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Chapter 2. Foundations for Decision Making

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Executive Summary

Decision support for impacts, adaptation and vulnerability is expanding from science-driven linear methods to a wide range of methods drawing from many disciplines *(high agreement, robust evidence)*. [2.1] This chapter introduces new material from disciplines including behavioural science, ethics and cultural and organizational theory, thus providing a broader perspective on climate change decision-making. Previous assessment methods and policy advice have been framed by the assumption that better science will lead to better decisions. [2.1.1] Extensive evidence from the decision sciences shows that while good scientific and technical information is necessary, it is not sufficient, and decisions require context-appropriate decision-support processes and tools *(high agreement, robust evidence)*. [2.1.2, 2.1.3, 2.2, 2.3] There now exists a sufficiently rich set of available methods, tools, and processes to support effective CCIAV decisions in a wide range of contexts *(medium agreement, medium evidence)*, although they may not always be appropriately combined or readily accessible to decision makers. [2.1.2, 2.1.3, 2.3]

Risk management provides a useful framework for most climate change decision making. [2.1.2] Iterative risk management is most suitable in situations characterised by large uncertainties, long time frames, the potential for learning over time, and the influence of both climate as well as other socio-economic and bio-physical changes *(high agreement, robust evidence)*. [2.1.2, 2.4.3] Complex decision-making contexts will ideally apply a broad definition of risk, address and manage relevant perceived risks, and assess the risks of a broad range of plausible future outcomes and alternative risk management actions *(medium agreement, robust evidence)*. [2.3] The resulting challenge is for people and organisations to apply CIAV decision-making processes in ways that address their specific aims. [2.2.1]

Decision support is situated at the intersection of data provision, expert knowledge and human decision-making at a range of scales from the individual to the organization and institution. 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. [2.1.3, 2.2.1, 2.2, 2.3] Such support is most effective when it is context-sensitive, taking account of the diversity of different types of decisions, decision processes, and constituencies *(high agreement, robust evidence)*. [2.3.1, 2.3.3, 2.3.4] Boundary organizations, including climate services, play an important role in climate change knowledge transfer and communication, including translation, engagement and knowledge exchange *(high agreement, medium evidence)*. [2.2.2.1, 2.4.1, 2.4.2, 2.4.3]

Scenarios are a key tool for addressing uncertainty *(high agreement, robust evidence)*. They can be divided into those that explore how futures may unfold under various drivers (problem exploration) and those that test how various interventions may play out (solution exploration). [2.2.1.3][2.3.2] Historically, most scenarios used for CIAV assessments have been of the former type, though the latter are becoming more prevalent *(high agreement, medium evidence)*. The new RCP scenario process can address both problem and solution framing in ways that previous IPCC scenarios have not been able to *(medium agreement, limited evidence)*. [2.3.2]

CIAV decision making involves ethical judgments expressed at a range of institutional scales; the resulting ethical judgements are a key part of risk governance *(medium agreement, robust evidence)*. [2.2.1.1, 2.2.1.2, 2.2.1.4] Recognition of local and indigenous knowledge, and diverse stakeholder interests, values and expectations is fundamental to building trust within decision-making processes *(high agreement, robust evidence)* [2.2.1.2, 2.2.1.3, 2.4, 2.4.1].

Climate services aim to make knowledge about climate accessible to a wide range of decision makers. [2.4.1] In doing so they have to consider information supply, competing sources of knowledge and user demand. Knowledge transfer is a negotiated process that takes a variety of cultural values, orientations and alternative forms of knowledge into account *(high agreement, medium evidence)*. [2.4.1, 2.4.2]

Climate change response can be linked with sustainable development through actions that enhance resilience, the capacity to change in order to maintain the same identity while also maintaining the capacity to adapt, learn and transform. Mainstreamed adaptation, disaster risk management, and new types of governance and institutional arrangements are being studied for their potential to support the goal of enhanced resilience *(high agreement, medium evidence)*. [2.5.2]

Transformational adaptation may be required if incremental adaptation proves insufficient *(high agreement, medium evidence)*. This process may require changes in existing social structures, institutions, and values, which can be facilitated by iterative risk management and triple-loop learning that considers a situation and its drivers, along with the underlying frames and values that provide the situation context. **[2.1.2, 2.5.3]**

2.1. Introduction and Key Concepts

This chapter addresses the foundations of decision making with respect to climate impact, adaptation and vulnerability (CIAV). The Fourth Assessment Report (AR4) summarized methods for assessing CIAV (Carter et al., 2007), which we build on by surveying the broader literature relevant for decision making.

Decision making under climate change has largely been modelled on the scientific understanding of the cause-and-effect process whereby increasing greenhouse gas emissions cause climate change, resulting in changing impacts and risks, potentially increasing vulnerability to those risks. The resulting decision-making guidance on impacts and adaptation follows a rational-linear process that identifies potential risks then evaluates management responses (e.g., Carter et al., 1994; Feenstra et al., 1998; Parry and Carter, 1998; Fisher et al., 2007). This process has been challenged on the grounds that it does not adequately address the diverse contexts within which climate decisions are being made, often neglects existing decision-making processes, and overlooks many cultural and behavioural aspects of decision-making (Smit and Wandel, 2006; Sarewitz and Pielke Jr, 2007; Dovers, 2009; Beck, 2010). While more recent guidance on CIAV decision-making typically accounts for sectoral, regional and socio-economic characteristics (21.3), the broader decision-making literature is still not fully reflected in current methods. This is despite an increasing emphasis on the roles of societal impacts and responses to climate change in decision-making methodologies *(high confidence)* (1.1, 1.2, 21.2.1).

The main considerations that inform the decision-making contexts addressed here are knowledge generation and exchange, who makes and implements decisions, the issues being addressed and how these can be addressed. These decisions occur within a broader social and cultural environment. Knowledge generation and exchange includes knowledge generation, development, brokering, exchange and application to practice. Decision makers include policy-makers, managers, planners and practitioners, and range from individuals to organizations and institutions (Table 21-1). Relevant issues include all areas affected directly and indirectly by climate impacts or by responses to those impacts, covering diverse aspects of society and the environment. These issues include consideration of values, purpose, goals, available resources, the time over which actions are expected to remain effective and the extent to which the objectives being pursued are regarded as appropriate. The purpose of the decision in question; e.g., assessment, strategic planning or implementation, will also define the framework and tools needed to enable the process. This chapter does not provide any standard template or instructions for decision-making, nor does it endorse particular decisions over others.

The remainder of this chapter is organized as follows. Section 2.1.2 addresses risk management, which provides an overall framework suitable for CIAV decision-making; Section 2.1.3 introduces decision support, Section 2.2 discusses contexts for decision-making, Section 2.3 methods, tools and process, Section 2.4 support for and application of decision-making and Section 2.5 describes some of the broader contexts influencing CIAV decision making.

2.1.1. Decision-Making Approaches in this Report

The overarching theme of the chapter and the AR5 report is managing current and future climate risks (1.2.4, 16.2, 19.1), principally through adaptation (Chapters 14–17), but also through resilience and sustainable development informed by an understanding of both impacts and vulnerability (19.2). The International Standard ISO:31000 defines risk as *the effect of uncertainty on objectives* (ISO, 2009) and the Working Group II glossary defines risk as: *The potential for consequences where something of human value (including humans themselves) is at stake and where the outcome is uncertain* (Rosa, 2003). However, the glossary also refers to a more operational definition for assessing climate-related hazards: *risk is often represented as probability of occurrence of hazardous events or trends multiplied by the consequences if these events occur.* Risk can also refer to an uncertain opportunity or benefit (see 2.2.1.3). This chapter takes a broader perspective than the latter by including risks associated with taking action (e.g., will this adaptation strategy be successful?) and the broader socially-constructed risks that surround ‘climate change’ (e.g., fatalism, hope, opportunity and despair).

Because all decisions on CIAV are affected by uncertainty and focus on valued objectives, all can be considered as decisions involving risk (e.g., Giddens, 2009)*(high confidence)*. AR4 endorsed iterative risk management as a suitable decision-support framework for CIAV assessment because it offers formalized methods for addressing uncertainty, involving stakeholder participation, identifying potential policy responses, and evaluation of those responses (Carter et al., 2007; IPCC, 2007a; Yohe et al., 2007). The literature shows significant advances on all these topics since AR4 (1.1.4), greatly expanding methodologies for assessing impacts, adaptation and vulnerability in a risk context (Agrawala and Fankhauser, 2008; Hinkel, 2011; Jones and Preston, 2011; Preston et al., 2011).

Many different risk methodologies, such as financial, natural disaster, infrastructure, environmental health and human health risk methodologies are relevant for CIAV decision-making *(very high confidence)*. Each methodology utilizes a variety of different tools and methods. For example, the standard CIAV methodology follows a top-down cause and effect pathway as outlined above. Others follow a bottom-up pathway, starting with a set of decision-making goals that may be unrelated to climate and consider how climate may affect those goals (see also 15.2.1, 15.3.1). Some methodologies such as vulnerability, resilience and livelihood assessments are often considered as being different from traditional risk assessment, but may be seen as dealing with particular stages within a longer term iterative risk management process. For example, developing resilience can be seen as managing a range of potential risks that are largely unpredictable; and sustainable development aims to develop a social-ecological system robust to climate risks.

A major aim of decision-making is to make good or better decisions. Good and better decisions with respect to climate adaptation are frequently mentioned in the literature but no universal criterion exists for a good decision, including a good climate-related decision (Moser and Ekstrom, 2010). This is reflected in the numerous framings linked to adaptation decision making, each having its advantages and disadvantages (Preston et al., 2013; 15.2.1). Extensive evidence from the decision sciences shows that good scientific and technical information alone is rarely sufficient to result in better decisions (Bell and Lederman, 2003; Jasanoff, 2010; Pidgeon and Fischhoff, 2011) *(high confidence)*. Aspects of decision-making that distinguish climate change from most other contexts are the long time scales involved, the pervasive impacts and resulting risks and the ‘deep’ uncertainties attached to many of those risks (Kandlikar et al., 2005; Ogden and Innes, 2009; Lempert and McKay, 2011). These uncertainties include not only future climate but also socio-economic change and potential changes in norms and values within and across generations.

2.1.2. Iterative Risk Management

Iterative risk management involves an ongoing process of assessment, action, reassessment, and response (Kambhu et al., 2007; IRGC, 2010) that will continue – in the case of many climate-related decisions – for decades if not longer (Committee on America's Climate Choices National Research Council, 2011). This development is consistent with an increasing focus on risk governance (Power, 2007; Renn, 2008), the integration of climate risks with other areas of risk management (Hellmuth et al., 2011; Measham et al., 2011) and a wide range of approaches for structured decision-making involving process uncertainty (Ohlson et al., 2005; Wilson and McDaniels, 2007; Ogden and Innes, 2009; Martin et al., 2011).

[INSERT FIGURE 2-1 HERE
Figure 2-1: Iterative risk management framework depicting the assessment process, and indicating multiple feedbacks within the system and extending to the overall context. Adapted from Willows and Connell (2003).]

Two levels of interaction can be recognised within the iterative risk management process: one internal and one external (Figure 2-1). External factors are present through the entire process and shape the process outcomes. The internal aspects describes the adaptation process itself. The first major internal iteration (in yellow) reflects the interplay with the analysis phase by addressing the interactions between evolving risks and their feedbacks (not shown) and during the development and choice of options. This process may also require a revision of criteria and objectives. This phase ends with decisions on the favoured options being made. A further internal iteration covers the implementation of actions and their monitoring and review (in orange). Throughout all stages the process is reflexive, in order to enable changes in knowledge, risks or circumstances to be identified and responded to. At the end of the implementation stage, all stages are evaluated and the process starts again with the scoping phase. Iterations can be successive, on a set timetable, triggered by specific criteria or informally by new information informing risk or a change in the policy environment. An important aspect of this process is to recognise emergent risks and respond to them (19.2.3–5, 19.3).

Complexity is an important attribute for framing and implementing decision-making processes *(very high confidence)*. Simple, well-bounded contexts involving cause and effect can be addressed by straightforward linear methods. Complicated contexts require greater attention to process but can generally be unravelled providing an ultimate solution (Figure 2-2). However, when complex environments interact with conflicting values they become associated with wicked problems. Wicked problems are not well bounded, are framed differently by various groups and individuals, harbour large scientific to existential uncertainties 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 (Dupuy and Grinbaum, 2005; Kandlikar et al., 2005). Another important attribute of complex systems is *reflexivity*, where cause and effect feed back into each other (see glossary). For example, actions taken to manage a risk will affect the outcomes, requiring iterative processes of decision-making *(very high confidence)*. Under climate change, calculated risks will also change with time as new knowledge becomes available (Ranger et al., 2010).

[INSERT FIGURE 2-2 HERE
Figure 2-2: Hierarchy of simple, complicated, and complex risks, showing how perceived risks multiply and become less connected with calculated risk with increasing complexity. Also shown are major characteristics of assessment methods for each level of complexity.]

In complex situations, socio-cultural and cognitive-behavioural contexts become central to decision-making. This requires combining the scientific understanding of risk with how risks are framed and perceived by individuals, organisations and institutions (Hansson, 2010). For that reason, formal risk assessment is moving 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), although this process is proceeding slowly (Christoplos et al., 2001; Pereira and Quintana, 2002; Bradbury, 2006; Mercer et al., 2008).

