HERITAGE RESEARCH

EXPLORING HERITAGE IN IPCC DOCUMENTS

A report on research conducted in June 2018 to explore references to heritage within IPCC publications

Produced by Hana Morel
Friday 15 June 2018

EXPLORING HERITAGE IN IPCC DOCUMENTS

SUMMER 2018

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

These reports produced by the United Nation's Intergovernmental Panel on Climate Change – which was founded in 1988 by the World Meteorological Organisation (WMO) and the UN Environment Programme (UNEP) – aim to provide periodic meta-analysis of scientific observations to work towards supporting the UN Framework Convention on Climate Change (UNFCCC).
The Fifth Assessment Report (AR5) is an update on the 2007 Fourth Assessment Report (AR4), and has involved over 800 authors to work together in three Working Groups to explore:

- Observations of changes in our ecosystem i.e. the land, air, and ocean
- Impacts on the socio-economic and natural systems of different sectors and regions of the world
- Potential practical solutions to mitigate further pollutant emissions

This quick report illustrates that references to heritage - explored here in a wide capacity to include areas such as climate change's impact on cultural and national landscapes, indigenous peoples, the use of traditional practices and the challenges and opportunities brought about by cultural factors, as explored as traditional practices – are largely focused on impact and vulnerabilities.

The IPCC publications do demonstrate that social and cultural determinants have been taken into account and that there is a further need for scientific data with more context specific focus. It also highlights that scientific data must localise global and scientific meta-narratives and recognises that cultural knowledge and practices do play decisive roles in responding to climate adaptation strategies.

Decision-making is strongly linked to socio-cultural dynamics and socio-processes.

Chapter 4 highlights some of the recurring themes in understanding the role of culture and heritage as acting as a barrier to adaptation strategies, being most at risk, as well as the need for further understanding in drawing on traditional and cultural values in the climate scientific discourse.

Box 16-4 on 'Historical Perspectives on Limits to Adaptation' (P. 86) and Box 18-5 on 'Detection, Attribution and Traditional Ecological Knowledge' (P. 31) are two of the boxes selected as relevant to the initial brief of this research.

2 BRIEF & STRATEGY OF RESEARCH SEARCH

The brief of this research is to explore where in recent IPPC publications there are references to heritage, to highlight how heritage is portrayed and what inferences are made in relation to the past, past societies and past practices.

A search of keywords within five documents was conducted, and some of the relevant texts collated here in Chapter 4. The keywords used were: heritage, archaeology, societies (looking predominantly for references to past or local societies, box (the publications have case study boxes relevant to heritage), culture*, tradition*, indigen*, prehistoric, memory and practices.

The publications that were explored for the purposes of this research were:

- Climate Change 2013: *The Physical Science Basis*
- Climate Change 2014: *Impacts, Adaptation, and Vulnerability Part A: Global and Sectoral Aspects*
- Climate Change 2014: *Impacts, Adaptation, and Vulnerability Part B: Regional Aspects*
- Climate Change 2014: Mitigation of Climate Change
- AR4, WG2, Full Report
- AR5 Final Full Synthesis Report

3 WORK SEARCH AND RESULTS

3.1 Climate Change 2013: The Physical Science Basis

3.1.1 Content of Publication and Relevance to Heritage

The publication is the Fifth Assessment report of the IPCC which provides an overview of the physical science basis of climate change and provides detailed assessments of changes observed within the climate system. There are chapters on sea-level change, biogeochemical cycles, clouds and aerosols, and regional climates. It also provides climate projections up to 2050.

3.1.2 Search Results

Word Search	Finds	Notes
Archaeology	9 finds	Sea level change & the Holocene. Holocene land use change/ CH_4 rise from domestication
Box	532 pages	Not relevant
Cultur*	0 finds	
Heritage	3 finds	Not relevant
Indigen*	0 finds	
Local Practices	1 find	Not relevant
Memory	2 finds	Not relevant
Prehistoric	1 find	Nesje, A., et al., 2011.[1]

[1] The climatic significance of artefacts related to prehistoric reindeer hunting exposed at melting ice patches in southern Norway. *Holocene*, **22**, 485–496.

Societies	35 finds	Not relevant
Tradition*	0 finds	

3.2 Climate Change 2014: Impacts, Adaptation, and Vulnerability Part A: Global and Sectoral Aspects, and Part B: Regional Aspects

3.2.1 Content of Publication and Relevance to Heritage

This report is over a thousand pages and has two volumes which explore both global and regional impacts of climate change. It looks into the impact of climate on urban and rural areas (i.e. heat, flooding, and the built environment), as well as interrelationships between poverty, wellbeing and vulnerability of communities. In relation to the previous report, this one focuses on the benefits and constraints of various factors such as culture, and the role of government and stakeholder involvement in adaptation strategies.

3.2.2 Search Results of Part A: Global and Sectoral Aspects

Word Search	Finds	Notes
Archaeology	1 find	Van de Noort, R. 2011
Box	429 pages	See Chapter 4
Cultur*	697 pages	See Chapter 4
Heritage	25 finds	See Chapter 4
Indigen*	147 pages	See Chapter 4
Local Practices	109 pages	Links w best practices, local resources/ See tradition*
Memory	4 finds	Not relevant
Prehistoric	1 find	Rosen & Rivera-Collazo, 2012
Societies	104 finds	See Chapter 4
Tradition*	121 finds	See Chapter 4

3.2.3 Search Results of Part B: Regional Aspects

Word Search	Finds	Notes
Archaeology	1 find	Bjordal 2012 on Climate Change and Marine Archaeology
Box	205 pages	See Chapter 4
Cultur*	425 pages	See Chapter 4
Heritage	24 pages	See Chapter 4
Indigen*	125 pages	See Chapter 4
Local Practices	102 pages	See Chapter 4
Memory	1 find	Solberg (2010)[2]
Prehistoric	1 find	Nunn (2007)[3]
Societies	23 finds	See Chapter 4
Tradition*	92 pages	See Chapter 4

[2] **Solberg**, K., 2010: Worst floods in living memory leave Pakistan in paralysis. *The Lancet*, **376(9746)**, 1039-1040.
[3] Nunn (2007) argues that past climate changes have had a "crisis effect" on prehistoric societies in much of the Pacific Basin.

3.3 Climate Change 2014: Mitigation of Climate Change

3.3.1 Content of Publication and Relevance to Heritage

This report focuses on human settlements, infrastructure and spatial planning as well as topics such as energy systems, transport, buildings, industry and agriculture, forestry and land use. It covers the drivers and links between Greenhouse Gas emissions and cityscapes and looks at some of the challenges met by current institutional arrangements of mitigation strategies in urban spaces.

3.3.2 Search Results

Word Search	Finds	Notes
Archaeology	0 finds	
Box	166 finds	Not relevant
Cultur*	469 finds	See Chapter 4
Heritage	4 pages	See Chapter 4
Indigen*	48 pages	See Chapter 4
Local Practices	61 pages	Not relevant
Memory	6 pages	Not relevant
Prehistoric	0 finds	
Societies	51 pages	See Chapter 4
Tradition*	131 pages	See Chapter 4

4 THEMES: EXTRACTS FROM DOCUMENTS

From the text, there were a number of themes that emerged. Below are extracts from each of the publications which have been categorised to each of the themes we assess them as falling into. Codes for each of the publications are:

- (2013) for Climate Change 2013: *The Physical Science Basis*
- (2014a) for Climate Change 2014: *Impacts, Adaptations and Vulnerability Part A*
- (2014b) for Climate Change 2014: *Impacts, Adaptations and Vulnerability Part B*
- (2014) for Climate Change 2014: *Mitigation of Climate Change*
- (AR4) for the Working Group 2 Full Report
- (AR5) for the Final Full Synthesis Report

The 'Limitations, Barriers and Cultural Differences' theme is used to categorise extracts from the publications which refer to culture, heritage, the past, or societies/community values as a barrier of mitigating climate change through the implementation of policy or decision-making activity. This can include socio-economic or cultural aspects such as poverty, or inequality.

The 'Benefits of Natural/Cultural Heritage' theme collates parts of publications which turn to heritage as potential asset to tackling climate change.

The 'Risks' section collates various extracts which directly suggest heritage and/or indigenous livelihoods are at risk because of climate changes.

The 'Practices and Knowlegde' section highlights references in the publications which suggest that indigenous or traditional/local practices are useful in tackling climate change and can provide an alternative to resilience.

In the 'Adaptation, Assessments and Responses' session has extracts which discuss adaptation methods, issues with assessing the impact of climate change on areas of heritage as well as issues concerning land use and rights of indigenous communities.

The 'Prehistoric or Past Society References' collates any information that directly suggests past societies have had to deal with climate change, and the possible outcome we can deduct from the data.

Lastly, the 'Gaps in Our Understanding' pulls together some of the extracts that suggest there are gaps in our understanding of particularly areas, and what areas we need to gather more scientific evidence of.

4.1 Glossary Definitions

Below are extracts of some of the definitions of terms relevant to the research undertaken. These definitions are taken from Climate Change 2014: *Impacts, Adaptations and Vulnerability Part B*'s glossary session.

Community-based adaptation

Local, community-driven adaptation. Community-based adaptation focuses attention on empowering and promoting the adaptive capacity of communities. It is an approach that takes context, culture, knowledge, agency, and preferences of communities as strengths.

Cultural impacts

Impacts on material and ecological aspects of culture and the lived experience of culture, including dimensions such as identity, community cohesion and belonging, sense of place, worldview, values, perceptions, and tradition. Cultural impacts are closely related to ecological impacts, especially for iconic and representational dimensions of species and landscapes. Culture and cultural practices frame the importance and value of the impacts of change, shape the feasibility and acceptability of adaptation options, and provide the skills and practices that enable adaptation.

Ecosystem approach
A strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way. An ecosystem approach is based on the application of scientific methodologies focused on levels of biological organization, which encompass the essential structure, processes, functions, and interactions of organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems. The ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning. Priority targets are conservation of biodiversity and of the ecosystem structure and functioning, in order to maintain ecosystem services.[8]

Exposure
The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Famine
Scarcity of food over an extended period and over a large geographical area, such as a country, or lack of access to food for socioeconomic, political, or cultural reasons. Famines may be caused by climate-related extreme events such as droughts or floods and by disease, war, or other factors.

Annex II: Indigenous peoples and nations are those that, having a historical continuity with pre-invasion and pre-colonial societies that developed on their territories, consider themselves distinct from other sectors of the societies now prevailing on those territories, or parts of them. They form at present principally non-dominant sectors of society and are often determined to preserve, develop, and transmit to future generations their ancestral territories, and their ethnic identity, as the basis of their continued existence as peoples, in accordance with their own cultural patterns, social institutions, and common law system.

Traditional knowledge
The knowledge, innovations, and practices of both indigenous and local communities around the world that are deeply grounded in history and experience. Traditional knowledge is dynamic and adapts to cultural and environmental change, and also incorporates other forms of knowledge and viewpoints. Traditional knowledge is generally transmitted orally from generation to generation. It is often used as a synonym for indigenous knowledge, local knowledge, or traditional ecological knowledge.

4.2 Limitations, Barriers and Cultural Differences

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, 2001; Hofstede et al., 2010)....[start of longer section] (2014a: 203)

...poverty is recognized as multidimensional (UNDP, 1990). It is influenced by social, economic, institutional, political, and cultural drivers; its reversal requires efforts in multiple domains that promote opportunities and empowerment, and enhance security (World Bank, 2001). In addition to material deprivation, multidimensional conceptions of poverty consider a sense of belonging and socio-cultural heritage (O'Brien and Leichenko, 2003), identity, and agency, or "the culturally constrained capacity to act" (Ahearn, 2001, p. 54). (2014a: 799-780).

Overwhelmed, aging, poorly maintained, and inadequate urban drainage infrastructure and limited ability to cope and adapt due to marginalization, high poverty, and culturally imposed gender roles...(2014a)

Figure TS.13 | Opportunity space and climate-resilient pathways. (A) Our world [Sections A-1 and B-1] is threatened by multiple stressors that impinge on resilience from many directions, represented here simply as biophysical and social stressors. Stressors include climate change, climate variability, land-use change, degradation of ecosystems, poverty and inequality, and cultural factors. (2014a)

Box TS.8 | Adaptation Limits and Transformation
Adaptation can expand the capacity of natural and human systems to cope with a changing climate. Risk-based decision making can be used to assess potential limits to adaptation. Limits to adaptation occur when adaptive actions to avoid intolerable risks for an actor's objectives or for the needs of a system are not possible or are not currently available. Limits to adaptation are context-specific and closely linked to cultural norms and societal values. Value-based judgments of what constitutes an intolerable risk may differ among actors, but understandings of limits to adaptation can be informed by historical experiences, or by anticipation of impacts, vulnerability, and adaptation associated with different scenarios of climate change. The greater the magnitude or rate of climate change, the greater the likelihood that adaptation will encounter limits. [16.2 to 16.4, 20.5, 20.6, 22.4, 25.4, 25.10, Box 16-2] (2014a)

Figure SPM.9 | Opportunity space and climate-resilient pathways. (A) Our world [Sections A-1 and B-1] is threatened by multiple stressors that impinge on resilience from many directions, represented here simply as biophysical and social stressors. Stressors include climate change, climate variability, land-use change, degradation of ecosystems, poverty and inequality, and cultural factors. (B) Opportunity space [Sections A-2, A-3, B-2, C-1, and C-2] refers to decision points and pathways that lead to a range of (C) possible futures [Sections C and B-3] with differing levels of resilience and risk. (D) Decision points result in actions or failures-to-act throughout the opportunity space, and together they constitute the process of managing or failing to manage risks related to climate change. (E) Climate-resilient pathways (in green) within the opportunity space lead to a more resilient world through adaptive learning, increasing scientific knowledge, effective adaptation and mitigation measures, and other choices that reduce risks. (F) Pathways that lower resilience (in red) can involve insufficient mitigation, maladaptation, failure to learn and use knowledge, and other actions that lower resilience; and they can be irreversible in terms of possible futures.

Box TS.4 | Multidimensional Inequality and Vulnerability to Climate Change
People who are socially, economically, culturally, politically, institutionally, or otherwise marginalized in society are especially vulnerable to climate change and also to some adaptation and mitigation responses (medium evidence, high agreement). This heightened vulnerability is rarely due to a single cause. Rather, it is the product of intersecting social processes that result in inequalities

in socioeconomic status and income, as well as in exposure. Such social processes include, for example, discrimination on the basis of gender, class, race/ethnicity, age, and (dis)ability. See Box TS.4 Figure 1 on previous page. Understanding differential capacities and opportunities of individuals, households, and communities requires knowledge of these intersecting social drivers, which may be context-specific and clustered in diverse ways (e.g., class and ethnicity in one case, gender and age in another). Few studies depict the full spectrum of these intersecting social processes and the ways in which they shape multidimensional vulnerability to climate change.
Examples of inequality-driven impacts and risks of climate change and climate change responses (medium evidence, high agreement):

- Privileged members of society can benefit from climate change impacts and response strategies, given their flexibility in mobilizing and accessing resources and positions of power, often to the detriment of others. [13.2, 13.3, 22.4, 26.8]
- Differential impacts on men and women arise from distinct roles in society, the way these roles are enhanced or constrained by other dimensions of inequality, risk perceptions, and the nature of response to hazards. [8.2, 9.3, 11.3, 12.2, 13.2, 18.4, 19.6, 22.4, Box CC-GC]
- Both male and female deaths are recorded after flooding, affected by socioeconomic disadvantage, occupation, and culturally imposed expectations to save lives. Although women are generally more sensitive to heat stress, more male workers are reported to have died largely as a result of responsibilities related to outdoor and indoor work. [11.3, 13.2, Box CC-GC]. (2014a)

FAQ 5: Can science identify thresholds beyond which climate change is dangerous?

[Chapters 1, 2, 4, 5, 6, 16, 17, 18, 19, 20, and 25; TS] Human activities are changing the climate. Climate-change impacts are already widespread and consequential. But while science can quantify climate change risks in a technical sense, based on the probability, magnitude, and nature of the potential consequences of climate change, determining what is dangerous is ultimately a judgment that depends on values and objectives. For example, individuals will value the present versus the future differently and will bring personal worldviews on the importance of assets like biodiversity, culture, and aesthetics. Values also influence judgments about the relative importance of global economic growth versus assuring the well-being of the most vulnerable among us. Judgments about dangerousness can depend on the extent to which one’s livelihood, community, and family are directly exposed and vulnerable to climate change. An individual or community displaced by climate change might legitimately consider that specific impact dangerous, even though that single impact might not cross the global threshold of dangerousness. Scientific assessment of risk can provide an important starting point for such value judgments about the danger of climate change. (2014a)

Reasons for gendered differences in mortality include various socially and culturally determined gender roles. Studies in Bangladesh, for example, show that women do not learn to swim and so are vulnerable when exposed to flooding (Rőhr, 2006) and that, in Nicaragua, the construction of gender roles means that middle-class women are expected to stay in the house, even during floods and in risk-prone areas (Bradshaw, 2010). (2014a)

The point of departure in the title alludes to the availability of new information concerning the interactions between climate change and other biophysical and societal stressors. Societal stressors include poverty and inequality, low levels of human development, and psychological, institutional, and cultural factors. Even in the presence of these multiple stressors, policy relevant information from scientific research, direct experience, and observation provides an opportunity space to choose and design climate-resilient development pathways (see Sections 1.1.4, 13.1.1, 14.2, 14.3; Figure 1-5). (2014a)

Recent literature points to changes in values, norms, belief systems, culture, and conceptions of progress and well-being as either facilitating or preventing transformation (Pelling, 2010; Stafford Smith et al., 2011; Kates et al., 2012; O’Brien, 2013). Transformation of this nature requires a particular understanding of risks, adaptive management, learning, innovation, and leadership, and may lead to climate resilient development pathways (see Section 1.2.3 and Chapter 20).

Transformational change is not called for in all circumstances (Pelling, 2010) and in some cases may lead to negative consequences for some locations or social groups, contributing to social inequities (O'Brien, 2013). Climate resilient pathways include actions, strategies, and choices that reduce climate change impacts while assuring that risk management and adaptation can be implemented and sustained.

Figure 1-5 | Opportunity space and climate-resilient pathways. (a) Our world is threatened by multiple stressors that impinge on resilience from many directions, represented here simply as biophysical and social stressors. Stressors include climate change, climate variability, land-use change, degradation of ecosystems, poverty and inequality, and cultural factors.

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). (2014a)

Acceptance of the science behind controversial risks is strongly influenced 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 behavior (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). (2014a)

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 utilized (Kuruppu, 2009). (2014a)

Legislative and policy frameworks for adaptation remain fragmented, adaptation policy approaches seldom take into account realities in the political and institutional spheres, and national policies are often at odds with autonomous local adaptation strategies, which can act as a barrier to adaptation, especially where cultural, traditional, and context-specific factors are ignored (Dube and Sekhwela, 2008; Patt and Schröter, 2008; Stringer et al., 2009; Bele et al., 2010; Hisali et al., 2011; Kalame et al., 2011; Naess et al., 2011; Lockwood, 2012; Sonwa et al., 2012; see also Section 22.4.6). (2014b)

While destocking of livestock during drought periods may also address desertification and adaptation, the lack of individual incentives and marketing mechanisms to destock and other cultural barriers inhibit their widespread adoption in the Sahel (Hein et al., 2009; Nielsen and Reenberg, 2010). Despite these provisos and other constraints (see, e.g., Nelson and Agrawal, 2008; Section 22.4.6 further highlights local- level institutional constraints), local stakeholder institutions for CBNRM do enable a more flexible response to changing climatic conditions; CBNRM is also a vehicle for improving links between ecosystem services and poverty reduction, to enable sustainable adaptation approaches (Shackleton et al., 2010; Chishakwe et al., 2012; Girot et al., 2012). Based on lessons learned in Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, and Zimbabwe, Chishakwe et al. (2012) point out the synergies between CBNRM and adaptation at the community level, notwithstanding institutional and other constraints experienced with CBNRM. (2014b)

A complex web of interacting barriers to local-level adaptation exists that manifests from national to local scales to constrain adaptation, which includes institutional, political, social, cultural, biophysical, cognitive, behavioral, and gender-related aspects (*high confidence*). (2014b)

In addition to unclear land tenure, legislation forbidding ecosystem use is one of the issues strengthening underlying conflicts over resources in Africa; resolving this would enable ecosystems to contribute to adaptation beyond short-term coping (Robledo et al., 2012). There is also evidence that innovation may be suppressed if the dominant culture disapproves of departure from the "normal way of doing things" (Jones, 2012; Ludi et al., 2012). (2014b)

At a policy level, studies have detected political, institutional, and discursive barriers to adaptation. Adaptation options in southern Africa have been blocked by political and institutional inefficiencies, lack of prioritization of climate change, and the dominance of other discourses, such as the mitigation discourse in South Africa and short-term disaster- focused views of climate variability (Madzwamuse, 2010; Bele et al., 2011; Berrang-Ford et al., 2011; Conway and Schipper, 2011; Kalame et al., 2011; Chevallier, 2012; Leck et al., 2012; Toteng, 2012). Lack of local participation in policy formulation, the neglect of social and cultural context, and the inadvertent undermining of local coping and adaptive strategies have also been identified by several commentators as barriers to appropriate national policies and frameworks that would support local-level adaptation (e.g., Brockhaus and Djoudi, 2008; Bele et al., 2011; Chevallier, 2012). (2014b)

...These include challenges related to competing national priorities, awareness and capacity, financial resources for adaptation implementation, institutional barriers, biophysical limits to ecosystem adaptation, and social and cultural factors (Lasco et al., 2009, 2012; Moser and Ekstrom, 2010). (2014b)

At the same time, social and cultural values and norms can constrain adaptation options for communities by limiting the range of acceptable responses and processes (e.g., place attachment, differing values relating to near- versus long-term, private versus public, and economic versus environmental or social costs and benefits, and perceived legitimacy of institutions). Examples of this are particularly prominent in Australasia in the coastal zone (e.g., Hayward, 2008a; King et al., 2010; Gorddard et al., 2012; Hofmeester et al., 2012) and acceptance of water recycling or pricing (e.g., Pearce et al., 2007; Kouvelis et al., 2010; Mankad and Tapsuwan, 2011). (2014b)

In terms of framing adaptation, as a constraint to affect the adaptation context, it is usually considered that a major barrier to adaptation is the perception of risks, and many studies focused on such an issue (e.g., Schlindwein et al., 2011). New studies (Adger et al., 2009) identified social limits to possible adaptation to climate change in relation with issues of values and ethics, risk, knowledge, and culture, even though such limits can evolve in time. Indeed, while being a necessary condition, perception may not be the main driver for initiating an adaptation process. (2014b)

Although lack of access to adequate financial, technological and human resources is often cited as the most critical constraint, experience has shown that endogenous factors such as culture, ethics, knowledge, and attitudes to risk are important in constraining adaptation. Translating the word “climate” into Marshallese implies cosmos, nature, and culture as well as weather and climate (Rudiak-Gould, 2012). Such cultural misunderstandings can create both barriers to action and novel ways of engaging with climate change. The lack of local support (owing to encroachment on traditional lands) for the development of new infiltration galleries to augment freshwater supply on Tarawa atoll, Kiribati, highlights the importance of social acceptability (Moglia et al., 2008a,b). Such considerations have led to the conclusion that there is still much to be learned about the drivers of past adaptation and how “mainstreaming” into national programs and policies, widely acclaimed to be a virtually indispensable strategy, can practically be achieved (Mercer et al., 2007; Adger et al., 2009; Mertz et al., 2009). (2014b)

Based on field research conducted in the Borana area of southern Ethiopia, Debsu (2012) highlights the complex way in which external interventions may affect local and indigenous institutions by strengthening some coping and adaptive mechanisms and weakening others. Restrictive institutions can block attempts to enhance local adaptive capacity by maintaining structural inequities related to gender and ethnic minorities (Jones, 2012). (2014b)

Major constraints related to the capacity and resources needed to support the implementation of adaptation policies and processes include: access to (Lemos et al., 2010) and exchange of knowledge (e.g., adaptive capacity can be enhanced by linking indigenous and scientific knowledge; Valdivia, 2010); access to and quality of natural resources (López- Marrero, 2010); access to financial resources, especially for poor households (Satterthwaite, 2011b; Hickey and Weis, 2012; Rubin and Rossing, 2012), as well as for institutions (Pereira et al., 2009); access to technological resources (López-Marrero, 2010) and technical assistance (Guariguata, 2009; Eakin et al., 2011), as well as the fostering of public- private technology transfer (La Rovere et al., 2009; Ramirez-Villegas et al., 2012) and promotion of technical skills (Hickey and Weis, 2012); and social asset-based formation at the local level (Rubin and Rossing, 2012). (2014b)

Typically, barriers and opportunities can be distinguished into the following categories:

- Technology: includes maturity, reliability, safety, performance, cost of technology options and systems, and gaps in information
- Physical: includes availability of infrastructure, geography, and space available
- Institutional and legal: includes regulatory frameworks and institutions that may enable investment
- Cultural: includes public acceptance, workforce capacity (e. g., education, training, and knowledge), and cultural norms. (2014)

Table 10.6 | Barriers (–) and opportunities (+) for GHG emission reduction options in industry. References and discussion appear in respective sub-sections of 10.9.

	Energy efficiency for reducing energy requirements	Emissions efficiency, fuel switching and CCS	Material efficiency	Product demand reduction	Non-CO_2 GHGs
Technological Aspects: Technology	+ many options available – technical risk + cogeneration mature in heavy industry – non-transparent and technically demanding interconnection procedures for cogeneration	+ fuels and technologies readily available – retrofit challenges + large potential scope for CCS in cement production, iron and steel, and petrochemicals – limited CCS technology development, demonstration and maturity for industry applications	+ options available	– slower technology turnover can slow technology improvement and operational emission reduction	+/– approaches and technologies available for some sources – lack of lower cost technology for PFC emission reduction in existing aluminium production plants
Technological Aspects: Physical	+ less energy and fuel use, lower cooling needs, smaller size – concentrating suitable heat loads for cogeneration – retrofit constraints on cogeneration	– lack of sufficient feedstock to meet demand – CCS retrofit constraints – lack of CO_2 pipeline infrastructure – limited scope and lifetime for industrial CO_2 utilization	+ reduction in raw and waste materials – transport infrastructure and industry proximity for material/waste reuse	+ reduction in raw materials and disposed products	– lack of control of HFC leakage in refrigeration systems
Institutional and Legal	– impact of non-energy policies + energy efficiency policies (10.11) – market barriers – regulatory, tax/tariff and permitting of cogeneration +/– grid access for cogeneration		– fragmented and weak institutions	– regulatory and legal instruments generally do not take account of externalities	– lack of certification of refrigeration systems – regulatory barriers to HFC alternatives in aerosols
Cultural	– lack of trained personnel +/– attention to energy efficiency – lack of acceptance of unconventional manufacturing processes – cogeneration outside core business – lack of consumer and policymaker knowledge of cogeneration	– social acceptance of CCS	+/– public participation – human capacity for management decisions	+/– user preferences drive demand	– lack of information/education about solvent replacements – lack of awareness of alternative refrigerants

Behavioural aspects: Level of education, cultural values and tradition, as well as access to markets and technology, and the decision power of individuals and social groups, all influence the perception of potential impacts and opportunities from AFOLU measures, and consequently have a great impact on local land management decisions (see Chapters 2, 3, and 4; Guthinga, 2008; Durand and Lazos, 2008; Gilg, 2009; Bhuiyan et al., 2010; Primmer and Karppinen, 2010; Durand and Vázquez, 2011). When decisions are taken at a higher administrative level (e.g., international corporations, regional authorities or national states), other factors or values play an important role, including national and international development goals and priorities, policies and commitments, international markets or corporate image (see Chapters 3 and 4). Table 11.7 summarizes the emerging behavioural aspects regarding AFOLU mitigation measures. (2014)

The literature on international environmental governance emphasizes the advantages of common objectives, common historical and cultural backgrounds, geographical proximity, and a smaller number of negotiating parties, which make it easier to come to agreement and to coordinate mitigation efforts. As a caveat, regional fragmentation might hamper the achievement of global objectives (Biermann et al., 2009; Zelli, 2011; Balsiger and VanDeveer, 2012). (2014)

With regard to traditional biomass, the conversion of wood to charcoal in traditional kilns results in low-conversion efficiencies. A wide range of interventions have tried to overcome this challenge by promoting more efficient kilns, but the adoption rate has been limited in many countries, particularly in sub-Saharan Africa (Chidumayo and Gumbo, 2013). (2014)

4.2.1 Different Values

Decision processes often include both deliberative and intuitive thinking

When making mitigation and adaptation choices, decision makers sometimes calculate the costs and benefits of their alternatives (deliberative thinking). They are also likely to utilize emotion- and rule-based responses that are conditioned by personal past experience, social context, and cultural factors (intuitive thinking). [2.4.2] (2014)

Choices are also affected by cultural differences in values and needs (Maslow, 1954), in beliefs about the existence and causes of climate change (Leiserowitz et al., 2008), and in the role of informal social networks for cushioning catastrophic losses (Weber and Hsee, 1998). (2014)

Sunstein (2006) discusses the use of the availability heuristics in response to climate change risks and how it differs among groups, cultures, and nations. (2014)

A national survey in the United States found that people's support for climate policy also depended on cultural factors, with regionally differentiated worldviews playing an important role (Leiserowitz, 2006), as did a cross-national comparison of Britain and the United States (Lorenzoni and Pidgeon, 2006), and studies comparing developing with developed countries (Vignola et al., 2012). (2014)

Any decision about climate change is likely to promote some values and damage others. These may be values of very different sorts. In decision making, different values must therefore be put together or balanced against each other. Some pairs of values differ so radically from each other that they cannot be determinately weighed together. For example, it may be impossible to weigh the value of preserving a traditional culture against the material income of the people whose culture it is, or to weigh the value of biodiversity against human well- being. Some economists claim that one person's wellbeing cannot be weighed against another's (Robbins, 1937; Arrow, 1963). When values cannot be determinately weighed, they are said to be 'incommensu- rable' or 'incomparable' (Chang, 1997). Multi-Criteria Analysis (MCA) (discussed in Section 3.7.2.1) is a technique that is designed to take account of several incommensurable values (De Montis et al., 2005; Zeleny and Cochrane, 1982). (2014)

4.3 Benefits of Natural/Cultural Heritage

Some heritage benefits of preserving marine ecosystems consist of the economic value of a healthy, diverse ecosystem to future generations. Any climate-related biodiversity loss or pollution of marine ecosystems would decrease the bank of resources for future opportunities. For example, the research and conservation value of coral reef biodiversity and its non-use value are estimated together at US$5.5 billion annually (Cesar et al., 2003). As with spiritual and aesthetic benefits, maintaining heritage benefits under climate change poses challenges for managers concerning equity and ethics as well as multigenerational (and possibly multi-cultural) ethical questions. (2014a: 453)

Coral reefs are shallow-water ecosystems that consist of reefs made of calcium carbonate which is mostly secreted by reef-building corals and encrusting macroalgae. They occupy less than 0.1% of the ocean floor yet play multiple important roles throughout the tropics, housing high levels of biological diversity as well as providing key ecosystem goods and services such as habitat for fisheries, coastal protection, and appealing environments for tourism (Wild et al., 2011). About 275 million people live within 30 km of a coral reef (Burke et al., 2011) and derive some benefits from the ecosystem services that coral reefs provide (Hoegh-Guldberg, 2011), including provisioning (food, livelihoods, construction material, medicine), regulating (shoreline protection, water quality), supporting (primary production, nutrient cycling), and cultural (religion, tourism) services. This is especially true for the many coastal and small island nations in the world's tropical regions (Section 29.3.3.1). (2014a)

Ecosystem-based adaptation (EBA), defined as the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change (CBD, 2009), integrates the use of biodiversity and ecosystem services into climate change adaptation strategies (e.g., CBD, 2009; Munroe et al., 2011; see IPCC AR5 WGII Chapters 3, 4, 5, 8, 9, 13, 14, 15, 16, 19, 22, 25, and 27). EBA is implemented through the sustainable management of natural resources and conservation and restoration of ecosystems, to provide and sustain services that facilitate adaptation both to climate variability and change (Colls et al., 2009). It also sets out to take into account the multiple social, economic, and cultural co-benefits for local communities (CBD COP 10 Decision X/33). (2014a)

Forests and woodlands are principal providers of timber, pulp, bioenergy, water, food, medicines, and recreation opportunities and can play prominent roles in cultural traditions. (2014a)

Box 23-1 | Assessment of Climate Change Impacts on Ecosystem Services by Sub-region

Ecosystems provide a number of vital provisioning, regulating, and cultural services for people and society that flow from the stock of natural capital (Stoate et al., 2009; Harrison et al., 2010). Provisioning services such as food from agro-ecosystems or timber from forests derive from intensively managed ecosystems; regulating services underpin the functioning of the climate and hydrological systems; and cultural services such as tourism, recreation, and aesthetic value are vital for societal well-being (see Section 23.5.4). The table summarizes the potential impacts of climate change on ecosystem services in Europe by sub-region based on an assessment of the published literature (2004–2013). The direction of change (increasing, decreasing, or neutral) is provided, as well as the number of studies/papers on which the assessment was based (in parentheses). Empty cells indicate the absence of appropriate literature. Unless otherwise stated, impacts assume no adaptation and are assessed for the mid-century (2050s). A decrease in natural hazard regulation (e.g., for wildfires) implies an increased risk of the hazard occurring. Biodiversity is included here as a service (for completeness), although it is debated whether biodiversity should be considered as a service or as part of the natural capital from which services flow. What is agreed, however, is that biodiversity losses within an ecosystem will have deleterious effects on service provision (Mouillot et al., 2013).
The provision of ecosystem services in Southern Europe is projected to decline across all service categories in response to climate change (*high confidence*). Other European sub-regions are

projected to have both losses and gains in the provision of ecosystem services (*high confidence*). The Northern sub-region will have increases in provisioning services arising from climate change (*high confidence*). Except for the Southern sub-region, the effects of climate change on regulating services are balanced with respect to gains and losses (*high confidence*). There are fewer studies for cultural services, although these indicate a balance in service provision for the Alpine and Atlantic regions, with decreases in service provision for the Continental, Northern, and Southern sub-regions (*low confidence*). (2014b)

Box 23-1 (continued)

			Southern	Atlantic	Continental	Alpine	Northern
Provisioning services	Food production		↓ (1)	↓ (1)	↓ (1)	No (1) ↓ (4)	↑ (1) ↓ (1)
	Livestock production					No (1) ↓ (1)	
	Fiber production					↓ (1)	
	Bioenergy production		↓ (1)			↑ (1)	↑ (1)
	Fish production		No (1) ↓ (2)	No (1) ↓ (1)	↓ (1)		No (1) ↓ (1)
	Timber production		↓ (2)	↑ (2) No (3)	↑ (1) No (2) ↓ (1)	↑ (5) No (2) ↓ (5)	↑ (6) No (1)
	Non-wood forest products		↓ (1)				↑ (1) No (1)
	Sum of effects on provisioning services		No (1) ↓ (7)	↑ (2) No (4) ↓ (2)	↑ (1) No (2) ↓ (3)	↑ (6) No (4) ↓ (11)	↑ (9) No (3) ↓ (2)
Regulating services	Climate regulation (carbon sequestration)	General/forests	↑ (3) ↓ (1)	↑ (4) No (1)	↑ (3) No (1)	↑ (4) No (1) ↓ (3)	↑ (4) No (1) ↓ (1)
		Wetland	No (1) ↓ (1)	No (1) ↓ (1)	↓ (1)		No (1) ↓ (1)
		Soil carbon stocks	No (1) ↓ (1)	No (1) ↓ (2)	No (1) ↓ (1)	No (1) ↓ (2)	↓ (3)
	Pest control		↓ (1)		↑ (1)	↑ (1)	↑ (1)
	Natural hazard regulation[a]	Forest fires/wildfires	↓ (1)	↓ (1)	↓ (2)		
		Erosion, avalanche, landslide				↑ (2) ↓ (1)	
		Flooding				↓ (1)	
		Drought	No (1) ↓ (1)		↓ (1)		
	Water quality regulation			↓ (1)			↓ (1)
	Biodiversity		↑ (1) ↓ (8)	↑ (2) No (1) ↓ (4)	↑ (2) ↓ (4)	↑ (2) ↓ (4)	↑ (3) ↓ (2)
	Sum of effects on regulating services		↑ (4) No (3) ↓ (14)	↑ (6) No (4) ↓ (9)	↑ (6) No (2) ↓ (9)	↑ (9) No (2) ↓ (11)	↑ (8) No (2) ↓ (8)
Cultural services	Recreation (fishing, nature enjoyment)		↑ (1)	↓ (1)			↑ (1) ↓ (2)
	Tourism (skiing)					↑ (1)	↑ (1)
	Aesthetic/heritage (landscape character, cultural landscapes)		↓ (1)	↓ (1)	No (1) ↓ (1)	↑ (1)	
	Sum of effects on cultural services		↓ (2)	↑ (1) ↓ (1)	No (1) ↓ (1)	↑ (1) ↓ (1)	↑ (1) ↓ (3)

↓ = Climate change impacts are decreasing ecosystem service

↑ = Climate change impacts are increasing ecosystem service

No = Neutral effect

(1) = Numbers in brackets refer to the number of studies supporting the change (increasing, decreasing, neutral) in ecosystem service.

[a]A decline in ecosystem services implies an increased risk of the specified natural hazard.

Entries for biodiversity are those that were found during the literature search for climate change impacts on ecosystem services. A wider discussion of the impacts of climate change on biodiversity can be found in Sections 4.3.4 and 23.6.

References: Wessel et al. (2004); Schroter et al. (2005); Fuhrer et al. (2006); Koca et al. (2006); Gret-Regamy et al. (2008); Hemery (2008); Metzger et al. (2008); Palahi et al (2008); Bolte et al. (2009); Garcia-Fayos and Bochet (2009); Johnson et al. (2009); Albertson et al. (2010); Canu et al. (2010); Clark et al. (2010a); Lindner et al (2010); Lorz et al. (2010); Milad et al. (2011); Okruszko et al. (2011); Seidl et al. (2011); Briner et al. (2012); Civantos et al. (2012); Rusch (2012); Bastian (2013); Forsius et al (2013); Gret-Regamy et al. (2013); Seidl and Lexer (2013).

