

Chapter 2. Foundations for Decision-making**Coordinating Lead Authors**

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- 20
- 21 • This is a new chapter. It provides the opportunity to bring new material into IPCC assessments, broadening
- 22 the decision-making methods that have been used to date. These assessments have been dominated by
- 23 rational science-driven models that rely on the information-gap model, which assumes that better science
- 24 will lead to better decisions. While this may be the case in some situations it is not sufficient in complex
- 25 situations with substantial uncertainty, especially those with contested values. [2.1]
- 26 • The chapter identifies a range of assessment settings that range from simple to complex. Simple or tame
- 27 climate-related problems can be assessed using the standard, linear methods developed over the last several
- 28 decades. Complex, or wicked problems require a range of participatory approaches that combine expert
- 29 assessment and social-learning processes to evaluate, implement and learn from actions. [2.1, 2.2.1.7]
- 30 • All decisions involving valued outcomes and uncertainty are risk assessments. Modern definitions of risk
- 31 that encompass both formal and informal decision-making are very broad, two being risk *is a situation or*
- 32 *an event where something of human value (including humans themselves) is at stake and where the*
- 33 *outcome is uncertain* and risk *is the effect of uncertainty on objectives*. Two very important aspects of risk
- 34 are calculated risk and perceived risk. Both need to be managed and understood in effective decision-
- 35 making processes aiming to manage climate-related risks. [2.2.1.2]
- 36 • Iterative risk assessment methods are recommended for managing climate-related risks in complex settings.
- 37 A particular aim is to utilise reflexive methods to develop adaptive management techniques. This places
- 38 great demands on institutions to manage that process. [2.2.1.2, 2.2.2]
- 39 • The literature contains a wide range of decision-making strategies with a number of entry points into
- 40 assessments of impacts, adaptation and vulnerability (scientific-rational, institutional, governance, power
- 41 discourse, economic, discursive-consensus based). The use of participatory approaches is increasing,
- 42 bringing scenario-based impacts and adaptation research outputs into decision-making environments,
- 43 particularly at sub-national scales. Levels of engagement are strongly linked to system complexity and
- 44 decision risk. [2.2.2.3]
- 45 • Decision support is situated at the intersection of data provision, expert knowledge and human decision-
- 46 making. Decision support is organized efforts to provide, disseminate, and encourage the use of
- 47 information that aim to improve climate-related decisions. Such support is most effective when it is
- 48 context-sensitive taking account of the diversity of different types of decisions, decision processes, and
- 49 constituencies. [2.2.1.1]
- 50 • Climate Services aim to make knowledge about climate regionally accessible. In doing so they have to
- 51 consider information supply, knowledge competition and user demand. Knowledge transfer is a dialogic
- 52 process and has to take cultural values, orientations and alternative forms of knowledge into account.
- 53 [2.3.3]

- For scenario-based impact assessments to contribute to vulnerability and risk assessment, a series of translations are required. Regardless of uncertainties within climate science itself, the translation process creates additional uncertainties, but more importantly, it presents an opportunity to communicate climate changes in terms of changes in risk and effectiveness of adaptation responses. [2.2.3] Institutionally, boundary organisations are important in translating and transferring these messages. [2.2.2.2]
- The potential of adaptation - mitigation trade-offs to indirectly influence other adaptation and/or mitigation outcomes does not automatically mean that such actions should be implemented or omitted on that basis, but decision making could benefit from the availability of a quantitative analysis of such trade-offs. [2.4.1]

2.1. Introduction and Key Concepts

This chapter addresses the foundations of decision-making within the limits of climate change impact, adaptation and vulnerability assessment (CCIAV). Decisions under CCIAV aim to yield benefits and reduce losses under climate change. The foundations of decision-making concern the decision itself, the decision-maker and the type of decision they make. This topic is complex; both scholars and the public have widely diverging views. These divergent views begin with the philosophical foundations of decision-making and continue through to the practical concerns of making good decisions.

We apply a broad structure to organize the chapter while aiming to represent this diversity (see Figure 2-1). Decision-makers range from individuals to systems made up of various institutions. Decision-makers are influenced by their physical and socio-cultural environments and have a knowledge base from which to draw, utilizing a range of methods and tools. Decisions are framed by aspirations and goals and informed by scenarios of how the future may play out. Two major influences on decision-making are socio-cultural (group) and cognitive/psychological (individual) factors, which are interrelated. Decisions may be exercised via one or more planning methods. Methods of reviewing and testing the decision round the structure out. And, as we will outline, methods for decision validation under CCIAV are rarely formalised.

[INSERT FIGURE 2-1 HERE

Figure 2-1: Schema for the chapter, showing a hierarchy of decision-makers in the centre and broad groupings of subjects addressed in the chapter. The decision-making environment is described by adaptation, mitigation and sustainable development, the methods and tools utilised include scenarios, decisions are made in the human context of individuals to groups and decisions can be assessed to measure varying degrees of success.]

The Fourth Assessment Report concluded that risk management provides a useful framework for CCIAV decision making because it offers formalized methods for addressing uncertainty, for including stakeholder participation, for identifying potential policy responses, and choosing among those responses (Carter et al., 2007b;Yohe et al., 2007). A risk management framework facilitates mainstreaming climate change concerns into broader decision-making processes in public and private sector organizations. The AR4 report also summarized advances in many CCIAV assessment approaches, such as impact, adaptation, vulnerability, and integrated assessment, and described how they can fit into a risk management framework. The literature shows significant advances on all these topics since AR4 (Agrawala and van Aalst, 2008;Jones and Preston, 2011;2012).

Because all decisions on CCIAV are affected by uncertainty, all are decisions of risk. We therefore apply a broad risk management approach within which specialist methods, such as financial, disaster, engineering, environmental and health risk, can be applied. The definition of risk management in the international standard ISO:31000 as *the effect of uncertainty on objectives* (ISO, 2009), is compatible with the aims of CCIAV. Two aspects of decision-making under climate change that differ from most other contexts are the long time scales involved and pervasive uncertainties. These uncertainties affect not only future climate change but include socio-economic change and potential changes in norms and values across generations.

Good decision-making is the basis of good risk management. **But what constitutes a “good” decision?** *A good decision is one where the outcomes sought when the decision was made and implemented are met over the life of that decision.* Many factors influence how a decision can be assessed, including who is making the decision, what it

1 is about, what information is used to make the decision, who implements its actions and who is affected by its
2 outcomes and how those outcomes are valued and assessed. Decisions can be evaluated during three main stages of
3 the risk assessment process: evaluating risk management options, assessing their implementation and assessing the
4 effect of those implementations on outcomes.

5
6 The decision process itself can be divided into four stages: scoping, assessment, implementation and review.
7 Although most steps within this process occur during the assessment stage where decisions are analysed, evaluated
8 and selected, implementation and review are required to complete the process. Decisions can be short lived, but
9 some adaptation decisions may be seeking outcomes that last decades or centuries.

10
11 Guidance on CCIAV has traditionally concentrated on describing methods and tools for making a decision rather
12 than the decision-making process itself. Method development has aimed for objectivity, often assuming that rational
13 knowledge will induce “rational” behavior. However, this is not consistent with the decision-making literature of the
14 last few decades. People make decisions based on a whole variety of criteria; for example, stakeholder groups show
15 multiple preferences for coastal protection leading to very different solutions for a single hazard (Mustelin et al.,
16 2010). To date, the socio-cultural and cognitive-behavioural aspects of CCIAV decision-making have largely been
17 restricted to descriptions of social learning processes; e.g., Section 2.3.2 on stakeholders in Carter et al. (2007).

18
19 Here, we discuss these aspects in more detail by applying a number of attributes to specific decision types.
20 Decisions come in two major types: problem-oriented and solution-oriented decisions. Problem-oriented decisions
21 are generally more analytic, with the solutions being drawn from an assessment of the problem and values attached
22 to problem outcomes; for example, actions designed to reduce climate damages. Solution-focused decisions are
23 broader in terms of the set of aspirations brought to bear, where the problem is addressed but perhaps in less detail
24 because it is integrated into a wider set of concerns; for example, mainstreaming adaptation into local government
25 planning.

26
27 Complexity is an important attribute for framing and implementing decisions. Simple decision-making contexts
28 describe well-bounded issues to which straightforward linear methods of decision-making can apply. These methods
29 cross seamlessly from problem to solution so that single solutions are often widely accepted. Complex contexts
30 characterised by wicked problems, are unbounded. Wicked problems are not well bounded, they are framed
31 differently by assorted actors and groups, they harbour large uncertainties that range from scientific to existential
32 and have unclear solutions and pathways to those solutions (Rittel and Webber, 1973; Australian Public Service
33 Commission, 2007). Such “deep uncertainty” cannot easily be quantified (Kandlikar et al., 2005); (Dupuy and
34 Grinbaum, 2005; Kandlikar et al., 2005). Here the socio-cultural and cognitive-behavioural aspects of decision-
35 making become central to the problem-solution construct inherent in complex decisions [high confidence].

36
37 The chapter focus is on supporting the decision-maker who is dealing directly with decisions on CCIAV or is
38 bringing aspects of CCIAV into broader environmental or social decision-making contexts (e.g., mainstreaming).
39 Socio-cultural aspects of decision-making cover influences at the societal scale, including attitudes to risk, political
40 stances, cultural constructions of knowledge and so on. The next section (2.2) describes the building blocks of
41 understanding risk from both the scientific and culturally constructed aspects and summarises a range of methods
42 and tools. Section 2.3 describes the attributes of decision-making that can be attached to problem- or solution-
43 oriented decisions or that are cross-cutting and illustrate those attributes with case studies. Section 2.4 deals with the
44 interaction between adaptation and mitigation, sustainable development and transformation.

45 46 47 **2.2. Aspects of Decision-making**

48
49 Since the AR4, the level of adaptation activity among organizations worldwide has increased substantially (Preston
50 et al., 2009). This activity has provided a broad experience on which practitioners can draw, as well as expanded
51 needs and opportunities for research. The literature draws a distinction between research for decision-making and
52 research on decision-making. The former aims to provide improved information, such as climate projections and
53 cost-benefit analysis of alternative options, to help inform decision-makers. The latter aims to improve

1 understanding of decision-making process themselves and how they can be made more effective. This chapter
2 largely focuses on the latter.

3
4 The field of decision sciences is quite heterogeneous, integrating “abstract” decision theory with economic
5 applications, cognitive psychology, and philosophy of action, theoretical computer science or neuroscience. It
6 represents complementary links between cognitive psychology and economics and, more generally, cognitive
7 sciences and social sciences (Kleindorfer et al., 1993; Buchanan and O’Connell, 2006). The field of decision science
8 is quite recent; the first institutional step toward this recognition was the creation of the Department of Decision
9 Sciences in the Wharton School of the University of Pennsylvania in the USA in 1974. Since then, the field of
10 decision sciences has developed a burgeoning literature and institutional forces, each following a different
11 orientation to understand and improve decision making.

12
13 In cognitive psychology, decision-making is part of the study of human reasoning—how we apply our reason to
14 make choices. The study of human reasoning has a long history, beginning, in the western tradition, by the
15 systematization of underlying logical rules of thinking in ancient Greece, around two and a half thousand years ago.
16 The study of reasoning until recently was dominated by objective methods aiming to identify normative standards
17 through logical rules. Around the turn of the 20th Century the new probabilistic paradigm tried to understand human
18 decision making related to probabilistic judgment. Recently, new findings show evidence of the limits of human
19 rational thinking, contrasting normative (the decision one should arrive at) and descriptive (what people actually do)
20 theories. A great deal of research explores the gaps between the ideal and the real human decision making. Their
21 findings can be integrated into climate change related decision-making.

22
23 As one example, people may often fail to take simple preparations for disasters such as earthquakes or floods even
24 when they have sufficient resources to do so and would, upon more careful reflection, come to believe that they
25 should (McClure et al., 1999; McIvor and Paton, 2007). People often do not take such precautions because they fail
26 to recognize they are at risk, and the literature offers ways to better align people’s choices with their goals. In other
27 cases, people may take actions seemingly inconsistent with some idealized analysis because they have goals and
28 values not well-reflected in that analysis (Davies and Walters, 1998; Helsloot and Ruitenbergh, 2004). Insights such as
29 these from the decision sciences can be important for CCIAV, and in recently years have become increasingly
30 integrated into CCIAV research and practice.

31
32 This literature emphasizes that the attributes of effective decision-making are strongly dependent on the
33 organizational and cultural context and describes important foundational themes that are broadly applicable to
34 CCIAV decisions. This section will first describe framework issues (Section 2.2.1), the importance of institutions to
35 decision-making (Section 2.2.2), and the cognitive and cultural aspects of decision-making (Section 2.2.3).

36 37 38 **2.2.1. Conceptual Frameworks for Climate-Related Decisions**

39
40 Most people use a variety of decision frameworks to make individual choices and as part of the groups and
41 institutions of which they are a part. By decision framework, we mean the sets of ideas, values, rules, heuristics, and
42 habits that people use to make the many choices they face. Many decision frameworks in use are appropriate in
43 different contexts. This section concerns itself with the decision frameworks that the literature suggests can be
44 effective at addressing climate-related decisions. Understanding the attributes of such frameworks is important for at
45 least two reasons. First it provides a context for understanding how to provide and use information such as that in
46 this assessment report. Second, existing decision-making processes in many organizations and communities may
47 need to be augmented to effectively address climate change. The decision sciences literature and emerging real-
48 world experience provides useful guidance for making such adjustments.

49
50 The rest of this section is organized around three sets of ideas important to such effective decision processes. First,
51 the section addresses *decision support*, a part of the decision sciences concerned with how information such as that
52 in this report can most effectively facilitate decision-making (Power and Sharda, 2009). Of particular relevance, this
53 concept emphasizes that decision processes are at least as important as good information in promoting effective
54 decisions [high confidence]. The section proposes that iterative risk management is the principal framework for

1 CCIAV, which the climate change literature has increasingly adopted to manage uncertainty inherent in estimates of
2 climate change and the other bio-physical and socio-economic factors that affect climate-related decisions (Carter et
3 al., 2007b; Jones and Preston, 2010).

6 2.2.1.1. *Decision Support*

8 Extensive evidence from the decision sciences shows that good scientific and technical information alone is rarely
9 sufficient to results in good decisions [high confidence]. Good decisions result from effective decision-making
10 processes that include, but are not limited to, access to appropriate scientific and technical information.

12 The concept of *decision support* provides a useful framework for understanding how risk-based concepts and
13 information can help enhance decision-making see (McNie, 2007; Moser, 2009; National Research Council,
14 2009; Romsdahl and Pyke, 2009; Kandlikar et al., 2011; Pidgeon and Fischhoff, 2011). Decision support is defined as
15 “a set of processes intended to create the conditions for the production of decision-relevant information and its
16 appropriate use.” Information is decision relevant if it yields deeper understanding or a choice or, if incorporated
17 into making a choice, yields better results for decision makers and their constituents.” These definitions, and criteria
18 that can be used to judge the effectiveness of decision processes and decision support, are drawn from surveys of
19 scientific communication and decision-making in many literatures, including public health, hazards management,
20 natural resource management, environmental management and policy-making, land use planning, environmental risk
21 communication, sustainability science, local air quality, as well as climate change mitigation and adaptation.

23 Decision support consists of three types of elements: 1) **products**: tangible deliverables including data, maps,
24 projections, etc., 2) **services**: activities, consultations, and other forms of interactions with decision makers, and 3)
25 **support systems**: individuals, organizations, communications networks, and supporting institutional structures that
26 provide decision support products and services. This report itself contains decision support products and itself forms
27 part of a decision support system. Much of the discussion in this report also seeks to describe and inform decision
28 support services that would use products from this report and other sources.

30 The effectiveness of decision support, as provided by this report and those using it, can be judged by the extent to
31 which it increases the likelihood that decision-relevant information is produced and incorporated into decision
32 making. The many elements of such judgments can be usefully grouped into three categories: 1) increased
33 usefulness of information, 2) improved relationships between knowledge producers and users, and 3) better
34 decisions. Effective decision support provides users with information they find useful because they consider it
35 credible, legitimate, actionable, and salient. Effective decision support improves relationships by engaging scientists
36 and decision makers in a process of mutual learning and co-production of new knowledge, which would not have
37 existed without this cooperation, and that yields increased mutual understanding, respect, and trust.

39 Decision makers and their constituents ultimately judge what constitutes a better decision. But effective decision
40 support can help ensure clarity about objectives and the reasoning regarding how the choice of actions aims to
41 achieve those objectives. In particular, effective decision support helps produce decision processes that include five
42 key elements: 1) defining the problem in a way that opens it up to thoughtful consideration, 2) defining the
43 objectives to be achieved, 3) laying out the alternative actions that might be taken in an attempt to achieve the
44 objectives, 4) estimating the consequences of each alternative, and 5) evaluating the trade-offs among the options in
45 terms of their ability to meet the objectives. Decision makers and their constituents are more likely to judge a
46 decision favourably, both at the time the decision is made and retrospectively, if they have been made through
47 processes that contain these elements.

49 The literature describes six principles that often lead to effective decision support. Effective decision support
50 generally:

- 51 1) Begins with users needs, not scientific research priorities. Users may not always know their needs in
52 advance, so user needs are often developed collaboratively and iteratively among users and researchers.
- 53 2) Emphasizes processes over products. While the information products are important, they are likely to be
54 ineffective if they are not developed to support well-considered processes.

- 1 3) Incorporates systems that link users and producers of information. These systems generally respect the
- 2 differing cultures of decision makers and scientists, but provide processes and institutions that effectively
- 3 link individuals from these differing communities
- 4 4) Builds connections across disciplines and organizations, in order to provide for the multidisciplinary
- 5 character of the needed information and the differing communities and organizations in which this
- 6 information resides
- 7 5) Seeks institutional stability, either through stable institutions and/or networks, which facilitates building the
- 8 trust and familiarity needed for effective links and connections among information users and producers in
- 9 many different organizations and communities.
- 10 6) Incorporates learning, so that all parties recognize the need for and contribute to the implementation of
- 11 decision support activities structured for flexibility, adaptability, and learning from experience.
- 12

13 These principles can lead to different decision support processes depending on the stage and context of the decision
14 in question. For instance, decision support for a large water management agency operating an integrated system
15 serving millions of people will have different needs than a small town seeking to manage its ground water supplies.
16 A community in the early stages of developing a response to climate change may be more focused on raising
17 awareness of the issue among its constituencies, while a community with a well-developed understanding of its risks
18 may be more focused on adjudicating trade-offs and the allocation of resources. Each community will have different
19 decision support needs.

20 21 22 2.2.1.2. *Iterative Risk Management*

23
24 The climate change literature has increasingly adopted an iterative risk management framework (Carter et al.,
25 2007b; Jones and Preston, 2010). This general framework is consistent with risk governance (Renn, 2008) and a wide
26 range of approaches for structured decision-making (Ohlson et al., 2005; McDaniels and Wilson, 2007; Ogden and
27 Innes, 2009; Martin et al., 2011). Iterative risk management recognizes that the process of anticipating and
28 responding to climate change does not constitute a single set of judgments at some point in time, but rather an
29 ongoing assessment, action, reassessment, and response that will continue – in the case of many climate-related
30 decisions – for decades if not longer (ACC 2010).

31
32 A tame risk that identifies hazards, analyses risk, evaluates and chooses options, and manages risk can be regarded
33 as a linear process. A risk such as climate change that can be identified as a wicked problem requires an iterative
34 process (see Figure 2-2). We can identify two levels of three iterations within that process. The first iteration is
35 during the assessment stage and addresses the interactions between the problem, proposed solutions and system
36 feedbacks where managing risk feeds back into the risk itself. The second iteration is during the management stage
37 occurs when a decision is implemented and the system changes over time due to the actions themselves and/or
38 autonomously. The third is the entire process itself when an assessment is exhausted and the decision process returns
39 to the scoping phase.

40
41 [INSERT FIGURE 2-2 HERE

42 Figure 2-2: Iterative Risk Management Framework, adapted from (CITE).]

43 44 45 2.2.1.3. *Idealized, Calculated, Perceived Risks*

46
47 Formal risk assessment has moved from a largely technocratic exercise carried out by experts to a more participatory
48 process of decision support (Fiorino, 1990; Pereira and Quintana, 2002; Renn, 2008). The variety of tools and
49 approaches used in risks assessment has expanded accordingly. As noted earlier, a similar expansion has been taking
50 place in CCI/AV-related assessments.

51
52 Earlier definitions of risk that invoked hazard times likelihood or probability and consequence, focused on a specific
53 event and response to that event and sought to be objective. More recent definitions are broader, moving from
54 objective analysis to values and governance (Power, 2007; Renn, 2008). For example, risk *is a situation or an event*

1 where something of human value (including humans themselves) is at stake and where the outcome is uncertain
2 (Rosa, 2003). The latest International Standard ISO:31000 definition of risk as *the effect of uncertainty on objectives*
3 is explicitly normative (ISO, 2009). Likewise CCAV methods are expanding from a direct focus on specific climate
4 risks to more mainstream settings where the management of climate risks is integrated with many other activities.
5 For example, climate risks affecting a local government area will have planning, legal, financial, health and
6 community aspects (Measham et al., 2011); therefore an assessment will be influenced by the different types of risk
7 management used in each of those areas. Mainstreaming may require trade-offs between climate and other risks
8 (Kok and de Coninck, 2007; Tompkins et al., 2008). Different areas of risk all have different institutional and
9 governance structures, and display different epistemologies (Althaus, 2005). In undertaking decision support, both
10 formal and informal understandings of risk are relevant.

11
12 Different epistemologies, or “ways of knowing” exist for risk (Althaus, 2005), vulnerability (Weichselgartner,
13 2001; O'Brien et al., 2007) and adaptation assessments (Adger et al., 2009a) affecting the way they are framed by
14 various disciplines and are also understood by the public (Garvin, 2001; Adger, 2006; Burch and Robinson, 2007).
15 These differences have been nominated as a source of widespread misunderstanding and disagreement. They are
16 also used as evidence to warn against a uniform epistemic approach (Hulme, 2008; Beck, 2010), a critique that has
17 been levelled against previous IPCC assessments (Hulme and Mahony, 2010).

18
19 The following five types of risk have been nominated as important epistemological constructs (Based on
20 (Thompson, 1986; Althaus, 2005; Jones, 2010):

- 21 1. Idealized risk: the event-consequence structure that is conceptually framed to address the problem at hand.
22 For example, dangerous anthropogenic interference with the climate system is how climate change risk is
23 idealized within the UNFCCC.
- 24 2. Calculated risk: the product of a model based on a mixture of historical (observed) and theoretical
25 information. Frequentist or recurrent risks often utilize historical information whereas single-event risks
26 may be unprecedented, requiring a more theoretical approach.
- 27 3. Subjective risk: the mental state of an individual who experiences uncertainty or doubt or worry as to the
28 outcome of a given event. Gives rise to:
- 29 4. Perceived risk: the rough estimate of real risk made by an untrained member of the general public.
- 30 5. Observed risk: the risk observed once an event is realized.

31 These different types show risk to be partly an objective threat of harm and partly a product of social and cultural
32 experience (Kasperson, 1992; Rosa, 2008). The aim of calculating risk is to be as objective as possible, but the
33 subjective nature of idealized and perceived risk reflect the division between positivist and constructionist
34 approaches to risk from the natural and social sciences respectively (Demeritt, 2001). Idealized risk will follow both
35 formal and informal pathways through the assessment process. Acceptance of the science behind controversial risks
36 is strongly influenced by social and cultural influences (Leiserowitz, 2006; Kahan et al., 2007). Science is most suited
37 to calculating risk in areas where it has predictive skill and will provide better estimates than may be obtained
38 through more arbitrary methods (Beck, 2000), but an assessment of what is at risk needs to be accepted, and
39 management options evaluated and applied. Therefore, the science always sits within a broader social setting, often
40 requiring a systems approach where science and policy are investigated in tandem, rather than separately (Pahl-
41 Wostl, 2007; Ison, 2010).

42
43 Despite a historical but limited literature in the sociology of science relevant to climate change risks (Jasanoff,
44 1996; Demeritt, 2001; Wynne, 2002; Demeritt, 2006) only recently are these approaches being built into CCAV
45 methods. The different epistemologically-based types of risk listed above give rise to complex interactions between
46 formal and informal knowledge that cannot be bridged by better science or better predictions but require socially
47 mediated processes of engagement [moderate confidence], as discussed in later sections. Idealised risk is important
48 for framing and conceptualising risk. Calculated risk covers the analytic side of risk that concentrates on quantitative
49 decision analysis. Perceived risk is closely aligned with socially constructed risk that emerges from the
50 psychological and behavioural sciences and from social sciences literatures such as anthropology, geography, ethics,
51 sociology, political science, and others.

52
53 A large literature describes best practice methods for incorporating and communicating information about risk and
54 uncertainties into decisions about climate change (Morgan et al., 2009; Pidgeon and Fischhoff, 2011). As described

1 elsewhere in this report, this literature suggests that effective communication of uncertainty requires products and
2 processes that: i) closes psychological distance, explaining why this information is important to the recipient; ii)
3 establishes self-agency, explaining what the recipient can do with the information; iii) recognizes that each person's
4 view of risks and opportunities depends on their values; iv) recognizes that emotion is a critical part of judgment;
5 and v) provides mental models that help recipients to understand the connection between cause and effect. In
6 addition, this literature emphasizes that information providers need to test their messages, since they may not be
7 communicating what they think they are.

10 2.2.1.4. *Treatment of Uncertainties*

11 Here we disregard the distinction proposed by Knight that frames quantified uncertainty as risk (Knight, 1921a),
12 which separates risk from uncertainty (unquantified) and instead view all risk as having various degrees of
13 uncertainty. Many types of uncertainty exist that can affect judgments and choices about risk. Uncertainty can range
14 from stochastic (aleatory), where a well-understood system (e.g. a coin flip) generates outcomes according to a well-
15 characterized probability distribution, to various levels of ignorance, where important parts of a system are not
16 known. This latter, epistemic, uncertainty can arise from imperfection on our knowledge or from the fact that some
17 systems may have performance that is inherently unpredictable. Uncertainty can reside in the behaviour of external
18 forces, such as the climate system, or in the behaviour of one's own organization.

19 The literature emphasizes the importance of quantifying uncertainty, because merely verbal descriptions can prove
20 ambiguous and do not provide the information necessary to adjudicate tradeoffs. Such quantification presents both a
21 technical challenge in using available scientific evidence to formally describe the uncertainty as well as cognitive
22 challenges, since both the producers and users of such information are prone to mis-estimation and over-confidence
23 in uncertainty estimation and prone to uncertainty aversion that may discourage decision makers from engaging in
24 situations where the uncertainty is perceived as too large. It is also important to identify where uncertainty lies
25 within the decision process. It may lie in predicting future events, potential values at risk, which methods to use or
26 how actors may behave.

27 A number of approaches thus exist for dealing with uncertainty in decisions about adaptation to climate change. We
28 can usefully characterize these as falling into three broad categories (Lempert and McKay, 2011): 1) a single joint
29 probability distribution over plausible states of the world; 2) sets of alternative representations, that is, either sets of
30 alternative states or sets of alternative distributions over those states; and 3) scenarios. Uncertainty over which
31 method to use needs to determine whether a problem is simple, where linear methods of assessment may prove to be
32 simple and largely technical, or complex, requiring process-based methods to determine such things as event risk,
33 stakeholder values and the likely efficacy of potential solutions.