Different traditional and modern epistemologies, or ‘ways of knowing’ exist for risk (Hansson, 2004; Althaus, 2005; Hansson, 2010), vulnerability (Weichselgartner, 2001; O'Brien et al., 2007) and adaptation assessments (Adger et al., 2009) 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 identified as a source of widespread misunderstanding and disagreement. They are also used to warn against a uniform epistemic approach (Hulme, 2009; Beck, 2010), a critique that has been levelled against previous IPCC assessments (e.g., Hulme and Mahony, 2010).

The following three types of risk have been identified as important epistemological constructs (Thompson, 1986; Althaus, 2005; Jones, 2012):

1) Idealized risk: the conceptual framing of 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) Perceived risk: the subjective judgement people make about an idealized risk (see also 19.6.1.4).

These different types show risk to be partly an objective threat of harm and partly a product of social and cultural experience (Kasperson et al., 1988; 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 reflects the division between positivist (imposed norms) and constructivist (derived norms) approaches to risk from the natural and social sciences respectively (Demeritt, 2001; Hansson, 2010). Idealized risk is important for framing and conceptualising risk and will often have formal and informal status in the assessment process, contributing to both calculated and perceived risk. These types of risk combine at the societal scale as socially constructed risk, described and assessed in a wide range of research literature such as psychology, anthropology, geography, ethics, sociology and political science (2.2.1.2, 19.6.1.4).

Acceptance of the science behind controversial risks is strongly influence by social and cultural values and beliefs (Leiserowitz, 2006; Kahan et al., 2007; Brewer and Pease, 2008). Risk perceptions can be amplified socially where events pertaining to hazards interact with psychological, social, institutional, and cultural processes in ways that heighten or attenuate individual and social perceptions of risk and shape risk behaviour (Kasperson et al., 1988; Renn et al., 1992; Pidgeon et al., 2003; Rosa, 2003; Renn, 2011). The media have an important role in propagating both calculated and perceived risk (Llasat et al., 2009), sometimes to detrimental effect (Boykoff and Boykoff, 2007; Oreskes and Conway, 2010; Woods et al., 2012).

Understanding how these perceptions resonate at an individual and collective level can help overcome constraints to action (Renn, 2011). 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 informal methods (Beck, 2000), but an assessment of what is at risk generally needs to be accepted by stakeholders (Richard Eiser et al., 2012). Therefore, the science always sits within a broader social setting (Jasanoff, 1996; Demeritt, 2001; Wynne, 2002; Demeritt, 2006), often requiring a systems approach where science and policy are investigated in tandem, rather than separately (Pahl-Wostl, 2007; Ison, 2010) *(very high confidence)*. These different types of risk give rise to complex interactions between formal and informal knowledge that cannot be bridged by better science or better predictions but require socially and culturally mediated processes of engagement *(high confidence)*.

2.1.3. Decision Support

The concept of *decision support* provides a useful framework for understanding how risk-based concepts and information can help enhance decision-making (McNie, 2007; National Research Council (US) Panel on Design Issues for the NOAA Sectoral Applications Research Program et al., 2007; Moser, 2009; Romsdahl and Pyke, 2009; Kandlikar et al., 2011; Pidgeon and Fischhoff, 2011) The concept also helps situate methods, tools, and processes intended to improve decision-making within appropriate institutional and cultural contexts.

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” (National Academy of Sciences, 2009). Information is decision-relevant if it yields deeper understanding of, or is incorporated into making a choice that improves outcomes for decision makers and stakeholder or precipitates action to manage known risks. Effective decision support provides users with information they find useful because they consider it credible, legitimate, actionable, and salient (e.g., Jones et al., 1999; Cash et al., 2003; Mitchell, 2006; Reid et al., 2007). Such criteria can be used to evaluate decision support and such evaluations lead to common principles of effective decision support, which have been summarized in (National Research Council, 2009) as:

1) Begins with user’s 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 than 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 constituents, while a community with a well-developed understanding of its risks may be more focused on assessing trade-offs and allocating resources.

2.2. Contexts for Decision-Making

This section surveys aspects of decision-making that relate to context setting. Social context addresses cultural values, psychology, language and ethics (2.2.1) and institutional context covers institutions and governance (2.2.2).

2.2.1. Social Context

Decision support for CIAV must recognize that diverse values, language uses, ethics and human psychological dimensions play a crucial role in the way that people use and process information and take decisions (Kahan and Braman, 2006; Leiserowitz, 2006). As illustrated in Figure 2-1, the context defines and frames the space in which decision-making processes operate.

2.2.1.1. Cultural Values and Determinants

Cultural differences allocate values and guide socially mediated change. Five value dimensions that show significant cross-national variations are: power distance, individualism/collectivism, uncertainty avoidance, long/short term orientation and masculinity/femininity (Hofstede, 1980; Hofstede and Hofstede, 2001; Hofstede et al., 2010). Power distance and individualism/collectivism both show a link to climate via latitude; the former relates to willingness to conform to top-down directives, whereas the latter relates to the potential efficacy of market/community-based strategies. Uncertainty avoidance and long-term orientation show considerable variation between countries (Hofstede et al., 2010) potentially producing significant differences in risk perception and agency.

Environmental values have also been linked to cultural orientation. Schultz et al. (2004) identified the association between self and nature in people as being implicit – informing actions without specific awareness. A strong association was linked to a more connected self and a weaker association with a more egoistic self. Explicit environmental values can substantially influence climate change-related decision-making processes (Nilsson et al., 2004; Milfont and Gouveia, 2006; Soyez et al., 2009) and public behaviour toward policies (Stern and Dietz, 1994; Xiao and Dunlap, 2007). Schaffrin (2011) concludes that geographical aspects, vulnerability and potential policy benefits associated with a given issue can influence individual perceptions and willingness to act (De Groot and Steg, 2007, 2008; Shwom et al., 2008; Milfont et al., 2010). Cultural values can interrelate with specific physical situations of climate change (Corraliza and Berenguer, 2000), or seasonal and meteorological factors influencing people’s implicit connections with nature (Duffy and Verges, 2010). Religious and sacred values are also important (Goloubinoff et al., 1998; Katz et al., 2002; Lammel et al., 2008), informing the perception of climate change and risk, as well as the actions to adapt (Crate and Nuttal, 2009; 16.3.1.3). The role of protected values (values that people will not trade off, or negotiate) can also be culturally and spiritually significant (Baron and Spranca, 1997; Baron et al., 2009; Hagerman et al., 2010). Adger et al. (2013) emphasise the importance of cultural values in assessing risks and adaptation options, suggesting they are at least as important as economic values in many cases, if not more so. These aspects are important for framing and conceptualizing CIAV decision-making. Cultural and social barriers are described in Chapter 16.3.2.7.

Two distinct ways of thinking – holistic and analytical thinking – reflect the relationship between humans and nature and are cross-culturally and even intra-culturally diverse (Gagnon Thompson and Barton, 1994; Huber and Pedersen, 1997; Atran et al., 2005; Ignatow, 2006; Descola, 2010; Ingold, 2011). Holistic thinking is primarily gained through experience and is dialectical, accepting contradictions and integrating multiple perspectives. Characteristic of collectivist societies, the holistic conceptual model considers that social obligations are reciprocal and individuals take an active part in the community for the benefit of all (Peng and Nisbett, 1999; Nisbett et al., 2001; Lammel and Kozakai, 2005; Nisbett and Miyamoto, 2005). Analytical thinking isolates the object from its broader context, understanding its characteristics through categorization, and predicting events based on intrinsic rules. In the analytic conceptual model, individual interests take precedence over the collective; the self is independent and communication comes from separate fields. These differences influence the understanding of complex systemic phenomena such as climate change (Lammel et al., 2011; Lammel et al., 2012; Lammel et al., 2013) and decision making practices (Badke-Schaub and Strohschneider, 1998; Strohschneider and Güss, 1999; Güss et al., 2010).

The above models vary greatly across the cultural landscape, but neither model alone is sufficient for decision making in complex situations *(high confidence)*. At a very basic level, egalitarian societies may respond more to community based adaptation in contrast to more individualistic societies that respond to market-based forces *(medium confidence)*. In small-scale societies, knowledge about climate risks are often integrated into a holistic view of community and environment (e.g., Katz et al., 2002; Strauss and Orlove, 2003; Lammel et al., 2008). Many studies highlight the importance of integrating local, traditional knowledge with scientific knowledge when assessing CIAV (Magistro and Roncoli, 2001; Krupnik and Jolly, 2002; Vedwan, 2006; Nyong et al., 2007; Dube and Sekhwela, 2008; Crate and Nuttal, 2009; Mercer et al., 2009; Roncoli et al., 2009; Green and Raygorodetsky, 2010; Orlove et al., 2010; Crate, 2011; Nakashima et al., 2012; Chapter 12.3, 12.3.1, 12.3.2, 12.3.3, 12.3.4, 14.4.5, 14.4.7, 15.3.2.7, 25.8.2, 28.2.6.1, 28.4.1). For example, a case study in Labrador (Canada) demonstrated the need to account for local material and symbolic values because they shape the relationship to the land, underlie the way of life, influence the intangible effects of climate change, and can lead to diverging views on adaptations (Wolf et al., 2012). In Kiribati, the integration of local cultural values attached to resources/assets is fundamental to adaptation planning and water management, otherwise technology will not be properly utilised (Kuruppu, 2009).

2.2.1.2. Psychology

Psychology plays a significant role in climate change decision-making (Gifford, 2008; Swim et al., 2010; Anderson, 2011). Important psychological factors for decision-making include: perception, representation, knowledge acquisition, memory, behaviour, emotions and understanding of risk (Böhm and Pfister, 2000; Leiserowitz, 2006; Lorenzoni et al., 2006; Oskamp and Schultz, 2006; Sterman and Sweeney, 2007; Gifford, 2008; Kazdin, 2009; Sundblad et al., 2009; Reser et al., 2011; Swim et al., 2011).

Psychological research contributes to understanding on both risk perception and the process of adaptation. Several theories, such as multi-attribute utility theory (Keeney, 1992), prospect theory (Kahneman and Tversky, 1979; Hardman, 2009), and cumulative prospect theory relate to decision making under uncertainty (Tversky and Kahneman, 1992), especially to risk perception and agency. Adaptation in complex situations pits an unsure gain against an unsure loss, so creates an asymmetry in preference that magnifies with time as gains/losses are expected to accrue in future. Decisions focusing on values and uncertainty are therefore subject to framing effects. Recent cognitive approaches include the one-reason decision process that uses limited data in a limited time period (Gigerenzer and Goldstein, 1996) or decision by sampling theory that samples real-world data to account for the cognitive biases observed in behavioural economics (Stewart et al., 2006; Stewart and Simpson, 2008). Risk perception is further discussed in Chapter 19.6.1.4.

Responses to new information can modify previous decisions, even producing contradictory results (Grothmann and Patt, 2005; Marx et al., 2007). Although knowledge about climate change is necessary (Milfont, 2012), understanding such knowledge can be difficult (Rajeev Gowda et al., 1997; Boyes et al., 1999; Andersson and Wallin, 2000). Cognitive obstacles in processing climate change information include psychological distances with four theorized dimensions: temporal, geographical, social distance and uncertainty (Spence et al., 2012, see also 25.4.3). Emotional factors also play an important role in climate change perception, attitudes, decision making and actions (Meijnders et al., 2002; Leiserowitz, 2006; Klöckner and Blöbaum, 2010; Fischer and Glenk 2011; Roeser, 2012) and even shape organizational decision making (Wright and Nyberg, 2012). Other studies on attitudes and behaviours relevant to climate change decision-making, include place attachment (Scannell and Gifford, 2013; chapter 25.4.3), political affiliation (Davidson and Haan, 2011), and perceived costs and benefits (Tobler et al., 2012). Time is a critical component of action-based decision making (Steel and König, 2006). As the benefits of many climate change actions span multiple temporal scales, this can create a barrier to effective motivation for decisions through a perceived lack of value associated with long term outcomes.

Protection Motivation Theory (Rogers, 1975; Maddux and Rogers, 1983), which proposes that a higher personal perceived risk will lead to a higher motivation to adapt, can be applied to climate change-related problems (e.g., Grothmann and Reusswig, 2006; Cismaru et al., 2011). The Person-relative-to-event approach predicts human coping strategies as a function of the magnitude of environmental threat (Mulilis and Duval, 1995; Duval and Mulilis, 1999; Grothmann et al., 2013). People's responses to environmental hazards and disasters are represented in the multistage Protective Action Decision Model (Lindell and Perry, 2012). This model helps decision makers to respond to long-term threat and apply it in long-term risk management. Grothmann and Patt (2005) developed and tested a socio-cognitive model of proactive private adaptation to climate change showing that perceptions of adaptive capacities were important as well as perceptions of risk. If a perceived high risk is combined with a perceived low adaptive capacity (see 2.4.2.2; Glossary), the response is fatalism, denial and wishful thinking.

Best-practice methods for incorporating and communicating information about risk and uncertainties into decisions about climate change (Climate Change Science Program, 2009; Pidgeon and Fischhoff, 2011) suggests that effective communication of uncertainty requires products and processes that: i) closes psychological distance, explaining why this information is important to the recipient; ii) distinguishes between and explains different types of uncertainty; iii) establishes self-agency, explaining what the recipient can do with the information and ways to make decisions under uncertainty (e.g., precautionary principle, iterative risk-management); iv) recognizes that each person's view of risks and opportunities depends on their values; v) recognizes that emotion is a critical part of judgment; vi) provides mental models that help recipients to understand the connection between cause and effect. Information providers also need to test their messages, since they may not be communicating what they think they are.