The subset of practices that are multi-sectoral, multi-scale, and based on the premise that ecosystem services reduce the vulnerability of society to climate change are known as Ecosystem-based Adaptation (EbA; Vignola et al., 2009; see Glossary and Box CC-EA). Schemes such as the payment for environmental services (PES) and community management fit the concept of EbA that begins to spread in CA and SA (Vignola et al., 2009). The principle behind these schemes is the valuation of ecosystem services that should reflect both the economic and cultural benefits derived from the human-ecosystem interaction and the capacity of ecosystems to secure the flow of these benefits in the future (Abson and Termansen, 2011). (201b)

The impacts of climate change on food security and basic nutrition are critical to human health because subsistence foods from the local environment provide Arctic residents, especially Indigenous peoples, with unique cultural and economic benefits necessary to well-being and contribute a significant proportion of daily requirements of nutrition, vitamins, and essential elements to the diet (Ford, 2009; Ford and Berrang-Ford, 2009). (2014b)

In West Africa, temperature increases above 2°C (relative to a 1961–1990 baseline) are estimated to counteract positive effects on millet and sorghum yields of increased precipitation (for B1, A1B, and A2 scenarios; Figure 22-5), with negative effects stronger in the savannah than in the Sahel, and with modern cereal varieties compared with traditional ones (Sultan et al., 2013). (2014b)

Adaptation planning can be greatly enhanced by incorporating regionally or locally specific vulnerability information (Clark et al., 1998; Barsugli et al., 2012; Romsdahl et al., 2013). Methods for mapping vulnerability have been improved and effectively utilized (Romero-Lankao et al., 2013b). Similarly, strategies supporting cultural preservation and subsistence livelihood needs among Indigenous peoples would enhance adaptation (Ford et al., 2010b), as would integrating traditional culture with other forms of knowledge, technologies, education, and economic development (Hardess et al., 2011). (2014b)

Nevertheless, examples of adaptation in CA and SA are predominantly related to MPAs. In Brazil, a protected area type known as "Marine Extractive Reserves" currently benefits 60,000 small-scale fishermen along the coast (de Moura et al., 2009). Examples of fisheries' co-management, a form of a participatory process involving local fishermen communities, government, academia, and non-governmental organizations, are reported to favor a balance between conservation of marine fisheries, coral reefs, and mangroves on the one hand (Francini-Filho and de Moura, 2008), and the improvement of livelihoods, as well as the cultural survival of traditional populations on the other (de Moura et al., 2009; Hastings, 2011). (2014b)

Some have argued that the bio-cultural heritage of indigenous peoples is a resource that should be valued and preserved as it constitutes an irreplaceable bundle of teachings on the practices of mitigation and sustainability (Sheridan and Longboat, 2006; Russell-Smith et al., 2009; Kronik and Verner, 2010). Sometimes local strategies and indices have metamorphosed into national policies, as in the case of '*Buen Vivir*' in Ecuador (Choquehuanca, 2010; Gudynas, 2011) and 'Gross National Happiness' (GNH), described in Box 3.11. In rich countries, and among social groups with high levels of environmental awareness, interest in sustainability has given rise to cultural movements promoting change in modes of thought, production, and consumption. Includ- ing the cultural dimension in mitigation policies facilitates social acceptability. (2014)

Local history and social culture can help shape the specific problem, together with equity implications and policy aspirations that ultimately determine what will become acceptable solutions (Vascon- cellos, 2001; Dimitriou, 2006; Kane, 2010; Li, 2011; Verma et al., 2011). (2014)

4.4 Risks to Cultural and Natural Heritage/Cultural Practices

Emergent Risks: Enhanced risk of loss of livelihoods and culture of increasing numbers of indigenous peoples, exacerbated by increasing loss of lands and sea ice for hunting, herding, fishing due to enhanced petroleum and mineral exploration, and increased maritime traffic. (2014a)

Climate change will compromise the cultural values that are important for community and individual well-being (*medium evidence*, *high agreement*). The effect of climate change on culture will vary across societies and over time, depending on cultural resilience and the mechanisms for maintaining and transferring knowledge. Changing weather and climatic conditions threaten cultural practices embedded in livelihoods and expressed in narratives, worldviews, identity, community cohesion, and sense of place. Loss of land and displacement, for example, on small islands and coastal communities, have well documented negative cultural and well-being impacts. [12.3, 12.4] (2014a)

People and societies may perceive or rank risks and potential benefits differently, given diverse values and goals. (2014a: 37)

Five integrative reasons for concern (RFCs) provide a framework for summarizing key risks across sectors and regions.
1) Unique and threatened systems: Some unique and threatened systems, including ecosystems and cultures, are already at risk from climate change (high confidence). The number of such systems at risk of severe consequences is higher with additional warming of around 1°C. Many species and systems with limited adaptive capacity are subject to very high risks with additional warming of 2°C, particularly Arctic-sea-ice and coral-reef systems. (2014a)

Climate change will compromise the cultural values that are important for community and individual well-being (*medium evidence*, *high agreement*). The effect of climate change on culture will vary across societies and over time, depending on cultural resilience and the mechanisms for maintaining and transferring knowledge. Changing weather and climatic conditions threaten cultural practices embedded in livelihoods and expressed in narratives, worldviews, identity, community cohesion, and sense of place. Loss of land and displacement, for example, on small islands and coastal communities, have well documented negative cultural and well-being impacts. [12.3, 12.4] (2014a: 72).
Repeated on page 757 with additional reference points {12.3.1, 12.3.3, 12.4.2}

The increased risks that climate change brings to the built environment (Spennemann and Look, 1998; Wilby, 2007) also apply to built heritage. This has led to the Venice Declaration on Building Resilience at the Local Level Towards Protected Cultural Heritage and Climate Change Adaptation Strategies, which brings together UNESCO, UN-HABITAT, EC, and individual city mayors. An example is Saint-Louis in Senegal, a coastal city and World Heritage Site on the mouth of the Senegal river, which has frequent floods and large areas at risk from river and coastal flooding. There are initiatives to reduce flooding risks and relocate families from locations most at risk, but the local authority has very limited investment capacity (Diagne, 2007; Silver et al., 2013). (2014a: 560)

Sabbioni et al. (2009) note that climate change may require a greater effort to protect cultural heritage. (2014a: 687)

Climate change will affect culturally valued buildings (Storm et al., 2008) through extreme events and chronic damage to materials (Brimblecombe et al., 2006; Brimblecombe and Grossi, 2010; Brimblecombe, 2010a, 2010b; Grossi et al., 2011; Sabbioni et al., 2012). Cultural heritage is a non-renewable resource and impacts from environmental changes are assessed over long time scales (Brimblecombe and Grossi, 2008, 2009, 2010; Grossi et al., 2008; Bonazza et al., 2009a,b). Climate change may also affect indoor environments where cultural heritage is preserved (Lankester and Brimblecombe, 2010) as well as visitor behavior at heritage sites (Grossi et al., 2010). There is also evidence to suggest that climate change and sea level rise will affect maritime heritage in the form of shipwrecks and other submerged archaeology (Björdal, 2012) (2014b: 1292)

Europe has many unique rural landscapes, which reflect the cultural heritage that has evolved from centuries of human intervention, for example, the cork oak based Montado in Portugal, the Garrigue of southern France, Alpine meadows, grouse moors in the UK, machair in Scotland, peatlands in Ireland, the polders of Belgium and the Netherlands, and vineyards. Many, if not all, of these cultural landscapes are sensitive to climate change and even small changes in the climate could have significant impacts (Gifford et al., 2011). (2014b: 1293)

The vulnerability of cultural heritage, including monuments/buildings and cultural landscapes, is an emerging concern. Some cultural landscapes will disappear. Grape production is highly sensitive to climate, but production (of grape varieties) is strongly culturally dependent and adaptation is potentially limited by the regulatory context. (2014b: 1303)

Polar Regions. Climate change and often-interconnected non-climate-related drivers, including environmental changes, demography, culture, and economic development, interact in the Arctic to determine physical, biological, and socioeconomic risks, with rates of change that may be faster than social systems can adapt (*high confidence*).

23.5.4. Cultural Heritage and Landscapes

Climate change will affect culturally valued buildings (Storm et al., 2008) through extreme events and chronic damage to materials (Brimblecombe et al., 2006; Brimblecombe and Grossi, 2010; Brimblecombe, 2010a, 2010b; Grossi et al., 2011; Sabbioni et al., 2012). Cultural heritage is a non-renewable resource and impacts from environmental changes are assessed over long time scales (Brimblecombe and Grossi, 2008, 2009, 2010; Grossi et al., 2008; Bonazza et al., 2009a,b). Climate change may also affect indoor environments where cultural heritage is preserved (Lankester and Brimblecombe, 2010) as well as visitor behavior at heritage sites (Grossi et al., 2010). There is also evidence to suggest that climate change and sea level rise will affect maritime heritage in the form of shipwrecks and other submerged archaeology (Björdal, 2012).

Surface recession on marble and compact limestone will be affected by climate change (Bonazza et al., 2009a). Marble monuments in Southern Europe will continue to experience high levels of thermal stress (Bonazza et al., 2009b) but warming is likely to reduce frost damage across Europe, except in Northern and Alpine Europe and permafrost areas (Iceland) (Grossi et al., 2007; Sabbioni et al., 2008). Damage to porous materials due to salt crystallization may increase all over Europe (Benavente et al., 2008; Grossi et al., 2011). In Northern and Eastern Europe, wood structures will need additional protection against rainwater and high winds (Sabbioni et al., 2012). AR4 concluded that current flood defenses would not protect Venice from climate change. Venice now has a flood forecasting system, and is introducing the MOSE (MOdulo Sperimentale Elettromeccanico) system of flood barriers (Keskitalo, 2010). Recent evidence suggests, however, that climate change may lead to a decrease in the frequency of extreme storm surges in this area (Troccoli et al., 2012a).

Europe has many unique rural landscapes, which reflect the cultural heritage that has evolved from centuries of human intervention, for example, the cork oak based Montado in Portugal, the Garrigue of southern France, Alpine meadows, grouse moors in the UK, machair in Scotland, peatlands in Ireland, the polders of Belgium and the Netherlands, and vineyards. Many, if not all, of these cultural landscapes are sensitive to climate change and even small changes in the climate could have significant impacts (Gifford et al., 2011). Alpine meadows, for example, are culturally important within Europe, but although there is analysis of the economics (tourism, farming) and functionality (water runoff, flooding, and carbon sequestration) of these landscapes there is very little understanding of how climate change will affect the cultural aspects on which local communities depend. Because of their societal value, cultural landscapes are often protected and managed through rural development and environmental policies. The peat-rich uplands of Northern Europe, for example, have begun to consider landscape management as a means of adapting to the effects of climate change (e.g., the moors for the future partnership in the Peak District National Park, UK). For a discussion of the cultural implications of climate change for vineyards, see Box 23-2. (2014b)

Table 23-4 | Assessment of climate change impacts by sub-region by 2050, assuming a medium emissions scenario and no planned adaptation. Impacts assume economic development, including land use change. Impacts are assessed for the whole sub-region, although differences in impact within sub-regions are estimated for some impacts.

		Southern	Atlantic	Continental	Alpine	Northern	Sections
Energy	Wind energy production	↗→↘ a	↗→↘	→	→	↗→	23.3.4
	Hydropower generation	↘	↘	↘	↗↘ b	↗→	
	Thermal power production	→↘	→↘	→↘	→↘	→	23.3.4, 8.2.3.2
	Energy consumption (net annual change)	↗	↘	↘	↘	↘	23.3.4, 23.8.1
Transport	Road accidents[c]	↘	→↘	→↘	→↘	→↘	23.3.3
	Rail delays (weather-related)	?	↗↘ d	?	?	↗	23.3.3, 8.3.3.6
	Load factor of inland ships	?	→↘	→↘	?	?	23.3.3
	Transport time and cost in ocean routes	?	?	↘	?	↘	23.3.3, 18.3.3.3.5
Settlements	River flood damages	→	↗↘	↗↘	→	→	23.3.1
	Coastal flood damages	↗→	↗→	↗→	N/A	↗→	
Tourism	Length of ski season	?	?	↘	→↘	↘	23.3.6, 3.5.7
Human health	Heat wave mortality and morbidity[e]	↗	↗	↗	→	↗	23.5.1
	Food-borne disease[e]	↗	↗	↗	→	↗	
Social and cultural impacts	Social costs of floods	↗→	↗↘	↗↘	→	↗→	23.5.3
	Damage to cultural buildings	↗↘	↗	↗	↗	↗	23.5.4
	Loss of cultural landscapes	?	↗	↗	↗	↗	
Environmental quality	Air quality (ozone background levels)	↗↘	↗↘	↗↘	?	↗↘	23.6.1
	Air quality (particulates)	↗↘	↗↘	↗↘	?	↗↘	
	Water quality	↘	↘	→	→	→	23.6.3

Increasing ↗	A range from no change to increasing ↗→	Green arrows mean a "beneficial change"
No change →	A range from no change to decreasing →↘	Red arrows means a "harmful change"
Decreasing ↘	A range from increasing to decreasing ↗↘	? means no relevant literature found

[a]Simulations have been performed, but mostly for the period after 2070.
[b]The increasing trend is for Norway.
[c]The decreasing trends refers mainly to the number of severe accidents.
[d]Impacts have been studied and quantified for UK only. The increasing trend stands for summer delays and the decreasing trends for winter delays.
[e]Impacts shown with respect to future world without climate change.

In the Colorado River basin, crop irrigation requirements for pasture grass are projected to increase by 20% by 2040 and by 31% by 2070 (Dwyer et al., 2012). In the Rio Grande basin, New Mexico, runoff is projected to decrease by 8 to 30% by 2080 due to climate change. Water transfers may entail significant transaction costs associated with adjudication and potential litigation, and might have economic, environmental, social, and cultural impacts that vary by water user (Hurd and Coonrod, 2012). In Mexico, water shortages combined with increased water demands are projected to increase surface and groundwater over-exploitation (CONAGUA, 2011) (2014b)

Box 23-2 | Implications of Climate Change for European Wine and Vineyards

Wine production in Europe accounts for more than 60% of the global total (Goode, 2012) and makes an important contribution to cultural identity. Apart from impacts on grapevine yield, higher temperatures are also expected to affect wine quality in some regions and grape varieties by changing the ratio between sugar and acids (Duchêne et al., 2010; Bock et al., 2011; Santos et al., 2011). In Western and Central Europe, projected future changes could benefit wine quality, but might also demarcate new potential areas for viticulture (Malheiro et al., 2010). Adaptation measures are already occurring in some vineyards (e.g., vine management, technological measures, production control, and to a smaller extent relocation; Battaglini et al., 2009; Holland and Smit, 2010; Malheiro et al., 2010; Duarte Alonso and O'Neill, 2011; Moriondo et al., 2011; Santos et al., 2011).Vineyards may be displaced geographically beyond their traditional boundaries ("terroir" linked to soil, climate, and traditions; Metzger and Rounsevell, 2011) and, in principle, wine producers could adapt to this problem by growing grape varieties that are more suited to warmer climates. Such technical solutions, however, do not account for the unique characteristics of wine production cultures and consumer perceptions of wine quality that strongly affect the prices paid for the best wines (White et al., 2009; Metzger and Rounsevell, 2011). It would become very difficult, for example, to produce fine wines from the cool-climate Pinot Noir grape within its traditional "terroir" of Burgundy under many future climate scenarios, but consumers may not be willing to pay current day prices for red wines produced from other grape varieties (Metzger and Rounsevell, 2011). An additional barrier to adaptation is that wine is usually produced within rigid, regionally specific, regulatory frameworks that often prescribe, among other things, what grapes can be grown where, for example, the French AOC (Appellation d'Origine Controlee) or the Italian DOC (Denominazione di Origine Controllata) and DOCG (Denominazione di Origine Controllata e Garantita) designations. Suggestions have been made to replace these rigid concepts of regional identity with a geographically flexible "terroir" that ties a historical or constructed sense of culture to the wine maker and not to the region (White et al., 2009).

Traditional food preservation methods such as drying of fish and meat, fermentation, and ice cellar storage are being compromised by warming temperatures, thus further reducing food available to the community (Brubaker et al., 2011b,c). For example, food contamination caused by thawing of permafrost "ice cellars" is occurring and increasingly wet conditions make it harder to dry food for storage (Hovelsrud et al., 2011). Indigenous people increasingly have to abandon their semi- nomadic lifestyles, limiting their overall flexibility to access traditional foods from more distant locations (www.arctichealthyukon.ca). These reductions in the availability of traditional foods plus general globalization pressures are forcing Indigenous communities to increasingly depend on expensive, non-traditional, and often less healthy Western foods, increasing the rates of modern diseases associated with processed food and its packaging, such as cardiovascular diseases, diabetes, dental caries, and obesity (Armitage et al., 2011; Berrang-Ford et al., 2011; Brubaker et al., 2011b,c). (2014b)

28.3.3.2. Antarctica

Projected effects of climate change on Antarctic terrestrial species are limited to knowledge of their ecophysiological tolerances to changes in air temperature, wind speed, precipitation (rain and snowfall), permafrost thaw, and exposure of new habitat through glacial/ice retreat. The climate is expected to become more tolerable to a number of species, leading to increases in biomass and extent of existing ecological communities.

The frequency with which new potential colonizing plant and animal species arrive in Antarctica (particularly the Antarctic Peninsula region) from lower latitudes, and the subsequent probability of their successful establishment, will increase with regional climate warming and associated environmental changes (*high confidence*; Chown et al., 2012). Human- assisted transfers of biota may be more important by two orders of magnitude than natural introductions (Frenot et al., 2005) as the transfer is faster and avoids extreme environments such as altitude or oceans (Barnes et al., 2006). The potential for anthropogenic introduction of non-indigenous species to Antarctic terrestrial areas, which could have devastating consequences to the local biodiversity, will increase (*high confidence*; Convey et al., 2009; Hughes and Convey, 2010; Convey, 2011; Braun et al., 2012). At present, established non-indigenous species in the sub- and maritime Antarctic are very restricted in their distributions (Frenot et al., 2005). Climate change could result in a greater rate of spread of invasive species through colonization of areas exposed by glacial retreat, as has occurred at South Georgia (Cook et al., 2010) and in the maritime Antarctic (Olech and Chwedorzewska, 2011). Biosecurity measures may be needed to help control dispersal of established non- indigenous

species to new locations, particularly given the expected increase in human activities in terrestrial areas (Hughes and Convey, 2010; Convey et al., 2011). An important gap in understanding is the degree to which climate change may facilitate some established but localized alien species to become invasive and widespread (Frenot et al., 2005; Convey 2010; Hughes and Convey, 2010; Cowan et al., 2011), which has been shown for the sub-Antarctic (Chown et al., 2012).
Overall, the likely impacts of existing and new non-indigenous species on the native terrestrial ecosystems of Antarctica and the sub-Antarctic islands, along with the continued increased presence of Antarctic fur seals, are likely to have far greater importance over the time scale under consideration than are those attributable to climate change itself (Convey and Lebouvier, 2009; Turner et al., 2009; Convey, 2010). (2014b)

'Risk' refers to the potential for adverse effects on lives, livelihoods, health status, economic, social and cultural assets, services (including environmental), and infrastructure due to uncertain states of the world. (2014)

4.5 Risks to Indigenous Communities/Marginalised Groups

12.3.2. Indigenous Peoples

There are around 400 million indigenous people worldwide (see Glossary for an inclusive definition), living under a wide range of social, economic, and political conditions and locations (Nakashima et al., 2012). Indigenous peoples represent the world's largest reserve of cultural diversity and the majority of languages (Sutherland, 2003). Climate change poses challenges for many indigenous peoples, including challenges to post-colonial power relations, cultural practices, their knowledge systems, and adaptive strategies. For example, the extensive literature on the Arctic shows that changing ice conditions pose risks in terms of access to food and increasingly dangerous travel conditions (Ford et al., 2008, 2009; Hovelsrud et al., 2011; see also Section 28.4.1). Accordingly, there is a strong research tradition on the impacts of climate change in regions with substantial indigenous populations that focuses on indigenous peoples and their attachment to place. Most studies focus on local, traditional, and rural settings (Cameron, 2012) and hence have been argued to create a knowledge gap regarding new urban indigenous populations. Indigenous peoples are often portrayed in the literature as victims of climate change (Salick and Ross, 2009) and as vulnerable to its consequences (ACIA, 2005). However, traditional knowledge is increasingly being combined with scientific understanding to facilitate a better understanding of the dynamic conditions of indigenous peoples (Huntington, 2011; see also Section 12.3.4)…. (2014a: 765)

Differences in vulnerability and exposure arise from non-climatic factors and from multidimensional inequalities often produced by uneven development processes *(very high confidence*). These differences shape differential risks from climate change. See Figure SPM.1. People who are socially, economically, culturally, politically, institutionally, or otherwise marginalized are especially vulnerable to climate change and also to some adaptation and mitigation responses (*medium evidence*, *high agreement*). This heightened vulnerability is rarely due to a single cause. Rather, it is the product of intersecting social processes that result in inequalities in socioeconomic status and income, as well as in exposure. Such social processes include, for example, discrimination on the basis of gender, class, ethnicity, age, and (dis)ability.[13] (2014a)

Cultural and social values

The value of human wellbeing is considered in Section 3.4.3, but the human world may also possess other values that do not form part of the wellbeing of individual humans. Living in a flourishing culture and society contributes to a person's wellbeing (Kymlicka, 1995; Appiah, 2010), but some authors claim that cultures and societies also possess values in their own right, over and above the contribution they make to wellbeing (Taylor, 1995). Climate change threatens damage to cultural artefacts and to cultures themselves (Adger et al., 2012). Evidence suggests that it may already be damaging the culture of Arctic indigenous peoples (Ford et al., 2006, 2008; Crate, 2008; Hassol, 2004; see also WGII Chapter 12). Cultural values and indigenous peoples are discussed in Section 3.10.2. (2014: 221)

Differences in vulnerability and exposure arise from non-climatic factors and from multidimensional inequalities often produced by uneven development processes (*very high confidence*). These differences shape differential risks from climate change. People who are socially, economically, culturally, politically, institutionally or otherwise marginalized are especially vulnerable to climate change and also to some adaptation and mitigation responses (*medium evidence, high agreement*). This heightened vulnerability is rarely due to a single cause. Rather, it is the product of intersecting social processes that result in inequalities in socio-economic status and income, as well as in exposure. Such social processes include, for example, discrimination on the basis of gender, class, ethnicity, age and (dis)ability. *{WGII SPM A-1, Figure SPM.1, 8.1–8.2, 9.3–9.4, 10.9, 11.1, 11.3–11.5, 12.2–12.5, 13.1–13.3, 14.1–14.3, 18.4, 19.6, 23.5, 25.8, 26.6, 26.8, 28.4, Box CC-GC}* (AR5: 54)

Key risks that span sectors and regions include the following (*high confidence*) *{WGII SPM B-1}*:

1. Risk of severe ill-health and disrupted livelihoods resulting from storm surges, sea level rise and coastal flooding; inland flooding in some urban regions; and periods of extreme heat.
2. Systemic risks due to extreme weather events leading to break- down of infrastructure networks and critical services.
3. Risk of food and water insecurity and loss of rural livelihoods and income, particularly for poorer populations.
4. Risk of loss of ecosystems, biodiversity and ecosystem goods, functions and services. (AR5: 65)

Livelihoods of indigenous peoples in the Arctic have been altered by climate change, through impacts on food security and traditional and cultural values (*medium confidence*). There is emerging evidence of climate change impacts on livelihoods of indigenous people in other regions. [18.4, Table 18-9, Box 18-5] (2014a)

25.8.2. Indigenous Peoples

25.8.2.1. Aboriginal and Torres Strait Islanders

Work since the AR4 includes a national Indigenous adaptation research action plan (Langton et al., 2012), regional risk studies (Green et al., 2009; DNP, 2010; TSRA, 2010; Nursey-Bray et al., 2013) and scrutiny from an Indigenous rights perspective (ATSISJC, 2009). Socioeconomic disadvantage and poor health (SCRGSP, 2011) indicate a disproportionate climate change vulnerability of Indigenous Australians (McMichael et al., 2009) although there are no detailed assessments. In urban and regional areas, where 75% of the Indigenous population lives (ABS, 2010b), assessments have not specifically addressed risks to Indigenous people (e.g., Guillaume et al., 2010). In other regions, all remote, there is limited empirical evidence of vulnerability (Maru et al., 2012). However, there is *medium evidence* and *high agreement* for significant future impacts from increasing heat stress, extreme events, and increased disease (Campbell et al., 2008; Spickett et al., 2008; Green et al., 2009).

The Indigenous estate comprises more than 25% of the Australian land area (Altman et al., 2007; NNTR, 2013). There is *high agreement* but *limited evidence* that natural resource dependence (e.g., Bird et al., 2005; Gray, M.C. et al., 2005; Kwan et al., 2006; Buultjens et al., 2010) increases Indigenous exposure and sensitivity to climate change (Green et al., 2009); climate change-induced dislocation, attenuation of cultural attachment to place, and loss of agency will disadvantage Indigenous mental health and community identity (Fritze et al., 2008; Hunter, 2009; McIntyre-Tamwoy and Buhrich, 2011); and, housing, infrastructure, services, and transport, often already inadequate for Indigenous needs especially in remote Australia (ABS, 2010c), will be further stressed (Taylor and Philp, 2010). Torres Strait island communities and livelihoods are vulnerable to major impacts from even small sea level rises (*high confidence*; DCC, 2009; Green, D. et al., 2010a; TSRA 2010).

Little adaptation of Indigenous communities to climate change is apparent to date (cf. Burroughs, 2010; GETF 2011; Nursey-Bray et al.,2013; Zander et al., 2013). Plans and policies that are imposed on Indigenous communities can constrain their adaptive capacity (Ellemor,2005; Petheram et al., 2010; Veland et al., 2010; Langton et al., 2012)but participatory development of adaptation strategies is challengedby multiple stressors and uncertainty about causes of observed changes (Leonard, S. et al., 2010; Nursey-Bray et al., 2013). Adaptation planning would benefit from a robust typology (Maru et al., 2011) across the diversity of Indigenous life experience (McMichael et al., 2009). Indigenous re-engagement with environmental management (e.g., Hunt et al., 2009; Ross et al., 2009) can promote health (Burgess et al., 2009) and may increase adaptive capacity (Berry et al., 2010; Davies et al., 2011). There is emerging interest in integrating Indigenous observations of climate change (Green, D. et al., 2010b; Petheram et al., 2010) and developing inter-cultural communication tools (Leonard, S. et al., 2010; Woodward et al., 2012). Extensive land ownership in northern and inland Australia and land management traditions mean that Indigenous people are well situated to provide greenhouse gas abatement and carbon sequestration services that may also support their livelihood aspirations (Whitehead et al., 2009; Heckbert et al., 2012).

25.8.2.2. New Zealand Māori

The projected impacts of climate change on Māori society are expected to be highly differentiated, reflecting complex economic, social, cultural, environmental, and political factors (*high confidence*).

Since the AR4, studies have been either sector-specific (e.g., Insley, 2007; Insley and Meade, 2008; Harmsworth et al., 2010; King et al., 2012) or more general, inferring risk and vulnerability based on exploratory engagements with varied stakeholders and existing social, economic, political, and ecological conditions (e.g., MfE, 2007b; Te Aho, 2007; King et al., 2010). The Māori economy depends on climate-sensitive primary industries with vulnerabilities to climate conditions (*high confidence*; Packman et al., 2001; NZIER, 2003; Cottrell et al., 2004; TPK, 2007; Tait et al., 2008b; Harmsworth et al., 2010; King et al., 2010; Nana et al., 2011a). Much of Māori-owned land is steep (>60%) and susceptible to damage from high intensity rainstorms, while many lowland areas are vulnerable to flooding and sedimentation (Harmsworth and Raynor, 2005; King et al., 2010). Land in the east and north is also drought prone, and this increases uncertainties for future agricultural performance, product quality, and investment (*medium confidence*; Cottrell et al., 2004; Harmsworth et al., 2010; King et al., 2010). The fisheries and aquaculture sector faces substantial risks (and uncertainties) from changes in ocean temperature and chemistry, potential changes in species composition, condition, and productivity levels (*medium confidence*; King et al., 2010; see also Section 25.6.2). At the community and individual level, Māori regularly utilize the natural environment for hunting and fishing, recreation, the maintenance of traditional skills and identity, and collection of cultural resources (King and Penny, 2006; King et al., 2012). Many of these activities are already compromised due to resource competition, degradation, and modification (Woodward et al., 2001; King et al., 2012). Climate change driven shifts in natural ecosystems will further challenge the capacities of some Māori to cope and adapt (*medium confidence*; King et al., 2012). (2014b)

Geographic isolation can be a key source of vulnerability for rural communities in North America, imposing long commutes to essential services like hospitals and non-redundant transportation corridors that can be compromised during extreme events (Chouinard et al., 2008). Many Indigenous communities are isolated, raising the costs and limiting the diversity of imported food, fuel, and other supplies, rendering the ability to engage in subsistence harvesting especially critical for both cultural and livelihood well-being (Andrachuk and Pearce, 2010; Hardess et al., 2011). Many Indigenous peoples also maintain strong cultural attachment to ancestral lands, and thus are especially sensitive to declines in the ability of that land to sustain their livelihoods and cultural well-being (Downing and Cuerrier, 2011). (2014b)

The Inuit and Saami have expressed strong concern about the effects of climate warming on their livelihoods (Forbes and Stammler, 2009; Magga et al., 2011). For the Inuit, the issues revolve around sea ice conditions, such as later freeze-up in autumn; earlier melt-out and faster sea ice retreat in spring; and thinner, less predictable ice in general (Krupnik and Jolly, 2002; Cochran et al., 2013). Diminished sea ice translates into more difficult access for hunting marine mammals, and greater risk for the long-term viability of subsistence species such as polar bear populations (*high confidence*; Laidre et al., 2008). Most Inuit communities depend to some extent on marine mammals for nutritional and cultural reasons, and many benefit economically from polar bear and narwhal hunting. A reduction in these resources represents a potentially significant economic loss (Hovelsrud et al., 2008). Among Fennoscandian Saami, the economic viability of reindeer herding is threatened by competition with other land users coupled with strict agricultural norms (Forbes, 2006; Magga et al., 2011). Reindeer herders are concerned that more extreme weather may exacerbate this situation (Oskal, 2008). (2014B)

There is general agreement that both Indigenous and non-Indigenous people in the Arctic have a history of adapting to natural variability in the climate and natural resource base, as well as recent socioeconomic, cultural, and technological changes (*high confidence*; Forbes and Stammler, 2009; Wenzel, 2009; Ford and Pearce, 2010; West and Hovelsrud, 2010; Bolton et al., 2011; Cochran et al., 2013). Climate change exacerbates the existing stresses faced by Arctic communities (*high confidence*; Crate and Nuttall, 2009; Rybråten and Hovelsrud, 2010), and is only one of many important factors influencing adaptation (Berrang-Ford et al., 2011). Climate adaptation needs to be seen in the context of these interconnected and mutually reinforcing factors (Tyler et al., 2007; Hovelsrud and Smit, 2010). The challenges faced today by communities in the Arctic are complex and interlinked and are testing their traditional adaptive capacity (*low* to *medium confidence*). (2014B)

Although wage employment may enhance the possibilities for adaptive capacity, greater involvement in full-time jobs can threaten social and cultural cohesion and mental well-being by disrupting the traditional cycle of land-based practices (Berner et al., 2005; Furgal, 2008). (2014b)

Worldwide, 850 million people live within 100 km of tropical coastal ecosystems such as coral reefs and mangroves deriving multiple benefits including food, coastal protection, cultural services, and income from industries such as fishing and tourism (Burke et al., 2011). (2014b)

Some chapters (Polar Regions, North America, Australasia) emphasize the challenges faced by indigenous peoples and communities in dealing with climate change (Sections 25.8.2, 26.8.2.2, 28.4.1). Although they are described as having some degree of adaptive capacity to deal with climate variability, shifts in lifestyles combined with a loss of traditional knowledge leave many groups more vulnerable to climate change (Section 28.2.4.2). Also, traditional responses have been found to be maladaptive because they are unable to adjust to the rate of change, or the broader context in which the change is taking place, as seen in the Arctic (28.4.1). In response to changing environmental conditions, people are taking on maladaptive behavior—for instance, by going further to hunt because of changed fish stocks and thus exposing themselves to greater risk, or changing to different species and depleting stocks (Section 28.4.1). Limits to traditional approaches for responding to changing conditions have also been observed in several Small Island States (29.8). (2014b)

In the European region, the indigenous populations present in the Arctic are considered vulnerable to climate change impacts on livelihoods and food sources (ACIA, 2005; see also Sections 12.3, 28.2.4). Research has focused on indigenous knowledge, impacts on traditional food sources, and community responses/adaptation (Mustonen and Mustonen, 2011a,b). However, these communities are also experiencing rapid social, economic, and other non-climate-related environmental changes (such as oil and gas exploration; see Section 28.2.4). There is evidence that climate change has altered the seasonal behavior of pastoralist populations, such as the Nenets reindeer herders in northern Russia (Amstislavski et al., 2013). However, socioeconomic factors may be more important than climate change for the future sustainability of reindeer husbandry (Rees et al., 2008; see also Section 28.2.3.5). (2014b)

28.2.5. Indigenous Peoples and Traditional Knowledge

Indigenous populations in the Arctic—the original Native inhabitants of the region—are considered especially vulnerable to climate change because of their close relationship with the environment and its natural resources for physical, social, and cultural well-being (Nuttall et al., 2005; Parkinson, 2009; Cochran et al., 2013). Although there are wide differences in the estimates, including variations in definitions of the Arctic region, Arctic Indigenous peoples are estimated to number between 400,000 and 1.3 million (Bogoyavlensky and Siggner, 2004; Galloway-McLean, 2010). According to 2010 census data, there are approximately 68,000 Indigenous people living in the Russian Arctic. These Arctic residents depend heavily on the region's terrestrial, marine, and freshwater renewable resources, including fish, mammals, birds, and plants; however, the ability of Indigenous peoples to maintain traditional livelihoods such as hunting, harvesting, and herding is increasingly being threatened by the unprecedented rate of climate change (*high confidence*; Nakashima et al., 2012; Cochran et al., 2013). In habitats across the Arctic, climate changes are affecting these livelihoods through decreased sea ice thickness and extent, less predictable weather, severe storms, sea level rise, changing seasonal melt/freeze-up of rivers and lakes, changes in snow type and timing, increasing shrub growth, permafrost thaw, and storm-related erosion, which, in turn, are causing such severe loss of land in some regions that a number of Alaskan coastal villages are having to relocate entire communities (Oskal, 2008; Forbes and Stammler, 2009; Mahoney et al., 2009; Bartsch et al., 2010; Weatherhead et al., 2010; ,Bronen, 2011; Brubaker et al., 2011b,c; Eira et al., 2012; Huntington and Watson, 2012; McNeeley, 2012; Maldonado et al., 2013). In addressing these climate impacts, Indigenous communities must at the same time consider multiple other stressors such as resource development (oil and gas, mining); pollution; changes in land use policies; changing forms of governance; and the prevalence in many Indigenous communities of poverty, marginalization, and

resulting health disparities (Abryutina, 2009; Forbes et al., 2009; Reinert et al., 2009; Magga et al., 2011; Vuojala-Magga et al., 2011; Nakashima et al., 2012; Mathiesen et al., 2013).
Traditional knowledge is the historical knowledge of Indigenous peoples accumulated over many generations and it is increasingly emerging as an important knowledge base for more comprehensively addressing the impacts of environmental and other changes as well as development of appropriate adaptation strategies for Indigenous communities (WGII AR4 Chapter 15; Oskal, 2008; Reinert et al., 2008; Wildcat, 2009; Magga et al., 2011; Vuojala-Magga et al., 2011; Nakashima et al., 2012; Vogesser et al, 2013). For example, Saami reindeer herders have specialized knowledge of dynamic snow conditions, which mediate access to forage on autumn, winter, and spring reindeer rangelands (Roturier and Roue, 2009; Eira et al., 2012; Vikhamar-Schuler et al., 2013) and traditional governance systems for relating to natural environments (Sara, 2013). Increasingly, traditional knowledge is being combined with Western scientific knowledge to develop more sustainable adaptation strategies for all communities in the changing climate.
For example, at Clyde River, Nunavut, Canada, Inuit experts and scientists both note that wind speed has increased in recent years and that wind direction changes more often over shorter periods (within a day) than it did during the past few decades (Gearheard et al., 2010; Overland et al., 2012). In Norway, Sámi reindeer herders and scientists are both observing direct and indirect impacts to reindeer husbandry such as changes in snow and ice cover, forage availability, and timing of river freeze-thaw patterns from increasing temperatures (Eira et al., 2012). On the Yamal Peninsula in western Siberia, detailed Nenets observations and recollections of iced-over autumn and winter pastures due to rain- on-snow events have proven suitable for calibrating the satellite-based microwave sensor SeaWinds (Bartsch et al., 2010) and NASA's AMSR-E sensor. (2014b)

In North Asia, climate-driven changes in tundra and forest-tundra biomes may influence indigenous peoples who depend on nomadic tundra pastoralism, fishing, and hunting (Kumpula et al., 2011). (2014b)

Indigenous peoples in both Australia and New Zealand have higher than average exposure to climate change because of a heavy reliance on climate-sensitive primary industries and strong social connections to the natural environment, and face particular constraints to adaptation (*medium confidence*). Social status and representation, health, infrastructure and economic issues, and engagement with natural resource industries constrain adaptation and are only partly offset by intrinsic adaptive capacity (*high confidence*). Some proposed responses to climate change may provide economic opportunities, particularly in New Zealand related to forestry. Torres Strait communities are vulnerable even to small sea level rises (*high confidence*). {25.3, 25.8.2} (2014b)

Significant advances had occurred in understanding future impacts on water, ecosystems, indigenous people and health, together with an increased focus on adaptation; potential impacts would be substantial without further adaptation, particularly for water security, coastal development, biodiversity, and major infrastructure, but impacts on agriculture and forestry would be variable across the region, including potential benefits in some areas. (2014b)

Indigenous peoples constitute about 2.5% and 15% of the Australian and New Zealand populations, respectively, but in Australia, their national share is growing and they constitute a much higher percentage of the population in remote and very remote regions (ABS, 2009, 2010b; SNZ, 2010a). Indigenous peoples in both countries have lower than average life expectancy, income, and education, implying that changes in socioeconomic status and social inclusion could strongly influence their future adaptive capacity (see Section 25.8.2). (2014b)

Observed impacts on livelihoods, economic activities, infrastructure, and access to services in North American urban and rural settlements have been attributed to SLR, changes in temperature and precipitation, and occurrences of such extreme events as heat waves, droughts, and storms (*high confidence*). {26.8.2.1} Differences in the severity of climate impacts on human settlements are strongly influenced by context-specific social and environmental factors and processes that contribute to risk, vulnerability, and adaptive capacity such as hazard magnitude, populations access to assets, built environment features, and governance (*high confidence*). {26.8.2.1-2}. Some of these processes (e.g., the legacy of previous and current stresses) are common to urban and rural settlements, while others are more pertinent to some types of settlements than others. For example, human and capital risks are highly concentrated in some highly exposed urban locations, while in rural areas, geographic isolation and institutional deficits are key sources of vulnerability. Among the most vulnerable are indigenous peoples due to their complex relationship with their ancestral lands and higher reliance on subsistence economies, and those urban centers where high concentrations of populations and economic activities in risk-prone areas combine with several socioeconomic and environmental sources of vulnerability (*high confidence*). {26.8.2.1-2} Although larger urban centers would have higher adaptation capacities, future climate risks from heat waves, droughts, storms, and SLR in cities would be enhanced by high population density, inadequate infrastructures, lack of institutional capacity, and degraded natural environments (*medium evidence*, *high agreement*). {26.8.3} (2014b)

Coffee, an economically important crop supporting 500,000 primarily indigenous households (González Martínez, 2006), is projected to decline 34% by 2020 in Veracruz if historic temperature and precipitation trends continue (Gay et al., 2006); see also Schroth et al. (2009), on declines in Chiapas. (2014b)

Impacts include the loss of 3.2 million tons of maize in Mexico, placing 2.5 million at risk of food insecurity (DGCS, 2012). Among the most severely affected were indigenous peoples, such as the Rarámuri of Chihuahua (DGCS, 2012). Closely associated with droughts, the impacts of recent wildfires have been significant (see Box 26-2), and have intensified inequalities in vulnerability between amenity migrants and low-income residents in peri-urban areas of California and Colorado (Collins and Bolin, 2009). (2014b)

Indigenous communities have lower education levels and high levels of poverty, but are younger than average populations (Downing and Cuerrier, 2011). The legacy of their colonial history, furthermore, has stripped Indigenous communities of land and many sources of social and human capital (Brklacich et al., 2008; Hardess et al., 2011). Conversely, rural and Indigenous community members possess valuable local and experiential knowledge regarding regional ecosystem services (Galloway McLean et al., 2011). (2014b)

Many Indigenous communities are isolated, raising the costs and limiting the diversity of imported food, fuel, and other supplies, rendering the ability to engage in subsistence harvesting especially critical for both cultural and livelihood well-being (Andrachuk and Pearce, 2010; Hardess et al., 2011). Many Indigenous peoples also maintain strong cultural attachment to ancestral lands, and thus are especially sensitive to declines in the ability of that land to sustain their livelihoods and cultural well-being (Downing and Cuerrier, 2011). (2014b)

Rural physical infrastructure is often inadequate to meet service needs or is in poor condition (McLeman and Gilbert, 2008; Krishnamurthy et al., 2011), especially for Indigenous communities (Brklacich et al., 2008; Hardess et al., 2011; Lal et al., 2011; see also Section 26.9). A lack of redundant power and communication services can compromise hazard response capacity.

