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# Framing vulnerability and adaptive capacity assessment: Discussion paper

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Helping Australia Adapt to a Changing Climate

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# EXECUTIVE SUMMARY

The purpose of this discussion paper is to briefly highlight various perspectives regarding key concepts associated with climate change vulnerability and adaptation, as well as some of the commonly used methodologies and frameworks for assessing vulnerability, adaptive capacity and risk. It was first written in March 2008 as part of a project by the CSIRO Climate Adaptation Flagship which aimed to build a shared understanding of relevant adaptation concepts and methods, and their utility for facilitating different adaptation challenges.

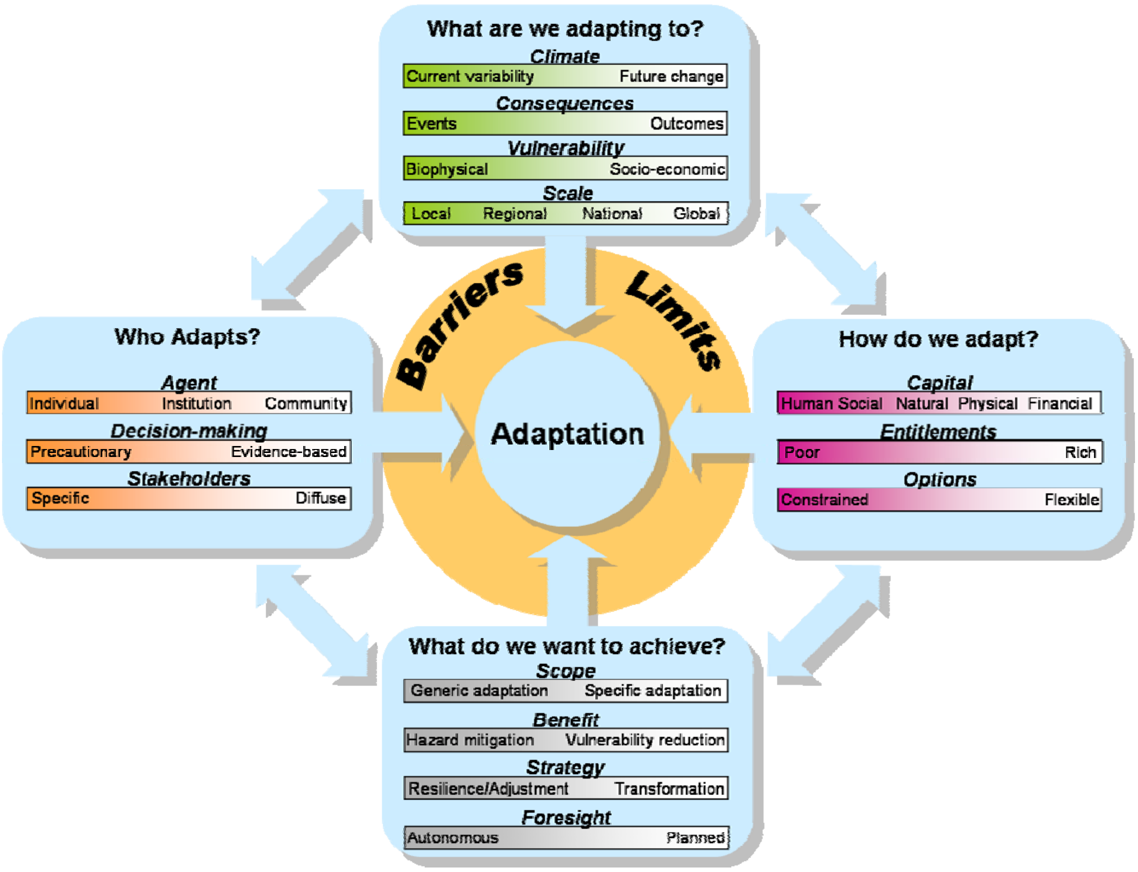


Figure A. Dimensions of adaptation. Adaptation is represented as a process driven by four sets of determinants, with each set comprised of multiple determinants with multiple dimensions. Adaptation barriers and limits disrupt the relationship between determinants and the adaptation process.

One of the central concepts in adaptation research is that of vulnerability. However, there are significant disciplinary differences with respect to how vulnerability is defined and framed. In some instances, it refers to biophysical vulnerability and is thus well-aligned with the concepts of hazard, exposure or event risk. In other uses, however, it emphasises social, economic, cultural and/or political processes that are more aligned with the concepts of resilience, coping capacity, and/or adaptive capacity. Still others employ more integrated conceptualisations of vulnerability as embodiments of both biophysical and socio-economic processes that collectively create the potential for harm. While there is likely little utility in being overly pedantic about definitions, different ways of framing vulnerability do influence assessment methods and, subsequently, information for decision-makers and how it is interpreted. Hence, attempts to develop some level of general agreement about vulnerability may be useful to researchers and end-users alike.

The process of adaptation itself, and therefore necessarily adaptation research, is driven by a broad range of multi-dimensional determinants. For the purposes of this paper, these different determinants are mapped to four core questions (Figure A). For example, traditional adaptation research has focused on the question of 'what are we adapting to?', yielding a large body of work on climate projections as well as impact and vulnerability assessment. Yet there are different ways of framing answers to this question, depending on the scale at which one is working, and whether one is focused on biophysical processes and events or socioeconomic processes and outcomes.

More recently, attention has shifted to some of the more neglected determinants of adaptation, such as capital and entitlements as well as agents and their decision-making processes. Furthermore, as adaptation research becomes more closely integrated with risk management, policy sciences and decision-making, questions surrounding the goals of adaptation strategies have also become more prevalent. Rather than simply considering adaptation policies and goals in the wake of an assessment process, there is increasing emphasis on using such goals to drive assessments.

There has been significant recent focus on the question of barriers and limitations to adaptation – factors that confound adaptation by, for example, inhibiting the delivery of capital into adaptation implantation, creating conflict among stakeholders and decision-makers, or contributing to the selection of adaptation goals that are rational over the short-term, but ultimately reinforce unsustainable strategies. While related to research into adaptive capacity, there is some acknowledgement that the concept of adaptive capacity perhaps has not been sufficiently inclusive to capture the myriad obstacles to adaptation.

One of the critical challenges to adaptation research that emerges from this paper is that of scale, particularly with respect to spatial and temporal scales, but also that associated with the complexity of social interactions involved in adaptation decision-making.

From a systems perspective, adaptation is a nested process – a vulnerability observed at one scale of the system may affect activities at another scale (Figure B). Similarly, adaptation responses implemented at one scale can, for better or worse, reverberate throughout the system. Meanwhile, the rate of such interactions and feedbacks may vary, on the order of hours to years, depending on the magnitude of the impact or adaptation response and the nature of the affected system.

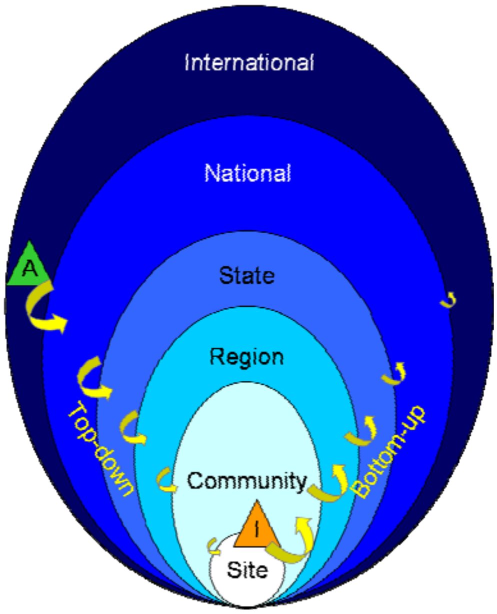


Figure B. The nested nature of climate change adaptation challenges. I indicates a local impact with cascading consequences at higher spatial scales. A indicates a high-level adaptation action that trickles down to affect local activities. The size of the arrows indicates the relative rate of transfer (i.e. large arrows are associated with rapid consequences to neighbouring scales, while small arrows are associated with more prolonged effects).

While a diversity of assessment approaches have been developed to inform stakeholders about vulnerability, risk and the efficacy of different adaptation policies and measures, it remains arguable whether the existing toolkit is sufficient to facilitate future adaptation. Many assessment methods neglect the complexities of both vulnerability and adaptation, particularly the decision framework needed to ensure assessment is ultimately translated into action. A central challenge is the identification of assessment approaches that reflect the nested nature of both vulnerability and adaptation, while avoiding paralysis through complexity. This may require the development of a novel framework and set of methods or simply the more thoughtful application of the existing toolkit.

# 1. INTRODUCTION

CSIRO's Climate Adaptation Flagship (CAF) represents a $45 million dollar investment in Australia's future that is designed to drive the fundamental research required to facilitate successful adaptation to climate variability and climate change. The Flagship is just one of a broad range of research and policy activities occurring throughout Australian research institutions, government agencies and the private sector (see Section 2.1). Similar efforts are underway or already well-established at the international level (e.g. Tyndall Centre in the UK, Climate and Weather Impact Assessment Science Program at the National Centre for Atmospheric Research in the USA, Potsdam Institute for Climate Impact Research in Germany).

The emphasis on adaptation as a risk management strategy has in many respects gained parity with that of greenhouse gas mitigation, and in some circles, may even have wider appeal. For example, a cursory examination of peer-reviewed publications referring to "climate change and adaptation" or "climate change and mitigation" indicates that interest in both has grown steadily since 1990 (Figure 1). However, adaptation publications have generally exceeded those for mitigation.

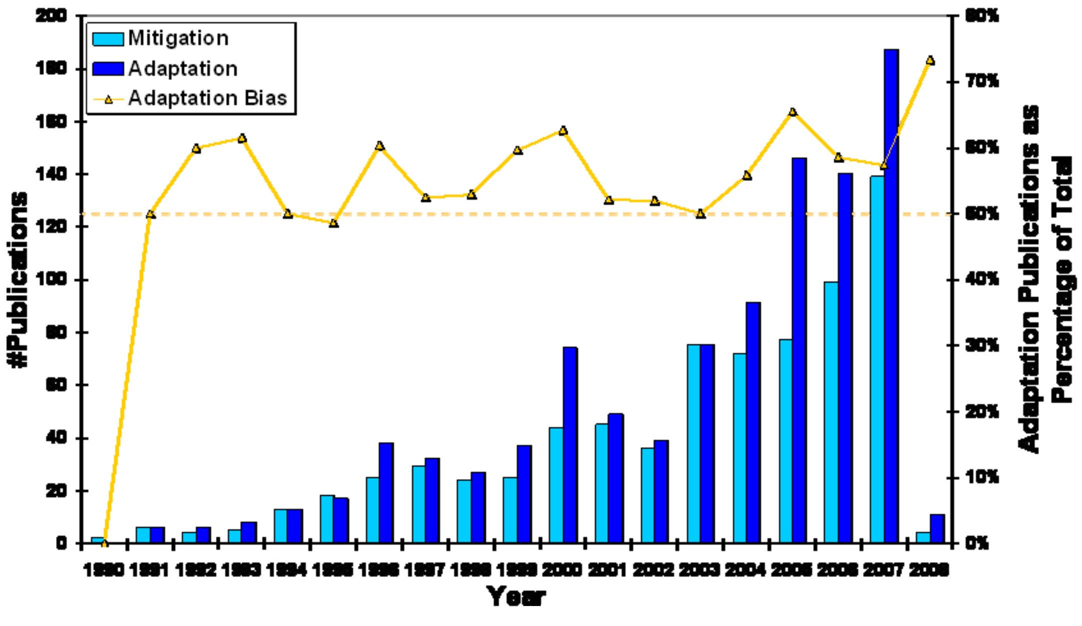


Figure 1. Number of publications associated with key words "climate change" and "mitigation" or "adaptation." Adaptation bias is simply the number of adaptation publications in any year minus mitigation publications. Source: ISI Web of Science.

A number of different factors may potentially account for this surge in adaptation research:

- Recognition that climate change is a problem has shifted discussions to the design of response strategies

- Climate adaptation is closely aligned the principles of sustainable development, with climate change being recognised as a potential threat to development, particularly in the least developed nations (IPCC, mainstreaming)
- Recognition of the inevitability of at least some existing and future climate change, with mitigation policy being seen as having a low likelihood of limiting global warming to less than 2°C above the pre-industrial concentration (Hare publications; Jones publications)
- Expansion of socially responsible decision-making
- Expansion of systems approaches to addressing social problems.

Nevertheless, while research into adaptation by natural and social scientists has expanded in recent years, the process of adaptation largely lies outside of the scientific realm. Rather, individuals and institutions must identify adaptation policies and measures that are aligned with their management goals and make decisions regarding their implementation. Hence, understanding of the concept of adaptation, how it might be pursued and why remains limited within many institutions and organisations.