2.2.1.3. Language and Meaning

Aspects of decision-making concerned with language and meaning include framing, communication, learning, knowledge exchange, dialogue and discussion. Most IPCC-related literature on language and communication deals with definitions, predictability and incomplete knowledge, with less emphasis given to other aspects of decision-support such as learning, ambiguity, contestedness and complexity. Three important areas assessed here are definitions, risk language and communication, and narratives.

Decision-making processes need to accommodate both specialist and non-specialist meanings of the concepts they apply. Various disciplines often have different definitions for the same terms or use different terms for the same action or object, which is a major barrier for communication and decision-making (Adger, 2003; Chapter 21). For example, adaptation is defined differently with respect to biological evolution, climate change and social adaptation. Budescu et al. (2012) found that people prefer imprecise wording but precise numbers when appropriate. Personal lexicons vary widely, leading to differing interpretations of uncertainty terms (Morgan et al., 1990); in the IPCC's case leading to uncertainty ranges often being interpreted differently than intended (Patt and Schrag, 2003; Patt and Dessai, 2005; Budescu et al., 2012). Addressing both technical and everyday meanings of key terms can help bridge the analytic and emotive aspects of cognition. For example, words like danger, disaster, uncertainty and catastrophe have technical and emotive aspects (Britton, 1986; Carvalho and Burgess, 2005). Terms where this issue is especially pertinent include adaptation, vulnerability, risk, dangerous, catastrophe, resilience and disaster. Other words have definitional issues because they contain different epistemological frames; sustainability and risk being key examples (Harding, 2006; Hamilton et al., 2007). Many authors advocate 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). This is a key role for risk communication, ensuring that different types of knowledge are integrated within decision context and outlining the different values – implicit and explicit – involved in the decision process (e.g., Morgan, 2002; Lundgren and McMakin, 2013).

The language of risk has a crucial role in framing and belief. Section 2.1.2 described over-arching and climate-specific definitions but risk enters into almost every aspect of social discourse, so is relevant to how risk is framed and communicated (e.g., Hansson, 2004). Meanings of risk range from its ordinary use in everyday language to power and political discourse, health, emergency, disaster and seeking benefits, ranging from specific local meanings to broad-ranging concepts such as the risk society (Beck and Ritter, 1992; Beck, 2000; Giddens, 2000). Complex framings in the word risk (Fillmore and Atkins, 1992; Hamilton et al., 2007) feature in general English as both a noun and a verb, reflecting harm and chance with negative and positive senses (Fillmore and Atkins, 1992). Problem analysis applies risk as a noun (at-risk), whereas risk management applies risk as a verb (to-risk) (Jones, 2011). For simple risks, this transition is straightforward because of agreement around values and agency (Figure 2-2). In complex situations, risk as a problem and as an opportunity can compete with each other, and if socially amplified can lead to action paralysis (Renn, 2011). For example, unfamiliar adaptation options that seem to be risky themselves will force a comparison between the risk of maladaptation and future climate risks, echoing the risk trap where problems and solutions come into conflict (Beck, 2000). Fear-based dialogues in certain circumstances can cause disengagement (O'Neill and Nicholson-Cole, 2009), by emphasising risk aversion. Young (2013) proposes framing adaptation as a solution to overcome the limitations of framing through the problem, and links it to innovation, which provides established pathways for the implementation of actions, proposing a problem-solution framework linking decision-making to action. Framing decisions and modelling actions on positive risk-seeking behaviour can help people to address uncertainty as opportunity (e.g., Keeney, 1992).

Narratives are accounts of events with temporal or causal coherence that may be goal directed (László and Ehmann, 2012) and play a key role in communication, learning and understanding. They operate at the personal to societal scales, are key determinants of framing and have a strong role in creating social legitimacy. Narratives can also be non-verbal: visualization, kinetic learning by doing and other sensory applications can be used to communicate science and art, and to enable learning through play (Perlovsky, 2009; Radford, 2009). Narratives of climate change have evolved over time and invariably represent uncertainty and risk (Hamblyn, 2009) being characterised as tools for analysis, communication and engagement (Cohen, 2011; Jones et al., 2013; Westerhoff and Robinson, 2013) by:

1) Providing a social and environmental context to modelled futures (Arnell et al., 2004; Kriegler et al., 2012; O'Neill et al., 2013), by describing aspects of change that drive or shape those futures as part of scenario construction (Cork et al., 2012).
2) Communicating knowledge and ideas to increase understanding and increase agency framing it in ways so that actions can be implemented (Juhola et al., 2011) or provide a broader socio-ecological context to specific knowledge (Burley et al., 2012). These narratives bridge the route between scientific knowledge and local understandings of adaptation, often by working with multiple actors in order to creatively explore and develop collaborative potential solutions (Turner and Clifton, 2009; Paton and Fairbairn-Dunlop, 2010; Tschakert and Dietrich, 2010).
3) Exploring responses at an individual/institutional level to an aspect of adaptation, and communicate that experience with others. (Bravo, 2009; Cohen, 2011). For example, a community that believes itself to be resilient and self-reliant is more likely to respond proactively, contrasted to a community that believes itself to be vulnerable (Farbotko and Lazrus, 2012). Bravo (2009) maintains that narratives of catastrophic risk and vulnerability demotivate indigenous peoples whereas narratives combining scientific knowledge and active citizenship promote resilience (2.5.2).

2.2.1.4. Ethics

Climate ethics can be used to formalize objectives, values (2.2.1.1), rights and needs into decisions, decision-making processes and actions (see also 16.7). Principal ethical concerns include: intergenerational equity; distributional issues; the role of uncertainty in allocating fairness or equity; economic and policy decisions; international justice and law; voluntary and involuntary levels of risk; cross-cultural relations; and human relationships with nature, technology and the socio-cultural world. Climate change ethics have been developing over the last 20 years (Jamieson, 1992, 1996; Gardiner, 2004; Gardiner et al., 2010), resulting in a substantial literature (Garvey, 2008; Harris, 2010; O'Brien et al., 2010; Arnold, 2011; Brown, 2012; Thompson and Bendik-Keymer, 2012). Equity, inequity and responsibility are fundamental concepts in the United Nations Framework Convention on Climate Change (United Nations, 1992) and therefore are important considerations in policy development for CIAV. Climate ethics examine effective responsible and ‘moral’ decision-making and action, not only by governments but also by individuals (Garvey, 2008).

An important discourse on equity is that industrialized countries have, through their historical emissions, created a natural debt (Green and Smith, 2002). Developing nations experience this debt through higher impacts and greater vulnerability combined with limited adaptive capacity. Regional inequity is also of concern (Green and Smith, 2002), particularly indigenous or marginalized populations exposed to current climate extremes, who may become more vulnerable under a changing climate (Tsosie, 2007; 12.3.3). With respect to adaptation assessment, cost-benefit or cost effectiveness methods combined with transfer of funds will not satisfy equity considerations (Broome, 2008; 17.3.1.4) and modifications such as equity weighting (Kuik et al., 2008) and cost-benefit under uncertainty (17.3.2.1), have not been widely used. Adaptation measures need to be evaluated by considering their equity implications (17.3.1.4) especially under uncertainty (Hansson, 2004).

Intergenerational issues are frequently treated as an economic problem, with efforts to address them through an ethical framework proving to be controversial (Nordhaus, 2007; Stern and Treasury of Great Britain, 2007; Stern, 2008). However, future harm may make the lives of future generations difficult or impossible, dilemmas that involve ethical choices (Broome, 2008), therefore discount rates matter (17.4.4.4). Some authors question whether the rights and interests of future people should even be subject to a positive discount rate Caney (2009). Future generations cannot defend themselves within current economic frameworks (Gardiner, 2011) nor can these frameworks properly account for the dangers, interdependency and uncertainty under climate change (Nelson, 2011), even though peoples’ values may change over time (16.7). The limits to adaptation raise questions of irreversible loss and the loss of unique cultural values that cannot necessarily be easily transferred (16.7), contributing to key vulnerabilities and informing ethical issues facing mitigation (see 19.7.1).

Environmental ethics considers the decisions humans may make concerning a range of biotic impacts (Schalow, 2000; Minteer and Collins, 2010; Nanda, 2012; Thompson and Bendik-Keymer, 2012). Intervention in natural systems through 'assisted colonization' or 'managed relocation' raises important ethical and policy questions (Minteer and Collins, 2010)(4.4.2.4) that include the risk of unintended consequences (4.4.4). Various claims are made for a more pragmatic ethics of ecological decision-making (Minteer and Collins, 2010), consideration of moral duties toward species (Sandler, 2009) and ethically explicit and defendable decision-making (Minteer and Collins, 2005b, a).

Cosmopolitan ethics and global justice can lead to successful adaptation and sustainability (Caney, 2006; Harris, 2010) and support collective decision-making on public matters through voting procedures (Held, 2004). Ethics also concerns the conduct and application of research, especially research involving stakeholders. Action-based and participatory research requires that a range of ethical guidelines be followed, taking consideration of the rights of stakeholders, respect for cultural and practical knowledge, confidentiality, dissemination of results and development of intellectual property (Macaulay et al., 1999; Kindon et al., 2007; Daniell et al., 2009; Pearce et al., 2009). Ethical agreements and processes are an essential part of participatory research, whether taking part as behavioural change processes promoting adaptation or projects of collaborative discovery *(High confidence)*. Although the climate change ethics literature is rapidly developing, the related practice of decision-making and implementation needs further development. Ethical and equity issues are discussed in WG III, Chapter 3 *Social, Economic, and Ethical Concepts and Methods*.

2.2.2. Institutional Context

2.2.2.1. Institutions

Institutions are rules and norms held in common by social actors that guide, constrain, and shape human interaction (North, 1990; Glossary). Institutions can be formal, such as laws and policies, or informal, such as norms and conventions. Organizations – such as parliaments, regulatory agencies, private firms, and community bodies – develop and act in response to institutional frameworks and the incentives they frame (Young et al., 2008). Institutions can guide, constrain, and shape human interaction through direct control, through incentives, and through processes of socialization (Glossary). Virtually all CIAV decisions will be made by or influenced by institutions because they shape the choices made by both individuals and organizations (Bedsworth and Hanak, 2012). Institutional linkages are important for adaptation in complex and multi-layered social and biophysical systems such as coastal areas (5.5.3.2) and urban systems (8.4.3.4), and are vital in managing health (11.6), human security (12.5.1, 12.6.2) and poverty (13.1). Institutional development and interconnectedness are vital in mediating vulnerability in social-ecological systems to changing climate risks, especially extremes (Chapters 5, 7–9, 11–13).

The role of institutions as actors in adaptation are discussed in Chapter 14.4, in planning and implementing adaptation in Chapter 15.5 and in providing barriers and opportunities in Chapter 16.3. Their roles can be very diverse. Local institutions usually play important roles in accessing resources and in structuring individual and collective responses (Agarwal, 2010; 14.4.2) but Madzwamuse (2010) found that in Africa, state level actors had significantly more influence on formal adaptation policies than did civil society and local communities. This suggests a need for greater integration and cooperation among institutions of all levels (15.5.1.2*)*. Chapter 14 identifies four institutional design issues: flexibility; potential for integration into existing policy plans and programs; communication, coordination and cooperation; and the ability to engage with multiple stakeholders (14.2.3).

Institutions are instrumental in facilitating adaptive capacity, by utilising characteristics such as variety, learning capacity, room for autonomous change, leadership, availability of resources and fair governance (Gupta et al., 2008). They play a key role in mediating the transformation of coping capacity into adaptive capacity and in linking short and long-term responses to climate change and variability (Berman et al., 2012). Most developing countries have weaker institutions that are less capable of managing extreme events, increasing vulnerability to disasters (Lateef, 2009; Biesbroek et al., 2013). Countries with strong functional institutions are generally assumed to have a greater capacity to adapt to current and future disasters. However, Hurricane Katrina of 2005 in the USA and the European heat wave of 2003 demonstrate that strong institutions and other determinants of adaptive capacity do not necessarily reduce vulnerability if the mechanisms are not translated to actions (IPCC, 2007b; Box 2-1, 2.4.2.2).

To facilitate adaptation under uncertainty, institutions need to be flexible enough to accommodate adaptive management processes such as evaluation, learning and refinement (Agarwal, 2010; Gupta et al., 2010; 14.2.3). Organizational learning can lead to significant change in organizations' purpose and function (Bartley, 2007), for example where non-governmental organizations have moved from advocacy to program delivery with local stakeholders (Ziervogel and Zermoglio, 2009; Kolk and Pinkse, 2010; Worthington and Pipa, 2010).

Boundary organisations are increasingly being recognised as important to CIAV decision support (Guston, 2001; Cash et al., 2003; McNie, 2007; Vogel et al., 2007). A boundary organization is a bridging institution, social arrangement, or network that acts as an intermediary between science and policy (Glossary). Its functions include facilitating communication between researchers and stakeholders, translating science and technical information, and mediating between different views of how to interpret that information. It will also recognize the importance of location-specific contexts (Ruttan et al., 1994), provide a forum in which information can be co-created by interested parties (Cash et al., 2003), and develop boundary objects, such as scenarios, narratives and model-based decision support systems (White et al., 2010). Adaptive and inclusive management practices are considered to be essential, particularly in addressing wicked problems such as climate change (Batie, 2008). Boundary organisations also link adaptation to other processes managing global change and sustainable development.