34 Traditional probabilistic approaches treat uncertainty with a single, well-characterize joint probability density
35 function over future states of the world. Such approaches have been used in a wide variety of adaptation studies
36 (Hobbs, 1997;Hobbs et al., 1997;Chao et al., 1999;Venkatesh and Hobbs, 1999). Such probability estimates can be
37 frequentist, that is, derive from repeated observations of data, or Bayesian, that is, derive from the subjective
38 estimates of knowledgeable individuals.

39 These approaches, however, do not explicitly address any imprecision or deep uncertainty in these probability
40 estimates, that is, address what Knight (Knight, 1921a, b) first contrasted as the difference between well-
41 characterized risks and more poorly-understood uncertainties. A variety of axiomatic approaches exist (Smithson,
42 1989), such as belief functions (Shafer 1976), imprecise probabilities (Walley, 1991), certainty factors (Clancy and
43 Shortliffe, 1984), and fuzzy logic (Zadeh, 1984;Prato, 2009;Prato, 2011), which aim to provide formalized
44 descriptions of such deep uncertainty, analogous to probability theory. Each of these approaches provides an
45 alternative calculus that relaxes axioms of probability, often trying to capture the idea that one can gain or lose
46 confidence in one of a mutually exclusive set of events without necessarily gaining or losing confidence in the other
47 events (Morgan et al., 2009).

1 In contrast to these axiomatic descriptions of imprecision, others approaches represent imprecision with sets of
2 alternative representations (see Parker, 2006) in the context of climate modelling). Such approaches can retain a
3 probabilistic formulation, but allow a range of probability values, for instance as suggested in the IPCC uncertainty
4 guidance (Mastrandrea et al., 2010), or use a non-probabilistic, set-based representation of alternative future states of
5 the world. Examples of such approaches include InfoGap (Ben Haim, 2001; Korteling et al., 2011), which
6 characterizes uncertainty with nested sets of plausible futures; RDM (robust decision making) (Lempert et al.,
7 2003; Lempert and Groves, 2010; Lempert and Kalra, 2011), which uses sets of plausible futures explicitly chosen to
8 inform the choice among alternative decisions; and robust control optimization and control theory (Hansen and
9 Sargent, 2008), which also use a nested set representation. Scenario approaches (Bradfield et al., 2006; Parson et al.,
10 2006) similarly present sets of multiple futures, but with the additional concept of choosing the futures and their
11 descriptions to explicitly engage decision makers' imaginations (Wack, 1985b, a; Schwartz, 1996).

12
13 CCIAV studies often must combine uncertainty estimates of the behaviour of a series of linked systems, resulting in
14 a cascade of uncertainty. Table 1 shows how a selection of climate change impacts studies have sampled parts of
15 this cascade, from greenhouse gas emissions to global climate change to (in these cases) the impacts of hydrology on
16 water availability. The uncertainty quantification choices made in each study differ in part due to the different
17 question asked, but also due to computational constraints, pragmatism and scientific tradition. Each study has gone
18 in depth at a particular stage(s) of the cascade of uncertainty. For example, Dessai and Hulme (2007) explored
19 'upstream' uncertainties in GHG emissions and climate sensitivity extensively but had simple assumptions on
20 'downstream' uncertainties such as hydrology. Wilby and Harris (2006) focused much more on the downstream
21 uncertainties (downscaling and hydrology) than the upstream uncertainties. Lopez et al. (2009) arguably conducted
22 the most extensive quantification of uncertainty in climate system response (AOGCM), which most studies identify
23 as the largest source of uncertainty in climate change impact assessments. Furthermore, the Lopez et al. (2009) study
24 goes further downstream than the other studies by examining multiple adaptation scenarios (Dessai and Hulme,
25 2007) only assess the merit of one adaptation plan). Manning et al. (2009) thoroughly explore the 'middle' stage
26 uncertainties by using a Bayesian framework to combine projections by weighting.

27
28 [INSERT TABLE 2-1 HERE

29 Table 2-1: Main characteristics of select number of climate change impact studies (Dessai and Van der Sluijs,
30 2011).]

31
32 There exist at least two distinct ways to organize descriptions of uncertainty and to interact with decision makers as
33 part of a decision support process (Weaver et al., 2011). One approach seeks to describe uncertainty as distinct
34 information, independent of other parts of the decision problem. Probabilistic descriptions often take this approach,
35 which follows the assess risks, identify options, evaluate tradeoffs loop in Figure 2-2a. For instance, probabilistic
36 climate projects are generated to support a wide range of decisions, and thus not tied to any specific choice. In
37 engaging with decision makers, information providers seek to understand what data would prove most useful, for
38 instance temperature and precipitation time series at some level of spatial and temporal resolution, and then seek to
39 provide that data to a wide community of decision makers. The basic structure of IPCC Assessment Reports also
40 follows this pattern, with WGI laying out what is known and uncertain about current and future changes to the
41 climate system. Working Groups II and III then describe impacts resulting from and potential policy responses to
42 those changes.

43
44 In contrast to this "predict-then-act" approach, a second approach seeks to describe uncertainty in the context of the
45 sets of uncertainty factors that would affect judgments about and choices among alternative policies, following the
46 identify options, assess risks, evaluate tradeoffs loop in Figure 2-2. The literature offers several names for such
47 approaches, including "context-first" (Ranger et al., 2010), "decision scaling" (Brown et al., 2010), "assess risk of
48 policy" (Lempert et al., 2004; UNDP, 2005; Carter et al., 2007b; Dessai and Hulme, 2007) that characterize those
49 uncertain states of the world that would cause a current or proposed policy to fail to meet its goals or the illuminate
50 the tradeoffs among particular policy choices. For instance, Kirshen et al. (2008) provided decision makers in New
51 York City plots that showed how the frequency of large-scale flooding would increase along the city's coastline,
52 without changes to the current infrastructure, as a function of various assumptions about sea level rise.

1 The IPCC's *Reasons for Concern* approach (Smith et al., 2009) aims to summarize the deleterious impacts implied
2 by various greenhouse gas emissions trajectories. In engaging with decision-makers, this assess-risk-of-policy
3 approach often requires that information providers work closely with decision makers to understand their plans and
4 goals, before customizing the uncertainty description to focus on those key factors that may affect the ability of the
5 plan to meet those goals. This approach can often prove very effective at communicating risk and uncertainty, but
6 often generates information that needs to be individually customized for each decision context (Lempert,
7 2011;Lempert and Kalra, 2011).

10 2.2.1.5. *Decision Criteria for Evaluating Tradeoffs*

11
12 CCIAV studies use a wide range of decision criteria to assess and evaluate alternative actions for reducing impacts
13 and vulnerabilities. The alternative criteria are appropriate in different circumstances, depending on the goals of the
14 effort, the data available, and the types of uncertainties involved. Implicitly and explicitly, these decision criteria are
15 used throughout the discussions of adaptation options, planning, and economics in Chapters 14 through 17 and WG
16 III Chapter 2.

17
18 It is useful to divide such decision criteria into two broad categories: outcomes-based, which compare alternative
19 actions according to the consequences expected to result from them, and process or rights-based, which compare
20 alternative actions according to the process by which any decision is arrived at and, in particular, the extent to which
21 various individuals consent to the risks, costs, and obligations being imposed upon them (Morgan and Henrion,
22 1990).

23
24 Process-based criteria often focus on the credibility and legitimacy of a decision process, shown in the “establish
25 criteria” step in Figure 2-2. For some participants, process criteria may prove decisive in their judgments about the
26 decision (Dietz and Stern, 2008;Sen, 2009). For instance, many environmental laws require advanced notice and
27 periods of public comment before the government issues any regulations. Legal systems with water rights often give
28 allocation decisions over certain water resources to individuals who can then choose, or not, to sell them to others
29 during periods of drought. Participants may regard any decision that fails to respect these rights as illegitimate.
30 Process-based criteria can also depend on judgments about uncertainty. For instance, the precautionary principle
31 contains an element of process-based criteria, placing the burden of proof on those introducing new impacts on the
32 environment to prove that they are not harmful. Some religious traditions regard system-wide outcomes as beyond
33 human understanding or control, and thus emphasize individual codes of conduct and de-emphasize attempts to
34 adjudicate broad social trade-offs. Some utilitarian-based ethical frameworks distrust the ability to compare in any
35 meaningful way social outcomes that make one person better off and another worse off, and thus seek to minimize
36 the scope of decision processes that adjudicate broad social outcomes and seek to expand the scope of decision
37 processes, often market-based, in which individuals only engage in transactions that transfer costs or risks with their
38 explicit consent.

39
40 Outcomes-based criteria help adjudicate the tradeoffs that arise in a well-structured decision process, as shown in the
41 “evaluate tradeoffs” step in Figure 2-2. A variety of alternative criteria have been used in CCIAV analyses. As laid
42 out in von Neumann-Morgenstern expected utility theory, *optimality* provides the best possible outcomes-based
43 choice in those situations where decision makers can quantify all the costs and benefits associated with the decision
44 in a common metric. *Cost effectiveness* criteria often prove useful in situations where decision makers can quantify
45 the costs but not the benefits of alternative actions. For instance a water management agency might determine it
46 necessary to be able to maintain a reliable supply of water in the face of the largest drought ever observed in their
47 region, and then choose to invest in the least expensive reservoir able to meet that criteria. *Bounded cost* criteria
48 often prove useful in situations where decision makers have fixed resources to address a problem. For instance, a
49 city might have a fixed budget to address adaptation to climate change and may wish to allocate those resources in
50 such a way as to reduce risks as much as possible. In situations where decision makers wish to balance among
51 multiple, potentially competing objectives, *multi-attribute decision theory* can either provide means to aggregate the
52 multiple criteria into a single utility measure (Keeney and Raiffa, 1993) or to summarize the key tradeoffs among
53 different objectives.

1 Alternative decision criteria also exist to address the various characterizations of uncertainty discussed in Section
2 2.3.2.2. While some criteria can be applied broadly, some are only applicable with some types of uncertainty
3 characterizations (Dessai and Sluijs, 2007). As above, *optimality* provides the best possible outcomes-based choice
4 when decision makers have high confidence in a single joint probability distribution over all plausible states of the
5 world. *Modern portfolio theory* (Crowe and Parker, 2008) provides a means to choose sets of multiple actions
6 balanced against both uncertainty and multiple objectives. A variety of criteria exist that consider only consequences
7 over a set of states, and not the probabilities of those states. For instance, the *maxi-min* criterion suggests choosing
8 the decision with the best worst-case outcome and the *mini-max regret* criterion (Savage, 1954) suggests choosing
9 the decision with the smallest deviation from optimality in any state of the world. Proposals for “no regrets”
10 adaptation decisions (Callaway and Hellmuth, 2007;Heltberg et al., 2009) employ such criteria, which are a special
11 case of robustness as described below. Hybrid criteria exist that combine both consequence-only and
12 probabilistically-weighted criteria (Hurwicz, 1951;Ellsberg, 1961;Rawls, 1971). For instance, decision criteria from
13 the financial literature, which employ various value-at-risk to optimize expected utility with the constraint on the
14 performance level of worst-performing cases, have been used to support climate related decisions (Hurwicz,
15 1951;Aaheim and Bretteville, 2001;Bretteville Froyn, 2005).

16
17 The related concepts of robustness (Rosenhead, 1990) and resilience (Folke, 2006;Gallopín, 2006) are often used in
18 the context of decisions about adaptation to climate change. The literature offers differing statements about the
19 relationship between these concepts, but resilience, described in detail in Chapter 20, tends to describe a property of
20 systems, which might be affected by decision makers’ choices, while robustness is a property (or not) of the choices
21 made by those decision makers. Adaptation to climate change literature that emphasizes robustness (Dessai and
22 Hulme, 2007;Groves et al., 2008;Brown et al., 2010;Wilby and Dessai, 2010;WUCA, 2010;Brown, 2011) generally
23 seeks strategies or plans that will perform well over a wide range of plausible climate futures, socio-economic
24 trends, and other factors (Lempert and Kalra, 2011). These studies often emphasize learning and strategies that
25 evolve over time in response to new information as a means to achieve robustness (Lempert and Groves, 2010).
26 Definitions for robust strategies include those which perform well over a wide range of plausible futures, trade some
27 optimal performance for less sensitivity to broken assumptions, or keep options open (Lempert and Collins, 2007).
28 Thus, robustness generally involves some type of satisficing concept and often employ a variety of decision criteria,
29 including mini-max (Hansen and Sargent, 2008) and hybrid criteria that balance between optimality and the
30 performance in worst cases. Robust decision methods also often include a process dimension that aims to achieve
31 consensus on actions even among diverse stakeholders who do not agree on expectations about the future or the
32 criteria for valuing alternative outcomes.

33
34 The five elements of effective decision processes (Section 2.1.1.1) can usefully be summarized as a choice task and
35 a decision structuring task. The former use decision criteria to help choose among a menu of alternative options. The
36 latter define the scope of the problem, goals, and options under consideration and are the focus of the first four steps
37 in Figure 2-2. Facilitating effective decision structuring is an important role for decision support, and the literature
38 describes a wide range of participatory methods designed for these purposes. Decision structuring processes can also
39 contribute to the framing of the problem, which involves a relatively small set of interpretive stories or contextual
40 clues that guide attention to particular problem features and influence decision making. The way groups agree to
41 frame a problem can affect the way in which information is used, the sources from which information is sought, and
42 the range of decision options considered.

43 44 45 2.2.1.6. *Scenarios*

46
47 Scenarios are cognitive tools central to scoping and assessing risk, and in managing risk, as adaptation planning
48 [very high confidence]. *A scenario is not a prediction of what the future will be but rather a description of how the*
49 *future might unfold. A scenario includes an interpretation of the present, a vision of the future and an internally*
50 *consistent account of the path from the present to the future* (Jäger et al., 2008). Scenario use has expanded
51 significantly as CCAV research has become more integrated with mainstream activities. Their application has
52 extended beyond climate as noted in the past two assessment reports (Carter et al., 2001;Carter et al., 2007b).
53 Climate change has also become a core feature of many scenarios used in regional and global assessments of
54 environmental and socio-economic change (Carpenter et al., 2005;Raskin et al., 2005). Scenarios can be used at a

1 number of stages within the assessment process or to underpin an entire assessment. They serve a variety of
2 purposes, including informing decisions under uncertainty, scoping and exploring poorly understood issues, and
3 integrating knowledge from diverse domains (Parson et al., 2006).

4
5 Existing scenario typologies tend to reflect the state of play at the time they are assembled, become outdated as the
6 field evolves and often fail to capture the full range of contemporary scenario development (van Notten, 2006). They
7 *seem to be regarded as products of research, rather than as tools designed to function in particular sorts of*
8 *inquiries* (Wilkinson and Eidinow, 2008). Recently published typologies include descriptive (van Notten, 2006),
9 philosophical underpinning (Borjeson et al., 2006) and decision-type (Wilkinson and Eidinow, 2008). These
10 typologies can be grouped according to their function in decision-making. The major groupings are problem-based,
11 solution- or actor-based and reflexive scenarios (Wilkinson and Eidinow, 2008). Exploratory scenarios that explore
12 value-neutral ‘what will happen if’ questions and normative scenarios that represent explicit values in a fore-casting
13 or back-casting mode are also important pairings (Carter et al., 2007b). Problem-based scenarios are developed
14 using deductive and inductive methods whereas actor-based scenarios are normative, so map well onto exploratory
15 and normative scenarios.

16
17 Reflexive scenarios are designed to work with wicked problems (Wilkinson and Eidinow, 2008). Problem
18 (exploratory) and solution- or actor-based (normative) scenarios are combined to assess problems, implement
19 decisions and apply ongoing learning in action-based research. Such scenarios require an institutional host, are
20 linked to data measuring progress towards outcomes and periodically updated within an iterative assessment
21 framework to revise decisions (Jones, 2012). Several generations of scenarios produced by IPCC assessments,
22 national climate scenarios in the UK and Australia indicate this capacity may be developing (CSIRO and BoM,
23 2007;Gawith et al., 2009;Moss et al., 2010) but would require parallel development in a wider set of variables
24 relevant to adaptation and a more institutionalised approach to decision-making support. The new scenario matrix
25 being developed for climate change (Kriegler et al., 2010;Moss et al., 2010) is one vehicle where this may happen.

26
27 Linking these typologies with research methods, the major determinants of scenarios can be described as problem-
28 actor, exploratory-normative, top-down-bottom-up (in terms of scale) and forward-looking-back-casting (or
29 prescriptive-diagnostic in terms of time). In methodological terms this sets up a process-goal construct. Forward
30 casting normative scenarios concentrate on the initial state and process, for example a set of specific policies,
31 whereas back-casting will define a normative state in the future; e.g., sustainability, then diagnose how to achieve
32 that state over time given specific starting conditions and a set of key drivers. Reflexive scenarios will combine
33 these approaches.

34
35 Scenarios have a somewhat uncomfortable place within the standard research methods applied to assess CCIIV. As
36 outlined in the earlier section on uncertainty, problem uncertainty can range from quantified distributions of
37 variables and outcomes known with high confidence to those that can at best be said to be ‘not implausible’
38 (Strzepek et al., 2001;Malone and Yohe, 2002) that are linked to complex situations with deep uncertainty.
39 There is a tension between the development of climate forecasting as pursued by the modelling community who aim
40 to improve future predictions and scenario development required by the CCIIV community, who require tools for
41 decision support. In terms of calculating event risk, scientific prediction is limited to what is represented in a model,
42 so while its theoretical application may be sound, in a system of multiple drivers and feedbacks, the model itself
43 may be incomplete. Scenarios can fill that gap. For example, Carter et al. (Carter et al., 2007a;2007b) emphasize that
44 climate scenarios are usually purpose built for specific impact assessments, often modifying climate model output,
45 but rarely use model output directly. Climate may also be only part of the total uncertainty if risk is being assessed
46 from the interaction between climate impacts and social vulnerability.

47
48 On the solution side, representing hard-to-define goals is also a difficult issue for prediction. For example, both
49 sustainability and ‘dangerous climate change’ are both difficult to define due to differing social and cultural
50 constructions of what they may mean. This uncertainty is reflected in the expert literature (Harding, 2006).
51 Uncertain predictions of uncertain goals invite controversy. Given that exploratory scenarios have the capacity to
52 survey a range of plausible pathways and goals in such cases, a participatory process is likely to achieve broader
53 agreement than expert judgment can by itself.

1 The inability to ascribe likelihood to a single scenario can be overcome by using scenario ensembles, allowing
2 storylines to be compared and contrasted. Quantitative estimates such as warming or population growth can be
3 assessed according to likelihood of exceedance because cumulative statistical functions are more robust to
4 uncertainty than probability distribution functions. Likelihood can be addressed in a Bayesian manner, where
5 participants use a scenario process to update their priors, but in a richer manner than can be achieved with
6 straightforward prediction. For example, a stakeholder's prior model may be completely altered, they may step away
7 from a focusing on the most likely outcome to survey the spectrum of potential likelihood consequence, or they may
8 completely reframe the way they see the issue. The ability to do this collectively also fosters social learning,
9 potentially building a community of practice (Wenger, 2000;Pahl-Wostl, 2002).

10
11 [Box on IPCC-sponsored scenario-building process to be developed in collaboration with Chapter 21 team.]
12

13 By separating risks into tame and wicked problem risks, the need for scenarios with the decision-making process can
14 be better identified [moderate confidence]. For tame risks, if probabilities cannot be easily calculated then scenarios
15 can be used to explore the problem and illustrate alternative solutions for evaluation. Wicked problems will probably
16 need to be thoroughly scoped to select the most suitable decision-making process. They may require separate
17 applications of problem and solution-based scenarios or the development of reflexive scenarios. Even if conditional
18 predictions can be used to illustrate climate futures, scenarios may be needed to explore the solutions space
19 involving strategic actions, options planning and governance using both process and goal-oriented methods.
20

21 22 2.2.1.7. *Learning and Review* 23

24 Climate change is sure to surprise us, both in its impacts and in the technological and behavioural changes that will
25 affect society's ability to respond (National Research Council (NRC), 2009). The iterative risk management
26 framework and much of the adaptation literature thus stresses the importance of decision, systems, and processes
27 that have the ability to learn and respond over time to new information. Learning is fundamental to the process
28 shown in Figure 2-2, both in the loop where risks are repeatedly assessed and appraised, and in the loop where the
29 monitoring and evaluation of ongoing adaptation efforts generally leads to adjustment and response. Chapter 18
30 discusses such monitoring of impacts and learning processes are central to the discussions in Chapters 14 through 17
31 and in Chapter 20.
32

33 The climate literature includes a variety of approaches for describing how policies evolve over time. These
34 approaches are often used to represent the benefits and costs of learning in studies and simulation models that
35 support climate-related decisions. The sequential decision approach, commonly used in the climate policy literature,
36 represents policies as a sequence of choices over time, made with different amounts of information (Nordhaus,
37 1994). The real options approach draws from the finance literature to represent a near-term choice as creating the
38 ability to make specific future choices under certain conditions. Real options approaches have recently been used in
39 some adaptation studies (Hertzler, 2007) as well as those addressing greenhouse gas emissions reductions (Blyth et
40 al., 2007) and investments in emissions reducing energy technologies (Mahnovski, 2007). Control theory provides
41 another such representation (Funke and Paetz, 2011).
42

43 The literature also describes a wide variety of formal frameworks, systems and processes by which organizations
44 can learn and adjust themselves to new conditions over time. In the context of providing information to the decision
45 processes within these organizations, it is useful to consider several types of modes of learning (National Research
46 Council (NRC), 2009):

- 47 1. Unplanned learning is a default mode: actions are undertaken without any explicit consideration of
48 learning, and any change that occurs is unplanned and often unbidden.
- 49 2. Evaluation involves formal assessment, often by outside parties, of a program's effectiveness, with the
50 expectation that adjustments will be made in response.
- 51 3. In adaptive management, actions are designed as experiments so that they will perturb the decision
52 environment and thereby generate information useful for future adjustment and improvement.
- 53 4. Deliberation with analysis is an iterative process that begins with the many participants to a decision
54 working together to define its objectives and other parameters, working with experts to generate and

1 interpret decision-relevant information, and then revisiting the objectives and choices based on that
2 information.

3
4 The main focus of adaptive management is on process and continuous learning (trial and error, small
5 step→evaluate→adjust) (Dessai and Sluijs, 2007). Adaptive management identifies uncertainties; methodologies are
6 then designed and applied to test hypotheses as to how those uncertainties may influence decision-making needs.
7 The goals of adaptive management are diverse, outcomes are delayed or hard to define and measure and the
8 relationships between decision-makers may be fragile. An example of proposed adaptive management is shown in
9 Table 2-2. Progress is being made in adaptive management but may be difficult to apply a decision support tool due
10 to the limitations of institutional settings (NSF, 2009). There are few successful applications of adaptive
11 management in the literature (National Research Council (NRC), 2009).

12
13 [INSERT TABLE 2-2 HERE

14 Table 2-2: Example of adaptive management plan for bleached coral reefs (Reef Resilience, 2011).]

15 16 17 **2.2.2. Institutional Context**

18
19 Virtually all CCAV decisions will be made by or influenced by institutions. The institutional context will thus
20 prove an important influence on these decisions and on the way decision support is organized.

21 22 23 **2.2.2.1. Decision-makers**

24
25 Institutions are an imperative to the effective management of climate changes risks through their role in proper
26 governance. The IHDP's project on the Institutional Dimensions of Global Environmental Change (IDGEC) defines
27 institutions as "...systems of rules, decision-making procedures, and programs that give rise to social practices,
28 assign roles to the participants in these practices, and guide interactions among the occupants of the relevant roles
29 (IDGEC Scientific Planning Committee, 1999). Each institution has a set of objectives and goals that may be
30 explicit or implicit and as such, each displays unique characteristics. The strength and nature of their role in
31 maintaining a cohesive society enables societies to adapt to crises (O'Riordan and Jordan, 1999). Institutions can
32 facilitate environmental protection on one hand but on the other can also accelerate resource depletion by designing
33 and implementing counter-productive policies (Scharpf, 1997). The rules and roles of institutions for whatever
34 reason(s) they have been created can be of many forms: formal and informal, visible and latent, and conscious and
35 unconscious (Arts et al., 2006). Governments create formal institutions that play an important role in vulnerability
36 reduction and adaptation (Gupta et al., 2008). As adaptation is generally a local issue, local institutions play
37 important roles in the process. (Agarwal et al., 2008) analyzed the roles of local institutions in adaptation and
38 categorized them into local public, civil society and private institutions.

39
40 Smit et al. (Smit et al., 2001) identified institutions as one of the key determinants of adaptive capacity. Countries
41 with strong institutions are generally assumed to have a greater capacity to adapt to current hazards and disasters as
42 well to the future. However, this is not necessarily true in all the cases. Hurricane Katrina of 2005 in the USA and
43 the European heat waves of 2003 demonstrated that strong institutions and other determinants of adaptive capacity
44 do not necessarily reduce vulnerability if not translated to actions (IPCC, 2007). Generally for economic and
45 technological reasons, most of the developing countries have weak institutions that are usually not capable of
46 managing hazards and disasters of catastrophic nature. In 2010, extreme floods killed 1800 people and made six
47 million homeless in *Pakistan*. Although severe flooding was forecast correctly, due to institutional and logistical
48 weaknesses, vulnerable people were highly exposed to flooding. A lack of properly-functioning shelters and medical
49 facilities led to outbreak of diseases and further human casualties. The country incurred an economic loss of US\$ 9.5
50 billion (Asian Development Bank (ADB), 2010;Munich Re, 2010) and the floods impoverished or destituted
51 millions of people. Recently *Bangladesh* suffered two devastating cyclones-*Sidr* (2007) and *Aila* (2009). Storm
52 surges generated by both the cyclones destroyed lengths coastal embankments and saline water engulfed large swath
53 of densely populated areas. Despite reasonably effective disaster management programs compared to many other

1 developing countries, institutional weaknesses surfaced during and after the cyclones. Some destroyed embankments
2 were not repaired two years after *Aila*. Many affected people are yet to be rehabilitated (Kartiki, 2011).

3
4 Climate change and its associated risks have catalysed changes at existing institutions and facilitated creation of new
5 institutions at international, regional, national and local levels. Since its creation in 1988, the IPCC has evolved
6 through substantial changes regarding the assessments of climate change science, vulnerability, impacts and
7 adaptation, economics and technology of mitigation. In 2010, the Inter-Academy Council requested by the UN
8 Secretary General completed a detailed review of the IPCC process and made many recommendations regarding
9 administrative and assessment related changes to make the organization and its assessments more transparent and
10 effective (InterAcademy Council (IAC), 2010). On the global scale, the UNFCCC and its Kyoto Protocol are at
11 present the principal institutional frameworks by which climate policy is developed. The initial focus of the
12 UNFCCC was only mitigation and adaptation made only slow in-roads into the negotiation process. In negotiating a
13 successor to the Kyoto Protocol, many developments have taken place since the negotiations began in Bali in 2007.
14 A consensus agreement on mitigation is still the largest stumbling block in designing an effective framework under
15 which all countries will work together to stabilize GHG emissions and also towards a low carbon society.

