Chapter 2. Foundations for Decision-making

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Executive Summary

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

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

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

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

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

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

2.2. Aspects of Decision-making

Since the AR4, the level of adaptation activity among organizations worldwide has increased substantially (Preston et al., 2009). This activity has provided a broad experience on which practitioners can draw, as well as expanded needs and opportunities for research. The literature draws a distinction between research for decision-making and research on decision-making. The former aims to provide improved information, such as climate projections and cost-benefit analysis of alternative options, to help inform decision-makers. The latter aims to improve understanding of decision–making process themselves and how they can be made more effective. This chapter largely focuses on the latter.

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

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

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

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

2.2.1. Conceptual Frameworks for Climate-Related Decisions

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

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

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

2.2.1.1. Decision Support

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

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

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

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

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

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

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

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

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

2.2.1.2. Iterative Risk Management

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

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

[INSERT FIGURE 2-2 HERE
Figure 2-2: Iterative Risk Management Framework, adapted from (CITE).]

2.2.1.3. Idealized, Calculated, Perceived Risks

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

Earlier definitions of risk that invoked hazard times likelihood or probability and consequence, focused on a specific event and response to that event and sought to be objective. More recent definitions are broader, moving from objective analysis to values and governance (Power, 2007;Renn, 2008). For example, risk *is a situation or an event* *where something of human value (including humans themselves) is at stake and where the outcome is uncertain* (Rosa, 2003). The latest International Standard ISO:31000 definition of risk as *the effect of uncertainty on objectives* is explicitly normative (ISO, 2009). Likewise CCIAV methods are expanding from a direct focus on specific climate risks to more mainstream settings where the management of climate risks is integrated with many other activities. For example, climate risks affecting a local government area will have planning, legal, financial, health and community aspects (Measham et al., 2011); therefore an assessment will be influenced by the different types of risk management used in each of those areas. Mainstreaming may require trade-offs between climate and other risks (Kok and de Coninck, 2007;Tompkins et al., 2008). Different areas of risk all have different institutional and governance structures, and display different epistemologies (Althaus, 2005). In undertaking decision support, both formal and informal understandings of risk are relevant.

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

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

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

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

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

A large literature describes best practice methods for incorporating and communicating information about risk and uncertainties into decisions about climate change (Morgan et al., 2009;Pidgeon and Fischhoff, 2011). As described elsewhere in this report, this literature suggestions that effective communication of uncertainty requires products and processes that: i) closes psychological distance, explaining why is this information is important to the recipient; ii) establishes self-agency, explaining what the recipient can do with the information; iii) recognizes that each person's view of risks and opportunities depends on their values; iv) recognizes that emotion is a critical part of judgment; and v) provides mental models that help recipients to understand the connection between cause and effect. In addition, this literature emphasizes that information providers need to test their messages, since they may not be communicating what they think they are.

2.2.1.4. Treatment of Uncertainties

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

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

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

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

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

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

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

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

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

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

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

2.2.1.5. Decision Criteria for Evaluating Tradeoffs

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

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

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

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

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

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

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

2.2.1.6. Scenarios

Scenarios are cognitive tools central to scoping and assessing risk, and in managing risk, as adaptation planning [very high confidence]. *A scenario is not a prediction of what the future will be but rather a description of how the future might unfold. A scenario includes an interpretation of the present, a vision of the future and an internally consistent account of the path from the present to the future* (Jäger et al., 2008). Scenario use has expanded significantly as CCIAV research has become more integrated with mainstream activities. Their application has extended beyond climate as noted in the past two assessment reports (Carter et al., 2001;Carter et al., 2007b). Climate change has also become a core feature of many scenarios used in regional and global assessments of environmental and socio-economic change (Carpenter et al., 2005;Raskin et al., 2005). Scenarios can be used at a number of stages within the assessment process or to underpin an entire assessment. They serve a variety of purposes, including informing decisions under uncertainty, scoping and exploring poorly understood issues, and integrating knowledge from diverse domains (Parson et al., 2006).