Boundary organizations already contributing to regional CIAV assessments include in the US, the Great Lakes Integrated Sciences and Assessments Center – GLISA (GLISA web site: http://www.glisa.umich.edu/), part of the Regional Integrated Sciences and Assessment s (RISA) Program of the US Government (Pulwarty et al., 2009), the UK Climate Impacts Program – UKCIP (UK Climate Impacts Program, 2011), the Alliance for Global Water Adaptation – AGWA (AGWA web site: http://alliance4water.org) and institutions working on water issues in the U.S., Mexico and Brazil (Kirchhoff et al., 2012; Varady et al., 2012).

2.2.2.2. Governance

Effective climate change governance is important for both adaptation and mitigation and is increasingly being seen as a key element of risk management *(high confidence)* (Renn, 2008; Renn et al., 2011). Some analysts propose that governance of adaptation requires knowledge of anticipated regional and local impacts of climate change in a more traditional planning approach (e.g., Meadowcroft, 2009), whereas others propose governance consistent with sustainable development and resilient systems (Adger, 2006; Nelson et al., 2007; Meuleman and in 't Veld, 2010). Quay (2010) proposes 'anticipatory governance'- a flexible decision framework based on robustness and learning (2.3.3, 2.3.4). Institutional decisions about climate adaptation are taking place within a multi-level governance system (Rosenau, 2005; Kern et al., 2008). Multi-level governance could be a barrier for successful adaptation if there is insufficient coordination as it is comprised of different regulatory, legal and institutional systems (16.3.1.4), but is required to manage the 'adaptation paradox' (Local solutions to a global problem), unclear ownership of risks and the adaptation bottleneck linked to difficulties with implementation (14.5.3). Lack of horizontal and vertical integration between organizations and policies leads to insufficient risk governance in complex social-ecological systems such as coasts (5.5.3.2) and urban areas (8.4), including in the management of compound risks (19.3.2.4).

Legal and regulatory frameworks are important institutional components of overall governance, but will be challenged by the pervasive nature of climate risks *(high confidence)*(Craig, 2010; Ruhl, 2010a, b). Changes proposed to better manage these risk under uncertainty include integration between different areas of law, jurisdictions and scale, changes to property rights, greater flexibility with respect to adaptive management and a focus on ecological processes rather than preservation (Craig, 2010; Ruhl, 2010a; Abel et al., 2011; Macintosh et al., 2013). With respect to human security, this report does not see them as an issue of rights alone, given that a minimum set of universal rights exists but they are not always exercised (Box 12-1) but instead investigates a wide range of forces. Internationally, sea level rise could alter the maritime boundaries of many nations that may lead to new claims by affected nations or loss of sovereignty (Barnett and Adger, 2003). New shipping routes, such as the North West Passage, will be opened up by losses in Arctic sea ice (6.4.1.6, 28.2.6). Many national and international legal institutions and instruments need to be updated to face climate related challenges and decision implementation *(medium confidence)* (Verschuuren, 2013).

2.3. Methods, Tools, and Processes for Climate-Related Decisions

This section deals with methods, tools and processes that deal with uncertainties (2.3.1), describe scenarios (2.3.2), cover trade-offs and multi-metric valuation (2.3.3) and learning review and reframing (2.3.4).

2.3.1. Treatment of Uncertainties

Most advice on uncertainty, including the latest guidance from the IPCC (Mastrandrea et al., 2010; 1.1.2.2), deals with uncertainty in scientific findings and to a lesser extent confidence. While this is important, uncertainty can invade all aspects of decision making, especially in complex situations. Whether embodied in formal analyses or in the training and habits of decision makers, applied management is often needed because unaided human reasoning can produce mismatches between actions and goals (Kahneman, 2011). A useful high-level distinction is between ontological uncertainty – what we know – and epistemological uncertainty – how different areas of knowledge and ‘knowing’ combine in decision making (van Asselt and Rotmans, 2002; Walker et al., 2003). Two other areas of relevance are ambiguity (Brugnach et al., 2008) and contestedness (Klinke and Renn, 2002; Dewulf et al., 2005), commonly encountered in wicked problems/systemic risks (Renn and Klinke, 2004; Renn et al., 2011).

Much of this uncertainty can be managed through framing and decision-processes. For example, a predict-then-act framing is different to an assess-risk-of-policy framing (IPCC SREX 6.3.1 and Fig 6.2; Lempert et al., 2004). In the former, also known as ‘top-down’; model or impacts-first; science-first; or standard approach, climate or impact uncertainty is described independently of other parts of the decision problem. For instance, probabilistic climate projections (see Chapter 21, Fig. 21-4 or IPCC WG1 Chapters 11 and 12; Murphy et al., 2009) are generated for wide application, thus are not tied to any specific choice. This follows the cause and effect model described in Section 2.1. The basic structure of IPCC Assessment Reports 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 (Jones and Preston, 2011).

In contrast, the ‘assess-risk-of-policy’ framing (Lempert et al., 2004; UNDP, 2005; Carter et al., 2007; Dessai and Hulme, 2007) starts with the decision-making context. This framing is also known as ‘context-first’ (Ranger et al., 2010), ‘decision scaling’ (Brown et al., 2011), ‘bottom-up’; vulnerability, tipping point (Kwadijk et al., 2010), critical threshold (Jones, 2001), or policy-first approaches (IPCC SREX 6.3.1). In engaging with decision-makers, the ‘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. This can be very effective, but often needs to be individually customized for each decision context (Lempert and Kalra, 2011; Lempert, 2012) requiring collaboration between researchers and users (see Box 2-1). A ‘predict-then-act’ framing is appropriate when uncertainties are shallow, but when uncertainties are deep, an ‘assess-risk-of-policy’ framing is more suitable (Dessai et al., 2009).

The largest focus on uncertainty in CIAV has been on estimating climate impacts such as streamflow or agricultural yield changes and their consequent risks. Since AR4, the treatment of these uncertainties has advanced considerably. For example, multiple models of crop responses to climate change have been compared to estimate intermodel uncertainty (Asseng et al., 2013). Although many impact studies still characterise uncertainty by using a few climate scenarios, there is a growing literature that uses many climate realisations and also assesses uncertainty in the impact model itself (Wilby and Harris, 2006; New et al., 2007). Some studies propagate uncertainties to evaluate adaptation options locally (Dessai and Hulme, 2007) by assessing the robustness of a water company’s plan to climate change uncertainties or regionally (Lobell et al., 2008) by identifying which regions are most in need of adaptation to food security under a changing climate. Alternatively, the critical threshold approach, where the likelihood of a given criterion can be assessed as a function of climate change, is much less sensitive to input uncertainties than assessments estimating the ‘most likely’ outcome (Jones, 2010). This is one of the mainstays of robustness assessment discussed in Section 2.3.3.

2.3.2. Scenarios

A scenario is a story or image that describes a potential future, developed to inform decision making under uncertainty (1.1.3). A scenario is not a prediction of what the future will be but rather a description of how the future might unfold (Jäger et al., 2008). Scenario use in the CIAV research area has expanded significantly beyond climate into broader socio-economic areas as it has become more mainstream *(high confidence)* (1.1.3, 2.4.2.1). 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 an assessment process or can 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., 2007; Parson, 2008).

Scenarios also contribute to learning and discussion, facilitate knowledge exchange and can be expressed using a range of media. Local scale visualization of impacts and adaptation measures, depicted on realistic landscapes, is an emerging technology that is being tested to support dialogue on adaptation planning at the local scale (Schroth et al., 2011; Sheppard, 2012). Although visual representations of scenario-based impact assessments may be available for a location, scenario-based adaptation assessments are usually not. Artistic depictions of potential adaptation measures and outcomes are being negotiated and assessed with local stakeholders in communities within Metro Vancouver, Canada (Shaw et al., 2009; Burch et al., 2010; Sheppard et al., 2011).

Climate, socio-economic or other types of scenarios are widely used to assess the impacts of climate change. Fewer studies report on the use of scenarios as participatory tools to enable decision-making on adaptation (e.g., Harrison et al., 2013). However, the scenario literature emphasises the importance of process over product. The new generation of climate and socio-economic scenarios being developed from the representative concentration pathways (RCP; 1.1.3.1) and Shared Socioeconomic Pathways (SSP; 1.1.3.2), which are storylines corresponding to the new RCPs (Moss et al., 2010; Kriegler et al., 2012) have yet to be applied within CIAV studies in any substantive way (Ebi et al., 2013; van Ruijven et al., 2013).

By separating risks into simple and systemic or wicked-problem risks, scenario needs for decision-making can be better identified *(medium confidence)*. For simple risks, if probabilities cannot be easily calculated then scenarios can be used to explore the problem, test for acceptable or unacceptable levels of risk and illustrate alternative solutions for evaluation and testing. Wicked problems will need to be thoroughly scoped to select the most suitable decision-making process, with scenarios playing an important role. They may require separate applications of problem (exploratory or descriptive) and solution-based (normative or positive) scenarios or the development of reflexive scenarios, the latter being updated with new knowledge over time that may re-examine values and goals (van Notten, 2006; Wilkinson and Eidinow, 2008; Jones, 2012); these categories can also be structured as top-down, bottom-up and interactive (Berkhout et al., 2013). Even if conditional probabilities can be used to illustrate climate futures, scenarios are needed to explore the solutions space involving strategic actions, options planning and governance using both process and goal-oriented methods *(high confidence)*.

2.3.3. Evaluating Trade-Offs and Multi-Metric Valuation

Decision makers bring diverse aims, interests, knowledge and values to CIAV decision-making. With effective decision support, parties to a decision can manage competing views by more clearly articulating their goals, understanding how various options affect trade-offs between goals, and making informed choices that participants regard as legitimate, salient, and credible *(high confidence)* (Cash et al., 2003). The decision theory, risk governance, and ethical reasoning literatures use two broad sets of criteria for decision making: outcome-based criteria focus on whether a decision is likely to meet specified goals; process-based criteria compare alternative actions according to the process by which a decision is arrived. In particular, decision process aims to help stakeholders choose between the risks, costs, and obligations being proposed (Morgan et al., 1990), including specified levels of risk tolerance. Such choices around risk tolerance, including acceptable levels of risk, are ethical choices (DesJardins, 2012; Nanda, 2012). Selection strategies informing context and process are described in

Section 14.3.5. Decision criteria inform the discussions of adaptation options, planning, and economics in Chapters 14–17 and WG III Chapter 2.

Multi-attribute decision theory (Keeney and Raiffa, 1993), or multi-criteria decision analysis (MCDA), provides the most general framework for assessing outcomes-based criteria. MCDA concepts and tools organize and display the implications of alternative decisions on differing objectives (e.g., cost and environmental quality), order and test preferences among trade-offs between potentially incommensurate objectives, and show how alternative processes for choosing options can lead to different decisions. Cost-benefit analysis under uncertainty, one key tool for evaluating trade-offs, is described in Chapter 17.3.2.1. Simple MCDA tools include scorecards that graphically display how alternative policy choices affect different goals. For example the 'burning embers' diagram displays how risks to various attributes (e.g., health of unique systems, extreme weather events) depend on targets for a given global mean temperature increase (Figure 19-5). More sophisticated MCDA tools can optimise a portfolio of choices in a variety of ways; for example, one recent method applies scenarios representing significant uncertainty to optimise between four or more choices in order to identify robust combinations and system vulnerabilities (e.g., Kasprzyk et al., 2013). Successfully use of MCDA in CIAV decisions, include the U.S. Bureau of Reclamation helping stakeholders with diverse interests and values to consider 26 alternative performance measures for the Colorado River system, agree on potential climate-related risks and consider options for reducing those risks. Trade-offs also occur where adaptation measures produce negative impacts in other areas of value; e.g., where adaptation in agricultural and urban areas negatively affect ecosystems (4.3.3.3). Korteling et al. (2013) assess the robustness of adaptation options for six criteria including risk of water shortage, environmental impact, local self-sufficiency, cost, carbon footprint and social acceptability. Chapter 17 describes many criteria commonly used in MCDA analyses.

Robustness is often nominated as the most appropriate criterion for managing large decision uncertainty. It is a satisficing (sufficient rather than optimal) criteria (Rosenhead, 1989) that seeks decisions likely to perform well over a wide range of plausible climate futures, socio-economic trends, and other factors (Dessai and Hulme, 2007; Groves et al., 2008; Wilby and Dessai, 2010; WUCA, 2010; Brown et al., 2011; Lempert and Kalra, 2011). Robust decisions often perform better than other methods if the future turns out differently than expected. Testing for robustness can often illuminate trade-offs that help decision makers achieve consensus even when they have different future expectations. Robust choices often trade some optimality for being able to manage unanticipated outcomes. Many forms of the precautionary principle are consistent with robustness criteria (Lempert and Collins, 2007). Flexible and reversible options are often needed to manage situations with significant potential for unanticipated outcomes and differences in values and interests among decision makers (Gallopín, 2006; Hallegatte, 2009; 2.3.4, 5.5.3.1). Flexibility is signalled by reaching of specific management thresholds, critical control points or design states (Box 5-1). The literature disagrees on the relationship between robustness and resilience (Folke, 2006). Chapter 20 describes resilience as a property of systems that might be affected by decision makers' choices, while robustness is a property of the choices made by those decision makers (SREX, Chapter 1).