16
17 Mirza (2003) argued that vulnerability to extreme weather events, disaster management and adaptation must be part
18 of the long-term sustainable development planning in developing countries. He further argued that the lending
19 agencies and donors/development partners need to reform their investment policies in developing countries to focus
20 more on capacity building to tackle climate change related risks instead of just investing in recovery operations and
21 infrastructure development. Over the last one decade, “climate change” has become important assistance and
22 investment portfolios of the major international financial institutions. For example, the World Bank has recently
23 completed an assessment of economic cost of adaptation in 7 developing countries-Bangladesh, Bolivia, Ethiopia,
24 Ghana, Mozambique, Samoa and Vietnam. The Bank supports both reactive and pro-active types of projects on
25 adaptation (Agarwal et al., 2008). The Asian Development Bank has also significantly working on climate change
26 issues in Asia and the Pacific Region and has developed implementation guidelines for its climate change fund
27 (Asian Development Bank (ADB), 2008).

28 29 30 2.2.2.2. *Governance and Decision Implementation*

31
32 Governance is usually visualized as a rigid, centralized, unitary, top-down process of rules and policy development
33 in the public interest which have to be implemented at local level (Commission on Global Governance, 1995).
34 Krahnmann (2003) argues that governance is considered as a flexible, diffuse, bottom-up and top down process which
35 interacts between different tiers of government as is with social actors. However, government is still the major actor
36 in the lives of public especially in the developing countries. Governance and good governance are often seen as key
37 institutional settings for addressing problems (Botchway, 2001). Climate change governance requires action for both
38 mitigation and adaptation and one cannot be complimentary to the other. (IPCC, 2007b) stressed on the
39 comprehensive adaptation programs in the short-term but mitigation is a must to reduce societal vulnerability to
40 climate change in the long-run. Governance of adaptation needs knowledge of anticipated regional and local impacts
41 of climate change and planning to tackle the future impacts is also required (Meadowcroft, 2009).

42
43 Climate change and the associated risks have national and international legal dimensions. One of the most
44 significant issues is the “inequity” that has been recognized in various international declarations and conventions.
45 Principal 7 of the 1992 Rio Declaration enunciated the principle of “common but differentiated responsibilities” of
46 states “in view of different contributions to global environmental degradation”. The UNFCCC also recognizes “The
47 specific needs and special circumstances of developing country Parties, especially those that are particularly
48 vulnerable to the adverse effects of climate change...”. The “precautionary approach” embedded in the 1992
49 UNFCCC was the most important new principle of international environmental policy and was emerging as
50 international environmental law (Freestone, 1991). **Article 3** of the Convention obliges precautionary action to
51 “anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are
52 threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for
53 postponing such measures...”. The *international aspects* of climate change impacts and risks would come from a
54 variety of angles. Sea level rise could alter the *maritime boundaries* of many nations that may lead to new claims by

1 the conflicting nations. Warming of ocean/sea water can bring in changes in traditional shipping lanes. Climate
2 change could also lead to access to resources that were previously technically inaccessible and that may result in
3 new territorial claims. Runoff changes in the international rivers due to reduced seasonal precipitation could result in
4 new *water conflicts* and *energy utilization* among the co-basin countries and can also pose challenges to the already
5 signed sharing agreements (Kim, 2010). Additional *food insecurity* due to climate change will pose a moral
6 challenge and human rights question regarding food supply from the developed countries to affected regions. There
7 will be many *national level* implications of climate change as well. Considering Bangladesh as a case study,
8 (Freestone et al., 1996) identified that nationally climate change and sea level rise would affect property rights and
9 land tenure, population displacement, rehabilitation and resettlement, and institutional frameworks involving with
10 these issues.

11
12 Climate change will have implications for insurance industry; legal challenges and litigations; businesses will be
13 impacted that would have legal implications nationally and internationally. Many national and international legal
14 institutions and instruments need to be updated to face climate related challenges.

15 16 17 2.2.2.3. *Evaluation and Reflexiveness*

18
19 Societies have long been adapting to the impacts of weather and climate through a wide range practices that include
20 crop diversification, irrigation, water management, disaster risk management and insurance. However, climate
21 change will be outside the range of historical experience requiring extensive further adaptation (Adger et al., 2007).
22 A range of interventions is either planned or underway by many national governments and international agencies.
23 For example, Bangladesh has already developed national adaptation strategy and action plan built over the following
24 six pillars- *food security, social protection and health; comprehensive disaster management; infrastructure;*
25 *research and knowledge management;* for immediate interventions (Government of Bangladesh, 2009).
26 Interventions need to be monitored and evaluated for three purposes: *first*, whether they are able to adequately
27 address climate change vulnerabilities of human populations and natural and economic systems; *second*, ensuring
28 efficiency, flexibility, equity, results, cost-effectiveness and sustainability of the interventions (Hedger et al.,
29 2008;Vidhi and Sharma, 2010); and *third*, to avoid any interventions turning to maladaptation (Mirza, 2009).
30

31 Monitoring and measuring adaptation policies, programs and projects are inherently complex (Governance and
32 Social Development Resource Center, 2001). There are two key questions that need to be answered. First, Do we
33 know the adaptation baseline(s)? Baselines are used to determine the effectiveness of planned interventions after a
34 project has started (Vidhi and Sharma, 2010). According to Ebi et al. (2005), an *adaptation baseline* is a
35 measurement valuing effectiveness of a “comprehensive description of adaptations that are in place to cope with
36 current climate...(t)he baseline may be both qualitative and quantitative, but should be operationally defined within
37 a limited set of parameters (indicators)” (p. 36) for evaluative purposes. Second, What do we measure: *adaptive*
38 *capacity, resilience, reduction of exposure, vulnerability?* Other dimensions include temporal scales, structural and
39 non-structural measures (e.g., information sharing-flood forecasting and warning and behavioral changes). In the
40 context of all these complexities, different approaches are required for monitoring and measuring adaptation
41 (Governance and Social Development Resource Center, 2001;Hedger et al., 2008).
42

43 Pandey et al. (2011) presented an indicator based framework (Figure 2-3) to assess the adaptive capacity of the
44 water resources system in the Bagmati River Basin, Nepal. The framework consists of seven indicators, four
45 parameters and an index. (UNFCCC, 2010) suggests that indicators to be formulated in a specific, measurable,
46 achievable, relevant and time-bound (SMART) manner. In the Bagmati case, Pandey et al. (2011) found that choice
47 of the framework, determinants and the indicators influenced how well adaptive capacity could be quantified at
48 different spatial and temporal scales. Based on these variations they suggested that a variety of policy interventions
49 be applied at a range of scales to achieve sufficient capacity to allow adaptive management. Schipper (2007) argues
50 that successful adaptation is linked to *development* and that adaptation measures should address the underlying
51 causes of vulnerability. Development initiatives can reduce sensitivity and exposure to climate hazards and
52 development processes reduce social vulnerability thus reducing vulnerability to climate change. (UNFCCC, 2010)
53 commented that the monitoring of adaptation measures is more advanced than the evaluation of adaptation policies.
54

1 [INSERT FIGURE 2-3 HERE

2 Figure 2-3: A conceptual framework of adaptation, adaptive capacity, and its parameters (Pandey et al., 2011).]

3
4 Monitoring and evaluation of adaptation measures is challenging. Planning, setting up and implementation of
5 monitoring and evaluation require substantial human and financial resources. A four-year project implemented by
6 the UNDP and the Secretariat of the Pacific Regional Environment Program required over \$400,000 (UNFCCC,
7 2010). Such a costly exercise exceeds budgets and capacity of many community-based adaptation projects in
8 developing countries. In order to make the project cost effective, the UNDP has developed an indicator based
9 simplified tool to monitor and evaluate locally-driven adaptation projects (UNFCCC, 2010).

10 11 12 **2.2.3. People Make Decisions**

13
14 Decision support for CCIIV must also recognize that individuals' values, culture, psychology, and the language
15 they use play a crucial role in the way they will use and process information (Kahan and Braman 2005).

16 17 18 **2.2.3.1. Value Setting**

19
20 The majority of climate change research conceptualizes values as monetary worth, relative worth, or fair return on
21 exchanges, drawing primarily on welfare economics and using cost-benefit analysis or contingent valuation to
22 estimate losses (Watkiss, 2011). Increasingly, however, a number of authors have argued that a broader
23 conceptualization of values is needed to understand and respond to climate change (Adger et al., 2009b; O'Brien,
24 2009; O'Brien and Wolf, 2010). In this broader conceptualization, values are also understood as the subjective,
25 qualitative and intangible dimensions of climate change and its impacts that are of importance to individuals and
26 cultures (O'Brien and Wolf, 2010). Drawing on this broader frame, values may concern the effects of climate change
27 on, for example, place identity, land-based or traditional practices important for cultures, and the symbolic meanings
28 of places and practices in particular where irreversible losses are likely. Such values are paramount in shaping how
29 the effects of climate change are perceived and how responses, including adaptation decisions, are shaped. In the
30 context of dangerous climate change, it has been acknowledged that judgment and "values matter for converting
31 science into policy" (p.1401) (Oppenheimer, 2005). Others have suggested that the difficulty in compensating for
32 irreversible losses due to incommensurable values points to a need for other principles, such as the precautionary
33 approach, to be utilised in global climate policy decision making (Adger et al., 2011). It has further been suggested
34 that people's value orientations determine what the effects of climate change mean to those affected and what is
35 perceived to be worth preserving and achieving through adaptation (and indeed mitigation) decision making
36 (O'Brien and Wolf, 2010). Despite a growing recognition that values matter, however, there is very little research
37 that explicitly considers the role that such values play in shaping adaptation decisions.

38
39 Literature that could provide empirical evidence and in-depth insight is even scarcer. Emerging results from research
40 in Arctic and subarctic settings, including northern Canada and Norway, highlight that sense of place is a key driver
41 in how unseasonal conditions and climate variability are responded to (Amundsen, 2010; Fresque, 2011). (Wolf et
42 al., In review) suggest that a sense of freedom is an essential characteristic of sense of place and facilitated by land-
43 based activities in two aboriginal communities in coastal Labrador. The most important expression of this freedom
44 included access the land, also, but not only, to hunt, fish or spend time at a cabin. In this part of northern Canada,
45 seasonal climatic conditions in winter typically facilitate travel overland on snow, over freshwater ice and on sea ice.
46 Responses to the unusually mild and rainy winter of 2009/10 show that participants felt stuck and trapped in their
47 communities that winter because a lack of snow, freshwater ice and sea ice prevented accessing the land for weeks
48 at a time. Climate change will and already does undermine this important yet subjective and intangible aspect of life
49 remote northern communities by closing a decision space (to be able to access the land) and by impacting
50 livelihoods. These results suggest arctic and subarctic communities may already be experiencing intangible (and
51 potentially irreversible) losses as a result of climate change. Further warming in the Arctic and subarctic could
52 create seasonal conditions in winter that prevent access to the land for weeks, months, and eventually altogether
53 (Crate, 2009). These types of impacts are arguably unaccounted for in current climate policy.

1 The available literature points to a substantive gap in research that examines the effects of and responses to the
2 changing climate; values play an important role and further research is required to make their multiple dimensions
3 explicit. Such research could assist in building legitimate, transparent and inclusive responses including policy on
4 climate change [moderate confidence].
5
6

7 2.2.3.2 *Cultural Determinants and Psychology* 8

9 Decision-making literature in psychology concerning climate change issues points out that at the individual level
10 decision-making is a multi-directional and non linear cognitive activity. Integration of new information can modify
11 previous decision-making outcomes, and can even produce contradictory results. Decision-making in climate change
12 problems is not really rational and can negatively affect environmental behaviour (Grothmann and Patt, 2005; Marx
13 et al., 2007). Recent research in social psychology and behavioural research also points out that a wide multiplicity
14 of strategies can be used by individuals in environmental decisions (Fischer and Glenk 2011).
15

16 However, cross-cultural and cultural psychology, as well as anthropology, demonstrates that decision-making is a
17 culturally shaped cognitive process. Environmental decision making is highly influenced by culturally elaborated
18 values. (Schultz et al., 2004) developed a model which is widely used in environmental psychology that links values,
19 attitudes, world views and behaviours to the environment. They differentiated three sets of values, associated with
20 attitudes toward the environment, described previously by (Stern et al., 1995): 1. "Egoistic", focused on values and
21 goals oriented toward the interest of the self (me, my future, my wealth, my health ...); 2. "Altruistic", values focus
22 on others (future generations, humanity, people of the community, children); 3. "Biospheric", values focusing on the
23 wellbeing of living things (plants, animals, marine life, birds). (Schultz et al., 2004) hypothesize that the type of
24 involvement of a person vis-à-vis the environment depends on whether that person sees themselves as more or less a
25 part of nature. They created a test INS (Inclusion of Self in Nature Scale) allowing respondents to indicate their
26 degree of "connection" with nature. (Schultz et al., 2004) also attempted to determine from an EFT test (Embedded
27 Figure Test), whether differences in information processing could be correlated with the degree of connection to
28 nature. They concluded that a weak connection with nature is associated with local information processing;
29 conversely, a greater connection with nature is associated with more comprehensive information processing. From
30 this evidence, cultural values can substantially influence the decision-making processes.
31

32 It is therefore important to consider the relationship between humans and the environment to understand cultural
33 determinants in decision-making processes. (Ignatow, 2006) distinguishes between two cultural models: the
34 "spiritual" and the "ecological". The spiritual perspective and the ecological point of view of the environment have
35 different social bases. Western education generally involves the second but not the first. In the spiritual model,
36 nature is sacred; it has its own rights and should be kept separate from human society. It is threatened by science and
37 technology and has to be respected. The ecological model represents nature as an ecosystem physically integrated
38 into human society (Bocking, 1994). This model does not provide inherent conflicts between the modern world and
39 nature, but considers that science and technology allow the integration of modern society within the natural
40 environment (Oates, 1989).
41

42 Another important aspect of decision-making is cultural influences on thinking. Perception and representation of
43 nature and the environment are influenced by the dominant modes of thought in a society. Cultural psychology
44 distinguishes between two main systems of thought: holistic and analytical thinking (Lammel and Kozakai,
45 2005; Lammel et al., 2011). The first type of thinking characteristic of collectivist societies consider that social
46 obligations are reciprocal and individuals take part in a community with strong ties (Peng and Nisbett, 1999; Nisbett
47 et al., 2001). Holistic thinking is built primarily on the knowledge gained through experience and not by way of
48 abstract logic. It is rather dialectical and accepts contradictions, multiple perspectives and tries to find a middle
49 stance between opposing propositions. Holistic thinking is associative and its computations reflect similarity and
50 contiguity.
51

52 In more individualistic societies, the analytical model is central. The interests of the individual take precedence over
53 the interests of the members of society, the self is independent and communication comes from separate fields:
54 benchmarks are not common. Analytical thinking dominates. Here the object is isolated from its context; the focus is

1 on understanding the characteristics of the object to determine its category membership, and explain and predict
2 events based on its intrinsic rules. Inferences are derived from contextualizing the content structure, using formal
3 logic and avoiding contradiction. Analytical thinking circumscribes symbolic representation systems; instead its
4 formalization is built on structures of rules. Several studies demonstrate the influence of this way of thinking on
5 complex problem-solving e.g., (Badke-Schaub and Strohschneider, 1998;Strohschneider and Güss, 1999;Güss et al.,
6 2010).

7
8 Finally it is important to note that an increasingly extensive literature highlights the importance of taking into
9 account cultural/local knowledge, traditional ways of thinking and traditional methods of decision-making when
10 assessing CCAV. Recent literature also emphasizes the importance of indigenous knowledge in decision-making on
11 climate change, dealing with both mitigation and adaptation e.g., (Vedwan, 2006;Nyong et al., 2007;Dube and
12 Sekhwela, 2008).

13 14 15 2.2.3.3. *Language and Meaning*

16
17 This section deals with two major issues: 1) the various terminologies used by different disciplines that intersect in
18 decision-making on climate change and 2) the relationship between technical and everyday definitions exercised in
19 the decision-making process. Decision-making processes need to accommodate both technical and non-technical
20 meanings of the concepts they apply; framing becomes very important in providing the context for meaning and
21 terms such as vulnerability and adaptation as defined by the IPCC have much broader meanings in general usage,
22 both in technical and everyday use.

23
24 Previous IPCC reports have addressed definitions with care, providing precise technical definitions for a range of
25 terms in order to focus climate research and provide rational policy advice. This model concentrates on the delivery
26 of findings in clear and precise terms. However, the decision-making process surrounding vulnerability and
27 adaptation assessment is broader than the technical aspects addressed in IPCC definitions and language (Adger,
28 2003;Fussel, 2007;O'Brien et al., 2007). Various disciplines may have different definitions for the same terms or
29 may use different terms for essentially the same thing. For example, adaptation is defined differently with respect to
30 biological evolution, climate change and social adaptation.

31
32 Technical language is necessary but not sufficient to convey the full range of meaning in a complex decision-making
33 process (Adger et al., 2003). Ancient wisdom, backed up by modern techniques of neurological mapping suggests
34 that a great deal of what exists in people minds and is translated through emotions, ethics and values is non-verbal.
35 Language is a tool for communicating these things but is by no means the only tool: visualization, kinetic learning
36 by doing and other sensory applications can be used to communicate science, art and through play (Perlovsky,
37 2009;Radford, 2009).

38
39 A major barrier to decision-making in complex and interdisciplinary environments is the different languages and
40 lexicons in use (Adger et al., 2003). Terms may contain different technical meanings but may also conceal different
41 epistemologies. The translation of research results will need to account for both technical and everyday meanings of
42 key terms. For example, words like danger, disaster and catastrophe have both technical and emotive aspects
43 (Britton, 1986;Carvalho and Burgess, 2005). Terms where this issue is especially pertinent include adaptation,
44 vulnerability, risk, dangerous, catastrophe and disaster. Other words have definitional issues because they contain
45 different frames; sustainability and risk being key examples (Harding, 2006;Hamilton et al., 2007).

46
47 Two important areas of applied interdisciplinary research centre on methodological approaches to decision-making.
48 As listed in the introduction, the two major types we apply to decision-making methods are normative and
49 descriptive. For normative methods values are held to be intrinsic to the decision whereas descriptive methods
50 gather knowledge about the process and values in use. Other synonyms for this typology are positivist/constructivist,
51 prescriptive/diagnostic and sometimes top-down and bottom up. These common threads that can be achieved
52 through interdisciplinary studies are just as important as the differences because of the central role it has in
53 managing environmental change e.g., (Adger et al., 2003).

1 The language of risk, because of its central role in decision-making on climate change, is especially important. Risk
2 is a polyseme, a word with multiple, related meanings. A definition of risk therefore needs to encompass its
3 polysemic nature, which technical definitions generally do not, addressing specific decision-making contexts such as
4 natural disasters, finance and security. Meanings of risk range from its ordinary use in everyday language to power
5 and political discourse, health, emergency, disaster and seeking benefits. Meanings range from specific local
6 meanings to broad-ranging concepts such as the risk society (Beck and Ritter, 1992;Beck, 2000;Giddens, 2000).

7
8 Many authors have described how modern technical definitions of risk have narrowed from older multiple meanings
9 of opportunity and loss to focus on loss (e.g., (Lupton, 1999;Füredi, 2006). Beck's *Risk Society* describes modernity
10 viewed through the lens of risk, how modern society structures itself around the threat of loss, described by risks,
11 where science is implicated in the articulation of those threats (Beck and Ritter, 1992). Overwhelmingly negative
12 definitions and discourses in the sociology of risk cannot however, be supported by linguistic analysis (Hamilton et
13 al., 2007).

14
15 Linguistic studies (Fillmore and Atkins, 1992) concluded that dictionary definitions were inadequate for
16 communicating the complex framings involved in the word risk, looking instead to the corpus linguistics – text
17 databases. The word risk occurs as both a noun and a verb. The frame RISK was divided into two subsidiary frames:
18 HARM and CHANCE with negative and positive senses (Fillmore and Atkins, 1992). Risk as a noun contained
19 thirteen separate meanings with five major senses: dangerous situation, unpleasant possibility, dangerous
20 person/thing, the outcome that one can insure against and the chance of commercial loss. The verb has three major
21 senses: to expose to danger or loss, to do something despite the chance of unfortunate consequences and to incur the
22 unfortunate consequences of doing something (Fillmore and Atkins, 1994).

23
24 (Hamilton et al., 2007) repeated the exercise with an updated database, the resulting frames being RUN_RISK as a
25 noun and DARING as noun and verb. They found no overwhelmingly negative or positive tendencies, confirming a
26 wide range of usage with an emphasis on health. Informal use tended towards personal risk, whereas formal use was
27 more abstract, being technical and pedagogical. They concluded that *the only observable pattern is the association*
28 *with some form of assessment of the risk involved and the uncertainty that defines this assessment* (Hamilton et al.,
29 2007). It suggests that people do assess risk, balancing likelihood and outcome in a similar manner to formal risk
30 assessment, confirming that risk, at least when consciously applied, forms the core of decision-making under
31 uncertainty. The view that the social meaning of risk has become more negative is not supported, although it may be
32 the case in some discourses associated with technology, globalization and global change. The broad, generic
33 description revealed by linguistic analysis is also consistent with the recent move in the risk literature to broad
34 definitions of risk away from narrow technical definitions (Rosa, 2003;ISO, 2009).

35
36 The change between the problem-oriented component of risk assessment to the solution-oriented component follows
37 the change in the term risk from a noun to a verb. Problem analysis applies risk as a noun (at-risk), whereas risk
38 management applies risk as a verb (to-risk) (Jones, 2011). This reflects a change from core risk types of Hamilton et
39 al., (2007) such as *asset* and *harm* associated with at-risk to *action* and *agent* associated with to-risk. For tame risks
40 in simple situations the transition from at-risk to to-risk is straightforward. Tame risks can be readily approached
41 using linear methods of assessment because of agreement around values and agency.

42
43 In complex situations, risk attached to the problem (at-risk) and the solution (to-risk) compete with each other. An
44 example is where uncertainty in estimating future climate risks may result in maladaptation that creates even more
45 risk. This is similar to the risk trap identified by Beck where problems and 'solutions' come into conflict (Beck,
46 2000). These risks are termed complex risks by Jones (2011) and are associated with wicked problems. Climate
47 change and many of its associated risks influenced by deep uncertainty (Kandlikar et al., 2005) are complex risks.
48 Consequently, the multiple frames in terms like risk, and related terms such as vulnerability, resilience need to be
49 addressed. This supports the conclusion by many authors that narrow definitions focused solely on climate need to
50 be expanded to suit the context in which they are being used (Huq and Reid, 2004;O'Brien et al., 2007;Schipper,
51 2007).

2.2.3.4. *Morals and Ethics*

Ethical concerns related to CCIAM concern the agency associated with anthropogenic climate change and consequent risks faced by current and future generations. Moral concerns deal with the vulnerability of people and places to climate risks irrespective of the role of agency in greenhouse gas emissions leading to change.

In general, adaptation takes a whole of climate approach to addressing potential harm because it is too difficult to attribute specific agency to a pool of well mixed greenhouse gas emissions in the atmosphere. Justice issues are distributional and temporal. However, the question of basic rights and challenges to those rights can be identified irrespective of specific attribution of blame.

Moral and ethical issues are discussed at length in WG III, Chapter 3 *Social, Economic, and Ethical Concepts and Methods*. The second order draft will develop some of the topics addressed in Chapter 3 specifically to issues surrounding CCIAM.

2.3. Toward Effective Decision-making

2.3.1. *Attributes*

Three characteristics of good decisions are that they are actionable, effective and produce the intended outcomes. Actionable decisions require a clear plan of implementation, have buy-in from stakeholders and if required, an institutional and governance framework. To be effective they need to have a noticeable and measurable result over a prescribed period of time. Outcomes are subject to how a system responds to the decisions that have been made combined with internally and externally-driven change processes. In a simple system, the response will be proportional to the action, but in a complex system, many other factors can intrude. A good decision in the short term may not prove to be good over the long-term if a system changes its behavior or the definition of what is considered good changes.

Attributes may be grouped into three broad categories: problem-based, solution-based and cross-cutting.

2.3.1.1. Problem Attributes

The framing of climate change as a problem is evolving, becoming more sophisticated and complex over time. This shows the increasing maturity of the science, especially climate modeling, but also reflects a greater involvement of the decision-making process in assessing vulnerability and adaptation. In simplest terms this means that climate information is being tailored for solutions, rather than solutions being tailored to fit the available climate information. An example is where adaptation is planned as a response to gradual mean change in regional climate indices because they can be quantified when the greatest risks come from changing extremes that are much more difficult to assess.

Problems can range from being simple problems where climate is the dominant stressor and direct cause and effect can be identified to complex problems where climate is one of multiple drivers of change, system feedbacks are strong and where adaptive responses are likely to change how the system behaves.

For climate, a whole of climate approach incorporating anthropogenic and natural influences with an emphasis on changing extremes as outlined in the IPCC SREX (Field et al., 2012) is becoming more common. As a stressor, climate can act through sudden onset (i.e., a shift or random set of extremes), via chronic stress (e.g., long-term drought or a system close to a threshold that experiences a series of short-term losses) or via inducing a threshold effect or tipping point in a system. Each of these phenomena may require a different type of response.

The role of attribution of climate change to anthropogenic or natural causes may be less important than recognizing that a whole of climate response is needed to manage whatever risks arise. However, some level of attribution may

1 be an institutional requirement, for example, for drawing from adaptation funds that are intended to be supplemental
2 to normal development. The inability to provide clear attribution is less likely to be a barrier in a system where
3 climate is recognized as having an influence that requires some degree of response. Autonomous adaptation will
4 respond to events and/or changes in exposure, whereas planned adaptation needs to respond to anticipated changes
5 no matter how they arise.

6 7 8 *2.3.1.2. Solution Attributes* 9

10 Decisions aiming to developing solutions have up to four attributes that contribute to their success: Creativity and
11 innovation, leadership, resources and learning.

12
13 When there is no learned or practical solution to a problem, some degree of creativity is required (Torrance, 1988).
14 Creativity followed by innovation provides the flexibility to explore the solution space combining problem solving
15 within the broader context of normative goals. Whereas process of problem definition is largely analytical, the
16 process of problem solving is largely expressive. Creativity can be linked to the decision-making process and
17 innovation to the development and implementation of tools, both cognitive and technological. Recent research into
18 creativity suggests that rather than being uncontrolled brainstorming where anything goes, creativity is developed
19 through a process of disciplined acts that seeks alternatives within a pre-defined set of boundary conditions
20 (Sternberg, 1988; Sawyer, 2007). For CCIAV these conditions include scientific plausibility and factors such as
21 economic efficiency, distributive fairness, scalability and so on.

22
23 Leadership has been described as the ability to motivate others to achieve a set of goals and can be a characteristic of
24 an individual within a group, or an organization (Vroom and Yetton, 1973; Chemers, 1997). Lack of leadership has
25 been identified as a barrier to adaptation (Moser and Ekstrom, 2010). Although there are several theories attached to
26 leadership, the most relevant to CCIAV is situational or contingency theory where leadership style is tailored to fit
27 the situation at hand. This fits the wide range of situations encountered within CCIAV. Situational theory describes
28 how normative or positivist methods are able achieve a particular set of goals. It also undertakes descriptive
29 assessment of how effective different leadership styles are in achieving their normative aims and proposes models
30 based on those findings (Vroom and Yetton, 1973; Margerison and Glube, 1979; Vroom and Jago, 1988; Chemers,
31 1997). Leadership can be understood through its role in a particular organization or institution via management lens
32 through how innovations implemented by an individual or organization are transferred to other actors. While the
33 expression of leadership may be in the operational arena (e.g., through inspiration by example) its overall aims are
34 generally considered to be strategic to transformational. Three important styles of leadership are transactional, based
35 on a reward/penalty strategy, laissez-faire and transformational, leaders who state goals, develop plans and
36 encourage others to achieve them in a variety of ways (Bass et al., 1996; Eagly et al., 2003).