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

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

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

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

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

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

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

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

2.2.1.7. Learning and Review

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

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

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

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

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

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

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

2.2.2. Institutional Context

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

2.2.2.1. Decision-makers

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

Smit et al. (Smit et al., 2001) identified institutions as one of the key determinants of adaptive capacity. Countries with strong institutions are generally assumed to have a greater capacity to adapt to current hazards and disasters as well to the future. However, this is not necessarily true in all the cases. Hurricane Katrina of 2005 in the USA and the European heat waves of 2003 demonstrated that strong institutions and other determinants of adaptive capacity do not necessarily reduce vulnerability if not translated to actions (IPCC, 2007). Generally for economic and technological reasons, most of the developing countries have weak institutions that are usually not capable of managing hazards and disasters of catastrophic nature. In 2010, extreme floods killed 1800 people and made six million homeless in *Pakistan*. Although severe flooding was forecast correctly, due to institutional and logistical weaknesses, vulnerable people were highly exposed to flooding. A lack of properly-functioning shelters and medical facilities led to outbreak of diseases and further human casualties. The country incurred an economic loss of US$ 9.5 billion (Asian Development Bank (ADB), 2010;Munich Re, 2010) and the floods impoverished or destituted millions of people. Recently *Bangladesh* suffered two devastating cyclones-*Sidr* (2007) and *Aila* (2009). Storm surges generated by both the cyclones destroyed lengths coastal embankments and saline water engulfed large swath of densely populated areas. Despite reasonably effective disaster management programs compared to many other developing countries, institutional weaknesses surfaced during and after the cyclones. Some destroyed embankments were not repaired two years after *Aila*. Many affected people are yet to be rehabilitated (Kartiki, 2011).

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

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

2.2.2.2. Governance and Decision Implementation

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

Climate change and the associated risks have national and international legal dimensions. One of the most significant issues is the “inequity” that has been recognized in various international declarations and conventions. Principal 7 of the 1992 Rio Declaration enunciated the principle of “common but differentiated responsibilities” of states “in view of different contributions to global environmental degradation”. The UNFCCC also recognizes “The specific needs and special circumstances of developing country Parties, especially those that are particularly vulnerable to the adverse effects of climate change…”. The “precautionary approach” embedded in the 1992 UNFCCC was the most important new principle of international environmental policy and was emerging as international environmental law (Freestone, 1991). **Article 3** of the Convention obliges precautionary action to “anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures…”. The *international aspects* of climate change impacts and risks would come from a variety of angles. Sea level rise could alter the *maritime boundaries* of many nations that may lead to new claims by the conflicting nations. Warming of ocean/sea water can bring in changes in traditional shipping lanes. Climate change could also lead to access to resources that were previously technically inaccessible and that may result in new territorial claims. Runoff changes in the international rivers due to reduced seasonal precipitation could result in new *water conflicts* and *energy utilization* among the co-basin countries and can also pose challenges to the already signed sharing agreements (Kim, 2010). Additional *food insecurity* due to climate change will pose a moral challenge and human rights question regarding food supply from the developed countries to affected regions. There will be many *national level* implications of climate change as well. Considering Bangladesh as a case study, (Freestone et al., 1996) identified that nationally climate change and sea level rise would affect property rights and land tenure, population displacement, rehabilitation and resettlement, and institutional frameworks involving with these issues.

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

2.2.2.3. Evaluation and Reflexiveness

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

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

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

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

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

2.2.3. People Make Decisions

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

2.2.3.1. Value Setting

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

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

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

2.2.3.2 Cultural Determinants and Psychology

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

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

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

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

In more individualistic societies, the analytical model is central. The interests of the individual take precedence over the interests of the members of society, the self is independent and communication comes from separate fields: benchmarks are not common. Analytical thinking dominates. Here the object is isolated from its context; the focus is on understanding the characteristics of the object to determine its category membership, and explain and predict events based on its intrinsic rules. Inferences are derived from contextualizing the content structure, using formal logic and avoiding contradiction. Analytical thinking circumscribes symbolic representation systems; instead its formalization is built on structures of rules. Several studies demonstrate the influence of this way of thinking on complex problem-solving e.g., (Badke-Schaub and Strohschneider, 1998;Strohschneider and Güss, 1999;Güss et al., 2010).

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

2.2.3.3. Language and Meaning

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

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

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

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

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

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

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

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

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

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

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

2.2.3.4. Morals and Ethics

Ethical concerns related to CCIAV 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 CCIAV.