Process-based criteria focus on the credibility and legitimacy of a decision process. Institutional (2.2.2) and cultural and ethical (2.2.1) contexts will strongly influence the appropriateness and importance of such criteria in a given situation *(high confidence)*. Process criteria provide institutional rules, and governance for decision-making in a wide range of circumstances (Dietz and Stern, 2008; Sen, 2009). For instance, many environmental laws require advanced notice and periods of public comment before any regulations are issued. Water rights can be made tradable, giving users extra flexibility during times of water shortage or oversupply. Participants may regard any decision that fails to respect such rights as illegitimate. In complex situations of a collaborative nature, both outcome and process-related criteria will be needed in a decision-making process *(high confidence)*.

Stakeholder involvement is a central process for climate-related decision making and since the AR4 has grown in importance, particularly for adaptation decision-making (e.g., Lebel et al., 2010), covering methods (Debels et al., 2009; Gardner et al., 2009; Salter et al., 2010; André et al., 2012) and reflecting concrete experiences with stakeholder involvement in CIAV assessments and adaptation processes (de la Vega-Leinert et al., 2008; Ebi and Semenza, 2008; Posthumus et al., 2008; Raadgever et al., 2008; Tompkins et al., 2008a; Tompkins et al., 2008b; Preston et al., 2009). Lebel et al. (2010) differentiate six advantages of social learning and stakeholder involvement for adaptation to climate change: i) reducing informational uncertainty; ii) reducing normative uncertainty; iii) helps to build consensus on criteria for monitoring and evaluation; iv) can empower stakeholders to influence adaptation and take appropriate actions themselves by sharing knowledge and responsibility in participatory processes; v) can reduce conflicts and identify synergies between adaptation activities of various stakeholders, thus improving overall chances of success; and vi) can improve the likely fairness, social justice and legitimacy of adaptation decisions and actions by addressing the concerns of all relevant stakeholders. Complex settings will require a detailed mapping of stakeholder roles and responsibilities (André et al., 2012).

2.3.4. Learning, Review, and Reframing

Effective decision support processes generally includes learning (Figure 2-1), where learning and review become important to track decision progress (National Research Council, 2009; see Box 2-1). This can be achieved by developing an ongoing monitoring and review process during the scoping stage of a project or program. If circumstances change so much that desired outcomes may not be achieved, then reframing of the decision criteria, process and goals may be required. This iterative approach 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 (Figure 2-1). Again, process is important. Pelling et al. (2008) found that accounting for different personal values in both an official and informal capacity could enhance social learning and therefore adaptive capacity. Measuring progress on adaptation and adaptive capacity, though tracking impacts, vulnerability and related adaptation metrics, and process indicators is discussed in Chapter 14.6. Such metrics are needed to transfer wider learning on adaptation to new situations.

Learning and review can range from periodic reporting through to adaptive management. Adaptive management refers to a choice of policy required to generate reliable new information (Holling, 1978, 1996) and involves a process of adjusting approaches in response to observations of their effect and changes in the system brought on by resulting feedback effects and other variables (Glossary). Adaptive strategies are designed to be robust over a wide range of futures by evolving over time in response to new information (Rosenhead, 1989; Walker et al., 2001; Lempert and Schlesinger, 2002; Swanson et al., 2006). Necessary components include: separating immediate actions from those that can be deferred (and that may require additional information); an explicit process to generate new information; institutional mechanisms for incorporating and acting on new information; and some understanding of the policy limits that, if exceeded, should lead to its re-evaluation (Swanson et al., 2012; Box 5-1). As indicated by Fig 2-1, effective decision making not only requires flows of appropriate information but people willing and able to act on it. While most policies change over time, very few follow the steps of an intentional adaptive strategy *(high confidence)*. For instance, McCray et al. (2010) survey 32 examples of U.S. environmental, health, and safety regulations – all legally required to be adaptive – and find only five instances where any policy change occurred as intended.

Reframing of an action can occur when an existing set of decisions and actions are failing to adequately manage risks (See Box 2-1).

_____ START BOX 2-1 HERE _____

Box 2-1. Managing Wicked Problems with Decision Support

A well-designed decision support process, combined with favourable political conditions, can effectively address ‘wicked’ (Section 2.1) decision challenges. The State of Louisiana faces a serious problem of coastal land loss, exposing the region’s fisheries and heightening the risk of storm surge damage to the City of New Orleans, one of the United States’ largest ports with facilities that account for about 20% of U.S. oil and gas production (Coastal Protection and Restoration Authority, 2007). Previous efforts at comprehensive coastal protection had been stymied by, among other factors, numerous competing jurisdictions and stakeholders with a wide range of conflicting interests.

In the aftermath of Hurricane Katrina, the state embarked on a new coastal planning effort, this time with extensive decision support. The Louisiana state Coastal Protection and Restoration Authority organized an extension decision support effort with a network of about a dozen research institutions interacting with a 33-member stakeholder group consisting of representatives from business and industry, federal, state, and local governments, nongovernmental organizations and coastal institutions. In dozens of workshops over the course of two years, these stakeholders influenced the development of and interacted with a decision support system consisting of two parts: 1) a regional model that integrated numerous strands of scientific data into projections of future flood risk (Fischbach et al., 2012) and 2) a multi-attribute planning tool that allowed stakeholders to explore the implications of alternative portfolios of hundreds of proposed risk reduction projects over alternative sea level rise scenarios (Groves et al., 2012). This decision support system allowed decision makers and stakeholders to first formulate alternative risk reduction plans and then to visualize outcomes and trade-offs up to fifty years into the future.

The resulting Master Plan for a Sustainable Coast passed the state legislature on a unanimous vote in May 2012. Deviating strongly from past practice, the plan allocates far more resources to restoring natural barriers than to structural measures such as levees. The plan balances between the interests of multiple stakeholders and contains some projects that offer near-term benefits and some whose benefits will be largely felt decades from now. Many participants and observers of this process credited the extensive analytic decision support for significant contributions to this plan.

_____ END BOX 2-1 HERE _____

Based on experience to date, there now exists a sufficiently rich set of available methods, tools, and processes to support effective CCIAV decisions in a wide range of contexts *(medium confidence)*, although they may not be combined appropriately, accessible or readily used by decision makers (Webb and Beh, 2013). Tools for decision-making, planning and development, transfer and diffusion are discussed in Chapter 15.4.

2.4. Support for Climate-Related Decisions

Growing understanding of the aspects of decision-making (2.2) and methods and tools (2.3) have led to improved support for CIAV decisions as shown by the provision of climate information and services (2.4.1), methods for impacts and vulnerability assessments (2.4.2) action, and decision support in practice (2.4.3). Figure 2-3 divides the decision-making process into four stages: scoping, analysis, implementation and review, outlining institutional, leadership, knowledge and information characteristics for each stage. Most effort in CIAV 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 are significant undertakings in any decision process, but that is where most current climate change assessments stop. Note that each of these stages can be divided into other quite distinct process elements.

[INSERT FIGURE 2-3 HERE
Figure 2-3. Four-stage process of decision making. Note that while adaptive management is located in the decision review quadrant here, when applied it will influence the entire process.]

2.4.1. Climate Information and Services

Climate Services are institutions that bridge the generation and application of climate knowledge. Their history and concepts are described in 2.4.1.1; how they apply decision support in 2.4.1.2, and the policy implications of climate services as a global practice in 2.4.1.3. They supply climate information on local, regional, national and global scales for the monitoring of risks, mitigation and adaptation planning “as an important component of sustainable development” (Sivakumar et al., 2011). The Global Framework for Climate Services (Hewitt et al., 2012) aims to “enable better management of the risks of climate variability and change and adaptation to climate change, through the development and incorporation of science-based climate information and prediction into planning, policy and practice on the global, regional and national scale” (http://www.wmo.int/pages/gfcs/index_en.php). Climate services focus on the connection between climate science and the public demand for information, however their development and deployment needs support from many other disciplines (Miles et al., 2006). This extended reach requires measures such as case-specific communication, engagement and knowledge exchange skills *(high confidence)*.

While many countries have already established national and regional climate services or are on the way to doing so, they show significant differences. The development of Regional Climate Services in the US and parts of Europe, with their increasing focus on communication and decision support, is well documented (DeGaetano et al., 2010; von Storch et al., 2011). Developing countries are becoming increasingly aware of the need for climate services (Semazzi, 2011), which is in part reflected in the migration of regional climate models into those countries. In 2001 only around 21 (mostly OECD) countries were running regional climate models (RCMs), but today over 100 countries are trained in using the PRECIS RCM (Jones et al., 2004; Edwards, 2010). Regional Climate Services are expanding geographically, shifting from simple understandings of climate cause and effect to ever more complex and wicked problem situations and are becoming more interdisciplinary.

2.4.1.1. Climate Services: History and Concepts

Early climate services in North America were seen as an expansion of weather services, mainly dealing with forecasts, seasonal outlooks, risk assessment in a mostly stationary but variable climate (Changnon et al., 1990; Miles et al., 2006; DeGaetano et al., 2010). This mainly technical outlook had limited effectiveness; for example, decision makers had difficulties understanding and using climate data for planning purposes (Changnon et al., 1990; Miles et al., 2006; Visbeck, 2008) and the data were slow to access and of poor quality (Changnon et al., 1990). As these services developed, formal definitions of their mission and scope shifted to being user-centric, focusing on active research, data stewardship and effective partnership (National Research Council, 2001). Climate services were understood as a clearinghouse and technical access point to stakeholders, providing education and user access to experts; the latter informing the climate forecast community of information needs, largely to inform adaptation (Miles et al., 2006).

Downscaling is a key product demanded by users for decision making (21.3.3.2). For example, in Africa, regional climate models play an increasing role in Regional Climate Outlook Forums arranged by WMO. The Global Framework for Climate Services was created in order to coordinate and strengthen activities and develop new infrastructure where needed, focusing on developing countries (World Meteorological Organization, 2011; Hewitt et al., 2012). From initially being supply-focused and static, public climate services increasingly need communication skills, engagement and knowledge exchange in a highly challenging environment of technical and institutional networks, monitoring systems, and collaborations with other institutions, stakeholders and decision-makers (DeGaetano et al., 2010).

2.4.1.2. Climate Services: Practices and Decision Support

Decision support is generally acknowledged as an integral part of climate services *(high confidence)* (Miles et al., 2006; DeGaetano et al., 2010). Depending on the stage and context in question (see 2.1.3.), ‘best’ data as framed by experts should be reconciled with user needs in order to produce scientific information that is relevant and suitable for decision making. Social and cultural determinants have to be taken into account (see 2.2.) and require the communication of scientific data to be context specific. Decision support for climate services consists of “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” (Moser, 2009). The climate service is a “process of two-way communication” and “involves providing context that turns data into information” (Shafer, 2004). Capacity building is required on all sides of the communication process. For Regional Climate Services, a successful learning process, engages both users and providers of knowledge in knowledge exchange. For example, the uptake and utility of climate forecasts in rural Africa is described in Box 9-4.

As knowledge brokers, climate services have to establish an effective dialogue between science and the public (von Storch et al., 2011). This dialogue undertakes two main tasks: One is to understand 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 to the public, media and stakeholders.

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This includes communicating the limitations of such knowledge, the known uncertainties and the unknowable, as well as the appropriate role of science in complex decision processes (von Storch et al., 2011).

2.4.1.3. The Geo-Political Dimension of Climate Services

Climate knowledge is continually being documented and assessed by the social sciences within a policy-relevant context (Yearley, 2009; Grundmann and Stehr, 2010). One focus is on the spread of climate knowledge into developing countries. Climate models distributed to users with no in-house capacity for model development build capacity in regional climate science, producing high resolution data for local decision-making. This mobility of knowledge has far-reaching implications for how climate knowledge is produced; strengthening the influence of epistemic communities such as the IPCC and other global governance mechanisms (Mahony and Hulme, 2012). Thus, while regional climate models play an increasingly important role in decision making processes, critics argue that climate monopolises planning and development strategies, rendering other forms of knowledge subordinate to this ‘climate reductionism’ (Dessai et al., 2009; Hulme, 2011).

Indigenous forms of knowledge – including the specialized knowledge of any stakeholder – are becoming increasingly relevant for climate services *(high confidence)* (Strauss and Orlove, 2003; Crate and Nuttal, 2009; Crate, 2011; Ulloa, 2011; Krauss and von Storch, 2012). Local forms of knowledge and scientific climate models are not necessarily mutually exclusive; individual case studies show how both forms of knowledge contribute jointly to place-based adaptation (Strauss and Orlove, 2003; Orlove and Kabugo, 2005; Orlove, 2009; Strauss, 2009; Orlove et al., 2010). Indigenous knowledge in the form of oral histories and other traditional knowledge are being compared or combined with remote sensing technologies and model-based scenarios to co-produce new knowledge, and to create a new discourse on adaptation planning (Nakashima et al., 2012; Table 15.1). The challenge will be to collaborate in a way that enables their integration into a shared narrative on future adaptation choices.