37
38 Resources for decision-making include the capitals that comprise the stock used to describe adaptive capacity, the
39 resources available to undertake a decision-making process and the tools and services available to provide decision
40 support. They are required when the need to address CCIAV lies outside the existing set of resources required to
41 undertake business as usual or existing developmental processes. Resources may be gained by re-allocating existing
42 resources or developing new ones. It follows that a relatively new process such as adaptation to climate change will
43 be relatively inefficient when compared to existing processes.

44
45 Learning covers both formal and informal processes of gaining, assessing and communicating experience following
46 a decision. It covers monitoring and assessment, ex post evaluation of decisions, adaptive management and the
47 reflexive processes required to implement such management. Learning also covers the hierarchy of agents ranging
48 from individuals and organizations to institutions. Building from the previous point, applied learning will make
49 climate-related decision making more efficient.

2.3.1.3. *Cross-cutting and Contextual Attributes*

Cross-cutting and contextual attributes include: scale (both spatial, institutional), institutional context, governance and information supply and demand.

Scales that affect decision-making include spatial, institutional and time scales. Spatial and institutional scales tends to be associated with top-down and bottom-up directions of assessment. Spatial scales range from local (bottom) to global (top) and institutional scale from local to international. Time scales are associated with short- and long-term as temporal scales and fore- and back-casting in terms of directional scale. These scales are cross-cutting in that they combine in a variety of ways.

Institutions have a large number of attributes that encompass the spectrum between defined roles and informal narratives. In some cases institutional change may be required if that institution is contributing to market failures associated with climate change, the perpetuation of unsustainable practises or maladaptation. Institutions in opposition to responses on climate change also influence decision-making, especially that affecting mitigation policy. Institutions can also respond to particular decisions on a need basis as an actor without altering its identity or path in the process. Institutions also act at different scales – some will be actors, some will provide resources and yet others governance. Boundary organisations that link different disciplines and or institutions are increasingly being recognised as important to adaptation (Guston, 2001;Cash et al., 2003;McNie, 2007;Vogel et al., 2007) . They also provide a bridge between adaptation to climate and to other processes managing global change processes and sustainable development.

Governance can be thought of the superstructure that provides a legal, regulatory, cultural or managerial framework to decision-making. Governance structures are formal or informal, and regulate resources, information and responsibility through institutions. Both problems and solutions can be mapped onto a governance structure to determine whether they are “owned” and managed.

Knowledge is a cultural resource that people can draw from and may also be generated for specific decisions. Malaska and Holstius (1999) describe an Aristotelian approach to good decision-making that requires three kinds of knowledge: purpose and objectives, situational knowledge and knowledge about means and resources. Situational knowledge for CCIIV requires historical and current knowledge of the system and scenarios and/or forecasts of the future. Some of the main challenges for knowledge are to transfer information from specialised sources, such as the scientific knowledge of climate change, through to where it can inform decisions. Often the transfer requires a transformation from specialised statistical knowledge to a generalised form of everyday information, such as may be used by a market or public good climate service. Knowledge generation, demand and transfer are cross-cutting issues that have a huge bearing on decision-making processes.

These attributes can be viewed in how they influence the decision process itself. Figure 2-4 divides the decision-making process into four stages: scoping, analysis, implementation and review, outlining institutional and leadership, and knowledge and information characteristics for each stage. The two loops reflect the loops in Figure 2-2. Most effort in CCIIV research has been put into the first two stages, whereas decision implementation and follow up have been minimal. This does not imply that the analysis stage is discounted – problem analysis and solution evaluation is a significant undertaking in any decision-process, but that is where most current assessments stop.

[INSERT FIGURE 2-4 HERE

Figure 2-4: Selected attributes and characteristics relevant to the decision-making process itself. The two loops in the decision-making process relate to the two loops in Figure 2-2.]

Figure 2-5 combines the time element in planning adaptation to climate change with a systems planning approach at the organisational level. The coping range of climate (covering the spectrum between thriving and tolerance) that a location or actor is adapted to will need to change over time if to avoid increasing vulnerability. The coping range for any activity, location or organisation may be unique. This is combined with scenario use, visioning and strategic planning carried out in an organisational environment. A simplified systems approach builds in levels of leadership

1 with research and development, strategic management and operations. Resources and directions are fed down
2 through the system and feedback detailing progress and exceptional circumstances fed back up. All levels take in the
3 environmental information needed for decision-making and where they cannot make decisions within limits set,
4 send that signal up the line. The risk of crossing a critical threshold may require actions grading from the exercise of
5 different options, revisiting strategic directions or, in extreme cases, revisiting the original vision.

6
7 [INSERT FIGURE 2-5 HERE

8 Figure 2-5: Planning frameworks for climate change showing the coping range, changing climate, thresholds and
9 vulnerability for a single-variable climate scenario with idealised adaptation pathways (top) shows with a systems
10 planning framework for organizations showing how...]

11
12 The cases that follow are intended to elaborate on the role and importance of these attributes and ways in which they
13 may matter. The cases are intended to be examples of situations where decisions could not (or were not) reached and
14 why and where there were effective decisions and why.

15 16 17 **2.3.2. Assessing Impacts, Vulnerabilities, and Risks**

18
19 If the goal of decision-making on climate change is to manage climate risks, then decision-making needs to ensure
20 this goal is being achieved. Reviews of previous research, confirmed here, is that the progress in CCIIV has been
21 gradual, evolving as the scientific understanding of climate change improves. As adaptation is increasingly reaching
22 the implementation and review stage it is important to ensure that current methods are appropriate and to indicate
23 where improvements may be needed. A number of global initiatives are taking place to ensure this including Provia,
24 the Nairobi Initiative and work by the World Bank and regional development banks.

25 26 27 **2.3.2.1. Assessing Impacts**

28
29 Climate impact assessment is an exercise in translation of climate trends and scenarios into diagnoses of impacts on
30 ecosystems and peoples. It draws on interdisciplinary studies that focus on the interaction between nature and
31 society. An early description of impact models is found in Kates et al. (1985), who summarize various case study
32 experiences based on historic events (such as droughts, tropical cyclones) in determining direct cause and effect, and
33 then proposing a more interactive model, in which initial societal responses would lead to a change in the climate-
34 society interface for a particular location or activity, and subsequently, a different impact in the future for a similar
35 climatic event. A short term adjustment following an individual weather/climate event could ultimately lead to
36 longer term adaptation by societies, as illustrated for drought adjustment in the Great Plains of the United States, in
37 which a ‘lessening’ of impacts was observed during subsequent drought events (Warrick, 1975, 1980).

38
39 Scenario-based climate impact assessments differed from assessments of observed events, however, in that it
40 challenged prevailing models of stability in climate-society relationships. A number of cases of historic events
41 identified how decision makers, when faced with an extreme weather/climate event, held on to old views of such
42 relationships and pursued a ‘muddling through’ approach (Glantz, 1988). Impact assessment of future climate
43 change would therefore challenge prevailing decision frameworks that implicitly assumed climate stationarity (Milly
44 et al., 2008).

45
46 In order for scenario-based impact assessments to contribute to vulnerability and risk assessment, there needs to be a
47 series of translations carried out. Information on greenhouse gas concentrations is converted to changes in
48 atmospheric conditions, subsequently to impacts without proactive adaptation, and finally, to an assessment of the
49 effectiveness of various adaptation options. As discussed in Section 2.2.1.6, climate change scenarios themselves
50 have changed dramatically since the 1980s with the continued evolution of climate models and emission scenarios.
51 During the 1980s and early 1990s, impact assessments were based on climate scenarios with a doubling of
52 atmospheric carbon dioxide concentrations. The 1992 IPCC Supplementary Report (Houghton et al., 1992) and
53 IPCC Special Report on Emission Scenarios or SRES (Nakicenovic and Swart, 2000) each provided a range of
54 future scenarios for different time periods available for impacts assessments (Carter et al., 1994; Feenstra et al.,

1 1998). A new scenario process for this AR5 report aims to provide Representative Concentration Pathway (RCP)
2 and corresponding climate projections and socio-economic driving scenarios (van Vuuren et al., 2012) that can be
3 used for impact assessments.

4
5 This series of translations requires the transformation of data across various scales of time and space, between
6 natural and social sciences, utilizing a wide range of analytical tools created by different fields of study, including
7 agriculture, forestry, water, economics, sociology, and systems modelling (Figure 2-6). Regardless of uncertainties
8 within climate science itself, the translation process creates additional uncertainties, but more importantly, it
9 presents an opportunity to express temperature and precipitation scenarios as scenarios of changes in, for example,
10 food supply, coastal flood risk, health risk, and viability of species conservation plans.

11
12 [INSERT FIGURE 2-6 HERE

13 Figure 2-6: Approach Used to Inform Adaptation Policy (Dessai and Hulme 2004).]
14

15 Previous IPCC reports have assessed a considerable range of impacts literature, summarizing both observed trends
16 and projected scenarios at global and local scales. A common starting point is to assess the projected impacts of one
17 or more scenarios of climate change as a difference from a current ‘baseline’ state, for example, in terms of tonnes
18 of wheat per hectare or changes in the geographic range for various species of pine trees. This offers context for
19 addressing the ‘adapt to what’ question. The next step is to place this projected change within the context of local
20 management and governance, and to anticipate how possible future changes in management and governance over
21 the scenario time frame of 50–100 years might influence how the effects of bio-physical changes would influence
22 economic and societal conditions for the location being assessed. This represents a combination of top-down
23 biophysical assessments of futures and bottom-up socioeconomic assessments of the past and present. An important
24 challenge, therefore, is to construct impact assessments in which biophysical futures are superimposed on
25 socioeconomic futures.

26
27 More recently, a new generation of scenario-based impact assessments has emerged in which regional case studies
28 are linking biophysical, economic and social analysis tools, in order to describe the interactions between projected
29 biophysical changes and managed systems, assuming various responses by the actors of those managed systems.
30 This new literature includes attempts to estimate the costs and benefits of climate change impacts and adaptation
31 measures. For example, Ciscar et al. (2011) estimated the costs of potential climate change impacts, without public
32 adaptation policies, in Europe in four market impact categories (agriculture, river floods, coastal areas, and tourism)
33 and one nonmarket impact (human health). The methodology integrates a set of coherent, high-resolution climate
34 change projections and physical models into an economic modelling framework. They found that if the climate of
35 the 2080s were to occur today, the annual loss in household welfare in the European Union resulting from the four
36 market impacts would range between 0.2–1%. A similar study was conducted in the UK for a number of sectors:
37 health, built environment, transport, energy, tourism, biodiversity, water resources and agriculture (Hunt, 2008).
38

39 Another recent innovation is the application of decision support tools within scenario-based impact and adaptation
40 assessments. By using outputs from first-order impact assessments, such tools can enable scenario-based impact
41 assessments of systems, rather than just individual components of systems. One example is an assessment of the
42 ability of a community water system in British Columbia, Canada, to meet regulated in-stream flow requirements
43 within scenarios of climate and forest cover changes. In this case, the decision tool used was the Water Evaluation
44 and Planning System model or WEAP. Of seven scenarios tested, the community water system failed in six
45 scenarios due to projected climate impacts on local stream flow. The exception was the case where forest cover was
46 depleted due to an insect epidemic, similar to what other regions in British Columbia have already experienced, and
47 which is also a projected impact of climate change (Harma et al., 2012). This means that if this region was to
48 experience an insect epidemic, a reforestation strategy would have to account for its collateral effects on future
49 water system performance, and not just on other forest objectives (e.g. timber supply, wildlife habitat).
50

51 First-order and higher-order impacts will be discussed in detail for various sections in Chapters 3 through 13 and for
52 various regions in Chapters 22 through 30.
53
54

2.3.2.2. *Assessing Vulnerability and Risks*

The adaptation to climate change, disaster risk management, and resilience literatures all address the concept of vulnerability, defined as a susceptibility to loss or damage (Adger, 2006;Fussel, 2007). Within IPCC AR4, Schneider et al. (2007) identified those vulnerabilities that might be considered ‘key’, and therefore potentially ‘dangerous’. What makes an impact ‘key’ depends on certain criteria related to the climatic event itself, but also to the location or activity of interest. Criteria related to the event itself include the magnitude and timing of the event, its persistence and reversibility, and the likelihood and confidence that the event would occur. Aspects of the location or activity include its importance in supporting society, its exposure to the event, and its capacity to adapt. Adaptive capacity has been defined as the ability to adjust, to take advantage of opportunities, or to cope with consequences (IPCC, 2007b). However, the relationship between adaptive capacity and vulnerability is not clear. Recent experiences with the 2003 heat wave in Europe (Haines et al., 2006) and Hurricane Katrina in the USA (Committee on New Orleans Regional Hurricane Protection Projects, 2009) have led to questions about attribution of causes for weather and climate-related impacts. High property damage and loss of life occurred in both cases because of failures in support systems (e.g. flood defence structures, coordinated heat relief programs). This illustrates that countries with high adaptive capacity can also have a high level of vulnerability.

The concept of ‘adaptation deficit’, in which barriers unrelated to scientific knowledge hamper effective decision making (Burton and May, 2004;Adger and Barnett, 2009;Berrang Ford et al., 2011), may help to explain why such events can create surprising levels of damage within developed countries. It has also been related to ‘residual impacts’, which occur due to insufficient adaptation to current or future climate (IPCC, 2007a). Within developing countries, (Narain et al., 2011) consider the adaptation deficit to be within what is termed a larger ‘development deficit’. Field et al. (2012) cite other ‘deficit’ indicators, including a Disaster Deficit Index (impact of extreme event combined with financial ability to cope), structural deficit (low income, high inequality, lack of access to resources, etc.), and risk communication deficit. These ‘deficits’ are further explored in Chapter 16, within the context of adaptation planning, adaptive capacity, and mainstreaming into development planning.

This difficulty in parsing out the relative influences of climate and development patterns has been identified within assessments of observed trends in property damage from atmospheric extreme events. Chapter 1 has already reviewed the findings of the IPCC Special Report on Extreme Events (IPCC, 2012), which indicated that overall economic losses due to climatic extreme events have increased since the 1980s. Such trends may be attributed to changes in probabilities of extreme events, changes in human development patterns (more people in harm’s way) without changes in climatic extremes, or a complex combination of both (Pielke, 1998;Mills, 2005;Munich Re Group, 2011). Given these difficulties in determining the relative influences of atmosphere and development patterns on observed damage trends, similar challenges will influence assessments of projected damage trends within future scenarios of climate change and development. The debate over the results of the Stern Review (Stern, 2007) includes disagreements about the use of particular discount rates for evaluating future damages, as well as assumptions about future vulnerability and access to resources that support adaptation (Weitzman, 2007;Yohe and Tol., 2008).

Assessing damage within future scenarios of climate change will require approaches that link both bio-physical futures and socio-economic futures. There are opportunities to expand scenario assessments beyond expressing future human behaviour only through the lens of population growth, GDP growth and discount rates.

Analyses of disaster losses are discussed in Chapter 18, including the need to account for both the growth in value of damaged assets, which would contribute to increasing loss trends, but also improved building codes and warning systems which should offset losses. This adds complexity to attribution of causes underlying observed trends. Similarly, vulnerability assessments need to incorporate social, economic, and institutional criteria that determine whether a particular climatic event will result in a consequence of greater or lesser magnitude. Such criteria are discussed in detail in Chapter 19.

The focus of the revised criteria listed in Chapter 19 is the vulnerability of social systems. Degree of exposure is still considered an important precondition, but for a vulnerability to be considered key, the community or system of interest would have one or more particular attributes, including; low capacity to cope, low capacity to adapt, high

1 local importance of system at risk, and high susceptibility to cumulative stressors. These can be influenced by future
2 economic and social development choices at regional and local scales.

3
4 It may be difficult to anticipate how a development choice taken in the current or near term could influence future
5 vulnerability to projected climate change, hence the interest in the study of *emergent risks*, also reviewed in Chapter
6 19. Interactions between development pathways, climate change impacts, and climate change responses, could
7 create situations for which there is little or no precedent. Examples include flooding and erosion in densely
8 populated deltas, land use change due to increased demand for biofuels, and climate-related health risks interacting
9 with increasing urbanization of an aging global population.

10 11 12 2.3.3. *Climate Services*

13
14 Climate services are the link between generation and application of climate knowledge, or between climate science
15 and public demand for information. There is a growing body of literature concerning the development of these
16 services (2.3.2.1.); on the history and concepts (2.3.2.2.); on decision support as its main feature (2.3.2.3.), and the
17 policy implications of climate service as a global practice (2.3.2.4).

18 19 20 2.3.3.1. *Introduction*

21
22 The concept of Climate Services becomes ever more relevant for the generation and application of climate
23 information on local and regional levels. Numerous questions arise for decision makers, stakeholders and other
24 private or public users concerning climate variability, monitoring of risks and adaptation planning on the regional
25 and local level. Climate services link climate science and this public demand for information. They serve as “a
26 mechanism (...) to connect climate science to decision-relevant questions and support building capacity to
27 anticipate, plan for, and adapt to climate fluctuations” (Miles et al., 2006).

28
29 While many countries have already established national and regional climate services or are on the way to do so, the
30 literature shows significant differences in the evolution, organization and practice of Regional Climate Services in
31 different countries and parts of the world. The development of Regional Climate Services in the US and parts of
32 Europe is well documented, with an increasing focus on the aspect of communication and decision support. (See for
33 example Europe and Eastern Asia (Ebinger et al., 2010); Germany’s Climate Service Centre CSC
34 (<http://www.climate-service-center.de/>) and the HGF Regional Climate Offices (Schipper et al., 2009); the Swedish
35 “SweClim” (Rummukainen et al., 2004), or the UK Climate Impacts Programme (<http://www.ukcip.org.uk/>).) An
36 awareness of the need for climate services in developing countries is also growing (Semazzi, 2011), which is
37 reflected in an increasing body of literature mostly from science and technology studies on the migration of
38 standardized regional climate models into the “global South”. While in 2001 only around 21 countries were running
39 regional climate models (RCMs) mostly in OECD states, there are today about 104 countries trained in using the
40 PRECIS RCM (Edwards, 2010). There are also considerable differences in size, scope and practises of the
41 respective climate services, which range from large-scale administrative services to ad hoc interventions of research
42 institutes (von Storch and Zwiers, 2012). The assessment of Regional Climate Services shows a geographical
43 expansion from the global North to the global South, a shift from simple understandings of climate information
44 covered by linear standard approaches to ever more complex and wicked problem situations, and finally towards an
45 increasing interdisciplinarity and relevance of the social and communication sciences.

46 47 48 2.3.3.2. *Climate Services: History and Concepts*

49
50 In the peer-reviewed literature, especially the development of North American climate services is well documented
51 (Changnon et al., 1990; Miles et al., 2006; DeGaetano et al., 2010). Climate services are an expansion of the tasks
52 provided by weather services and similar operational organizations, mainly dealing with forecasts, seasonal
53 outlooks, and assessments of risks in a mostly stationary but variable climate. The idea of establishing climate
54 services on both national and regional levels resulted from the growing concern over the consequences of climate

1 fluctuations and the difficulties to provide and to distribute adequate information. In the beginning, those services
2 were barely effective for decision makers, who had difficulties understanding and using climate data for planning
3 purposes (Changnon et al., 1990; Miles et al., 2006; Visbeck, 2008). Furthermore, data were delivered slowly and
4 were of poor quality; there were problems in obtaining data on appropriate time and space scales, and there was an
5 “inability to access available datasets held by the private sector, states, regional and some federal agencies”
6 (Changnon et al., 1990).

7
8 Regional climate services became increasingly sophisticated concerning their methods, infrastructure, tools, and
9 collaborations (for example in the US through the 1978 Climate Program Act). In 2001, the US National Research
10 Council (National Research Council, 2001) outlined five guiding major principles for the mission of regional
11 climate services: “i) user-centric services, ii) active research, iii) a range of space and time scales, iv) active data
12 stewardship, and v) effective partnership” (DeGaetano et al., 2010): 1633).

13
14 Miles et al. (2006) define the mission and scope of climate services as follows: They

- 15 1. “Serve as a clearinghouse and technical access point to stakeholders for regionally and nationally relevant
16 information on climate, climate impacts, and adaptation; developing comprehensive databases of
17 information relevant to specific regional and national stakeholder needs.
- 18 2. Provide education on climate impacts, vulnerabilities, and application of climate information in decision-
19 making
- 20 3. Design decision-support tools that facilitate use of climate information in stakeholders’ near-term
21 operations and long-term planning
- 22 4. Provide user access to climate and climate impacts experts for technical assistance in use of climate
23 information and to inform the climate forecast community of their information needs
- 24 5. Provide researcher, modeller, and observations experts access to users to help guide direction of research,
25 modelling, and observation activities
- 26 6. Propose and evaluate adaptation strategies for climate variability and change”.

27 Climate services aim to provide exactly this kind of communication in the highly challenging environment of
28 technical and institutional networks, monitoring systems, and collaborations with other institutions, stakeholders and
29 decision-makers (DeGaetano et al., 2010).

30 31 32 2.3.3.3. *Climate Services: Practices / Decision Support*

33
34 Decision support in the form of science communication is an integral part of the climate service concept and is
35 generally acknowledged among government agencies and researchers as necessary for its functioning (Miles et al.,
36 2006; DeGaetano et al., 2010). There is an intense discussion in the literature about climate services about the role of
37 decision-support and its products, services and support systems with a growing awareness of the question how to
38 reconcile the supply of scientific information with user demands. Originally, linear models of society and
39 environment relations (Hasselmann, 1990) presented science as a monolithic knowledge provider, which is free of
40 conflicts about the quality of data and the nature of facts and were supposed to provide decision-makers with cost
41 effective solutions for adaptation and mitigation (c.f. Nordhaus, 1991). This “linear model” revealed many deficits
42 in the interaction between science and policy-makers or the public and is generally disqualified as inefficient (Pielke
43 and Carbone, 2002; McNie, 2007; Pielke, 2007; Sarewitz and Pielke Jr, 2007; Meyer, 2011).

44
45 Instead, the dynamic relationship between information and knowledge supply and demand for it are considered as
46 the focal point for a successful climate service; the supply of scientific information has to be reconciled with user
47 demands in order to produce scientific information which is relevant and suitable for decision making (McNie,
48 2007; Moser, 2009; Romsdahl and Pyke, 2009; Kandlikar et al., 2011; Pidgeon and Fischhoff, 2011). Furthermore, the
49 communication of uncertainty and risk play a special role in framing science, and scientific data have to be turned in
50 useful information (Shafer, 2004). According to Moser (2009) decision support is a diverse set of meanings and
51 definitions that has come to mean “processes of interaction, different forms of communication, potentially useful
52 data sets or models, reports and training workshops, data ports and websites, engaging any level of governance, at
53 any stage in the policy- or decision- making process”. Climate decision support should be based on six points: (1)
54 begin with users’ needs; (2) give priority to process over products; (3) link information producers and users; (4)

1 build connections across disciplines and organizations; (5) seek institutional stability; and (6) design processes for
2 learning (NCR 2009).

3
4 For (Shafer, 2004), the climate service is a “process of two-way communication” and “involves providing context
5 that turns data into information”. For (von Storch et al., 2011) p8), climate services are “knowledge brokers” that
6 have to establish an effective dialogue between science and the public. This dialogic communication contains two
7 main tasks: “One is to explore the range of perceptions, views, questions, needs, concerns and knowledge in the
8 public and among stakeholders about climate, climate change and climate risks. The other task is to convey the
9 content of scientific knowledge into the public, to media and the stakeholders. This includes communicating the
10 limitations of such knowledge, the known uncertainties and the unknowable, as well as the limited role of science in
11 complex decision processes.”

12
13 These demands outlined in the discussion and evaluation of decision-support on the regional level rely on and
14 strongly support interdisciplinary approaches, combining information gained from climate science with knowledge
15 gained from the social and communication sciences.

16 17 18 *2.3.3.4. The Geo-political Dimension of Climate Services*

19
20 There is an emerging body of literature from social sciences which takes into account the practices and implications
21 of the expansion of climate knowledge into policy-relevant contexts (Yearley, 2009;Grundmann and Stehr, 2010).
22 Science and technology inspired studies focus on the mobility of climate knowledge into the “global South’ or
23 developing countries. Decision support tools developed in universities in the global North such as the climate model
24 PRECIS spread all over the world and turn into an obligatory passage point for developing countries seeking to
25 adapt to future climates. This mobility of knowledge at the interface of science and politics has far reaching
26 implications for the shaping of global geographies of climate knowledge production; these models carry epistemic
27 power and establish a discursive hegemony of the IPCC and global governance mechanisms (Mahony and Hulme,
28 2012). Regional climate models play an increasingly important role in decision making processes,(Dessai et al.,
29 2009), while climate becomes the focal point of planning and development strategies and renders local forms of
30 knowledge subordinate to this ‘climate reductionism’ (Hulme, 2011).

31
32 Anthropological studies demonstrate that local forms of knowledge and scientific climate models are not necessarily
33 mutual exclusive; instead, individual case studies show how both forms of knowledge inform each other to the
34 benefit of a place based adaptation to climate variations (Strauss and Orlove, 2003;Orlove and Kabugo,
35 2005;Orlove, 2009;Strauss, 2009;Orlove et al., 2010). Endfield (2011) consequently argues for a ‘reculturing and
36 reparticularizing of climate discourses’.

37
38 Insights from science studies and actor-network-theory reveal hidden and taken-for-granted cultural assumptions in
39 the production, migration and problem-definition of scientific climate knowledge. These ‘frames’ act as organizing
40 principles and should as well as the inherent uncertainties made be explicit to decision makers. The same is true for
41 the often times subjective and value-laden assumptions in model-based decision processes, which have to be
42 considered systematically and communicated to the audience (Kloprogge et al., 2009). Such a “frame-based guide to
43 situated decision-making” (de Boer et al., 2010) opens up multiple opportunities in the decision process.

44
45 In this process, social, cultural and communication sciences play a decisive role (Pidgeon and Fischhoff, 2011;von
46 Storch et al., 2011). Cultural values, social actors, national and regional politics enter the stage; science becomes
47 part and parcel of the negotiation process entailing mitigation and adaptation decisions on various scales. To
48 position itself and to react according to the diverse demands, climate science has to become “rooted in society”
49 (Krauss, 2011). In this process, climate science necessarily becomes interdisciplinary, as politics, culture, religion,
50 values etc. become part of climate communication.

2.3.4. *Natural Resource Management*

Decision-making in the context of natural resource management (e.g. water, forests) generally occurs within the context of achieving multiple objectives. A watershed may be managed for domestic water supply, hydroelectricity, agriculture, navigation, recreation, and in-stream requirements for aquatic ecosystems. These may be influenced by requirements for flood control, including maintenance of engineered structures that control flow and levels of lakes, rivers and water storage for later use (dams, reservoirs, canals). A forested region can include timber supply areas, lands set aside for parks and wildlife habitat, and other lands managed to support biofuels. These may be influenced by changes in disturbance regimes (insects, disease, fire, invasive species), and requirements to protect endangered species.

Projected climate change could influence the achievement of management objectives, as regional water cycles and forest growth cycles may become altered. There may be changes in comparative advantage of fish and tree species, crop varieties, and renewable energy supplies. Concurrently, demands for climate-sensitive resources may change as regions continue to develop. Population and economic changes could lead to new pressures on land-based and water-based resources, and new opportunities and risks for communities dependant on these resources.