To pave the way for the CAF to support adaptation within Australia, a ‘Foundation Project’ was undertaken to clarify the conceptualisation of climate change vulnerability and adaptation. The goals of the Foundation Project were three-fold:

1. Underpin productive debate, disagreement, research and action to address Australian climate-related vulnerability and adaptive capacity through:
   a. developing a shared appreciation of alternative approaches and general frameworks for understanding impacts, vulnerability and adaptation
   b. agreeing a common lexicon of key terms and concepts
   c. identifying the range of specific tools and methods available, and their suitability for addressing different needs
   d. identifying gaps in data, tools and methods and prospective opportunities for addressing these
   e. highlighting the emphasis of the Flagship on adaptation and adaptive capacity, rather than research only into impacts or vulnerability
2. Contribute to the development and adoption of strategies to enhance synergies across projects and research teams, across research into potential impacts, vulnerabilities, adaptation options, and intervention strategies
3. Contribute to the identification of research priorities expected to contribute to Australian adaptive capacity in the face of climate change.

This document was written as a background paper to initiate discussion and stimulate thinking at a workshop held in Canberra in March 2008 as part of the Foundation Project.

# 2. WHAT IS THE STATUS OF CLIMATE ADAPTATION ACTIVITIES IN AUSTRALIA?

## 2.1 Key players

Research into the nation's vulnerability to climate change has been ongoing for decades. A recent review of climate modelling in Australia traces the investigation of anthropogenic forcing back to the early 1980s (Smith, 2007). Meanwhile, seminal conferences such as Greenhouse 1987 brought national attention to both changes in the climate system and the potential implications for Australian ecosystems and communities (Pearman, 1988), well in advance of the Intergovernmental Panel on Climate Change's (IPCC) assessment process. The Australian Climate Change Science Program has been funding basic research into global and Australian climate change since 1989 (AGO, 2005a, 2005b). The Climate Impacts Group at CSIRO was launched in the late 1980s, and has been a major contributor to impacts and adaptation research. Such efforts have grown steadily over the past decade, to the extent that multiple divisions of CSIRO are currently engaged in research on the effects of climate change both domestically and internationally, across the natural and social sciences.

In 2004, the Australian Greenhouse Office launched its $14.2 million National Climate Change Adaptation Programme, designed to expand assessment efforts on the impacts of climate change and initiate thinking about adaptive responses. In 2007, another wave of investment and collaboration was launched at both the policy level and the level of R&D. The Council of Australian Governments agreed to the National Climate Change Adaptation Framework (NCCAF), which articulates a national agreement among national, state, and territory governments to work both individually and in collaboration to implement policies and measures that promote awareness build adaptive capacity, and facilitate adaptation (COAG, 2007). All of the states have also prepared greenhouse strategies that acknowledge adaptation and are investing in a broad range of adaptation-related projects. This reflects the important responsibilities that state governments have in regard to planning and infrastructure management for climate change. Activity within local government on adaptation is also expanding rapidly (AGO, 2007; Government of Victoria, 2007)

Meanwhile, the $126 million channelled through the Department of Climate Change will play a key role in implementing parts of the NCCAF and "*represents the Australian Government's focal point for*" climate change adaptation. The related research effort will be managed by the National Climate Change Adaptation Research Facility hosted by Griffith University, creating sector- or topic-based National Adaptation Research Plans collaboratively with other research institutions and end-users.

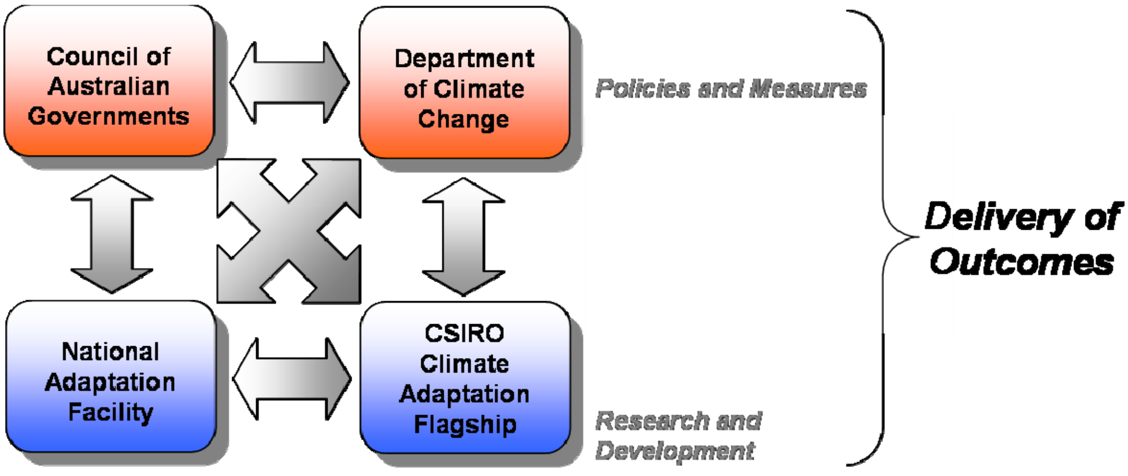


Figure 2. Key initiatives leading climate adaptation policy and research in Australia.

The rapid expansion of resources for facilitating adaptation and adaptation research in Australia offers many opportunities for the improvement of climate risk management. Nevertheless, developing an adequate understanding of the range of biophysical and socioeconomic processes that underlie climate vulnerability and adaptation as well as implementing adaptation policies and measures will require coordination among a growing suite of institutions and – at times – synthesis of a diversity of perspectives and research efforts (

Figure 2). Investing some effort in the development of a shared understanding of different perspectives on climate change vulnerability and adaptation as well as the development of a common language for framing and discussing issues is essential for making progress.

## 2.2 Adaptation bottlenecks

Human beings are inherently a highly adaptable species, and Australians have undoubtedly been adapting to climate variability and change throughout the course of human occupation of the continent. In the modern era, Australia's agricultural sector, in particular, has proved adept at managing a highly variable climate. As such, the capacity for adapting to future climate change within Australia should be relatively high.

There is already significant evidence of climate change adaptation occurring, with activities in the water resources sector perhaps most illustrative. Within the past few years, there have been changes in policy (e.g. the National Water Initiative) as well as massive investments in infrastructure (e.g. piping projects, desalination facilities, water tanks), changes in consumptive use (e.g. temporary and permanent water restrictions and conservation) and a host of other measures. A survey of a range of water resource managers found that 77 per cent were reportedly already planning and/or implementing adaptation actions in response to recent downward trends in rainfall in southern

Australia (Jones et al., forthcoming). Climate change scenarios have been used directly in decision-making about water infrastructure in the Australian Capital Territory (Dessai et al., 2005; Chong et al., 2007), New South Wales (Kirono et al., 2007), Victoria (CSIRO and Melbourne Water, 2005) and Western Australia (O'Connor et al., 2004; Power et al., 2005).

While such examples are promising, they are by no means representative of adaptation efforts across Australian communities, economies and ecosystems. Many institutions and enterprises feel pressured to make prudent decisions in light of current and future climate change. Yet specific understanding of climate changes relevant to a particular enterprise and how such climate changes should be incorporated into existing risk management strategies is often quite limited. This is confounded by persistent and deep uncertainty regarding how climate change may manifest at regional to local scales, particularly decades into the future (Dessai et al., 2005). In many instances, institutions lack clear understanding of their own vulnerability to climate variability in the present day (Preston et al., 2008). This reflects an adaptation 'bottleneck' – the challenge of moving beyond acknowledgement of a changing climate in a general sense into the implementation of context-specific adaptation policies and measures that can have an appreciable influence on vulnerability (Burton et al., 2002; Næss et al., 2007; Vogel et al., 2007).

To some extent, this bottleneck is reinforced by traditional climate change research methods that focus primarily on assessing likely physical changes in the climate system and their potential to cause consequences in regions or sectors valued by humans (see Section 6). Such work is often conducted in a decision vacuum, where assessments are conducted, but are not linked to any particular decision-making event or question. A key role for the CAF and other institutions working in the adaptation arena is therefore to accelerate the adaptation process by defining pathways for moving beyond simply the assessment of vulnerability and impacts to ensure that those assessments are delivering policies, programs and measures that reduce vulnerability.

An additional research challenge in this regard is that there are many adaptation case studies which are locally informative but cannot be generalised; and there are very broad principles which are generally applicable but not specific enough to drive local action. Research methods have meant that local case studies rarely use the same methodology in multiple regions, nor apply different methods in the same regions, rendering generalisation or comparison of alternative approaches formally difficult. As a consequence, we lack a framework for linking these elements in a necessary but sufficiently complex way that will enable sectors or regions to see the specific types of actions that are likely to be appropriate in the general context that they face. This challenge will be addressed in the next section.

# 3. WHAT ARE THE DIFFERENT PERSPECTIVES REGARDING VULNERABILITY AND ADAPTIVE CAPACITY?

As will be discussed further in section 4, adaptation is a procedural response to a real or perceived potential for harm. That potential may arise from a range of drivers. Some drivers are biophysical in nature (e.g. climate hazards and extremes) while others are socially constructed (e.g. demographics, environmental injustice or consequences of decision-making). Furthermore, the potential for harm may be expressed through a multitude of concepts such as 'vulnerability', 'risk', 'hazard', 'impact' or 'consequence'. As such terms are often core components of the lexicon of adaptation research it is useful to first highlight some of the different ways in which vulnerability is conceptualised among researchers.

## 3.1 Vulnerability

A formal definition of the concept of vulnerability can be taken from the literature on sustainability science:

> *"Vulnerability is the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation of stress/stressor."* (White, 1974)

This suggests vulnerability is a reflection of the potential for a system to experience harm in response to some external influence, pressure or hazard. The relevant system or process may be an individual or population; a business enterprise or an entire regional economy; a single species or an entire ecosystem. The concept of vulnerability is broadly used across a range of disciplines, including finance, security, public health, economic development, natural hazards and, of course, climate change (Janssen et al., 2006). However, the diversity of disciplines where the concept of vulnerability is employed ultimately generates problems for its definition and operationalisation.

For example, Turner et al. (2003) identify two classic approaches to viewing vulnerability across different disciplines (see also Füssel, 2007):

- **Risk-hazard (RH) models** that aim *"to understand the impact of hazard as a function of exposure to the hazard event and the dose-response (sensitivity) of the entity exposed."*
- **Pressure-and-release (PAR) models** in which *"risk is explicitly defined as a function of the perturbation, stressor, or stress and the vulnerability of the exposed unit."*

The two different frameworks are both incomplete in their conceptualisation of vulnerability with the former emphasising biophysical processes but neglecting the factors that contribute to system sensitivity or the capacity to affect such sensitivity (Turner et al., 2003). Meanwhile, the latter places greater emphasis on social processes that contribute to vulnerability, but underemphasises dynamic relationships and feedbacks among biophysical hazards and processes and social vulnerability processes.

Such differing perspectives are typical of the debate about the meaning of vulnerability, even within the climate change community. Specifically, does vulnerability arise from the interaction between external climate hazards and the internal social, economic, cultural and biophysical workings of social and ecological systems, or is vulnerability simply a product of the system itself, independent of climate hazards or climate change? This latter perspective is best typified from a development perspective, whereby vulnerability arises from, for example, poverty, limited access to technology, and other social, economic and cultural drivers. Such conditions exist independently of a climate hazard, although their implications may be become acutely apparent when exposure to such a hazard occurs, e.g. the 2003 heatwave in Europe that killed tens of thousands of people (Stott et al., 2004). While one can identify the heatwave itself as an anomalous climate hazard, clearly there were various social factors that pre-existed the heatwave that contributed to the high numbers of fatalities (Vandentorren et al., 2006).

Turner et al. (2003) argue that these two concepts can be unified under a more integrated view of vulnerability, and Figure 4 summarises the relationship between the various components of vulnerability as well as some potentially relevant determinants of different aspects of vulnerability. This movement toward more integrated views regarding vulnerability is reflected within the IPCC's definition of vulnerability that is specific to climate change (see also Adger, 2006):

> *"Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes."* (Carter et al., 2007)

While the earlier (i.e. White, 1974) definition of vulnerability emphasises exposure (hazard), this one emphasises the potential for harm, and is therefore more focused on outcomes resulting from climate change. It also explicitly recognises the social dimensions of vulnerability in the form of coping capacity. For example, human beings manage many systems (e.g. agriculture and water resources) to cope with what is an inherently variable climate through a broad array of decision support tools (e.g. seasonal forecasts), system operations (e.g. planting times), infrastructure (e.g. flood defences), or policy (e.g. water restrictions or development guidelines). This issue of human agency and capacity is therefore fundamental to considerations of vulnerability to climate change.

Assuming the aforementioned provides a better understanding of what vulnerability is (or at least its different incarnations), additional attention can be given to the determinants of vulnerability, as these typically form the backbone of vulnerability assessments. The primary determinants of vulnerability are often referred to as exposure, sensitivity and adaptive capacity (Figure 4).