These examples show that adaptation needs both to be implemented locally and to be informed by larger scale (inter-) national policies and directions. One strategy will not suit every location. Endfield (2011) argues for a ‘reculturing and particularizing of climate discourses’ in order to successfully localize global and scientific meta-narratives. Climate service development combines very different types of knowledge and the social, cultural and communication sciences play a decisive role in this process (Pidgeon and Fischhoff, 2011; von Storch et al., 2011). To position itself and to react according to the diverse demands, science-based climate services have to become “rooted in society” (Krauss, 2011). The climate science community does not necessarily take the lead, but becomes part of an inter- and trans-disciplinary process, where politics, culture, religion, values and so forth become part of climate communication *(medium confidence)*.

2.4.2. Assessing IAV on a Range of Scales

CIAV assessments address the ‘adapt to what’ question, which can enable a dialogue among practitioners, stakeholders, and the public on planning and implementation of adaptation measures within prevailing mechanisms for governance. To date, however, assessments have focused more on I than A (see Chapter 1, Figure 1-1d). A number of global initiatives are taking place to enable knowledge generation, transfer and use, including the Programme of Research on Climate Change Vulnerability, Impacts and Adaptation – PROVIA (http://www.provia-climatechange.org/), the Nairobi Work Programme on impacts, vulnerability and adaptation to climate change (http://unfccc.int/adaptation/nairobi_work_programme/items/3633.php), and work by the World Bank and regional development banks (http://climatechange.worldbank.org/).

2.4.2.1. Assessing Impacts

For scenario-based impact assessments to contribute to vulnerability and risk assessment, a series of translations need to be performed. Scenarios of projected greenhouse gas concentrations are converted to changes in climate, impacts are assessed, perhaps with autonomous adaptation, leading to the evaluation of various adaptation options.

This series of translations requires the transformation of data across various scales of time and space, between natural and social sciences, utilizing a wide variety of analytical tools representing areas such as agriculture, forestry, water, economics, sociology, and social-ecological systems. Climate scenarios are translated into scenarios or projections for biophysical and socio-economic impact variables such as river flow, food supply, coastal erosion, health outcomes and species distribution (e.g., European Climate Adaptation Platform, http://climate-adapt.eea.europa.eu). Climate services help establish and support the translation process (Section 2.4.1).

The resulting climate impacts and risks are then subject to decision making on risk management and governance. Assessments of observed events combine biophysical and socioeconomic assessments of the past and present (Table 2-1, top row). Most scenario-based assessments superimpose biophysical ‘futures’ onto present-day socio-economic conditions (Table 2-1, middle row). This is useful for assessing the how current socio-economic conditions may need to change in response to biophysical impacts but raises inconsistencies when future socio-economic states are out of step with biophysical states. This will hamper assessments of future adaptation responses in coupled social-ecological systems (see Chapter 16). An important challenge, therefore, is to construct impact assessments in which biophysical futures are coupled with socioeconomic futures (Table 2-1, bottom row). A new set of socioeconomic futures, known as Shared Socioeconomic Pathways (SSP), which are storylines corresponding to the new RCPs (Moss et al., 2010; Kriegler et al., 2012) are being developed to assist this process (1.1.3.2).

[INSERT TABLE 2-1 HERE
Table 2-1: Nature of published IAV assessments.]

A new generation of assessments links biophysical, economic and social analysis tools in order to describe the interactions between projected biophysical changes and managed systems. For example, Ciscar et al. (2011) estimated the costs of potential climate change impacts, without public adaptation policies, in four European market sectors (agriculture, river floods, coastal areas, and tourism) and one nonmarket sector (human health). A similar study in the UK was conducted for tourism, health and transportation maintenance, buildings and transportation infrastructure, and residential water supplies (Hunt, 2008). In the US, Backus et al. (2013) assessed national and state level GDP and employment impacts, incorporating direct impacts on water resources, secondary impacts on agriculture and other water interests, and indirect impacts through interstate migration of affected populations. Decision support tools are being integrated into scenario-based impact and adaptation assessments. For example, the Water Evaluation and Planning System model has been used to assess a community water system in British Columbia, Canada (Harma et al., 2012). Incorporation of stakeholder dialogue processes within scenario construction (Parson, 2008), and Participatory Integrated Assessment (Salter et al., 2010), enables inclusion of local knowledge as part of scenario-based assessments.

2.4.2.2. Assessing Vulnerability, Risk, and Adaptive Capacity

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; Füssel, 2007), or, the propensity or predisposition to be adversely affected (glossary). Within IPCC AR4, Schneider et al. (2007) identified vulnerabilities that might be considered ‘key’, and therefore potentially ‘dangerous’ (see glossary). Criteria denoting a key vulnerability include its magnitude and timing, persistence and reversibility, and the likelihood and confidence that the contributing event(s) would occur (Sections 19.2.5, 19.6). Other criteria include the importance of a location or activity to society, society’s exposure to potential loss 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 (Adger et al., 2007; glossary). However, adaptive capacity is context specific, related to both availability of resources, capacity to learn, and governance measures (Gupta et al., 2010; 14.5); Section 14.5). Actions that illustrate how adaptive capacity and climate resilience can be mutually reinforcing include disaster risk management (2.5.2, 15.3.2, 16.7.2) and ‘triple-win’ interventions where adaptation, mitigation, and sustainable development goals are integrated so as to find climate-resilient pathways (20.3.3, 20.4.2).

The concept of an ‘adaptation deficit’ (Burton and May, 2004) is applicable to cases such as Hurricane Katrina (Committee on New Orleans Regional Hurricane Protection Projects, 2009; Freudenberg et al., 2009; Box 2-1) or the 2003 European heat wave (Haines et al., 2006) where substantial vulnerability follows a climate event. An adaptation deficit represents a gap between an existing state of adaptation and an idealized state of adaptation where adverse impacts are avoided (Chapter 17, Glossary). The adaptation deficit has also been related to 'residual impacts', which occur due to insufficient adaptation to current or future climate (IPCC, 2007b). Within developing countries, Narain et al. (2011) consider the adaptation deficit as being part of a larger 'development deficit'. Cardona et al. (2012) cite other 'deficit' indicators, including a Disaster Deficit Index (extreme event impact combined with financial ability to cope), structural deficit (low income, high inequality, lack of access to resources, etc.), and a risk communication deficit. Maladaptation occurs where a short-term response inadvertently leads to an increase in future vulnerability (Glantz, 1988; Barnett and O'Neill, 2010; McEvoy and Wilder, 2012). Barriers unrelated to scientific knowledge can hamper effective decision making (Adger and Barnett, 2009; Berrang Ford et al., 2011). This may help to explain why some extreme events create surprising levels of damage within developed countries. The adaptation deficit has also been related to 'residual impacts', which occur due to insufficient adaptation to current or future climate (IPCC, 2007b).

The assessment of potential future damages and loss requires approaches that link bio-physical and socio-economic futures. An example is the assessment of climate change effects on human health, including research-to-decision pathways, monitoring of social vulnerability indicators and health outcomes (English et al., 2009; Portier et al., 2010), and tools for enabling adaptive management (Hess et al., 2012). Examples of regional scale scenario-based vulnerability assessments are case studies for North Rhine-Westphalia in Germany (Holsten and Kropp, 2012) and agriculture in Mexico (Monterroso et al., 2012). An example of a larger scale study is a vulnerability assessment of ecosystem services for Europe, in which future adaptive capacity was based on indicators from the SRES storylines (Metzger and Schröter, 2006). Difficulty in separating the relative influences of changing climate and development patterns hampers assessments of observed trends in property damage caused by atmospheric extreme events. Recent increases in economic losses may be due 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 combination of both (Pielke, 1998; Mills, 2005; Munich Re Group, 2011). IPCC (2012) concluded that increasing exposure has been the major cause, but a role for climate change has not been excluded.

Development choices taken in the current or near term can potentially influence future vulnerability to projected climate change, hence the interest in the study of emergent risks (Sections 19.3, 19.4). Interactions between development pathways, and climate change impacts and responses, could create situations with little or no precedent. Assessments based on gradual shifts in mean conditions could underestimate future risk and consequent damage, suggesting the need for process-based methodologies that focus on enhancing resilience (Jones et al., 2013; Sections 2.5.2, 20.2.3). An example of assessing this type of risk, and the costs and benefits of potential adaptation responses, is a resilience assessment framework for infrastructure networks (Vugrin et al., 2011; Turnquist and Vugrin, 2013).

2.4.3. Climate-Related Decisions in Practice

Implementation of adaptation actions, resilience strategies and capacity building can take place as stand-alone actions or be integrated into other management plans and strategies. Recent literature on potential climate change effects on natural resources, public health and community planning and management is reviewed in Chapters 3–12. As the complexity of management challenges increases due to climate change, development and other pressures, a range of reflexive decision-making processes are emerging under the general topics of adaptive management, iterative risk management and community-based adaptation (e.g., 5.5.4.1). However, there are few assessments of adaptation delivery and effectiveness (15.6). Cross-sectoral integrated approaches such as Integrated Water Resources Management (IWRM), sustainable forestry management (SFM) and Integrated Coastal Zone Management (ICZM) are viewed as being more effective than stand-alone efforts (16.5.1).

Adaptive approaches to water management can potentially address uncertainty due to climate change (3.6.1) but there is a limited number of examples in practice (3.6.4). Examples of recent strategies include an IWRM roadmap prepared for the state of Orissa, India (Jønch-Clausen, 2010) and seven cases in the US (Bateman and Rancier, 2012) some of which are applying adaptive water management using a scenario-based experimental approach intending to align with IWRM and promote resilience. Adaptations in urban systems following integrated urban water management principles are becoming widespread (8.3.3.4) and in rural systems are more advanced in developed countries and less so in developing countries, especially those within transboundary basins (9.4.3.2, 24.4.1.5, 24.4.2.5, 25.5.3, 26.3.3, 27.3.1.2, 27.3.2.2).

Adaptation in agriculture ranges from small adjustments made to current activities through to transformative adaptations across whole systems. (7.5.1, 9.4.3.1, 22.4.5.7, 23.4.1, 24.4.4.5, 25.7.2, 26.5.4, 27.3.4.2). Diversified systems are more resilient with some diversification coming from off farm sources (9.4.3.1). There are few unequivocal adaptations to climate, but the development of adaptive capacity is more widespread (7.5.1.2). Adaptation in forestry has expanded since the AR4 (9.4.3.3) and is aiming to develop towards SFM by focusing on biological diversity, productive and protective functions of forests, maintenance of their social and economic benefits, and governance (McDonald and Lane, 2004; Wijewardana, 2008; Montréal Process, 2009). Although SFM is still largely an abstract concept (Seppälä et al., 2009), managing climate change risks is seen as necessary for achieving its objectives (Montréal Process, 2009). Governments and companies are also considering assisted migration of forest species as an adaptation strategy (Pedlar et al., 2012) and payment for ecosystem services is becoming more common (9.4.3.3). Sustainable Fisheries Management has long-term ecological and productivity goals (FAO, 2013) but climate change has generally not been included in strategic guidance for fisheries management (Brander, 2010). Ecosystem-based approaches to management e.g., (Zhou et al., 2010) and transformative approaches will be required (7.5.1.1.2, 9.4.3.4). Sustainable livelihoods approaches are also being applied for populations dependent on marine resources (9.4.3.4, 30.6.2.1, Table 30-2).

National Adaptation Programmes of Action (NAPA) for least developed countries (LDCs) are designed to be flexible, action-oriented and country-driven (UNFCCC, 2009). Key preparatory steps include the synthesis of available information on vulnerability and impacts via extensive public participation (see Chapter 14). The NAPA process has assisted least-developed countries to assess climate sensitive sectors and prioritize projects to address the most urgent adaptation issues (Lal et al., 2012; UNFCCC, 2012). Integrating NAPAs with other socio-economic programs can help develop resilience. However, although many countries have linked their NAPAs with development programs, Hardee and Mutunga (2010) argue that they have had limited success in aligning the NAPA priorities with existing national priorities such as population growth. To this end, scaling up and institutionalization of the NAPA process has commenced. Under the Cancun Adaptation Framework, a process was established that enables LDCs to formulate and implement National Adaptation Plans (NAPs) building upon the NAPA experience (UNFCCC, 2013). The NAP’s main objectives are to identify vulnerabilities, medium- and long-term adaptation needs and to develop and implement strategies and programmes to address those needs and also to mainstream climate change risks. The NAPs are also an opportunity to align with other global initiatives such as the Millennium Development Goals and Hyogo Framework for Action.

Many developed countries are developing adaptation strategy documents at different scales of governance (European Environmental Agency, 2013). Biesbroek et al. (2010) analysed National Adaptation Strategies (NAS) of nine European nations, examining their decision making aspects and finding both ‘top-down’ and ‘bottom-up’ (delegation of authorities to local governments) approaches. Dissemination of information on weather, climate, impacts, vulnerability and scenarios was found to be a critical element for adaptation decision making.