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

2.3.1.2. Solution Attributes

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

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

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

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

Learning covers both formal and informal processes of gaining, assessing and communicating experience following a decision. It covers monitoring and assessment, ex post evaluation of decisions, adaptive management and the reflexive processes required to implement such management. Learning also covers the hierarchy of agents ranging from individuals and organizations to institutions. Building from the previous point, applied learning will make 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 CCIAV 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 CCIAV 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 with research and development, strategic management and operations. Resources and directions are fed down through the system and feedback detailing progress and exceptional circumstances fed back up. All levels take in the environmental information needed for decision-making and where they cannot make decisions within limits set, send that signal up the line. The risk of crossing a critical threshold may require actions grading from the exercise of different options, revisiting strategic directions or, in extreme cases, revisiting the original vision.

[INSERT FIGURE 2-5 HERE
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…]

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

2.3.2. Assessing Impacts, Vulnerabilities, and Risks

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

2.3.2.1. Assessing Impacts

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

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

In order for scenario-based impact assessments to contribute to vulnerability and risk assessment, there needs to be a series of translations carried out. Information on greenhouse gas concentrations is converted to changes in atmospheric conditions, subsequently to impacts without proactive adaptation, and finally, to an assessment of the effectiveness of various adaptation options. As discussed in Section 2.2.1.6, climate change scenarios themselves have changed dramatically since the 1980s with the continued evolution of climate models and emission scenarios. During the 1980s and early 1990s, impact assessments were based on climate scenarios with a doubling of atmospheric carbon dioxide concentrations. The 1992 IPCC Supplementary Report (Houghton et al., 1992) and IPCC Special Report on Emission Scenarios or SRES (Nakicenovic and Swart, 2000) each provided a range of future scenarios for different time periods available for impacts assessments (Carter et al., 1994; Feenstra et al., 1998). A new scenario process for this AR5 report aims to provide Representative Concentration Pathway (RCP) and corresponding climate projections and socio-economic driving scenarios (van Vuuren et al., 2012) that can be used for impact assessments.

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

[INSERT FIGURE 2-6 HERE
Figure 2-6: Approach Used to Inform Adaptation Policy (Dessai and Hulme 2004).]

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

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

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

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

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

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

2.3.3. Climate Services

Climate services are the link between generation and application of climate knowledge, or between climate science and public demand for information. There is a growing body of literature concerning the development of these 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 policy implications of climate service as a global practice (2.3.2.4).

2.3.3.1. Introduction

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

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

2.3.3.2. Climate Services: History and Concepts

In the peer-reviewed literature, especially the development of North American climate services is well documented (Changnon et al., 1990;Miles et al., 2006;DeGaetano et al., 2010). Climate services are an expansion of the tasks provided by weather services and similar operational organizations, mainly dealing with forecasts, seasonal outlooks, and assessments of risks in a mostly stationary but variable climate. The idea of establishing climate services on both national and regional levels resulted from the growing concern over the consequences of climate fluctuations and the difficulties to provide and to distribute adequate information. In the beginning, those services were barely effective for decision makers, who had difficulties understanding and using climate data for planning purposes (Changnon et al., 1990;Miles et al., 2006;Visbeck, 2008). Furthermore, data were delivered slowly and were of poor quality; there were problems in obtaining data on appropriate time and space scales, and there was an "inability to access available datasets held by the private sector, states, regional and some federal agencies" (Changnon et al., 1990).