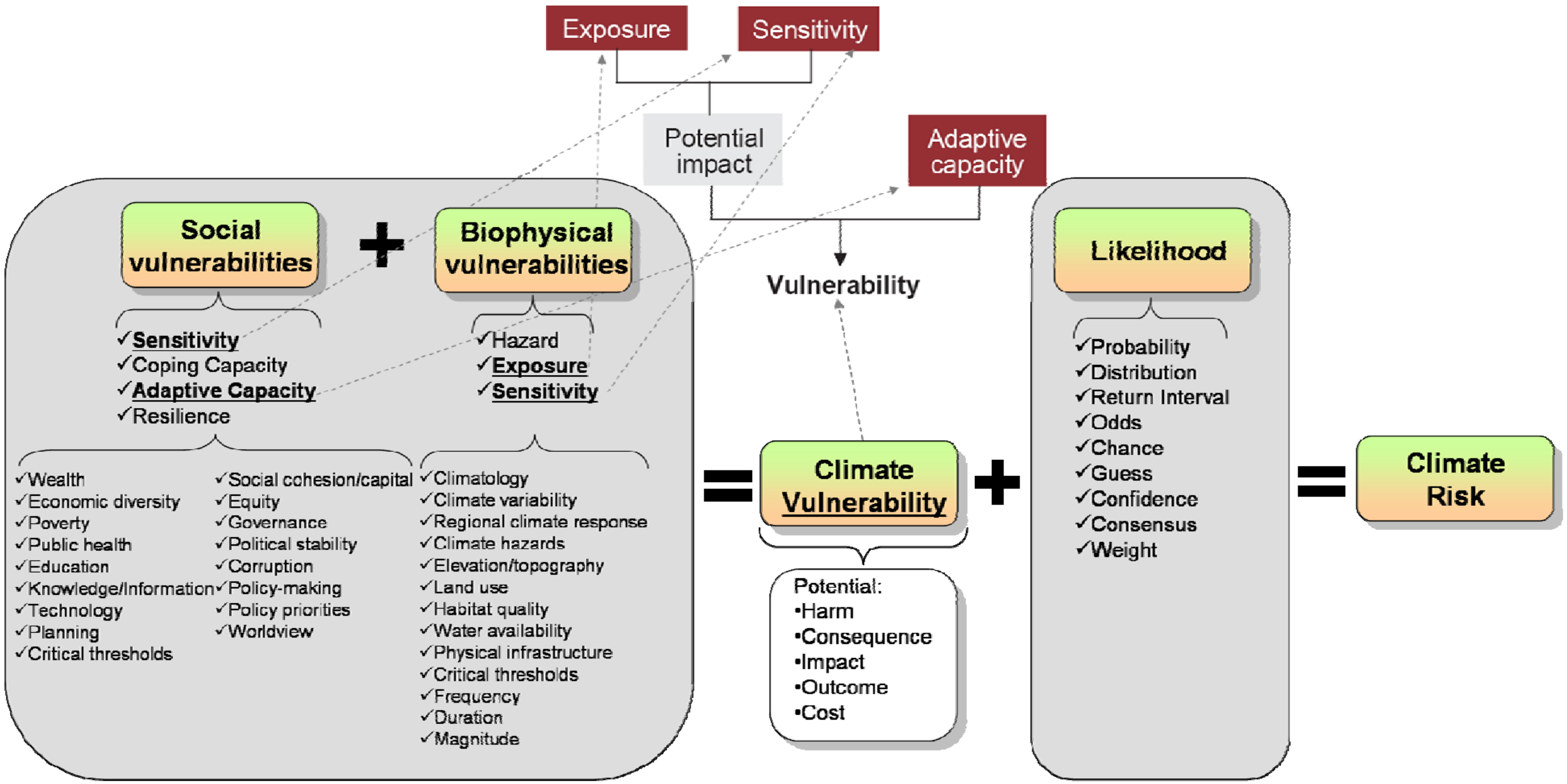


Figure 3. Relationships among different concepts associated with vulnerability and risk. Climate vulnerability is a function of both social and biophysical vulnerabilities. Proximal vulnerabilities commonly appearing in the literature include sensitivity, coping and adaptive capacities, hazard, and exposure. A broad range of ultimate vulnerabilities lie upstream of these proximal vulnerabilities. Climate vulnerability is commonly associated with the potential for harm or varying adverse consequences. When specific likelihoods are incorporated (either associated with biophysical changes or socioeconomic variables), vulnerability becomes risk. The traditional conceptual model for climate vulnerability is inserted and relevant determinants are mapped (from Allen Consulting, 2005). In reality all these processes occur at multiple (somewhat nested) scales with cross-scale interactions.

### 3.1.1 Exposure, sensitivity and adaptive capacity

Assessments commonly decompose climate change vulnerability into three constituent components: exposure, sensitivity and adaptive capacity, each capturing different elements of vulnerability (Figure 4; from Preston et al., 2008; based on Allen Consulting, 2005; Metzger et al., 2005; Smit and Wandel, 2006)..

***Exposure*** refers to the exposure of a system of interest to stimuli that act on that system. This can be readily conceptualised as climate variability and/or the various changes in the climate system that are often of concern to stakeholders: temperature increases, rainfall variability and change (including extremes), or changes in the frequency or intensity of tropical cyclones. Communities or systems are often exposed to hazards through natural climate variability, independent of future changes in the climate system, yet climate change may alter the nature of those hazards, potentially increasing future exposure.

***Sensitivity*** refers to the responsiveness of a system to climate hazards. This is often represented conceptually as a dose-response model – the more sensitive a system, the larger the rate or magnitude of an adverse response to a given hazard. However, the nature of the response may often be secondary to the mechanisms by which it is realised. Sensitivity may vary considerably from one system, sector or population to another.

***Adaptive capacity*** refers to the ability of a system to change in a way that makes it better equipped to manage its exposure and/or sensitivity to climatic influences. Although a broad range of factors have been identified which are argued to reflect adaptive capacity, it remains a difficult concept to define explicitly within vulnerability assessments (Adger and Vincent, 2005). Capacity is often measured in terms of resource availability (e.g. human, technological, and financial capital; Nelson et al., 2007; Preston et al., 2008). Yet the institutional and governance networks that exist to deploy those resources are also essential, and any number of socio-political barriers may exist that impede successful adaptation (Hulme et al., 2007; Koch et al., 2007; Lorenzoni et al., 2007; Urwin and Jordan, 2008). As a consequence, *"the contextual nature of vulnerability, the difficulties of validating indicators, and considerations of timescale, provide challenges to the development of robust indicators"* (Adger and Vincent, 2005; see also Vincent, 2007). Nonetheless, parallel approaches in regional development have identified a reasonably well-defined list of attributes of regional communities that are known to affect or 'condition' adaptive capacity (e.g. RWAC, 2001; SGS Economics and Planning, 2002; Plowman et al., 2003; Cavaye, 2004; Bellamy et al., 2005).

Traditionally, the first two determinants (exposure and sensitivity) have been viewed as dictating the potential for adverse consequences to occur (or 'gross' vulnerability), thereby providing an indication of potential susceptibility to adverse impacts. Meanwhile, the third determinant (adaptive capacity) reflects the ability of the system to manage, and thereby reduce, 'gross' vulnerability. Further confusion can arise in practice because adaptation actions at one level, such as national policy making, can alter the exposure, sensitivity and adaptive capacity at other levels, such as in regions, that in turn can affect individuals or firms in their region; thus the concepts are really nested and (technically) heterarchical (i.e. with cross-scale links that are not necessarily hierarchical). Approaches which allow these multi-scalar aspects to be expressed would be useful but have not yet emerged.

Caution must be exercised to avoid interpreting any of these concepts in an overly rigid fashion. For example, adaptive capacity can be conceptualised quite broadly, recognising that successful adaptation is a function of not only capacity in the form of the availability of resources to address vulnerability, but also the institutional barriers or constraints on the application of that capacity (Adger et al., 2007; Hulme et al., 2007). While some broad boundaries for terms and concepts associated with vulnerability can be identified, in practical attempts to apply vulnerability in the pursuit of adaptation some flexibility must be retained due to inherent differences among different stakeholders, institutions, spatial scales and adaptation problems (Lynch et al, 2008).

## 3.2 Adaptive capacity

Although acknowledged as a fundamental component of vulnerability (to the extent that in some instances no distinction is made between the two), adaptive capacity has received significant attention as a core component of the vulnerability equation. The focus on adaptive capacity stems from a range of sources. These are:

- an awareness that understanding the biophysical component of vulnerability is not sufficient for reducing vulnerability
- an understanding that it is a limiting step for adaptation
- an awareness that it is the component of vulnerability that is perhaps most amenable to management
- an interest in adaptation within the development community which is generally sensitive to the importance of capacity-building in achieving development goals
- an understanding that adaptive capacity plays a dual role, in that constraints on adaptive capacity can constrain future adaptation policies and measures, yet adaptation measures may specifically target increasing adaptive capacity as an adaptation measure.

The IPCC has defined adaptive capacity (also referred to as response capacity; Tompkins and Adger, 2004) as:

> *"the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."*

The broader concept of adaptive capacity has its roots in the natural sciences, specifically ecology, where 'adaptability' refers to the ability of individuals to adjust to changes in environmental conditions (Smit et al., 2000). Some have taken issue with this phrasing, interpreting "adjustment" in the context of systems being 'tweaked' through minor management measures to cope with variability or disturbance. As such, the system has not changed fundamentally. Hence, vulnerability remains, which is antagonistic to the goal of adaptation. In this argument, adaptive capacity represents the ability to make fundamental changes in systems to alter their relationship with the climate and/or how the system responds.

## Box 1. Key challenges in operationalising vulnerability

A number of issues associated with adaptation and its effective use in adaptation research and planning have emerged in the literature. Generally, these issues have not (and in some instances cannot) be readily resolved generally, but must be addressed specifically within climate change assessments and their application.

- Whether vulnerability is the starting point, an intermediate element, or the outcome of an assessment (O'Brien et al., 2004; Füssel and Klein, 2006)
- Whether vulnerability should be defined in relation to an external stressor such as climate change, or in relation to an undesirable outcome such as famine – and if so, which outcome is relevant (Sarewitz et al., 2003; Füssel and Klein, 2006)
- Whether vulnerability is an inherent property of a system (e.g. inherent threshold) or contingent upon a specific scenario of external stresses and internal responses (Füssel and Klein, 2006)
- Whether vulnerability is a static or a dynamic concept (O'Brien et al., 2004; Füssel and Klein, 2006)
- What scale is appropriate for the definition and assessment of vulnerability (Mearns et al., 2004).

*Adapted from Füssel and Klein, 2006*

Similar distinctions have been made between the concepts of 'adaptation' and 'resilience', with the latter again representing a return to the prior state after disturbance while adaptation is a fundamental shift in state or transformation (Klein et al., 2003; Easterling et al., 2004; Folke, 2006). Presumably the latter is more desirable from the perspective of vulnerability reduction. However others have suggested that adaptation implies the ability to anticipate future states, which is dubious given deep uncertainty in climate change, and thus maladaptation may inadvertently result. Meanwhile, resilience is seen as a more robust strategy regardless of the future. The circuity of this debate clouds the fundamental intent of enhancing adaptive capacity, namely increasing capacity for institutions to reduce their vulnerability by whatever means are at their disposal. Enhancing the ability to recover from disturbance and facilitating the transformation of institutions both promise a reduction in vulnerability, but the academic arguments that arise over semantic treatment of terminology is illustrative of the manner in which confusion over meaning can derail otherwise productive discussion and pursuits. It is also an indication of disciplines currently involved in climate change research and their growing integration in sustainability sciences (Janssen et al., 2006)

# 4. WHAT ARE WE ADAPTING TO AND WHY?

Whereas once adaptation was seen to exist in opposition to greenhouse mitigation (Pielke et al., 2007), there is now widespread recognition that adaptation is one critical response strategy for addressing climate change, and one that it is complementary to greenhouse gas mitigation (Carter et al., 2007). Yet as ‘deep’ understanding of climate change and its implications has often not penetrated into many institutions within Australia, there is little awareness of what types of climate changes and downstream consequences should be anticipated and where policies and measures for adaptation should be targeted.

The prevailing wisdom suggests that societies and ecosystems are tasked with adapting to changing climate conditions (i.e. the biophysical contributions to vulnerability), or as Smit et al. (1999) phrase it, “*the various manifestations of climatic stimuli*”. Notice this does not necessarily exclude climate variability from being part of the range of stimuli to which adaptation must occur (more on that later in this paper). While it is seemingly self-evident that climate adaptation must be a response to the dynamics of the physical climate system, the response to date has largely been one of different institutions and enterprises arming themselves with various incarnations of climate projections at various temporal and spatial scales under the assumption that such projections address the question of “what are we adapting to?”.

While true to an extent, one quickly runs into the subsequent problem of what to do with that information. Preston et al. (2007), for example, note that the climate data and variables needed to assess the potential consequences of climate change vary significantly from one application to another, and scientific assessments that yield general projected changes for a battery of variables may not actually include those variables that are actually relevant to the system of interest or its stakeholders. Hence, in the absence of a particular management decision or goal, the acquisition of climate projections and information about future states may do little to directly advance adaptation efforts. The point here is that the question of to what stimuli ecosystems and communities must adapt is a function not so much of the climate system itself, but the nature of the system of interest, with different regions, sectors, communities and enterprises having to adapt to highly diverse aspects of climate change, depending upon those manifestations of climate that are relevant to stakeholders.