Climate risk is being increasingly factored into existing decision-making processes (15.2.1). For example, learning from the 2003 heat waves that killed some 35,000 people across Europe, many European countries have implemented health-watch warning systems (Alcamo et al., 2007; WHO, 2008). Vietnam has initiated large-scale mangrove restoration and rehabilitation programs with the support of international institutions to protect coastal settlements and aquaculture industry (World Resources Institute et al., 2011). The Tsho Rolpa glacier lake in Nepal was at the risk of outburst due to glacial melt (Adger et al., 2007) so the Government of Nepal introduced both short- and long-term measures to prevent the outburst flood event (World Resources Institute et al., 2011). In many ways, local government is at the coal face of adaptation decision making (Pelling et al., 2008; Measham et al., 2011; Roberts et al., 2012). Municipal governments are incorporating climate change adaptation planning within municipal planning instruments, including energy and water system design, disaster risk reduction and sustainability plans (Ford and Berrang-Ford, 2011; Rosenzweig et al., 2011). In human health, two main areas of benefit are occurring through improvements in current health patterns being exacerbated by changing climate and in reducing pollutants associated with co-pollutants of greenhouse gas emissions (11.7, 11.9). Climate is being increasingly recognised as a component of human conflict and insecurity, so is becoming a factor in governance arrangements affecting security and peace building programs (12.5).

Details of adaptation planning within urban and rural settlements are addressed in Chapters 8 and 9, respectively. In urban settlements, adaptations are occurring in areas of energy, water, transport, housing and green infrastructure (8.3.3) but opportunities for broader integration into planning and the urban economy are largely being missed (8.4). The overall status of adaptation implementation is assessed in Chapter 15. Although there is a rapidly growing list of adaptation plans being generated at multiple scales, an evaluation of adaptation plans from Australia, United Kingdom and the United States suggests they are under-developed (Berrang Ford et al., 2011). These plans reflect a preference for capacity building over the delivery of specific vulnerability-reduction measures, indicating that current adaptation planning is still informal and ad hoc (Preston et al., 2011; Bierbaum et al., 2013). Capacity barriers have hampered the transition from planning to implementation, so only a small number of jurisdictions have been successful at implementing adaptation measures (15.2). However, there has been growth in community-based adaptation initiatives (Baer and Risbey, 2009; Rudiak-Gould, 2011; 15.1, 15.2, 15.5, 15.6)

Various enabling factors for implementation have been identified in stakeholder engagement processes. Such factors include access to resources, sharing observations, language specific information and ICT tools (e.g., wireless sensor networks, geographic information systems and Web-based tools) that increase local awareness, allowing for good public understanding of stresses, risks and trade-offs (15.4.2). These factors allow new strategies to be explored, evaluated and implemented (Shepherd et al., 2006; Hewitt et al., 2013). Enabling factors also include customized impact and vulnerability assessments for communities of interest and local practitioners who would serve as champions for adaptation planning, and the existence of local social influences/networks and capacity that enable long term strategic planning and mainstreaming (Gardner et al., 2009; Cohen, 2010). These factors are further discussed in Chapters 15 and 16. Local government officials often lack training on climate change adaptation and require capacity to be built in a number of areas. To assist this process, guidebooks have been produced, framing the process of adaptation planning 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; CARE International in Vietnam, 2009; Ayers et al., 2012). Practitioner engagement in decision ‘games’ can offer another training resource (Black et al., 2012).

2.5. Linking Adaptation with Mitigation and Sustainable Development

2.5.1. Assessing Synergies and Trade-offs with Mitigation

Capacities to adapt to and mitigate climate change are broadly similar. Opportunities for synergies are particularly relevant for the agriculture, forestry, urban infrastructure, energy and water sectors (Chapters 3, 4, 7–10). The IPCC AR4 (Klein et al., 2007) concluded that a lack of information made it difficult to assess these synergies. Assessing the synergies and trade-offs that face both adaptation and mitigation is an important goal of the new IPCC scenario process (Kriegler et al., 2012; O'Neill et al., 2013). These synergies and trade-offs between adaptation and mitigation are illustrated in Figure 2-4. The negatives associated with ‘adaptive emissions’ or ‘new vulnerabilities’ arising from mitigation do not necessarily mean that such measures should not be contemplated, but they do need to be assessed within a larger portfolio of actions where losses and gains have been sufficiently well quantified (19.7). Limits of adaptation emphasise the different reach of adaptation and mitigation in managing climate risks (16.6, 19.7.5).

Mitigation can affect, for example, the water (3.7.2.1), terrestrial and freshwater ecosystems (4.4.4, 19.3.2.2), agriculture (19.3.2.2, 19.4.1) and livelihoods and poverty (13.3.1) sectors and will in turn be affected by the water sector (3.7.3.2), terrestrial ecosystems (4.3.3.1, 4.2.4.1). Adaptation actions for agriculture generally tend to reduce emissions (7.5.1.4). Potential losses of human security associated with climate policy are discussed in 12.5.2 and 19.4.2.2. Recent literature on potential interactions between mitigation and adaptation is reviewed in Sections 16.4.3, 19.7.1–5. Chapter 20 discusses the relationship between adaptation, mitigation, and sustainable development including sustainable risk management (20.3.3).

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[INSERT FIGURE 2-4 HERE
Figure 2-4: Examples of adaptation (A) – mitigation (M) trade-offs and synergies (adapted from Cohen and Waddell, 2009). The upper right quadrant (sustainable win-win) illustrates synergies in which actions enable the achievement of both adaptation and mitigation goals. The lower left quadrant (unsustainable) shows the opposite condition. The upper left (adaptive emissions) and lower right (new vulnerabilities) quadrants illustrate trade-offs that can result from actions within particular local-regional circumstances.]

2.5.2. Linkage with Sustainable Development – Resilience

The idea that climate change response and sustainable development should be integrated within a more holistic decision framework was assessed in IPCC AR4 (Robinson et al., 2006; Klein et al., 2007; Yohe et al., 2007). Practical aspects of this integration are being tested as decision makers endeavour to incorporate adaptation measures within official long-term development plans (15.3.3). A typical example is the engagement of researchers and practitioners (planners, engineers, water managers, etc.) in scenario-based exercises to build local capacity to plan for a wide range of climate outcomes (Bizikova et al., 2010). Development can yield adaptation co-benefits if climate change is factored into its design (17.2.7.2, 20.3, 20.4).

Resilience is the capacity to change in order to maintain the same identity (see Glossary) and can be assessed through participatory research (Tyler and Moench, 2012) or through system modelling. Chapter 20 examines climate-resilient pathways, which are development trajectories of combined mitigation and adaptation to realize the goal of sustainable development while meeting the goals of the UNFCCC (Box 20-1). An example of resilience assessment at the landscape scale is in the Arctic, where local sources of important productivity and biodiversity are being mapped and their future capacity in supporting larger ecoregions under climate change is being assessed (Christie and Sommerkorn, 2012). An industry example covers the resilience analysis of supply chains, specifically petrochemical supply chains exposed to a hurricane in south-eastern United States (Vugrin et al., 2011). For urban areas, Leichenko (2011) categorize four types of urban resilience studies: i) urban ecological resilience, ii) urban hazards and disaster risk reduction, iii) resilience of urban and regional economies, and iv) urban governance and institutions. Boyd et al. (2008) promote resilience as a way of guiding future urbanization that would be better ‘climatized’. The Asian Cities Climate Change Resilience Network is applying a resilience planning framework, with attention given to the role of agents and institutions (Tyler and Moench, 2012).

Adaptive capacity is seen as an important component of resilience on a range of scales (Sections 2.1.1, 2.2.3, 2.3.4, 2.4.2, 20.3). Local cases, such as King County (Seattle) USA, illustrate the importance of researcher–practitioner collaboration for knowledge exchange (Snover et al., 2007) and iterative and reflexive processes that enable local ownership, and adjustment to new information and evaluation of actions taken (Saavedra and Budd, 2009). However, in regions with high and chronic poverty, coupled with low awareness of global change drivers, adaptation as a process is not well understood and tools that enable anticipatory learning are lacking (Tschakert and Dietrich, 2010).

The normative concept of sustainable adaptation has been proposed to manage adaptation’s unintended consequences (Eriksen et al., 2011). It considers effects on social justice and environmental integrity, challenging current (unsustainable) development paths rather than seeking adjustments within them. This concept recognizes the role of multiple stressors in vulnerability, the importance of values in affecting adaptation outcomes (Section 2.2.1), and potential feedbacks between local and global processes. Little is known about the long-term effects of adaptation on livelihoods and poverty (13.3.2) although focussing on poverty alleviation as part of adaptation is thought to build capacity (13.4.1, 13.4.2).

The Hyogo Framework for Action on disaster risk reduction considers climate change as an underlying risk factor, and promotes the integration of risk reduction and climate change adaptation (UNISDR, 2007; 2011; 15.3.2). Social development is being integrated with disaster risk management in order to enhance adaptive capacity and address the structural causes of poverty, vulnerability and exposure.. In small island states, this integration is being enabled through focused institutional coordination, greater stakeholder engagement and promotion of community-based adaptation and resilience-building projects (UNISDR, 2012b). Similar initiatives are underway in urban areas (UNISDR, 2012a; 15.3.2, 15.3.3, 15.5 and Chapter 24, Box CC-TC).

Resilience is also being explored as an outcome of social contracts that underpin governance. O'Brien et al. (2009) use examples from Norway, New Zealand and Canada to illustrate how resilience thinking on climate does not easily fit into existing social contracts, and that new types of arrangements may better serve the goals of resilience and sustainable development within the context of climate change. Chapter 20 describes climate-resilient development pathways as being an explicit objective of long-term planning and decision making and considers the need for transformational adaptation aiming to achieve sustainable development (20.5).

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

Much of the existing adaptation literature examines gradual adjustment or accommodation to change. But a growing literature highlights the importance of transformative adaptation (14.3.5, 16.4.2), both in the context of a world where global temperature raise above 2°C (Kates et al., 2012; PIK, 2012) and in the context of climate resilient pathways that manage risk through combinations of adaptation and mitigation (20.5).

In concluding this chapter, we therefore reflect on some emerging, though still sparse literature that examines such transformational adaptation, how it differs from incremental adaptation (O'Brien, 2012; Park et al., 2012), and how it might occur in specific sectors and systems (Rickards and Howden, 2012). This early literature suggests that many themes raised in this chapter may prove important to transformational adaptation, including: iterative risk management with a broad view of risk, adaptive management, robustness and resilience and deliberation (McGray et al., 2007; Leary et al., 2008; Hallegatte, 2009; Tschakert and Dietrich, 2010; Hallegatte et al., 2011; Stafford Smith et al., 2011). For instance, Irvin and Stansbury (2004) identify situations where participatory processes may be most effective for bringing about positive social and environmental change. Recently, Park et al. (2012) have proposed the Adaptation Action Cycles concept as a means to delineate incremental and transformative adaptation and the role of learning in the decision-making process. Similarly to the learning process called 'triple-loop' that considers a situation, its drivers plus the underlying frames and values that provide the situation context (Argyris and Schön, 1978; Peschl, 2007; Hargrove, 2008), transformational adaptation may involve decision makers questioning deep underlying principles (Flood and Romm, 1996; Pelling et al., 2008) and seeking changes in institutions, such as legal and regulatory structures underlying environmental and natural resource management (Craig, 2010 ; Ruhl, 2010a), as well as in cultural values (O'Brien, 2012; O'Brien et al., 2013).

Frequently Asked Questions

FAQ 2-1: What constitutes a good (climate) decision? *[to be inserted after Section 2.1.1]*
No universal criterion exists for a good decision, including a good climate-related decision. Seemingly reasonable decisions can turn out badly, and seemingly unreasonable decisions can turn out well. However, findings from decision theory, risk governance, ethical reasoning and related fields offer general principles that can help improve the quality of decisions made.

Good decisions tend to emerge from processes in which people are explicit about their goals; consider a range of alternative options for pursuing their goals; use the best available science to understand the potential consequences of their actions; carefully consider the trade-offs; contemplate the decision from a wide range of views and vantages, including those who are not represented but may be affected; and follow agreed-upon rules and norms that enhance the legitimacy of the process for all those concerned. A good decision will be implementable within constraints such as current systems and processes, resources, knowledge and institutional frameworks. It will have a given lifetime over which it is expected to be effective, and a process to track its effectiveness. It will have defined and measurable criteria for success, in that monitoring and review is able to judge whether measures of success are being met, or whether those measures, or the decision itself, need to be revisited.

A good climate decision requires information on climate, its impacts, potential risks and vulnerability to be integrated into an existing or proposed decision-making context. This may require a dialogue between users and specialists to jointly ascertain how a specific task can best be undertaken within a given context with the current state of scientific knowledge. This dialogue may be facilitated by individuals, often known as knowledge brokers or extension agents, and boundary organizations, who bridge the gap between research and practice. Climate services are boundary organizations that provide and facilitate knowledge about climate, climate change and climate impacts for planning, decision making and general societal understanding of the climate system.

FAQ 2.2: Which is the best method for climate change decision-making/assessing adaptation?

[to be inserted in Section 2.3.4]

No single method suits all contexts, but the overall approach used and recommended by the IPCC is iterative risk management. The International Standards Organization defines risk as *the effect of uncertainty on objectives*. Within the climate change context, risk can be defined as the potential for consequences where something of human value (including humans themselves) is at stake and where the outcome is uncertain. Risk management is a general framework that includes alternative approaches, methodologies, methods and tools. Although the risk management concept is very flexible, some methodologies are quite prescriptive; for example, legislated emergency management guidelines and fiduciary risk. At the operational level, there is no single definition of risk that applies to all situations. This gives rise to much confusion about what risk is and what it can be used for.