Associated with inequality are disparities in access to water, sanitation, and adequate housing for the most vulnerable groups—for example, indigenous peoples, Afro-descendants, children, and women living in poverty—and in their exposure to the effects of climate change. The strong heterogeneity of subnational territorial entities in the region takes the form of high spatial concentration and persistent disparities in the territorial distribution of wealth (ECLAC, 2010g,h, 2011b). (2014b)

28.2.4. Health and Well-being of Arctic Residents

The warming Arctic and major changes in the cryosphere are significantly impacting the health and well-being of Arctic residents and projected to increase, especially for many Indigenous peoples. Although impacts are expected to vary among the diverse settlements that range from small, remote, predominantly Indigenous to large cities and industrial settlements, this section focuses more on health impacts of climate change on Indigenous, isolated, and rural populations because they are especially vulnerable to climate change owing to a strong dependence on the environment for food, culture, and way of life; their political and economic marginalization; existing social, health, and poverty disparities; as well as their frequent close proximity to exposed locations along ocean, lake, or river shorelines (Ford and Furgal, 2009; Galloway-McLean, 2010; Larsen et al., 2010; Cochran et al., 2013).

Changing river and sea ice conditions affect the safety of travel for Indigenous populations especially, and inhibit access to critical hunting, herding, and fishing areas (Andrachuk and Pearce, 2010; Derksen et al., 2012; Huntington and Watson, 2012).

The consumption of traditional foods by Indigenous peoples places these populations at the top of the Arctic food chain and through biomagnification, therefore, they may receive some of the highest exposures in the world to certain contaminants (Armitage et al., 2011; UNEP and AMAP, 2011). Contaminants such as POPs are known for their adverse neurological and medical effects on humans, particularly the developing fetus, children, women of reproductive age, and the elderly; thus it is important to include contaminants as a significant part of any climate impact assessment (UNEP and AMAP, 2011).

Sharp increases in future oil and gas and other resource development in the Russian north and other Arctic regions are anticipated—along with associated infrastructure, pollution, and other development byproducts— which will reduce the availability of pasturelands for reindeer and use by Indigenous communities (Derome and Lukina, 2011; Degteva and Nellermann, 2013).

28.3.4. Economic Sectors
Projections of economic costs of climate change impacts for different economic sectors in the Arctic are limited, but current assessments suggest that there will be both benefits and costs (AMAP, 2011a; Forbes, 2011). Non-Arctic actors are likely to receive most of the benefits from increased shipping and commercial development of renewable and non-renewable resources, while Indigenous peoples and local Arctic communities will have a harder time maintaining their way of life (Hovelsrud et al., 2011). (2014b)

3.10.2.2 Indigenous peoples

Indigenous peoples number millions across the globe (Daes, 1996). Land and the natural environment are integral to their sense of identity and belonging and to their culture, and are essential for their survival (Gilbert, 2006; Xanthaki, 2007). The ancestral lands of indigenous peoples contain 80% of the earth's remaining healthy eco-systems and global biodiversity priority areas, including the largest tropical forests (Sobrevila, 2008). Because they depend on natural resources and inhabit biodiversity-rich but fragile ecosystems, indigenous peoples are particularly vulnerable to climate change and have only limited means of coping with such change (Henriksen, 2007; Permanent Forum on Indigenous Issues, 2008). They are often marginalized in decision making and unable to participate adequately in local, national, regional, and international climate-change mechanisms. Yet, it is increasingly being recognized that indigenous peoples can impart valuable insights into ways of managing mitigation and adaptation (Nakashima et al., 2012), including forest governance and conserving ecosystems (Nepstad et al., 2006; Hayes and Murtinho, 2008; Persha et al., 2011). (2014)

4.6 Practices and Knowledge

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, 1997; 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; see also Section 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) emphasize 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 Section 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). (2014a)

Box Intro 1: Risk and the Management of an Uncertain Future

- Climate change exposes people, societies, economic sectors and ecosystems to risk. Risk is the potential for consequences when some- thing of value is at stake and the outcome is uncertain, recognizing the diversity of values. {WGII SPM Background Box SPM.2, WGIII 2.1, SYR Glossary}
- Risk can be understood either qualitatively or quantitatively. It can be reduced and managed using a wide range of formal or informal tools and approaches that are often iterative. Useful approaches for managing risk do not necessarily require that risk levels can be accurately quantified. Approaches recognizing diverse qualitative values, goals and priorities, based on ethical, psychological, cultural or social factors, could increase the effectiveness of risk management. {WGII 1.1.2, 2.4, 2.5, 19.3, WGIII 2.4, 2.5, 3.4} (AR5)

Some have argued that the bio-cultural heritage of indigenous peoples is a resource that should be valued and preserved as it constitutes an irreplaceable bundle of teachings on the practices of mitigation and sustainability (Sheridan and Longboat, 2006; Russell-Smith et al., 2009; Kronik and Verner, 2010). Sometimes local strategies and indices have metamorphosed into national policies, as in the case of '*Buen Vivir*' in Ecuador (Choquehuanca, 2010; Gudynas, 2011) and 'Gross National Happiness' (GNH), described in Box 3.11. In rich countries, and among social groups with high levels of environmental awareness, interest in sustainability has given rise to cultural movements promot-ing change in modes of thought, production, and consumption. Includ- ing the cultural dimension in mitigation policies facilitates social acceptability. (2014: 225)

12.3.3. Local and Traditional Forms of Knowledge

There is *high agreement* among researchers that involvement of local people and their local, traditional, or indigenous forms of knowledge in decision making is critical for ensuring their security (Ellemor, 2005; Kesavan and Swaminathan, 2006; Burningham et al., 2008; Mercer et al., 2009; Pearce et al., 2009; Anik and Khan, 2012). Such forms of knowledge include categories such as traditional ecological knowledge, indigenous science, and ethnoscience (Nakashima and Roué, 2002)…. (2014a)

Frequently Asked Questions

FAQ 12.2 | Can lay knowledge of environmental risks help adaptation to climate change?

Lay knowledge about the environment and climate is deeply rooted in history, and encompasses important aspects of human life. Lay knowledge is particularly pertinent in cultures with an intimate relationship between people and the environment. For many indigenous and rural communities, for example, livelihood activities such as herding, hunting, fishing, or farming are directly connected to and dependent on climate and weather conditions. These communities thus have critical knowledge about dealing with environment changes and associated societal conditions. In regions around the world, such knowledge is commonly used in adapting to environmental conditions and is directly relevant to adaptation to climate change. (2014a: also see 779-791; 920)

Indigenous peoples

Indigenous peoples and nations are those that, having a historical continuity with pre-invasion and pre-colonial societies that developed on their territories, consider themselves distinct from other sectors of the societies now prevailing on those territories, or parts of them. They form at present principally non-dominant sectors of society and are often determined to preserve, develop, and transmit to future generations their ancestral territories, and their ethnic identity, as the basis of their continued existence as peoples, in accordance with their own cultural patterns, social institutions, and common law system.[12] (2014b: 1767)

The relevance of values to SD and, particularly, to ecologically conscious (consumer) behaviour, is related to the nature of environmental issues as 'social dilemmas', where short-term narrow individual interests conflict with the longer term social interest (Pepper et al., 2009). Researchers have highlighted the role of non-selfish values that promote the welfare of others (including nature), noting that some but not all indigenous societies are known to focus on 'collective' as opposed to 'individual' interests and values, which often result in positive resource conservation strategies and wellbeing (Gadgil et al., 1993; Sobrevila, 2008; Watson et al., 2011). However, it is well known that a range of factors also mediate the impact of values on behaviour so that the link from values to ecologically conscious behaviour is often loose (Pepper et al., 2009). (2014: 230)

Box 18-5 | Detection, Attribution, and Traditional Ecological Knowledge

Indigenous and local peoples often possess detailed knowledge of climate change that is derived from observations of environmental conditions over many generations. Consequently, there is increasing interest in merging this traditional ecological knowledge (TEK)—also referred to as indigenous knowledge—with the natural and social sciences in order to better understand and detect climate change impacts (Huntington et al., 2004; Parry et al., 2007; Salick and Ross, 2009; Green and Raygorodetsky, 2010; Ford et al., 2011; Diemberger et al., 2012). TEK, however, does not simply augment the sciences, but rather stands on its own as a valued knowledge system that can, together with or independently of the natural sciences, produce useful knowledge for climate change detection or adaptation (Agrawal, 1995; Cruikshank, 2001; Hulme, 2008; Berkes, 2009; Byg and Salick, 2009; Maclean and Cullen, 2009; Wohling, 2009; Ziervogel and Opere, 2010; Ford et al., 2011; Herman-Mercer et al., 2011).

Cases in which TEK and scientific studies both detect the same phenomenon offer a higher level of confidence about climate change impacts and environmental change (Huntington et al., 2004; Laidler, 2006; Krupnik and Ray, 2007; Salick and Ross, 2009; Gamble et al., 2010; Green and Raygorodetsky, 2010; Alexander et al., 2011; Cullen-Unsworth et al., 2012). Evidence is available in particular from Nordic and Mountain peoples, for example, from Peru's Cordillera Blanca mountains (Bury et al., 2010; Carey, 2010; Baraer et al., 2012; Carey et al., 2012b), Tibet (Byg and Salick, 2009), and Canada (Nichols et al., 2004; Laidler, 2006; Krupnik and Ray, 2007; Ford et al., 2009; Aporta et al., 2011). TEK can also inspire scientists to study new issues in the detection of climate change impacts. In one case, experienced Inuit weather forecasters in Baker Lake, Nunavut, Canada, reported that it had become increasingly difficult for them to predict weather, suggesting an increase of weather variability and anomalies in recent years. To test Inuit observations, scientists analyzing hourly temperature data over a 50-year period confirmed that afternoon temperatures fluctuated much more during springtime during the last 20 years—precisely when Inuit forecasters noted unpredictability—than they had during the previous 30 years (Weatherhead et al., 2010).

Despite frequent confluence between TEK and scientific observations, there are sometimes discrepancies between them, indicating uncertainty in the identification of climate change impacts. They can arise because TEK and scientific studies frequently focus on different and distinct scales that make comparison difficult. Local knowledge may fail to detect regional environmental changes while scientific regional or global scale analyses may miss local variation (Wohling, 2009; Gamble et al., 2010). Furthermore, TEK- based observations and related interpretations necessarily need to be

viewed within the context of the respective cultural, social, and political backgrounds (Agrawal, 1995). Therefore, a direct translation of TEK into a natural science perspective is often not feasible. (2014a: 1001)
The above box, Box 18-5, was referenced three times in the rest of the publication.
Text references are below:

- Livelihoods of indigenous peoples in the Arctic have been altered by climate change, through impacts on food security and traditional and cultural values (*medium confidence*). There is emerging evidence of climate change impacts on livelihoods of indigenous people in other regions. [18.4, Table 18-9, Box 18-5]. (P. 50)
- The rate of Arctic sea ice decline has increased significantly during the first decade of the 21st century, due to warming (WGI AR5 Section 4.2.2). It is *very likely* that at least some of the decline in Arctic sea ice extent can be attributed to anthropogenic climate forcing (WGI AR5 Section 10.5.1). Observations by Inuit people in the Canadian Arctic confirm with *high confidence* the instrumental observations on the various changes of sea ice (see Box 18-5). Antarctic sea ice has slightly increased over the past 30 years, yet with strong regional differences (WGI AR5 Section 4.2.3). (P. 986)
- Livelihoods of indigenous people in the Arctic have been identified as among the most severely affected by climate change, including food security aspects, traditional travel and hunting, and cultural values and references (Hovelsrud et al., 2008; Ford et al., 2009; Ford, 2009a,b; Beaumier and Ford, 2010; Pearce et al., 2010; Olsen et al., 2011; Eira, 2012; Crate, 2013; see also Box 18-5, Table 18-9). Impacts of rising temperatures, increased variability, and weather extremes on crops and livestock of indigenous people in highlands were reported from Tibet Autonomous Region, China (Byg and Salick, 2009), and the Andes of Bolivia (McDowell and Hess, 2012). (P. 1003)

15.6.1 Case Study: traditional knowledge for adaptation
Among Arctic peoples, the selection pressures for the evolution of an effective knowledge base have been exceptionally strong, driven by the need to survive off highly variable natural resources in the remote, harsh Arctic environment. In response, they have developed a strong knowledge base concerning weather, snow and ice conditions as they relate to hunting and travel, and natural resource availability (Krupnik and Jolly, 2002). These systems of knowledge, belief and practice have been developed through experience and culturally transmitted among members and across generations (Huntington, 1998; Berkes, 1999). This Arctic indigenous knowledge offers detailed information that adds to conventional science and environmental observations, as well as to a holistic understanding of environment, natural resources and culture (Huntington et al., 2004). There is an increasing awareness of the value of Arctic indigenous knowledge and a growing collaborative effort to document it. In addition, this knowledge is an invaluable basis for developing adaptation and natural resource management strategies in response to environmental and other forms of change…(AR4: 674)

Box 20.1. Role of local and indigenous knowledge in adaptation and sustainability research
Research on indigenous environmental knowledge has been undertaken in many countries, often in the context of understanding local oral histories and cultural attachment to place. A survey of research during the 1980s and early 1990s was produced by Johnson (1992). Reid et al. (2006) outline the many technical and social issues related to the intersection of different knowledge systems, and the challenge of linking the scales and contexts associated with these forms of knowledge. With the increased interest in climate change and global environmental change, recent studies have emerged that explore how indigenous knowledge can become part of a shared learning effort to address climate-change impacts and adaptation, and its links with sustainability. Some examples are indicated here.
Sutherland et al. (2005) describe a community-based vulnerability assessment in Samoa, addressing both future changes in climate-related exposure and future challenges for improving adaptive capacity. Twinomugisha (2005) describes the dangers of not considering local knowledge in dialogues on food security in Uganda.

A scenario-building exercise in Costa Rica has been undertaken as part of the Millennium Ecosystem Assessment (MA, 2005). This was a collaborative study in which indigenous communities and scientists developed common visions of future development. Two pilot five-year storylines were constructed, incorporating aspects of coping with external drivers of development (Bennett and Zurek, 2006). Although this was not directly addressing climate change, it demonstrates the potential for joint scenario-building incorporating different forms of knowledge.
In Arctic Canada, traditional knowledge was used as part of an assessment which recognised the implications of climate change for the ecological integrity of a large freshwater delta (NRBS, 1996). In another case, an environmental assessment of a proposed mine was produced through a partnership with governments and indigenous peoples. Knowledge to facilitate sustainable development was identified as an explicit goal of the assessment, and climate-change impacts were listed as one of the long-term concerns for the region (WKSS, 2001).
Vlassova (2006) describes results of interviews of indigenous peoples of the Russian North on climate and environmental trends within the Russian boreal forest. Additional examples from the Arctic are described in ACIA (2005), Reidlinger and Berkes (2001), Krupnik and Jolly (2002), Furgal et al. (2006) and Chapter 15. (AR4)

The evolution of the IPCC assessments of impacts, adaptation, and vulnerability indicates an increasing emphasis on human beings, their role in managing resources and natural systems, and the societal impacts of climate change. The expanded focus on societal impacts and responses is evident in the composition of the IPCC author teams, the literature assessed, and the content of the IPCC assessment reports. Characteristics in the evolution of the Working Group II assessment reports are an increasing attention to (1) adaptation limits and transformation in social and natural systems; (2) synergies between multiple variables and factors that affect sustainable development; (3) risk management; and (4) institutional, social, cultural, and value-related issues. {1.1, 1.2} (2014a)

Reindeer herders have developed a wide range of adaptation strategies in response to changing pasture conditions. These include moving herds to better pastures (Bartsch et al., 2010), providing supplemental feeding (Helle and Jaakkola, 2008; Forbes and Kumpula, 2009), retaining a few castrated reindeer males to break through heavy ice crust (Oskal, 2008; Reinert et al., 2008), ensuring an optimal herd size (Tyler et al., 2007; Forbes et al., 2009), and creating multicultural initiatives combining traditional with scientific knowledge (Vuojala-Magga et al., 2011). Coastal fishers have adapted to changing climate by targeting different species and diversifying income sources (Hovelsrud et al., 2010). (2014b)

28.2.5. Indigenous Peoples and Traditional Knowledge

Indigenous populations in the Arctic—the original Native inhabitants of the region—are considered especially vulnerable to climate change because of their close relationship with the environment and its natural resources for physical, social, and cultural well-being (Nuttall et al., 2005; Parkinson, 2009; Cochran et al., 2013). Although there are wide differences in the estimates, including variations in definitions of the Arctic region, Arctic Indigenous peoples are estimated to number between 400,000 and 1.3 million (Bogoyavlensky and Siggner, 2004; Galloway-McLean, 2010). According to 2010 census data, there are approximately 68,000 Indigenous people living in the Russian Arctic. These Arctic residents depend heavily on the region's terrestrial, marine, and freshwater renewable resources, including fish, mammals, birds, and plants; however, the ability of Indigenous peoples to maintain traditional livelihoods such as hunting, harvesting, and herding is increasingly being threatened by the unprecedented rate of climate change (*high confidence*; Nakashima et al., 2012; Cochran et al., 2013). In habitats across the Arctic, climate changes are affecting these livelihoods through decreased sea ice thickness and extent, less predictable weather, severe storms, sea level rise, changing seasonal melt/freeze-up of rivers and lakes, changes in snow type and timing, increasing shrub growth, permafrost thaw, and storm-related erosion, which, in turn, are causing such severe loss of land in some regions that a number of Alaskan coastal villages are having to relocate entire communities (Oskal, 2008; Forbes and Stammler, 2009; Mahoney et al., 2009; Bartsch et al., 2010; Weatherhead et al., 2010; ,Bronen, 2011; Brubaker et al., 2011b,c; Eira et al., 2012; Huntington and Watson, 2012; McNeeley, 2012; Maldonado et al., 2013). In addressing these climate impacts, Indigenous communities must at the same time consider multiple other stressors such as resource development (oil and gas, mining); pollution; changes in land use policies; changing forms of governance; and the prevalence in many Indigenous communities of poverty, marginalization, and resulting health disparities (Abryutina, 2009; Forbes et al., 2009; Reinert et al., 2009; Magga et al., 2011; Vuojala-Magga et al., 2011; Nakashima et al., 2012; Mathiesen et al., 2013). (2014b)

Several Arctic coastal sea-run fishes are targeted for subsistence and commercial use in the Arctic. Commercial transactions from fishing are typically for local markets; however, the socioeconomic and cultural importance of these fishes to Indigenous peoples far outweighs their monetary value. Reist et al. (2006) and Fechhelm et al. (2007) found that climate-related factors that influenced the water level and freshening of rivers were related to run size of Arctic cisco (*Coregonus autumnalis*). Similarly, a recent study based on Chinook salmon (*Oncorhynchus tshawytscha*) run timing for the period 1961–2009 showed that success in the fishery was dependent on the timing of the marine exit, which was tightly coupled to environmental conditions that were linked to climate (Mundy and Evenson, 2011). (2014b)

The adaptive capacity of Arctic Indigenous peoples is largely due to an extensive traditional knowledge and cultural repertoire, and flexible social networks (*medium confidence*; Williams and Hardison, 2013; see Section 12.3). The dynamic nature of traditional knowledge is valuable for adapting to current conditions (Kitti et al., 2006; Tyler et al., 2007; Eira et al., 2012). The sharing of knowledge ensures rapid responses to crises (Ford et al., 2007). In addition, cultural values such as sharing, patience, persistence, calmness, and respect for elders and the environment are important. Some studies suggest that traditional knowledge may not always be sufficient to meet the rapid changes in climate (see Chapter 12) and it may be perceived to be less reliable because the changing conditions are beyond the current knowledge range (Ingram et al., 2002; Ford et al., 2006; Hovelsrud et al., 2010; Valdivia et al., 2010). (2014b)

Over the last half-century, the adaptive capacity in some Indigenous communities has been challenged by the transition from semi-nomadic hunting groups to permanent settlements, accompanied by impacts to health and well-being from loss of connection to the land, traditional foods, and culture (Ford et al., 2010; Galloway-McLean, 2010). Forced or voluntary migration as an adaptation response can have deep cultural impacts (Shearer, 2011, 2012; Maldonado et al., 2013). On the other hand, the establishment of permanent communities, particularly those associated with new industrial development, can also lead to increasing employment opportunities and income diversification for Indigenous peoples. The intergenerational transfers of knowledge and skills through school curricula, land camps, and involvement in community-based monitoring programs may strengthen adaptive capacity (Forbes 2007; Ford et al., 2007; Hovelsrud and Smit, 2010; Bolton et al., 2011). (2014b)

An obvious implication of the mentioned impacts is the need to replace the energy lost through alternative (see Section 27.3.6.2) or traditional sources. (2016b)

Table 21-4 (continued)

Community-based adaptation and traditional practices in small island contexts	
Exposure and vulnerability	With small land area, often low elevation coasts, and concentration of human communities and infrastructure in coastal zones, small islands are particularly vulnerable to rising sea levels and impacts such as inundation, saltwater intrusion, and shoreline change. [29.3.1, 29.3.3, 29.6.1, 29.6.2, 29.7.2]
Climate information at the global scale	**Observed:** • *Likely* increase in the magnitude of extreme high sea level events since 1970, mostly explained by rising mean sea level. [WGI AR5 3.7.5] • *Low confidence* in long-term (centennial) changes in tropical cyclone activity, after accounting for past changes in observing capabilities. [WGI AR5 2.6.3] • Singe 1950 the number of heavy precipitation events over land has *likely* increased in more regions than it has decreased. [WGI AR5 2.6.2] **Projected:** • *Very likely* significant increase in the occurrence of future sea level extremes by 2050 and 2100. [WGI AR5 13.7.2] • In the 21st century, *likely* that the global frequency of tropical cyclones will either decrease or remain essentially unchanged. *Likely* increase in both global mean tropical cyclone maximum wind speed and rainfall rates. [WGI AR5 14.6] • Globally, for short-duration precipitation events, *likely* shift to more intense individual storms and fewer weak storms. [WGI AR5 12.4.5]
Climate information at the regional scale	**Observed:** Change in sea level relative to the land (relative sea level) can be significantly different from the global mean sea level change because of changes in the distribution of water in the ocean and vertical movement of the land. [WGI AR5 3.7.3] **Projected:** • *Low confidence* in region-specific projections of storminess and associated storm surges. [WGI AR5 13.7.2] • Projections of regional changes in sea level reach values of up to 30% above the global mean value in the Southern Ocean and around North America, and between 10% and 20% above the global mean value in equatorial regions. [WGI AR5 13.6.5] • *More likely than not* substantial increase in the frequency of the most intense tropical cyclones in the western North Pacific and North Atlantic. [WGI AR5 14.6]
Description	Traditional technologies and skills can be relevant for climate adaptation in small island contexts. In the Solomon Islands, relevant traditional practices include elevating concrete floors to keep them dry during heavy precipitation events and building low aerodynamic houses with palm leaves as roofing to avoid hazards from flying debris during cyclones, supported by perceptions that traditional construction methods are more resilient to extreme weather. In Fiji after Cyclone Ami in 2003, mutual support and risk sharing formed a central pillar for community-based adaptation, with unaffected households fishing to support those with damaged homes. Participatory consultations across stakeholders and sectors within communities and capacity building taking into account traditional practices can be vital to the success of adaptation initiatives in island communities, such as in Fiji or Samoa. [29.6.2]
Broader context	• Perceptions of self-efficacy and adaptive capacity in addressing climate stress can be important in determining resilience and identifying useful solutions. • The relevance of community-based adaptation principles to island communities, as a facilitating factor in adaptation planning and implementation, has been highlighted, for example, with focus on empowerment and learning-by-doing, while addressing local priorities and building on local knowledge and capacity. Community-based adaptation can include measures that cut across sectors and technological, social, and institutional processes, recognizing that technology by itself is only one component of successful adaptation. [5.5.4, 29.6.2]

Community-based adaptation is happening and being planned in many developing regions, especially in locations that are particularly poor. In small islands, where a significant increase in the occurrence of future sea level extremes by 2050 and 2100 is anticipated, traditional technologies and skills may still be relevant for adapting (Table 21-4). In the Solomon Islands, relevant traditional practices include elevating concrete floors to keep them dry during heavy precipitation events and building low aerodynamic houses with palm leaves as roofing to avoid hazards from flying debris during cyclones, supported by perceptions that traditional construction methods are more resilient to extreme weather. In Fiji, after Cyclone Ami in 2003, mutual support and risk sharing formed a central pillar for community-based adaptation, with unaffected households fishing to support those with damaged homes. Participatory consultations across stakeholders and sectors within communities and capacity building taking into account traditional practices can be vital to the success of adaptation initiatives in island communities, such as in Fiji or Samoa. These actions provide more than just the immediate benefits; they empower people to feel in control of their situations. (2014b)

Traditional knowledge: African communities have prior experience with climate variability, although this knowledge will not be sufficient to face climate change impacts. (2014b)

Inherent adaptation-related strengths in Africa include the continent's wealth in natural resources, well-developed social networks, and longstanding traditional mechanisms of managing variability through, for example, crop and livelihood diversification, migration, and small-scale enterprises, all of which are underpinned by local or indigenous knowledge systems for sustainable resource management (Eyong, 2007; Nyong et al., 2007; UNFCCC, 2007; Cooper et al., 2008; Macchi et al., 2008; Nielsen, 2010; Castro et al., 2012). (2014b)

Community-level DRR initiatives include activities that link food security, household resilience, environmental conservation, asset creation, and infrastructure development objectives and co-benefits (Parry et al., 2009a; UNISDR, 2011; Frankenberger et al., 2012). Food security and nutrition-related safety nets and social protection mechanisms can mutually reinforce each other for DRR that promotes adaptation, as in Uganda's Karamoja Productive Assets Program (Government of Uganda and WFP, 2010; WFP, 2011). Initiatives in Kenya, South Africa, Swaziland, and Tanzania have also sought to deploy local and traditional knowledge for the purposes of disaster preparedness and risk management (Mwaura, 2008; Galloway McLean, 2010). Haan et al. (2012) highlight the need for increased donor commitment to the resilience-building agenda within the framework of DRR, based on lessons from the 2011 famine in Somalia. (2014b)

Transdisciplinary approaches, which hold promise for enhancing linkages between sectors and thus reducing maladaptation are also starting to be adopted, as for example in the urban context (Evans, 2011). Learning approaches for adaptation may involve co-production of knowledge—such as combining local and traditional knowledge with scientific knowledge (Section 22.4.5.4). (2014b)

Recent literature has confirmed the positive role of local and traditional knowledge in building resilience and adaptive capacity, and shaping responses to climatic variability and change in Africa (Nyong et al., 2007; Osbahr et al., 2007; Goulden et al., 2009b; Ifejika Speranza et al., 2010; Jalloh et al., 2011b; Newsham and Thomas, 2011). (2014b)

Water harvesting refers to a collection of traditional practices in which farmers use small planting pits, half-moon berms, rock bunds along contours, and other structures to capture runoff from episodic rain events (Kandji et al., 2006). (2016b)

The political context can also undermine autonomous adaptation and lead to maladaptation; for instance, Smucker and Wisner (2008) found that political and economic changes in Kenya meant that farmers could no longer use traditional strategies for coping with climatic shocks and stressors, with the poorest increasingly having to resort to coping strategies that undermined their long-term livelihood security, also known as erosive coping, such as more intensive grazing of livestock and shorter crop rotations (van der Geest and Dietz, 2004). In a case from the Simiyu wetlands in Tanzania, Hamisi et al. (2012) find that coping and reactive adaptation strategies may lead to maladaptation—for instance, through negative impacts on natural vegetation because of increased intensity of farming in wetter parts of the floodplain, where farmers have moved to exploit the higher soil water content.
Some diversification strategies, such as charcoal production and artisanal mining, may increase risk through promoting ecological change and the loss of ecosystem services to fall back on (Paavola, 2008; Adger et al., 2011; Shackleton and Shackleton, 2012). Studies also highlight risks that traditional adaptive pastoralism systems may be replaced by maladaptive activities. For example, charcoal production has become a major source of income for 70% of poor and middle-income pastoralists in some areas of Somaliland, with resultant deforestation (Hartmann and Sugulle, 2009). (2014b)

Indigenous Peoples

Although Arctic indigenous peoples with traditional lifestyles are facing unprecedented impacts to their ways of life from climate change and resource development (oil and gas, mining, forestry, hydropower, tourism, etc.), they are already implementing creative ways of adapting (*high confidence*; Cruikshank, 2001; Forbes et al., 2006; Krupnik and Ray, 2007; Salick and Ross, 2009; Green and Raygorodetsky, 2010; Alexander et al., 2011; Cullen-Unsworth et al., 2011).
While many of these adaptation activities tend to be short term or reactive in nature (e.g., dealing with other issues such as disaster response planning), some Indigenous communities are beginning to develop more formal adaptation plans (Galloway-McLean, 2010; Brubaker et al., 2011b,c; Nakashima et al., 2012). Comprehensive adaptation planning must take into account underlying social issues of some Indigenous populations when addressing the new challenges from climate and development. Indigenous communities are especially vulnerable to climate change because of their strong dependence on the environment for food, culture, and way of life; their political and economic marginalization; the social, health, and poverty disparities; and community locations
along exposed ocean, lake, or river shorelines (Ford and Furgal, 2009; Galloway-McLean, 2010; Larsen et al., 2010; Cochran et al., 2013).
The adaptive capacity of Arctic Indigenous peoples is largely due to an extensive traditional knowledge and cultural repertoire, and flexible social networks (*medium confidence*; Williams and Hardison, 2013; see Section 12.3). The dynamic nature of traditional knowledge is valuable for

adapting to current conditions (Kitti et al., 2006; Tyler et al., 2007; Eira et al., 2012). The sharing of knowledge ensures rapid responses to crises (Ford et al., 2007). In addition, cultural values such as sharing, patience, persistence, calmness, and respect for elders and the environment are important. Some studies suggest that traditional knowledge may not always be sufficient to meet the rapid changes in climate (see Chapter 12) and it may be perceived to be less reliable because the changing conditions are beyond the current knowledge range (Ingram et al., 2002; Ford et al., 2006; Hovelsrud et al., 2010; Valdivia et al., 2010).

Over the last half-century, the adaptive capacity in some Indigenous communities has been challenged by the transition from semi-nomadic hunting groups to permanent settlements, accompanied by impacts to health and well-being from loss of connection to the land, traditional foods, and culture (Ford et al., 2010; Galloway-McLean, 2010). Forced or voluntary migration as an adaptation response can have deep cultural impacts (Shearer, 2011, 2012; Maldonado et al., 2013). On the other hand, the establishment of permanent communities, particularly those associated with new industrial development, can also lead to increasing employment opportunities and income diversification for Indigenous peoples. The intergenerational transfers of knowledge and skills through school curricula, land camps, and involvement in community-based monitoring programs may strengthen adaptive

capacity (Forbes 2007; Ford et al., 2007; Hovelsrud and Smit, 2010; Bolton et al., 2011).

Examples of Indigenous adaptation strategies have included changing resource bases; shifting land use and/or settlement areas; combining technologies with traditional knowledge; changing timing and location of hunting, gathering, herding, and fishing areas; and improving communications and education (Galloway-McLean, 2010). Protection of grazing land will be the most important adaptive strategy for reindeer herders under climate change (Forbes et al., 2009; Magga et al., 2011; Kumpula et al., 2012; Degteva and Nellemann, 2013; Mathiesen et al., 2013). Renewable resource harvesting remains a significant component of Arctic livelihoods, and with climate change hunting and fishing has become a riskier undertaking and many communities are already adapting (Gearheard et al., 2011; Laidler et al., 2011). Adaptation includes taking more supplies when hunting, constructing permanent shelters on land as refuges from storms, improved communications infrastructure, greater use of global positioning systems (GPS) for navigation, synthetic aperture radar (SAR) to provide estimates of sea ice conditions (Laidler et al., 2011), and the use of larger or faster vehicles (Ford et al., 2010). Avoiding dangerous terrain can result in longer and time-consuming journeys that can be inconvenient to those with wage-earning employment (Ford et al., 2007). (2014b)

22.4.5.4. Knowledge Development and Sharing

Recent literature has confirmed the positive role of local and traditional knowledge in building resilience and adaptive capacity, and shaping responses to climatic variability and change in Africa (Nyong et al., 2007; Osbahr et al., 2007; Goulden et al., 2009b; Ifejika Speranza et al., 2010; Jalloh et al., 2011b; Newsham and Thomas, 2011). This is particularly so at the community scale, where there may be limited access to, quality of, or ability to use scientific information. The recent report on extreme events and disasters (IPCC, 2012) supports this view, finding *robust evidence* and *high agreement* of the positive impacts of integrating indigenous and scientific knowledge for adaptation. Concerns about the future adequacy of local knowledge to respond to climate impacts within the multi-stressor context include the decline in intergenerational transmission; a perceived decline in the reliability of local indicators for variability and change, as a result of sociocultural, environmental, and climate changes (Hitchcock 2009; Jennings and Magrath 2009); and challenges of the emerging and anticipated climatic changes seeming to overrun indigenous knowledge and coping mechanisms of farmers (Berkes, 2009; Ifejika Speranza et al., 2010; Jalloh et al., 2011b; see also Section 22.4.6). Based on analysis of the responses to the Sahel droughts during the 1970s and 1980s, Mortimore (2010) argues that local knowledge systems are more dynamic and robust than is often acknowledged. Linking indigenous and conventional climate observations can add value to climate change adaptation within different local communities in Africa (Roncoli et al., 2002; Nyong et al., 2007; Chang'a et al., 2010; Guthiga and Newsham, 2011). (2014b)

22.4.5.6. Ecosystem Services, Biodiversity, and Natural Resource Management

Africa's longstanding experiences with natural resource management, biodiversity use, and ecosystem-based responses such as afforestation, rangeland regeneration, catchment rehabilitation, and community- based natural resource management (CBNRM) can be harnessed to develop effective and ecologically sustainable local adaptation strategies (*high confidence*). Relevant specific experiences include using mobile grazing to deal with both spatial and temporal rainfall variability in the Sahel (Djoudi et al., 2013); reducing the negative impacts of drought and floods on agricultural and livestock-based livelihoods through forest goods and services in Mali, Tanzania, and Zambia (Robledo et al., 2012); and ensuring food security and improved livelihoods for indigenous and local communities in West and Central Africa through the rich diversity of plant and animal genetic resources (Jalloh et al., 2011b).

Frequently Asked Questions

FAQ 24.2 | How will climate change affect food production and food security in Asia?

Climate change impacts on temperature and precipitation will affect food production and food security in various ways in specific areas throughout this diverse region. Climate change will have a generally negative impact on crop production Asia, but with diverse possible outcomes (*medium confidence*). For example most simulation models show that higher temperatures will lead to lower rice yields as a result of a shorter growing period. But some studies indicate that increased atmospheric CO2 that leads to those higher temperatures could enhance photosynthesis and increase rice yields. This uncertainty on the overall effects of climate change and CO2 fertilization is generally true for other important food crops such as wheat, sorghum, barley, and maize, among others.
Yields of some crops will increase in some areas (e.g., cereal production in north and east Kazakhstan) and decrease in others (e.g., wheat in the Indo-Gangetic Plain of South Asia). In Russia, climate change may lead to a food production shortfall, defined as an event in which the annual potential production of the most important crops falls 50% or more below its normal average. Sea level rise is projected to decrease total arable areas and thus food supply in many parts of Asia. A diverse mix of potential adaptation strategies, such as crop breeding, changing crop varieties, adjusting planting time, water management, diversification of crops, and a host of indigenous practices will all be applicable within local contexts.

Indigenous and local adaptation strategies have been documented for Southeast Asia (Peras et al., 2008; Lasco et al., 2010, 2011) and could be used as a basis for future climate change adaptation. Crop breeding for high temperature conditions is a promising option for climate change adaptation in Asia. For example, in the North China Plain, simulation studies show that using high-temperature sensitive varieties, maize yield in the 2050s could increase on average by 1.0 to 6.0%, 9.9 to 15.2%, and 4.1 to 5.6%, by adopting adaptation options of early planting, fixing variety growing duration, and late planting, respectively (Tao and Zhang, 2010). In contrast, no adaptation will result in yield declines of 13.2 to 19.1%. (2014b)

Mechanized farming, agro-industrial production, and cattle ranching are the major land use change drivers in eastern Bolivia but subsistence agriculture by indigenous colonists is also important (Killeen et al., 2008)... (2014b)

Local and indigenous knowledge has the potential to bring solutions even in the face of rapidly changing climatic conditions (Folke et al., 2002; Altieri and Koohafkan, 2008), although migration, climate change, and market integration are reducing indigenous capacity for dealing with weather and climate risk (Pérez et al., 2010; Valdivia et al., 2010). Crop diversification is used in the Peruvian Andes to suppress pest outbreaks and dampen pathogen transmission (Lin, 2011). In Honduras, Nicaragua, and Guatemala traditional practices have proven more resilient to erosion and runoff and have helped retain more topsoil and moisture (Holt-Gimenez, 2002). In El Salvador, if local sustainability efforts continue, the future climate vulnerability index could only slightly increase by 2015 (Aguilar et al., 2009). Studies with Indigenous farmers in highland Bolivia and Peru indicate that constraints on access to key resources must be addressed for reducing vulnerability over time (McDowell and Hess, 2012; Sietz et al., 2012). In Guatemala and Honduras adaptive response between coffees farmers is mainly related to land availability, while participation in organized groups and access to information contribute to adaptive decision making (Tucker et al., 2010). Otherwise, adaptation may include an orientation toward non- farming activities to sustain their livelihoods and be able to meet their food requirements (Sietz, 2011). In NEB increasing vulnerability related to degradation of natural resources (due to overuse of soil and water) encouraged farmers toward off-farm activities; however, they could not improve their well-being (Sietz et al., 2006, 2011). Migration is another strategy in ecosystems and regions at high risk of climate hazards (see Section 27.3.1.1). During 1970–2000 LA and the Caribbean has had a great rate of net migration per population in the dryland zones (de Sherbinin et al., 2012). In CA nearly 25% of the surveyed households reported some type of migration during the coffee crisis (Tucker et al., 2010). Some migrations—for example, Guatemala, 1960s–1990s; El Salvador, 1950s–1980s; NEB, 1960s–present—have provoked conflict in receiving areas (Reuveny, 2007). (2014b)

The cultural context in which an individual lives and the inherent values of a society also shape the intrinsic motivation underlying consumer choices (Fuhrer et al., 1995; Chawla, 1998, 1999). As an example, the high proportion of people following a vegetarian diet in India can be attributed to its cultures and religions, resulting in lower GHG emissions per caloric intake (Ghosh, 2006). Similar explanations are given for India's relatively low levels of waste generation coupled with higher levels of waste recycling and re-use (Ghosh, 2006). Cross-cultural differences are also revealed at higher-income levels. In some high-income countries people appreciate high-density neighbourhoods and public transport more as compared to other countries (Roy and Pal, 2009). (2014)

Lifestyle, culture and behaviour significantly influence energy consumption in buildings (*limited evidence, high agreement*). A three- to five-fold difference in energy use has been shown for provision of similar building-related energy service levels in buildings. For developed countries, scenarios indicate that lifestyle and behavioural changes could reduce energy demand by up to 20 % in the short term and by up to 50 % of present levels by mid-century. In developing countries, integrating elements of traditional lifestyles into building practices and architecture could facilitate the provision of high levels of energy services with much lower energy inputs than baseline. [9.3] (2014)

Traditional ecological knowledge is embedded in value-institutions and belief systems related to historical modes of experimentation and is transferred from generation to generation (Pierotti, 2011). (2014)

Social learning and cultural transmission

Section 9.3.10 suggests that indigenous building practices in many parts of the world provide important lessons for affordable low- energy housing design and that developed countries can learn from traditional building practices, transmitted over generations, the social- scale equivalent of 'intuitive' processing and learning at the individual level. (2014)

It is important to distinguish between formally acquired knowledge on climate change—often based on scientific developments—and traditional knowledge on climate-related issues (Smith and Sharp, 2012), as well as to recognize that the relative validity of both types of knowledge to different audiences, and the meaning and relevance of personal engagement, will be influenced by individual perceptions, preferences, values, and beliefs. Therefore, knowledge on climate issues does not alone explain individual and collective responses to the climate challenge (Whitmarsh, 2009; Sarewitz, 2011; Wolf and Moser, 2011; Berkhout, 2012). There is evidence of cognitive dissonance and strategic behaviour in both mitigation and adaptation. (2014)

Indigenous climate change knowledge contributions from Africa (Orlove et al., 2010), the Arctic (Gearheard et al., 2009), Australia (Green et al., 2010), or the Pacific Islands (Lefale, 2010), derive from accumulated and transmitted experience and focus mostly on predicting seasonal or interannual climate variability. Indigenous knowledge can supplement scientific knowledge in geographic areas with a paucity of data (Green and Raygorodetsky, 2010) and can guide knowledge generation that reduces uncertainty in areas that matter for human responses (ACI, 2004). Traditional ecological knowledge is embedded in value-institutions and belief systems related to historical modes of experimentation and is transferred from generation to generation (Pierotti, 2011). (2014)

Another example is The Western Arnhem Land Fire Abatement Project (WALFA), a fire management project in Australia initiated in 2006 that produces a tradable carbon offset through the application of improved fire management using traditional management practices of indigenous land owners (Whitehead et al., 2008; Bradstock et al., 2012). (2014)

4.7 Adaptation, Assessments & Responses

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. (2014a)

Throughout history, people and societies have adjusted to and coped with climate, climate variability, and extremes, with varying degrees of success. This section focuses on adaptive human responses to observed and projected climate-change impacts, which can also address broader risk-reduction and development objectives. (2014a: 8)

Adaptation planning and implementation at all levels of governance are contingent on societal values, objectives, and risk perceptions (*high confidence*). Recognition of diverse interests, circumstances, social-cultural contexts, and expectations can benefit decision-making processes. Indigenous, local, and traditional knowledge systems and practices, including indigenous peoples' holistic view of community and environment, are a major resource for adapting to climate change, but these have not been used consistently in existing adaptation efforts. Integrating such forms of knowledge with existing practices increases the effectiveness of adaptation. (2014a)

The federal government supported a first-pass national coastal risk assessment (DCC, 2009; DCCEE, 2011), is developing indicators and criteria for assessing adaptation progress and outcomes (DIICCSRTE, 2013), and commissioned targeted reports addressing impacts and management options for natural and managed landscapes (Campbell, 2008; Steffen et al., 2009; Dunlop et al., 2012), National and World Heritage areas (ANU, 2009; BMT WBM, 2011), and indigenous and urban communities (Green et al., 2009; Norman, 2010). Most State and Territory governments have also developed adaptation plans (e.g., DSE, 2013). (2014b: 1383)

Schneider et al. (2000) advocates the use of a suite of five metrics: (1) monetary loss, (2) loss of life, (3) quality of life (taking account of forced migration, conflict over resources, cultural diversity, and loss of cultural heritage sites), (4) species or biodiversity loss, and (5) distribution and equity. (2014: 221)

How Culture Interacts with Climate Impacts and Adaptation

Culture is a contested and highly fluid term that is defined in this chapter as material and non-material symbols that express collective meaning. In all societies culture is expressed in knowledge, worldviews, beliefs, norms, values, and social relationships (Crate, 2008, 2011; Heyd, 2008; Roncoli et al., 2009; Strauss, 2009; O'Brien and Wolf, 2010; Tingley et al., 2010; Rudiak-Gould, 2012; Sudmeier-Rieux et al., 2012). In this definition culture shapes the relationship of society to environments and is a significant determinant of responses to environmental and other risks and challenges (Siurua and Swift, 2002; Pearce et al., 2009; Buikstra et al., 2010; Nielsen and Reenberg, 2010; Petheram et al., 2010; Paul and Routray, 2011). (2014a: 762)

Box 13.2. Adaptation capacity of the South American highlands' pre-Colombian communities

The subsistence of indigenous civilisations in the Americas relied on the resources cropped under the prevailing climate conditions around their settlements. In the highlands of today's Latin America, one of the most critical limitations affecting development was, as currently is, the irregular distribution of water. This situation is the result of the particularities of the atmospheric processes and extremes, the rapid runoff in the deep valleys, and the changing soil conditions. The tropical Andes' snowmelt was, as it still is, a reliable source of water. However, the streams run into the valleys within bounded water courses, bringing water only to certain locations. Moreover, valleys and foothills outside of the Cordillera Blanca glaciers and extent of the snow cover, as well as the Altiplano, receive little or no melt-water at all. Therefore, in large areas, human activities depended on seasonal rainfall. Consequently, the pre-Colombian communities developed different adaptive actions to satisfy their requirements. Today, the problem of achieving the necessary balance between water availability and demand is practically the same, although the scale might be different.