Conceptualisations of adaptation as solely being a response to biophysical drivers is incomplete, however. If one shifts one’s thinking regarding adaptation away from biophysical stimuli to socio-economic factors affecting adaptive capacity, then it is those factors that contribute to social vulnerability to which we are adapting. This ultimately leads one back to the concept of adaptive capacity, the enhancement of which is effectively an adaptation strategy targeting social rather than biophysical vulnerabilities. Yet such efforts can nevertheless still be considered adaptations (see Section 5.1).

Just because one can implement an adaptation to address climate vulnerabilities doesn't necessarily mean that one should. So why adapt? Generally, there are two different justifications for implementing adaptation policies and measures:

- **Persistent vulnerability** – Many economic enterprises and ecosystems are exposed to climate variability and hazards on a periodic basis (e.g. drought, flooding, tropical cyclones). Such exposures may be associated with adverse impacts that exceed the coping capacities of communities and ecosystems, particularly when there are underlying social vulnerabilities (general or specific) that enhance vulnerability. As such, there is a persistent vulnerability where investments in adaptation to better 'climate proof' such systems could be beneficial (independent of future climate change).
- **Emergent risk –** Climate change is posed to introduce new risks or substantially shift existing risks in some regions. For example, the penetration of invasive species and/or disease vectors into new areas may require management activities among institutions that have no prior experience or risk management protocols in place. Alternatively, climate change may create the potential for natural hazards to exceed critical levels which previously were managed within acceptable limits (e.g. Thames flood barrier), necessitating upgrades or new investments in risk management policies and measures. In some instances, socio-economic changes may increase exposure of systems to climate (e.g. flood plain and/or coastal development), independent of anthropogenic climate changes.

A major challenge for implementing adaptation options is the inherent dynamic nature of the climate, ecological and socio-economic systems. In a very real sense, climate adaptation is an attempt to hit a moving target from a moving foundation, as neither climate nor society is stationary nor are they ever likely to reach a truly static state in the future. Climate change research itself contributes to this dynamism, as ideally, the climate change assessments and social learning of today will push the development and decisions of tomorrow down alternative pathways. For lack of a better alternative, we commonly superimpose our current preferences and normative values onto the future and hope they remain robust. Yet we always run the risk that seemingly adaptive actions taken today will eventually prove to be maladaptive in a future context, due to changes in societal preferences or simply the acquisition of new knowledge.

## 4.1 Climate change vs. climate variability

One common question in making decisions about what future to anticipate is that of whether we adapt to climate change or climate variability. The distinction between the two is largely, but not completely, artificial, as variability is a fundamental component of climates past, present and future. The assessment of climate change and its impacts has traditionally conceptualised climate change as changes in the mean state of the climate system (e.g. average annual means). Such mean changes have subsequently been applied in various process models and transfer functions to estimate mean impacts (Preston et al., 2007). While useful for conducting sensitivity analyses, it is increasingly apparent that failure to integrate mean changes in the climate with natural climate variability can impede the generation of environmentally relevant consequences. It is also true that there is extensive existing experience (e.g. in agricultural RD&E) in how to adapt better to changing understanding of current climatic variability, which provides a significant opportunity to learn for the future if translated correctly. As such, a 'whole-of-climate' approach is increasingly advocated in climate change assessment and adaptation planning (Jones et al., forthcoming). Inter-annual to multi-decadal climate variability (e.g. El Niño Southern Oscillation or Interdecadal Pacific Oscillation) has a significant influence on water resources and agricultural management in Australia, independent of climate change, but climate change will certainly influence such variability and the likelihood of exceeding thresholds.

Another aspect of climatic change that is receiving attention is the rate of future change. The average rate of increase in the radiative forcing from greenhouse gases is currently larger than at any time in at least the past 16,000 years (Joos and Spahni, 2008). Rapid rates of change may be a greater adaptation challenge for many systems (particularly biological systems) than the actual magnitude of the change (Parmesan and Yohe, 2003; Visser, 2008). However, there have been few attempts to assess vulnerability to rates of change and whether or how adaptation may vary when it targets rates and trajectories.

## 4.2 Current vulnerability vs. future vulnerability

One finds widely divergent perspectives on whether adaptation research and activities should focus on the social determinants that contribute to current vulnerability within communities and systems or future biophysical changes that will affect future exposures and vulnerability. Arguably, this divide reflects the various disciplinary schools that are currently involved in adaptation research. Natural scientists and those actively involved in the development and application of climate projections to assess the future consequences of climate change are sensitive to the additional risk associated with future changes in climate conditions. Meanwhile, those who view adaptation from the social sciences (e.g. development, cultural anthropology or human ecology) are sensitive to socio-economic and cultural factors that currently contribute to vulnerability. This tends to be reinforced by international adaptation funding mechanisms that support projects that facilitate "urgent and immediate adaptation needs" (i.e. the Global Environment Facility's Least Developed Countries Fund) or "increase the resilience of national development sectors" (i.e. the Global Environment Facility's Special Climate Change Fund). Both funds are biased toward the present day.

Efforts that focus on current or future vulnerability are each valid and, in fact, it may be useful to maintain these different perspectives (Figure 4). There are quite justifiable reasons for focusing on future biophysical change in the pursuit of adaptation – primarily to ensure that adaptation actions designed in the present are robust to future changes. For example, modification of coastal defences should be undertaken in anticipation of future sea-level rise. In so doing, those modifications will be not only robust to future changes but also robust to existing exposures. For social determinants of vulnerability, however, targeting adaptations in anticipation of future socio-economic changes may not necessarily adequately address current vulnerabilities. Yet as current socio-economic conditions are critical antecedents that will drive future changes, adaptations focused on reducing current vulnerability may be beneficial in driving future development pathways that are also less vulnerable to climate change.

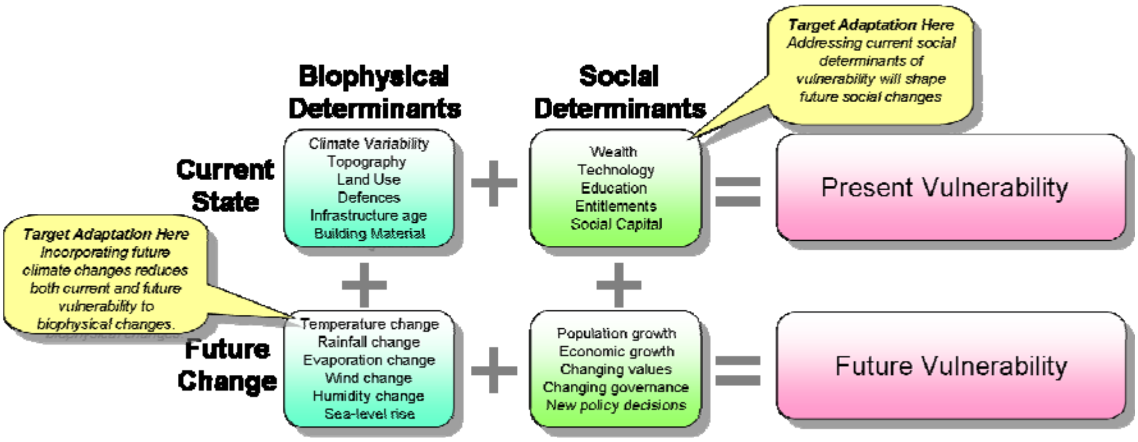


Figure 4. Relationships among current and future determinants of vulnerability and the appropriate targets of adaptation.

Another way of expressing this dichotomy is to distinguish between 'project-based' (or 'specific') adaptation and 'capacity-based' (or 'generic') adaptations (see also Section 5.1). Adaptations designed to address biophysical determinants tend to be project-based, such as sea-walls, infrastructure, or specific management techniques. Meanwhile, adaptations targeting social determinants tend to focus on increasing adaptive capacity and resilience.

# 5. HOW IS ADAPTATION FACILITATED?

The process by which adaptation policies are implemented are, suffice to say, complex. While often conceptualised quite narrowly as simply the implementation of a policy decision, a broader view of the adaptation process recognises it as a more extensive exercise in social learning. A vast array of debate, analysis and communication, and decision-making lies upstream of the implementation of any particular adaptation. From the climate change literature, a view of four core components of adaptation processes emerges (see also Smit et al., 1999; 2000) (the first of which has already been identified in Section 4):

1. **Incentive/stimulus (or *what are we adapting to?*)** – The pursuit of adaptation must be a response to some stimulus or incentive. This might be as simple as a general public awareness that climate change is occurring and therefore may pose consequences. Alternatively, sufficient incentive may be provided from experience in managing climate variability that suggests a need to transform an enterprise to reduce vulnerability. Generally, incentives for adaptation are closely affiliated with perceptions of risk which are, in turn, often influenced by climate change science and assessments that provide evidence that the dynamics of climate risk are changing (see Section 6). What institutions adapt to will vary significantly depending upon the impact as well as the institution and the scale at which it is operating (Vincent, 2007; Table 1).

2. **Agent (or *who adapts?*)** – For any given adaptation measure one or more individuals or institutions will be responsible for making a decision regarding the selection of the adaptation and overseeing its implementation (although within ecological systems, the adaptation may obviously not be a matter of policy but instinct). The relevant agent(s) will be determined by the system itself, its internal processes and characteristics, its external relationships with other systems and its governance structure (Smit et al., 1999; 2000).

3. **Capability/entitlement (or *how do we adapt*?)** – Agents must draw from a broad array of capabilities to initiate and implement and adaptation. Such capabilities include resources including both material and social capital as well as entitlements that represent designated authority or customary rights to access and draw upon that capital (Kelly and Adger, 2000; Turner et al., 2003). This determinant of adaptation is perhaps most synonymous with adaptive capacity (although one can readily propose methods by which incentives or agents can influence the capacity to adapt).

4. **Goal (or *what do we want to achieve?*)** – Adaptation cannot be successfully pursued in a policy vacuum. Some management goal, be it generic or specific, must be identified that guides the selection of adaptation strategies and the criteria for assessing their efficacy. Such management goals should be included in any assessment process, either implicitly as an underpinning consideration or explicitly as a component of a modelling or simulation process.

Table 1. Agricultural example of the effect of geopolitical scale on adaptation policies and measures.

| Geopolitical Scale | Targets of Adaptation Policies and Measures |
|---|---|
| National | National export volumes<br>Commodity prices<br>Terms of trade<br>Drought relief |
| State | Agricultural assessment<br>Land use planning and optimisation<br>Water entitlements and allocations<br>Extension services |
| Catchment Management Authority | Salinity management<br>Weed management<br>Preservation of native vegetation<br>Water quality management |
| Local Government Area | Community education<br>Zoning to reduce subdivision of quality agricultural land<br>Water conservation |
| Farm | Crop selection<br>Timing of sowing and harvesting<br>Water trading<br>Fertiliser application<br>Off-farm income |

### Box 2. Key challenges in developing an adaptation decision framework for Australia

- Rapidly evolving discipline that is currently in its infancy. A range of prior concepts and frameworks exist, which often generates confusion rather than clarity.
- Rapidly expanding suite of players, particularly in Australia, where there is ample disciplinary breadth, but little depth specific to climate change (see Section 2.1). Coordination and collaboration among institutions and researchers is needed.
- Lack of shared understanding of relevant concepts, arising from diversity of disciplinary backgrounds involved in research efforts as well as complexity generated by different perspectives arising from different scales, institutions, stakeholders and associated decision-making contexts and processes.
- Past and current adaptation activities are assessment-oriented rather than adaptation-oriented, limiting the utility of knowledge for decision support.
- Sensitivity to climate uncertainty is often quite high among different institutions and stakeholders. Institutions that maintain a high demand for evidence to support decision-making may be reluctant to adopt costly adaptation policies and measures.

## 5.1 Generic vs. specific adaptation

Adger et al. (2004) differentiate between adaptations that target generic vulnerabilities and those that target specific vulnerabilities (see also Section 4.2). A number of factors that may contribute to climate vulnerability are common, cutting across various sectors and geopolitical scales. This is particularly true with respect to adaptive capacity, where lack of information or resources or insufficient entitlements may be common across a region, affecting the ability of multiple institutions or sectors to adapt to climate change. As such, generic policies and measures may be broad-spectrum adaptations that provide benefit to the greatest number of institutions. However, their lack of specificity means attributing benefits to such measures (e.g. measuring the effectiveness of adaptation measures; see Section 7) may be difficult, and they are unlikely to be sufficient in and of themselves as a risk management strategy. Nevertheless, they may provide critical capacity that facilitates specific adaptation measures. As broad strategies, generic adaptation measures are likely to be implemented by public institutions.

Specific adaptation, in contrast, targets individual systems, processes or activities whereby the adaptation measure is 'built-to-suit' and the adaptation measure may only be relevant to those entities. For example, water infrastructure projects, such as pipes to enable inter-basin transfer, will likely only provide direct benefits to the connected basins and the direct effects will be confined to the those entities involved in the water resources management sector (although the indirect effects may spill-over to affect a broader range of activities or stakeholders). As the costs and benefits of such measures are likely to be borne by a relatively small number of institutions, these are likely to be implemented locally, and the benefits may be more readily assessed.