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

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

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

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

2.3.3.3. Climate Services: Practices / Decision Support

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

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

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

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

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

2.3.3.4. The Geo-political Dimension of Climate Services

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

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

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

In this process, social, cultural and communication sciences play a decisive role (Pidgeon and Fischhoff, 2011;von Storch et al., 2011). Cultural values, social actors, national and regional politics enter the stage; science becomes part and parcel of the negotiation process entailing mitigation and adaptation decisions on various scales. To position itself and to react according to the diverse demands, climate science has to become "rooted in society" (Krauss, 2011). In this process, climate science necessarily becomes interdisciplinary, as politics, culture, religion, 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 ecological zones, 32 projects were identified. They were ranked in order of their importance. In the second step, the national level stakeholders involving specialists, practitioners and NGO representatives endorsed the prioritized projects identified at the regional level (World Resources Institute et al., 2011). NAPA should not be a stand-alone program and its integration with other socio-economic programs is necessary for creation of comprehensive resiliency. For some instances, integration of NAPA with other programs has occurred for better decision making. Rwanda and Bangladesh created a link between their NAPAs and the Poverty Reduction Strategy Papers (PRSPs) with an objective to facilitate mainstreaming of climate change adaptation. The selection process of priority adaptation activities in the Rwanda NAPA was intimately linked with various national and sectoral policies. For example, the process took into account the urgent and immediate need of the country identified in the PRSP, economic development and poverty reduction strategy (EDPRS) and other development programmes (OECD, 2009). The Bangladesh NAPA also strenuously considered the PRSP and identified prioritized adaptation strategies that complimented the PRSP (OECD, 2009). Being a flat deltaic country, Bangladesh identified coastal afforestation as a highly prioritized program which can reduce the impact of cyclonic storms and associated surges. The project received approval of the Global Environment Facility (GEF) for funding (Lebel et al., 2012). Bangladesh's Climate Change Strategy and Action Plan (BCCSAP) was highly influenced by the country's NAPA. As a follow-up of NAPA, Cambodia is now pursuing a project for promoting climate resilient water management and agricultural practices in rural areas (Lebel et al., 2012). There are many institutional and individual adaptive capacity gaps in the population affected by extreme hazards in rural Cambodia. This project, the first of its nature is closely examining those gaps so that the communities would be able to manage agricultural water resources under future climate change. Developing country like India is following a different track than NAPA for decision making. The country has prepared its 'National Action Plan' on climate change. The plan document addresses both adaptation and mitigation measures which will promote the development goals and simultaneously generate co-benefits for effectively addressing climate change. The document set measurable sectoral targets. For example, a 20% improvement in water use efficiency through pricing and other measures is set to achieve by 2017 (Government of India, 2008).

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

Climate risk based decision making is increasingly becoming a practice in many developing and developed countries. Agriculture especially the staple rice crop and water resources sectors of Vietnam are highly vulnerable to current climatic variability and extremes. The degree of vulnerability may increase due to intrusion of saline water and floods under future climate change. Aquaculture industry is rapidly developing in the coasts of Vietnam. The coastal infrastructure and the dikes and structures that protect this industry may be severely damaged by storm surges. In response to climate risks, Vietnam initiated large-scale mangrove restoration and rehabilitation programs with the support of international institutions (World Resources Institute et al., 2011). The Tsho Rolpa glacier lake in Nepal was at the risk of outburst due to rapid melting of the glaciers (Adger et al., 2007). Considering the risks, the Government of Nepal started implementing both short- and long-term measures to prevent the outburst flood event (Adger et al., 2007;World Resources Institute et al., 2011). There are many instances of risk based decision making in the developed countries as well. The District of Elkford with only 2500 people is located in the Rocky Mountains of south-eastern of British Columbia, Canada. In the past, the community tackled many climate related extreme hazards that include floods, droughts and wildfires. These hazards may be intensified in a changing climatic environment. Based on the participatory risk assessment, the community identified 26 actions that were integrated in the Elkford's Official Community Plan (OCP) (Natural Resources Canada, 2012). Frequent heatwaves cause health risks to people in some parts of Europe, particularly in central and southern Europe. The 2003 heat waves killed 35,000 people across Europe. Taking lessons from this event, many European countries have already implemented 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 assessments are readily available for many locations, scenario-based adaptation assessments are not, so visual representation of specific adaptation outcomes would be negotiated with local stakeholders as an artistic rendering of what an adaptation measure might look like. This kind of exercise is currently being tested in communities within Metro Vancouver, British Columbia, Canada (Shaw et al., 2009;Burch et al., 2010;Sheppard et al., 2011).

2.3.7. Synthesis

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

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

[INSERT FIGURE 2-7 HERE
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.]

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

Climate Services aim to make knowledge about climate regionally accessible. In doing so they have to consider information supply, knowledge competition and user demand. Knowledge transfer is a dialogic process and has to take cultural values, orientations and alternative forms of knowledge into account. 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. Institutionally, boundary organisations are important in climate services, translating and 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.