As management challenges increase in complexity, including the incorporation of climate change impacts, new concepts are emerging, such as Integrated Water Resources Management (IWRM) and Sustainable Forest Management (SFM). IWRM is briefly reviewed in Bates et al. (2008), in which it is described as a participatory process that recognizes water as a finite resource that has economic value in all its competing uses. SFM aims to maintain and enhance the economic, social and environmental values of forests, but is still an abstract concept (Seppälä et al., 2009).

Climate change is one of several drivers influencing these new paradigms, so the challenge is to find entry points for incorporating climate change information and impact/vulnerability assessment results within these and other natural resource management processes. Participatory processes supported by scenario-based assessments, including application of decision models, can enable climate scenarios to be translated into indicators of interest to resource managers. A regional example is an assessment of the South Saskatchewan River Basin in Canada. Climate change and socio-economic scenarios, and stakeholder consultation, contributed to constructing water supply and demand scenarios with the Water Use Analysis Model or WUAM. Management scenarios assessed in this study include business-as-usual combined with reduced water supply, higher minimum flow requirements, marginal cost pricing, introduction of water trading, and water reallocation among provinces (Martz et al., 2007).

Additional discussion on IWRM and SFM is found in chapters 3 and 4, respectively, as well as in regional chapters.

2.3.5. *Climate Action Plans*

For facilitating climate change adaptation, many processes have been initiated at national and international levels. Such processes in the context of mainstreaming were discussed in the AR4 Report of the IPCC (Adger et al., 2007). At the national level in the least developed countries (LDCs), the most important initiative launched by the UNFCCC was ‘National Adaptation Programmes of Action (NAPA)’. Building upon the existing coping strategies, the main objective of the NAPA is to identify, prioritize and implement projects to satisfy urgent and immediate needs of the LDCs so that even with their limited ability, they can adapt to the adverse impacts of climate change. As per the UNFCCC Guideline, the NAPAs must be action-oriented and country-driven and be flexible and based on national circumstances. The key steps for the preparation of NAPAs include synthesis of available information on the anecdotal evidence of vulnerability to and impacts of climate change and variability, extensive public participation and consultation and be presented in a simple format that can be easily understood by the policy-level decision makers and the public.

In the least developed countries, NAPAs are being used as decision-making tools for prioritization of adaptation projects (UNFCCC, 2010). In the NAPA process, Sudan identified the prioritized projects through a two-part step. In the first step, based on quantitative and consultative criteria developed by the stakeholders in five different

1 ecological zones, 32 projects were identified. They were ranked in order of their importance. In the second step, the
2 national level stakeholders involving specialists, practitioners and NGO representatives endorsed the prioritized
3 projects identified at the regional level (World Resources Institute et al., 2011). NAPA should not be a stand-alone
4 program and its integration with other socio-economic programs is necessary for creation of comprehensive
5 resiliency. For some instances, integration of NAPA with other programs has occurred for better decision making.
6 Rwanda and Bangladesh created a link between their NAPAs and the Poverty Reduction Strategy Papers (PRSPs)
7 with an objective to facilitate mainstreaming of climate change adaptation. The selection process of priority
8 adaptation activities in the Rwanda NAPA was intimately linked with various national and sectoral policies. For
9 example, the process took into account the urgent and immediate need of the country identified in the PRSP,
10 economic development and poverty reduction strategy (EDPRS) and other development programmes (OECD,
11 2009). The Bangladesh NAPA also strenuously considered the PRSP and identified prioritized adaptation strategies
12 that complimented the PRSP (OECD, 2009). Being a flat deltaic country, Bangladesh identified coastal afforestation
13 as a highly prioritized program which can reduce the impact of cyclonic storms and associated surges. The project
14 received approval of the Global Environment Facility (GEF) for funding (Lebel et al., 2012). Bangladesh's Climate
15 Change Strategy and Action Plan (BCCSAP) was highly influenced by the country's NAPA. As a follow-up of
16 NAPA, Cambodia is now pursuing a project for promoting climate resilient water management and agricultural
17 practices in rural areas (Lebel et al., 2012). There are many institutional and individual adaptive capacity gaps in the
18 population affected by extreme hazards in rural Cambodia. This project, the first of its nature is closely examining
19 those gaps so that the communities would be able to manage agricultural water resources under future climate
20 change. Developing country like India is following a different track than NAPA for decision making. The country
21 has prepared its 'National Action Plan' on climate change. The plan document addresses both adaptation and
22 mitigation measures which will promote the development goals and simultaneously generate co-benefits for
23 effectively addressing climate change. The document set measurable sectoral targets. For example, a 20%
24 improvement in water use efficiency through pricing and other measures is set to achieve by 2017 (Government of
25 India, 2008).

26
27 Many developed countries have made progresses towards developing adaptation strategy documents. Swart et al.
28 (2009) analysed 'National Adaptation Strategies (NAS) of nine European nations. They examined the decision
29 making aspects of the NASs and found both 'top-down and 'bottom-up (delegation of authorities to local
30 governments)' approaches. Dissemination of information on weather, climate, impacts, vulnerability, scenarios, etc.
31 for was found very critical element for adaptation decision making. From the strategy documents, Swart et al. (2009)
32 also identified multiple scales and actors involved in the decision-making process for adaptation. These actors may
33 have different and contradictory views of adaptation measures that would be required to tackle future climate
34 change.

35
36 Climate risk based decision making is increasingly becoming a practice in many developing and developed
37 countries. Agriculture especially the staple rice crop and water resources sectors of Vietnam are highly vulnerable to
38 current climatic variability and extremes. The degree of vulnerability may increase due to intrusion of saline water
39 and floods under future climate change. Aquaculture industry is rapidly developing in the coasts of Vietnam. The
40 coastal infrastructure and the dikes and structures that protect this industry may be severely damaged by storm
41 surges. In response to climate risks, Vietnam initiated large-scale mangrove restoration and rehabilitation programs
42 with the support of international institutions (World Resources Institute et al., 2011). The Tsho Rolpa glacier lake in
43 Nepal was at the risk of outburst due to rapid melting of the glaciers (Adger et al., 2007). Considering the risks, the
44 Government of Nepal started implementing both short- and long-term measures to prevent the outburst flood event
45 (Adger et al., 2007; World Resources Institute et al., 2011). There are many instances of risk based decision making
46 in the developed countries as well. The District of Elkford with only 2500 people is located in the Rocky Mountains
47 of south-eastern of British Columbia, Canada. In the past, the community tackled many climate related extreme
48 hazards that include floods, droughts and wildfires. These hazards may be intensified in a changing climatic
49 environment. Based on the participatory risk assessment, the community identified 26 actions that were integrated in
50 the Elkford's Official Community Plan (OCP) (Natural Resources Canada, 2012). Frequent heatwaves cause health
51 risks to people in some parts of Europe, particularly in central and southern Europe. The 2003 heat waves killed
52 35,000 people across Europe. Taking lessons from this event, many European countries have already implemented
53 health-watch warning systems (Alcamo et al., 2007).

2.3.6. *Local Responses*

Awareness of climate change risks have been propagated to local levels in many countries. Initiatives are underway to reduce future vulnerability and risks through planning and implementation of adaptation measures. Some municipal governments are already embracing the idea of incorporating climate change adaptation planning within municipal planning instruments, including sustainability plans (Ford and Berrang-Ford, 2011).

In British Columbia, Canada, the Provincial Regional Adaptation Collaborative (RAC) is assisting developing new tools and information to help local governments and other stakeholders so that they can identify potential impacts of climate change and appropriate adaptation options. They will include adaptation plans for watersheds in the Skeena, Okanagan, West Kootenay, Lower Mainland, and Vancouver Island regions (Government of British Columbia, 2010). In Ontario, Canada the provincial government is developing a risk management tool to assist the municipalities for crafting their adaptation strategies (Ontario Ministry of the Environment, 2011). The City of Pune in India is highly vulnerable to flood hazard. The City Government has developed a climate change plan with comprehensive disaster management measures (UNISDR, 2009). Key economic sectors especially agriculture and water of Bangladesh are highly vulnerable to extreme climatic hazards. Although over the decades, the country has made tremendous progress in tackling them, small and marginal farmers still remain at risks. With an objective of promoting livelihoods based adaptation and reducing vulnerability to climate variability and change, Department of Agricultural Extension (DAE), Bangladesh implemented a project entitled “Livelihood Adaptation to Climate Change (LACC) with international assistance. The project particularly targeted the women and poor communities with limited adaptive capacity (Baas and Ramasamy, 2008). Details of adaptation planning within urban and rural settlements are addressed in chapters 8 and 9, respectively.

Comprehensive participation of stakeholders is essential for successful adaptation planning at local level. Various enabling factors have been identified in stakeholder engagement processes. An enabling factor could be access to resources, high levels of local awareness, or political leadership. This contrasts with ‘drivers’ in that they are factors that ‘allow’ the implementation of a new strategy (Shepherd et al., 2006). Examples of drivers include availability of customized impact and vulnerability assessments for the community of interest and for local practitioners (engineers, planners, resource managers, political leaders) who would serve as champions for adaptation planning, as well as local social influences/networks and capacity for long term strategic planning (Gardner et al., 2009;Cohen, 2010).

The important role of local social networks is particularly evident in rural indigenous communities, where indigenous knowledge has enabled long term coping in the face of historic variability in climate. Indigenous knowledge for climate change adaptation was reviewed in IPCC AR4 (IPCC, 2007b), in which various examples of local knowledge systems were now being applied to the newer challenge of proactive adaptation to projected climate change. This increased attention to oral histories is leading to new experiments in which these are compared or combined with model-based scenarios to create a new discourse on adaptation planning. The challenge will be to carry out these new kinds of collaborations in a manner that enables their integration into a holistic narrative on future adaptation choices.

Local government officials often lack training on climate change adaptation and they also require comprehensive guidance. To fill this gap, guidebooks have been produced, in which the process of adaptation planning is framed as both a team-building and project management exercise, activities that are already part of usual practice (Snover et al., 2007;Bizikova et al., 2008;ICLEI Oceania, 2008).

Other tools/technologies are also being developed to facilitate adaptation planning at local level. Participatory GIS was reviewed in IPCC AR4 (Yohe et al., 2007). More recently, local scale visualization of impacts and adaptation measures, depicted on realistic landscapes, has become an emerging technology that is beginning to be tested to support dialogue on adaptation planning at the local scale (Sheppard, 2012). Visualizations could be used to display the spatial extent of climate change impacts on landscapes, or built infrastructure, with varying levels of exposure to particular climate-related risks. Outputs from impact assessments could be portrayed on three-dimensional (3D) surfaces (Schroth et al., 2011). The challenge with applying this technology is that while scenario-based impact

1 assessments are readily available for many locations, scenario-based adaptation assessments are not, so visual
2 representation of specific adaptation outcomes would be negotiated with local stakeholders as an artistic rendering
3 of what an adaptation measure might look like. This kind of exercise is currently being tested in communities within
4 Metro Vancouver, British Columbia, Canada (Shaw et al., 2009;Burch et al., 2010;Sheppard et al., 2011).

7 2.3.7. *Synthesis*

9 All decisions involving valued outcomes and uncertainty are risk assessments. Modern definitions of risk that
10 encompass both formal and informal decision-making are very broad. Two very important aspects of risk are
11 calculated risk and perceived risk. Both need to be managed and understood in effective decision-making processes
12 aiming to manage climate-related risks. Iterative risk assessment methods are recommended for managing climate-
13 related risks in complex settings. A particular aim is to utilise reflexive methods to develop adaptive management
14 techniques. This places great demands on institutions to manage that process. Two aspects of the decision-making
15 process: implementing decisions and follow up monitoring and assessment to assess whether a decision is “good”
16 over the life of that decision, have not been widely applied in CCIAV research. However, the literature emphasises
17 that these steps are required for effective decision-making linked to adaptive management.

19 The literature contains a wide range of decision-making strategies with a number of entry points into assessments of
20 impacts, adaptation and vulnerability (scientific-rational, institutional, governance, power discourse, economic,
21 discursive-consensus based). Traditionally CCIAV assessments have been dominated by rational science-driven
22 models that rely on the information-gap model, which assumes that better science will lead to better decisions.
23 While this may be the case with simple decisions it is not sufficient in complex situations with substantial uncertainty,
24 especially those with contested values and risky solutions. Complex, or wicked problems require a range of
25 participatory approaches that combine expert assessment and social-learning processes to evaluate, implement and
26 learn from actions. The use of participatory approaches is increasing, bringing scenario-based impacts and
27 adaptation research outputs into decision-making environments, particularly at sub-national scales. Levels of
28 engagement are strongly linked to system complexity and decision risk (Figure 2-7a). Likewise solution-based
29 strategies are also dependent on system complexity (Figure 2-7b).

31 [INSERT FIGURE 2-7 HERE

32 Figure 2-7: Two perspectives on decision complexity. On the left the relationship between decision risk and system
33 complexity is used to suggest levels of engagement (adapted from Robinson (2002)). On the right a problem-
34 solution uncertainty matrix delineating solution-based decision-making strategies.]

36 Decision support is situated at the intersection of data provision, expert knowledge and human decision-making.
37 Decision support is organized efforts to provide, disseminate, and encourage the use of information that aim to
38 improve climate-related decisions. Such support is most effective when it is context-sensitive taking account of the
39 diversity of different types of decisions, decision processes, and constituencies.

41 Climate Services aim to make knowledge about climate regionally accessible. In doing so they have to consider
42 information supply, knowledge competition and user demand. Knowledge transfer is a dialogic process and has to
43 take cultural values, orientations and alternative forms of knowledge into account. For scenario-based impact
44 assessments to contribute to vulnerability and risk assessment, a series of translations are required. Regardless of
45 uncertainties within climate science itself, the translation process creates additional uncertainties, but more
46 importantly, it presents an opportunity to communicate climate changes in terms of changes in risk and effectiveness
47 of adaptation responses. Institutionally, boundary organisations are important in climate services, translating and
48 transferring messages in impacts and other aspects of decision support.

2.4. Linking Adaptation with Mitigation and Sustainable Development

2.4.1. Assessing Synergies and Tradeoffs with Mitigation

The IPCC AR4 explored inter-relationships between adaptation and mitigation (Klein et al., 2007). Capacities to adapt and mitigate are driven by similar sets of factors, and opportunities for synergies may be available particularly for agriculture, forestry, urban infrastructure and some other sectors. However, the AR4 concluded that a lack of information made it difficult to assess these synergies.

Similarly, assessments of trade-offs were at an early stage. The AR4 cited some case studies which indicated that if both the effects of mitigation efforts on climate, and the costs of implementing mitigation measures were accounted for, any benefits from reduced climate change impacts (for example, on malaria) would be offset by losses due to reduced rates of economic growth. However, the general state of the literature was that information on trade-offs was scarce, since mitigation studies rarely addressed implications for adaptation, while adaptation studies did not assess implications for emissions ('adaptive emissions').

An illustration of trade-offs and synergies is shown in Figure 2-8. The upper left and lower right quadrants illustrate trade-offs that can result from actions that may be necessary under particular local-regional circumstances. The potential of these trade-offs to indirectly influence other adaptation and/or mitigation outcomes do not necessarily mean that such actions should be omitted from a climate change response portfolio, but decision making could benefit from the availability of a quantitative analysis of such trade-offs. Recent literature on methods for articulating such trade-offs is beginning to emerge. Proposed methods include the social cost of carbon, which is the marginal cost of emitting an extra tonne of carbon, expressed as the equivalent climate change impacts when that tonne was emitted (Yohe et al., 2007; Tol, 2008). Social cost estimates available for review by the AR4 were highly uncertain, ranging from US\$-10 to US\$+350 per tonne of carbon, with a mean value of US\$43 per tonne (Yohe et al., 2007). High social costs would infer high sensitivity or exposure, in that every additional tonne of carbon emitted would result in high costs of impacts, which would not be offset by adaptation. Low social costs would suggest high adaptive capacity or low exposure, thereby reducing the magnitude of climate change damage.

[INSERT FIGURE 2-8 HERE

Figure 2-8: Adaptation – mitigation trade-offs and synergies (adapted from (Cohen and Waddell, 2009).]

Chapter 19 offers additional discussion of recent literature on the relationship between adaptation, mitigation, and residual impacts, which are impacts that would not be offset by the combination of planned adaptation and mitigation efforts originating from planned reductions of greenhouse gas emissions. This is related to the 'adaptation deficit' described in 2.2.3.

2.4.2. Linkage with Sustainable Development – Resilience

The idea that climate change response and sustainable development should be integrated within a more holistic decision framework has been broadly discussed (Robinson et al., 2006; Klein et al., 2007; Yohe et al., 2007), and is the subject of more extensive review in Chapter 20. Practical aspects are being explored as local and sub-national scale actors (such as municipalities, regional districts, states/provinces) seek to incorporate proactive adaptation within long-term official development plans. This has enabled local case studies to be initiated, engaging researchers and practitioners (planners, engineers, water managers, etc.) in scenario-based exercises, building local capacity to plan for a range of climate change scenarios (Bizikova et al., 2010).

(Folke et al., 2010) argue that people and nature are interdependent systems, and adaptability is enhanced when actors can enable systems and places to absorb disturbance and reorganize while undergoing change, so as to retain the same function, structure and identity. In other words, this characteristic, known as resilience, is the capacity to change in order to maintain the same identity.

1 An example of local capacity building to promote resilience is King County (Seattle) Washington, USA, in which
2 collaboration between researchers and practitioners enables translation of scientific information from the global
3 scale to local conditions (Snover et al., 2007). This conveys local ownership on impacts and adaptation assessments
4 that feed into long-term decision making, creating a ‘climate plan’ that is meant to be flexible, adjusting to new
5 information as it becomes available, and supporting permanent research and monitoring of local environmental
6 changes and evaluation of results of actions taken (Saavedra and Budd, 2009).

7
8 The King County example describes a shared learning approach to promoting climate change adaptation without
9 being solely focused on ‘hard’ (technology, infrastructure, etc.) paths. Strengthening adaptive capacity promotes
10 resilience by creating a place-based constituency for long-term monitoring, evaluation and assessment of changing
11 conditions, and of local system performance. However, King County may be seen as a place that already has strong
12 adaptive capacity, and is well endowed with human and financial resources that could be engaged in proactive
13 adaptation within long term sustainable development planning. (Tschakert and Dietrich, 2010) indicate that in
14 regions with high and chronic poverty, coupled with low awareness of drivers of global change, there is a gap in
15 understanding about adaptation as a process, and that tools are needed to enable anticipatory learning.

16
17 Part of learning about adaptation as a process that can promote resilience is good communication about management
18 paradigms within various disciplines and fields of practice, and how these paradigms can shift as awareness of
19 climate change and global change increases. Within renewable resource management, there has been a paradigm
20 shift from a focus on exploitation to ecosystem stewardship, in which the central goal is to sustain ecosystem
21 capacity to provide services that benefit society as a whole. (Chapin et al., 2009) identify differences in
22 characteristics between steady-state resource management and ecosystem stewardship, in that the former would aim
23 to achieve ecological integrity through managing stocks, while the latter’s goal would be attaining sustainability
24 benefits through managing feedbacks. A similar notion of resilience has been described for urban areas, in which a
25 city or urban system could be managed to withstand various shocks and stresses while continuing to provide services
26 to residents in a sustainable manner. (Leichenko, 2011) categorizes 4 types of urban resilience studies: a) urban
27 ecological resilience, b) urban hazards and disaster risk reduction, c) resilience of urban and regional economies, and
28 d) urban governance and institutions. (Boyd et al., 2008) have promoted resilience as a way of guiding future
29 urbanization that would be better ‘climatized’. As densification, urban agriculture, green buildings, improved public
30 transit and other actions continue to be identified as key elements of the urban sustainability portfolio, how can
31 implementation occur when questions about governance and ability to pay continue to challenge many urban areas?
32 Beyond paradigm shifts within individual fields of practice, resilience is also being explored as an outcome of social
33 contracts which underpin governance. (O’Brien, 2009) uses examples from Norway, New Zealand and Canada to
34 illustrate how resilience thinking would frame climate change as a challenge that does not easily fit into existing
35 social contracts of individual communities and nation states, and that new types of arrangements may better serve
36 the goals of resilience and sustainable development within the context of climate change. Human capacity to adapt
37 to climate-related shocks and stressors is a function of values and power, and not just the more easily defined
38 economic and technological factors.

39 40 41 **2.4.3. Transformation – How Do We Make Decisions Involving Transformation?**

42
43 How can decisions be made when climate change impacts require activities to transform? Climate change impacts
44 can oblige firms to transform their activities. One reason of transformation can be related to needs of economic and
45 industrial systems to find safe geographical conditions. Decision making can consist in moving from regions
46 affected by climate change. (Linnenluecke et al., 2011) while proposing a framework of three assessment step to
47 help firms with relocation decisions: the evaluation of the impact of climate change, the feasibility of the project,
48 costs and benefits). Authors provide two case examples in Australia with suggestions for further research. This field
49 seems to be very recent and lacks relevant literature.

50 51 52 **Frequently Asked Questions**

53
54 To be done

References

- 1
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3
4
5 Aaheim, H. and C. Bretteville, 2001: Decision-making frameworks for climate policy under uncertainty. *Working*
6 *paper 2001:02*, , CICERO, Oslo, Norway.
- 7 Adger, W., S. Agrawala, M. Mirza, C. Conde, K. O'Brien, J. Pulhin, R. Pulwarty, B. Smit and K. Takahashi, 2007:
8 Assessment of adaptation practices, options, constraints and capacity. *Climate Change 2007: Impacts,*
9 *Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the*
10 *Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and
11 C.E. Hanson, Eds. Cambridge University Press, Cambridge, UK, 717-743.
- 12 Adger, W., S. Dessai, M. Goulden, M. Hulme, I. Lorenzoni, D. Nelson, L. Naess, J. Wolf and A. Wreford, 2009a:
13 Are there social limits to adaptation to climate change? *Climatic Change*, **93**, 335-354.
- 14 Adger, W., S. Dessai, M. Goulden, M. Hulme, I. Lorenzoni, D. Nelson, L. Naess, J. Wolf and A. Wreford, 2009b:
15 Are there social limits to adaptation to climate change? *Climatic Change*, **93**, 335-354.
- 16 Adger, W.N., 2003: Social capital, collective action, and adaptation to climate change. *Economic Geography*, **79**,
17 387-404.
- 18 Adger, W.N., K. Brown, J. Fairbrass, A. Jordan, J. Paavola, S. Rosendo and G. Seyfang, 2003: Governance for
19 sustainability: towards a 'thick' analysis of environmental decisionmaking *Environment and Planning A*, **35**,
20 1095-1110.
- 21 Adger, W.N., 2006: Vulnerability. *Global Environmental Change*, **16**, 268-281.
- 22 Adger, W.N. and J. Barnett, 2009: Four reasons for concern about adaptation to climate change. *Environment and*
23 *Planning A*, **41**, 2800-2805.
- 24 Adger, W.N., J. Barnett, F.S. Chapin and H. Ellemor, 2011: This must be the place: Underrepresentation of identity
25 and meaning in climate change decision-making. *Global Environmental Politics*, **11**, 1-25.
- 26 Agarwal, A., C. McSweeney and N.Perrin, 2008: The Role of Local Institutions in Adaptation to Climate Change,
27 Social Dimensions of Climate Change, Social Development Department, The World Bank, Washington DC.
28 , City, 183-193 pp.
- 29 Alcamo, J., J.M. Moreno, B. Nováky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E.
30 Olesen and A. Shvidenko, 2007: Europe. *Climate Change 2007: Impacts, Adaptation and Vulnerability.*
31 *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate*
32 *Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds. Cambridge
33 University Press, Cambridge, UK, 541-580.
- 34 Althaus, C.E., 2005: A Disciplinary Perspective on the Epistemological Status of Risk. *Risk Analysis*, **25**, 567-588.
- 35 Amundsen, H., 2010: Sense of Place as a Driver for Adaptation to Changes in Coastal Communities in Northern
36 Norway. *ArcticNet Annual Scientific Meeting, Ottawa ON*, ArcticNet, City, pp.
- 37 Arts, B., P. Leroy and J. van Tatenhove, 2006: Political Modernisation and Policy Arrangements: A Framework for
38 Understanding Environmental Policy Change. *Public Organization Review*, **6**, 93-106.
- 39 Asian Development Bank (ADB), 2010: *ADB-World Bank Assess Pakistan Flood Damage at \$9.7 Billion*, (Last
40 accessed,
- 41 Australian Public Service Commission, 2007: *Tackling wicked problems : a public policy perspective*. Australian
42 Public Service Commission, [Canberra], pp.
- 43 Baas, S. and S. Ramasamy, 2008: Community Based Adaptation in Action: A case study from Bangladesh, FAO,
44 Rome.
- 45 Badke-Schaub, P. and S. Strohschneider, 1998: Complex problem solving in the cultural context. *Le Travail*
46 *Humain*, **61**, 1-28.
- 47 Bass, B.M., B.J. Avolio and L. Atwater, 1996: The Transformational and Transactional Leadership of Men and
48 Women. *Applied Psychology*, **45**, 5-34.
- 49 Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., 2008: *Climate Change and Water. Technical Paper*
50 *of the Intergovernmental Panel on Climate Change*, IPCC Secretariat, Geneva, 210 pp.
- 51 Beck, U. and M. Ritter, 1992: *Risk society : towards a new modernity*. Sage, London, pp.
- 52 Beck, U., 2000: Risk society revisited: theory, politics and research programmes. *The risk society and beyond:*
53 *critical issues for social theory*, B. Adam, U. Beck and J. van Loon, Eds. Sage, London, London.
- 54 Beck, U., 2010: Climate for change, or how to create a green modernity? *Theory, Culture & Society*, **27**, 254-266.