In parallel with the discussion of generic vs. specific resilience in the resilience literature, one may note that a balance is needed – too much optimisation with respect to a specific adaptation may in fact reduce the generic resilience and adaptive capacity of the system with respect to other surprises. For example, the provision of air conditioners to all may make a city population less resilient to heatwaves in the event of a power system collapse or fuel price rises.

## 5.2 Autonomous vs. planned adaptation

Adaptation policies and measures are also frequently divided into two categories: autonomous (occasionally referred to as reactive) adaptations and anticipatory (or proactive) adaptations (Easterling et al., 2004). Autonomous adaptations are often those that are undertaken spontaneously as routine adjustments to conditions. For example, activities with short planning horizons (e.g. cropping) are constantly implementing autonomous adaptations based upon weather and market conditions, such as timing of planting and harvesting, switching from cropping to grazing, etc. Such operational decisions are made independently of policy or regulatory incentives, and are tactical rather than strategic.

Such autonomous adaptations have often been the norm with respect to managing climate risk, under the assumption that climate is stationary. In other words, tactical planning is sufficient because the long-term climate outlook is assumed to be constant, despite significant inter-annual variability in conditions. Under such stationarity, strategic planning conveys fewer benefits. Similarly, many hazard management decisions (e.g. flood risk, coastal hazards, bushfire hazard) are made using historical averages or trends as an indicator of the future. As conditions remain within certain boundaries, then risk management is largely a function of tactical adjustments to the conditions of the day. While autonomous adaptation will certainly comprise a significant and important fraction of the overall adaptation response to climate change, there are drawbacks that deter one from relying upon it as the sole response. For example, autonomous adaptations may be inefficient in that they are often undertaken only after losses are incurred through existing management strategies. In addition, Easterling et al. (2004) suggest that autonomous adaptations tend to be incremental and therefore may be only partial solutions to particular challenges which may require continual and costly adjustment. Furthermore, autonomous adaptations that are perceived successful over the short-term may delay transformational changes to operations that are required for long-term sustainability.

In contrast, planned adaptation is explicitly strategic and tends to involve planning in anticipation of future states and structural or transformational changes in operations. Planned adaptation is often facilitated by external parties, such as governments and research institutions. It tends to affect activities associated with long planning horizons. As such it is particularly relevant to infrastructure decisions, where infrastructure has a high capital cost and is long-lived. Planning infrastructure to accommodate future climate change upfront may often be less costly than having to retrofit or upgrade infrastructure at a future date. However, even in primary industries there is scope for strategic planning, such as securing irrigation entitlements and allocations or planning for large-scale expansion or contraction of certain production systems.

An interesting research question is at what point are planned adaptations triggered? For example, at what point does a farmer or water resource manager switch from using short-term adjustments to manage for changing conditions and undertake a system-wide transformation? Such a decision is associated with perceptions of risk, the value and quality of information about future conditions, and the availability of capital to invest in system transformation. The goal of institutions charged with facilitating adaptation may therefore be seen as accelerating the switch to strategic planning, particularly given the fact that short-term autonomous adaptations may entrench maladaptive activities that would otherwise be avoided through more strategic planning.

## 5.3 ‘Positive’ vs. ‘negative’ adaptation

Not all adaptations are equal with respect to how they address a particular challenge or in how they are perceived by stakeholders. Davies and Hossain (1997) make a distinction between ‘positive’ and ‘negative’ adaptations in the context of sustainable livelihoods:

- *"**Positive adaptation** is by choice, can be reversed if fortunes change, and usually leads to increased security and sometimes wealth. It is concerned with risk reduction and is likely to involve an intensification of existing livelihood strategies or a diversification into neighbouring livelihood systems."*
- *"**Negative adaptation**, which is of necessity, tends to be irreversible, and frequently fails to contribute to a lasting reduction in vulnerability. It occurs when the poor are forced to adapt their livelihoods because they can no longer cope with short-term shocks and need to alter fundamentally the ways in which they subsist."*

The issue of human migration is a useful example for illustrating this distinction. Migration is a fundamental adaptation measure for species, including humans, attempting to cope with stress or disturbance. While it is a valid mechanism for maintaining life and livelihood (although perhaps in a markedly changed form), forced relocation (due to policy or circumstance) is seldom considered a positive action. Migration can be highly disruptive and costly, reducing the security of populations and livelihoods. Furthermore, there are significant socio-cultural ties to place that are often lost with migration. Thus, even when effective for reducing certain kinds of vulnerability, migration may be associated with strong negative perceptions and may in fact enhance other forms of vulnerability.

There are also a range of adaptations that may be judged to be negative simply because they displace risk temporally or spatially, create new risks, or fail to achieve desired outcomes. Clearly, what constitutes 'positive' or 'negative' adaptation is a normative judgment. This is evident with ongoing adaptation measures for water scarcity in Australia, where water diversion projects, recycling proposals, and desalination facilities are advocated by some as effective management solutions, yet ones which are deemed unacceptable to some populations (Jones et al., forthcoming).

## 5.4 Limits and barriers to adaptation

Perhaps one of the most neglected aspects of adaptive research and assessment is the evaluation of constraints on adaptation (Howden et al., 2007; Adger et al., 2008). Hulme et al. (2007) distinguish between two different types of constraints, limits and barriers, as follows:

- A *limit* to adaptation implies an absolute barrier, i.e. one that is unsurpassable.
- A *barrier* to adaptation exists as a constraint because of the way a society is organised or because of the values it propagates.

Limits to adaptation often arise from biophysical constraints. For example, although climate conditions and extremes vary from location to location, exposure to natural hazards is endemic throughout the world. While it may be possible to expand the capacity of communities to cope with, say, a tropical cyclone or flood event, it is difficult to conceive of adaptive capacity being leveraged to the point of eliminating vulnerability to such hazards. Such limits may be particularly relevant to highly vulnerable communities such as those associated with low-lying small island nations – there are fundamental limits with respect to what capacity-building can do to 'climate-proof' such communities to the effects of sea-level rise. Another dimension to adaptation limits is the inherent uncertainties in estimating future climate and societal change – despite the best efforts of research, ranges of uncertainty are likely to stay relatively wide. The ultimate implications of uncertainty as a limit to adaptation are inherently linked to the decision-making framework (e.g. different frameworks may have a different evidential burdens-of-proof to justify adaptation actions) which leads conveniently to a discussion of barriers.

It is the barriers associated with adaptive capacity and adaptation that increasingly are attracting the attention of researchers, as addressing these social, cultural and economic phenomena is fundamental to facilitating adaptation. Such barriers are often tied to measures of wealth – such as access to financial capital and credit, access to technology and education, and access to knowledge (e.g. climate change assessments or best-practice management methods). Such conceptualisations of adaptation barriers are why developing nations are generally regarded as having low adaptive capacity. However, barriers can run much deeper within the community and individuals, including social, cultural and even cognitive barriers (Adger et al., 2007; Koch et al., 2007; Marx et al., 2007; Lorenzoni et al., 2007; Urwin and Jordan, 2008). These may arise from differences in worldviews of the environment and economy, different perceptions of vulnerability, adaptive capacity and risk, and competition among issues for public attention and a space on political agendas (e.g. climate change or environmental issues in general versus the economy or national security).

### Box 3. Overcoming complexity in adaptation research

The discussion within this background paper illustrates the diversity of dimensions associated with the process of climate change adaptation. The pragmatic issue here is how to deal with such diversity of conditions while avoiding complexity that is overly burdensome for research and implementation. One approach might be to assume the 80:20 rule, that 80 per cent of the benefit is obtained from 20 per cent of the cases. One might identify a small number of critical decisions and embrace the complexity of possible responses for these on the assumption that they contain the vast majority of adaptation value; but can such a limited set of decisions be usefully defined?

A second approach may be to devise a functional typology of intermediate ('necessary but sufficient') complexity for regions, sectors or communities based on their existing characteristics and potential exposures, and seek a differentiated set of responses for each member of the typology. Such typologies are increasingly being developed for regions based on their trajectories from past conditions into the future (e.g. Holmes (1997) for rangeland regions; Baum (2006) for non-metropolitan cities, towns and regions; and Neil Barr in recent studies of regional land use change in Victoria and New South Wales; see also international work on regional syndromes, e.g., Ludeke et al. (2004)). These are also being pursued by research under CSIRO's Sustainable Regional Development theme. Such a typology could be nested, in the sense that a national set of 7–10 major types of regional trajectories or 'syndromes' (e.g. perhaps (i) metropolitan areas, (ii) coastal areas with high urbanisation, (iii) low density coastal areas, (iv) core rural production areas, (v) rural areas moving to amenity uses, (vi) depopulating rural areas, and (vii) remote areas) might then be subdivided to the alternative major futures for a particular regional type (e.g. the fast developing coastal regions may have good governance and planning, such that adaptation will emerge simply from access to the appropriate climate impacts information; or it may have town councils still based in a rural history and poor planning capacity, in which case capacity building and awareness building among elected members may need to precede any use of climate information for planning). Even within a specific regional trajectory there may be another scale of nesting of trajectories at a farm or factory scale, such that some individual cases will respond one way and others another (see Lorent et al. (2008) in Greece, and Ward et al. (2007) in the Murray-Darling Basin).

Again, the European heat wave of 2003 offers a practical illustration of various types of barriers that may exist in addressing climate risks to public health – despite well organised, technologically proficient communities of relative wealth that suggest they should have high adaptive capacity, their capacity must ultimately be discounted due to underlying barriers that hinder the deployment of that capacity to address risk, not the least of which is failure to identify a significant public threat. In this context, (Nelson, 2004, 2007) has applied the five capitals approach from the development literature's Sustainable Livelihoods Framework to capture different aspects of adaptive capacity in agriculture (see Appendix A). Neither the limits nor barriers to adaptation are static, but evolve over time through social learning, changing preferences of the individuals and the public, and the acquisition of knowledge (e.g., reductions in uncertainty about future states).

# 6. HOW DO CLIMATE CHANGE ASSESSMENTS CONTRIBUTE TO ADAPTATION?

Climate change assessments are regarded as a principal vehicle for informing the need for adaptation, addressing the question of "what are we adapting to?" as well as aiding the selection and evaluation of specific adaptation options (for a suite of example assessment, see Appendix A). To this end, they are considered a fundamental part of adaptive decision-making, which can be viewed as a process of social learning consisting of various steps:

- **Education and building shared understanding –** Definition of the characteristics of the system and the larger context (be it biophysical or socio-economic) in which it resides as well as acquisition of knowledge regarding how it is likely to behave in response to climate change.
- **Priority setting –** Identification of particularly vulnerable or at-risk regions/locations, communities, populations, sectors or activities for further assessment, evaluation and adaptation.
- **Evaluation of decision alternatives –** Assessment of the costs and benefits (broadly defined) of different adaptation actions to facilitate the selection of one or more options for implementation.
- **Implementation –** The actual implementation of a particular adaptation policy or measure (which ideally includes provisions for subsequent monitoring and assessment).

Assessments can contribute to each of these steps (although an assessment generated for educational purposes may vary significantly from one designed to evaluate different adaptation options). Yet one should not assume that the execution of a climate change assessment in and of itself will lead linearly to an adaptation. In particular, climate change assessments have been affected by a range of biases:

- Biophysical processes are often assumed to be the major driver of outcomes
- Socioeconomic change has been poorly accounted for (despite plentiful evidence of indicating economic development can both enhance or reduce vulnerability depending upon context)
- Adaptive capacity has focused on material capital at the expense of social capital, despite plentiful evidence from political theory of the important role of social capital in decision-making (Adger, 2003).

| | Approach | | | |
|---|---|---|---|---|
| | **Impact** | **Vulnerability** | **Adaptation** | **Integrated** |
| **Scientific objectives** | Impacts and risks under future climate | Processes affecting vulnerability to climate change | Processes affecting adaptation and adaptive capacity | Interactions and feedbacks between multiple drivers and impacts |
| **Practical aims** | Actions to reduce risks | Actions to reduce vulnerability | Actions to improve adaptation | Global policy options and costs |
| **Research methods** | Standard approach to CCIAV<br>Drivers-pressure-state-impact-response (DPSIR) methods<br>Hazard-driven risk assessment | Vulnerability indicators and profiles<br>Past and present climate risks<br>Livelihood analysis<br>Agent-based methods<br>Narrative methods<br>Risk perception including critical thresholds<br>Development/sustainability policy performance<br>Relationship of adaptive capacity to sustainable development | | Integrated assessment modelling<br>Cross-sectoral interactions<br>Integration of climate with other drivers<br>Stakeholder discussions Linking models across types and scales<br>Combining assessment approaches/methods |
| **Spatial domains** | Top-down<br>Global → Local | Bottom-up<br>Local → Regional<br>(macro-economic approaches are top-down) | | Linking scales<br>Commonly global/regional<br>Often grid-based |
| **Scenario types** | Exploratory scenarios of climate and other factors (e.g., SRES)<br>Normative scenarios (e.g., stabilisation) | Socio-economic conditions<br>Scenarios or inverse methods | Baseline adaptation<br>Adaptation analogues from history, other locations, other activities | Exploratory scenarios: exogenous and often endogenous (including feedbacks)<br>Normative pathways |
| **Motivation** | Research-driven | Research-/stakeholder-driven | Stakeholder-/research-driven | Research-/stakeholder-driven |

Figure 5. Characteristics of approaches to impact and adaptation assessment (Carter et al., 2007)

While these biases remain problematic, assessments themselves have undergone a significant evolution over the past 15 years (Füssel and Klein, 2006). In the late 1980s and early 1990s, the IPCC was instrumental in developing a standard protocol for the assessment of climate change impacts (Carter et al., 1992). The standard method focused on the selection of climate change scenarios which are then utilised to estimate biophysical and socio-economic impacts. Reactive/autonomous adaptations and proactive adaptation strategies that might influence the rate and magnitude of those impacts are subsequently considered.