- Under such limitations, from today's Mexico to northern Chile and Argentina, the pre-Colombian civilisations developed the necessary capacity to adapt to the local environmental conditions. Such capacity involved their ability to solve some hydraulic problems and foresee climate variations and seasonal rain periods. On the engineering side, their developments included rainwater cropping, filtration and storage; the construction of surface and underground irrigation channels, including devices to measure the quantity of water stored (Figure 13.4) (Treacy, 1994; Wright and Valencia Zegarra, 2000; Caran and Nelly, 2006). They also were able to interconnect river basins from the Pacific and Atlantic watersheds, in the Cumbe valley and in Cajamarca (Burger, 1992).
- Figure 13.4. Nasca (southern coast of Peru) system of water cropping for underground aqueducts and feeding the phreatic layers.
- Other capacities were developed to foresee climate variations and seasonal rain periods, to organise their sowing schedules and to programme their yields (Orlove et al., 2000). These efforts enabled the subsistence of communities which, at the peak of the Inca civilisation, included some 10 million people in what is today Peru and Ecuador.
- Their engineering capacities also enabled the rectification of river courses, as in the case of the Urubamba River, and the building of bridges, either hanging ones or with pillars cast in the river bed. They also used running water for leisure and worship purposes, as seen today in the 'Baño del Inca' (the spa of the Incas), fed from geothermal sources, and the ruins of a musical garden at Tampumacchay in the vicinity of Cusco (Cortazar, 1968). The priests of the Chavin culture used running water flowing within tubes bored into the structure of the temples in order to produce a sound like the roar of a jaguar; the jaguar being one of their deities (Burger, 1992). Water was also used to cut stone blocks for construction. As seen in Ollantaytambo, on the way to Machu Picchu, these stones were cut in regular geometric shapes by leaking water into cleverly made interstices and freezing it during the Altiplano night, reaching below zero temperatures. They also acquired the capacity to forecast climate variations, such as those from El Niño (Canziani and Mata, 2004), enabling the most convenient and opportune organisation of their foodstuff production. In short, they developed pioneering efforts to adapt to adverse local conditions and define sustainable development paths.
- Today, under the vagaries of weather and climate, exacerbated by the increasing greenhouse effect and the rapid retreat of the glaciers (Carey, 2005; Bradley et al., 2006), it would be extremely useful to revisit and update such adaptation measures. Education and training of present community members on the knowledge and technical abilities of their ancestors would be the way forward. ECLAC's procedures for the management of sustainable development (Dourojeanni, 2000), when considering the need to manage the extreme climate conditions in the highlands, refer back to the pre-Colombian irrigation strategies.

(AR4: 605)

Adaptation planning and implementation at all levels of governance are contingent on societal values, objectives, and risk perceptions (*high confidence*). Recognition of diverse interests, circumstances, social-cultural contexts, and expectations can benefit decision-making processes. (2014a)

In complex situations, sociocultural and cognitive-behavioral contexts become central to decision making. This requires combining the scientific understanding of risk with how risks are framed and perceived by individuals, organizations, 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). (2014a)

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 sociocultural world. (2014a)

The limits to adaptation raise questions of irreversible loss and the loss of unique cultural values that cannot necessarily be easily transferred (Section 16.7), contributing to key vulnerabilities and informing ethical issues facing mitigation (see Section 19.7.1). (2014a)

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. Similar to the learning process called “triple-loop”—which 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). (2014a)

Climate uncertainty, high levels of variability, lack of access to appropriate real-time and future climate information, and poor predictive capacity at a local scale are commonly cited barriers to adaptation from the individual to national level (Repetto, 2008; Dinku et al., 2011; Jones, 2012; Mather and Stretch, 2012). Despite the cultural and psychological barriers noted earlier, several studies have shown that farmers with access to climate information are more predisposed to adjust their behavior in response to perceived climate changes (Mubaya et al., 2012). (2014b)

Despite this progress in mainstreaming climate risk in policy and planning, significant disconnects still exist at the national level, and implementation of a more integrated adaptation response remains tentative (*high confidence*) (Koch et al., 2007; Fankhauser and Schmidt- Traub, 2010; Madzwamuse, 2010; Oates et al., 2011; UNDP-UNEP Poverty- Environment Initiative, 2011a). Legislative and policy frameworks for adaptation remain fragmented, adaptation policy approaches seldom take into account realities in the political and institutional spheres, and national policies are often at odds with autonomous local adaptation strategies, which can act as a barrier to adaptation, especially where cultural, traditional, and context-specific factors are ignored (Dube and Sekhwela, 2008; Patt and Schröter, 2008; Stringer et al., 2009; Bele et al., 2010; Hisali et al., 2011; Kalame et al., 2011; Naess et al., 2011; Lockwood, 2012; Sonwa et al., 2012; see also Section 22.4.6). (2014b)

Inherent adaptation-related strengths in Africa include the continent’s wealth in natural resources, well-developed social networks, and longstanding traditional mechanisms of managing variability through, for example, crop and livelihood diversification, migration, and small-scale enterprises, all of which are underpinned by local or indigenous knowledge systems for sustainable resource management (Eyong, 2007; Nyong et al., 2007; UNFCCC, 2007; Cooper et al., 2008; Macchi et al., 2008; Nielsen, 2010; Castro et al., 2012). However, it is uncertain to what extent these strategies will be capable of dealing with future changes, among them climate change and its interaction with other development processes (Leary et al., 2008b; Paavola, 2008; van Aalst et al., 2008; Conway, 2009; Jones, 2012; see also Section 22.4.6). Since Africa is extensively exposed to a range of multiple stressors (Section 22.3) that interact in complex ways with longer term climate change, adaptation needs are broad, encompassing institutional, social, physical, and infrastructure needs, ecosystem services and environmental needs, and financial and capacity needs. (2014b)

Moreover, effective adaptation responses necessitate differentiated and targeted actions from the local to national levels, given the differentiated social impacts based on gender, age, disability, ethnicity, geographical location, livelihood, and migrant status (Tanner and Mitchell, 2008; IPCC, 2012). Additional attention to equity and social justice aspects in adaptation efforts in Africa, including the differential distribution of adaptation benefits and costs, would serve to enhance adaptive capacity (Burton et al., 2002; Brooks et al., 2005; Thomas and Twyman, 2005; Madzwamuse, 2010); nevertheless, some valuable experience has been gained recently on gender-equitable adaptation, human rights-based approaches, and involvement of vulnerable or marginalized groups such as indigenous peoples and children, aged and disabled people, and internally displaced persons and refugees (see Table 22-5; ADF, 2010; UNICEF, 2010, 2011; Levine et al., 2011; Romero González et al., 2011; IDS, 2012; Tanner and Seballos, 2012). See also Box CC-GC on Gender and Climate Change. (2014b)

22.4.4.5. Community-Based Adaptation and Local Institutions

Since AR4, there has been progress in Africa in implementing and researching community-based adaptation (*high confidence*), with broad agreement that support to local-level adaptation is best achieved by starting with existing local adaptive capacity, and incorporating and building upon present coping strategies and norms, including indigenous practices (Dube and Sekhwela, 2007; Archer et al., 2008; Huq, 2011). Community-based adaptation is community initiated, and/or draws upon community knowledge or resources (see Glossary). Some relevant initiatives include the Community-Based Adaptation in Africa (CBAA) project, which implemented community-level pilot projects in eight African countries (Sudan, Tanzania, Uganda, Zambia, Malawi, Kenya, Zimbabwe, South Africa) through a learning-by-doing approach; the Adaptation Learning Program, implemented in Ghana, Niger, Kenya, and Mozambique (CARE International, 2012b); and UNESCO Biosphere Reserves, where good practices were developed in Ethiopia, Kenya, South Africa, and Senegal (German Commission for UNESCO, 2011). See Section 22.4.5.6 on institutions for community-based adaptation. The literature includes a wide range of case studies detailing involvement of local communities in adaptation initiatives and projects facilitated by non- governmental organizations (NGOs) and researchers (e.g., Leary et al., 2008a; CCAA, 2011; CARE International, 2012b; Chishakwe et al., 2012); these and other initiatives have generated process-related lessons (Section 22.4.5), with positive assessments of effectiveness in improving adaptive capacity of African communities, local organizations, and researchers (Lafontaine et al., 2012). (2014b)

Disaster preparedness on a local community level could include a combination of indigenous coping strategies, early-warning systems, and adaptive measures (Paul and Routray, 2010). Heat warning systems have been successful in preventing deaths among risk groups in Shanghai (Tan et al., 2007). (2014b)

Government agencies and nonprofit organizations have established initiatives that emphasize the value of collaborative dialog between scientists and practitioners, indigenous communities, and grass- roots organizations to develop no-regrets and co-benefits adaptation strategies (Ogden and Innes, 2009; Gleeson et al., 2011; Halofsky et al., 2011; Cross et al., 2012, 2013; INECC and SEMARNAT, 2012b). (2014b)

Even where there are opportunities, managers face challenges in designing management practices that favor carbon stocks, while at the same time maintaining biodiversity, recognizing the rights of indigenous people, and contributing to local economic development (FAO, 2012). (2014b)

Even with technological changes that might result in agricultural intensification, the expansion of pastures and croplands is expected to continue in the coming years (Wassenaar et al., 2007; Kaimowitz and Angelsen, 2008), particularly from an increasing global demand for food and biofuels (Gregg and Smith, 2010) with the consequent increase in commodity prices. This agricultural expansion will be mainly in LA and sub-Saharan Africa as these regions hold two-thirds of the global land with potential to expand cultivation (Nepstad and Stickler, 2008). It is important to consider the policy and legal needs to keep this process of large-scale change under control as much as possible; Takasaki (2007) showed that policies to eliminate land price distortions and promote technological transfers to poor colonists could reduce deforestation. It is also important to consider the role of indigenous groups; there is a growing acknowledgment that recognizing the land ownership and authority of indigenous groups can help central governments to better manage many of the natural areas remaining in the region (Oltremari and Jackson, 2006; Larson, 2010). The impact of indigenous groups on land use change can vary: de Oliveira et al. (2007) found that only 9% of the deforestation in the Peruvian Amazon between 1999 and 2005 happened in indigenous territories, but Killeen et al. (2008) found that Andean indigenous colonists in Bolivia were responsible for the largest land cover changes in the period 2001–2004. Indigenous groups are important stakeholders in many territories in the region and their well- being should be considered when designing responses to pressures on the land by a globalized economy (Gray et al., 2008; Killeen et al., 2008). (2014b)

Autonomous adaptation experience is mainly realized at local levels (individual or communitarian) with examples found, for instance, for rural communities in Honduras (McSweeney and Coomes, 2011), Indigenous communities in Bolivia (Valdivia et al., 2010), and coffee agroforestry systems in Brazil (de Souza et al., 2012). However, such adaptation processes do not always respond specifically to climate forcing. For instance, the agricultural sector adapts rapidly to economic stressors, although, despite a clear perception of climate risks, it may last longer before responding to climate changes (Tucker et al., 2010). In certain regions or communities, such as Anchioreta in Brazil (Schlindwein et al., 2011), adaptation is part of a permanent process and is actually tackled through a clear objective of vulnerability reduction, maintaining and diversifying a large set of natural varieties of corn, allowing the farmers to diversify their planting. Another kind of autonomous adaptation is the southward displacement of agriculture activities (e.g., wine, coffee) through the purchase of lands, which will become favorable for such agriculture activities in a warmer climate. In Argentina, the increase of precipitation observed during the last 30 years contributed to a westward displacement of the annual crop frontier. (2014b)

Ecosystem- based adaptation practices, such as the establishment of protected areas and their effective management, conservation agreements, community management of natural areas, and payment for ecosystem services are increasingly more common across the region. (2014b)

Others argue that donor-led initiatives may unintentionally cause enhanced vulnerability by supporting adaptation strategies that are externally derived, rather than optimizing the benefits of local practices that have proven to be efficacious through time (Reenberg et al., 2008; Campbell and Beckford, 2009; Kelman and West, 2009). (2014b)

Need to acknowledge the heterogeneity and complexity of small island states and territories. Although small islands have several characteristics in common, neither the variety nor complexity of small islands is sufficiently reflected in the literature. Thus, transfer of data and practices from a continental situation, or from one small island state to another, needs to be done with care and in a manner that takes full cognizance of such heterogeneity and complexity. (2014b)

Prioritizing action on climate change over other significant social goals with more near-term payoffs is particularly difficult in developing countries. Because social concerns and objectives, such as the preservation of traditional values, cannot always be easily quantified or monetized, economic costs and benefits are not the only input into decision making about climate change. (2014)

For example, it may be impossible to weigh the value of preserving a traditional culture against the material income of the people whose culture it is, or to weigh the value of biodiversity against human well-being. Some economists claim that one person's wellbeing cannot be weighed against another's (Robbins, 1937; Arrow, 1963). When values cannot be determinately weighed, they are said to be 'incommensurable' or 'incomparable' (Chang, 1997). Multi-Criteria Analysis (MCA) (discussed in Section 3.7.2.1) is a technique that is designed to take account of several incommensurable values (De Montis et al., 2005; Zeleny and Cochrane, 1982). (2014)

... measuring non-market values—such as the existence of species, natural environments, or traditional ways of life of local societies—is fraught with difficulty... (2014)

11.7.1 Socio-economic effects

AFOLU mitigation measures can affect institutions and living conditions of the various social groups involved. This section includes potential effects of AFOLU mitigation measures on three dimensions of sustain- able development: institutional, social, and economic (Section 11.4.5).
AFOLU mitigation measures may have impacts on *land tenure and land-use rights* for several social groups including indigenous peoples, local communities and other social groups, dependant on natural assets. Co-benefits from AFOLU mitigation measures can be clarification of land tenure and harmonization of rights, while adverse side-effects can be lack of recognition of customary rights, loss of tenure or possession rights, and even displacement of social groups (Sunderlin et al., 2005; Chhatre and Agrawal, 2009; Blom et al., 2010; Sikor et al., 2010; Robinson et al., 2011; Rosemary, 2011; Larson, 2011; Rosendal and Andresen, 2011). Whether an impact on land tenure and use rights is positive or negative depends upon two factors: (a) the institutions regulating land tenure and land-use rights (e.g., laws, policies), and (b) the level of enforcement by such institutions (Corbera and Brown, 2008; Araujo et al., 2009; Rosemary, 2011; Larson et al., 2013; Albers and Robinson, 2013). More research is needed on specific tenure forms (e.g., individual property, state ownership or community rights), and on the specific effects from tenure and rights options, on enabling
AFOLU mitigation measures and co-benefits in different regions under specific circumstances (Sunderlin et al., 2005; Katila, 2008; Chhatre and Agrawal, 2009; Blom et al., 2010; Sikor et al., 2010; Robinson et al., 2011; Rosemary, 2011; Larson, 2011; Rosendal and Andresen, 2011).

Capacity building for adaptation includes (i) risk management approaches to address adverse effects of climate change, (ii) maintenance and revision of a database on local coping strategies, and (iii) maintenance and revision of the adaptation practices interface (Yohe, 2001; UNFCCC, 2009b). The process of preparing the National Adaptation Programmes of Action (NAPAs) for and by LDCs identifies their most 'urgent' adaptation needs. However, capacity building for adaptation is likely insufficient because the costs in such regards are rarely estimated (Smith et al., 2011; see also WGII, 3.6.4). At the community level, adaptation projects require time and patience and can be successful if they raise awareness, develop and use partnerships, com- bine reactive and anticipatory approaches, and are in line with local culture and context (Engels, 2008; Dumaru, 2010). (2014)

4.7.1 Education Strategies

Many suggested adaptation strategies with anticipated economic benefits are often not adopted by farmers, suggesting the need for more attention to culture and behavior (Moran et al., 2013). Attitudinal studies among US farmers indicate limited acknowledgment of anthropogenic climate change, associated with lower levels of support for adaptation (*medium evidence*, *high agreement*; Arbuckle, Jr. et al., 2013; Gramig et al., 2013). (2014b)

Adaptation planning can be greatly enhanced by incorporating regionally or locally specific vulnerability information (Clark et al., 1998; Barsugli et al., 2012; Romsdahl et al., 2013). Methods for mapping vulnerability have been improved and effectively utilized (Romero-Lankao et al., 2013b). Similarly, strategies supporting cultural preservation and subsistence livelihood needs among Indigenous peoples would enhance adaptation (Ford et al., 2010b), as would integrating traditional culture with other forms of knowledge, technologies, education, and economic development (Hardess et al., 2011). (2014b)

Traditional and autonomous adaptation strategies, particularly in the drylands, have been constrained by social-ecological change and drivers such as population growth, land privatization, land degradation, widespread poverty, HIV/AIDS, poorly conceived policies and modernization, obstacles to mobility and use of indigenous knowledge, as well as erosion of traditional knowledge, to the extent that it is difficult or no longer possible to respond to climate variability and risk in ways that people did in the past (Dabi et al., 2008; Leary et al., 2008b; Paavola, 2008; Smucker and Wisner, 2008; Clover and Eriksen, 2009; Conway, 2009; UNCCD et al., 2009; Bunce et al., 2010b; Quinn et al., 2011; Jones, 2012; see also Section 22.4.5.4). As a result of these multiple stressors working together, the number of response options has decreased and traditional coping strategies are no longer sufficient (Dube and Sekhwela, 2008). Studies have shown that most autonomous adaptation usually involves minor adjustments to current practices (e.g., changes in planting decisions); there are simply too many barriers to implementing substantial changes that require investment (e.g., agroforestry and irrigation) (Bryan et al., 2011). Such adaptation strategies would be enhanced through government and private sector/NGO support, without which many poor groups in Africa may face real limits to adaptation (Vincent et al., 2011a; Jones, 2012). (2014b)

Some adaptation practices provide unexpected livelihood benefits, as with the introduction of traditional flood mitigation measures in China, which could positively impact local livelihoods, leading to reductions in both the physical and economic vulnerabilities of communities (Yu et al., 2009). A greater role of local communities in decision making is also proposed (Alauddin and Quiggin, 2008) and in prioritization and adoption of adaptation options (Prabhakar et al., 2010; Prabhakar and Srinivasan, 2011). (2014b)

Forests and their management are also often emphasized for providing resilient livelihoods and reducing poverty (Chhatre and Agrawal, 2009; Noordwijk, 2010; Persha et al., 2010; Larson, 2011). Securing rights to resources is essential for greater livelihood benefits for poor indigenous and traditional people (Macchi et al., 2008) and the need for REDD+ schemes to respect and promote community forest tenure rights has been emphasized (Angelsen, 2009). (2014b)

Similarly, strategies supporting cultural preservation and subsistence livelihood needs among Indigenous peoples would enhance adaptation (Ford et al., 2010b), as would integrating traditional culture with other forms of knowledge, technologies, education, and economic development (Hardess et al., 2011). (2014b)

4.8 Prehistoric or Past Society References

There is disagreement about whether islands and islanders have successfully adapted to past weather variability and climate change. Nunn (2007) argues that past climate changes have had a "crisis effect" on prehistoric societies in much of the Pacific Basin (2014b: 1636)

Box 16-4 | Historical Perspectives on Limits to Adaptation

Does human history provide insights into societal resilience and vulnerability under conditions of environmental change? Archaeological and environmental reconstruction provides useful perspectives on the role of environmental change in cases of significant societal change, sometimes termed "collapse" (Diamond, 2005). These may help to illuminate how adaptation limits were either exceeded, or where collapse was avoided to a greater or lesser degree. Great care is necessary to avoid oversimplifying cause and effect, or overemphasizing the role of environmental change, in triggering significant societal change, and the societal response itself. Coincidence does not demonstrate causality, such as in the instance of matching climatic events with social crises through the use of simple statistical tests (Zhang et al., 2011), or through derivative compilations of historical data (deMenocal, 2001; Thompson et al., 2002; Drysdale et al., 2006; Butzer, 2012). Application of social theories may not explain specific cases of human behavior and community decision making, especially because of the singular importance of the roles of leaders, elites, and ideology (Hunt, 2007; McAnany and Yoffee, 2010; Butzer, 2012; Butzer and Endfield, 2012).

There are now roughly a dozen case studies of historical societies under stress, from different time ranges and several parts of the world, that are sufficiently detailed (based on field, archival, or other primary sources) for relevant analysis (Butzer and Endfield, 2012). These include Medieval Greenland and Iceland (Dugmore et al., 2012; Streeter et al., 2012), Ancient Egypt (Butzer, 2012), Colonial Cyprus (Harris, 2012), the prehistoric Levant (Rosen and Rivera-Collazo, 2012), Islamic Mesopotamia and Ethiopia (Butzer, 2012), the Classic Maya (Dunning et al., 2012; Luzzadder-Beach et al., 2012), and Colonial Mexico (Endfield, 2012). Seven such civilizations underwent drastic transformation in the wake of multiple inputs, triggers, and feedbacks, with unpredictable outcomes. These can be seen to have exceeded adaptation limits. Five other examples showed successful adaptation through the interplay of environmental, political, and socio-cultural resilience, which responded to multiple stressors (e.g., insecurity, environmental or economic crises, epidemics, famine). In these cases, climatic perturbations are identified as only one of many "triggers" of potential crisis, with preconditions necessary for such triggers to stimulate transformational change. These preconditions include human- induced environmental decline mainly through overexploitation.

Avoidance of limits to adaptation requires buffering feedbacks that encompass social and environmental resilience. Exceedance of limits occurred through cascading feedbacks that were characterized by social polarization and conflict that ultimately result in societal disruption. Political simplification undermined traditional structures of authority to favor militarism, while breakdown was accompanied or followed by demographic decline. Although climatic perturbations and environmental degradation did contribute to triggering many cases of breakdown, the most prominent driver at an early stage was institutional failure, which refers to the inability of societal institutions to address collective-action problems (Acheson, 2006). In these cases, collapse was neither abrupt nor inevitable, often playing out over centuries. Lessons from the implementation of adaptation responses over historical time periods in Mexico City suggest that some responses may create new and even more significant risks (Sosa-Rodriguez, 2010).

Recent work on resilience and adaptation synthesizes lessons from extreme event impacts and responses in Australia (Kiem et al., 2010). This further emphasizes an institutional basis for resilience, finding that government intervention through the provision of frameworks to enable adaptation is beneficial. Furthermore, it was found that a strong government role may be necessary to absorb a portion of the costs associated with natural disasters. On the other hand, community awareness and recognition of novel conditions were also found to be critical elements of effective responses. It would be useful to consider how lessons learned from historical experience may relate to the perceived multiple environmental changes characterized by the "Anthropocene" era (Crutzen, 2002). (2014a: 920)

The above box, Box 14-4, was referenced five times in the rest of the publication.

Text references are below:

- *In footnote for:*
  Greater rates and magnitude of climate change increase the likelihood of exceeding adaptation limits (*high confidence*). Limits to adaptation occur when adaptive actions to avoid intolerable risks for an actor's objectives or for the needs of a system are not possible or are not currently available. Value-based judgments of what constitutes an intolerable risk may differ. Limits to adaptation emerge from the interaction among climate change and biophysical and/or socioeconomic constraints. Opportunities to take advantage of positive synergies between adaptation and mitigation may decrease with time, particularly if limits to adaptation are exceeded. In some parts of the world, insufficient responses to emerging impacts are already eroding the basis for sustainable development.[79] (P. 28)
- *In footnote for:*
  Transformations in economic, social, technological, and political decisions and actions can enable climate-resilient pathways (*high confidence*). Specific examples are presented in Table SPM.1. Strategies and actions can be pursued now that will move towards climate-resilient pathways for sustainable development, while at the same time helping to improve livelihoods, social and economic well-being, and responsible environmental management. At the national level, transformation is considered most effective when it reflects a country's own visions and approaches to achieving sustainable development in accordance with its national circumstances and priorities. Transformations to sustainability are considered to benefit from iterative learning, deliberative processes, and innovation.[80] (P. 29)
- Adaptation planning and implementation at all levels of governance are contingent on societal values, objectives, and risk perceptions (*high confidence*). Recognition of diverse interests, circumstances, social-cultural contexts, and expectations can benefit decision-making processes. Awareness that climate change may exceed the adaptive capacity of some people and ecosystems may have ethical implications for mitigation decisions and investments. Economic analysis of adaptation is moving away from a unique emphasis on efficiency, market solutions, and benefit/cost analysis to include consideration of non-monetary and non-market measures, risks, inequities, behavioral biases, barriers and limits, and ancillary benefits and costs. [2.2 to 2.4, 9.4, 12.3, 13.2, 15.2, 16.2 to 16.4, 16.6, 16.7, 17.2, 17.3, 21.3, 22.4, 24.4, 24.6, 25.4, 25.8, 26.9, 28.2, 28.4, Table 15-1, Boxes 16-1, 16-4, and 25-7] (P. 85)
- Greater rates and magnitude of climate change increase the likelihood of exceeding adaptation limits (*high confidence*). See Box TS.8. Limits to adaptation occur when adaptive actions to avoid intolerable risks for an actor's objectives or for the needs of a system are not possible or are not currently available. Value-based judgments of what constitutes an intolerable risk may differ. Limits to adaptation emerge from the interaction among climate change and biophysical and/or socioeconomic constraints. Opportunities to take advantage of positive synergies between adaptation and mitigation may decrease with time, particularly if limits to adaptation are exceeded. In some parts of the world, insufficient responses to emerging impacts are already eroding the basis for sustainable development. [1.1, 11.8, 13.4, 16.2 to 16.7, 17.2, 20.2, 20.3, 20.5, 20.6, 25.10, 26.5, Boxes 16-1, 16-3, and 16-4] (P. 88)
- Limits to adaptation can emerge as a result of the interactions among climate change and biophysical and socioeconomic constraints (*medium evidence*, *high agreement*). An adaptation limit occurs owing to the inability to avoid an intolerable risk to an actor's objectives and/or to the sustainability of a natural system. Understanding of limits is informed by historical and recent experience where limits to adaptation have been observed, as well as by limits that are anticipated to arise as a consequence of future global change. Recent studies have provided valuable insights regarding global "tipping points," "key vulnerabilities," or "planetary boundaries" as well as evidence of climate thresholds for agricultural crops, species of fish, forest and coral reef communities, and humans. However, for most regions and sectors, there is a lack of empirical evidence to quantify magnitudes of climate change that would constitute a future adaptation limit. Furthermore, economic development, technology, and cultural norms and values can change over time to enhance or reduce the capacity of systems to avoid limits. As a consequence, some limits may be

considered “soft” in that they may be alleviated over time. Nevertheless, some limits may be “hard” in that there are no reasonable prospects for avoiding intolerable risks. Recent literature suggests that incremental adaptation may not be sufficient to avoid intolerable risks, and therefore transformational adaptation may be required to sustain some human and natural systems. {16.2-7; Table 16-3; Boxes 16-1, 16-4} (P. 902-3)

4.9 Gaps in Our Understanding

Uncertainties about future vulnerability, exposure, and responses of interlinked human and natural systems are large (*high confidence*). This motivates exploration of a wide range of socioeconomic futures in assessments of risks. Understanding future vulnerability, exposure, and response capacity of interlinked human and natural systems is challenging due to the number of interacting social, economic, and cultural factors, which have been incompletely considered to date. These factors include wealth and its distribution across society, demographics, migration, access to technology and information, employment patterns, the quality of adaptive responses, societal values, governance structures, and institutions to resolve conflicts. International dimensions such as trade and relations among states are also important for understanding the risks of climate change at regional scales. [11.3, 12.6, 21.3 to 21.5, 25.3, 25.4, 25.11, 26.2] (2014a)

Disaster loss estimates are lower-bound estimates because many impacts, such as loss of human lives, cultural heritage, and ecosystem services, are difficult to value and monetize, and thus they are poorly reflected in estimates of losses. Impacts on the informal or undocumented economy as well as indirect economic effects can be very important in some areas and sectors, but are generally not counted in reported estimates of losses. [SREX 4.5] (2014a: footnote 59 of Global economic impacts from climate change)

Decision support for impacts, adaptation, and vulnerability is expanding from science-driven linear methods to a wide range of methods drawing from many disciplines (*robust evidence*, *high agreement*). This chapter introduces new material from disciplines including behavioral 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. 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 (*robust evidence*, *high agreement*). There now exists a sufficiently rich set of available methods, tools, and processes to support effective climate impact, adaptation, and vulnerability (CIAV) decisions in a wide range of contexts (*medium evidence*, *medium agreement*), although they may not always be appropriately combined or readily accessible to decision makers. {2.1.1, 2.1.2, 2.1.3, 2.3}
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 and 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 behavioral aspects of decision making (Smit and Wandel, 2006; Sarewitz and Pielke, 2007; Dovers, 2009; Beck, 2010). While more recent guidance on CIAV decision making typically accounts for sectoral, regional, and socioeconomic characteristics (Section 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*) (Sections 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, and 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 policymakers, 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, for example, assessment, strategic planning, or implementation, will also define the framework and tools needed to enable the process. This chapter neither provides any standard template or instructions for decision making, nor does it endorse particular decisions over others. (2014a, Executive Summary)

Others, especially at the local level, such as decision making in traditional communities, are often made more intuitively, with a much greater role for a wide range of social and cultural aspects. These may benefit much more from experience-based approaches, participatory risk assessments, or story- telling to evaluate future implications of possible decisions (e.g., van Aalst et al., 2008; World Bank, 2010a). (2014b)

There is agreement that culture—or the shaping social norms, values, and rules including those related to ethnicity, class, gender, health, age, social status, cast, and hierarchy—is of crucial importance for adaptive capacity as a positive attribute but also as a barrier to successful local adaptation (Section 22.4.6); further research is required in this field, not least because culture is highly heterogeneous within a society or locality (Adger et al., 2007, 2009; Ensor and Berger, 2009; Nielsen and Reenberg, 2010; Jones, 2012). Studies show that, while it is important to develop further the evidence base for the effectiveness of traditional knowledge, integrating cultural components such as stories, myths, and oral history into initiatives to document local and traditional knowledge on adaptive or coping mechanisms is a key to better understanding how climate vulnerability and adaptation are framed and experienced (Urquhart, 2009; Beardon and Newman, 2011; Ford et al., 2012). Appropriate and equitable processes of participation and communication between scientists and local people have been found to prevent misuse or misappropriation of local and scientific knowledge (Nyong et al., 2007; Crane, 2010; Orlove et al., 2010). (2016b)

Understanding of future vulnerability of human and mixed human-natural systems to climate change remains limited due to incomplete consideration of socioeconomic dimensions (*very high confidence*). Future vulnerability will depend on factors such as wealth and its distribution across society, patterns of aging, access to technology and information, labor force participation, societal values, and mechanisms and institutions to resolve conflicts. These dimensions have received only limited attention and are rarely included in vulnerability assessments, and frameworks to integrate social, psychological, and cultural dimensions of vulnerability with biophysical impacts and economic losses are lacking. In addition, conclusions for New Zealand in many sectors, even for biophysical impacts, are based on limited studies that often use a narrow set of assumptions, models, and data and hence have not explored the full range of potential outcomes. {25.3-4, 25.11} (2014b)

Although these small islands nations are by no means homogeneous politically, socially, or culturally, or in terms of physical size and character or economic development, there has been a tendency to generalize about the potential impacts on small islands and their adaptive capacity. (2014b)

Studies from the Pacific have also shown that culture, lifestyle, and a connection to place are more significant drivers of migration than climate (Barnett and Webber, 2010). For example, a Pacific Access Category of migration has been agreed between New Zealand and Tuvalu that permits 75 Tuvaluans to migrate to New Zealand every year (Kravchenko, 2008). (2014b)

Islands are heterogeneous in geomorphology, culture, ecosystems, populations, and hence also in their vulnerability to climate change. Vulnerabilities and adaptation needs are as diverse as the variety of islands between regions and even within nation states (e.g., in Solomon Islands; Rasmussen et al., 2011), often with little climate adaptation occurring in peripheral islands, for example, in parts of the Pacific (Nunn et al., 2013). Quantitative comparison of vulnerability is difficult owing to the paucity of vulnerability indicators. Generic indices of national level vulnerability continue to emerge (Cardona, 2007) but only a minority are focused on small islands (e.g., Blancard and Hoarau, 2013). The island-specific indicators that exist often suffer from lack of data (Peduzzi et al., 2009; Hughes et al., 2012), use indicators that are not relevant in all islands (Barnett and Campbell, 2010), or use data of limited quality for islands, such as SLR (as used in Wheeler, 2011). As a result indicators of vulnerability for small islands often misrepresent actual vulnerability. Recent moves toward participatory approaches that link scientific knowledge with local visions of vulnerability (see Park et al., 2012) offer an important way forward to understanding island vulnerability in the absence of certainty in model-based scenarios. (2014b)

Despite some claims that vulnerability reduction in indigenous communities in small islands may be best tackled by combining indigenous and Western knowledge in a culturally compatible and sustainable manner (Mercer et al., 2007), given the small number of studies in this area, there is not sufficient evidence to determine the effectiveness and limits to the use of traditional methods of weather forecasting under climate change on small islands. (2014b)

Traditional technologies and skills can be effective for current disaster risk management but there is currently a lack of supporting evidence to suggest that they will be equally appropriate under changing cultural conditions and future climate changes on islands. (2014b)

There is agreement that culture—or the shaping social norms, values, and rules including those related to ethnicity, class, gender, health, age, social status, cast, and hierarchy—is of crucial importance for adaptive capacity as a positive attribute but also as a barrier to successful local adaptation (Section 22.4.6); further research is required in this field, not least because culture is highly heterogeneous within a society or locality (Adger et al., 2007, 2009; Ensor and Berger, 2009; Nielsen and Reenberg, 2010; Jones, 2012). Studies show that, while it is important to develop further the evidence base for the effectiveness of traditional knowledge, integrating cultural components such as stories, myths, and oral history into initiatives to document local and traditional knowledge on adaptive or coping mechanisms is a key to better understanding how climate vulnerability and adaptation are framed and experienced (Urquhart, 2009; Beardon and Newman, 2011; Ford et al., 2012). Appropriate and equitable processes of participation and communication between scientists and local people have been found to prevent misuse or misappropriation of local and scientific knowledge (Nyong et al., 2007; Crane, 2010; Orlove et al., 2010). (2014b)

In developing and emergent countries, there exists a general consensus that the adaptive capacity is low, strengthened by the fact that poverty is the key determinant of vulnerability in LA (to climate-related natural hazards; see Rubin and Rossing, 2012) and thus a limit to resilience (Pettengell, 2010) leading to a “low human development trap” (UNDP, 2007). However, Magnan (2009, p. 1) suggests that this analysis is biased by a “relative immaturity of the science of adaptation to explain what are the processes and the determinants of adaptive capacity.” Increasing research efforts on the study of adaptation is therefore of great importance to improve understanding of the actual societal, economical, community, and individual drivers defining the adaptive capacity. Especially, a major focus on traditions and their transmission (Young and Lipton, 2006) may actually indicate potential adaption potentials in remote and economically poor regions of SA and CA. Such a potential does not dismiss the fact that the nature of future challenges may actually not be compared to past climate variability (e.g., glacier retreat in the Andes). (2014b)

Research on adaptation and the scientific understanding of the various processes and determinants of adaptive capacity is also mandatory for the region, with particular emphasis on increasing adaptation capacity involving the traditional knowledge of ancestral cultures and how this knowledge is transmitted. Linking indigenous knowledge with scientific knowledge is important. The concept of “mother earth” (madre tierra in Spanish) as a living system has been mentioned in recent years, as a key sacred entity on the view of indigenous nations and as a system that may be affected and also resilient to climate change. Although some adaptation processes have been initiated in recent years dealing with this and other indigenous knowledge, there is only very limited scientific literature discussing these subjects so far. (2014b)

There are more specific research gaps, including:

- Many mechanisms of how climate change and ocean acidification may be affecting polar ecosystems have been proposed but few studies of physiological tolerances of species, long-term field studies of ecosystem effects, and ecosystem modeling studies are available to be able to attribute with high confidence current and future change in these ecosystems to climate change.
- More comprehensive studies including long-term monitoring on the increasing impacts from climate changes on Arctic communities (urban and rural) and their health, well-being, traditional livelihoods, and life ways are needed. There is a need to assess more fully vulnerabilities and to develop response capacities at the local and regional levels. (2014b)

29.6.2.1. Building Adaptive Capacity with Traditional Knowledge, Technologies, and Skills on Small Islands

As in previous IPCC assessments, there is continuing strong support for the incorporation of indigenous knowledge into adaptation planning. However, this is moderated by the recognition that current practices alone may not be adequate to cope with future climate extremes or trend changes. The ability of a small island population to deal with current climate risks may be positively correlated with the ability to adapt to future climate change, but evidence confirming this remains limited (such as Lefale, 2010). Consequently, this section focuses on evidence for adaptive capacity that reduces vulnerability to existing stressors, enables adaptation to current stresses, and supports current disaster risk management.