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

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

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

2.4.3. Transformation – How Do We Make Decisions Involving Transformation?

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

Frequently Asked Questions

To be done

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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: • 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

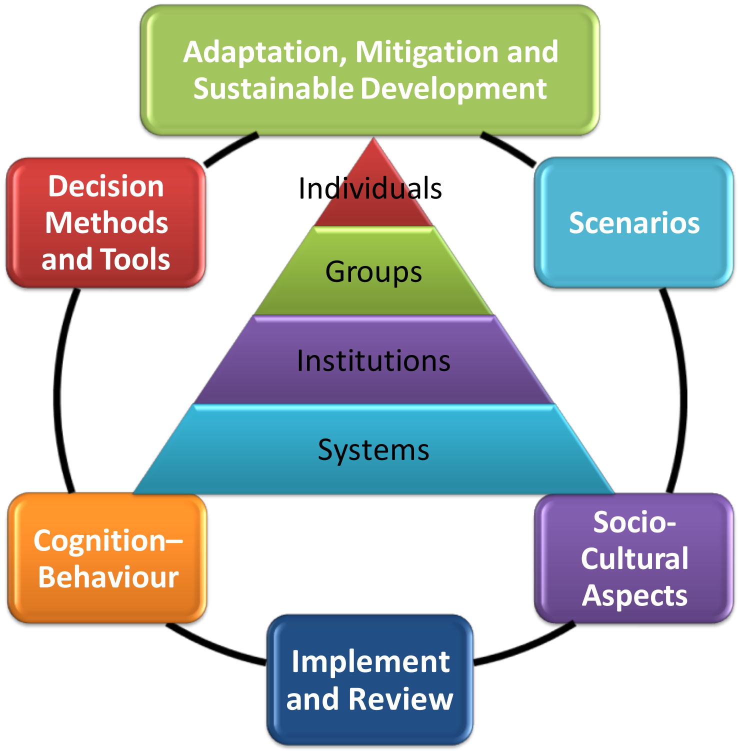


Figure 2-1: Schema for the chapter, showing a hierarchy of decision-makers in the centre and broad groupings of subjects addressed in the chapter. The decision-making environment is described by adaptation, mitigation and sustainable development, the methods and tools utilised include scenarios, decisions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

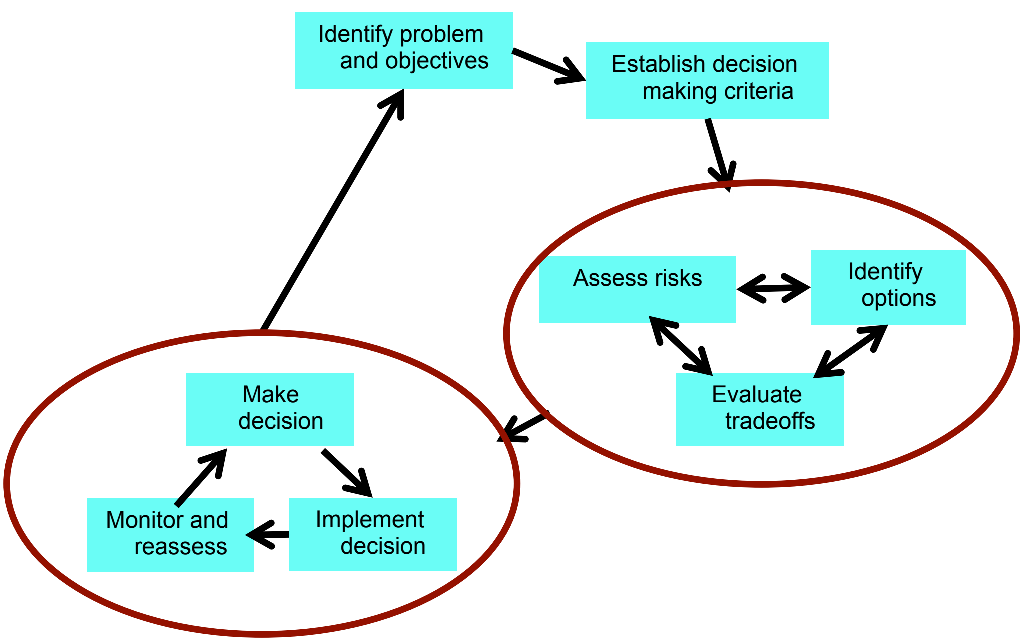


Figure 2-2: Iterative Risk Management Framework, adapted from (CITE).