Principle criticisms of impact assessment are that it tends to be a top-down process, driven by climate scenarios, and its focus on estimate of consequences often comes at the expense of both the biophysical and socioeconomic processes that contribute to adverse outcomes. They tend to be undertaken by researchers, with little or no participation from stakeholders, and thus do not necessarily express impacts in a manner that is widely relevant to different parties. Furthermore, while scenarios provide an indication of the sensitivity of systems to different assumptions about future climate change, in the absence of information on the relative likelihood of different scenarios, impact assessments can generate false perceptions of risk. However, Carter et al. (2007) note that methods for probabilistic impact assessment (see Appendix A), have expanded and are more frequently employed (e.g. Preston, 2006; Carter et al., 2007; Preston and Jones, 2008; Kirono et al., 2007).

Due to the limitations of impact assessment in capturing the complexity of societal and ecological responses to climate change, vulnerability assessment has been advanced as a potentially more robust tool (Füesel, 2006, 2007; Turner et al., 2003). Vulnerability assessments tend to be bottom-up, driven first and foremost by the vulnerability of social and ecological systems and the factors that contribute to that vulnerability.

Furthermore, vulnerability assessments tend to investigate coping and adaptive capacities more thoroughly, including the identification of critical thresholds that represent 'points-of-no-return' where systems are pushed to the point of failure.

While vulnerability assessments may be more robust from an academic perspective, the fact that they often do not generate quantitative estimates of consequence or likelihood creates challenges for their utility in decision-making. Comparative vulnerability assessments (e.g. Allen Consulting, 2005) or attempts to map vulnerability (e.g. Jones et al., 2008; Preston et al., 2008) often leave one with an indication of areas of greater or lesser vulnerability (based upon a combination of climate, landscape, economic and social indicators) and are often constructed around a suite of subjective assumptions. Such analyses do not necessarily provide one with an indication of what specific adaptation measures should be implemented or their relative costs and benefits. This, combined with their subjective nature, often impedes their utility in decision-support. Vulnerability assessments, as with impact assessments, may also suffer from being overly constrained to the direct effects of climate change on systems. Other known and important stressors may not be addressed, even when they may interact in significant ways with the effects of climate change.

Integrated assessment may be one of the most informative assessment approaches for capturing diverse drivers (biophysical and socioeconomic) of outcomes, system interactions and feedbacks, and the evaluation of different adaptation decisions. Scenarios that represent different futures (climate, society, economy) can be modelled along with different decision scenarios. In so doing, a reasonable representation of the system may be generated that captures its complexities, quantitative outcomes can be generated, and the appropriateness of different decision options can be tested. Such integrated assessments, however, have been primarily focused on mitigation questions rather than adaptation, and have largely been conducted at large spatial scales (e.g. national to international) (e.g. Jones and Preston, 2007).

Other investigators have focused less on the development of specific methodologies for climate change assessments and more on identifying broad decision-making frameworks for guiding responses, which may incorporate an array of tools and assessment approaches. For example, the risk assessment and management paradigm has been advocated as a robust strategy for assessing the efficacy of mitigation and adaptation strategies (Jones et al., 2001), and a number of institutions have developed risk management guidelines for scoping climate risks and evaluating specific management options (Willows and Connell, 2003; Lim et al., 2004; AGO, 2006). The advantage of this framing of the adaptation challenge is the general familiarity of a broad range of sectors with the concept of risk management. For example, the corporate sector and financial institutions as well as disaster managers and farmers all commonly employ risk management techniques in operations and decision-making. Therefore, there are opportunities to pose adaptation in a familiar context rather than as a novel decision-making challenge. Lynch et al. (2008) have pursued a policy sciences approach as a means of facilitating stakeholder participation and overcoming common barriers to policy implementation. Meanwhile, Dessai (2005), Dessai and Hulme (2007) and Dessai et al. (2008) emphasise 'robust strategies' for identifying adaptation options, which generally involve testing one or more plausible adaptation options over a broad range of scenarios about future climate and socio-economic change and then subsequently selecting options that are most robust to the greatest range of possible futures.

What is important for CSIRO's future research activities is the fact that there are a broad range of assessment approaches available to investigators. Different approaches tend to be labelled in specific and distinctive ways (e.g. impact vs. vulnerability vs. integrated assessment), although these distinctions are almost certainly not uniform across disciplines, and stakeholders cannot be expected to appreciate such distinctions without participating directly in the assessments themselves. In addition, the bulk of prior climate change assessments that have been conducted in Australia have been conducted outside of (or with little appreciation for) a decision-making environment (Næss et al., 2007; Vogel et al., 2007). In other words, they were not executed in support of a specific adaptation event, but rather to educate the public, specific sectors, or levels of government about the potential for adverse consequences and perhaps the relative magnitude of those consequences. Again, this has contributed to a bottleneck, where there is an array of assessments available to stakeholders, yet few provide sufficient information to inform specific adaptation options.

The diversity of climate change assessments and methodologies also creates challenges for synthesising information about vulnerability, impacts and risk or making comparisons across sectors or regions (Box 4). For example, different assessments evaluate different endpoints, and it is often difficult to compare different assessments on common terms. A vulnerability assessment for infrastructure may identify factors that contribute to vulnerability (e.g. age, building material, usage). A risk assessment may generate qualitative descriptions of consequences and likelihoods. Meanwhile, an impact assessment may generate quantitative estimates of climate impacts for a series of scenarios. Although there are reasons why one would seek to employ different methods (not the least of which may be the pursuit of a hierarchical assessment approach) their lack of common metrics hinders comparison across assessments. However, Polsky et al. (2007) suggest at least one method for pursuing vulnerability meta-analyses among disparate assessments (see also Rudel, 2007).

There are an increasing number of efforts to create typologies or functional classifications of regions in Australia, which may contribute a level of intermediate complexity within which generalisations from individual case studies becomes possible (Box 3). These include typologies of socio-economic advantages (Baum 2006; Baum et al. 2007), of rangelands regions (Maru et al. 2007) and regional trajectories (Holmes 1997), as well as of agricultural regions in Victoria and New South Wales (Barr 2002) and his more recent work distinguishing amenity compared to core agricultural regions. It may be possible to develop these approaches towards a nested set of typologies (see Box 3).

## Box 4. Key challenges in climate change assessments for adaptation

- A major challenge for translating climate change assessments into adaptation policies and measures is persistent and deep uncertainty about future changes in climate conditions. Some decision-makers may require vulnerability and risk to be well-constrained to justify the implementation of a policy or measure out of fear of type I or type II decision errors (despite the fact decision frameworks that cope with such uncertainty exist). This leads to the question of whether proactive adaptations are inherently limited to those that represent 'no regrets' actions or at least ones where the marginal cost associated with increased climate protection is negligible relative to the total project cost.

- As with climate uncertainty, uncertainty about future socio-economic states may be just as profound and important as climate uncertainty. However, climate assessments commonly estimate the impacts of future climate changes based upon current social and economic conditions. This can lead to distorted perceptions of risk and appropriate adaptation responses.

- Climate change assessments often treat vulnerability, impacts, adaptive capacity and the implications of adaptation actions as characteristics associated with discrete spatial and temporal scales. In reality, these are multi-scaled characteristics and processes driven by interactions from the bottom-up as well as the top-down. Such complexity is often excluded in assessments, in part due to the understandable need to limit scope. However, methods for overcoming or effectively embracing such complexity in assessments are needed if the linkages between science, assessment and decision-making are to be strengthened.

- Designing 'built-for-purpose' assessments that maintain some level of consistency in methodology, reporting and assumptions is quite difficult, particularly given the diversity of institutions and researchers conducting assessment in Australia at present and the diversity of decision frameworks employed by diverse stakeholders. The emergence of probabilistic projection methods and climate model performance weighting may further confound attempts to harmonise assessment methods, as they introduce additional points of divergence in assessments. At present we have too many case studies using different methods in different regions/sectors, but not the same methods in multiple cases or different methods in the same case, thus hindering generalisation.

# 7. HOW DO WE KNOW IF ADAPTATION HAS BEEN SUCCESSFUL (AND DOES IT MATTER)?

There have been few attempts to evaluate and assess adaptation policies and measures, in part due to the rather recent emergence and uptake of adaptation as a risk management strategy (at least in the context of future climate change) as well as the inherent difficulties of evaluating actions largely designed to address future vulnerabilities. The bulk of work on evaluation of adaptation measures is related to costing of policies and measures (Smit et al., 2000; Adger et al., 2007; UNDP, 2007).

A range of studies have attempted to cost reactive/autonomous adaptations to climate change –estimating the (largely) hidden costs of adaptation to society as individuals, enterprises and ecosystems adjust to ongoing changes in the climate system. Such studies represent estimates of the opportunity costs of climate change adaptation – investments diverted to climate adaptation (even if anthropogenic climate change is not identified as the cause of that investment) which can subsequently be incorporated into the calculus of the costs of climate change mitigation or lack thereof. While logical in that some of the costs of climate change are, in essence, the costs of adaptation (e.g. coastal impacts; Fankhauser, 1995; Yohe and Schlesigner, 1998; Nicholls and Tol, 1996), such approaches are problematic in that they assume that adaptation will in fact occur to varying degrees. For example, agricultural impacts studies have varied from assumptions about the ‘dumb farmer’ who continues to conduct operations the same way when there is clear evidence that this is a losing strategy to the ‘optimal farmer’ that maximises the productivity of his land, reacting instantly to changing climate and market signals (Mendelsohn, 1994; 1999; Rosenzweig and Parry, 1994; Adams et al., 2003; Reilly et al., 2003). Such assumptions can only be illustrative (but not necessarily unhelpful), and agricultural simulations in particular have since largely moved into a realm of more robust simulations involving more nuanced management levers. Nevertheless, assumptions about adaptive capacity and the degree of autonomous adaptation that will occur (and how efficient it will be) are precarious.

The other type of adaptation assessment addresses proactive adaptation events and occurs in the form of traditional policy analysis (i.e. what are the costs and benefits of implementing a particular adaptation) (Smit et al., 2000). Such analysis may be confined to economic cost-benefit analyses, or more comprehensive integrated assessments or multi-criteria analyses. However, to date, such studies have dealt largely with hypotheticals and have occasionally strayed into the realm of attempting to identify ‘optimal’ levels of adaptation investments (based upon varying criteria) (e.g. Smith and Lenhart, 1996; Tol, 1996; Klein and Tol, 1997). As these have largely been global assessments of adaptation investment, their relevance to community-based adaptation is questionable, other than to say that there is obvious utility in developing methods for evaluating potential adaptation policies for effectiveness (be it economic, financial, social, political, cultural or all of the above). It seems unlikely, however, that there is one optimal solution that can be broadly applied. Rather, such evaluation criteria will have to be determined on a case-by-case basis.

Ultimately, assessing adaptation centres on the questions of first, “what is a ‘good’ adaptation?” and second, “how will we know?” These are questions that are not satisfactorily addressed simply by examining the costs of adaptation, but also questions for which there are no straightforward answers. Only within the past few years have studies emerged looking at more nuanced assumptions about adaptation as a process of “muddling through” (Easterling et al., 2004) and/or the effects of frictions or inefficiencies in the adaptation processes (Easterling et al., 2003; Kelly et al., 2005). Addressing the question of what is a good adaptation depends upon the performance of a particular adaptation option against predetermined criteria, which, again, can only be defined on a case-by-case basis (see Section 5.3).

Meanwhile, demonstrating adaptation successes speaks to the issue of uncertainty about the future. An adaptation option may prove to have been excessively costly should future climate change prove milder than the assumptions utilised in the original decision. On the other hand, should those assumptions prove overly optimistic, the adaptation option may be inadequate to future risk, in which case one is still left with the bill for the original adaptation as well as the subsequent damages. Which option eventuates cannot be known with certainty at the time the adaptation is implemented, which may in fact be one form of barrier (or perceived barrier) to adaptation. Arguably, however, decision-makers are likely to be more sensitive to current perceptions of risk (upon which political opinion is based) than what eventuates years to decades into the future (depending on the time horizon of the adaptation).