Traditional knowledge has proven to be useful in short-term weather forecasting (e.g., Lefale, 2010) although evidence is inconclusive on local capacity to observe long-term climate change (e.g., Hornidge and Scholtes, 2011). In Solomon Islands, Lauer and Aswani (2010) found mixed ability to detect change in spatial cover of seagrass meadows. In Jamaica, Gamble et al. (2010) reported a high level of agreement between farmers' perception of increasing drought incidence and statistical analysis of precipitation and vegetation data for the area. In this case farmers' perceptions clearly validated the observational data and vice versa. Despite some claims that vulnerability reduction in indigenous communities in small islands may be best tackled by combining indigenous and Western knowledge in a culturally compatible and sustainable manner (Mercer et al., 2007), given the small number of studies in this area, there is not sufficient evidence to determine the effectiveness and limits to the use of traditional methods of weather forecasting under climate change on small islands.

Traditional technologies and skills can be effective for current disaster risk management but there is currently a lack of supporting evidence to suggest that they will be equally appropriate under changing cultural conditions and future climate changes on islands. Campbell (2009) identified that traditional disaster reduction measures used in Pacific islands focused around maintaining food security, building community cooperation, and protecting settlements and inhabitants. Examples of actions to maintain food security include: the production and storage of food surpluses, such as yam and breadfruit buried in leaf-lined pits to ferment; high levels of agricultural diversity to minimize specific damage to any one crop; and the growth of robust famine crops, unused in times of plenty that could be used in emergencies (Campbell, 2009). Two discrete studies from Solomon Islands highlight the importance of traditional patterns of social organization within communities to support food security under social and environmental change (Reenberg et al., 2008; Mertz et al., 2010). In both studies the strategy of relying on traditional systems of organization for farming and land use management have been shown to work effectively—largely as there has been little cultural and demographic change. Nonetheless there are physical and cultural limits to traditional disaster risk management. In relation to the ability to store surplus production on atoll islands, on Rongelap in the Marshall Islands, surpluses are avoided, or are redistributed to support community bonds (Bridges and McClatchey, 2009). Further, traditional approaches that Pacific island communities have used for survival for millennia (such as building elevated settlements and resilient structures, and working collectively) have been abandoned or forgotten due to processes of globalization, colonialism, and development (Campbell, 2009). Ongoing processes of rapid urbanization and loss of language and

tradition suggest that traditional approaches may not always be efficacious in longer term adaptation.
Traditional construction methods have long been identified across the Pacific as a means of reducing vulnerability to tropical cyclones and floods in rural areas. In Solomon Islands traditional practices include: elevating concrete floors on Ontong Java to keep floors dry during heavy rainfall events; building low, aerodynamic houses with sago palm leaves as roofing material on Tikopia as preparedness for tropical cyclones; and in Bellona local perceptions are that houses constructed from modern materials and practices are more easily destroyed by tropical cyclones, implying that traditional construction methods are perceived to be more resilient in the face of extreme weather (Rasmussen et al., 2009). In parallel, Campbell (2009) documents the characteristics of traditional building styles (in Fiji, Samoa, and Tonga) where relatively steep hipped roofs, well bound connections and joints, and airtight spaces with few windows or doors offer some degree of wind resistance. Traditional building measures can also reduce damages associated with earthquakes, as evidenced in Haiti (Audefroy, 2011). By reducing damage caused by other stresses (such as earthquakes), adaptive capacity is more likely to be maintained. The quality of home construction is critical to its wind resistance. If inadequately detailed, home construction will fail irrespective of method. Although some traditional measures could be challenged as potentially risky—for example, using palm leaves, rather than metal roofs as a preparation for tropical cyclone impacts—the documentation of traditional approaches, with an evaluation of their effectiveness remains urgently needed. Squatter settlements in urban areas, especially on steep hillsides in the Caribbean, often use poor construction practices frequently driven by poverty and inadequate building code enforcement (Prevatt et al., 2010).
Traditional systems appear less effective when multiple civilization- nature stresses are introduced. For example, in Reunion and Mayotte, population growth, and consequent rises in land and house prices, have led low-income families to settle closer to hazardous slopes that are prone to landslides and to river banks which are prone to flooding (Le Masson and Kelman, 2011). Traditional belief systems can also limit adaptive capacity. Thus, for example, in two Fijian villages, approximately half of survey respondents identified divine will as the cause of climate change (Lata and Nunn, 2012). These findings reinforce earlier studies in Tuvalu (Mortreux and Barnett, 2009), and more widely across the Pacific (Barnett and Campbell, 2010). The importance of taking into account local interests and traditional knowledge in adaptation in small islands is emphasized by Kelman and West (2009) and McNamara and Westoby (2011), yet evidence does not yet exist that reveals the limits to such knowledge, such as in the context of rapid socio-ecological change, or the impact of belief systems on adaptive capacity.
While there is clear evidence that traditional knowledge networks, technologies, and skills can be used effectively to support adaptation in certain contexts, the limits to these tools are not well understood. To date research in the Pacific and Caribbean dominates small island climate change work. More detailed studies on small islands in the central and western Indian Ocean, the Mediterranean, and the central and eastern Atlantic would improve understanding on this topic. (2016b)

Securing rights to resources is essential for greater livelihood benefits for poor indigenous and traditional people (Macchi et al., 2008) and the need for REDD+ schemes to respect and promote community forest tenure rights has been emphasized (Angelsen, 2009). It has been suggested that indigenous people can provide a bridge between biodiversity protection and climate change adaptation (Salick and Ross, 2009): a point that appears to be missing in the current discourse on ecosystem-based adaptation. (2014b)

Research on adaptation and the scientific understanding of the various processes and determinants of adaptive capacity is also mandatory for the region, with particular emphasis on increasing adaptation capacity involving the traditional knowledge of ancestral cultures and how this knowledge is transmitted. Linking indigenous knowledge with scientific knowledge is important. The concept of "mother earth" (madre tierra in Spanish) as a living system has been mentioned in recent years, as a key sacred entity on the view of indigenous nations and as a system that may be affected and also resilient to climate change. Although some adaptation processes have been initiated in recent years dealing with this and other indigenous knowledge, there is only very limited scientific literature discussing these subjects so far. (2014b)

Perceptions and responses to risk and uncertainty: Examine cross-cultural differences in human perception and reaction to climate change and response options. (2014)

A person's wellbeing will be affected by many of the other values that are mentioned above, and by many of the considerations of justice mentioned in Section 3.3. It is bad for a person to have their rights infringed or to be treated unfairly, and it is good for a person to live within a healthy culture and society, surrounded by flourishing nature.
Various concrete measures of wellbeing are in use (Fleurbaey, 2009; Stiglitz et al., 2009). Each reflects a particular view about what well- being consists in. For example, many measures of 'subjective wellbeing' (Oswald and Wu, 2010; Kahneman and Deaton, 2010) assume that wellbeing consists in good feelings. Monetary measures of wellbeing, which are considered in Section 3.6, assume that wellbeing consists in the satisfaction of preferences. Other measures assume wellbeing consists in possessing a number of specific good things. The Human Development Index (HDI) is intended to be an approximate measure of wellbeing understood as capabilities and functionings (UNDP, 2010). It is based on three components: life expectancy, education, and income. The capabilities approach has inspired other measures of wellbeing too (Dervis and Klugman, 2011). In the context of climate change, many different metrics of value are intended to measure particular components of wellbeing: among them are the numbers of people at risk from hunger, infectious diseases, coastal flooding, or water scarcity. These metrics may be combined to create a more general measure. Schneider et al. (2000) advocates the use of a suite of five metrics: (1) monetary loss, (2) loss of life, (3) quality of life (taking account of forced migration, conflict over resources, cultural diversity, and loss of cultural heritage sites), (4) species or biodiversity loss, and (5) distribution and equity. (2014)

In fact, this 'value-action' gap suggests that pursuing climate change mitigation and SD globally may require substantial changes in behaviour in the short term along with a transformation of human values in the long term, e.g., progressively changing conceptions and attitudes toward biophysical systems and human interaction (Gladwin et al., 1995; Leiserowitz et al., 2005; Vlek and Steg, 2007; Folke et al., 2011a). Changing human values would require a better understanding of cross-cultural behavioural differences that in turn relate to environ- mental, economic, and political histories (Norenzayan, 2011). (2014)

Monitoring and evaluation activities are important to ensure effective implementation of a capacity-building framework, helping to understand gaps and needs in capacity building, share best practices, and promote resource efficiency (UNFCCC, 2009c). There are few empirical assessments of current capacity building approaches in relation to cli- mate change (Virji et al., 2012). (2014)

5 RELEVANT REFERENCES

This section is not an exhaustive list of all the relevant references in each of the publications nor a reference of all the citations extracted in the above section. It is simply a few selections which were collected using the keywork search system.

Abryutina, L.I., 2009: Indigenous peoples of the Russian North: social and climatic changes. In: *Climate Change and Arctic Sustainable Development: Scientific, Social, Cultural, and Educational Challenges.* United Nations Educational, Scientific, and Cultural Organization (UNESCO), Paris, France, pp. 164-173.

Acheson, J.M., 2006: Institutional failure in resource management. *Annual Review of Anthropology*, **35**, 117-134.

Adger, W.N., J. Barnett, K. Brown, N. Marshall, and K. O'Brien, 2013: Cultural dimensions of climate change impacts and adaptation. *Nature Climate Change*, **3**, 112-117.

Agrawal, A., 1995: Dismantling the divide between indigenous and scientific knowledge. *Development and Change*, **26(3)**, 413-439.

Akimoto, A, Nair, P K R, Nair, and V D (2008) Carbon stock and sequestration potential of traditional and improved agroforestry systems in the West African Sahel. *Agriculture, Ecosystems and Environment*, 159–166.

Akullo, D., R. Kanzikwer, P. Birungi, W. Akum, L. Aliguma, and M. Barwogeza, 2007:

Alcántara-Ayala, I., M. López-Mendoza, G. Melgarejo-Palafox, R.C. Borja-Baeza, and R. Acevo-Zarate, 2004: Natural hazards and risk communication strategies among indigenous communities. *Mountain Research and Development*, **24(4)**, 298-302.

Alexander, C., N. Bynum, E. Johnson, U. King, T. Mustonen, P. Neofotis, N. Oettle, C. Rosenzweig, C. Sakakibara, V. Shadrin, M. Vicarelli, J. Waterhouse, and B. Weeks, 2011: Linking indigenous and scientific knowledge of climate change. *BioScience*, **61**, 477-484.

Altieri, M. and P. Koohafkan, 2008: *Enduring Farms: Climate Change, Smallholders and Traditional Farming Communities.* TWN Environment and Development Series 6, Third World Network (TWN), Penang, Malaysia, 63 pp.

Altman, J., G. Buchanan, and L. Larsen, 2007: *The Environmental Significance of the Indigenous Estate: Natural Resource Management as Economic Development in Remote Australia.* CAEPR Discussion Paper No. 286/2007, Centre for Aboriginal Economic Policy Research (CAEPR), The Australian National University (ANU), Canberra, ACT, Australia, 65 pp.

Anderson, I., S. Crengle, M. Leialoha Kamaka, T.-H. Chen, N. Palafox, and L. Jackson- Pulver, 2006: Indigenous health in Australia, New Zealand, and the Pacific. *The Lancet*, **367(9524)**, 1775-1785.

Aporta, C. and E. Higgs, 2005: Satellite culture: global positioning systems, Inuit wayfinding, and the need for a new account of technology. *Current Anthropology*, **46**, 729-753.

Aporta, C., D.R.F. Taylor, and G.J. Laidler, 2011: Geographies of Inuit sea ice use. Introduction. *Canadian Geographer / Le Géographe Canadien*, **55**, 1-5.

Atran, S., D.L. Medin, and N.O. Ross, 2005: The cultural mind: environmental decision making and cultural modeling within and across populations. *Psychological Review*, **112(4)**, 744-776.

Audefroy, J.F., 2011: Haiti: post-earthquake lessons learned from traditional construction. *Environment and Urbanization*, **23(2)**, 447-462.

Badke-Schaub, P. and S. Strohschneider, 1998: Complex problem solving in the cultural context. *Le Travail Humain*, **61**, 1-28.

Baraer, M., B.G. Mark, J.M. McKenzie, T. Condom, J. Bury, K.I. Huh, C. Portocarrero, J. Gómez, and S. Rathay, 2012: Glacier recession and water resources in Peru's Cordillera Blanca. *Journal of Glaciology*, **58(207)**, 134-150.

Bark R�H�, D�E� Garrick, C�J� Robinson, and S� Jackson (2012)� Adaptive basin governance and the prospects for meeting Indigenous water claims. *Environ- mental Science & Policy* **19–20**, 169–177. doi: 10.1016/j.envsci.2012.03.005, ISSN: 1462–9011.

Batterbury, S., 2001: Landscapes of diversity: a local political ecology of livelihood diversification in south-western Niger. *Cultural Geographies*, **8(4)**, 437-464.

Battiste, M., 2008: Research ethics for protecting indigenous knowledge and heritage: institutional and researcher responsibilities. In: *Handbook of Critical and Indigenous Methodologies* [Denzin, N.K., Y.S. Lincoln, and L.T. Smith (eds.)]. SAGE Publications, Thousand Oaks, CA, USA, pp. 497-510.

Beck, U., 2010: Climate for change, or how to create a green modernity? *Theory, Culture & Society*, **27**, 254-266.

Bellon, M.R., D. Hodson, and J. Hellin, 2011: Assessing the vulnerability of traditional maize seed systems in Mexico to climate change. *Proceedings of the National Academy of Sciences of the United States of America*, **108(33)**, 13432-13437.

Bellona, M.R., D. Hodson, and J. Hellin, 2011: Assessing the vulnerability of traditional maize seed systems in Mexico to climate change. *Proceedings of the National Academy of Sciences of the United States of America*, **108(33)**, 13432-13437.

Beniston, M., 2010: Climate change and its impacts: growing stress factors for human societies. *International Review of the Red Cross*, **92(879)**, 557-568.

Berkes F�, J� Colding, and C� Folke (2000)� Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications* **10**, 1251–1262.

Berkes, F., 2009: Indigenous ways of knowing and the study of environmental change. *Journal of the Royal Society of New Zealand*, **39**, 151-156.

Brimblecombe, P., 2010a: Heritage climatology. In: *Climate Change and Cultural Heritage* [Lefèvre, R.-A. and C. Sabbioni (eds.)]. Edipuglia, Bari, Italy, pp. 49-56.

Brimblecombe, P., 2010b: Mapping heritage climatologies. In: *Effect of Climate Change on Built Heritage* [Bunnik, T., H. de Clercq, R. van Hees, H. Schellen, and L. Schueremans (eds.)]. Wissenschaftlich-Technische Arbeitsgemeinschaft für Bauwerkserhaltung und Denkmalpflege (WTA) Publications, Pfaffenhofen, Germany, pp. 18-30.

Brimblecombe, P., M.C. Grossi, and I. Harris, 2006: Climate change critical to cultural heritage. In: *Heritage Weathering and Conservation: Proceedings of the International Heritage, Weathering and Conservation Conference (HWC-2006), 21-24 June 2006, Madrid, Spain – Two Volumes* [Fort, R., M. Alvarez de Buergo, M. Gomez-Heras, and C. Vazquez-Calvo (eds.)]. Taylor and Francis, London, UK, pp. 387-393.

Bronen, R., 2009: Forced migration of Alaskan indigenous communities due to climate change: creating a human rights response. In: *Linking Environmental Change, Migration and Social Vulnerability* [Oliver-Smith, A. and X. Shen (eds.)]. Outcomes of the 3rd UNU-EHS Summer Academy of the Munich Re Chair on Social Vulnerability, 27 July-2 August 2008, Hohenkammer, Germany, Studies of the University: Research, Counsel, and Education (SOURCE) publication 12/2009, United Nations University Institute for Environment and Human Security (UNU- EHS), Bonn, Germany, pp. 68-73.

Burgess, C.P., F.H. Johnston, H. Berry, J. McDonnell, D. Yibarbuk, C. Gunabarra, A. Mileran, and R. Bailie, 2009: Healthy country healthy people: superior indigenous health outcomes are associated with ‘caring for country’. *Medical Journal of Australia*, **190(10)**, 567-572.

Burroughs, S., 2010: Sustainable housing for Indigenous populations in remote regions: a case study from Nguiu, Northern Australia. In: *CESB 10: Central Europe towards Sustainable Building: From Theory to Practice*. *Keynote Lectures.* Czech Technical University, Prague, Czech Republic, pp. 11-18.

Bury, J., B.G. Mark, J. McKenzie, A. French, M. Baraer, K. In Huh, M. Zapata Luyo, and R.J. Gómez López, 2010: Glacier recession and human vulnerability in the Yanamarey Watershed of the Cordillera Blanca, Peru. *Climatic Change*, **105(1-2)**, 179-206.

Butzer, K.W. and G.H. Endfield, 2012: Critical perspectives on historical collapse. *Proceedings of the National Academy of Sciences of the United States of America*, **109(10)**, 3628-3631.

Butzer, K.W., 2012: Collapse, environment, and society. *Proceedings of the National Academy of Sciences of the United States of America*, **109(10)**, 3632-3639.

Buultjens, J., D. Gale, and N.E. White, 2010: Synergies between Australian Indigenous tourism and ecotourism: possibilities and problems for future development. *Journal of Sustainable Tourism*, **18(4)**, 497-513.

Byg, A. and J. Salick, 2009: Local perspectives on a global phenomenon – climate change in Eastern Tibetan villages. *Global Environmental Change*, **19(2)**, 156-166.

Cameron, E.S., 2012: Securing indigenous politics: a critique of the vulnerability and adaptation approach to the human dimensions of climate change in the Canadian Arctic. *Global Environmental Change*, **22(1)**, 103-114.

Carey, M., 2010: *In the Shadow of Melting Glaciers: Climate Change and Andean Society*. Oxford University Press, Inc., New York, NY, USA, 273 pp.

Carey, M., A. French, and E. O'Brien, 2012a: Unintended effects of technology on climate change adaptation. An historical analysis of water conflicts below Andean glaciers. *Journal of Historical Geography*, **38**, 181-191.

Carey, M., C. Huggel, J. Bury, C. Portocarrero, and W. Haeberli, 2012b: An integrated socio-environmental framework for glacier hazard management and climate change adaptation. Lessons from Lake 513, Cordillera Blanca, Peru. *Climatic Change*, **112(3-4)**, 733-767.

Carrabine E, and B Longhurst (2002) Consuming the car: anticipation, use and meaning in contemporary youth culture. *The Sociological Review* **50**, 181–196. doi: 10.1111/1467-954X.00362, ISSN: 1467-954X.

Carvalho, A. and J. Burgess, 2005: Cultural circuits of climate change in U.K. Broadsheet Newspapers, 1985–2003. *Risk Analysis*, **25(6)**, 1457-1469

Chang'a, L.B., P.Z. Yanda, and J. Ngana, 2010: Indigenous knowledge in seasonal rainfall prediction in Tanzania: a case of the South-western Highland of Tanzania. *Journal of Geography and Regional Planning*, **3(4)**, 66-72.

Chown, S.L., A.H.L. Huiskes, N.J.M. Gremmen, J.E. Lee, A. Terauds, K. Crosbie, Y. Frenot, K.A. Hughes, S. Imura, K. Kiefer, M. Lebouvier, B. Raymond, M. Tsujimoto, C. Ware, B. van den Vijver, and D.M. Bergstrom, 2012: Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. *Proceedings of the National Academy of Sciences of the United States of America*, **109(13)**, 4938-4943.

Climate Alliance (2013) *Members of Climate Alliance*. Climate Alliance of Euro- pean Cities with Indigenous Rainforest Peoples, Frankfurt, Germany, Available at: http://www.climatealliance.org/fileadmin/inhalte/dokumente/2013/Mitgliederliste_international_September_2013.pdf.

Cobo, J.R.M., 1987: *Study of the Problem of Discrimination Against Indigenous Populations. Volume 5: Conclusions, Proposals and Recommendations*. Sub- commission on Prevention of Discrimination and Protection of Minorities, United Nations, New York, NY, USA, 46 pp.

Cochran, P., O.H. Huntington, C. Pungowiyi, S. Tom, F.S. Chapin III, H.P. Huntington, N.G. Maynard, and S.F. Trainor, 2013: Indigenous frameworks for observing and responding to climate change in Alaska. *Climatic Change*, **12(3 SI)**, 557-567.

Collier U, and RE Löfstedt (1997) Think globally, act locally?: Local climate change and energy policies in Sweden and the UK. *Global Environmental Change* **7**, 25–40. doi: 10.1016/S0959-3780(96)00025-8, ISSN: 0959-3780.

Commonwealth of Australia, 2010: *Securing our Water Future.* Australian Government, Department of the Environment, Water, Heritage and the Arts, Canberra, ACT, Australia, 24 pp.

Cowan, D.A., S.L. Chown, P. Convey, M. Tuffin, K. Hughes, S. Pointing, and W.F. Vincent, 2011: Non-indigenous microorganisms in the Antarctic: assessing the risks. *Trends in Microbiology*, **19(11)**, 540-548.

Crane, T.A., 2010: Of models and meanings: cultural resilience in social-ecological systems. *Ecology and Society*, **15(4)**, 19, www.ecologyandsociety.org/vol15/ iss4/art19/.

Crate, S.A., 2008: Gone the bull of winter? Grappling with the cultural implications of and anthropology's role(s) in global climate change. *Current Anthropology*, **49(4)**, 569-595.

Crate, S.A., 2011: Climate and culture: anthropology in the era of contemporary climate change. *Annual Review of Anthropology*, **40**, 175-194.

Crate, S.A., 2013: *Climate Change and Human Mobility in Indigenous Communities of the Russian North.* Brookings-LSE Project on Internal Displacement, The Brookings Institution, Washington, DC, USA, 45 pp.

Cruikshank, J., 2001: Glaciers and climate change: perspectives from oral tradition. *Arctic*, **54(4)**, 377-393.

Crutzen, P.J., 2002: Geology of mankind. *Nature*, **415(6867)**, 23.

Cullen-Unsworth, L.C., R. Hill, J.R.A. Butler, and M. Wallace, 2011: A research process for integrating indigenous and scientific knowledge in cultural landscapes: principles and determinants of success in the Wet Tropics World Heritage Area, Australia. *The Geographical Journal*, **178(4)**, 351-365.

Daes I� (1996)� *Supplementary Report of the Special Rapporteur on the Protection of the Heritage of Indigenous Peoples*. United Nations Sub-Commission on Pre- vention of Discrimination and Protection of Minorities.

De Groot, J.I. and L. Steg, 2007: Value orientations and environmental beliefs in five countries: validity of an instrument to measure egoistic, altruistic and biospheric value orientations. *Journal of Cross-Cultural Psychology*, **38**, 318-332.

Deak, J. and E. Bucht, 2011: Planning for climate change: the role of indigenous blue infrastructure, with a case study in Sweden. *Town Planning Review*, **82(6)**, 669- 685.

Dekens, J., 2008: Local knowledge on flood preparedness: examples from Nepal and Pakistan. In: *Indigenous Knowledge for Disaster Risk Reduction: Good Practices and Lessons Learned from Experiences in the Asia-Pacific Region* [Shaw, R., N. Uy, and J. Baumwoll (eds.)]. European Union (EU), Kyoto University International Environment and Disaster Management Laboratory, Graduate School of Global Environmental Studies, and the United Nations Office for Disaster Risk Reduction – Regional Office for Asia and Pacific (UNISDR AP), UNISDR AP, Bangkok, Thailand, pp. 35-40.

DeMenocal, P.B., 2001: Cultural responses to climate change during the late Holocene. *Science*, **292(5517)**, 667-673.

Descola, P., 2010: *Diversité des Natures, Diversité des Cultures*. Bayard, Paris, France, 88 pp.

Diagne, K., 2007: Governance and natural disasters: addressing flooding in Saint Louis, Senegal. *Environment and Urbanization*, **19(2)**, 552-562.

Diamond, J.D., 2005: *Collapse: How Societies Choose to Fail or Succeed*. Penguin Books, New York, NY, USA, 575 pp.

Diemberger, H., K. Hastrup, S. Schaffer, C.F. Kennel, D. Sneath, M. Bravo, H.F. Graf, J. Hobbs, J. Davis, and M.L. Nodari, 2012: Communicating climate knowledge: proxies, processes, politics. Commentaries. *Current Anthropology*, **53(2)**, 226-244.

Douglas, M. and A. Wildavsky, 1982: *Risk and Culture: An Essay on the Selection of Technological and Environmental Dangers.* University of California Press, Berkeley, CA, USA, 224 pp.

Downing, A. and A. Cuerrier, 2011: A synthesis of the impacts of climate change on the First Nations and Inuit of Canada. *Indian Journal of Traditional Knowledge*, **10(1)**, 57-70.

Drysdale, R., G. Zanchetta, J. Hellstrom, R. Maas, A. Fallick, M. Pickett, I. Cartwright, and L. Piccini, 2006: Late Holocene drought responsible for the collapse of Old World civilizations is recorded in an Italian cave flowstone. *Geology*, **34(2)**, 101-104.

Dube, O.P. and B.M. Sekhwela, 2008: Indigenous knowledge, institutions and practices for coping with variable climate in the Limpopo basin of Botswana. In: *Climate Change and Adaptation* [Leary, N., J. Adejuwon, V. Barros, I. Burton, J. Kulkarni, and R. Lasco (eds.)]. Earthscan, London, UK, pp. 71-99.

Dugmore, A.J., C. Keller, T.H. McGovern, A.F. Casely, and K. Smiarowski, 2009: Norse Greenland settlement and limits to adaptation. In: *Adapting to Climate Change: Thresholds, Values, Governance* [Adger, W.N., I. Lorenzoni, and K.L. O'Brien (eds.)]. Cambridge University Press, Cambridge, UK, pp. 96-113.

Dugmore, A.J., T.H. McGovern, O. Vesteinsson, J. Arneborg, R. Streeter, and C. Keller, 2012: Cultural adaptation, compounding vulnerabilities and conjunctures in Norse Greenland. *Proceedings of the National Academy of Sciences of the United States of America*, **109(10)**, 3658-3663.

Dunlop, M. and P. Brown, 2008: *Implications of Climate Change for Australia's National Reserve System: A Preliminary Assessment.* A Report to the Australian Government, Department of Climate Change and the Department of the Environment, Water, Heritage and the Arts, Department of Climate Change, Canberra, ACT, Australia, 188 pp.

Dunning, N.P., T.P. Beach, and S. Luzzadder-Beach, 2012: Kax and kol: collapse and resilience in lowland Maya civilization. *Proceedings of the National Academy of Sciences of the United States of America*, **109(10)**, 3652-3657. edu/ucp/books/book/chicago/M/bo3631823.html.

Eira, I.M.G., 2012: *Muohttaga Jávohis Giella: Sámi Árbevirolaš Máhttu Muohttaga Birra Dálkkádatrievdanáiggis (The Silent Language of Snow: Sámi Traditional Knowledge of Snow in Times of Climate Change).* Ph.D. Dissertation, University of Tromsø, Tromsø, Norway.

Eira, I.M.G., C. Jaedicke, O.H. Magga, N.G. Maynard, D. Vikhamar-Schuler, and S.D. Mathiesen, 2013: Traditional Sámi snow terminology and physical snow classification – two ways of knowing. *Cold Regions Science and Technology*, **85**, 117-130.

Ellemor, H., 2005: Reconsidering emergency management and indigenous communities in Australia. *Global Environmental Change Part B: Environmental Hazards*, **6(1)**, 1-7.

Emperaire, L. and N. Peroni, 2007: Traditional management of agrobiodiversity in Brazil: a case study of manioc. *Human Ecology*, **35(6)**, 761-768.

Endfield, G.H., 2012: The resilience and adaptive capacity of social-environmental systems in colonial Mexico. *Proceedings of the National Academy of Sciences of the United States of America*, **109(10)**, 3676-3681.

Engels A (2008) Local environmental crises and global sea level rise: the case of coastal zones in Senegal. In: *Culture and the changing environment: uncer- tainty, cognition and risk management in cross-cultural perspective*. Berghahn Books, New York, pp. 175–195. ISBN: 9781571814784.

Ensor, J. and R. Berger, 2009: Community-based adaptation and culture in theory and practice. In: *Adapting to Climate Change: Thresholds, Values and Governance* [Adger, W.N., I. Lorenzoni, and K. O'Brien (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 227-239.

Eyong, C.T., 2007: Indigenous knowledge and sustainable development in Africa: case study on central Africa. In: *Indigenous Knowledge Systems and Sustainable Development: Relevance for Africa* [Boon, E.K. and L. Hens (eds.)]. Tribes and Tribals, Special Volume No. 1, Kamla-Raj Enterprises, Delhi, India, pp. 121-139.

Finley-Brook M, and C Thomas (2010) From malignant neglect to extreme intervention: treatment of displaced indigenous populations in two large hydro projects in Panama. *Water Altern.* **3**, 269–290.

Flint, C.G., E.S. Robinson, J. Kellogg, G. Ferguson, L. BouFajreldin, M. Dolan, I. Raskin, and M.A. Lila, 2011: Promoting wellness in Alaskan villages: integrating traditional knowledge and science of wild berries. *Ecohealth*, **8(2)**, 199-209, doi:10.1007/s10393-011-0707-9.

Foale, S.J., 2008: Conserving Melanesia's coral reef heritage in the face of climate change. *Historic Environment* **18**, 30-36.

Ford, J.D., 2009a: Vulnerability of Inuit food systems to food insecurity as a consequence of climate change: a case study from Igloolik, Nunavut. *Regional Environmental Change*, **9(2)**, 83-100.

Ford, J.D., 2009b: Dangerous climate change and the importance of adaptation for the Arctic's Inuit population. *Environmental Research Letters*, **4(2)**, 024006, doi:10.1088/1748-9326/4/2/024006.

Ford, J.D., W. Vanderbilt, and L. Berrang-Ford, 2011: Authorship in IPCC AR5 and its implications for content. Climate change and indigenous populations in WGII. *Climatic Change*, **113(2)**, 201-213.

Ford, J.D., W.A. Gough, G.J. Laidler, J. MacDonald, C. Irngaut, and K. Qrunnut, 2009: Sea ice, climate change, and community vulnerability in northern Foxe Basin, Canada. *Climate Research*, **38**, 137-154.

Gadgil M, F Berkes, and C Folke (1993) Indigenous Knowledge for Biodiversity Conservation. *AMBIO: A Journal of the Human Environment* **22**, 151–156.

Galloway McLean, K., 2010: *Advance Guard: Climate Change Impacts, Adaptation, Mitigation and Indigenous Peoples – A Compendium of Case Studies.* United Nations University (UNU), Traditional Knowledge Initiative, Darwin, Australia, 124 pp.

Galloway McLean, K., A. Ramos-Castillo, and J.T. Rubis (eds.), 2011: *Indigenous Peoples, Marginalized Populations and Climate Change:Vulnerability, Adaptation and Traditional Knowledge*. IPMPCC/2011/MEX/3/REPORT, IPMPCC Meeting Report of the Expert Workshop on Indigenous Peoples, Marginalized Populations and Climate Change, July 19-21, 2011, Mexico City, DF, Mexico, Co-convened by the United Nations University (UNU), Intergovernmental Panel on Climate Change (IPCC), United

Nations Educational, Scientific and Cultural Organization (UNESCO), Secretariat of the Convention on Biological Diversity (CBD), United Nations Development Program (UNDP)/GEF Small Grants Programme, and Mexican National Institute of Ecology, United Nations University-Institute of Advanced Studies: Traditional Knowledge Initiative, Darwin, NT, Australia and UNESCO-Local and Indigenous Knowledge Systems (LINKS) Programme, Paris, France, 49 pp., www.unutki.org/downloads/File/2011_IPMPCC_Mexico_ Workshop_Summary_Report-Final.pdf.

Galloway-McLean, K., 2010: *Advance Guard: Climate Change Impacts, Adaptation, Mitigation and Indigenous Peoples – A Compendium of Case Studies.* United Nations University, Institute for Advanced Studies (UNU-IAS), Traditional Knowledge Initiative, Darwin, NT, Australia, 124 pp.

Gamble, D.W., D. Campbell, T.L. Allen, D. Barker, S. Curtis, D. McGregor, and J. Popke, 2010: Climate change, drought, and Jamaican agriculture: local knowledge and the climate record. *Annals of the Association of American Geographers*, **100(4)**, 880-893.

Garschagen, M., 2013: Resilience and organisational institutionalism from a cross- cultural perspective: an exploration based on urban climate change adaptation in Vietnam. *Natural Hazards*, **67(1)**, 25-46.

Gieryn, T.F., 1999: *Cultural Boundaries of Science: Credibility on the Line.* University of Chicago Press, Chicago, IL, USA, 398 pp.

Gilbert J. (2006). *Indigenous Peoples' Land Rights Under International Law: From Victims to Actors*. BRILL, 352 pp. ISBN: 9781571053695.

Gilles, J.L., J.L. Thomas, C. Valdivia, and E.S. Yucra, 2013: Laggards or leaders: conservers of traditional agricultural knowledge in Bolivia. *Rural Sociology*, **78(1)**, 51-74.

Gómez-Baggethun, E., V. Reyes-García, P. Olsson, and C. Montes, 2012: Traditional ecological knowledge and community resilience to environmental extremes: a case study in Doñana, SW Spain. *Global Environmental Change*, **22(3)**, 640-650.

Gorman-Murray, A., 2010: An Australian feeling for snow: towards understanding cultural and emotional dimensions of climate change. *Cultural Studies Review*, **16**, 60-81.

Goulden, M., L.O. Naess, K. Vincent, and W.N. Adger, 2009: Diversification, networks and traditional resource management as adaptations to climate extremes in rural Africa: opportunities and barriers. In: *Adapting to Climate Change: Thresholds, Values and Governance* [Adger, W.N., I. Lorenzoni, and K. O'Brien (eds.)]. Cambridge University Press, Cambridge, UK, pp. 448-464.

Gray, C.L., R.E. Bilsborrow, J.L. Bremner, and F. Lu, 2008: Indigenous land use in the Ecuadorian Amazon: a cross-cultural and multilevel analysis. *Human Ecology*, **36(1)**, 97-109.

Gray, M.C., J.C. Altman, and N. Halasz, 2005: *The Economic Value of Wild Resources to the Indigenous Community of the Wallis Lake Catchment.* CAEPR Discussion Paper No 272/2005, Centre for Aboriginal Economic Policy Research (CAEPR), The Australian National University (ANU), Canberra, ACT, Australia, 40 pp.

Green D., and G. Raygorodetsky (2010). Indigenous knowledge of a changing climate. *Climatic Change* **100**, 239–242. Available at: http://www.springerlink.com/index/27kg6682148j0670.pdf.

Green D., J. Billy, and A. Tapim (2010). Indigenous Australians' knowledge of weather and climate. *Climatic Change* **100**, 337–354.Available at: http://www. springerlink.com/index/u04024q252848663.pdf.

Green, D. and G. Raygorodetsky, 2010: Indigenous knowledge of a changing climate. *Climatic Change*, **100(2)**, 239-242.

Green, D., J. Billy, and A. Tapim, 2010: Indigenous Australians' knowledge of weather and climate. *Climatic Change*, **100(2)**, 337-354.

Green, D., S. Jackson, and J. Morrison (eds.), 2009: *Risks from Climate Change to Indigenous Communities in the Tropical North of Australia*. Department of Climate Change and Energy Efficiency, Canberra, ACT, Australia, 185 pp.

Gregory, R. and W. Trousdale, 2009: Compensating aboriginal cultural losses: an alternative approach to assessing environmental damages. *Journal of Environmental Management*, **90(8)**, 2469-2479.

Grossi, C.M., P. Brimblecombe, and I. Harris, 2007: Predicting long term freeze–thaw risks on Europe built heritage and archaeological sites in a changing climate. *Science of the Total Environment*, **377(2-3)**, 273-281.

Gujja, B., S. Dalai, H. Shaik, and V. Goud, 2009: Adapting to climate change in the Godavari River basin of India by restoring traditional water storage systems. *Climate and Development*, **1(3)**, 229-240.

Halls, A.S., 2009: Addressing fisheries in the Climate Change and Adaptation Initiative. *Catch and Culture: Fisheries Research and Development in the Mekong Region*, **15(1)**, 12-16.

Harberger, A.C., 1984: Basic needs versus distributional weights in social cost- benefit analysis. *Economic Development and Cultural Change*, **32(3)**, 455-474.

Hardess, L., A. Karst, M. M'Lot, S. Morgan, S. Wolfe, R. Matthews, and R. Sydneysmith, 2011: *Climate Change and Adaptive Capacity in Aboriginal Communities South of 60 Assessment Report.* Centre for Indigenous Environmental Resources (CIER) and the University of British Columbia (UBC), CIER, Winnipeg, MB, Canada, and UBC, Vancouver, BC, Canada, 413 pp.
596 pp.

Harris, S.E., 2012: Cyprus as a degraded landscape or resilient environment in the wake of colonial intrusion. *Proceedings of the National Academy of Sciences of the United States of America*, **109(10)**, 3670-3675.

Hayes T.M., and F. Murtinho (2008). Are indigenous forest reserves sustainable? An analysis of present and future land-use trends in Bosawas, Nicaragua. *Inter- national Journal of Sustainable Development & World Ecology* **15**, 497–511. doi: 10.1080/13504500809469845, ISSN: 1350-4509.

Henriksen J.B. (2007). *Highly Vulnerable Indigenous and Local Communities, Inter Alia, of the Arctic, Small Island States and High Altitudes, Concerning the Impacts of Climate Change and Accelerated Threats, such as Pollution, Drought and Desertification, to Traditional Knowledge and Practices with a Focus of Causes and Solution*. United Nations Environmental Program, 36 pp. Available at: http://www.cbd.int/doc/meetings/tk/emccilc-01/other/emccilc-01-wg8j- 05-inf-18-en.pdf.

Henriksen J.B. (2007). *Highly Vulnerable Indigenous and Local Communities, Inter Alia, of the Arctic, Small Island States and High Altitudes, Concerning the Impacts of Climate Change and Accelerated Threats, such as Pollution, Drought and Desertification, to Traditional Knowledge and Practices with a Focus of Causes and Solution*. United Nations Environmental Program, 36 pp. Available at: http://www.cbd.int/doc/meetings/tk/emccilc-01/other/emccilc-01-wg8j- 05-inf-18-en.pdf.

Herman-Mercer, N., P.F. Schuster, and K.B. Maracle, 2011: Indigenous observations of climate change in the Lower Yukon River Basin, Alaska. *Human Organization*, **70**, 244-252.

Heyd, T. and N. Brooks, 2009: Exploring cultural dimensions of adaptation to climate change. In: *Adapting to Climate Change: Thresholds, Values, Governance* [Adger, W.N., I. Lorenzoni, and K.L. O'Brien (eds.)]. Cambridge University Press, Cambridge, UK, pp. 269-82.

Heyd, T., 2008: Cultural responses to natural changes such as climate change. *Espace populations sociétés*, **1**, 83-88.

Hofstede, G., 1980: *Culture's Consequences: International Differences in Work-related Values*. Sage Publications, Beverly Hills, CA, USA, 327 pp.

Hofstede, G., 2001: *Culture's Consequences: Comparing Values, Behaviors, Institutions and Organizations Across Nations*. SAGE Publications, Thousand Oaks, CA, USA,

Hofstede, G., G.J. Hofstede, and M. Minkov, 2010: *Cultures and Organizations: Software of the Mind*. McGraw-Hill, New York, NY, USA, 562 pp.