Simple climate risks can be assessed and managed by the standard methodology of making up the ‘adaptation deficit’ between current practices and projected risks. Where climate is one of several or more influences on risk, a wide range of methodologies can be used. Such assessments need to be context-sensitive, involve those who are affected by the decision (or their representatives), use both expert and practitioner knowledge, and need to map a clear pathway between knowledge generation, decision-making and action.

FAQ 2.3: Is climate change decision-making different from other kinds of decision-making?

[to be inserted after Section 2.4.3]

Climate-related decisions have similarities and differences with decisions concerning other long-term, high consequence issues. Commonalities include the usefulness of a broad risk framework and the need to consider uncertain projections of various biophysical and socioeconomic conditions. However, climate change includes longer time-horizons and affects a broader range of human and earth systems as compared to many other sources of risk. Climate change impact, adaptation and vulnerability assessments offer a specific platform for exploring long term future scenarios in which climate change is considered along with other projected changes of relevance to long term planning.

In many situations, climate change may lead to non-marginal and irreversible outcomes, which pose challenges to conventional tools of economic and environmental policy. In addition, the realization that future climate may differ significantly from previous experience is still relatively new for many fields of practice (e.g., food production, natural resources management, natural hazards management, insurance, public health services and urban planning).

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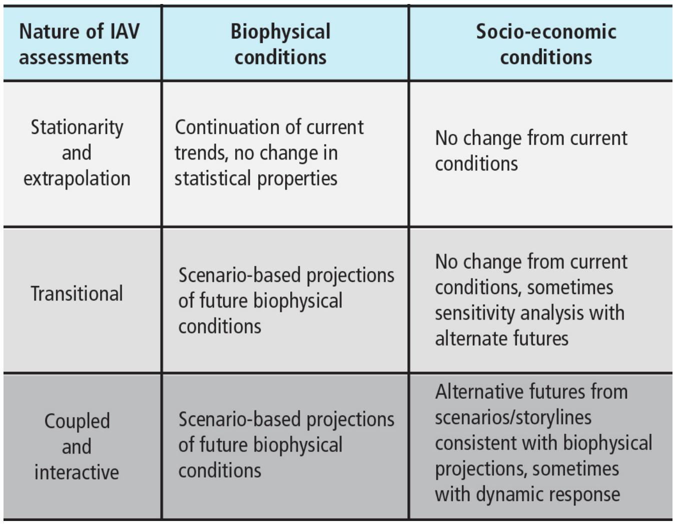


Nature of IAV assessments	Biophysical conditions	Socio-economic conditions
Stationarity and extrapolation	Continuation of current trends, no change in statistical properties	No change from current conditions
Transitional	Scenario-based projections of future biophysical conditions	No change from current conditions, sometimes sensitivity analysis with alternate futures
Coupled and interactive	Scenario-based projections of future biophysical conditions	Alternative futures from scenarios/storylines consistent with biophysical projections, sometimes with dynamic response

Table 2-1: Nature of published IAV assessments.

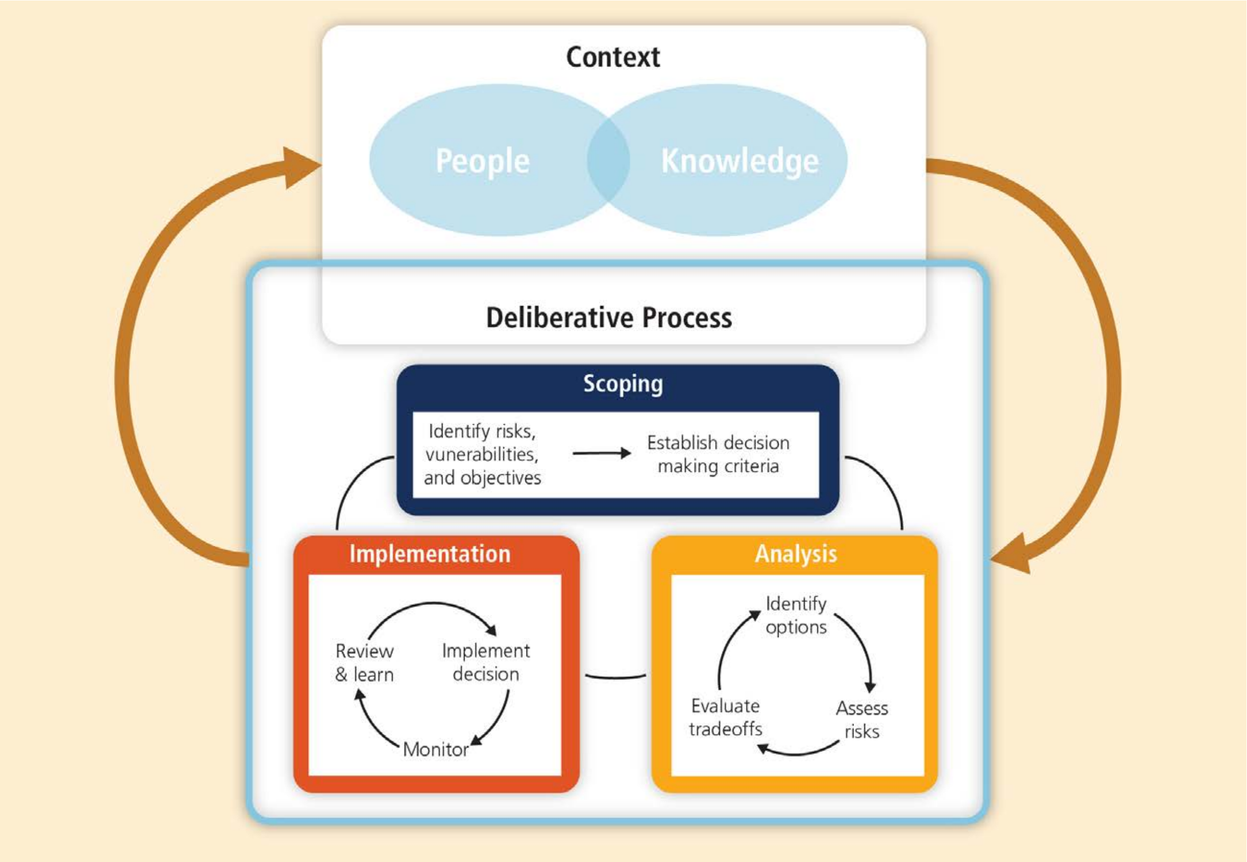
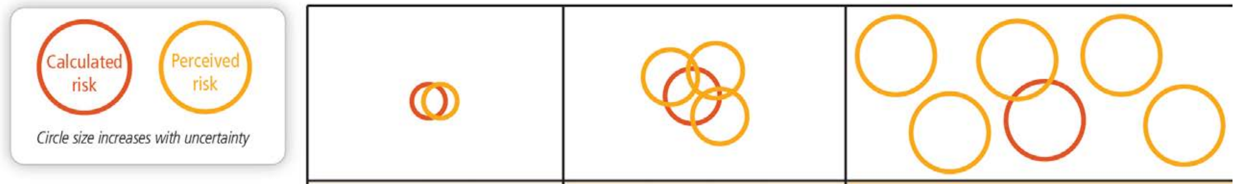


Figure 2-1: Iterative risk management framework depicting the assessment process, and indicating multiple feedbacks within the system and extending to the overall context. Adapted from Willows and Connell (2003).



Characteristics of decision making	Simple risk	Complicated risk	Complex risk
Methodology	Linear, cause and effect	Top down and/or bottom up, iterative	Iterative and/or adaptive, ongoing and systemic
Approach	Analytic and technical	Collaborative process with technical input	Process driven. Frame and model multiple drivers and valued outcomes
Stakeholder strategy	Communication	Collaboration	Deliberation, creating shared understanding and ownership
Mental models	Common model	Negotiated and shared	Contested initially and negotiated over project
Values and outcomes	Widely accepted	Negotiated over project by user perspectives and calculated risk	Contested initially and negotiated over project
Monitoring	Straightforward	With review and trigger points	As real-time as possible, adaptive with management feedback and trigger points

Figure 2-2: Hierarchy of simple, complicated, and complex risks, showing how perceived risks multiply and become less connected with calculated risk with increasing complexity. Also shown are major characteristics of assessment methods for each level of complexity.

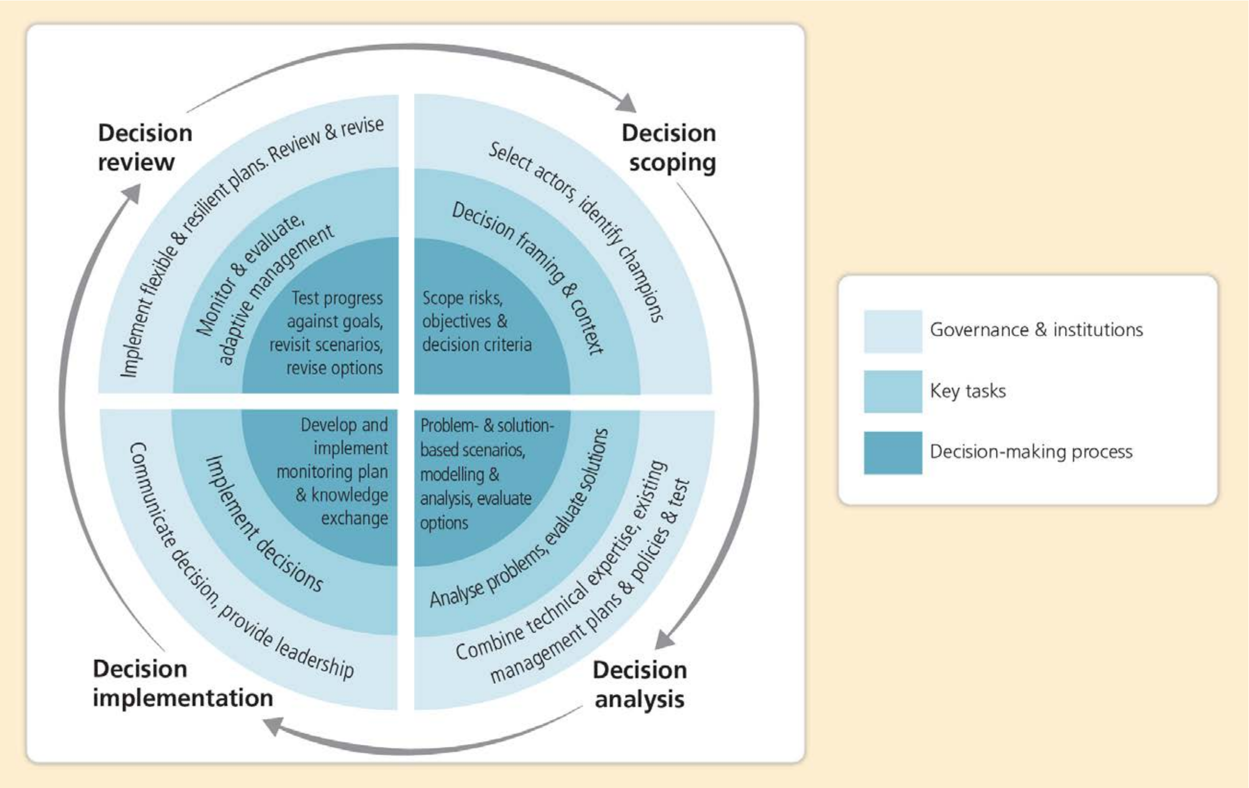


Figure 2-3. Four-stage process of decision making. Note that while adaptive management is located in the decision review quadrant here, when applied it will influence the entire process.

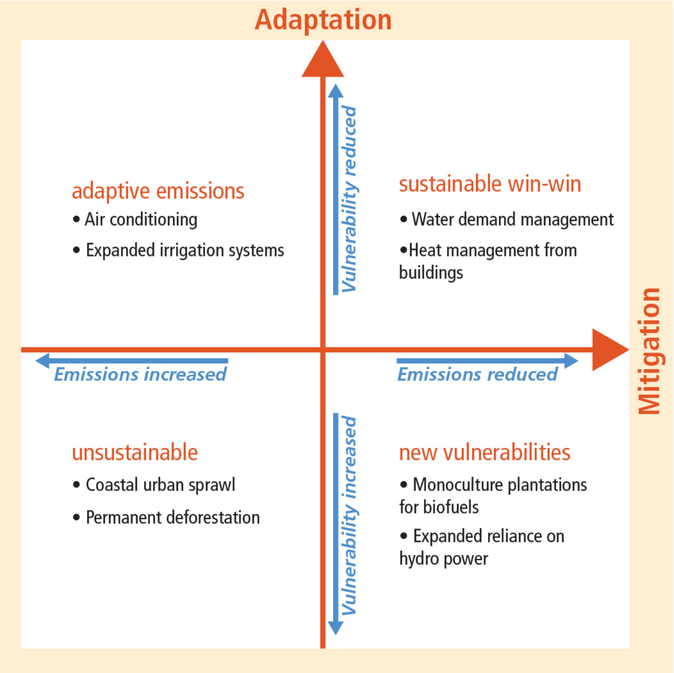


Figure 2-4: Examples of adaptation (A) – mitigation (M) trade-offs and synergies (adapted from Cohen and Waddell, 2009). The upper right quadrant (sustainable win-win) illustrates synergies in which actions enable the achievement of both adaptation and mitigation goals. The lower left quadrant (unsustainable) shows the opposite condition. The upper left (adaptive emissions) and lower right (new vulnerabilities) quadrants illustrate trade-offs that can result from actions within particular local-regional circumstances.