- 1 Ben Haim, Y., 2001: *Information-Gap Decision Theory: Decisions Under Severe Uncertainty*. Academic Press, pp.
2 Berrang Ford, L., J.D. Ford and J. Paterson, 2011: Are we adapting to climate change? *Global Environmental*
3 *Change*, **21**, 25-33.
- 4 Bizikova, L., T. Neale and I. Burton, 2008: *Canadian communities' guidebook for adaptation to climate change.*
5 *Including an approach to generate mitigation co-benefits in the context of sustainable development*, First Edn.
6 Environment Canada and University of British Columbia, Vancouver, 97 pp.
- 7 Bizikova, L., S. Burch, S. Cohen and J. Robinson, 2010: Linking sustainable development with climate change
8 adaptation and mitigation. *Climate Change, Ethics and Human Security*, K. O'Brien, A.L.S. Clair and B.
9 Kristoffersen, Eds. Cambridge University Press, Cambridge, UK, 157-179.
- 10 Blyth, W., R. Bradley, D. Bunn, C. Clarke, T. Wilson and M. Yang, 2007: Investment risks under uncertain climate
11 change policy. *Energy Policy*, **35**, 5766-5773.
- 12 Bocking, S., 1994: Vision of nature and society: A history of the ecosystem concept. *Alternatives*, **20**, 12-18
13
- 14 Borjeson, L., M. Hojer, K. Dreborg, T. Ekvall and G. Finnveden, 2006: Scenario types and techniques: towards a
15 user's guide. *Futures*, **38**, 723-739.
- 16 Botchway, F.N., 2001: Good governance: the old, the new, the principle, and the elements. *Florida Journal of*
17 *International Law*, **13**, 159-210.
- 18 Boyd, E., H. Osbahr, P.J. Ericksen, E.L. Tompkins, M.C. Lemos and F. Miller, 2008: Resilience and 'Climatizing'
19 Development: Examples and policy implications. *Development*, **51**, 390-396.
- 20 Bradfield, R., G. Wright, G. Burt, G. Cairns and K.V.D. Heijden, 2006: The origins and evolution of scenario
21 techniques in long range business planning. *Futures* **37** 795-812.
- 22 Bretteville Froyn, C., 2005: Decision criteria, scientific uncertainty, and the global warming controversy. *Mitigation*
23 *and Adaptation Strategies for Global Change*, **10**, 183-211.
- 24 Britton, N.R., 1986: Developing an understanding of disaster. *Journal of Sociology*, **22**, 254-271.
- 25 Brown, C., W. Werick, W. Leger and D. Fay, 2010: A decision analytic approach to managing climate risks –
26 Application to the Upper Great Lakes. *JAWRA*, **in review**.
- 27 Brown, C., 2011: Decision-scaling for Robust Planning and Policy under Climate Uncertainty, World Resources
28 Institute, Washington, DC.
- 29 Buchanan, L. and A. O'Connell, 2006: A brief history of decision making. *Harvard Business Review*, **84**, 32-41.
- 30 Burch, S. and J. Robinson, 2007: A framework for explaining the links between capacity and action in response to
31 global climate change. *Climate Policy*, **7**, 304-316.
- 32 Burch, S., S.R.J. Sheppard, A. Shaw and D. Flanders, 2010: Planning for climate change in a flood-prone
33 community: municipal barriers to policy action and the use of visualizations as decision-support tools. *Journal*
34 *of Flood Risk Management*, **3**, 126-139.
- 35 Burton, I. and E. May, 2004: The adaptation deficit in water resources management. *IDS Bulletin*, **35**, 31-37.
- 36 Callaway, J. and M. Hellmuth, 2007: Assessing the incremental benefits and costs of coping with development
37 pressure and climate change: A South African case study. *Submissions from admitted non-governmental*
38 *organizations on socio-economic information under the Nairobi work programme*. , United Nations, Geneva.
- 39 Carpenter, S.R., P.L. Pingali, E.M. Bennet and M.B. Zurek, Eds., 2005: *Ecosystems and human well-being:*
40 *scenarios*, Vol. 2, Island Press, Washington, DC, 596 pp.
- 41 Carter, T.R., E.L.L. Rovere, R.N. Jones, R. Leemans, L.O. Mearns, N. Nakićenović, A.B. Pittock, S.M. Semenov
42 and J. Skea, 2001: Developing and applying scenarios. *Climate Change 2001: Impacts, Adaptation, and*
43 *Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel*
44 *on Climate Change*, J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, Eds. Cambridge
45 University Press, Cambridge, 145-190.
- 46 Carter, T.R., R.N. Jones, X. Lu, S. Bhadwal, C. Conde, L.O. Mearns, B.C. O'Neill, M.D.A. Rounsevell and M.B.
47 Zurek, 2007a: New Assessment Methods and the Characterisation of Future Conditions. *Climate Change 2007:*
48 *Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of*
49 *the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden
50 and C.E. Hanson, Eds. Cambridge University Press, Cambridge, UK, 133-171.
- 51 Carter, T.R., R.N. Jones, S.B. X. Lu, C. Conde, L.O. Mearns, B.C. O'Neill, M.D.A. Rounsevell and M.B. Zurek,
52 2007b: New Assessment Methods and the Characterisation of Future Conditions. *Climate Change 2007:*
53 *Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of*

- 1 *the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J.v.d. Linden and
2 C.E. Hanson, Eds. Cambridge University Press, 1, Cambridge, UK., 33-171.
- 3 Carvalho, A. and J. Burgess, 2005: Cultural Circuits of Climate Change in U.K. Broadsheet Newspapers, 1985–
4 2003. *Risk Analysis*, **25**, 1457-1469.
- 5 Cash, D.W., W.C. Clark, F. Alcock, N.M. Dickson, N. Eckley, D.H. Guston, J. Jaeger and R.B. Mitchell, 2003:
6 Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences of the*
7 *United States of America*, **100**, 8086-8091.
- 8 Changnon, S.A., P.J. Lamb and K.G. Hubbard, 1990: Regional Climate Centers: New institutions for climate
9 services and climate-impact research. *Bulletin of the American Meteorological Society*, **71**, 527-537.
- 10 Chao, P.T., B.F. Hobbs and B.N. Venkatesh, 1999: How climate uncertainty should be included in Great Lakes
11 management: Modeling workshop results. *Journal of the American Water Resources Association*, **35**, 1485-
12 1497.
- 13 Chapin, F.S.I., G.P. Kofinas, C. Folke, S.R. Carpenter, P. Olsson, N. Abel, R. Biggs, R.L. Naylor, E. Pinkerton,
14 A.M.S. Smith, W. Steffen, B. Walker and O.R. Young., 2009: Resilience-based stewardship: strategies for
15 navigating sustainable pathways in a changing world. *Principles of Ecosystem Stewardship*, F.S. Chapin III,
16 G.P. Kofinas and C. Folke, Eds. Springer, Dordrecht, 319-337.
- 17 Chemers, M.M., 1997: *An integrative theory of leadership*. Lawrence Erlbaum Associates, Mahwah, N.J., 200 pp.
- 18 Ciscar, J.-C., A. Iglesias, L. Feyen, L.s. Szabó³, D. Van Regemorter, B. Amelung, R. Nicholls, P. Watkiss, O.B.
19 Christensen, R. Dankers, L. Garrote, C.M. Goodess, A. Hunt, A. Moreno, J. Richards and A. Soria, 2011:
20 Physical and economic consequences of climate change in Europe. *Proceedings of the National Academy of*
21 *Sciences*, **108**, 2678-2683.
- 22 Clancy, W.J. and E.H. Shortliffe, Eds., 1984: *Readings in Medical Artificial Intelligence: The First Decade.*,
23 Addison-Wesley., Reading, MA: pp.
- 24 Cohen, S.J. and M.W. Waddell, 2009: *Climate Change in the 21st Century*. McGill-Queen's University Press,
25 Montreal, 379 pp.
- 26 Cohen, S.J., 2010: From observer to extension agent – using research experiences to enable proactive response to
27 climate change. *Climatic Change*, **100**, 131-136.
- 28 Commission on Global Governance, 1995: *Our Global Neighbourhood: the Report of the Commission on Global*
29 *Governance*. Oxford University Press, Oxford, pp.
- 30 Committee on New Orleans Regional Hurricane Protection Projects, N.A.o.S., 2009: The New Orleans Hurricane
31 Protection System, The National Academies Press, Washington.
- 32 Crate, S., 2009: Gone the bull of winter? Contemplating climate change's cultural implications in Northeastern
33 Siberia, Russia. . *Anthropology & climate change*, S.A. Crate and M. Nuttal, Eds. Left Coast Press, Walnut
34 Creek, USA, 139-152.
- 35 Crowe, K.A. and W.H. Parker, 2008: Using portfolio theory to guide reforestation and restoration under climate
36 change scenarios. *Climatic Change*, **89**, 355-370.
- 37 CSIRO and BoM, Eds., 2007: *Climate Change in Australia*, CSIRO, Melbourne, 148 pp.
- 38 Davies, H. and M. Walters, 1998: Do all crises have to become disasters? Risk and risk mitigation. *Disaster*
39 *Prevention and Management*, **7**, 396-400.
- 40 de Boer, J., J.A. Wardekker and J.P. van der Sluijs, 2010: Frame-based guide to situated decision-making on climate
41 change. *Global Environmental Change*, **20**, 502-510.
- 42 DeGaetano, A.T., T.J. Brown, S.D. Hilberg, K. Redmond, K. Robbins, P. Robinson, M. Shulski and M. McGuirk,
43 2010: Toward regional climate services: The role of NOAA's Regional Climate Centers. *Bulletin of the*
44 *American Meteorological Society*, **91**, 1633-1644.
- 45 Demeritt, D., 2001: The Construction of Global Warming and the Politics of Science. *Annals of the Association of*
46 *American Geographers*, **91**, 307-337.
- 47 Demeritt, D., 2006: Science studies, climate change and the prospects for constructivist critique. *Economy and*
48 *Society*, **35**, 453-479.
- 49 Dessai, S. and M. Hulme, 2007: Assessing the Robustness of Adaptation Decisions to Climate Change
50 Uncertainties: A Case Study on Water Resources Management in the East of England. *Global Environmental*
51 *Change*, **17**, 59-72.
- 52 Dessai, S. and J.P.v.d. Sluijs, 2007: Uncertainty and Climate Change Adaptation - a Scoping Study, Copernicus
53 Institute for Sustainable Development and Innovation, Utrecht.

- 1 Dessai, S., M. Hulme, R.J. Lempert and R.J. Pielke, 2009: Climate prediction: a limit to adaptation? *Living with*
2 *climate change: are there limits to adaptation?*, N. Adger, M. Goulden and I. Lorenzoni, Eds. Cambridge
3 University Press, Cambridge.
- 4 Dietz, T. and P.C. Stern, 2008: Public Participation in Environmental Assessment and Decision Making National
5 Research Council Washington, DC.
- 6 Dube, O.P. and B.M. Sekhwela, 2008: Indigenous knowledge, institutions and practices for coping with variable
7 climate in the Limpopo basin of Botswana. *Climate Change and Adaptation*, N. Leary, J. Adejuwon, V. Barros,
8 I. Burton, J. Kulkarni and R. Lasco, Eds. Earthscan, London, 71-99.
- 9 Dupuy, J.-P. and A. Grinbaum, 2005: Living with uncertainty: from the precautionary principle to the methodology
10 of ongoing normative assessment. *Comptes Rendus Geosciences*, **337**, 457-474.
- 11 Eagly, A.H., M.C. Johannesen-Schmidt and M.L.v. Engen, 2003: Transformational, Transactional, and Laissez-
12 Faire Leadership Styles: A Meta-Analysis Comparing Women and Men. *Psychological Bulletin*, **129**, 569–591.
- 13 Ebi, K.L., B. Lim and Y. Aguilar, 2005: Scoping and Designing an Adaptation Project. *Adaptation Policy*
14 *Frameworks for Climate Change: Developing Strategies, Policies and Measures*, B. Lim and E. Spanger-
15 Siegfried, Eds. Cambridge University Press, Cambridge and New York, 33-46.
- 16 Ebinger, J., L. Hancock and V. Tsirkunov, 2010: Weather/Climate Services in Europe and Central Asia: A Key Tool
17 for Energy Sector Adaptation to Climate Change. *Management of Weather and Climate Risk in the Energy*
18 *Industry*, A. Troccoli, Ed. Springer, Dordrecht, 105-120.
- 19 Edwards, P.N., 2010: *A vast machine : computer models, climate data, and the politics of global warming*. MIT
20 Press, Cambridge, Mass., 518 pp.
- 21 Ellsberg, D., 1961: Risk, Ambiguity, and the Savage Axioms. *The Quarterly Journal of Economics*, **75**, 643-669.
- 22 Endfield, G., 2011: Reculturing and Particularizing Climate Discourses: Weather, Identity, and the Work of George
23 Manley. *Osiris*, **26**, 142–162.
- 24 Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner,
25 S.K. Allen, M. Tignor and P.M. Midgley, Eds., 2012: *Managing the Risks of Extreme Events and Disasters to*
26 *Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental*
27 *Panel on Climate Change.*, Cambridge University Press, Cambridge, UK and New York, USA, 582 pp.
- 28 Fillmore, C.J. and B.T. Atkins, 1992: Towards a frame-based organization of the lexicon: The semantics of RISK
29 and its neighbors. *Frames, Fields, and Contrasts: New Essays in Semantics and Lexical Organization*, A.
30 Lehrer and E. Kittay, Eds. Lawrence Erlbaum, Mahwah, New Jersey USA, 75-102.
- 31 Fillmore, C.J. and B.T.S. Atkins, 1994: Starting where the dictionaries stop: The challenge for computational
32 lexicography. *Computational Approaches to the Lexicon*, B.T.S. Atkins and A. Zampolli, Eds. Clarendon Press,
33 Oxford, 349-392.
- 34 Fiorino, D.J., 1990: Citizen participation and environmental risk: A survey of institutional mechanisms. *Science,*
35 *Technology & Human Values*, **15**, 226-243.
- 36 Fischer, A. and K. Glenk 2011: One model fits all? - On the moderating role of emotional engagement and
37 confusion in the elicitation of preferences for climate change adaptation policies. *Ecological Economics*, **70**,
38 1178-1188.
- 39 Folke, C., 2006: Resilience: The emergence of a perspective for social-ecological systems analyses.
40 *. Global Environmental Change* **16 (3)**, 253–267.
- 41 Folke, C., S.R. Carpenter, B. Walker, M. Scheffer, T. Chapin and J. Rockstrom, 2010: Resilience thinking:
42 integrating resilience, adaptability and transformability. *Ecology and Society*, **14**, 20.
- 43 Ford, J.D. and L. Berrang-Ford, Eds., 2011: *Climate Change Adaptation in Developed Nations: From Theory to*
44 *Practice*, Springer, Dordrecht, 490 pp.
- 45 Freestone, D., 1991: The precautionary principle. *International Law and Global Climate Change*, R. Churchill and
46 D. Freestone, Eds. Graham and Trotman/Martinus Nijhoff, London/Dordrecht, 21-39.
- 47 Freestone, D., M.Farooque and S.R.Jahan, 1996: Legal Implications of Global Climate Change for Bangladesh. *The*
48 *Implications of Climate and Sea-Level Change for Bangladesh*, R.A.Warrick and Q.K.Ahmad, Eds. Kluwer
49 Academic Publishers, Dordrecht, The Netherlands, 289-334.
- 50 Fresque, J., 2011: *When places change, people change: Exploring the link between place identity, water and*
51 *adaptive capacity*. PhD, Wilfred Laurier University, Waterloo, ON, Canada.
- 52 Füredi, F., 2006: *Culture of fear revisited : risk-taking and the morality of low expectation*, 4th Edn. Continuum,
53 London ; New York, pp.

- 1 Funke, M. and M. Paetz, 2011: Environmental policy under model uncertainty: a robust optimal control approach.
2 *Climatic Change*, **107**, 225-239.
- 3 Fussler, H.M., 2007: Vulnerability: A generally applicable conceptual framework for climate change research.
4 *Global Environmental Change-Human and Policy Dimensions*, **17**, 155-167.
- 5 Gallopín, G.C., 2006: Linkages between vulnerability, resilience and adaptive capacity. *Global Environmental*
6 *Change* **16** (3)
7 293–303.
- 8 Gardner, J., A.-M. Dowd, C. Mason and P. Ashworth, 2009: A framework for stakeholder engagement on climate
9 adaptation. *CSIRO Climate Adaptation Flagship Working Paper No. 3*, CSIRO, Canberra.
- 10 Garvin, T., 2001: Analytical paradigms: The epistemological distances between scientists, policy makers, and the
11 public. *Risk Analysis*, **21**, 443-456.
- 12 Gawith, M., R. Street, R. Westaway and A. Steynor, 2009: Application of the UKCIP02 climate change scenarios:
13 Reflections and lessons learnt. *Global Environmental Change*, **19**, 113-121.
- 14 Giddens, A., 2000: *Runaway world : how globalization is reshaping our lives*. Routledge, New York, pp.
- 15 Glantz, M.H., Ed. 1988: *Societal Responses to Regional Climate Change. Forecasting by Analogy.*, Westview Press,
16 Boulder, 428 pp.
- 17 Governance and Social Development Resource Center, 2001: *Climate Change and Adaptation*, (Last accessed July 3
18 2011),
- 19 Government of Bangladesh, 2009: *Bangladesh Climate Change Strategy and Action Plan*. Ministry of Environment
20 and Forests, Dhaka, 98 pp.
- 21 Government of British Columbia, 2010: *British Columbia: Climate Action for the 21st Century*, Government of
22 British Columbia, Vancouver.
- 23 Government of India, 2008: *National Action Plan on Climate Change*, Prime Minister’s Council on Climate Change,
24 New Delhi.
- 25 Grothmann, T. and A. Patt, 2005: Adaptive capacity and human cognition: The process of individual adaptation to
26 climate change. *Global Environmental Change-Human and Policy Dimensions*, **15**, 199-213.
- 27 Groves, D.G., M. Davis, R. Wilkinson and R. Lempert, 2008: Planning for Climate Change in the Inland Empire:
28 Southern California. *Water Resources IMPACT*, **July**.
- 29 Grundmann, R. and N. Stehr, 2010: Climate change: what role for sociology? A response to Constance Lever-Tracy.
30 *Current Sociology*, **58**, 897-910.
- 31 Güss, C.D., M.T. Tuason and C. Gerhard, 2010: Cross-national comparisons of complex problem-solving strategies
32 in two microworlds. *Cognitive Science*, **34**, 489-520.
- 33 Gupta, J., T. K., K. J., M. S., M. van dam Brink, P. Jong and S. Nooteboom, 2008: *Institutions for Climate Change:*
34 *A Method to assess the Inherent Characteristics of Institutions to enable the Adaptive Capacity of Society*. IVM,
35 Amsterdam, the Netherlands, pp.
- 36 Guston, D.H., 2001: Boundary Organizations in Environmental Policy and Science: An Introduction. *Science,*
37 *Technology & Human Values*, **26**, 399-408.
- 38 Haines, A., R.S. Kovats, D. Campbell-Lendrum and C. Carvalan, 2006: Climate change and human health: impacts,
39 vulnerability, and mitigation. *Lancet*, 2101-2109.
- 40 Hamilton, C., S. Adolphs and B. Nerlich, 2007: The meanings of 'risk': a view from corpus linguistics. *Discourse*
41 *Society*, **18**, 163-181.
- 42 Hansen, L.P. and T.J. Sargent, 2008: *Robustness*. Princeton University Press, pp.
- 43 Harding, R., 2006: Ecologically sustainable development: origins, implementation and challenges. *Desalination*,
44 **187**, 229-239.
- 45 Harma, K.J., M.S. Johnson and S.J. Cohen, 2012: Future water supply and demand in the Okanagan Basin, British
46 Columbia: A scenario-based analysis of multiple, interacting stressors. *Water Resources Management*, **26**, 667-
47 689.
- 48 Hasselmann, K., 1990: How well can we predict the climate crisis? . *Environmental Scarcity - the International*
49 *Dimension*, H. Siebert, Ed. JCB Mohr, Tübingen, 165 - 183.
- 50 Hedger, M., T. Mitchell, J. Leavy, M. Greeley, A. Downie and A. Horrocks, 2008: *Evaluation of Adaptation to*
51 *Climate Change from a Development Perspective*, Institute of Development Studies, Brighton, UK.
- 52 Helsloot, I. and A. Ruitenbergh, 2004: Citizen Response to Disasters: a Survey of Literature and Some Practical
53 Implications. *Journal of Contingencies and Crisis Management*, **12**, 98-111.

- 1 Heltberg, R., P.B. Siegel and S. Jorgensen, 2009: Addressing human vulnerability to climate change: Toward a "no-
2 regrets" approach. *Global Environmental Change*, **19**(1), 89-99.
- 3 Hertzler, G., 2007: Adapting to climate change and managing climate risks by using real options. *Australian Journal*
4 *of Agricultural Research*, **58**, 985-992.
- 5 Hobbs, B.F., 1997: Bayesian methods for analysing climate change and water resource uncertainties. *Journal of*
6 *Environmental Management*, **49**, 53-72.
- 7 Hobbs, B.J., P.T. Chao and B.N. Venkatesh, 1997: Using decision analysis to include climate change in water
8 resources decision making. *Climatic Change*, **37**, 177-202.
- 9 Houghton, J.T., B.A. Callander, S.K. Varney and Intergovernmental Panel on Climate Change., Eds., 1992: *Climate*
10 *change 1992: the supplementary report to the IPCC scientific assessment*, Cambridge University Press for the
11 Intergovernmental Panel on Climate Change, Cambridge, xii, 200 pp.
- 12 Hulme, M., 2008: Geographical work at the boundaries of climate change. *Transactions of the Institute of British*
13 *Geographers*, **33**, 5-11.
- 14 Hulme, M. and M. Mahony, 2010: Climate change: What do we know about the IPCC? *Progress in Physical*
15 *Geography*, **34**, 705-718.
- 16 Hulme, M., 2011: Reducing the Future to Climate: A Story of Climate Determinism and Reductionism. *Osiris*, **26**,
17 245-266.
- 18 Hunt, A., 2008: Informing adaptation to climate change in the UK: Some sectoral impact costs. *Integrated*
19 *Assessment*, **8**, 41-71.
- 20 Huq, S. and H. Reid, 2004: Mainstreaming adaptation in development. *IDS Bulletin*, **35**, 15-21.
- 21 Hurwicz, L., 1951: Optimality criteria for decision-making under ignorance. *Cowles Commission Discussion Paper*,
22 *Statistics*, **370**.
- 23 ICLEI Oceania, 2008: *Local government climate change adaptation toolkit*. Government of Australia and
24 International Council for Local Environment Initiatives (ICLEI) – Australia/New Zealand Limited, Melbourne,
25 pp.
- 26 IDGEC Scientific Planning Committee, 1999: Institutional dimensions of global environmental change. *IHDP*
27 *Report*, International Human Dimensions Programme, Bonn.
- 28 Ignatow, G., 2006: Cultural models of nature and society. *Environment and Behaviour*, **38**, 441-461.
- 29 InterAcademy Council (IAC), 2010: *Review of the processes and procedures of the IPCC*. InterAcademy Council,
30 Amsterdam, the Netherlands, 123 pp.
- 31 IPCC, 2007a: Cross-chapter case study. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution*
32 *of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L.
33 Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds. Cambridge University Press,
34 Cambridge, 843-868.
- 35 IPCC, 2007b: *Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the*
36 *fourth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge University Press,
37 Cambridge, U.K., pp.
- 38 ISO, 2009: *ISO Guide 73:2009*. International Standards Organisation, Geneva, 15 pp.
- 39 Ison, R., 2010: *Systems Practice: How to Act in a Climate Change World*. Springer, London, UK, 324 pp.
- 40 Jäger, J., D. Rothman, C. Anastasi, S. Kartha and P. van Notten, 2008: Training Module 6: Scenario development
41 and analysis *GEO Resource Book: A training manual on integrated environmental assessment and reporting*
42 IISD and UNEP, Canada and Nairobi.
- 43 Jasanoff, S., 1996: Beyond epistemology: relativism and engagement in the politics of science. *Social Studies of*
44 *Science*, **26**, 393-418.
- 45 Jones, R., 2012: Applying scenarios to complex issues: Australia 2050. *Negotiating Our Future: Living scenarios*
46 *for Australia to 2050*, M.R. Raupach, T. McMichael, John J. Finnigan, L. Manderson and B.H. Walker, Eds.,
47 Vol. 2 In press.
- 48 Jones, R.N., 2010: The use of scenarios in adaptation planning: managing risks in simple to complex settings,
49 Victorian Centre for Climate Change Adaptation Research, Melbourne.
- 50 Jones, R.N. and B.L. Preston, 2010: Adaptation and Risk Management. *WIREs Climate Change*, **1**.
- 51 Jones, R.N. and B.L. Preston, 2011: Adaptation and risk management *WIREs Climate Change*, **2**, 296-308.
- 52 Kahan, D.M., D. Braman, P. Slovic, J. Gastil and G.L. Cohen, 2007: The Second National Risk and Culture Study:
53 Making Sense of - and Making Progress In - The American Culture War of Fact. *SSRN eLibrary*.

- 1 Kandlikar, M., J. Risbey and S. Dessai, 2005: Representing and communicating deep uncertainty in climate-change
2 assessments. *Comptes Rendus Geoscience*, **337**, 443-455.
- 3 Kandlikar, M., H. Zerriffi and C. Ho Lem, 2011: Science, decision-making and development: managing the risks of
4 climate variation in less-industrialized countries. *Wiley Interdisciplinary Reviews: Climate Change*, **2**, 201-219.
- 5 Kartiki, K., 2011: Climate change and migration: a case study from rural Bangladesh. *Gender & Development*, **19**,
6 23-38.
- 7 Kasperson, R.E., 1992: The Social Amplification of Risk: Progress in Developing an Integrative Framework in
8 Social Theories of Risk. *Social Theories of Risk*, S. Krimsky and D. Golding, Eds. Praeger, Westport, CT, USA,
9 53-178.
- 10 Keeney, R.L. and H. Raiffa, 1993: *Decisions with Multiple Objectives*. Cambridge University Press, Cambridge,
11 UK, pp.
- 12 Kim, J.-Y., 2010: Climate change: new challenge to the law of the sea regime. *Dodko Research Journal*, **11**, 101-
13 105.
- 14 Kirshen, P., C. Watson, E. Dougla, A. Gontz, J. Lee and Y. Tian, 2008: Coastal flooding in the northeastern United
15 States due to climate change. *Mitigation and Adaptation Strategies for Global Change*, **13**, 437-451.
- 16 Klein, R.J.T., S. Huq, F. Denton, T.E. Downing, R.G. Richels, J.B. Robinson and F.L. Toth, 2007: Inter-
17 relationships between adaptation and mitigation. *Climate Change 2007: Impacts, Adaptation and Vulnerability.*
18 *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate*
19 *Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J.v.d. Linden and C.E. Hanson, Eds. Cambridge University
20 Press, Cambridge, UK, 745-777.
- 21 Kleindorfer, P.R., H. Kunreuther and P.J.H. Schoemaker, 1993: *Decision Sciences: An Integrative Perspective*.
22 Cambridge University Press, Cambridge, 470 pp.
- 23 Klopogge, P., J.P. van der Sluijs and A.C. Petersen, 2009: A method for the analysis of assumptions in model-based
24 environmental assessments. *Environmental Modelling & Software*, **26**, 289-301.
- 25 Knight, F.H., 1921a: *Risk, uncertainty and profit*. Hart, Schaffner & Marx; Houghton Mifflin Co., Boston, pp.
- 26 Knight, F.H., 1921b: *Risk, Uncertainty, and Profit*. Houghton Mifflin, Boston, MA, pp.
- 27 Kok, M.T.J. and H.C. de Coninck, 2007: Widening the scope of policies to address climate change: directions for
28 mainstreaming. *Environmental Science & Policy*, **10**, 587-599.
- 29 Year: *11th International Conference on Computing and Control for the Water Industry, Exeter, UK*, City, (in press)
30 pp.
- 31 Krahmman, E., 2003: National, regional, and global governance: One phenomenon or many? *Global Governance*, **9**,
32 323-357.
- 33 Krauss, W., 2011: Rooted in society. *Nature Geoscience*, **3**, 513-514.
- 34 Kriegler, E., B.C. O'Neill, S. Hallegatte, T. Kram, R. Lempert, R.H. Moss and T.J. Wilbanks, 2010: Socio-economic
35 Scenario Development for Climate Change Analysis. *CIREN Working Paper DT/WP No 2010-23*, Centre
36 International de Recherche sur l'Environnement et le Développement, Paris.
- 37 Lammel, A. and T. Kozakai, 2005: Percepción y representación de los riesgos de la contaminación atmosférica
38 según el pensamiento holístico y el pensamiento analítico. *Desacatos*, **19**, 85-98.
- 39 Lammel, A., E. Dugas and C. Guillen, 2011: Traditional way of thinking and prediction of climate change in New
40 Caledonia (France). *Indian Journal of Traditional Knowledge*, **10**, 13-20.
- 41 Lebel, L., L. Li, C. Krittasudthacheewa, M. Juntopas, T. Vijitpan, T. Uchiyama and D. Krawanchid, 2012:
42 Mainstreaming Climate Change Adaptation into Development Planning, Adaptation Knowledge Platform and
43 Stockholm Environment Institute, Bangkok.
- 44 Leichenko, R., 2011: Climate change and urban resilience. *Current Opinion in Environmental Sustainability*, **3**, 164-
45 168.
- 46 Leiserowitz, A., 2006: Climate change risk perception and policy preferences: the role of affect, imagery, and
47 values. *Climatic Change*, **77**, 45-72.
- 48 Lempert, R., N. Nakicenovic, D. Sarewitz and M. Schlesinger, 2004: Characterizing Climate-Change Uncertainties
49 for Decision-Makers. An Editorial Essay. *Climatic Change*, **65**, 1-9.
- 50 Lempert, R., 2011: Climate Scenarios that Illuminate Vulnerabilities and Robust Responses *submitted*.
- 51 Lempert, R. and N. Kalra, 2011: Managing Climate Risks in Developing Countries with Robust Decision Making,
52 World Resources Report, Washington DC.
- 53 Lempert, R.J., S.W. Popper and S.C. Bankes, 2003: *Shaping the Next One Hundred Years : New Methods for*
54 *Quantitative, Long-term Policy Analysis*. RAND Corporation, Santa Monica, CA, pp.