Hovelsrud, G., B. Poppel, B. Oort, and J. Reist, 2011: Arctic societies, cultures, and peoples in a changing cryosphere. *Ambio*, **40(1)**, 100-110.

Hovelsrud, G.K., B. Poppel, B.E.H. van Oort, and J.D. Reist, 2011: Arctic societies, cultures, and peoples. In: *Snow, Water, Ice and Permafrost in the Arctic (SWIPA).* Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway, pp. 445- 483.

Howitt, R., O. Havnen, and S. Veland, 2012 Natural and unnatural disasters: responding with respect for indigenous rights and knowledges. *Geographical Research*, **50(1)**, 47-59.

Huber, T. and P. Pedersen, 1997: Meteorological knowledge and environmental ideas in traditional and modern societies: the case of Tibet. *Journal of the Royal Anthropological Institute*, **3**, 577-597.

Hugo, G., 2011: Lessons from past forced resettlement for climate change migration. In: *Migration and Climate Change* [Piguet, É., A. Pécoud, and P.d. Guchteneire (eds.)]. United Nations Educational, Scientific and Cultural Organization (UNESCO), Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 260-288.

Hulme, M., 2008: Geographical work at the boundaries of climate change. *Transactions of the Institute of British Geographers*, **33(1)**, 5-1

Hunt, T.L., 2007: Rethinking Easter Island's ecological catastrophe. *Journal of Archaeological Science*, **34(3)**, 485-502.

Hunter, E., 2009: 'Radical hope' and rain: climate change and the mental health of Indigenous residents of northern Australia. *Australasian Psychiatry*, **17(6)**, 445- 452.

Huntington, H., T. Callaghan, S. Fox, and I. Krupnik, 2004: Matching traditional and scientific observations to detect environmental change: a discussion on Arctic terrestrial ecosystems. *Ambio*, **13**, 18-23.

Ifejika Speranza, C., B. Kiteme, P. Ambenje, U. Wiesmann, and S. Makali, 2010: Indigenous knowledge related to climate variability and change: insights from droughts in semi-arid areas of former Makueni District, Kenya. *Climatic Change*, **100(2)**, 295-315.

Ignatow, G., 2006: Cultural models of nature and society. *Environment and Behaviour*, **38**, 441-461.

Ignatowski, J. and J. Rosales, 2013: Identifying the exposure of two subsistence villages in Alaska to climate change using traditional ecological knowledge. *Climatic Change*, **121(2)**, 285-299.
Indigenous knowledge in agriculture: a case study of the challenges in sharing knowledge of past generations in a globalized context in Uganda. In: *Programme and Proceedings of the World Library and Information Congress: 73rd IFLA General Conference and Council, "Libraries for the Future: Progress, Development and Partnerships,"19-23, August 2007, Durban, South Africa, Session: 120 – Agricultural Libraries: Impact of Globalisation on Small Farmers Worldwide: Implications on Information Transfer*. International Federation of Library Associations and Institutions (IFLA), Royal National Library, The Hague, Netherlands, 14 pp.

IUCN, 2008: *Ecosystem-based Adaptation: An Approach for Building Resilience and Reducing Risk for Local Communities and Ecosystems.* A submission by International Union for Conservation of Nature (IUCN) to the Chair of the AWG- LCA with respect to the Shared Vision and Enhanced Action on Adaptation, on behalf of: IUCN, The Nature Conservancy, WWF, Conservation International, BirdLife International, Indigenous Peoples of Africa Co-ordinating Committee, Practical Action, WILD Foundation, Wildlife Conservation Society, Fauna and Flora International and Wetlands International, IUCN, Gland, Switzerland, 2 pp.

Jacob, C., T. McDaniels, and S. Hinch, 2010: Indigenous culture and adaptation to climate change: sockeye salmon and the St'át'imc people. *Mitigation and Adaptation Strategies for Global Change*, **15**, 859-876.

Kahan, D.M. and D. Braman, 2006: Cultural cognition and public policy. *Yale Law and Policy Review*, **24**, 147-171.

Kahan, D.M., D. Braman, P. Slovic, J. Gastil, and G.L. Cohen, 2007: *The Second National Risk and Culture Study: Making Sense of – and Making Progress In – The American Culture War of Fact*. GWU Legal Studies Research Paper No. 370, Yale Law School Public Law Working Paper No. 154, GWU Law School Public Law Research Paper No. 370, Harvard Law School Program on Risk Regulation Research Paper No. 08

Kalame, F.B., M. Brockhaus, J. Nkem, M. Idinoba, and M. Kanninen, 2008: Using forest ecosystem goods and services for climate change adaptation in Burkina Faso and Ghana: policy gaps and constraints. In: *International Conferences on Adaptation of Forests and Forest Management to Changing Climate with Emphasis on Forest Health: A Review of Science, Policies and Practices: Book of Abstracts and Preliminary Programme, August 25-28 2008, Umea, Sweden*. Organized by Swedish University of Agricultural Sciences (SLU), Umea, Sweden, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, and International Union of Forest Research Organizations (IUFRO), Vienna, Austria, p. 37.

Kalanda-Joshua, M., C. Ngongondo, L. Chipeta, and F. Mpembeka, 2011: Integrating indigenous knowledge with conventional science: enhancing localised climate and weather forecasts in Nessa, Mulanje, Malawi. *Physics and Chemistry of the Earth*, **36(14)**, 996-1003.

Kiem, A.S. and E.K. Austin, 2013: Drought and the future of rural communities: opportunities and challenges for climate change adaptation in regional Victoria, Australia. *Global Environmental Change*, **23(5)**, 1307-1316.

Kiem, A.S., D.C. Verdon-Kidd, S.L. Boulter, and J.P. Palutikof, 2010: *Learning from Experience: Historical Case Studies and Climate Change Adaptation*. Report for the National Climate Change Adaptation Research Facility (NCCARF), Griffith University, Gold Coast Campus, Southport, Australia, 33 pp.

Kirschbaum, M.U.F., N.W.H. Mason, M.S. Watt, A. Tait, A.E. Ausseil, D.J. Palmer, and F.E. Carswell, 2011a: *Productivity Surfaces for* Pinus radiata *and a Range of Indigenous Forest Species under Current Climatic Conditions.* MAF Technical Paper No: 2011/45, Full report prepared for the Ministry of Agriculture and Forestry (MAF) by Landcare Research (CO9X0902), MAF, Wellington, New Zealand, 119 pp.

Krauss, W. and H. von Storch, 2012: Post-normal practices between regional climate services and local knowledge. *Nature and Culture*, **7**, 213-230.

Kronik J, and D Verner (2010) The Role of Indigenous Knowledge in Crafting Adaptation and Mitigation Strategies for Climate Change in Latin America. In: *The Social Dimensions of Climate Change: Equity and Vulnerability in a Warm- ing World*. World Bank Publications, pp. 145–169. ISBN: 9780821378878.

Krupnik, I. and D. Jolly (eds.), 2002: *The Earth Is Faster Now: Indigenous Observations of Arctic Environmental Change.* Frontiers in Polar Social Science, Arctic Research Consortium of the United States, Fairbanks, AK, USA, 384 pp.

Krupnik, I. and D. Jolly (eds.), 2002: *The Earth Is Faster Now: Indigenous Observations of Arctic Environmental Change.* Frontiers in Polar Social Science, Arctic Research Consortium of the United States, Fairbanks, AK, USA, 383 pp. **Krupnik**, I. and G.C. Ray, 2007: Pacific walruses, indigenous hunters, and climate change: bridging scientific and indigenous knowledge. *Deep-Sea Research Part II: Topical Studies in Oceanography*, **54(23-26)**, 2946-2957.

Krupnik, I. and G.C. Ray, 2007: Pacific walruses, indigenous hunters, and climate change: bridging scientific and indigenous knowledge. *Deep Sea Research Part II: Topical Studies in Oceanography*, **54**, 2946-2957.

Kuruppu, N. and D. Liverman, 2011: Mental preparation for climate adaptation: the role of cognition and culture in enhancing adaptive capacity of water management in Kiribati. *Global Environmental Change*, **21(2)**, 657-669.

Kuruppu, N., 2009: Adapting water resources to climate change in Kiribati: the importance of cultural values and meanings. *Environmental Science & Policy*, **12**, 799-809.

Kwan, D., H. Marsh, and S. Delean, 2006: Factors influencing the sustainability of customary dugong hunting by a remote indigenous community. *Environmental Conservation*, **33(2)**, 164-171.

Kymlicka W (1995) *Multicultural Citizenship: A Liberal Theory of Minority Rights*. Cambridge University Press, 290 pp. Available at: http://journals.cambridge. org.proxy.library.ucsb.edu:2048 / production / action / cjoGetFulltext?fulltextid=6258800.

Laidler, G.J., 2006: Inuit and scientific perspectives on the relationship between sea ice and climate change: the ideal complement? *Climatic Change*, **78(2-4)**, 407- 444.

Lammel, A., C. Guillen, E. Dugas, and F. Jamet, 2010: Cultural and environmental changes: cognitive adaptation to global warming. In: *Steering the Cultural Dynamics: Selected Papers from the 2010 Congress of the International Association for Cross-Cultural Psychology* [Kashima, Y., E. Kashima, and R. Beatson (eds.)]. eBook, International Association for Cross-Cultural Psychology (IACCP), Melbourne, Australia, pp. 49-58, www.iaccp.org/drupal/sites/default/ files/melbourne_pdf/Melbourne%20Proceedings.pdf.

Lammel, A., E. Dugas, and C. Guillen, 2011: Traditional way of thinking and prediction of climate change in New Caledonia (France). *Indian Journal of Traditional Knowledge*, **10**, 13-20.

Langton, M., M. Parsons, S. Leonard, K. Auty, D. Bell, C.P. Burgess, S. Edwards, R. Howitt, S. Jackson, V. McGrath, and J. Morrison, 2012: *National Climate Change Adaptation Research Plan: Indigenous Communities.* NCCARF Publication 11/12, National Climate Change Adaptation Research Facility (NCCARF), Griffith University, Gold Coast Campus, Southport, QLD, Australia, 48 pp.

Larson, A.M., 2010: Making the 'rules of the game': constituting territory and authority in Nicaragua's indigenous communities. *Land Use Policy*, **27(4)**, 1143- 1152.

Lauer, M. and S. Aswani, 2010: Indigenous knowledge and long-term ecological change: detection, interpretation, and responses to changing ecological conditions in Pacific Island Communities. *Environmental Management*, **45(5)**, 985-997.

LDC Expert Group, 2011: *Best Practices and Lessons Learned in Addressing Adaptation in the Least Developed Countries through the National Adaptation Programme of Action Process.* Vol. 1, Least Developed Countries (LCD) Expert Group (LEG), in consultation with LDC Parties and the Global Environment Facility (GEF) and its agencies, with support from the United Nations Convention on Climate Change (UNFCCC) Secretariat, UNFCCC Secretariat, Bonn, Germany, 78 pp.

Leck, H., C. Sutherland, D. Scott, and G. Oelofse, 2012: Social and cultural barriers to adaptation implementation: the case of South Africa. In: *Overcoming Barriers to Climate Change Adaptation Implementation in Southern Africa* [Masters, L. and L. Duff (eds.)]. Africa Institute of South Africa, Pretoria, South Africa, pp. 61-82.

Lefale P (2010) Ua ‘afa le Aso Stormy weather today: traditional ecological knowl- edge of weather and climate. The Samoa experience. *Climatic Change* **100**, 317–335. doi: 10.1007/s10584-009-9722-z.

Lefale, P., 2010: *Ua ‘afa le Aso* Stormy weather today: traditional ecological knowledge of weather and climate. The Samoa experience. *Climatic Change*, **100(2)**, 317-335.

Leonard, S., J. Mackenzie, F. Kofod, M. Parsons, M. Langton, P. Russ, L. Ormond-Parker, K. Smith, and M. Smith, 2013: *Indigenous Climate Change Adaptation in the Kimberley Region of North-Western Australia: Learning from the Past, Adapting in the Future: Identifying Pathways to Successful Adaptation in Indigenous Communities*. National Climate Change Adaptation Research Facility (NCCARF), Griffith University, Gold Coast Campus, Southport, QLD, Australia, 131 pp.

Leonard, S., M. Parsons, K. Olawsky, and F. Kofod, 2013: The role of culture and traditional knowledge in climate change adaptation: insights from east Kimberley, Australia. *Global Environmental Change*, **23(3)**, 623-632.

Luzar, J.B., K.M. Silvius, H. Overman, S.T. Giery, J.M. Read, and J.M.V. Fragoso, 2011: Large-scale environmental monitoring by indigenous peoples. *BioScience*, **61(10)**, 771-781.

Luzzadder-Beach, S., T.P. Beach, and N.P. Dunning, 2012: Wetland fields as mirrors of drought and the Maya abandonment. *Proceedings of the National Academy of Sciences of the United States of America*, **109(10)**, 3646-3651.

Lynn, K., J. Daigle, J. Hoffman, F. Lake, N. Michelle, D. Ranco, C. Viles, G. Voggesser, and P. Williams, 2013: The impacts of climate change on tribal traditional foods. *Climatic Change*, **120(3)**, 545-556, doi:10.1007/s10584-013-0736-1.

Macchi, M., G. Oviedo, S. Gotheil, K. Cross, A. Boedhihartono, C. Wolfangel, and M. Howell, 2008: *Indigenous and Traditional Peoples and Climate Change*. Int’l Union for Conservation of Nature (IUCN), Gland, Switzerland

Maclean, K. and L. Cullen, 2009: Research methodologies for the co-production of knowledge for environmental management in Australia. *Journal of the Royal Society of New Zealand*, **39**, 205-208.

Magga, O.H., S.D. Mathiesen, R.W. Corell, and A. Oskal, 2011: *Reindeer Herding, Traditional Knowledge and Adaptation to Climate Change and Loss of Grazing Land*. Part of the Ipy Ealát Consortium, the Ealát Project (Ipy # 399), Reindeer Herders Vulnerability Network Study: Reindeer Pastoralism in a Changing Climate, A Project led by Norway and the Association of World Reindeer Herders (WRH) in Arctic Council, Sustainable Development Working Group (SDWG), International Centre for Reindeer Husbandry, Kautokeino, Norway, 75 pp.

Mallawaarachchi, T. and A. Foster, 2009: *Dealing with Irrigation Drought: The Role of Water Trading in Adapting to Water Shortages in 2007-08 in the Southern Murray-Darling Basin*. ABARE Research Report 09.6 to the Department of the Environment, Water, Heritage, and the Arts, Australian Bureau of Agriculture and Resource Economics (ABARE), Canberra, Australia, 32 pp.

Masike, S. and P. Urich, 2008: Vulnerability of traditional beef sector to drought and the challenges of climate change: the case of Kgatleng District, Botswana. *Journal of Geography and Regional Planning*, **1(1)**, 12-18.

Maynard, N.G., A. Oskal, J.M. Turi, S.D. Mathiesen, I.M.G. Eira, B. Yurchak, V. Etylin, and J. Gebelein, 2011: Impacts of Arctic climate and land use changes on reindeer pastoralism: indigenous knowledge and remote sensing. In: *Eurasian Arctic Land Cover and Land Use in a Changing Climate* [Gutman, G. and A. Reissell (eds.)]. Springer, Dordrecht, Netherlands, pp. 177-205.

McAnany, P.A. and N. Yoffee, 2010: Questioning how different societies respond to crises. *Nature*, **464(7291)**, 977-977.

McNamara, K.E. and J.P. McNamara, 2011: Using participatory action research to share knowledge of the local environment and climate change: case study of Erub Island, Torres Strait. *The Australian Journal of Indigenous Education*, **40**, 30-39.

Mercer, J., D. Dominey-Howes, I. Kelman, and K. Lloyd, 2007: The potential for combining indigenous and western knowledge in reducing vulnerability to environmental hazards in small island developing states. *Environmental Hazards*, **7(4)**, 245-256.

Mercer, J., I. Kelman, S. Suchet-Pearson, and K. Lloyd, 2009: Integrating indigenous and scientific knowledge bases for disaster risk reduction in Papua New Guinea. *Geografiska Annaler: Series B, Human Geography*, **91**, 157-183.

Meyer L� H� (2003)� Past and Future: The Case for an Identity-Independent Notion of Harm. In: *Rights, culture, and the law: themes from the legal and political philosophy of Joseph Raz*. L.H. Meyer, S.L. Paulson,T.W.M. Pogge, (eds.), Oxford University Press, Oxford ; New York, pp. 143–159. ISBN: 0199248257.

Milfont, T.L., C.G. Sibley, and J. Duckitt, 2010: Testing the moderating role of the components of norm activation on the relationship between values and environmental behavior. *Journal of Cross-Cultural Psychology*, **41**, 124-131.

Miller D� (1998)� *Material Cultures: Why Some Things Matter*. University of Chi- cago Press, Chicago, US, 243 pp. Available at: http://www.press.uchicago.

Mills, E., 2005: Insurance in a climate of change. *Science*, **309**, 1040-1044.

Montefrio, M.J.F. and D.A. Sonnenfeld, 2013: Global-local tensions in contract farming of biofuel crops involving indigenous communities in the Philippines. *Society & Natural Resources*, **26(3)**, 239-253.

Montefrio, M.J.F., 2012: Privileged biofuels, marginalized indigenous peoples: the coevolution of biofuels development in the tropics. *Bulletin of Science, Technology & Society*, **32(1)**, 41-55.

Mooney, C. and P. Tan, 2012: South Australia's River Murray: social and cultural values in water planning. *Journal of Hydrology*, **474**, 29-37.

Mustonen, T. and K. Mustonen, 2011b: *Drowning Reindeers, Drowning Homes – Indigenous Saami and Hydroelectricity in Sompio, Finland.* Snowchange Cooperative, Helsinki, Finland, 115 pp.

Mwaura, P., 2008: *Indigenous Knowledge in Disaster Management in Africa.* United Nations Environment Programme (UNEP), Nairobi, Kenya, 117 pp.

Nakashima, D. and M. Rou´e, 2002: Indigenous knowledge, peoples and sustainable practice. In: *Social and Economic Dimensions of Global Environmental Change* [Timmerman, M.P. (ed.)]. John Wiley, Chichester, UK, pp. 314-324.

Nakashima, D.J., K.G. McLean, H. Thulstrup, R.C. Ameyali, and J. Rubis, 2012: *Indigenous Knowledge, Marginalized Peoples and Climate Change: Foundations for Assessment and Adaptation*. Technical Report prepared for Working Group II of the Intergovernmental Panel on Climate Change, United Nations Educational, Scientific, and Cultural Organization (UNESCO), Paris, France, and United Nations University (UNU), Darwin, Australia, 82 pp.

Nakashima, D.J., K.G. McLean, H.D. Thulstrup, A.R. Castillo, and J.T. Rubis, 2012: *Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation.* United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris, France and United Nations University (UNU), Darwin, Australi

Ndegwa, W., K.P.C. Rao, R.K. Ngugi, and K. Kwena, 2010: *Improving Farmer Adaptive Capacity by Integrating Local and Indigenous Knowledge in Climate Forecasting and Adaptive Response.* Adaptation Insights No. 4, International Development Research Centre (IDRC) Ottawa, ON, Canada and th

Nelson, V. and T. Stathers, 2009: Resilience, power, culture, and climate: a case study from semi-arid Tanzania, and new research directions. *Gender & Development*, **17**(**1**), 81-94.

Nepstad D�, S� Schwartzman, B� Bamberger, M� Santilli, D� Ray, P� Schlesinger, P� Lefebvre, A� Alencar, E� Prinz, G� Fiske, and A� Rolla (2006)� Inhibition of Amazon deforestation and fire by parks and indigenous lands. *Conservation Biology* **20**, 65–73. doi: 10.1111/j.1523-1739.2006.00351.x, ISSN: 1523-1739.

Nichols, T., F. Berkes, D. Jolly, N.B. Snow, and The Community of Sachs Harbour, 2004: Climate change and sea ice: local observations from the Canadian Western Arctic. *Arctic*, **57(1)**, 68-79.

Nielsen, J.O. and A. Reenberg, 2010: Cultural barriers to climate change adaptation: a case study from Northern Burkina Faso. *Global Environmental Change*, **20(1)**, 142-152.

Nisbett, R.E. and Y. Miyamoto, 2005: The influence of culture: holistic versus analytic perception. *Trends in Cognitive Sciences*, **9**, 467-473.

Nisbett, R.E., K. Peng, I. Choi, and A. Norenzayan, 2001: Culture and system of thought: holistic versus analytic cognition. *Psychological Review*, **108**, 291-310.

Nkem, J.N., O.A. Somorin, C. Jum, M.E. Idinoba, Y.M. Bele, and D.J. Sonwa, 2012: Profiling climate change vulnerability of forest indigenous communities in the Congo Basin. *Mitigation and Adaptation Strategies for Global Change*, **18(5)**, 513-533.

Nunavut Social Development Council, 1999: On our own terms: the state of Inuit culture and society. In: *Taking Stock: A Review of the First Five Years of Implementing the Nunavut Land Claims Agreement* [Nunavut Social Development Council (ed.)]. Nunavut Tunngavik, Inc., Iqaluit, NU, Canada, pp. 70-97.

Nuttall, M., 1998: *Protecting the Arctic: Indigenous Peoples and Cultural Survival*. Routledge, London, 195 pp.

Nyong, A., F. Adesina, and B. Elasha, 2007: The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitigation and Adaptation Strategies for Global Change*, **12**, 787-797.

Oltremari, J.V. and R.G. Jackson, 2006: Conflicts, perceptions, and expectations of indigenous communities associated with natural areas in Chile. *Natural Areas Journal*, **26(2)**, 215-220.

Orlove B□, C□ Roncoli, and A□ Majugu (2009)□ Indigenous climate knowledge in Southern Uganda: the multiple components of a dynamic regional system. *Cli- matic Change* **100**(2), 243–265. doi: 10.1007/s10584-009-9586-2.

Orlove, B., C. Roncoli, M. Kabugo, and A. Majugu, 2010: Indigenous climate knowledge in southern Uganda: the multiple components of a dynamic regional system. *Climatic Change*, **100(2)**, 243-265.

Oskal, A., 2008: Old livelihoods in new weather: Arctic indigenous reindeer herders face the challenges of climate change. *Development Outreach*, **10(1)**, 22-25.

Pareek, A. and P. Trivedi, 2011: Cultural values and indigenous knowledge of climate change and disaster prediction in Rajasthan India. *Indian Journal of Traditional Knowledge*, **10**, 183-189.

Parkinson, A.J., 2009: Sustainable development, climate change and human health in the Arctic. In: *Climate Change and Arctic Sustainable Development: Scientific, Social, Cultural, and Educational Challenges.* United Nations Educational, Scientific, and Cultural Organization (UNESCO), Paris, France, pp. 156-163.

Parks, B.C. and J.T. Roberts, 2010: Climate change, social theory and justice. *Theory, Culture & Society*, **27(2-3)**, 134-166.

Parry, M.L., O.F. Canziani, J.P. Palutikof, van der Linden, P J, and C.E. Hanson, 2007: Cross-chapter case study. In: *Climate Change 2007: Impacts*, *Adaptation and Vulnerability*. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 864-868.

Peng, K. and R.E. Nisbett, 1999: Culture, dialectics, and reasoning about conradiction. *American Psychologist*, **54**, 741-754.

Percival, G.S., 2008: *An Assessment of Indigenous Environmental Knowledge (IEK) in the Pacific Region to Improve Resilience Environmental Change*. Climate Change Research Centre, University of New South Wales, Kensington, Australia, 37 pp.

Permanent Forum on Indigenous Issues (2008)□ *Inter-Agency Support Group on Indigenous Peoples' Issues: Collated Paper on Indigenous Peoples and Climate Change*. Permanent Forum on Indigenous Issues, Available at: http://www.cbd.int/doc/meetings/tk/emccilc-01/other/emccilc-01-ipcc-en.pdf.

Petheram, L., K. Zander, B. Campbell, C. High, and N. Stacey, 2010: 'Strange changes': indigenous perspectives of climate change and adaptation in NE Arnhem Land (Australia). *Global Environmental Change*, **20(4)**, 681-692.

Quist, D. and I.H. Chapela, 2001: Transgenic DNA introgressed into traditional maize landraces in Oaxaca, Mexico. *Nature*, **414(6863)**, 541-543.

Rautela, P., 2005: Indigenous technical knowledge inputs for effective disaster management in the fragile Himalayan ecosystem. *Disaster Prevention and Management*, **14(2)**, 233-241.

Read J□M□, JM□V□ Fragoso, K□M□ Silvius, J□ Luzar, H□ Overman, A□ Cummings, S□T□ Giery, and L□F□ de Oliveira (2010)□ Space, Place, and Hunting Patterns among Indigenous Peoples of the Guyanese Rupununi Region. *Journal of Latin American Geography* **9**, 213–243. ISSN: 1548-5811.

Resurreccion, B.P., 2011: *The Gender and Climate Debate: More of the Same or New Pathways of Thinking and Doing?* Asia Security Initiative Policy Series, Working Paper No. 10, RSIS Centre for Non-Traditional Security (NTS) Studies, Singapore, 19 pp.

Rivera-Ferre, M.G., M. Di Masso, M. Mailhost, F. López-i-Gelats, D. Gallar, I. Vara, and M. Cuellar, 2013b: *Understanding the Role of Local and Traditional Agricultural Knowledge in a Changing World Climate: The Case of the Indo- Gangetic Plains.* CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), a collaboration of the Consultative Group on International Agricultural Research (CGIAR) and the Earth System Science Partnership (ESSP), Frederiksberg, Denmark, 98 pp.

Romero González, A.M., A. Belemvire, and S. Saulière, 2011: *Climate Change and Women Farmers in Burkina Faso: Impact and Adaptation Policies and Practices.* Oxfam Research Reports, Published by Oxfam GB for Oxfam International, Oxford, UK, 45 pp.

Roncoli, C., T. Crane, and B. Orlove, 2009: Fielding climate change in cultural anthropology. In: *Anthropology and Climate Change: From Encounters to Actions* [Crate, S.A. and M. Nuttall (eds.)]. Left Coast Press, San Francisco, CA, USA, pp. 87-115.

Rosen, A.M. and I. Rivera-Collazo, 2012: Climate change, adaptive cycles, and the persistence of foraging economies during the late Pleistocene/Holocene transition in the Levant. *Proceedings of the National Academy of Sciences of the United States of America*, **109(10)**, 3640-3645.

Ross,H.,C.Grant,C.J.Robinson,A.Izurieta,D.Smyth,andP.Rist,2009:Co-management and Indigenous protected areas in Australia: achievements and ways forward. *Australasian Journal of Environmental Management*, **16(4)**, 242-252.

Rothlisberger J.D., D.M. Lodge, R.M. Cooke, and D.C. Finnoff (2009). Future declines of the binational Laurentian Great Lakes fisheries: the importance of environmental and cultural change. *Frontiers in Ecology and the Environment* **8**, 239–244.

Russell-Smith J., P. Whitehead, and P. Cooke (2009). *Culture, Ecology and Econ- omy of Fire Management in North Australian Savannas: Rekindling the Wurrk Tradition*. Csiro Publishing, 417 pp. ISBN: 9780643099999.

Sabbioni, C., A. Bonazza, and P. Messina, 2008: Global climate change and archaeological heritage: prevision, impact and mapping. In: *ARCHAIA. Case Studies on Research Planning, Characterisation, Conservation and Management of Archaeological Sites* [Marchetti, N. and I. Thuesen (eds.)]. Archaeopress, Oxford, UK, pp. 295-300.

Sabbioni, C., M. Cassar, P. Brimblecombe, and R.A. Lefevre, 2009: Vulnerability of cultural heritage to climate change. *Pollution Atmospherique*, **(202)**, 157-169.

Sabbioni, C., P. Brimblecombe, and M. Cassar, 2012: *Atlas of Climate Change Impact on European Cultural Heritage: Scientific Analysis and Management Strategies.* Anthem Press, London, UK, 146 pp.

Salick, J. and N. Ross, 2009: Introduction.Traditional peoples and climate change. *Global Environmental Change*, **19**, 137-139.

Salick, J. and N. Ross, 2009: Traditional peoples and climate change. *Global Environmental Change*, **19(2)**, 137-139.

Salick, J. and N. Ross, 2009: Traditional peoples and climate change. *Global Environmental Change*, **19(2)**, 137-139.

Sánchez-Cortés, M. and E. Chavero, 2011: Indigenous perception of changes in climate variability and its relationship with agriculture in a Zoque community of Chiapas, Mexico. *Climatic Change*, **107(3-4)**, 363-389.

Schroeder, H., 2010: Agency in international climate negotiations: the case of indigenous peoples and avoided deforestation. *International Environmental Agreements: Politics, Law and Economics*, **10(4)**, 317-332.

SCRGSP, 2011: *Overcoming Indigenous Disadvantage: Key Indicators 2011*. Steering Committee for the Review of Government Service Provision (SCRGSP), Productivity Commission, Canberra, ACT, Australia, 830 pp.

Selin, H. and N.E. Selin, 2008: Indigenous peoples in international environmental cooperation: Arctic management of hazardous substances. *Review of European Community & International Environmental Law*, **17(1)**, 72-83.

Shankland, A. and L. Hasenclever, 2011: Indigenous peoples and the regulation of REDD+ in Brazil: beyond the War of the Worlds? *IDS Bulletin*, **42(3)**, 80- 88.

Shelby, R., D. Edmunds, A. James, J.A. Perez, Y. Shultz, and T. Angogino, 2012: Partnering with the Pinoleville Pomo Nation: co-design methodology case study for creating sustainable, culturally-inspired renewable energy systems and infrastructure. *Sustainability*, **4**, 794-818.

Sheridan J□, and R□ "He C□ the S□ Longboat (2006)□ The Haudenosaunee Imagination and the Ecology of the Sacred. *Space and Culture* **9**, 365–381. ISSN: 1206-3312.

Smith H□A□, and K□ Sharp (2012)□ Indigenous climate knowledges. *Wiley Inter- disciplinary Reviews: Climate Change* **3**, 467–476. doi: 10.1002/wcc.185, ISSN: 17577780.

Smith, B.J., M. Gomez-Heras, and S. McCabe, 2008: Understanding the decay of stone-built cultural heritage. *Progress in Physical Geography*, **32(4)**, 439- 461.

Sobrevila C□ (2008)□ *The Role of Indigenous Peoples in Biodiversity Conservation: The Natural but Often Forgotten Partners*. The International Bank for Reconstruc- tion and Development, The World Bank, 84 pp. Available at: http://siteresources. worldbank.org / INTBIODIVERSITY / Resources / RoleofIndigenousPeoples inBiodiversityConservation.pdf.

Solomon, T.B., H.A. Snyman, and G.N. Smit, 2007: Cattle-rangeland management practices and perceptions of pastoralists towards rangeland degradation in the Borana zone of southern Ethiopia. *Journal of Environmental Management*, **82(4)**, 481-494.

Sosa-Rodriguez, F.S., 2010: Impacts of water management decisions on the survival of a city: from ancient Tenochtitlan to modern Mexico City. *Journal of Water Resources Development*, **27(4)**, 667-689.

Sosa-Rodriguez, F.S., 2013: From federal to city mitigation and adaptation: climate change policy in Mexico City. *Mitigation and Adaptation Strategies for Global Change*, doi:10.1007/s11027-013-9455-1.

Soto-Pinto, L. and M. Anzueto, 2010: Carbon sequestration through agroforestry in indigenous communities of Chiapas, Mexico. *Agroforestry Systems*, **78(1)**, 39-51.

Soyez, K., S. Hoffmann, S. Wünschmann, and K. Gelbrich, 2009: Proenvironmental value orientation across cultures. *Social Psychology*, **40**, 222-233.

Spennemann, D.H.R. and D.W. Look (eds.), 1998: *Disaster Management Programs for Historic Sites*. Proceedings of a symposium organized by the U.S. National Park Service, Western Regional Office, San Francisco, CA in collaboration with the Western Chapter of the Association for Preservation Technology held June 27 – 29, 1997 in San Francisco, CA, Western Chapter of the Association for Preservation Technology, San Francisco, CA, USA, U.S. National Park Service, and The Johnstone Centre of Parks, Recreation, and Heritage at Charles Sturt University, Albury, Australia, U.S. Government Printing Office, Washington, DC, USA, 195 pp.

Spennemann, D.H.R., 1996: Nontraditional settlement patterns and typhoon hazard on contemporary Majuro Atoll, Republic of Marshall Islands. *Environmental Management*, **20(3)**, 337-348.

Speranza, C.I., B. Kiteme, P. Ambenje, U. Wiesmann, and S. Makali, 2010: Indigenous knowledge related to climate change variability and change: insights from droughts in semi-arid areas of former Makueni Distict, Kenya. *Climatic Change*, **100**, 295-315.

Stammler, F., 2005: *Reindeer Nomads Meet the Market: Culture, Property and Globalisation at the End of the Land.* LIT Verlag, Berlin, Germany and Transaction Publishers, Piscataway, NJ, USA, 379 pp.

Strauss, S. and B. Orlove, 2003: Up in the air: the anthropology of weather and climate. In: *Weather, Climate and Culture* [Strauss, S. and B. Orlove (eds.)]. Berg, Oxford, UK and New York, NY, USA, pp. 3-14.

Strauss, S., 2012: Are cultures endangered by climate change? Yes, but.... *Wiley Interdisciplinary Reviews: Climate Change*, **3(4)**, 371-377.

Streeter, R., A.J. Dugmore, and O. Vesteinsson, 2012: Plague and landscape resilience in premodern Iceland. *Proceedings of the National Academy of Sciences of the United States of America*, **109(10)**, 3664-3669.

Streftaris, N., A. Zenetos, and E. Papathanassiou, 2005: Globalisation in marine ecosystems: the story of non-indigenous marine species across European seas. *Oceanography and Marine Biology – an Annual Review*, **43**, 419-453.

Strohschneider, S. and D. Güss, 1999: The fate of the Moros: a cross-cultural exploration of strategies in complex and dynamic decision making. *International Journal of Psychology*, **34**, 235-252.

Talen E (2005) *New Urbanism and American Planning: The Conflict of Cultures*. Routledge, New York, US, 329 pp. ISBN: 9780203799482.

Thompson, L.G., E. Mosley-Thompson, M.E. Davis, K.A. Henderson, H.H. Brecher, V.S. Zagorodnov, T.A. Mashiotta, P.N. Lin, V.N. Mikhalenko, D.R. Hardy, and J. Beer, 2002: Kilimanjaro ice core records: evidence of Holocene climate change in tropical Africa. *Science*, **298(5593)**, 589-593.

Travers, J. and V.G. Payne, 1998: The impact of climate change on traditional seasonal ranges for High Street women's wear in England. *Journal of Fashion Marketing and Management*, **2(4)**, 370-382.

Tsosie, R., 2007: Indigenous people and environmental justice: the impact of climate change. *University of Colorado Law Review*, **78**, 1625-1677.

Turner N.J, and H. Clifton (2009) "It's so different today": Climate change and indigenous lifeways in British Columbia, Canada. *Global Environmental Change* **19**, 180–190. Available at: http://www.sciencedirect.com/science/article/pii/S0959378009000223.

Turner, N. and H. Clifton, 2009: 'It's so different today': climate change and indigenous lifeways in British Colombia, Canada. *Global Environmental Change*, **19**, 180-190.

UNPFII, 2008: *Conference on Indigenous Peoples and Climate Change, Copenhagen, 21-22 February 2008: Meeting Report.* E/C.19/2008/CRP. 3, Submitted by the International Work Group for Indigenous Affairs (IWGIA), United Nations Permanent Forum on Indigenous Issues (UNPFII), Seventh session, New York, 21 April - 2 May 2008, UN DESA, Division for Social Policy and Development, PFII Secretariat, New York, NY, USA, 11 pp.

Van Dam, C., 2011: Indigenous territories and REDD in Latin America: opportunity or threat? *Forests*, **2(1)**, 394-414.

Vedwan, N., 2006: Culture, climate and the environment: local knowledge and perception of climate change among apple growers in northwestern India. *Journal of Ecological Anthropology*, **10**, 4-18.

Veland, S., R. Howitt, and D. Dominey-Howes, 2010: Invisible institutions in emergencies: evacuating the remote Indigenous community of Warruwi, Northern Territory Australia, from Cyclone Monica. *Environmental Hazards: Human and Policy Dimensions*, **9(2)**, 197-214.

Viana, V.M., 2008: *Bolsa Floresta* (Forest Conservation Allowance): an innovative mechanism to promote health in traditional communities in the Amazon. *Estudos Avançados*, **22(64)**, 143-153.

Voggesser, G., K. Lynn, J. Daigle, F. Lake, and D. Ranco, 2013: Cultural impacts to tribes from climate change influences on forests. *Climatic Change*, **12(3)**, 615-626.

Watson A, R Matt, K Knotek, D Williams, and L Yung (2011) Traditional wis- dom: protecting relationships with wilderness as a cultural landscape. *Ecology and Society* **16**, 1–14.

Weatherhead, E., S. Gearheard, and R.G. Barry, 2010: Changes in weather persistence: insight from Inuit knowledge. *Global Environmental Change*, **20(3)**, 523-528.

Weber EU, and C Hsee (1998) Cross-cultural differences in risk perception, but cross-cultural similarities in attitudes towards perceived risk. *Management Sci- ence*, 1205–1217.

Wenzel, G., 2004: From TEK to IQ: Inuit Qaujimajatuqangit and Inuit cultural ecology. *Arctic Anthropology*, **41(2)**, 238-250.

Whitehead P, P Purdon, J Russel-Smith, PM Cooke, and S Sutton (2008) The management of climate change through prescribed Savanna burning: Emerging contributions of indigenous people in Northern Australia. *Public Administration and Development Special Issue: Symposium on Climate Change, Governance and Environmental Services* **28**, 374–385.

Whitehead, P.J., P. Purdon, P.M. Cooke, J. Russell-Smith, and S. Sutton, 2009: The West Arnhem Land Fire Abatement (WALFA) project: the institutional environment and its implications. In: *Culture, Ecology and Economy of Fire Management in North Australia Savannas: Rekindling the Wurrk Tradition* [Russell-Smith, J., P.J. Whitehead, and P.M. Cooke (eds.)]. Commonwealth Scientific and Industrial Research Organization (CSIRO) Publishing, Collingwood, VIC, Australia, pp. 287- 312.

Wilby, R., 2007: A review of climate change impacts on the built environment. *Built Environment*, **33(1)**, 31-45.

Wildcat, D., 2009: *Red Alert! Saving the Planet with Indigenous Knowledge*. Fulcrum Publishing, Golden, CO, USA, 143 pp.

Wilhite H, H Nakagami, T Masuda, Y Yamaga, and H Haneda (1996) A cross-cultural analysis of household energy use behaviour in Japan and Nor- way. *Energy Policy* **24**, 795–803. doi: 10.1016/0301-4215(96)00061-4, ISSN: 0301-4215.

Williams, J., 2012: The impact of climate change on indigenous people – the implications for the cultural, spiritual, economic and legal rights of indigenous people. *International Journal of Human Rights*, **16(4)**, 648-688.

Williams, T. and P. Hardison, 2013: Culture, law, risk and governance: contexts of traditional knowledge in climate change adaptation. *Climatic Change*, **12(3)**, 531-544.

Wohling, M., 2009: The problem of scale in indigenous knowledge: a perspective from Northern Australia. *Ecology and Society*, **14(1)**, 1-14.

Woodward, E., S. Jackson, M. Finn, and P.M. McTaggart, 2012: Utilising Indigenous seasonal knowledge to understand aquatic resource use and inform water resource management in northern Australia. *Ecological Management & Restoration*, **13(1)**, 58-64.

Xanthaki A (2007) *Indigenous Rights and United Nations Standards: Self-Deter- mination, Culture and Land*. Cambridge University Press, Cambridge, UK ; New York, 314 pp. ISBN: 9780521835749.

Zhang, D.D., H.F. Lee, C. Wang, B.S. Li, Q. Pei, J. Zhang, and Y.L. An, 2011: The causality analysis of climate change and large-scale human crisis. *Proceedings of the National Academy of Sciences of the United States of America*, **108(42)**, 17296- 17301.