At present, there is no framework or formal mechanism in place for monitoring and evaluation of adaptation policies and measures in Australia. As a consequence, a significant opportunity for social learning consistent with the principles of adaptive management is being missed. Yet clearly Australia is a nation that has by-and-large demonstrated a high capacity to adapt to a variable and changing climate. Mining this knowledge could prove quite beneficial in informing current adaptation discussions and the design and implementation of adaptation policies and measures in the future (e.g. Easterling et al., 2004).

# 8. CONCLUSION

Given the preceding discussion, it is apparent that climate adaptation has evolved into a jargon-rich, multi-disciplinary research arena, often burdened, but also enriched, by debate and confusion over meaning. This is reflective of the diversity of expertise and disciplines that are needed to progress climate adaptation, from climate modelling through to environmental assessments and institutional decision-making. However, this diversity of meaning can also be problematic for adaptation in that is hinders consistent communication among researchers, decision-makers and stakeholders. For example, developing some common guidelines and endpoints for use in vulnerability and impact assessments in Australia is problematic when such terms are used in varying ways by different investigators (see Section 6). Therefore, Appendix B summarises some of the key concepts and terms relevant to climate change vulnerability and adaptation and their assessment. An attempt is made to present divergent definitions of terms where significant differences arise in the literature and also identify common distinctions that are made in their application. Ultimately, it would be useful for some consensus to be reached regarding which terms and definitions are most relevant for Australia and its efforts in climate adaptation, emphasising those that are both academically robust and which can be readily communicated to diverse audiences and stakeholders. It is also appropriate to acknowledge that singular definitions may not always be desirable or necessary where there are legitimate different conceptualisations for different purposes (Lynch et al. 2008). However, in these cases it would still be useful to recognise the different uses, so that different users acknowledge and accept the alternatives, rather than talking at cross-purposes.

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# APPENDIX A: AUSTRALIAN VULNERABILITY AND IMPACT ASSESSMENT IN PRACTICE

A variety of climate change assessment methods have been applied to a range of regions and sectors within Australia (Hennessy et al., 2007). Although diverse, many are generally consistent with the commonly utilised assessment typologies: impacts assessment, vulnerability assessment, integrated assessment, etc. Here we summarise several recent assessments to illustrate some of these different approaches and the resulting outputs.

## Impact assessment

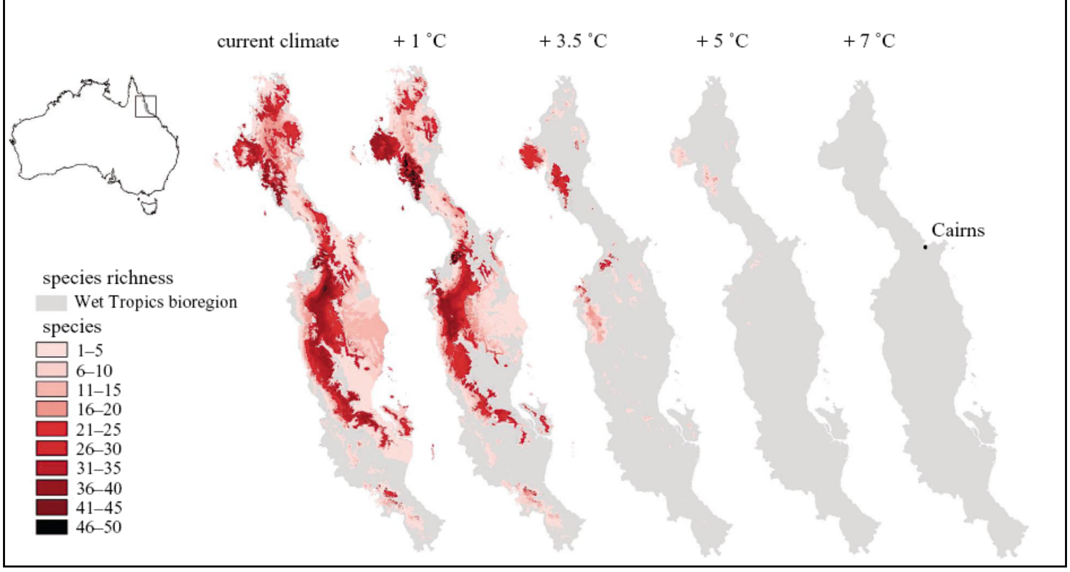
Impact assessments conducted within Australia have tended to be quantitative, scenario-driven *"if...then"* analyses of the sensitivity of a particular system to changes in climatic conditions (generally represented by shifts in the mean climate state). Examples of impact assessments using focussing on both biophysical and socio-economic consequences are presented below.

### Biophysical

Williams et al. (2003) conducted an impact assessment of temperature increases on species richness of the wet tropics. Observational data of species distributions were integrated with climatic and topographic data to develop a bioclimatic model (BIOCLIM) of the study area. This model was perturbed with deterministic climate scenarios of +1, +3.5, +5 and +7°C (encompassing the IPCC's *Third Assessment Report* projected range of global mean temperature change). This resulted in spatial maps of projected changes in species richness in the wet tropics (Figure A2.1), but no likelihoods (qualitative or quantitative) were assigned to these different outcomes. The authors subsequently highlighted the importance of conservation management for maintaining the resilience of ecological communities as a means of minimising adverse consequences of climate change. However, the potential effects of different conservation strategies on impact mitigation were not assessed.

### Socioeconomic

In addition to simply looking at the response of ecosystems to climatic change, a number of impact assessments have also focused on impacts to ecosystem services, particularly the implications of climate effects on agricultural productivity and downstream industries and enterprises. Howden and Jones (2004) conducted a probabilistic risk assessment on winter wheat productivity for several locations in the Australian wheat belt, extrapolating these results to national estimates. APSIM, I-Wheat was used to simulate crop production at study sites based upon a combination of temperature, rainfall and carbon dioxide concentrations. These sensitivity analyses were used to estimate a production response function.




A2.1. Geographical pattern of species richness of regionally endemic rainforest vertebrates at each temperature scenario (Williams et al., 2003).

Monte Carlo techniques were used to generate production distributions in response to probability distributions for monthly temperature and rainfall changes (2030 and 2070) based upon the results of nine global climate models. These results were then scaled-up from study sites to estimate national-scale impacts to crop value (Figure A2.2). The study also attempted to capture the effects of adaptation (in the form of changing planting windows and varieties) on impact estimates (Figure A2.2). Various components of this study including the incorporation of specific adaptation responses as well as the use of GCM climate data and probabilistic methods for treating uncertainty provide examples of how to maximise rigour and decision-relevance of climate change assessments.

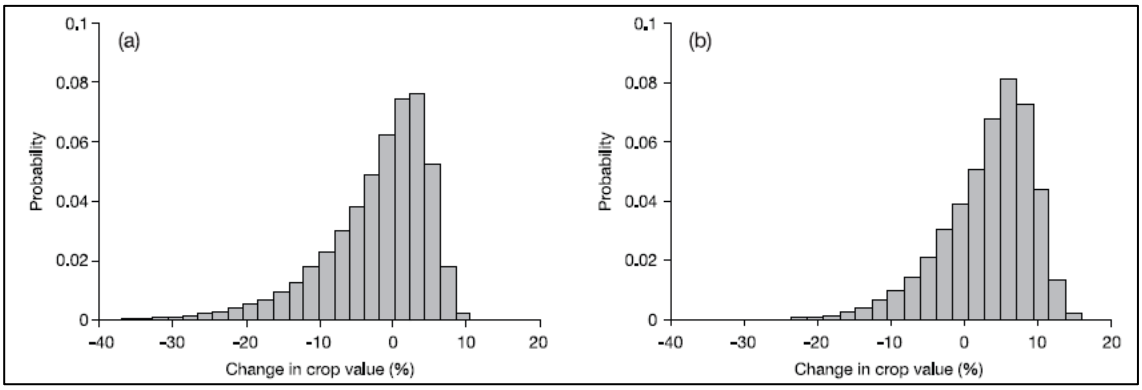



Figure A2.2. Change in national gross value of wheat from historical baseline values (%) for 2070 as a result of increases in carbon dioxide and changes in temperature and rainfall: (a) without adaptation and (b) with adaptations of changed planting dates and varieties (Howden and Jones, 2004).

## Vulnerability and adaptive capacity assessment

A common criticism of impact assessment methods is the relatively confined dimensions of the analyses, which tend to focus on direct cause-and-effect relationships. In the real-world, climate is frequently just one driver of system behaviour, and other drivers may also be undergoing significant change (e.g. land use and/or demographic change; Malhi et al., 2008). In particular, impact assessments often apply climate states decades into the future to current socio-economic states, despite the fact that how systems are stressed or managed in the future may be significantly different from the present. Hence, the capacity for systems to adapt to changing conditions is now accepted as fundamental for the assessment of future consequences. Vulnerability assessment has emerged as one of the preferred frameworks for incorporating such diverse drivers and concepts within a common analytical environment.

### Adaptive capacity

Nelson et al. (2007) conducted a rural landscape vulnerability assessment based upon an analysis of the adaptive capacity of rural livelihoods. Their analysis focused on the evaluation of the ‘five capitals’ that influence (through entitlements granted to various agents) the adaptability of rural livelihoods: human capital, social capital, natural capital, physical capital and financial capital (Figure A2.3). The spatial distribution of these capitals was informed through the identification of indicators from Australian Bureau of Statistics (ABS) data including the agricultural census as well as the Population and Housing Census, the General Social Survey, the NRM survey, and the National Health Survey.

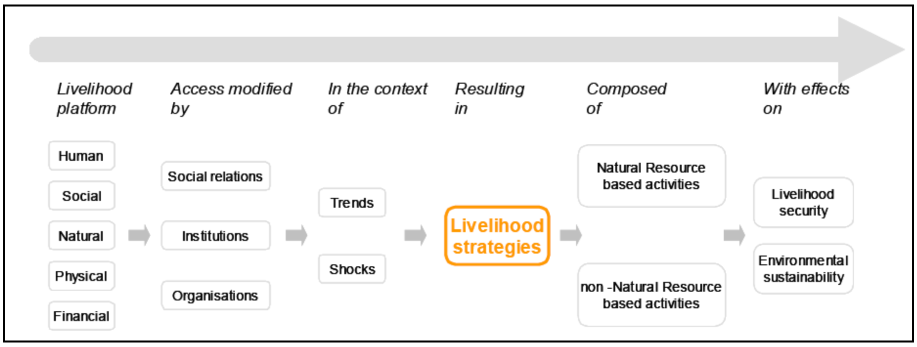



Figure A2.3. A framework for the analysis of rural livelihoods (Nelson et al., 2007).

The integration of different indictors of the five capitals resulted in a series of maps for each of the capitals as well as a net aggregate map of rural adaptive capacity (Figure A2.4). While directly attempting to address the multi-dimensional complexity of rural adaptive capacity and resilience, interpreting such information in the context of climatic change and its consequences is challenging. For example, while it is readily possible to identify deficiencies in certain regions with respect to one or more of the five capitals, it is impossible to say what effect addressing such deficiencies may have on future consequences (other than perhaps to say that vulnerability is reduced by some unknown magnitude). To what extent can such information be applied with stakeholders in rural communities to make adaptive management decisions? The answer is debateable. Nevertheless, as autonomous adaptation is an inherent activity of agricultural enterprises, factors that influence the capacity to adapt remain relevant for assessing vulnerability, particularly to researchers and higher levels of government charged with strategic planning about adaptation and its facilitation.