- 1 Lempert, R.J. and M. Collins, 2007: Managing the Risk of Uncertain Threshold Responses: Comparison of Robust,
2 Optimum, and Precautionary Approaches. *Risk Analysis*, **27**, 1009-1026.
- 3 Lempert, R.J. and D.G. Groves, 2010: Identifying and evaluating robust adaptive policy responses to climate change
4 for water management agencies in the American west. *Technological Forecasting and Social Change*, **77**, 960-
5 974.
- 6 Lempert, R.J. and S.C. McKay, 2011: Some thoughts on the role of robust control theory in climate-related decision
7 support. *Climatic Change*.
- 8 Linnenluecke, M.K., A. Stathakis and A. Griffiths, 2011: Firm relocation as adaptive response to climate change and
9 weather extremes. *Global Environmental Change*, **21**, 123-133.
- 10 Lopez, A., F. Fung, M. New, G. Watts, A. Weston and R.L. Wilby, 2009: From climate model ensembles to climate
11 change impacts and adaptation: A case study of water resource management in the southwest of England. *Water*
12 *Resources Research*, **45**, -.
- 13 Lupton, D., 1999: *Risk*. Routledge, London, New York, pp.
- 14 Mahnovski, S., 2007: *Robust decisions and deep uncertainty: An Application of real options to public and private*
15 *investment in hydrogen and fuel cell technologies*. PhD, Pardee RAND Graduate School, Santa Monica, CA.
- 16 Mahony, M. and M. Hulme, 2012: Model Migrations: Mobility and Boundary Crossings in Regional Climate
17 Prediction. *Transactions of the Institute of British Geographers*, **37**, 197-211.
- 18 Malaska, P. and K. Holstius, 1999: Visionary management. *Foresight*, **1**, 353 - 361.
- 19 Malone, T.F. and G.W. Yohe, 2002: Knowledge partnerships for a sustainable, equitable and stable society. *Journal*
20 *of Knowledge Management*, **6**, 368-378.
- 21 Manning, L.J., J.W. Hall, H.J. Fowler, C.G. Kilsby and C. Tebaldi, 2009: Using probabilistic climate change
22 information from a multimodel ensemble for water resources assessment. *Water Resources Research*, **45**, -.
- 23 Margerison, C. and R. Glube, 1979: Leadership decision-making: an empirical test of the Vroom and Yetton model.
24 *Journal of Management Studies*, **16**, 45-55.
- 25 Martin, J., P. Fackler, J. Nichols, B. Lubow, M. Eaton, M. Runge, B. Stith and C. Langtimm, 2011: Structured
26 decision making as a proactive approach to dealing with sea level rise in Florida. *Climatic Change*, **107**, 185-
27 202.
- 28 Martz, L., J. Bruneau and J.T. Rolfe, 2007: Climate Change and Water. *SSRB Final Technical Report*, University of
29 Saskatchewan, Saskatoon, Canada.
- 30 Marx, S.M., E.U. Weber, B.S. Orlove, A. Leiserowitz, D.H. Krantz, C. Roncoli and J. Phillips, 2007:
31 Communication and mental processes: Experiential and analytic processing of uncertain climate information.
32 *Global Environmental Change*, **17**, 47-58.
- 33 Mastrandrea, M.D., C.B. Field, T.F. Stocker, O. Edenhofer, K.L. Ebi, D.J. Frame, H. Held, E. Kriegler, K.J. Mach,
34 P.R. Matschoss, G.-K. Plattner, G.W. Yohe and F.W. Zwiers, 2010: Guidance Note for Lead Authors of the
35 IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties, Intergovernmental Panel on Climate
36 Change.
- 37 McClure, J., F. Walkey and M. Allen, 1999: When Earthquake Damage is Seen as Preventable: Attributions, Locus
38 of Control and Attitudes to Risk. *Applied Psychology*, **48**, 239-256.
- 39 Mcdaniels, T. and C. Wilson, 2007: Structured decision-making to link climate change and sustainable development.
40 *Climate Policy*, **7**, 353-370.
- 41 McIvor, D. and D. Paton, 2007: Preparing for natural hazards: normative and attitudinal influences. *Disaster*
42 *Prevention and Management*, **16**, 79-88.
- 43 McNie, E.C., 2007: Reconciling the supply of scientific information with user demands: an analysis of the problem
44 and review of the literature. *Environmental Science & Policy*, **10**, 17-38.
- 45 Meadowcroft, J., 2009: Climate Change Governance. Background Paper to the 2010 World Development Report. .
46 *World Bank Policy Research Working Paper*, World Bank, Washington, DC.
- 47 Measham, T., B. Preston, T. Smith, C. Brooke, R. Gorddard, G. Withycombe and C. Morrison, 2011: Adapting to
48 climate change through local municipal planning: barriers and challenges. *Mitigation and Adaptation Strategies*
49 *for Global Change*, 1-21.
- 50 Meyer, R., 2011: The public values failures of climate science in the US. *Minerva*, **49**, 47-70.
- 51 Miles, E.L., A.K. Snover, L.C. Whitely Binder, E.S. Sarachik, P.W. Mote and N. Mantua, 2006: An approach to
52 designing a national climate service. *Proceedings of the National Academy of Sciences*, **103**, 19616-19623.
- 53 Mills, E., 2005: Insurance in a climate of change. *Science*, **309**, 1040-1044.

- 1 Milly, P.C.D., J. Betancourt, M. Falkenmark, R.M. Hirsch, Z.W. Kundzewicz, D.P. Lettenmaier and R.J. Stouffer,
2 2008: Stationarity is dead: whither water management? . *Science*, **319**, 573-574.
- 3 Mirza, M.M.Q., 2003: Climate change and extreme weather events: can developing countries adapt? *Climate Policy*,
4 **3**, 233-248.
- 5 Mirza, M.M.Q., 2009: Climate Change and Adaptation Accounting for Flood Hazard in Bangladesh. *Evaluating*
6 *Climate Change and Development*, R. van den Berg and O. Feinstein, Eds. World Bank Series on Development,
7 New York, 299-323.
- 8 Morgan, M.G. and M. Henrion, 1990: *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and*
9 *Policy Analysis*. Cambridge University Press, Cambridge, UK, pp.
- 10 Morgan, M.G., H. Dowlatabadi, M. Henrion, D. Keith, R.J. Lempert, S. McBride, M. Small and T. Wilbanks, 2009:
11 Best practice approaches for characterizing, communicating, and incorporating scientific uncertainty in
12 decisionmaking. Synthesis and Assessment Product 5.2 U.S. Climate Change Science Program, National
13 Oceanic and Atmospheric Administration, Washington D.C.
- 14 Moser, S., 2009: Making a difference on the ground: the challenge of demonstrating the effectiveness of decision
15 support. *Climatic Change*, **95**, 11-21.
- 16 Moser, S.C. and J.A. Ekstrom, 2010: A framework to diagnose barriers to climate change adaptation. *Proceedings of*
17 *the National Academy of Sciences*, **107**, 22026-22031.
- 18 Moss, R.H., J.A. Edmonds, K.A. Hibbard, M.R. Manning, S.K. Rose, D.P. van Vuuren, T.R. Carter, S. Emori, M.
19 Kainuma, T. Kram, G.A. Meehl, J.F.B. Mitchell, N. Nakicenovic, K. Riahi, S.J. Smith, R.J. Stouffer, A.M.
20 Thomson, J.P. Weyant and T.J. Wilbanks, 2010: The next generation of scenarios for climate change research
21 and assessment. *Nature*, **463**, 747-756.
- 22 Munich Re, 2010: *Natural catastrophes 2010: Analyses, assessments, positions*. Munich Re, Munich, 78 pp.
- 23 Munich Re Group, 2011: Topics Geo: Natural catastrophes 2010 analyses, assessments, positions. *Münchener Rück-*
24 *Munich Re Group*, Münchener Rück-Munich Re Group, Munich.
- 25 Mustelin, J., R. Klein, B. Assaid, T. Sitari, M. Khamis, A. Mzee and T. Haji, 2010: Understanding current and
26 future vulnerability in coastal settings: community perceptions and preferences for adaptation in Zanzibar,
27 Tanzania. *Population & Environment*, **31**, 371-398.
- 28 Nakicenovic, N. and R. Swart, 2000: *Special report on emissions scenarios: a special report of Working Group III*
29 *of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, pp.
- 30 Narain, U., S. Margulis and T. Essam, 2011: Estimating costs of adaptation to climate change. *Climate Policy*, **11**,
31 1001-1019.
- 32 National Research Council, 2001: *A climate services vision: first step toward the future*. National Academic Press,
33 Washington DC, 84 pp.
- 34 National Research Council, 2009: Informing Decisions in a Changing Climate, Panel on Strategies and Methods for
35 Climate-Related Decision Support, Committee on the Human Dimensions of Climate Change, Division of
36 Behavioral and Social Sciences and Education, Washington, DC.
- 37 National Research Council (NRC), 2009: Informing Decisions in a Changing Climate, Panel on Strategies and
38 Methods for Climate-Related Decision Support, Committee on the Human Dimensions of Climate Change,
39 Division of Behavioral and Social Sciences and Education, Washington, DC.
- 40 Nisbett, R., K. Peng, I. Choi and A. Norenzayan, 2001: Culture and system of thought: Holistic versus analytic
41 cognition. *Psychological Review*, **108**, 291-310.
- 42 Nordhaus, W.D., 1991: To slow or not to slow: The economics of the greenhouse effect. *The Economic Journal*,
43 **101**, 920-937.
- 44 Nordhaus, W.D., 1994: *Managing the Global Commons: The Economics of Climate Change*. MIT Press,
45 Cambridge, MA, pp.
- 46 Nyong, A., F. Adesina and B. Osman Elasha, 2007: The value of indigenous knowledge in climate change
47 mitigation and adaptation strategies in the African Sahel. *Mitigation and Adaptation Strategies for Global*
48 *Change*, **12**, 787-797.
- 49 O'Brien, K., S. Eriksen, L.P. Nygaard and A. Schjolden, 2007: Why different interpretations of vulnerability matter
50 in climate change discourses. *Climate Policy*, **7**, 73-88.
- 51 O'Brien, K.L., 2009: Climate Change and Values: Do Changing Values Define the Limits to Successful Adaptation?
52 *Adapting to Climate Change: Governance, Values and Limits*, W.N. Adger, I. Lorenzoni and K. O'Brien, Eds.
53 Cambridge University Press, Cambridge.

- 1 O'Brien, K.L. and J. Wolf, 2010: A values-based approach to vulnerability and adaptation to climate change. *Wiley*
2 *Interdisciplinary Reviews: Climate Change*, **1**, 232-242.
- 3 O'Riordan, T. and A. Jordan, 1999: Institutions, climate change and cultural theory: towards a common analytical
4 framework. *Global Environmental Change*, **9**, 81-93.
- 5 Oates, D., 1989: *Earth rising: Ecological Belief In An Age Of Science*. Oregon State University Press, Corvallis, 264
6 pp.
- 7 OECD, 2009: *Integrating Climate Change Adaptation into Development Co-operation: Policy Guidance*.
8 Organization for Economic Cooperation and Development, Paris, pp.
- 9 Ogden, A.E. and J.L. Innes, 2009: Application of Structured Decision Making to an Assessment of Climate Change
10 Vulnerabilities and Adaptation Options for Sustainable Forest Management. *Ecology and Society*, **14**.
- 11 Ohlson, D.W., G.A. McKinnon and K.G. Hirsch, 2005: A structured decision-making approach to climate change
12 adaptation in the forest sector. *Forestry Chronicle*, **81**, 97-103.
- 13 Ontario Ministry of the Environment, 2011: Climate Ready—Ontario's Adaptation Strategy and Action Plan: 2011–
14 2014, Ontario Ministry of the Environment, Toronto.
- 15 Oppenheimer, M., 2005: Defining Dangerous Anthropogenic Interference: The Role of Science, the Limits of
16 Science. *Risk Analysis*, **25**, 1399-1407.
- 17 Orlove, B. and M. Kabugo, 2005: Signs and Sight in Southern Uganda: Representing Perception in Ordinary
18 Conversation. *Etnofoor*, **18**, 124-141.
- 19 Orlove, B., 2009: The Past, the Present, and Some Possible Futures of Adaptation. *Adapting to Climate Change:
20 Thresholds, Values, Governance*, N. Adger, I. Lorenzoni and K. O'Brien, Eds. Cambridge University Press,
21 Cambridge, 131-163.
- 22 Orlove, B., C. Roncoli, M. Kabugo and A. Majugu, 2010: Indigenous Climate Knowledge in Southern Uganda: the
23 Multiple Components of a Dynamic Regional System. *Climatic Change*, **100**, 243–265.
- 24 Pahl-Wostl, C., 2002: Towards sustainability in the water sector - The importance of human actors and processes of
25 social learning. *Aquatic Sciences*, **64**, 394-411.
- 26 Pahl-Wostl, C., 2007: Transitions towards adaptive management of water facing climate and global change. *Water
27 Resources Management*, **21**, 49-62.
- 28 Pandey, V.P., M.S. Babel, S. Shrestha and F. Kazama, 2011: A framework to assess adaptive capacity of the water
29 resources system in Nepalese river basins. *Ecological Indicators*, **11**, 480-488.
- 30 Parker, W., 2006: Understanding Pluralism in Climate Modeling. *Foundations of Science*, **11**, 349-368.
- 31 Parson, E.A., V. Burkett, K. Fischer-Vanden, D. Keith, L. Mearns, H. Pitcher, C. Rosenweig and M. Webster, 2006:
32 Global-Change Scenarios: Their Development and Use, Synthesis and Assessment Product 2.1b, US Climate
33 Change Science Program.
- 34 Peng, K. and R.E. Nisbett, 1999: Culture, dialectics, and reasoning about contradiction. *American Psychologist*, **54**,
35 741-754.
- 36 Pereira, Â.G. and S.C. Quintana, 2002: From technocratic to participatory decision support systems: responding to
37 the new governance initiatives. *Journal of Geographic Information and Decision Analysis*, **6**, 95-107.
- 38 Perlovsky, L., 2009: Language and cognition. *Neural Networks*, **22**, 247-257.
- 39 Pidgeon, N. and B. Fischhoff, 2011: The role of social and decision sciences in communicating uncertain climate
40 risks. *Nature Climate Change*, **1**, 35-41.
- 41 Pielke, R. and R.E. Carbone, 2002: Weather impacts, forecasts, and policy: An integrated perspective. *Bulletin of the
42 American Meteorological Society*, **83**, 393-403.
- 43 Pielke, R.A., 1998: Rethinking the role of adaptation in climate policy. *Global Environmental Change*, **8**, 159-170.
- 44 Pielke, R.A., Jr., 2007: *The honest broker: making sense of science in policy and politics*. Cambridge University
45 Press, Cambridge ; New York, pp.
- 46 Power, D.J. and R. Sharda, 2009: Decision Support Systems. *Springer Handbook of Automation*, S.Y. Nof, Ed.
47 Springer Berlin, Heidelberg, 1539-1548.
- 48 Power, M., 2007: *Organized uncertainty: designing a world of risk management*. Oxford University Press, Oxford ;
49 New York, pp.
- 50 Prato, T., 2009: Evaluating and managing wildlife impacts of climate change under uncertainty. *Ecological
51 Modelling*, **220**, 923-930.
- 52 Prato, T., 2011: Adaptively Managing Wildlife for Climate Change: A Fuzzy Logic Approach. *Environmental
53 Management*, **48**, 142-149.

- 1 Preston, B., R. Westaway, S. Dessai and T. Smith, 2009: Are we adapting to climate change? Research and methods
2 for evaluating progress. *Fourth Symposium on Policy and Socio-Economic Research, AMS Annual Meeting,*
3 *Phoenix, AZ., City, pp.*
- 4 Radford, L., 2009: Why do gestures matter? Sensuous cognition and the palpability of mathematical meanings.
5 *Educational Studies in Mathematics, 70*, 111-126.
- 6 Ranger, N., A. Millner, S. Dietz, S. Fankhauser, A. Lopez and G. Ruta, 2010: Adaptation in the UK: a decision
7 making process. *Grantham/CCCEP Policy Brief*, Environment Agency, London, UK.
- 8 Raskin, P., F. Monks, T. Ribeiro, D.v. Vuuren and M. Zurek, 2005: Global scenarios in historical perspective.
9 *Ecosystems and Human Well-Being: Scenarios. Findings of the Scenarios Working Group, Millennium*
10 *Ecosystem Assessment*, S.R. Carpenter, P.L. Pingali, E.M. Bennett and M.B. Zurek, Eds. Island Press,
11 Washington, DC, 35-44.
- 12 Rawls, J., 1971: *A Theory of Justice*. Harvard University Press pp.
- 13 Renn, O., 2008: *Risk Governance. Coping with Uncertainty in a Complex World*. Earthscan, London pp.
- 14 Rittel, H. and M. Webber, 1973: Dilemmas in a general theory of planning. *Policy Sciences, 4*, 155-169.
- 15 Robinson, J., M. Bradley, P. Busby, D. Connor, A. Murray, B. Sampson and W. Soper, 2006: Climate change and
16 sustainable development: realizing the opportunity. *AMBIO: A Journal of the Human Environment, 35*, 2-8.
- 17 Robinson, L., 2002: Two tools for choosing the appropriate depth of public participation in decision-making,
18 http://www.enablingchange.com.au/Two_decision_tools.pdf, Enabling Change, Sydney.
- 19 Romsdahl, R. and C. Pyke, 2009: What does decision support mean to the climate change research community?
20 *Climatic Change, 95*, 1-10.
- 21 Rosa, E., 2003: The logical structure of the social amplification of risk framework (SARF): metatheoretical
22 foundations and policy implications. *The Social Amplification of Risk*, N. Pidgeon, R. Kaspersen and P. Slovic,
23 Eds. Cambridge University Press, Cambridge, 46-76.
- 24 Rosa, E.A., 2008: White, black, and gray: critical dialogue with the International Risk Governance Council's
25 Framework for Risk Governance. *Global Risk Governance*, C. Bunting, Ed., Vol. 1 Springer Netherlands, 101-
26 118.
- 27 Rosenhead, J., 1990: Rational Analysis: Keeping Your Options Open. *Rational Analysis for a Problematic World:*
28 *Problem Structuring Methods for Complexity, Uncertainty and Conflict*, J. Rosenhead and J. Mingers, Eds. John
29 Wiley & Sons, Chichester, England.
- 30 Rummukainen, M., S. Bergström, G. Persson, J. Rodhe and M. Tjernström, 2004: The Swedish Regional Climate
31 Modelling Programme, SWECLIM: A Review. *Ambio, 33*, 176-182.
- 32 Saavedra, C. and W.W. Budd, 2009: Climate change and environmental planning: Working to build community
33 resilience and adaptive capacity in Washington State, USA. *Habitat International, 33*, 246-252.
- 34 Sarewitz, D. and R.A. Pielke Jr, 2007: The neglected heart of science policy: reconciling supply of and demand for
35 science. *Environmental Science & Policy, 10*, 5-16.
- 36 Savage, L.J., 1954: *The Foundation of Statistics*, 2nd revised edition Edn. Dover Publications, pp.
- 37 Sawyer, R.K., 2007: *Group genius: the creative power of collaboration*. Basic Books, New York, 274 pp.
- 38 Scharpf, F.W., 1997: Employment and the Welfare State: A Continental Dilemma, Max Planck Institute for the
39 Study of Societies Working Paper, Cologne.
- 40 Schipper, E.L.F., 2007: Climate Change Adaptation and Development: Exploring the Linkages. *Tyndall Centre for*
41 *Climate Change Research Working Paper*, Tyndall Centre for Climate Change Research, Norwich, UK.
- 42 Schipper, J.W., I. Meinke, S. Zacharias, R. Treffeisen, C. Kottmeier, H.v. Storch and P. Lemke, 2009: Regionale
43 Helmholtz Klimabüros bilden bundesweites Netz. *DMG Nachrichten, 1-2009*, 10-12.
- 44 Schneider, S.H., S. Semenov, A. Patwardhan, I. Burton, C.H.D. Magadza, M. Oppenheimer, A.B. Pittock, A.
45 Rahman, J.B. Smith, A. Suarez and F. Yamin, 2007: Assessing key vulnerabilities and the risk from climate
46 change. *Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the*
47 *fourth assessment report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P.
48 Palutikof, P.J. van der Linden and C.E. Hanson, Eds. Cambridge University Press, Cambridge, U.K., 779-810.
- 49 Schroth, O., E. Pond, C. Campbell, P. Cizek, S. Bohus and S.R.J. Sheppard, 2011: Tool or toy? Virtual globes in
50 landscape planning. *Future Internet, 3*, 204-227.
- 51 Schultz, W.P., C. Shriver, J.J. Tanbanico and A.M. Khazian, 2004: Implicit connections with nature. *Journal of*
52 *Environmental Psychology, 24*, 31-42.
- 53 Schwartz, P., 1996: *The Art of the Long View - Planning for the Future in an Uncertain World*, 1996 edition Edn.
54 Currency-Doubleday, New York, NY, pp.

- 1 Semazzi, F.H.M., 2011: Framework for climate services in developing countries. *Climate Research*, **47**, 145-150.
- 2 Sen, A., 2009: *The Idea of Justice*. Belknap Press, Cambridge, Massachusetts, pp.
- 3 Seppälä, R., A. Buck and P. Katila, Eds., 2009: *Adaptation of Forests and People to Climate Change. A Global*
- 4 *Assessment Report.*, IUFRO, Helsinki, 224 pp.
- 5 Year: *14th Conference on Applied Climatology, Seattle, WA*. American Meteorological Society, Citypp.
- 6 Shaw, A., S. Sheppard, S. Burch, D. Flanders, A. Wiek, J. Carmichael, J. Robinson and S. Cohen, 2009: Making
- 7 local futures tangible--Synthesizing, downscaling, and visualizing climate change scenarios for participatory
- 8 capacity building. *Global Environmental Change*, **19**, 447-463.
- 9 Shepherd, P., J. Tansey and H. Dowlatabadi, 2006: Context matters: what shapes adaptation to water stress in the
- 10 Okanagan? *Climatic Change*, **78**, 31-62.
- 11 Sheppard, S.R.J., A. Shaw, D. Flanders, S. Burch, A. Wiek, J. Carmichael, J. Robinson and S. Cohen, 2011: Future
- 12 visioning of local climate change: a framework for community engagement and planning with scenarios and
- 13 visualisation. *Futures*, **43**, 400-412.
- 14 Sheppard, S.R.J., 2012: *Visualizing Climate Change: A Guide to Visual Communication of Climate Change and*
- 15 *Developing Local Solutions*. Earthscan, Routledge, London, 514 pp.
- 16 Smit, B., O. Pilifosova, I. Burton, B. Challenger, S. Huq, R.J.T. Klein and G. Yohe, 2001: Adaptation to climate
- 17 change in the context of sustainable development and equity. *Impacts, Adaptation and Vulnerability.*
- 18 *Contribution of the Working Group II to the Third Assessment Report of the Intergovernmental Panel on*
- 19 *Climate Change*, O.C. J.J. McCarthy, N.A. Leary, D.J. Dokken and K.S. White, Ed. Cambridge University
- 20 Press, Cambridge, 877-912.
- 21 Smith, J.B., S.H. Schneider, M. Oppenheimer, G.W. Yohe, W. Hare, M.D. Mastrandrea, A. Patwardhan, I. Burton,
- 22 J. Corfee-Morlot, C.H.D. Magadza, H.-M. Fuessel, A.B. Pittock, A. Rahman, A. Suarez and J.-P.v. Ypersele,
- 23 2009: Assessing Dangerous Climate Change Through an Update of the Intergovernmental Panel on Climate
- 24 Change (IPCC) "reasons for concern". *Proceedings of the National Academy of Sciences of the United States of*
- 25 *America*, **106**, 4133-4137.
- 26 Smithson, M., 1989: *Ignorance and Uncertainty - Emerging paradigms*. Springer-Verlag, New York, NY, pp.
- 27 Snover, A.K., L.W. Binder, J. Lopez, E. Willmott, J. Kay, D. Howell and J. Simmonds, 2007: *Preparing for climate*
- 28 *change: A guidebook for local, regional and state governments*. ICLEI-Local Government for Sustainability,
- 29 Oakland, pp.
- 30 Stehr, N. and R. Grundmann, 2010: *Expertenwissen: die Kultur und die Macht von Experten, Beratern und*
- 31 *Ratgebern*, 1. Aufl. Edn. Velbrück Wissenschaft, Weilerswist, 125 pp.
- 32 Stern, N., 2007: *The economics of climate change: the Stern review*. Cambridge University Press, Cambridge, pp.
- 33 Stern, P.C., L. Kalof, T. Dietz and G.A. Guagnano, 1995: Values, beliefs, and proenvironmental action: Attitude
- 34 formation toward emergent attitude objects. *Journal of Applied Social Psychology*, **25**, 1611-1636.
- 35 Sternberg, R.J., 1988: *The Nature of Creativity: Contemporary Psychological Perspectives*. Cambridge University
- 36 Press, Cambridge and New York, pp.
- 37 Strauss, S. and B. Orlove, 2003: Up in the Air: The Anthropology of Weather and Climate. *Weather, Climate and*
- 38 *Culture*, S. Strauss and B. Orlove, Eds. Berg, Oxford, 3-14.
- 39 Strauss, S., 2009: Global Models, Local Risks: Responding to Climate Change in the Swiss Alps. *Anthropology &*
- 40 *Climate Change. From Encounters to Actions*, S.A. Crate and M. Nuttall, Eds. Left Coast Press, Walnut Creek,
- 41 166-174.
- 42 Strohschneider, S. and D. Güss, 1999: The fate of the Moros: A cross-cultural exploration of strategies in complex
- 43 and dynamic decision making. *International Journal of Psychology*, **34**, 235-252.
- 44 Strzepek, K., D. Yates, G. Yohe, R. Tol and N. Mader, 2001: Constructing "Not Implausible" Climate and
- 45 Economic Scenarios for Egypt. *Integrated Assessment*, **2**, 139-157.
- 46 Swart, R., R. Biesbroek, S. Binnerup, T.R. Carter, C. Cowan, T. Henrichs, S. Loquen, H. Hanna Mela, M.
- 47 Morecroft, M. Reese and D. Rey, 2009: Europe Adapts to Climate Change: Comparing National Adaptation
- 48 Strategies. *PEER Report No 1*, PEER, Helsinki.
- 49 Thompson, P.B., 1986: The philosophical foundations of risk. *Southern Journal of Philosophy*, **24**, 273-286.
- 50 Tol, R.S.J., 2008: The social cost of carbon: trends, outliers and catastrophes. *Economics: The Open-Access, Open-*
- 51 *Assessment E-Journal*, **2**.
- 52 Tompkins, E.L., H. Eakin, D.R. Nelson and J.M. Anderies, 2008: Hidden costs and disparate uncertainties: trade-
- 53 offs involved in approaches to climate policy. *Living with Climate Change: Are there limits to adaptation?*,
- 54 London, Royal Geographical Society, City, pp.