Ziervogel, G. and A. Opere, 2010: *Integrating Meteorological and Indigenous Knowledge-Based Seasonal Climate Forecasts for the Agricultural Sector: Lessons from Participatory Action Research in Sub-Saharan Africa.* Climate Change Adaptation in Africa (CCAA) Learning Paper Series, International Development Research Centre (IDRC), Ottawa, ON, Canada, 19 pp.

Ziervogel, G., A. Opere, I. Chagonda, J. Churi, A. Dieye, B. Houenou, S. Hounkponou, E. Kisiangani, E. Kituyi, C. Lukorito, A. Macharia, H. Mahoo, A. Majule, P. Mapfumo, F. Mtambanengwe, F. Mugabe, L. Ogallo, G. Ouma, A. Sall, and G. Wanda, 2010b: *Integrating Meteorological and Indigenous Knowledge-Based Seasonal Climate Forecasts for the Agricultural Sector. Lessons from Participatory Action Research in sub-Saharan Africa*. International Development Research Centre and the UK Department for International Development, IDRC, Ottawa, ON, Canada, 24 pp.

6 ANNEX 1: UNCATEGORISED EXTRACTS FROM 2014A

The remainder of this paper is of extracts from Climate Change 2014: *Impacts, Adaptation, and Vulnerability Part A: Global and Sectoral Aspects* that has not been categorised into any of the themes in Chapter 4.

4.3.3.5.3. Cultural landscapes

Cultural landscapes are characterized by a long history of human-nature interactions, which results in a particular configuration of species and landscape pattern attaining high cultural significance (Rössler, 2006). Examples are grassland or mixed agriculture landscapes in Europe, rice landscapes in Asia (Kuldna et al., 2009), and many others across the globe (e.g., Rössler, 2006; Heckenberger et al., 2007). Such landscapes are often agricultural, but we deal with them here because their perceived value is only partly in terms of their agricultural products.

It has been suggested that protected area networks (such as Natura 2000 in Europe, which includes many cultural landscape elements) be adjusted to take into account climate change (Bertzky et al., 2010). Conserving species in cultural landscapes (e.g., EU Council, 1992) generally depends on maintaining certain types of land use. Doing so under climate change requires profound knowledge of the systems and species involved, and conservation success so far has been limited (see Thomas et al., 2009, for a notable exception). Understanding the relative importance of climate change and land management change is critical (Settele and Kühn, 2009). To date land use changes have been the most obvious driver of change (Nowicki et al., 2007); impacts have been attributed to climate change (with *low* to *medium confidence*) in only a few examples (Devictor et al., 2012). Even in these, combined land use-climate effects explain the pattern of observed threats better than either alone (Schweiger et al., 2008, 2012; Clavero et al., 2011).

There is *very high confidence* that species composition and landscape structure are changing in cultural landscapes such as Satoyama landscapes in Japan or mixed forest, agricultural landscapes in Europe. Models and experiments suggest that climate change should be contributing to these observed changes. The land use and land management signal is so strong in these landscapes that there is *very low confidence* that we can attribute these observations to climate change (Figure 4-4).

Protective and restorative actions aimed at increasing resilience can also be a cost-effective means as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change and may have other social, economic, and cultural benefits. This is part of "ecosystem-based adaptation" (Colls et al., 2009; Box CC-EA).

Human societies benefit from and depend on marine ecosystem services, including the provisioning of food and other goods, regulation of climate and extreme events, and cultural and supporting services (Section 6.4.1). Attributing and projecting climate-change-mediated shifts in these services remains a challenge, due to the intrinsic difficulty of assessments, lack of baseline and long time series data, and confounding human impacts. However, empirical and modeling studies indicate that climate change impacts on marine ecosystems lead to changes in provisioning, regulating, and supporting services (*high confidence*), as well as cultural services (*limited evidence*, *medium agreement*).

Climate change may also have affected cultural services (*limited evidence*, *medium agreement*) but attribution of impacts to these services remains a challenge (*low confidence*), owing to the intrinsic difficulties of assessing these services, the lack of long time-series data, and confounding human impacts. In light of available understanding of cause and effect of climate change impacts on marine ecosystems (*high confidence*), future climate change will affect some ecosystem services (*high confidence* in projection, *medium confidence* in attribution). Projected changes in the availability of marine resources and ecosystem services are expected to affect economics, human livelihood, and food security. Vulnerability is highest for the national economies of tropical coastal countries (*high confidence*).

Several barriers to adaptation of food systems have been raised including inadequate information on the climate and climate impacts and on the risks and benefits of the adaptation options, lack of adaptive capacity, inadequate extension, institutional inertia, cultural acceptability, financial constraints including access to credit, insufficient fertile land, infrastructure, lack of functioning markets, and insurance systems (Bryan et al., 2009; Deressa et al., 2009; Kabubo-Mariara, 2009; De Bruin and Dellink, 2011, Silvestri et al., 2012; see also Chapter 16).

Adaptation in marine ecosystems is also of relevance to rural areas. As with terrestrial natural resources, evidence from the marine resources sphere shows that a transformative approach to fisheries co-management, introducing ecosystem rights, and participation principles is essential for adaptation (Andrew and Evans, 2011; Charles, 2011). Such an approach, involving local fishermen and allowing limited extraction of resources, favors a balance between resource conservation and livelihoods, for example, in Brazil (Francini-Filho and Moura, 2008), and the improvement of livelihoods, as well as the cultural survival of traditional populations (Moura et al., 2009; Hastings, 2011) (see also Section 30.6.2.1). Selective use of fishing gear is a recommended management measure, based on 15 global sites, to ensure sustainable harvesting of remaining fish stocks (Cinner et al., 2009). A

Human security will be progressively threatened as the climate changes (*robust evidence*, *high agreement*). Human insecurity almost never has single causes, but instead emerges from the interaction of multiple factors. {12.1.2, 12.2} Climate change is an important factor threatening human security through (1) undermining livelihoods {12.2}; (2) compromising culture and identity {12.3}; (3) increasing migration that people would rather have avoided {12.4}; and (4) challenging the ability of states to provide the conditions necessary for human security. {12.6}

Climate change will compromise the cultural values that are important for community and individual well-being (*medium evidence*, *high agreement*). The effect of climate change on culture will vary across societies and over time, depending on cultural resilience and the mechanisms for maintaining and transferring knowledge. Changing weather and climatic conditions threaten cultural practices embedded in livelihoods and expressed in narratives, world views, identity, community cohesion, and sense of place. Loss of land and displacement, for example on small islands and coastal communities, has well documented negative cultural and well-being impacts. {12.3.1, 12.3.3, 12.4.2}

12.1. Definition and Scope of Human Security

There are many definitions of human security, which vary according to discipline. This chapter defines human security, in the context of climate change, as a condition that exists when the vital core of human lives is protected, and when people have the freedom and capacity to live with dignity. In this assessment, the vital core of human lives includes the universal and culturally specific, material and non-material elements necessary for people to act on behalf of their interests. Many phenomena influence human security, notably the operation of markets, the state, and civil society. Poverty, discrimination of many kinds, and extreme natural and technological disasters undermine human security.

The concept of human security has been informed and debated by many disciplines and multiple lines of evidence, by studies that use diverse methods (Paris, 2001; Alkire, 2003; Owen, 2004; Gasper, 2005; Hoogensen and Stuvøy, 2006; Mahoney and Pinedo, 2007; Brauch et al., 2009; Inglehart and Norris, 2012). The concept was developed in parallel by UN institutions, and by scholars and advocates in every region of the world (UNDP, 1994; Commission on Human Security, 2003; Najam, 2003; Kaldor, 2007; Black and Swatuk, 2009; Chourou, 2009; Othman, 2009; Poku and Sandkjaer, 2009; Rojas, 2009; Sabur, 2009; Wun Gaeo, 2009).

This chapter assesses the risks climate change poses to individuals and communities, including threats to livelihoods, culture, and political stability. Chapters in Working Group II (WGII) in the Fourth Assessment Report (AR4) identified the risk climate change poses to livelihoods, cultures, and indigenous peoples globally (Chapters 5, 7, 9 10, 16, and 17) and that migration and violent conflicts increase vulnerability to climate change (Chapter 19), as well as highlighting that migration plays a role in adaptation. But this chapter is the first systematic assessment across the dimensions of human security.

Research since publication of the AR4 has addressed the linkages between climate change and human security through concerted international research programs and initiatives (Afifi and Jäger, 2010; Matthew et

al., 2010; O'Brien et al., 2010; Gleditsch, 2012; Oswald Spring, 2012; Scheffran et al., 2012a; Sygna et al., 2013). Specific dimensions of human security, such as food security, public health and well-being, livelihoods, and regional perspectives, are examined systematically in Chapters 11, 13, and 19, and in Chapters 22 to 29 of this report, and this chapter cross-refers to those assessments.

The assessment in this chapter is based on structured reviews of scientific literature. These were carried out first using searches of scientific databases of relevant studies published from 2000 until 2013, with searches targeted at the core dimensions of culture, indigenous peoples, traditional knowledge, migration, conflict, and transboundary resources. These searches were supplemented by open searches to capture book and other non-journal literature. The comprehensive review in this chapter reflects the dominant findings from the scientific literature that the impacts of climate change on livelihoods, cultures, migration, and conflict are negative, but that some dimensions of human security are less sensitive to climate change and driven by economic and social forces.

This chapter assesses research on how climate change may exacerbate specific threats to human security, and how factors such as lack of mobility or the presence of conflict restrict the ability to adapt to climate change. Research on the specific interaction of human security and climate change focuses on how cultural, demographic, economic, and political forces interact with direct and indirect climate change impacts, affecting individuals and communities (Krause and Jütersonke, 2005; Hoogensen and Stuvøy, 2006; O'Brien, 2006; Betancourt et al., 2010; Sygna et al., 2013). The analysis concerns drivers of vulnerability across multiple scales and sectors, including gender relations, culture, political institutions, and markets. Each of these areas has its distinct disciplinary focus, methods, and levels of evidence as discussed in Box 12-2.

Box 12-2 | The Nature of Evidence about Climate Change and Human Security

Understanding the effects of climate change on human security requires evidence about social and environmental processes across multiple scales and sectors. This process-based analysis is informed by a wide array of theories, methods, and evidence used in different academic disciplines, and so is not contiguous. For example, this chapter assesses anthropological research where culture influences responses to climate change or may be shaped by climate change; alongside political and economic studies which use data sets to test for correlations between climatic factors and violent conflicts; and historical observations using documentary and archaeological methods. These diverse sources strengthen the robustness of the conclusions for this assessment when they converge on similar findings (Van de Noort, 2011; Nielsen and Reenberg, 2012).

This chapter reviews empirical studies from the social and physical sciences using both quantitative and qualitative data. Some studies examine the interactions between environmental changes and social outcomes. Few explicitly address climate change and human security links, but provide evidence of climate change impacts on human security (Ford et al., 2010). Individual case studies often make causal claims in given contexts, but their results may not be generalized. Where results from multiple comparative case studies agree, generalization is sometimes possible. This chapter also assesses quantitative studies about large social units with correlations among different factors. Correlations alone do not explain causality, although they are important in testing theories.

Given the many and complex links between climate change and human security, uncertainties in the research on the biophysical dimensions of climate change, and the nature of the social science, highly confident statements about the influence of climate change on human security are not possible (Scheffran et al., 2012a). Yet there is good evidence about many of the discrete links in the chains of causality between climate change and human insecurity. In this chapter the standardized IPCC language of uncertainty is applied to those linkages where appropriate.

Many climate change risks to human security warrant further investigation. There is a need for more comprehensive evidence, collected across multiple locations, and over long durations, to build and test theories about relationships between climate change and livelihoods, culture, migration, and conflict. Meeting this need requires analysis of the sensitivity of diverse livelihood systems to climate change; and the effects of cultural, economic, and political changes on the vulnerability and adaptability of livelihoods. Questions surrounding the cultural dimensions of climate require much more research using multiple methods to enable more general conclusions to be drawn, in particular about the effects of culture on climate change mitigation and adaptation. The sensitivity of human mobility to climate also requires new investigation, including, importantly, systematic long-term monitoring of population changes. The effects of migration on the vulnerability and adaptation of migrants, migrant sending areas, and destination communities also warrants more research, to permit scope for targeted policy interventions to reduce vulnerability. Finally, with respect to advancing knowledge of climate change and violence, extensive as well as case-based research is necessary to build theories of causality, including examination of cases where climate changes and variability were managed peacefully, in addition to cases where conflict emerged. Explanations of processes that reduce violence despite climate variability and change are necessary for responses that help sustain and improve peace in a future where the climate is changing.

Hence, although attributing changes in climate directly to human security is difficult, some major risks are well documented. This chapter builds on that knowledge base to assess the interaction of those risks with cultural dimensions of change, and the risks of migration and conflict. It is well established that direct risks of climate change to life and livelihoods are highly differentiated by socio- demographic factors, such as by age, wealth, and gender. Box CC-GC, for example, highlights how specific populations of men and women are vulnerable to weather extremes.

Frequently Asked Questions

FAQ 12.1 | What are the principal threats to human security from climate change?

Climate change threatens human security because it undermines livelihoods, compromises culture and individual identity, increases migration that people would rather have avoided, and because it can undermine the ability of states to provide the conditions necessary for human security. Changes in climate may influence some or all of the factors at the same time. Situations of acute insecurity, such as famine, conflict, and sociopolitical instability, almost always emerge from the interaction of multiple factors. For many populations that are already socially marginalized, resource dependent, and have limited capital assets, human security will be progressively undermined as the climate changes.

12.3. Cultural Dimensions of Human Security

12.3.1. How Culture Interacts with Climate Impacts and Adaptation

Culture is a contested and highly fluid term that is defined in this chapter as material and non-material symbols that express collective meaning. In all societies culture is expressed in knowledge, worldviews, beliefs, norms, values, and social relationships (Crate, 2008, 2011; Heyd, 2008; Roncoli et al., 2009; Strauss, 2009; O'Brien and Wolf, 2010; Tingley et al., 2010; Rudiak-Gould, 2012; Sudmeier-Rieux et al., 2012). In this definition culture shapes the relationship of society to environments and is a significant determinant of responses to environmental and other risks and challenges (Siurua and Swift, 2002; Pearce et al., 2009; Buikstra et al., 2010; Nielsen and Reenberg, 2010; Petheram et al., 2010; Paul and Routray, 2011).

There has been significant new research from psychology, anthropology, sociology, and human geography in the period since AR4 on the lived experience of weather extremes and observed climate change, driven in part by observed warming trends in regions. This body of knowledge from across social science disciplines argues that climate change is embedded in and acts on culture in myriad ways. For example, all consumption patterns are culturally embedded and therefore culture influences greenhouse gas emissions. The phenomenon of climate change itself is perceived differently depending on the culture in which it is viewed, with scientific expression representing only one possibility (Norgaard, 2011). Similarly, there are widely different cultural expressions of weather, risk, and the need for adaptation to such hazards (Hulme, 2008; Adger et al., 2013). Therefore, since climate change has consequences for people this emerging body of knowledge shows with *high confidence* that climate change has significant cultural implications (Crate, 2011; Strauss, 2012). Anthropological analysis of culture focuses on identity, community, and economic activities. There is a growing body of research on how climate and other environmental change affects livelihood activities such as pastoralism, herding, farming, fishing and hunting, and gathering in places where there is significant observed change. Research has documented how rural livelihoods and, therefore, cultural practices have been affected by changes in climate and associated impacts on natural capital. Many anthropological studies suggest that further significant changes in the natural resource base on which many cultures depend would directly affect the cultural core, worldviews, cosmologies, and mythological symbols of indigenous cultures (Crate, 2008; Gregory and Trousdale, 2009; Jacka, 2009). While changing socioeconomic and environmental conditions may constrain existing community coping mechanisms (Rattenbury et al., 2009; West and Hovelsrud, 2010; Quinn et al., 2011), other studies focus on how cultures adapt to significant societal and environmental changes. Many successful examples of the persistence of cultures despite significant upheaval exist throughout history (Nuttall, 2009; Cameron, 2012; Strauss, 2012). Culture also interacts with adaptation through the way that cultural, local, and individual perceptions affect narratives of risk, resilience, and adaptive capacity. A body of research across disciplines argues that incorporation of cultural understanding of environment, risk, and social practices increases the explanatory power of models of risk (Ifejika Speranza et al., 2008; Jacka, 2009; Adger et al., 2011a). The way in which resource-dependent communities articulate and perceive climate change is often based on how English language terms are translated and understood in the local language (Rudiak-Gould, 2012). Furthermore, information is interpreted through personal life stories and culture (Kuruppu and Liverman, 2011). Local perceptions of what kind of knowledge is trustworthy may in fact lead to questioning of scientific findings (Ingram et al., 2002; Burns et al., 2010; Roncoli et al., 2011).

Culturally embedded perceptions of climate change may either facilitate or hinder adaptation with implications for human security (Zamani et al., 2006; Burningham et al., 2008; West and Hovelsrud, 2010; Gómez- Baggethun et al., 2012; Nursey-Bray et al., 2012; Rudiak-Gould, 2012). Scientific information on weather variability and change is framed through cultural practices that can both enable (Dannevig et al., 2012) and constrain (Roncoli, 2006) adaptation. There are a number of anthropological studies that document how some cognitive frames do not perceive a changing climate and hence the concept of climate change itself does not have cultural resonance, whether or not the parameters of climate have been observed (Kuruppu and Liverman, 2011; Lipset, 2011; Sánchez-Cortés and Chavero, 2011; Rudiak-Gould, 2012). Most of these studies conclude that climate policies do not have legitimacy and salience when they do not consider how individual behavior and collective norms are embedded in culture (Stadel, 2008; Jacka, 2009).

Table 12-2 | Cultural dimensions of climate science, policy, impacts, and extreme events in the context of climate change.

Core climate change dimensions	Cultural dimensions	Role in human security	Sources
Climate science and policy	Framing of climate change in a dominant language Global climate change policy implemented at international scales	How concepts and uncertainties are translated, imported, and incorporated can facilitate or hinder adaptation: *Facilitate adaptation*: available explanatory tools; successful translation of climate change impacts; awareness of culture *Hinder adaptation*: lack of trust in science and in policy; policy not recognizing the connection between nature and culture Policy and decision making that is inclusive of cultural perspectives *increases security*.	Ifejika Speranza et al. (2008); Stadel (2008); Jacka (2009); Green et al. (2010); Osbahr et al. (2010); Schroeder (2010); Gero et al. (2011); Kuruppu and Liverman (2011); Roncoli et al. (2011); Sánchez-Cortés and Chavero (2011); McNeely (2012); Rudiak-Gould (2012)
Impacts of environmental conditions, extreme events, and changing natural resource base	Elements of collective understanding such as: • Worldviews • Coupling of nature–culture • Power relations • Heterogeneity within groups and communities	*Facilitate adaptation*: New technologies; livelihood diversification and flexibility; perceptions of resilience; narratives and history about past changes and current conditions; co-management of resources increases adaptive capacity. *Hinder adaptation*: limitations of local knowledge; lack of awareness and understanding of culture constrains action; knowledge and cultural repertoire limited for responding to new challenges; perceptions of resilience Erosion of cultural core potentially *decreases human security*. Institutional responses and resource management will impact human security either negatively or positively.	Nunn (2000); Davidson et al. (2003); Desta and Coppock (2004); Ford et al. (2006, 2008); Furgal and Seguin (2006); Kesavan and Swaminathan (2006); Zamani et al. (2006); Nyong et al. (2007); Tyler et al. (2007); Angassa and Oba (2008); Burningham et al. (2008); Crate (2008); de Sherbinin et al. (2008); King (2008); Gregory and Trousdale (2009); Jacka (2009); Pearce et al. (2009); Berkes and Armitage (2010); Dumaru (2010); Fazey et al. (2010); Hovelsrud and Smit (2010); Hovelsrud et al. (2010a,b); Kalikoski et al. (2010); Kuhlicke (2010); Lefale (2010); Nielsen and Reenberg (2010); Osbahr et al. (2010); Rybråten and Hovelsrud (2010); Valdivia et al. (2010); West and Hovelsrud (2010); Armitage et al. (2011); Gero et al. (2011); Harries and Penning-Rowsell (2011); Kuruppu and Liverman (2011); Marshall (2011); Onta and Resurrection (2011); Roncoli et al. (2011); Adler et al. (2012); Anik and Khan (2012); Eakin et al. (2012); Ford and Goldhar (2012); Gómez-Baggethun et al. (2012); McNeeley (2012); Nursey-Bray et al. (2012); Rudiak-Gould (2012); Sudmeier-Riuex et al. (2012)
Scientific observations, monitoring, models, projections, scenarios	Local, traditional, and indigenous knowledge through observations and experience	*Facilitate adaptation*: mutual integration of traditional, local, and scientific knowledge; climate projections with local relevance; intergenerational knowledge transfers Local knowledge included in climate policy and decision making *increases human security*. Knowledge not included in adaptation planning *decreases human security*.	Orlove et al. (2000, 2010); Ingram et al. (2002); Tàbara et al. (2003); Alcántara-Ayala et al. (2004); Roncoli (2006); Anderson et al. (2007); Forbes (2007); Nyong et al. (2007); Tyler et al. (2007); Vogel et al. (2007); Catto and Parewick (2008); Marfai et al. (2008); Mercer et al. (2009); Pearce et al. (2009); Burns et al. (2010); Frazier et al. (2010); Gearheard et al. (2010); Hovelsrud and Smit (2010); Marin (2010); Mark et al. (2010); Smit et al. (2010); Flint et al. (2011); Huntington (2011); Kalanda-Joshua et al. (2011); Ravera et al. (2011); Sánchez-Cortés and Chavero (2011); Dannevig et al. (2012); Eira et al. (2013)

12.3.2. Indigenous Peoples

There are around 400 million indigenous people worldwide (see Glossary for an inclusive definition), living under a wide range of social, economic, and political conditions and locations (Nakashima et al., 2012). Indigenous peoples represent the world's largest reserve of cultural diversity and the majority of languages (Sutherland, 2003). Climate change poses challenges for many indigenous peoples, including challenges to post-colonial power relations, cultural practices, their knowledge systems, and adaptive strategies. For example, the extensive literature on the Arctic shows that changing ice conditions pose risks in terms of access to food and increasingly dangerous travel conditions (Ford et al., 2008, 2009; Hovelsrud et al., 2011; see also Section 28.4.1). Accordingly, there is a strong research tradition on the impacts of climate change in regions with substantial indigenous populations that focuses on indigenous peoples and their attachment to place. Most studies focus on local, traditional, and rural settings (Cameron, 2012) and hence have been argued to create a knowledge gap regarding new urban indigenous populations. Indigenous peoples are often portrayed in the literature as victims of climate change (Salick and Ross, 2009) and as vulnerable to its consequences (ACIA, 2005). However, traditional knowledge is increasingly being combined with scientific understanding to facilitate a better understanding of the dynamic conditions of indigenous peoples (Huntington, 2011; see also Section 12.3.4).

There is *high agreement* that, historically, indigenous peoples have had a high capacity to adapt to variable environmental conditions. This literature also suggests indigenous peoples also have less capacity to cope with rapidly changing socioeconomic conditions and globalization (Tyler et al., 2007; Crate and Nuttall, 2009). Documented challenges for indigenous cultures to adapt to colonization and globalization may reflect resilience and the determination of indigenous peoples to maintain cultures and identities. Furthermore, historical legacies affect the way that indigenous populations adapt to modern challenges: anthropological research has documented clear linkages between historical colonization and the way the way indigenous peoples respond to current climatic changes (Salick and Ross, 2009; Cameron, 2012; Howitt et al., 2012; Marino, 2012).

Most of the literature in this area emphasizes the significant challenge of maintaining cultures, livelihoods, and traditional food sources under the impacts of climate change (Crate and Nuttall, 2009; Rybråten and Hovelsrud, 2010; Lynn et al., 2013). Examples from the literature show that traditional practices are already under pressure from multiple sources, reducing the ability of such practices to enable effective responses to climate variability (Green et al., 2010). Empirical evidence suggests that the efficacy of traditional practices can be eroded when governments relocate communities (Hitchcock, 2009; McNeeley, 2012; Maldonado et al., 2013); if policy and disaster relief creates dependencies (Wenzel, 2009; Fernández-Giménez et al., 2012); in circumstances of inadequate entitlements, rights, and inequality (Shah and Sajitha, 2009; Green et al., 2010; Lynn et al., 2013); and when there are constraints to the transmission of language and knowledge between generations (Forbes, 2007). Some studies show that current indigenous adaptation strategies may not be sufficient to manage the projected climate changes (Wittrock et al., 2011).

Assessments of the cultural implications of climate change for human security illustrate similarities across indigenous peoples. Indigenous peoples have a right to maintain their livelihoods and their connections to homeland and place (Howitt et al., 2012) and it is suggested that the consequences of climate change are challenging this right (Box 12-1; Crate and Nuttall, 2009). Some raise the question whether the Western judicial system can uphold indigenous rights in the face of climate change (Williams, 2012) and that there is a need for justice that facilitates adaptation (Whyte, 2013). In addition, there are uneven societal consequences related to climate change impacts (e.g., use of sea ice: Ford et al., 2008), which add complexity to adaptation in indigenous societies. Heterogeneity within indigenous groups and differentiated exposure to risk has been found in other contexts, for example, in pastoralist groups of the Sahel (Barrett et al., 2001).

Frequently Asked Questions

FAQ 12.2 | Can lay knowledge of environmental risks help adaptation to climate change?

Lay knowledge about the environment and climate is deeply rooted in history, and encompasses important aspects of human life. Lay knowledge is particularly pertinent in cultures with an intimate relationship between people and the environment. For many indigenous and rural communities, for example, livelihood activities such as herding, hunting, fishing, or farming are directly connected to and dependent on climate and weather conditions. These communities thus have critical knowledge about dealing with environment changes and associated societal conditions. In regions around the world, such knowledge is commonly used in adapting to environmental conditions and is directly relevant to adaptation to climate change.

12.3.3. Local and Traditional Forms of Knowledge

There is *high agreement* among researchers that involvement of local people and their local, traditional, or indigenous forms of knowledge in decision making is critical for ensuring their security (Ellemor, 2005; Kesavan and Swaminathan, 2006; Burningham et al., 2008; Mercer et al., 2009; Pearce et al., 2009; Anik and Khan, 2012). Such forms of knowledge include categories such as traditional ecological knowledge, indigenous science, and ethnoscience (Nakashima and Roué, 2002). Collectively they are defined as "a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations" (Berkes, 2012, p. 7). In addition to reasserting culture, identity, and traditional values, such forms of knowledge are experiential, dynamic, and highly context dependent, developed through interactions with other forms of knowledge (Ford et al., 2006; Orlove et al., 2010; Sánchez-Cortés and Chavero, 2011; Eira et al., 2013). Despite recognition in studies of the value of local and traditional knowledge, such knowledge is most often not included in adaptation planning (Tàbara et al., 2003; King et al., 2007; Ifejika Speranza et al., 2008; Huntington, 2011). There are many challenges in managing, utilizing, acknowledging, and incorporating local and traditional knowledge into adaptation practices (Huntington, 2011). Such knowledge is often generated and collected through participatory approaches, an approach that may not be sufficient because of the cultural and social

dynamics of power and interpretation (Roncoli et al., 2011). Local and traditional knowledge itself may have its limits. Some studies suggest that local or traditional knowledge may not be sufficient to provide the proper response to unexpected or infrequent risks or events (Nunn, 2000; Burningham et al., 2008; Kuhlicke, 2010).

There is also concern, documented in many anthropological studies, that indigenous and traditional knowledge is itself under threat. If local or traditional knowledge is perceived to be less reliable because of changing environmental conditions (Ingram et al., 2002; Ford et al., 2006) or because of extreme or new events that are beyond the current local knowledge and cultural repertoire (Valdivia et al., 2010; Hovelsrud et al., 2010a), then community vulnerability, and the vulnerability of local or traditional knowledge itself, may increase (Kalanda-Joshua et al., 2011). New conditions may require new knowledge to facilitate and maintain flexibility and improve livelihoods (see also Homann et al., 2008). Kesavan and Swaminathan (2006) documented how societal and environmental conditions have changed to the point that local knowledge is supplemented with new technologies and new knowledge in coastal communities in India. A study in the Himalayas found that erosion of traditional knowledge occurs through government regulations of traditional building materials and practices (Rautela, 2005). The social cohesion embedded in such practices is weakened because of a move toward concrete construction which changes the reliance on and usefulness of traditional knowledge about wood as a building material (Rautela, 2005).

Even in areas under threat from long-term climate change and sea level rise, observations show that populations at risk do not always choose to migrate. For example, a series of studies have sought to explain population stability in low-lying island nations. Mortreux and Barnett (2009) found that migration from Tuvalu was not driven by perceptions of climate change and that, despite forecasts that the island could become uninhabitable, residents have remained for reasons of culture and identity. Shen and Gemenne (2011) concur that both Tuvalu residents and migrants from Tuvalu did not cite climate change as a reason for the migration that occurs. Similarly, in the Peruvian Andes, Adams and Adger (2013) found that cultural ecosystem services and place attachment shape decisions not to migrate and hence populations persist despite difficult environmental conditions. However, these studies also find that environmental risks directly affect perceptions of well-being, cultural integrity, and economic opportunities. They conclude that the impacts of climate change may be a more significant driver of migration in the future.

Bronen (2010) and Bronen and Chapin (2013) conclude that while the relocations are feasible, there are significant perceptions of cultural loss and related studies report psychological stress and community dislocation (Cunsolo- Wilcox et al., 2012, 2013). The studies argue that legitimacy and success depend on incorporating cultural and psychological factors in the planning processes (Bronen and Chapin, 2013). There is significant resistance to relocation, even where such options are well planned and have robust justifications, as demonstrated by Marino (2012) for relocation in Alaska.

Box 12-6 | Evidence on Security and Geopolitical Dimensions of Climate Change Impacts in the Arctic

Impacts of climate change on the Arctic region exemplify the multiple interactions of human security with geopolitical risks. System- wide changes in the Arctic region affect multiple countries and a global commons resource given Arctic roles in regulating the global climate and ocean systems (Carmack et al., 2012; Duarte et al., 2012). Anticipated changes will contribute to greater geopolitical considerations and human insecurity in the Arctic region. They include food insecurity affecting specific cultures and knowledge systems (outlined in Section 12.3); energy security implications through opening of sub-sea oil and gas reserves; increased shipping; increased pollution; search and rescue challenges; and increased military presence in the region.

The Arctic has been warming at about twice the global rate since 1980, resulting in unprecedented loss in sea ice. The Arctic Ocean is projected to experience major reductions in sea ice, and under some projections would be ice-free by the end of the century (WGI AR5 SPM, *medium confidence*; see also Section 28.1). These changes have implications for land-based infrastructure, shipping, resource extraction, coastal communities, and transport (Holland et al., 2006; Larsen et al., 2008; Stephenson et al., 2011; see also Section 28.3.4). There is *medium evidence* that changes will create or revive terrestrial and maritime boundary disputes among Arctic countries (Borgerson, 2008; Ebinger and Zambetakis, 2009; Lusthaus, 2010). There is little evidence the changing Arctic will become a site for violent conflict between states (Young, 2009; Berkman, 2010; Brosnan et al., 2011). At present, political institutions are providing forums for managing resource competition, new transportation practices, and boundary disputes, but anticipated increased stresses will test these institutions in the future (Ebinger and Zambetakis, 2009).

12.7. Synthesis

This chapter shows that climate change and climate variability pose risks to various dimensions of human security, which arise through diverse causal processes and which will be manifest at different scales. There is *high agreement* in the literature for this conclusion that comes from multiple lines of evidence. There are, however, multiple and competing perspectives on the nature and causes of insecurity arising from climate change. For example, farmers in the Sahel are concerned about the risks weather extremes pose to their livelihoods (Mertz et al., 2009), whereas people in Tuvalu report that the cultural impacts of migration are a primary concern rather than climate change directly (Mortreux and Barnett, 2009). Organizations whose mandates include aspects of human security prioritize some risks of climate change over others in line with organizational priorities. For example, the

International Organization for Migration is concerned with the implications of climate change for migration, and the U.S. National Intelligence Council is focused on the risk that climate change will increase political instability and geopolitical rivalry. In this respect the framing of climate change as an issue of human security enables conversations across the boundaries of diverse policy communities (Gasper, 2010).

The risks that climate change poses to human security arise through multiple and interacting processes. Those processes also operate across diverse spatial and temporal scales. High levels of complexity mean that no conceptual model or theory captures the full extent of the interactions between all of climate change, livelihoods, culture, migration, and violent conflict. However, as this chapter has shown, there are feedbacks between the key elements of livelihoods, culture, migration, and violent conflict. Figure 12-3 depicts one scenario of interactions between the primary elements discussed in this chapter. Deterioration in livelihoods, influenced in certain cases by climate change and climate variability, is a human security issue in its own right. But such stress to livelihoods also gives rise to migration, which may be unavoidable and undesirable. Such movements, in turn, imply changes in important cultural expressions and practices, and, in the absence of institutions to manage the settlement and integration of migrants in destination areas, can increase the risk of violent conflict. This conflict can in turn undermine livelihoods, impel migration, and weaken valued cultural expressions and practices.

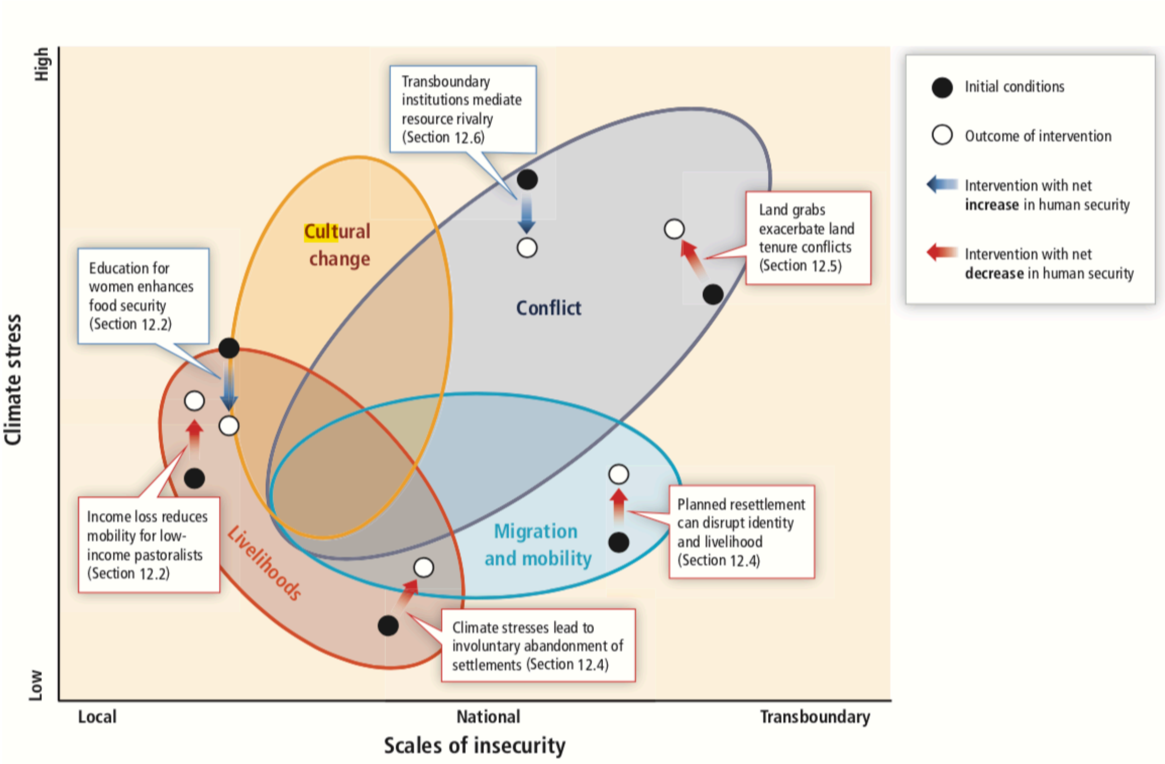

Figure 12-3 | Synthesis of evidence on the impacts of climate change on elements of human security and the interactions between livelihoods, conflict, culture, and migration. Interventions and policies indicated by difference between initial conditions (solid black) and outcome of intervention (white circles). Some interventions (blue arrows) show net increase human security while others (red arrows) lead to net decrease in human security.

Table 12-4 | Examples of important risks from climate change for elements of human security and the potential for risk reduction through mitigation and adaptation. These risks are identified based on this chapter assessment and expert judgments of the authors, with supporting evaluation of evidence and agreement in the relevant chapter sections. Each risk is characterized as *very low, low, medium, high*, or *very high*. Risk levels are presented for the near-term era of committed climate change (here, for 2030–2040), in which projected levels of global mean temperature increase do not diverge substantially across emissions scenarios. Risk levels are also presented for the longer-term era of climate options (here, for 2080–2100), for global mean temperature increase of 2°C and 4°C above pre-industrial levels. For each time frame, risk levels are estimated for the current state of adaptation and for a hypothetical highly adapted state. Relevant climate variables are indicated by symbols. As the assessment considers potential impacts on diverse and incompatible elements and systems, risk levels should not be used to evaluate relative risk between the rows.

Climate-related drivers of impacts									Level of risk & potential for adaptation
Warming trend	Extreme temperature	Drying trend	Extreme precipitation	Damaging cyclone	Storm surge	Sea level	Ocean acidification	Carbon dioxide fertilization	Potential for additional adaptation to reduce risk; Risk level with **high** adaptation; Risk level with **current** adaptation

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Displacement associated with extreme events (*high confidence*) [12.4.1]	Adaptation to extreme events is well understood but poorly implemented even under present climate conditions. Displacement and involuntary migration are often temporary. With increasing climate risks, displacement is more likely to involve permanent migration.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low – Medium – Very high
Loss of land, cultural and natural heritage disrupting cultural practices embedded in livelihoods and expressed in narratives, world views, identity, community cohesion, and sense of place (*high confidence*) [12.3.2, 12.3.4]	Cultural values and expressions are dynamic and inherently adaptable and hence adaptation is possible to avoid losses of cultural assets and expressions. Nevertheless cultural integrity will be compromised in these circumstances.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low – Medium – Very high
Violent conflict arising from deterioration in resource dependent livelihoods such as agriculture and pastoralism (*high confidence*) [12.5.1]	Adaptation options: Buffering rural incomes against climate shocks, e.g., through livelihood diversification, income transfers, and social safety net provision; Early warning mechanisms to promote effective risk reduction; Well-established strategies for managing violent conflict that are effective but require significant resources, investment, and political will.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low – Medium – Very high
Geopolitical competition over access to Arctic resources that escalates into dangerous tensions and crises (*high confidence*) [12.6.2]	There are international organizations and elements of international law that regulate competition and access and provide mechanisms for resolving disputes. There are strong transnational networks that are relevant for joint problem solving. Hence adaptation action has significant potential to reduce risks associated with geopolitical rivalry.		Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low – Medium – Very high
New or exacerbated conflict through land acquisition for climate change mitigation and adaptation (*medium confidence*) [12.5.2]	Climate change mitigation (e.g., expansion of biofuel production area) and adaptation action (e.g., set-back of coastal land) can exacerbate conflicts when they are already manifest around land and water availability and scarcity. The extent of insecurity and instability from such mitigation and adaptation activities depends on the displacement of populations and the inclusiveness of the planning processes. Careful planning processes can therefore be used to ameliorate the risk of conflict	*Cumulative climate risks act as incentives for mitigation and adaptation action*	Present; Near term (2030 – 2040); Long term (2080 – 2100) 2°C, 4°C	Very low – Medium – Very high

Adaptation strategies that seek to reduce exposure to climate change, through the development of large infrastructure or the resettlement of communities against their will, carry risks of disrupted livelihoods, displaced populations, deterioration of valued cultural expressions and practices, and in some cases violent conflict (Table 12-4). Similarly, mitigation policies that entail changes in property regimes that are not consistent with resource ownership and use can impact negatively on human security. There is strong evidence to demonstrate that mitigation activities that align with local interests and institutions can have significant co-benefits for human security, especially through human health (Klein et al., 2005; Ayers and Huq, 2009; Laukkonen et al., 2009; Haines et al., 2009; Moser 2012; West et al., 2013).