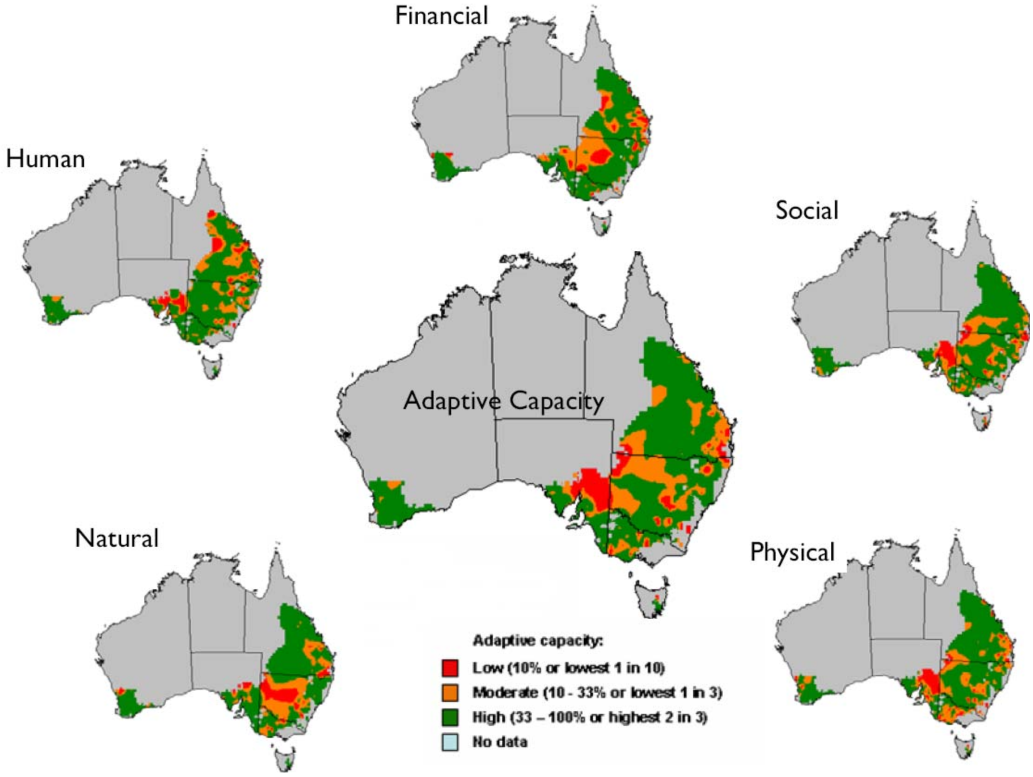



Figure A2.4. The adaptive capacity of Australian rural communities involved in broadacre agricultural industries estimated using ABARE farm survey data (Nelson et al., 2007)

## Vulnerability

While Nelson et al. (2007) focused specifically on the adaptive capacity component of vulnerability, other assessments have either targeted the biophysical components (e.g. exposure to climate hazards) or have attempted to integrate multiple components (e.g. exposure, sensitivity and adaptive capacity). Sharples et al. (2006) conducted a biophysical vulnerability assessment of coastal Tasmania, using indicators of exposure to storm surges and geomorphological susceptibility to physical degradation such as erosion (Figure A2.5a). While identifying stretches of coastline at potential risk of experiencing inundation or degradation, no indication is provided of the potential magnitude of the future impact, the time-scale involved, or how different management options may mitigate risk. Hence, subsequent work is required for elucidating risk at sties judged to be particularly critical (e.g. located in close proximity to high-value property, infrastructure or human populations).

a) b)

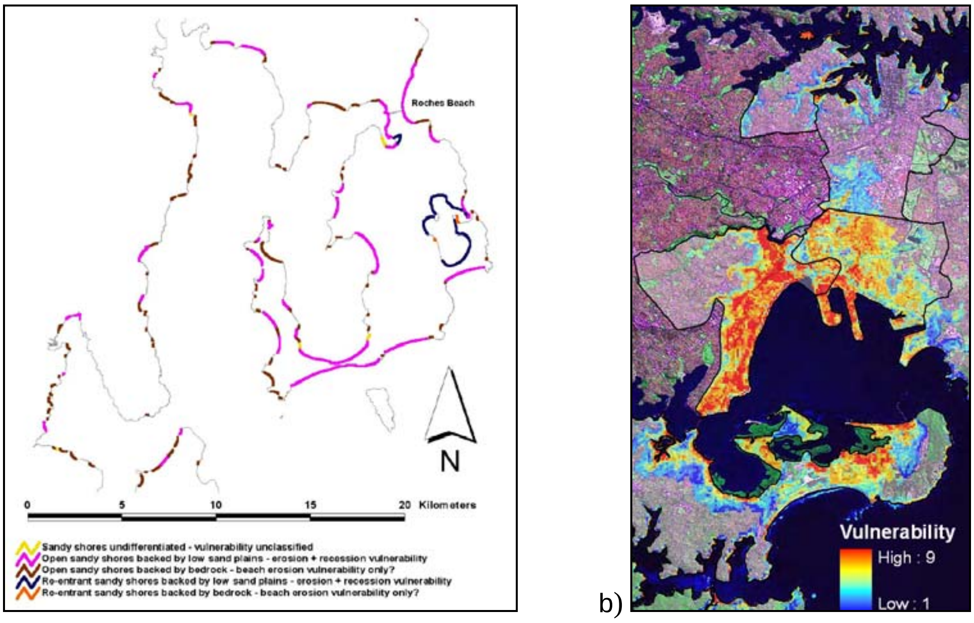



Figure A2.5. Examples of coastal vulnerability assessments. a) Biophysical vulnerability assessment for sandy shores in the Hobart region of Tasmania (Sharples et al., 2006). b) Integrated biophysical and social vulnerability assessment for Botany Bay, NSW (Preston et al., 2008).

Like the national-scale Allen Consulting (2005) vulnerability assessment, Preston et al. (2008) developed indicators of coastal vulnerability in the Sydney metropolitan region that spanned both biophysical components (e.g. exposure to various climate conditions and future changes) as well as socio-economic components (e.g. indicators of landscape sensitivity to different climate impacts and community adaptive capacity). For exposure, the assessment considered relative storm surge heights along the coast as well as topography and elevation. For sensitivity, the assessment examined the spatial distribution of development to estimate the relative spatial density of assets in harm's way. For adaptive capacity, the assessment relied upon household indicators (from ABS census data) of wealth, technology and communication as well as local government indicators of revenue and expenditures. These indicators were integrated to map coastal vulnerability (Figure A2.5b). While incorporating a broader array of information into the analysis, the Preston et al. (2008) assessment still suffers some of the same challenges as Sharples et al. (2008) with respect to moving beyond simply identifying areas of greater or lesser relative vulnerability and providing an indication of consequence and management options.

## Integrated assessment

In a decision-making context, assessment approaches that provide information on the efficacy of different decision options are particularly valuable. However, evaluating decisions about the management of consequences necessitates consideration of future changes in both socio-economic and biophysical conditions. Such so-called integrated assessments often test management policies under different socio-economic scenarios (e.g. population growth, economic growth) and biophysical responses.

Jones and Preston (2008) generated probabilistic estimates of global mean temperature change in 2100 in response to a range of scenarios of future greenhouse gas emissions (reflecting ‘business-as-usual’ and different greenhouse gas mitigation scenarios) (Figure A2.6). Such temperature changes were used to estimate the likelihood of different global biophysical (i.e. species extinction, slowing of thermohaline circulation, or loss of the Greenland ice sheet) and socioeconomic impacts (i.e. global GDP). Economic modelling of the costs of achieving different mitigation scenarios were compared with the GDP damages from climate change to determine which mitigation scenarios could be justified on economic grounds, with additional consideration given to the reduction in risk of other biophysical impacts. This approach combined probabilistic assessment of impacts with explicit assumptions about future socio-economic states to support decision-making (or at least the evaluation of different potential options). However, the quantitative nature of such assessments may make them difficult to parameterise, and the search for realism can quickly lead to overwhelming analytical complexity. Executing such work for decision-support of adaptation would require building understanding of the qualitative and quantitative relationships among future socio-economic change, adaptive capacity, and adaptation policies and measures.

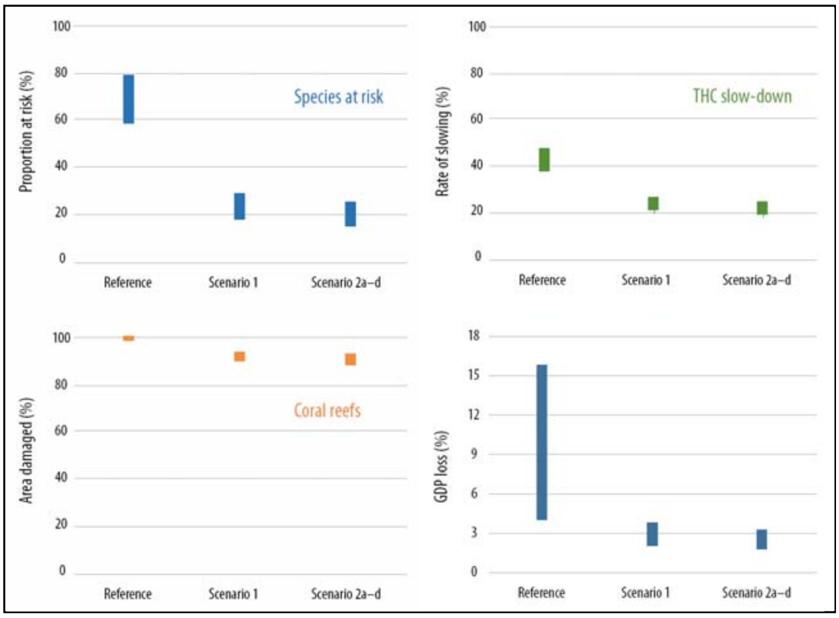



Figure A2.6. Results of integrated assessment of global climate impacts in response to different emissions scenarios (Jones and Preston, 2007). ‘Reference’ represents a ‘business-as-usual’ case, while the different scenarios (1, 2a-d), represent different mitigation trajectories.

# APPENDIX B: ILLUSTRATIVE ANALYSIS OF KEY TERMS

| Term | Definition | Alternative terms | Related terms | Notes | References |
|---|---|---|---|---|---|
| *Adaptation* | System adjustments (tactical) or transformations (strategic) that contribute to a system being less vulnerable to the effects of climate variability and climate change. Adaptations may target either biophysical or social and current or future vulnerabilities. | Adjustment<br>Response<br>Reaction<br>Management | Vulnerability<br>Risk management<br>Sensitivity<br>Adaptive capacity | Further distinctions can be made between:<br>Proactive (anticipatory) adaptation = tactical adjustments<br>Reactive (autonomous) adaptation = strategic transformation | Adger et al. (2007) |
| *Adaptive capacity* | Ability or potential of a system to respond to climate variability and change in a manner that reduces vulnerability | Response capacity<br>Flexibility<br>Coping capacity<br>Resilience | Adaptation<br>Vulnerability | Includes both material and social capital, behaviour. May refer to 'potential adaptive capacity' or 'realised adaptive capacity', with the latter including ability to deploy or make use of capital in an actual adaptation implementation | Adger et al. (2007); Brooks and Adger (2005); Smit and Wandel (2006) |
| *Climate change* | Trend change in physical climate parameters, usually involving change in the frequency of high or low values as well as changes in mean and median values | Non-stationary climate conditions | Global change<br>Earth system science<br>Global environmental change | | IPCC (2007) |
| *Climate variability* | Variability around trend | Climate extremes<br>Climate uncertainty<br>Weather | | Variability often associated with extremes of distributions and their implications for vulnerability | IPCC (2007) |
| *Exposure* | Exposure to physical climate variability | Risk | Vulnerability | Strong bias toward exposure to biophysical processes, yet there is | Adger et al. (2004); Carter et |

| Term | Definition | Alternative terms | Related terms | Notes | References |
|---|---|---|---|---|---|
| | and change (including climate hazards) | | Sensitivity<br>Adaptive capacity | potential to expand this to include exposure to broader range of vulnerability factors (e.g., exposure to war, debt, etc.) | al. (2007); Lindley et al. (2006); Metzger et al. (2005) |
| *Hazard* | Potential threat to the welfare of systems | Risk | Exposure | Often focused on physical hazards (e.g., natural hazards) | Downing et al. (2001) |
| *Impact* | Consequence (positive or negative) of climate variability, climate change and may include consideration of other non-climatic causal factors | Outcome<br>Consequence | | Changes in the level or frequency of 'high' and 'low' values may be more significant than changes in averages | Carter et al. (1992) |
| *Outcome* | Changes in performance or dynamics of social and economic systems as a result of physical climate impacts | Impact<br>Consequence | Vulnerability<br>Risk | | Sarewitz et al. (2003) |
| *Projection* | A description of the future | | Forecast<br>Prediction<br>Scenario | May be applied narrowly as a description of future climate states as derived from coupled climate models. Care is often taken to distinguish between a projection and a prediction (although this distinction becomes blurred when probabilistic projections are used) | IPCC DDC |
| *Resilience* | Resistance to change<br>Ability to return to original state following disturbance | | | | Gallopin (2006); Folke (2006; Janssen et al. (2006); Klein et al. (2003) |
| *Risk* | Product of vulnerability and likelihood<br>Product of consequence and likelihood | Vulnerability | Probability<br>Hazard | Risk can be either qualitative or quantitative | Jones (2001); AGO (2006) |

| Term | Definition | Alternative terms | Related terms | Notes | References |
|---|---|---|---|---|---|
| | | | Outcome | | |
| *Scenario* | A coherent, internally consistent and plausible description of a possible future state of the world | | Projection | | IPCC DDC |
| *Sensitivity* | Degree to which a system will change or respond to a change in climatic condition | Dose-response | Vulnerability<br>Exposure<br>Adaptive capacity | | |
| *Vulnerability* | Potential for, or susceptibility to, harm<br>Degree to which a system is sensitive to pressures and disturbances including climate change due to social, economic, political or cultural characteristics and/or processes<br>Degree to which climate change is expected to result in adverse outcomes, accounting for coping and adaptation strategies | Sensitivity<br>Susceptibility<br>Risk | Exposure<br>Sensitivity<br>Adaptive capacity<br>Hazard<br>Outcome | Further distinctions can be made between:<br>Social Vulnerability -arising due to social, economic, political or cultural processes<br>Biophysical Vulnerability- arising due to biophysical processes | Adger (2006);Adger et al. (2004); Adger et al. (2007); Bogardi et al. (2005); Füssel (2007); Füssel and Klein (2006); Gallopin (2006); O’Brien et al. (2004); Schneider et al. (2007); Turner et al. (2003) |

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