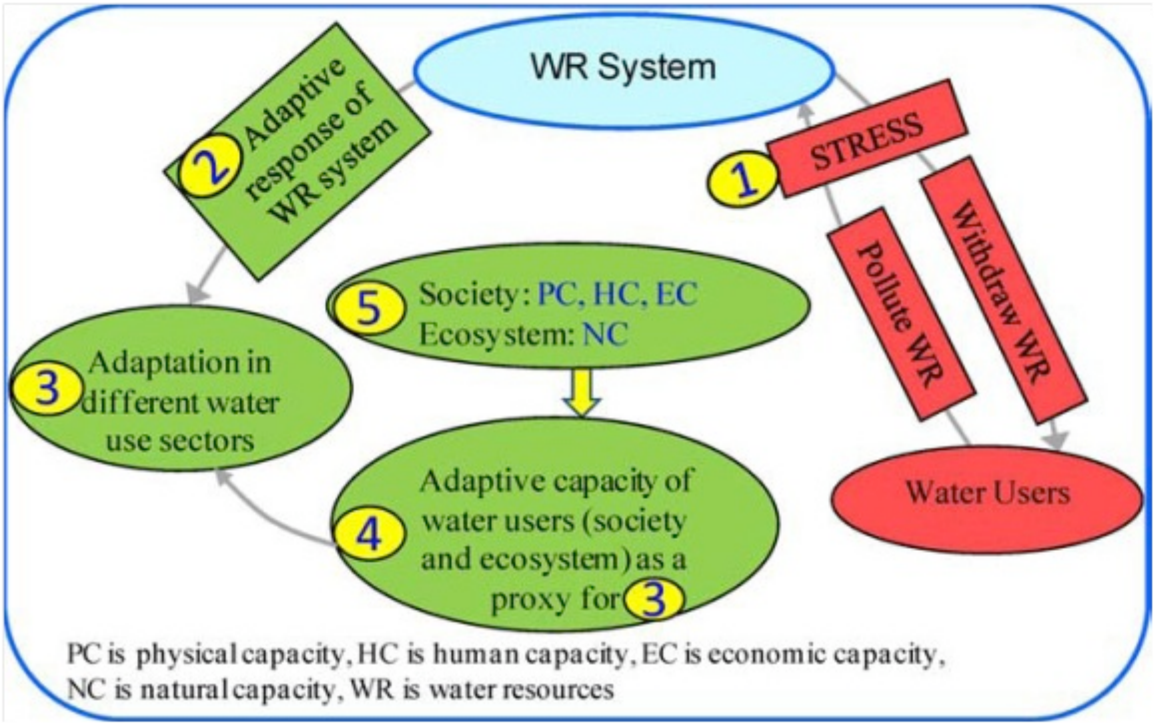


Figure 2-3: A conceptual framework of adaptation, adaptive capacity, and its parameters (Pandey et al., 2011).

