. *PROVIA Guidance on assessing vulnerability, impacts and adaptation (VIA)*, The Programme of Research on Climate Change Vulnerability, Impacts and Adaptation (PROVIA). United Nations Environment Programme (UNEP), www.provia-climatechange.org/.
- van Aalst, M.K., Cannon, T., Burton, I., 2008. Community level adaptation to climate change: the potential role of participatory community risk assessment. *Global Environmental Change* 18 (1) 165–179.
- van der Brugge, R., Rotmans, J., Loorbach, D., 2005. The transition in Dutch water management. *Regional Environmental Change* 5, 164–176.
- van Vuuren, D.P., Isaac, M., Kundzewicz, Z.W., Arnell, N., Barker, T., Criqui, P., Berkhout, F., Hilderink, H., Hinkel, J., Hof, A., Kitous, A., Kram, T., Mechler, R., Scricciu, S., 2011. The use of scenarios as the basis for combined assessment of climate change mitigation and adaptation. *Global Environmental Change* 21 (2) 575–591.
- Vervoort, M., Thornton, P.K., Kristjansson, P., Foerch, W., Ericksen, P.J., Kok, K., Ingram, J.S., Herrero, M., Palazzo, A., Helfgott, A., Wilkinson, A., 2013. *Food systems futures: towards adaptation pathways across multiple dimensions and levels*. Global Environmental Change, this issue.
- Voß, J.-P., Newig, J., Kastens, B., Monstadt, J., Nölting, B., 2007. Steering for sustainable development: a typology of problems and strategies with respect to ambivalence, uncertainty and distributed power. *Journal of Environmental Policy and Planning* 9 (3) 193–212.
- Wade, D.H., 1968. Critical path analysis and civil engineering industry. *Proceedings of the Institution of Civil Engineers* 39, 289.
- Weaver, C.P., Lempert, R.J., Brown, C., Hall, J.A., Revell, D., Sarewitz, D., 2013. Improving the contribution of climate model information to decision making: the value and demands of robust decision frameworks. *Wiley Interdisciplinary Reviews: Climate Change* 4 (1) 39–60.
- Webb, R.J., McKellar, R., and Kay, R., Climate change adaptation in Australia: Experience, challenges and capacity building, Report submitted to the National Climate Change Adaptation Research Facility, Australia, under review.
- Willows, R., Connell, R. (Eds.), 2003. *Climate Adaptation: Risk, Uncertainty and Decision-Making*. UKCIP, Oxford. , <http://www.ukgbc.org/site/resources/show-resource-details?id=81>.
- World Bank, 2010. *Convenient Solutions to an Inconvenient Truth: Ecosystem-Based Approaches to Climate Change*. The World Bank, Washington, DC. , <http://www.worldbank.org/biodiversity>.
- World Bank, 2012. *Turn Down the Heat: Why a 4 Degree C Warmer World Must Be Avoided*. International Bank for Reconstruction and Development/The World Bank.
- WRI, 2011. *World Resources 2010-2011: Decision Making in a Changing Climate—Adaptation Challenges and Choices*, World Resources Institute (WRI) in Collaboration with the United Nations Development Programme and United Nations Environment Programme and World Bank. WRI, Washington, DC. , http://pdf.wri.org/world_resources_report_2010-2011.pdf.
- Yohe, G., Leichenko, R., 2010. Chapter 2: adopting a risk-based approach. *Annals of the New York Academy of Sciences* 1196 (1) 29–40.
- Young, O.R., King, L.A., Schroeder, H. (Eds.), 2008. *Institutions and Environmental Change: Principal Findings, Applications, and Research Frontiers: Summary for Policy Makers*. The MIT Press, Cambridge.