- 1 Torrance, E.P., 1988: The nature of creativity as manifest in its testing. *The Nature of Creativity: Contemporary*
2 *Psychological Perspectives*, R.J. Sternberg, Ed. Cambridge University Press, Cambridge and New York, 43-75.
- 3 Tschakert, P. and K.A. Dietrich, 2010: Anticipatory learning for climate change adaptation and resilience. *Ecology*
4 *and Society*, **15**, 11.
- 5 UNDP, 2005: *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*.
6 Cambridge University Press, Cambridge and New York, 268 pp.
- 7 UNFCCC, 2010: Synthesis report on efforts undertaken to monitor and evaluate the implementation of adaptation
8 projects, policies and programmes and the costs and effectiveness of completed projects, policies and
9 programmes, and views on lessons learned, good practices, gaps and needs, UNFCCC Secretariat, Bonn,
10 Germany.
- 11 UNISDR, 2009: Adaptation to Climate Change by Reducing Disaster Risks: Country Practices and Lessons.
12 Briefing Note #2, UNISDR, Geneva.
- 13 van Notten, P., 2006: Scenario Development: A Typology of Approaches. *Schooling for Tomorrow: Think*
14 *Scenarios, Rethink Education*, OECD, Ed. OECD, Paris, 66-92.
- 15 van Vuuren, D.P., K. Riahi, R. Moss, J. Edmonds, A. Thomson, N. Nakicenovic, T. Kram, F. Berkhout, R. Swart, A.
16 Janetos, S.K. Rose and N. Arnell, 2012: A proposal for a new scenario framework to support research and
17 assessment in different climate research communities. *Global Environmental Change*, **22**, 21-35.
- 18 Vedwan, N., 2006: Culture, climate and the environment: Local knowledge and perception of climate change among
19 apple growers in northwestern India. *Journal of Ecological Anthropology*, **10**, 4-18.
- 20 Venkatesh, B.N. and B.F. Hobbs, 1999: Analyzing investments for managing Lake Erie levels under climate change
21 uncertainty. *Water Resources Research*, **35**, 1671-1683.
- 22 Vidhi and P. Sharma, 2010: A Framework for Monitoring and Evaluation of Climate Change Adaptation
23 Interventions. Discussion Paper 5, Sambodhi Research & Communications Pvt. Ltd, New Delhi.
- 24 Visbeck, M., 2008: From climate assessment to climate services. *Nature Geoscience*, **1**, 2-3.
- 25 Vogel, C., S.C. Moser, R.E. Kasperson and G.D. Dabelko, 2007: Linking vulnerability, adaptation, and resilience
26 science to practice: Pathways, players, and partnerships. *Global Environmental Change-Human and Policy*
27 *Dimensions*, **17**, 349-364.
- 28 von Storch, H., I. Meinke, N. Stehr, B. Ratter, W. Krauss, R.A. Pielke Jr, R. Grundmann, M. Reckermann and R.
29 Weisse, 2011: Regional Climate Services illustrated with experiences from Northern Europe. *Zeitschrift für*
30 *Umweltpolitik & Umweltrecht*, **1/2011**, 1-15.
- 31 von Storch, H. and F. Zwiers, 2012: Exploring Climate services: Meeting Stakeholder Needs for Practical Climate
32 Information. *Eos*, **In Press**.
- 33 Vroom, V.H. and P.W. Yetton, 1973: *Leadership and Decision-Making*. University of Pittsburgh Press, Pittsburgh,
34 248 pp.
- 35 Vroom, V.H. and A.G. Jago, 1988: *The new leadership: managing participation in organizations*. Prentice Hall,
36 Englewood Cliffs, N.J., 244 pp.
- 37 Wack, P., 1985a: The Gentle Art of Reperceiving - Scenarios: Uncharted Waters Ahead (part 1 of a two-part
38 article). *Harvard Business Review* 73-89.
- 39 Wack, P., 1985b: The Gentle Art of Reperceiving - Scenarios: Shooting the Rapids (part 2 of a two-part article).
40 *Harvard Business Review* 2-14.
- 41 Walley, P., 1991: *Statistical reasoning with imprecise probabilities*. Chapman and Hall 706 p pp.
- 42 Warrick, R.A., 1975: *Drought Hazard in the United States: A Research Assessment*. Institute of Behavioral Science,
43 University of Colorado, Boulder, pp.
- 44 Warrick, R.A., 1980: Drought in the Great Plains: A case study of research on climate and society in the U.S.A.
45 Climatic Constraints and Human Activities, J. Ausubel and A.K. Biswas, Eds. Pergamon, Oxford, 93-123.
- 46 Watkiss, P., 2011: Aggregate economic measures of climate change damages: explaining the differences and
47 implications. *Wiley Interdisciplinary Reviews: Climate Change*.
- 48 Weaver, C.P., C. Brown, J.A. Hall, R. Lempert, D. Revell and D. Sarewitz, 2011: Unifying Climate Modeling and
49 Climate Change Adaptation Planning *submitted*.
- 50 Weichselgartner, J., 2001: Disaster mitigation: the concept of vulnerability revisited. *Disaster Prevention and*
51 *Management*, **10**, 85-95.
- 52 Weitzman, M.L., 2007: A review of the Stern review on the economics of climate change. *Journal of Economic*
53 *Literature*, **45**, 703-724.
- 54 Wenger, E., 2000: Communities of practice and social learning systems. *Organization*, **7**, 225-246.

- 1 Wilby, R.L. and I. Harris, 2006: A framework for assessing uncertainties in climate change impacts: Low-flow
2 scenarios for the River Thames, UK. *Water Resources Research*, **42**, W02419, doi:10.1029/2005WR004065.
- 3 Wilby, R.L. and S. Dessai, 2010: Robust adaptation to climate change. *Weather*, **65**, 180-185.
- 4 Wilkinson, A. and E. Eidinow, 2008: Evolving practices in environmental scenarios: a new scenario typology.
5 *Environmental Research Letters*, **3**, 045017.
- 6 Wolf, J., I. Allice and T. Bell, In review: The freedom of the land: Subjective, intangible impacts of a changing
7 climate in Labrador, Canada. *Weather, Climate & Society*.
- 8 World Resources Institute, United Nations Development Programme, United Nations Environment Programme and
9 World Bank, 2011: *World Resources 2010–2011: Decision Making in a Changing Climate—Adaptation*
10 *Challenges and Choices*. World Resources Institute, Washington, DC, pp.
- 11 WUCA, W.U.C.A., 2010: Decision Support Planning Methods: Incorporating Climate Change into Water Planning,
12 Water Utility Climate Alliance.
- 13 Wynne, B., 2002: Risk and environment as legitimacy discourses of technology: reflexivity inside out? *Current*
14 *Sociology*, **50**, 459-477.
- 15 Yearley, S., 2009: Sociology and climate change after Kyoto: what roles for social science in understanding climate
16 change? *Current Sociology*, **57**, 389-405.
- 17 Yohe, G.W., R.D. Lasco, Q.K. Ahmad, N.W. Arnell, S.J. Cohen, C. Hope, A.C. Janetos and R.T. Perez, 2007:
18 Perspectives on climate change and sustainability. . *Climate Change 2007: Impacts, Adaptation and*
19 *Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental*
20 *Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J.v.d. Linden and C.E. Hanson, Eds.
21 Cambridge University Press, Cambridge, UK, 811-841.
- 22 Yohe, G.W. and R.S.J. Tol., 2008: The Stern review and the economics of climate change: an editorial essay.
23 *Climatic Change*, **89**, 231-240. *Climatic Change*, **89**, 231-240.
- 24 Zadeh, L.A., 1984: The role of fuzzy logic in the management of uncertainty in expert systems. *Fuzzy Sets and*
25 *Systems*, **11**, 199-227.

Table 2-1: Main characteristics of select number of climate change impact studies (Dessai and Van der Sluijs, 2011).

	New and Hulme, 2000 + Prudhomme et al. 2003	Wilby and Harris 2006	Dessai and Hulme 2007	Lopez et al. 2009	Manning et al. 2009
GHG emissions scenarios	4	2	40	1 (SRES A1B)	4 (Most results for SRES A2)
Carbon cycle response	1 model		1 model with uniform PDF		
Global climate sensitivity	Triangular PDF		Multiple PDFs from the literature		
AOGCMs	7	4	9	21 + 1 (w/u 246)	2
Downscaling		2 Statistical downscaling techniques	19 RCMs (dynamical downscaling, but not linked to above)	Bias correction and temporal downscaling using a gamma transform	14 RCMs + stochastic Weather Generator
Impacts	1 hydrological model	2 hydrological model structures (w/u 2)	Simple linear transfer function	1 hydrological model (w/u) + water resource model	1 hydrological model (w/u)
Unit of assessment	Flood regime of 5 small catchments	Low flows in the Thames	Additional water required due to climate change in the East of England	Reservoir storage level and supply failure under a number of demand and supply scenarios	Abstraction availability in the Thames

Table 2-2: Example of adaptive management plan for bleached coral reefs (Reef Resilience, 2011).

Indicators reveal that:	Adaptive management response
Coral reef biodiversity has not been maintained at pre-bleaching levels.	Reassess and revise strategy for maintaining coral reef biodiversity to ensure that: <ul style="list-style-type: none"> • resilience to global change has been addressed through adequate protection of bleaching-resistant/resilient sites; and • other threats to biodiversity have been adequately addressed
Coral reef communities are not in better condition at bleaching-resistant and/or resilient sites than at control sites.	Reconsider selection of bleaching-resistant/resilient sites and make new selections based on monitoring data and/or new observations on bleaching resistance.
Other threats have not been reduced on protected reefs.	Implement more effective strategies for reducing other threats to Marine Protected Area (MPA)
Socioeconomic benefits of reefs have not been maintained at pre-bleaching levels or above.	In consultation with primary stakeholders, consider how management actions can be modified to improve impacts on reef users while still achieving management objectives.
Herbivorous coral reef fish populations have declined	Implement more effective fishery management strategies (e.g. regulations or protected area) to enhance the survival of reef fish populations and corals

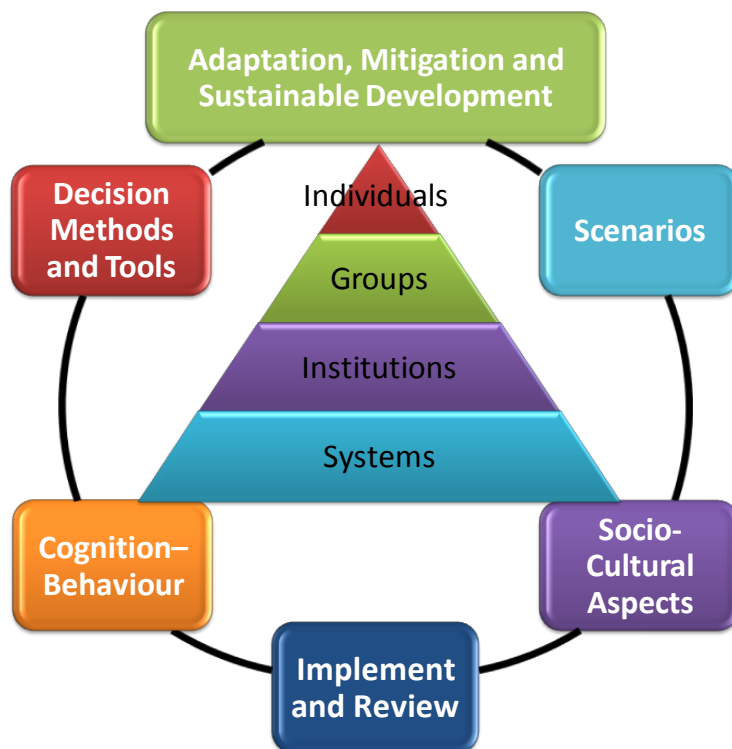


Figure 2-1: Schema for the chapter, showing a hierarchy of decision-makers in the centre and broad groupings of subjects addressed in the chapter. The decision-making environment is described by adaptation, mitigation and sustainable development, the methods and tools utilised include scenarios, decisions are made in the human context of individuals to groups and decisions can be assessed to measure varying degrees of success.

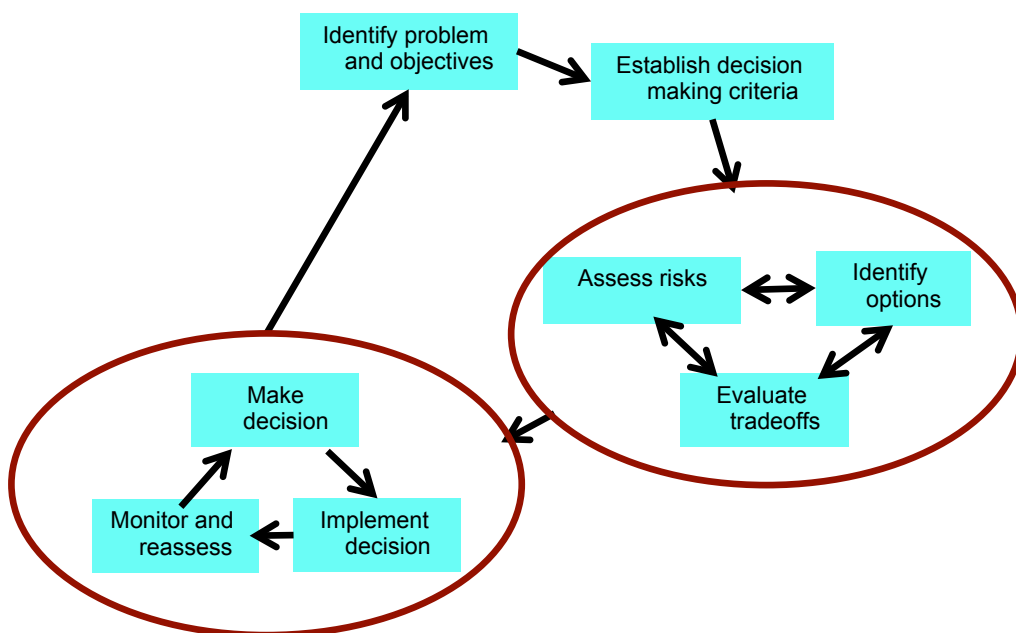


Figure 2-2: Iterative Risk Management Framework, adapted from (CITE).

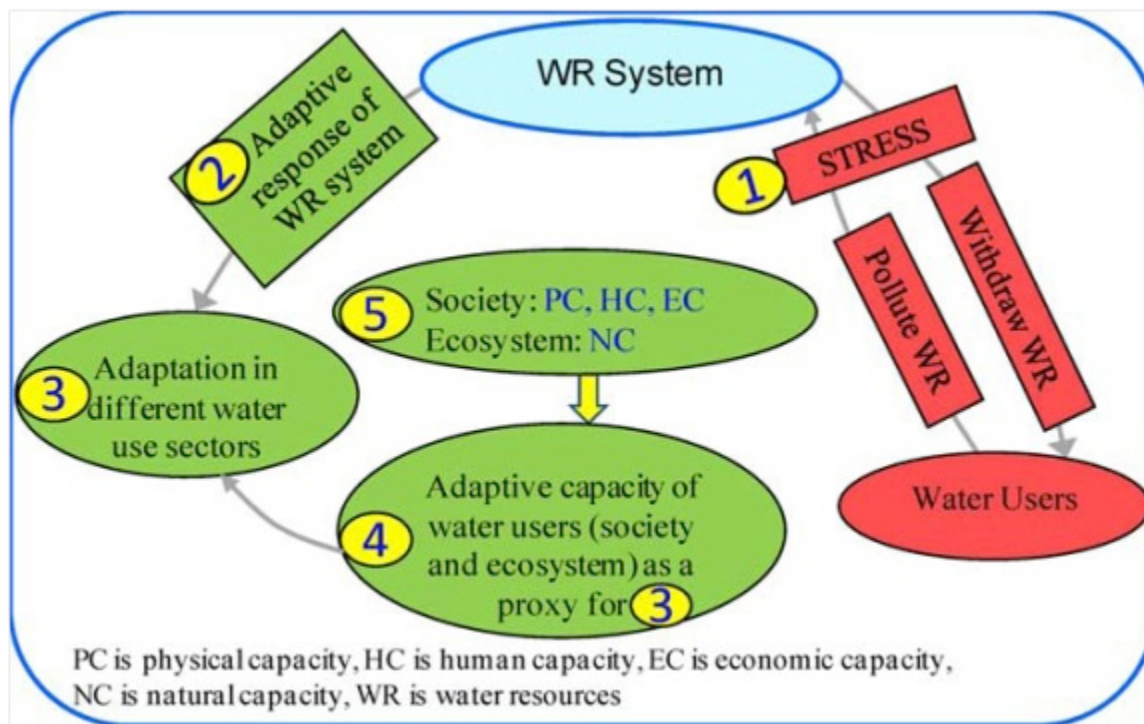


Figure 2-3: A conceptual framework of adaptation, adaptive capacity, and its parameters (Pandey et al., 2011).

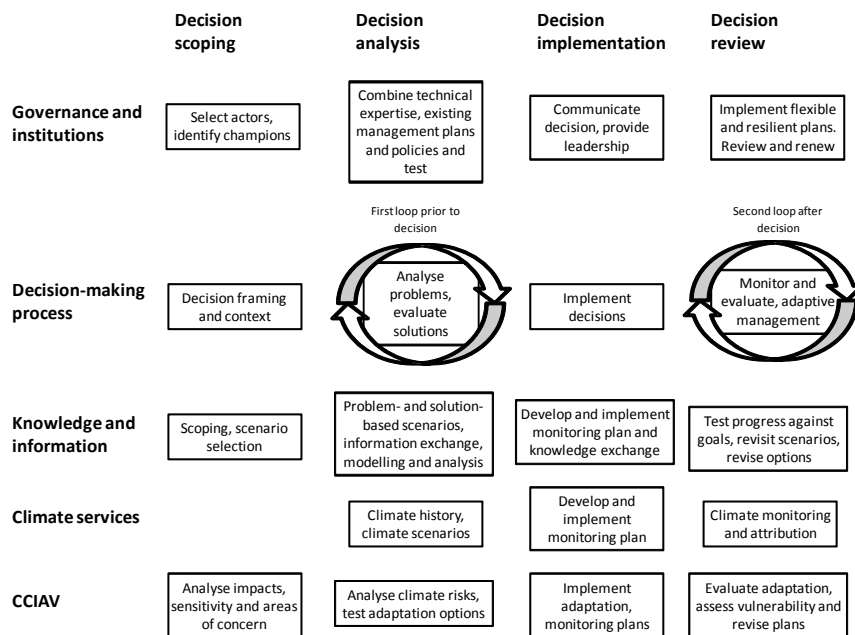


Figure 2-4: Selected attributes and characteristics relevant to the decision-making process itself. The two loops in the decision-making process relate to the two loops in Figure 2-2.

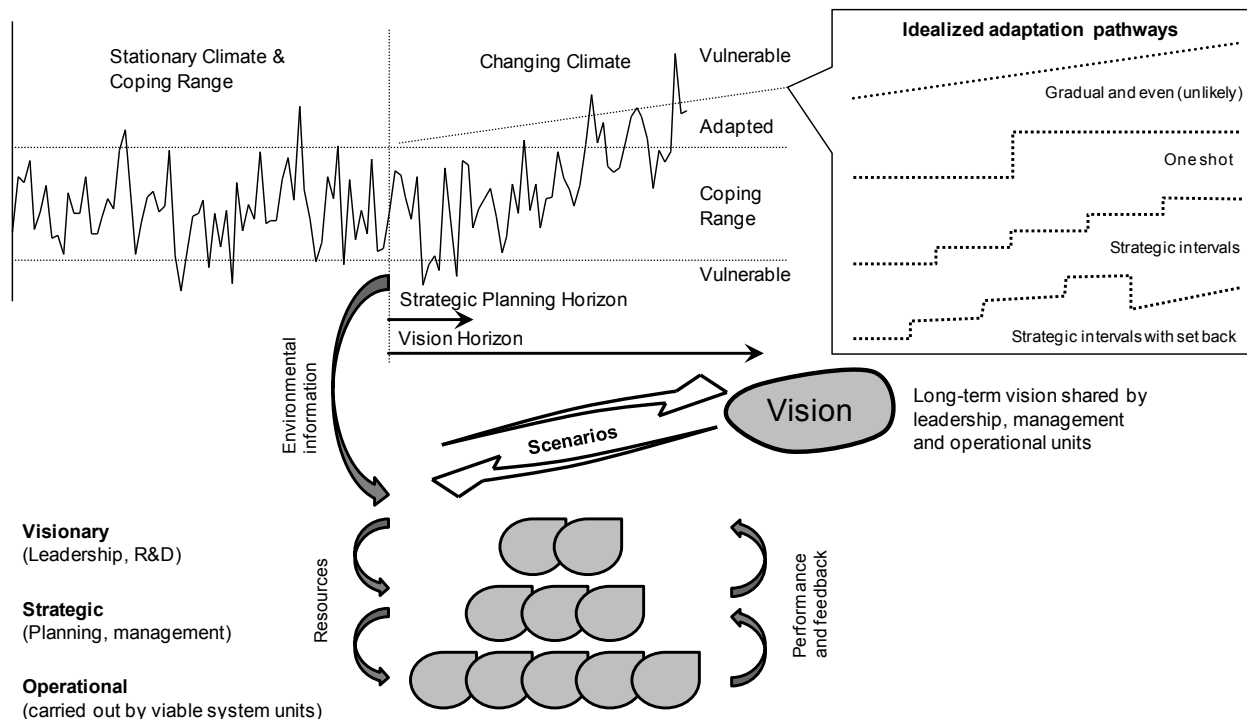


Figure 2-5: Planning frameworks for climate change showing the coping range, changing climate, thresholds and vulnerability for a single-variable climate scenario with idealised adaptation pathways (top) shows with a systems planning framework for organizations showing how....

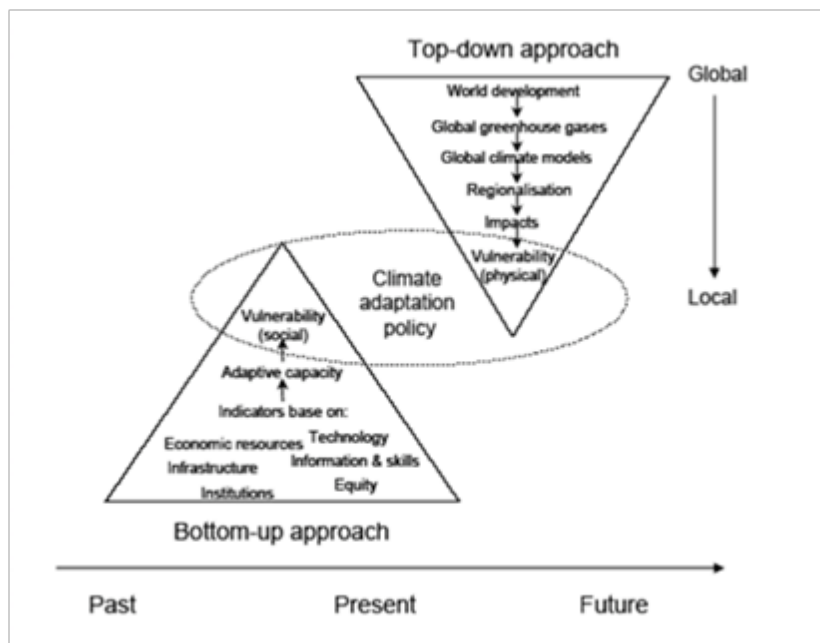


Figure 2-6: Approach Used to Inform Adaptation Policy (Dessai and Hulme 2004).

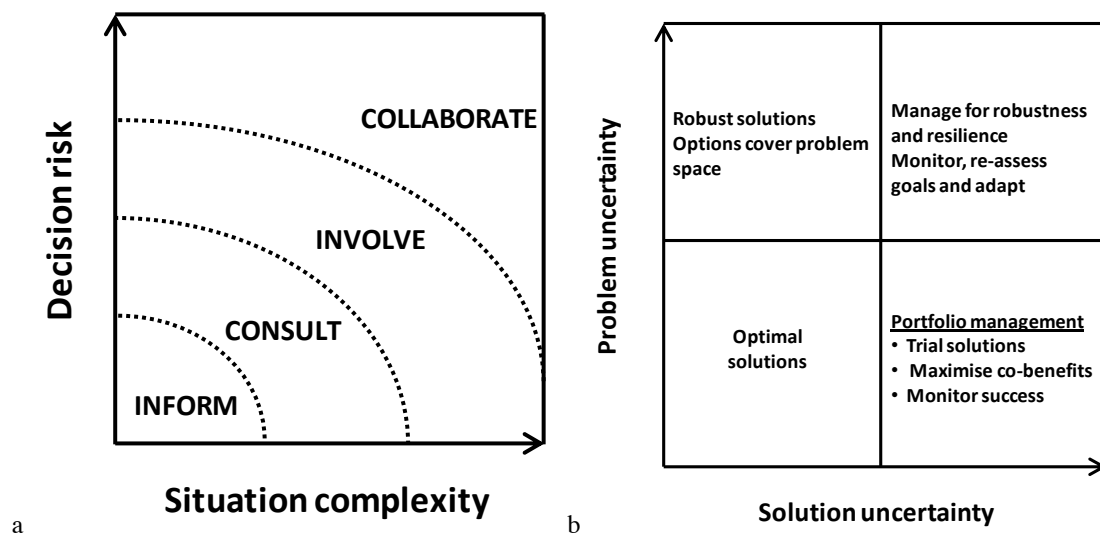


Figure 2-7: Two perspectives on decision complexity. On the left the relationship between decision risk and system complexity is used to suggest levels of engagement (adapted from Robinson (2002)). On the right a problem-solution uncertainty matrix delineating solution-based decision-making strategies.

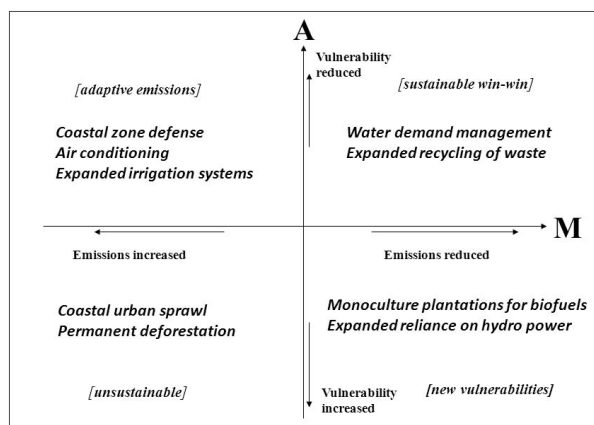


Figure 2-8: Adaptation – mitigation trade-offs and synergies (adapted from (Cohen and Waddell, 2009)).