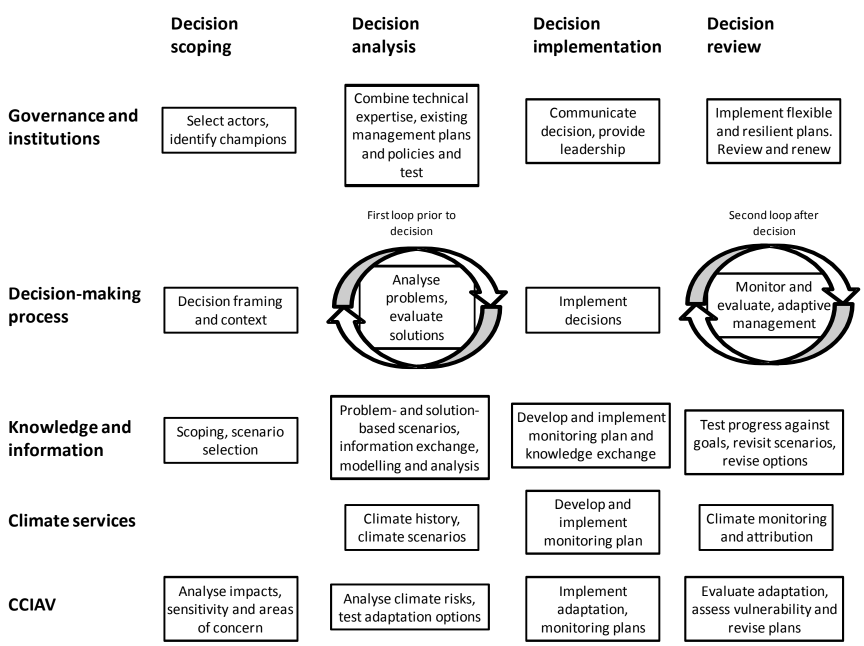


Figure 2-4: Selected attributes and characteristics relevant to the decision-making process itself. The two loops in the decision-making process relate to the two loops in Figure 2-2.

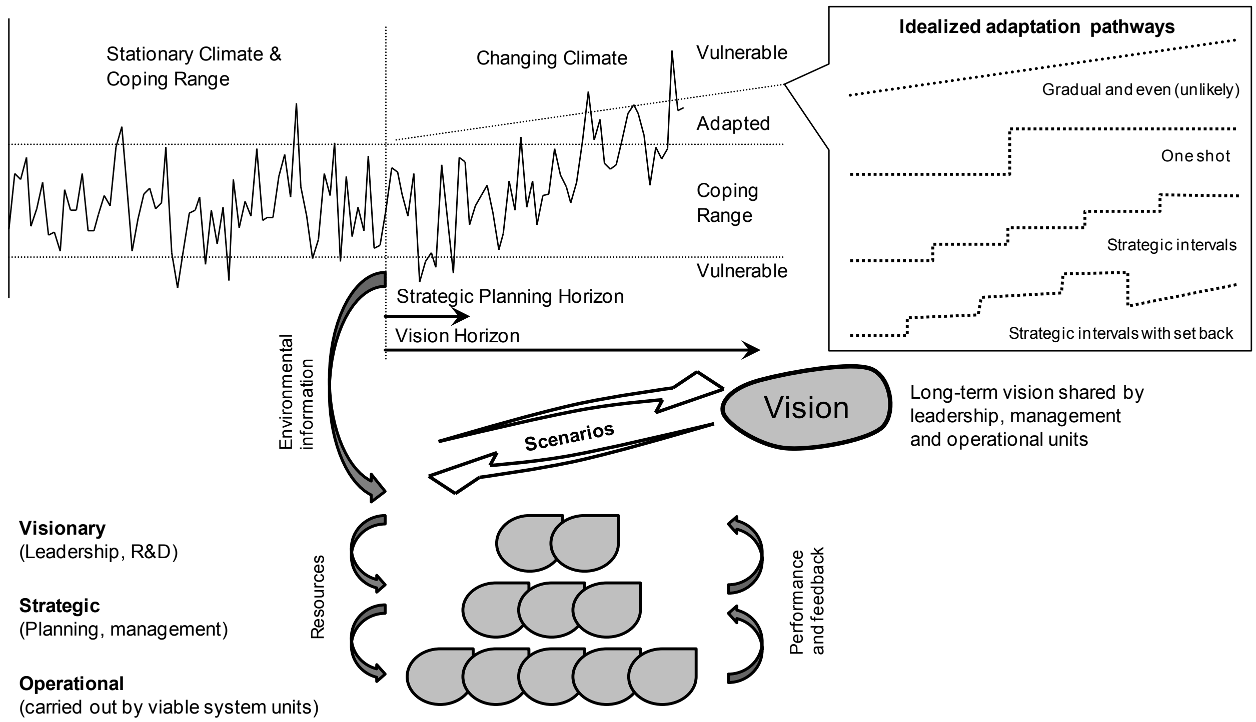


Figure 2-5: Planning frameworks for climate change showing the coping range, changing climate, thresholds and vulnerability for a single-variable climate scenario with idealised adaptation pathways (top) shows with a systems planning framework for organizations showing how….

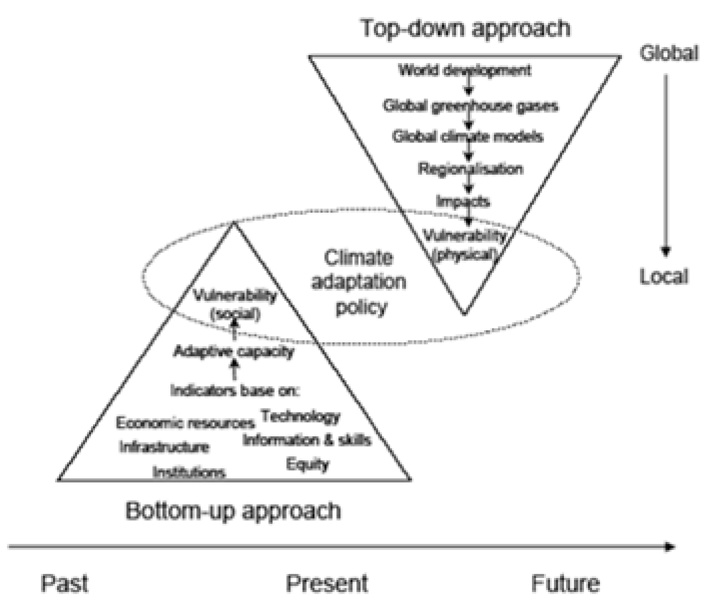
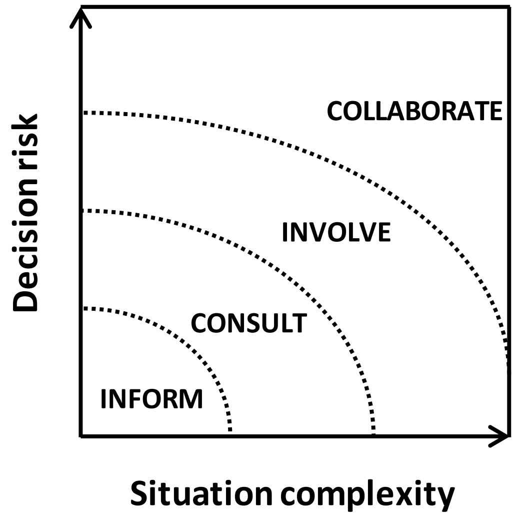


Figure 2-6: Approach Used to Inform Adaptation Policy (Dessai and Hulme 2004).



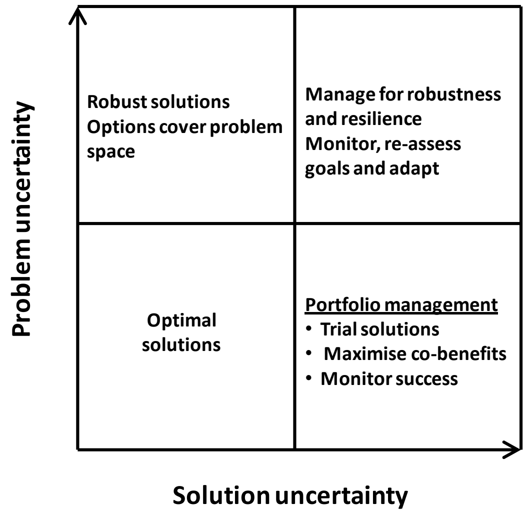


Figure 2-7: Two perspectives on decision complexity. On the left the relationship between decision risk and system complexity is used to suggest levels of engagement (adapted from Robinson (2002)). On the right a problem-solution uncertainty matrix delineating solution-based decision-making strategies.

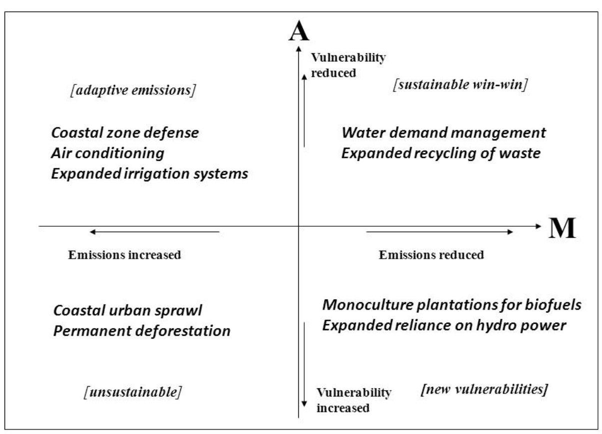


Figure 2-8: Adaptation – mitigation trade-offs and synergies (adapted from (Cohen and Waddell, 2009).