In summary, climate change is one of many risks to the vital core of material well-being and culturally specific elements of human security that vary depending on location and circumstance. While there is much uncertainty about the future impacts of climate change on human security, on the basis of current evidence about the observed impacts of climate change on environmental conditions, climate change will be an increasingly important driver of human insecurity in the future (see Figure 12-3).

Livelihoods (see also Glossary) are understood as the ensemble or opportunity set of capabilities, assets, and activities that are required to make a living (Chambers and Conway, 1992; Ellis et al., 2003). They depend on access to natural, human, physical, financial, social, and cultural capital (assets); the social relations people draw on to combine, transform, and expand their assets; and the ways people deploy and enhance their capabilities to act and make lives meaningful (Scoones, 1998; Bebbington, 1999).

Poverty is a complex concept with conflicting definitions and considerable disagreement in terms of framings, methodologies, and measurements. Despite different approaches emphasizing distinct aspects of poverty at the individual or collective level—such as income, capabilities, and quality of life (Laderchi et al., 2003)—poverty is recognized as multidimensional (UNDP, 1990). It is influenced by social, economic, institutional, political, and cultural drivers; its reversal requires efforts in multiple domains that promote opportunities and empowerment, and enhance security (World Bank, 2001). In addition to material deprivation, multidimensional conceptions of poverty consider a sense of belonging and socio-cultural heritage (O'Brien and Leichenko, 2003), identity, and agency, or "the culturally constrained capacity to act" (Ahearn, 2001, p. 54). The AR4 identified poverty as "the most serious obstacle to effective adaptation" (Confalonieri et al., 2007, p. 417).

Finally, weather events and climate also erode *social and cultural assets*. In some contexts, climatic and non-climatic stressors and changing trends disrupt informal social networks of the poorest, elderly, women, and women-headed households, preventing mobilization of labor and reciprocal gifts (Osbahr et al., 2008; Buechler, 2009) as well as formal social networks, including social assistance programs (Douglas et al., 2008). Indigenous peoples (see Chapter 12) witness their cultural points of reference disappearing (Ford, 2009; Bell et al., 2010; Green et al., 2010).

Feminization of responsibilities: Campbell et al. (2009) and Resurreccion (2011), in case studies from Vietnam, found increased workloads for both partners linked to weather events and climate, contingent on socially accepted gender roles: men tended to work longer hours during extreme events and women adopted extra responsibilities during disaster preparation and recovery (e.g., storing food and water and taking care of the children, the sick, and the elderly) and when their husbands migrated. In Cambodia, Khmer men and women accepted culturally taboo income-generating activities under duress, when rice cropping patterns shifted due to higher temperatures and more irregular rainfall (Resurreccion, 2011).

Inequality and disproportionate effects of climate-related impacts also occur along the axes of *indigeneity and race*. Disproportionate climate impacts are documented for Afro-Latinos and displaced indigenous groups in urban Latin America (Hardoy and Pandiella, 2009), and indigenous peoples in the Russian North (Crate, 2013) and the Andes (Andersen and Verner, 2009; Valdivia et al., 2010; McDowell and Hess, 2012; Sietz et al., 2012). See Chapter 12 for impacts on indigenous cultures. In the USA, low-income people of color are more affected by climate-related disasters (Sherman and Shapiro, 2005; Morello-Frosch et al., 2009; Lynn et al., 2011) as demonstrated in the case of low- income African American residents of New Orleans after Hurricane Katrina (Elliott and Pais, 2006).

Social needs include the range of needs for human security (see Section 12.1.2), which include the universal and culturally specific, material, and non-material elements necessary to people to act on behalf of their interests.

The plant also affected significant cultural sites of the Bunurong Aboriginal community (Lee and Chung, 2007).

Many dedicated researches have become engaged in smaller, often community-based or urban activities where results can be gathered in relatively short time frames and direct interactions between the researchers and the implementers are common. Here research and action can, and are, serving each other and these interactions can be encouraged with support for further cross-community, cross-cultural, and cross-sectoral comparisons.

The national level plays a key role in adaptation planning and implementation, while adaptation responses have diverse processes and outcomes at the subnational and local levels (*robust evidence, high agreement*). National governments assume a coordinating role of adaptation actions in subnational and local levels of government, including the provision of information and policy frameworks, creating legal frameworks, actions to protect vulnerable groups, and, in some cases, providing financial support to other levels of government. In the increasing number of adaptation responses at the local level in developed and developing countries, local agencies and planners are often confronted by the complexity of adaptation without adequate access to guiding information or data on local vulnerabilities and potential impacts. Even when information is available, they are left with a portfolio of options to prepare for future climatic changes and the potential unanticipated consequences of their decisions. Therefore, linkages with national and subnational levels of government, as well as the collaboration and participation of a broad range of stakeholders, are important. Steps for mainstreaming adaptation have been identified but challenges remain in their operationalization within the current structures or operational cultures of national, subnational, and local agencies. {15.2.1, 15.5.1}

Indigenous communities are those populations that have cultural and historical ties to specific homelands. They are generally distinct from politically dominant populations (Battiste, 2008). Because of these characteristics, they are particularly vulnerable to climate change impacts. When assessing indigenous vulnerability and developing CCA strategies and resilience to climate change, the following issues need to be examined and addressed: the relationship of indigenous peoples to land, the degree of migration or displacement of indigenous communities (Miron, 2008), and their adaptive capacity. Vulnerability and challenges to adaptation for indigenous people are discussed broadly in Chapters 13, 27, and 28.

Adaptation planning and implementation follows formal institutions associated with regulations, policies, and standards created and enforced by government actors but also requires the participation of informal institutions through interactions among stakeholders according to cultural, social, and political conditions in societies (Moser and Satterthwaite, 2008; Carmin et al., 2012). Chapter 14 describes the importance of these institutional frameworks for adaptive capacity.

Preston et al. (2011) have determined that adaptation plans from Australia, the UK, and the USA largely frame adaptation in a narrow sense overlooking the capacity and institutional challenges involved in the process of mainstreaming in other sectors. Institutional rigidity also takes the form of path dependency where past policies, decisions, habits, and traditions constrain the extent to which systems can learn or adapt to climate change (Garrelts and Lange, 2011; Berkhout, 2012; Runhaar et al., 2012; Preston et al., 2013). Some authors have identified such cultures of reactive management or structural engineered approaches to climate adaptation negatively influencing institutional change (Næss et al., 2005; Harries and Penning-Rowsell, 2011; Measham et al., 2011).

A range of biophysical, institutional, financial, social, and cultural factors constrain the planning and implementation of adaptation options and potentially reduce their effectiveness (*very high confidence*). Adaptation of both human and natural systems is influenced by the rate of climate change as well as rates of economic development, demographic change, ecosystem alteration, and technological innovation. Adaptation planning and implementation may require significant inputs of knowledge as well as human, social, and financial capital. Real or perceived deficiencies in access to such resources can and do constrain adaptation efforts in both developing and developed nations. Public and private institutions influence the distribution of such resources as well as the development of policies, legal instruments, and other measures that facilitate adaptation. Therefore, institutional weaknesses, lack of coordinated governance, and conflicting objectives among different actors can constrain adaptation. Cultural characteristics including age, gender, and sense of place influence risk perception, entitlements to resources, and choices about adaptation. Societal actors and natural systems may experience multiple constraints that interact. {16.2, 16.3.2, 16.5; Tables 16-2, 16-3; Boxes 16-1, 16-3}

Limits to adaptation can emerge as a result of the interactions among climate change and biophysical and socioeconomic con- straints (*medium evidence, high agreement*). An adaptation limit occurs owing to the inability to avoid an intolerable risk to an actor's objectives and/or to the sustainability of a natural system. Understanding of limits is informed by historical and recent experience where limits to adaptation have been observed, as well as by limits that are anticipated to arise as a consequence of future global change. Recent studies have provided valuable insights regarding global "tipping points," "key vulnerabilities," or "planetary boundaries" as well as evidence of climate thresholds for agricultural crops, species of fish, forest and coral reef communities, and humans. However, for most regions and sectors, there is a lack of empirical evidence to quantify magnitudes of climate change that would constitute a future adaptation limit. Furthermore, economic development, technology, and cultural norms and values can change over time to enhance or reduce the capacity of systems to avoid limits. As a consequence, some limits may be considered "soft" in that they may be alleviated over time. Nevertheless, some limits may be "hard" in that there are no reasonable prospects for avoiding intolerable risks. Recent literature suggests that incremental adaptation may not be sufficient to avoid intolerable risks, and therefore transformational adaptation may be required to sustain some human and natural systems. {16.2-7; Table 16-3; Boxes 16-1, 16-4}

The authors go on to discuss biophysical and technological limits to adaptation as well as barriers arising from technological, financial, cognitive and behavioral, and social and cultural factors. The authors also noted both significant knowledge gaps and impediments to the sharing of relevant information to alleviate those gaps.

A limit to adaptation means that, for a particular actor, system, and planning horizon of interest, no adaptation options exist, or an unacceptable measure of adaptive effort is required, to maintain societal objectives or the sustainability of a natural system. Objectives include, for example, maintaining safety standards such as those codified in laws, regulations, or engineering design standards (e.g., 1-in-500 year levees); security of air or water quality; as well as equity, cultural cohesion, and preservation of livelihoods. Requirements for sustaining natural systems might include temperature ranges or moisture availability. In the case of hard limits, no adaptation options are foreseeable, even when looking beyond the current planning horizon. For soft limits, however, adaptation options could become available in the future owing to changing attitudes or values or as a result of innovation or other resources becoming available to an actor. For example, 31 Native Alaskan villages are facing "imminent threats" due to coastal erosion and at least 12 of the 31 have begun to explore relocation or have decided to partially or totally relocate (US GAO, 2009). In the case of these communities with minimum local revenue, the ability to relocate depends on the political and financial support of the U.S. federal government (Huntingon et al., 2012). Therefore, limits are strongly influenced by relationships among public and private actors and institutions across different spatial, temporal, and jurisdictional scales (Cash et al., 2006; see also Section 16.4.1).

Similar tensions arise with respect to the role of traditional knowledge in adaptation. For example, cultural preferences regarding the value of traditional versus more formal scientific forms of knowledge influence what types of knowledge, and therefore adaptation options, are considered legitimate (Jones and Boyd, 2011). In the Arctic, Inuit traditional knowledge (*Inuit Qaujimajatuqangit*, IQ) encompasses all aspects of traditional Inuit culture including values, world-view, language, life skills, perceptions, and expectations (Nunavut Social Development Council, 1999; Wenzel, 2004). IQ includes, for example, weather forecasting, sea ice safety, navigation, and hunting and animal preparation skills that may have value for managing climate risk. Yet, as noted in the AR4 and more recent studies, these skills are declining among youth (*medium evidence*, *medium agreement*; Adger et al., 2007; Pearce et al., 2011). Increasing reliance on non-traditional forecasting (national weather office forecasts) and other technologies (GPS) in Arctic communities is in part responsible for increased risk taking when traveling on the land and sea ice (*medium evidence*, *medium agreement*; Aporta and Higgs, 2005; Ford et al., 2006; Pearce et al., 2011). Collectively, the recent literature suggests the extent to which knowledge acts to constrain or enable adaptation is dependent on how that knowledge is generated, shared, and used to achieve desired adaptation objectives (*very high confidence*; Patt et al., 2007; Nelson et al., 2008; Tribbia and Moser, 2008; Moser, 2010a,b).

…state and local government representatives in Australia indicate that the costs of investigating and responding to climate change are perceived to be significant constraints on adaptation at these levels of governance (Smith et al., 2008b; Gardner et al., 2010; Measham et al., 2011). However, Burch (2010) argues that financial constraints on adaptation reported by local governments in Canada are secondary to other institutional practices and cultures (Section 16.3.2.8).

16.3.2.7. Social and Cultural Constraints

Adaptation can be constrained by social and cultural factors that are linked to societal values, world views, and cultural norms and behaviors (*very high confidence*; O'Brien, 2009; Moser and Ekstrom, 2010; O'Brien and Wolf, 2010; Hartzell-Nichols, 2011). These social and cultural factors can influence perceptions of risk, what adaptation options are considered useful and by whom, as well as the distribution of vulnerability and adaptive capacity among different elements of society (Grothmann and Patt, 2005; Weber, 2006; Patt and Schröter, 2008; Adger et al., 2009; Kuruppu, 2009; O'Brien, 2009; Nielsen and Reenberg, 2010; Wolf and Moser, 2011; Wolf et al., 2013). Although the AR4 noted that social and cultural constraints on adaptation have not been well researched, more recent literature has significantly expanded their understanding. As a case in point, the erosion of traditional knowledge among the Arctic Inuit is the consequence of a long-term process of changing livelihoods, technology, and sources of knowledge (Pearce et al., 2011; see also Section 16.3.2.1).

Recent studies from Nepal and India report that adaptation decisions among women, in particular, can be constrained by cultural and institutional pressures that favor male land ownership (Jones and Boyd, 2011) and constrain access to hazard information (Ahmed and Fajber, 2009), respectively. Studies of evacuation during Hurricane Katrina suggest that females were more likely to evacuate New Orleans than males (Brunsma et al., 2010), as were individuals without sufficient resources and access to transportation (Cutter and Emrich, 2006). Studies from both the USA and UK find that the elderly do not necessarily perceive themselves as vulnerable to extreme heat events (Sheridan, 2007; Wolf et al., 2009), which may create disincentives to react to such events (Chapter 11).

Box 16-4 | Historical Perspectives on Limits to Adaptation

Does human history provide insights into societal resilience and vulnerability under conditions of environmental change? Archeological and environmental reconstruction provides useful perspectives on the role of environmental change in cases of significant societal change, sometimes termed "collapse" (Diamond, 2005). These may help to illuminate how adaptation limits were either exceeded, or where collapse was avoided to a greater or lesser degree. Great care is necessary to avoid oversimplifying cause and effect, or overemphasizing the role of environmental change, in triggering significant societal change, and the societal response itself. Coincidence does not demonstrate causality, such as in the instance of matching climatic events with social crises through the use of simple statistical tests (Zhang et al., 2011), or through derivative compilations of historical data (deMenocal, 2001; Thompson et al., 2002; Drysdale et al., 2006; Butzer, 2012). Application of social theories may not explain specific cases of human behavior and community decision making, especially because of the singular importance of the roles of leaders, elites, and ideology (Hunt, 2007; McAnany and Yoffee, 2010; Butzer, 2012; Butzer and Endfield, 2012).

There are now roughly a dozen case studies of historical societies under stress, from different time ranges and several parts of the world, that are sufficiently detailed (based on field, archival, or other primary sources) for relevant analysis (Butzer and Endfield, 2012). These include Medieval Greenland and Iceland (Dugmore et al., 2012; Streeter et al., 2012), Ancient Egypt (Butzer, 2012), Colonial Cyprus (Harris, 2012), the prehistoric Levant (Rosen and Rivera-Collazo, 2012), Islamic Mesopotamia and Ethiopia (Butzer, 2012), the Classic Maya (Dunning et al., 2012; Luzzadder-Beach et al., 2012), and Colonial Mexico (Endfield, 2012). Seven such civilizations underwent drastic transformation in the wake of multiple inputs, triggers, and feedbacks, with unpredictable outcomes. These can be seen to have exceeded adaptation limits. Five other examples showed successful adaptation through the interplay of environmental, political, and socio-cultural resilience, which responded to multiple stressors (e.g., insecurity, environmental or economic crises, epidemics, famine). In these cases, climatic perturbations are identified as only one of many "triggers" of potential crisis, with preconditions necessary for such triggers to stimulate transformational change. These preconditions include human- induced environmental decline mainly through overexploitation.

Avoidance of limits to adaptation requires buffering feedbacks that encompass social and environmental resilience. Exceedance of limits occurred through cascading feedbacks that were characterized by social polarization and conflict that ultimately result in societal disruption. Political simplification undermined traditional structures of authority to favor militarism, while breakdown was accompanied or followed by demographic decline. Although climatic perturbations and environmental degradation did contribute to triggering many cases of breakdown, the most prominent driver at an early stage was institutional failure, which refers to the inability of societal institutions to address collective-action problems (Acheson, 2006). In these cases, collapse was neither abrupt nor inevitable, often playing out over centuries. Lessons from the implementation of adaptation responses over historical time periods in Mexico City suggest that some responses may create new and even more significant risks (Sosa-Rodriguez, 2010).

Recent work on resilience and adaptation synthesizes lessons from extreme event impacts and responses in Australia (Kiem et al., 2010). This further emphasizes an institutional basis for resilience, finding that government intervention through the provision of frameworks to enable adaptation is beneficial. Furthermore, it was found that a strong government role may be necessary to absorb a portion of the costs associated with natural disasters. On the other hand, community awareness and recognition of novel conditions were also found to be critical elements of effective responses. It would be useful to consider how lessons learned from historical experience may relate to the perceived multiple environmental changes characterized by the "Anthropocene" era (Crutzen, 2002).

Similarly, Meze-Hausken (2008) views adaptation as being triggered in part by subjective thresholds including perceptions of change; choices, needs, and values; and expectations about the future (see also O'Brien, 2009). For instance, the distribution of grape suitability will change in response to climate change, but the potential for relocation as an adaptation is limited by the concept of "terroir," which reflects biophysical traits and local knowledge and wine making traditions to a cultural landscape (Box 23-1). However, terroir could become a soft limit if the rigid, regionally defined regulatory frameworks and concepts of regional identity that prescribe what grapes can be grown where were to become more geographically flexible and tied to the culture and history of the winemakers rather than regional climate and grape suitability (Box 23-1).

Strategies such as migration, for example, may involve the loss of sense of place and cultural identity, particularly if migration is involuntary (Adger et al., 2009). The feasibility of transformational adaptation may therefore be dependent in part on whether it results in outcomes that are perceived to be positive versus negative (Preston and Stafford Smith, 2009). This suggests that the factors that constrain incremental adaptation (e.g., Section 16.3.2) also can constrain transformation, but the greater level of investment and/or shift in fundamental values and expectations required for transformational change may create greater resistance (*limited evidence*, *medium agreement*; Pelling, 2010; O'Brien, 2012; O'Neill and Handmer, 2012; Park et al., 2012).

Table 16-3 | Sectoral and regional synthesis of adaptation opportunities, constraints, and limits. Each icon represents types of opportunities, constraints, and limits (described below). The size of the icon represents when there is relatively little (small icon) or relatively ample (large icon) information in the sectoral and regional chapters to describe each type of opportunity, constraint, or limit. If no information was presented, the table cell is blank.

***Opportunities** are defined as factors that make it easier to plan and implement adaptation actions, that expand adaptation options, or that provide ancillary co-benefits*. Types of opportunities include (1) **Awareness**: communication, education, and awareness raising; (2) **Capacity**: human and institutional capacity building including preparedness, resource provision, and development of human and social capital; (3) **Tools**: decision making, vulnerability and risk analysis, decision support, and early warning tools; (4) **Policy**: integration and mainstreaming of policy, governance, and planning processes including sustainable development, resource and infrastructure planning, and design standards; (5) **Learning**: mutual experiential learning and knowledge management of climate vulnerability, adaptation options, disaster risk response, monitoring, and evaluation; and (6) **Innovation**: development and dissemination of new information, technology development, and technology application.

***Constraints** are defined as factors that make it harder to plan and implement adaptation actions*. Types of constraints include (1) **Economic**: existing livelihoods, economic structures, and economic mobility; (2) **Social/cultural**: social norms, identity, place attachment, beliefs, worldviews, values, awareness, education, social justice, and social support; (3) **Human capacity**: individual, organizational, and societal capabilities to set and achieve adaptation objectives over time including training, education, and skill development; (4) **Governance**, Institutions & Policy: existing laws, regulations, procedural requirements, governance scope, effectiveness, institutional arrangements, adaptive capacity, and absorption capacity; (5) Financial: lack of financial resources; (6) **Information**/Awareness/Technology: lack of awareness or access to information or technology; (7) **Physical**: presence of physical barriers; and (8) **Biological**: temperature, precipitation, salinity, acidity, and intensity and frequency of extreme events including storms, drought, and wind.

*A **Limit** is defined as the point at which an actor's objectives or system's needs cannot be secured from intolerable risks through adaptive actions*. Types of limits include (1) **Biophysical**: temperature, precipitation, salinity, acidity, and intensity and frequency of extreme events including storms, drought, and wind; (2) **Economic**: existing livelihoods, economic structures and economic mobility; and (3) **Social/cultural**: social norms, identity, place attachment, beliefs, worldviews, values, awareness, education, social justice, and social support.

Berkes (2008, p. 163), for instance, documents that in Inuit culture, the loss of sea ice in summer months leaves some people "lonely for the ice." Whether the risk of irreversible cultural losses would be seen as intolerable remains a complicated question, but has been noted to manifest in a psychological response termed “solastalgia” (Albrecht et al., 2007). The loss of traditional ways of experiencing and seeing the world is a common occurrence throughout human history. The ethical question is whether such losses should be acknowledged in considering adaptation opportunities, constraints, and limits (as well as in human responses to climate change more generally).

Nevertheless, the complexity of international law comprises a significant constraint to making the case for addressing the breaching of adaptation limits (Koivurova, 2007). At national and subnational levels, cultural attitudes can contribute to stakeholder marginalization from adaptation processes (Section 16.3.2.7), thus preventing some constraints and limits from being identified (such as gender issues and patriarchal conventions).

Broad Definition of Benefits and Costs

The consequences of adaptation decisions cannot be expressed comprehensively through standard economic accounting of costs and revenues. Adaptation decisions can also affect other items such as income distribution and poverty (Jacoby et al., 2011); the regional distribution of economic activity, including employment; non-market factors such as water quality, ecosystem function, and human health; and social organization and cultural practices.

Incentives for private adaptation actions may also be lacking for public goods and common resources without property rights (e.g., biodiversity and natural areas, tradition, and culture). And adaptation may exhibit increasing returns or large fixed costs, leading to insufficient adaptation investments (e.g., Eisenack, 2013).

Particularly important is the fact that the provision of climate information needs to account for cognitive failures (Suarez and Patt, 2004; Osberghaus et al., 2010b). Individual behavioral barriers extend to cultural factors and social norms, which can support or impair adaptation as illustrated by Nielsen and Reenberg (2010) in Burkina Faso.

Application of cost-benefit or real option analysis requires evaluations in monetary terms. For market impacts, prices may need to be corrected for policies, monopoly power, or other external factors distorting market prices (Squire and van der Tak, 1975). But a cost-benefit analysis also often requires the valuation of non-market costs and benefits. This is the case for impacts on public health, cultural heritage, environmental quality and ecosystems, and distributional impacts. Valuation of non- market impact is difficult because of values and preferences heterogeneity, and subject to controversies—for example, on the value to attribute to avoided death (see Viscusi and Aldy, 2003).

Livelihoods of indigenous peoples in the Arctic have been altered by climate change, through impacts on food security and traditional and cultural values (*medium confidence*). There is emerging evidence of climate change impacts on livelihoods of indigenous people in other regions. {18.4.6, Box 18-5, Table 18-9}

Livelihoods of indigenous people in the Arctic have been identified as among the most severely affected by climate change, including food security aspects, traditional travel and hunting, and cultural values and references (Hovelsrud et al., 2008; Ford et al., 2009; Ford, 2009a,b; Beaumier and Ford, 2010; Pearce et al., 2010; Olsen et al., 2011; Eira, 2012; Crate, 2013; see also Box 18-5, Table 18-9).

AR4 emphasized the differences in vulnerability between developed and developing countries but also assessed new literature describing vulnerability pertaining to various aggregations of people (such as by ethnic, cultural, age, gender, or income status) and response strategies for avoiding key impacts. The RFCs were updated and the Synthesis Report (IPCC, 2007a) noted that they "remain a viable framework to consider key vulnerabilities" (IPCC, 2007a, Section 5.2).

Frequently Asked Questions

FAQ 19.1 | Does science provide an answer to the question of how much warming is unacceptable?

No. Careful, critical scientific research and assessment can provide information to help society consider what levels of warming or climate change impacts are unacceptable. However, the answer is ultimately a subjective judgment that depends on values and culture, as well as socioeconomic and psychological factors, all of which influence how people perceive risk in general and the risk of climate change in particular. The question of what level of climate change impacts is unacceptable is ultimately not just a matter of the facts, but of how we feel about those facts.

This question is raised in Article 2 of the UNFCCC. The criterion, in the words of Article 2, is "dangerous anthropogenic interference with the climate system"—a framing that invokes both scientific analysis and human values.

Agreements reached by governments since 2009, meeting under the auspices of the UNFCCC, have recognized "the scientific view that the increase in global temperature should be below 2 degrees Celsius" (Section 19.1, UNFCCC, Copenhagen Accord). Still, as informed on the subject as the scientists referred to in this statement may be, theirs is just one valuable perspective. How each country or community will define acceptable or unacceptable levels, essentially deciding what is "dangerous," is a societal judgment.

Science can certainly help society think about what is unacceptable. For example, science can identify how much monetary loss might occur if tropical cyclones grow more intense or heat waves more frequent, or identify the land that might be lost in coastal communities for various levels of higher seas. But "acceptability" depends on how each community values those losses. This question is more complex when loss of life is involved and yet more so when damage to future generations is involved. These are highly emotional and controversial value propositions that science can only inform, not decide.

The purpose of this chapter is to highlight key vulnerabilities and key risks that science has identified; however, it is up to people and governments to determine how the associated impacts should be valued, and whether and how the risks should be acted upon.

Box 19-2 | Definitions

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure,

or economic, social, or cultural assets in places and settings that could be adversely affected.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

A broad set of factors such as wealth, social status, and gender determine vulnerability and exposure to climate-related risk.

Impacts: (Consequences, Outcomes) Effects on natural and human systems. In this report, the term *impacts* is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as *consequences* and *outcomes*. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

Importance of the vulnerable system(s). Views on the importance of different aspects of societies or ecosystems can vary across regions and cultures (see Kienberger, 2012)

Magnitude. Risks are key if associated harmful consequences have a large magnitude, determined by a variety of metrics including human mortality and morbidity, economic loss, losses of cultural importance, and distributional consequences (see Schneider et al., 2007; IPCC, 2012a). Magnitude and frequency of the hazard as well as socioeconomic factors that determine vulnerability and exposure contribute.

Key risks are determined by the interaction of climate-related hazards with exposure and vulnerabilities of societies or ecosystems. Development pathways describing possible trends in demographic, economic, technological, environmental, social, and cultural conditions (Hallegatte et al., 2011) will affect key risks because they influence both the likelihood and nature of climate-related hazards, and the societal and ecological conditions determining exposure and vulnerability.

The particular elements of the social-ecological system that are most exposed and sensitive to climate hazards, and that are considered most important, will depend on spatial development patterns as well as on cultural preferences, attitudes toward nature/biodiversity, and reliance on climate-sensitive resources or services, among other factors (Adger, 2006; Füssel, 2009). The degree to which persistent or difficult to reverse vulnerabilities are built into social systems, as well as the degree of inequality in exposure and vulnerability across social groups or regions, also depend on characteristics of development pathways (Adger et al., 2009).

The end result opened 285,000 acres of public land for large-scale solar deployment while blocking development on 78 million acres to protect “natural and cultural” resources (US DOE and BLM, 2012).

SREX states with *high confidence* that vulnerability and exposure of communities or social-ecological systems to climatic hazards related to extreme events are dynamic, thus varying across temporal and spatial scales due to influences of and changes in social, economic, demographic, cultural, environmental, and governance factors (IPCC, 2012c, SPM.B).

Vulnerability and exposure of societies and social-ecological systems to hazards linked to climate change are dynamic and depend on economic, social, demographic, cultural, institutional, and governance factors (see IPCC, 2012c, p. 7).

Public perceptions of risks are not determined solely by the “objective” information, but rather are the product of the interaction of such information with psychological, social, institutional, and cultural processes and norms that are partly subjective, as demonstrated in various crises in the context of extreme events (Kasperson et al., 1988; Funabashi and Kitazawa, 2012)

This chapter integrates a variety of complex concepts in assessing climate-resilient pathways. It takes sustainable development as the ultimate goal, and considers mitigation as a way to keep climate change moderate rather than extreme. Adaptation is considered a response strategy to anticipate and cope with impacts that cannot be (or are not) avoided under different scenarios of climate change. In most cases, sustainable development will also involve capacities for implementing and sustaining appropriate risk management. Responses may differ from situation to situation, calling for a multiscale perspective that takes the socioeconomic, cultural, biophysical, and institutional context into account. Nonetheless, most situations share at least one fundamental characteristic: threats to sustainable development are greater if climate change is substantial rather than moderate. Similarly, opportunities for sustainable development are greater if climate change is moderate rather than substantial.

"Institutions" refer not only to formal structures and processes but also to the rules of the game and the norms and cultures that underpin environmental values and belief systems (see Glossary). Ostrom (1986) defines institutions as the rules, norms, and practices defining social behavior in a particular context—the action arena. Institutions define roles and provide social context for action and structure social interactions (Hodgson, 2003). Definitions of sustainability are shaped largely by institutional values, cultures, and norms. Institutions also critically influence our ability to govern and manage the resources and systems that shape adaptation, mitigation, and sustainable development. Fostering climate- resilient pathways requires strong institutions that are able to create an enabling environment through which adaptive and mitigative capacities can be built (IPCC, 2007a, Chapter 20; Gupta et al., 2010).

Transformational change is often difficult to order or plan, and there are many social, political, and cultural barriers and resistances. Transformational change can threaten vested interests, or prioritize the interests of some over the well-being of others, and it is never a neutral process (Meadowcroft, 2009; Smith and Stirling, 2010).

However, these transformations are often constrained by larger systems and structures, including financial, political, legal, social, economic, ecological, and cultural systems that define the boundaries for action. The "political sphere" is where systems and structures are transformed (intentionally or unintentionally) through politics and social movements, or through changes in social and cultural norms and power relations. Systems and structures often reflect dominant cultural beliefs and worldviews, and it is here where value conflicts may be experienced or resolved. A third sphere of transformation is the "personal sphere," which includes individual and collective beliefs, values, and worldviews, as well as the dominant paradigms.

Other key elements associated with transformations include adaptable institutions (cultural, economic, and governance), all types of capital, diversity in landscapes, seascapes and institutions, learning platforms, collective action and networks, as well as reflexivity and the capacity to take different perspectives (Loorbach 2007; Folke et al., 2010; Schlitz et al., 2010; Westley et al., 2011). Many of the elements of climate-resilient pathways discussed in Box 20-3 can, in fact, support transformation.

Ehrenfeld, J., 2008: *Sustainability by Design: A Subversive Strategy for Transforming Our Consumer Culture.* Yale University Press, New Haven, CT, USA, 246 pp.

Traditional

Human Health, Well-Being, and Security

The three chapters in this group, (11) Human health: impacts, adaptation, and co-benefits, (12) Human security, and (13) Livelihoods and poverty, increase the focus on people. These chapters address a wide range of processes, from vector-borne disease through conflict and migration. They assess the relevance of local and traditional knowledge.

- In the Arctic, some communities have begun to deploy adaptive co-management strategies and communications infrastructure, combining traditional and scientific knowledge.[24]

Assessment Box SPM.2 Table 1 (continued)

Continued next page →

Central and South America				
Key risk	**Adaptation issues & prospects**	**Climatic drivers**	**Timeframe**	**Risk & potential for adaptation** (Very low – Medium – Very high)
Water availability in semi-arid and glacier-melt-dependent regions and Central America; flooding and landslides in urban and rural areas due to extreme precipitation (*high confidence*) [27.3]	• Integrated water resource management • Urban and rural flood management (including infrastructure), early warning systems, better weather and runoff forecasts, and infectious disease control		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	
Decreased food production and food quality (*medium confidence*) [27.3]	• Development of new crop varieties more adapted to climate change (temperature and drought) • Offsetting of human and animal health impacts of reduced food quality • Offsetting of economic impacts of land-use change • Strengthening traditional indigenous knowledge systems and practices		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	
Spread of vector-borne diseases in altitude and latitude (*high confidence*) [27.3]	• Development of early warning systems for disease control and mitigation based on climatic and other relevant inputs. Many factors augment vulnerability. • Establishing programs to extend basic public health services		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	Long term 2°C: not available Long term 4°C: not available

Adaptation planning and implementation at all levels of governance are contingent on societal values, objectives, and risk perceptions (*high confidence*). Recognition of diverse interests, circumstances, social-cultural contexts, and expectations can benefit decision-making processes. Indigenous, local, and traditional knowledge systems and practices, including indigenous peoples' holistic view of community and environment, are a major resource for adapting to climate change, but these have not been used consistently in existing adaptation efforts. Integrating such forms of knowledge with existing practices increases the effectiveness of adaptation.[70]

Technological options: New crop & animal varieties; Indigenous, traditional, & local knowledge, technologies, & methods; Efficient irrigation; Water-saving technologies; Desalinization; Conservation agriculture; Food storage & preservation facilities; Hazard & vulnerability mapping & monitoring; Early warning systems; Building insulation; Mechanical & passive cooling; Technology development, transfer, & diffusion.

Indigenous, local, and traditional knowledge systems and practices, including indigenous peoples' holistic view of community and environment, are a major resource for adapting to climate change (*robust evidence*, *high agreement*). Natural resource dependent communities, including indigenous peoples, have a long history of adapting to highly variable and changing social and ecological conditions. But the salience of indigenous, local, and traditional knowledge will be challenged by climate change impacts. Such forms of knowledge have not been used consistently in existing adaptation efforts. Integrating such forms of knowledge with existing practices increases the effectiveness of adaptation. [9.4, 12.3, 15.2, 22.4, 24.4, 24.6, 25.8, 28.2, 28.4, Table 15-1]

Table TS.2 (continued)

Community-based adaptation and traditional practices in small island contexts	
Exposure and vulnerability	With small land area, often low elevation coasts, and concentration of human communities and infrastructure in coastal zones, small islands are particularly vulnerable to rising sea levels and impacts such as inundation, saltwater intrusion, and shoreline change. [29.3.1, 29.3.3, 29.6.1, 29.6.2, 29.7.2]
Climate information at the global scale	**Observed:** • *Likely* increase in the magnitude of extreme high sea level events since 1970, mostly explained by rising mean sea level. [WGI AR5 3.7.5] • *Low confidence* in long-term (centennial) changes in tropical cyclone activity, after accounting for past changes in observing capabilities. [WGI AR5 2.6.3] • Since 1950 the number of heavy precipitation events over land has *likely* increased in more regions than it has decreased. [WGI AR5 2.6.2] **Projected:** • *Very likely* significant increase in the occurrence of future sea level extremes by 2050 and 2100. [WGI AR5 13.7.2] • In the 21st century, *likely* that the global frequency of tropical cyclones will either decrease or remain essentially unchanged. *Likely* increase in both global mean tropical cyclone maximum wind speed and rainfall rates. [WGI AR5 14.6] • Globally, for short-duration precipitation events, *likely* shift to more intense individual storms and fewer weak storms. [WGI AR5 12.4.5]
Climate information at the regional scale	**Observed:** Change in sea level relative to the land (relative sea level) can be significantly different from the global mean sea level change because of changes in the distribution of water in the ocean and vertical movement of the land. [WGI AR5 3.7.3] **Projected:** • *Low confidence* in region-specific projections of storminess and associated storm surges. [WGI AR5 13.7.2] • Projections of regional changes in sea level reach values of up to 30% above the global mean value in the Southern Ocean and around North America, and between 10% and 20% above the global mean value in equatorial regions. [WGI AR5 13.6.5] • *More likely than not* substantial increase in the frequency of the most intense tropical cyclones in the western North Pacific and North Atlantic. [WGI AR5 14.6]
Description	Traditional technologies and skills can be relevant for climate adaptation in small island contexts. In the Solomon Islands, relevant traditional practices include elevating concrete floors to keep them dry during heavy precipitation events and building low aerodynamic houses with palm leaves as roofing to avoid hazards from flying debris during cyclones, supported by perceptions that traditional construction methods are more resilient to extreme weather. In Fiji after Cyclone Ami in 2003, mutual support and risk sharing formed a central pillar for community-based adaptation, with unaffected households fishing to support those with damaged homes. Participatory consultations across stakeholders and sectors within communities and capacity building taking into account traditional practices can be vital to the success of adaptation initiatives in island communities, such as in Fiji or Samoa. [29.6.2]
Broader context	• Perceptions of self-efficacy and adaptive capacity in addressing climate stress can be important in determining resilience and identifying useful solutions. • The relevance of community-based adaptation principles to island communities, as a facilitating factor in adaptation planning and implementation, has been highlighted, for example, with focus on empowerment and learning-by-doing, while addressing local priorities and building on local knowledge and capacity. Community-based adaptation can include measures that cut across sectors and technological, social, and institutional processes, recognizing that technology by itself is only one component of successful adaptation. [5.5.4, 29.6.2]

TS

Table TS.5 (continued)

Continued next page →

Central and South America

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation (Very low – Medium – Very high)
Water availability in semi-arid and glacier-melt-dependent regions and Central America; flooding and landslides in urban and rural areas due to extreme precipitation (*high confidence*) [27.3]	• Integrated water resource management • Urban and rural flood management (including infrastructure), early warning systems, better weather and runoff forecasts, and infectious disease control		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	
Decreased food production and food quality (*medium confidence*) [27.3]	• Development of new crop varieties more adapted to climate change (temperature and drought) • Offsetting of human and animal health impacts of reduced food quality • Offsetting of economic impacts of land-use change • Strengthening traditional indigenous knowledge systems and practices		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	
Spread of vector-borne diseases in altitude and latitude (*high confidence*) [27.3]	• Development of early warning systems for disease control and mitigation based on climatic and other relevant inputs. Many factors augment vulnerability. • Establishing programs to extend basic public health services		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	Long term 2°C: not available Long term 4°C: not available

Table TS.7 | Approaches for managing the risks of climate change. These approaches should be considered overlapping rather than discrete, and they are often pursued simultaneously. Mitigation is considered essential for managing the risks of climate change. It is not addressed in this table as mitigation is the focus of WGIII AR5. Examples are presented in no specific order and can be relevant to more than one category. [14.2, 14.3, Table 14-1]

Overlapping Approaches	Category	Examples	Chapter Reference(s)
Vulnerability & Exposure Reduction through development, planning, & practices including many low-regrets measures	Human development	Improved access to education, nutrition, health facilities, energy, safe housing & settlement structures, & social support structures; Reduced gender inequality & marginalization in other forms.	8.3, 9.3, 13.1 to 13.3, 14.2, 14.3, 22.4
	Poverty alleviation	Improved access to & control of local resources; Land tenure; Disaster risk reduction; Social safety nets & social protection; Insurance schemes.	8.3, 8.4, 9.3, 13.1 to 13.3
	Livelihood security	Income, asset, & livelihood diversification; Improved infrastructure; Access to technology & decision-making fora; Increased decision-making power; Changed cropping, livestock, & aquaculture practices; Reliance on social networks.	7.5, 9.4, 13.1 to 13.3, 22.3, 22.4, 23.4, 26.5, 27.3, 29.6, Table SM24-7
	Disaster risk management	Early warning systems; Hazard & vulnerability mapping; Diversifying water resources; Improved drainage; Flood & cyclone shelters; Building codes & practices; Storm & wastewater management; Transport & road infrastructure improvements.	8.2 to 8.4, 11.7, 14.3, 15.4, 22.4, 24.4, 26.6, 28.4, Table 3-3, Box 25-1
	Ecosystem management	Maintaining wetlands & urban green spaces; Coastal afforestation; Watershed & reservoir management; Reduction of other stressors on ecosystems & of habitat fragmentation; Maintenance of genetic diversity; Manipulation of disturbance regimes; Community-based natural resource management.	4.3, 4.4, 8.3, 22.4, Table 3-3, Boxes 4-3, 8-2, 15-1, 25-8, 25-9, & CC-EA
	Spatial or land-use planning	Provisioning of adequate housing, infrastructure, & services; Managing development in flood prone & other high risk areas; Urban planning & upgrading programs; Land zoning laws; Easements; Protected areas.	4.4, 8.1 to 8.4, 22.4, 23.7, 23.8, 27.3, Box 25-8
...tion ...sformational adjustments	Structural/physical	***Engineered & built-environment options***: Sea walls & coastal protection structures; Flood levees; Water storage; Improved drainage; Flood & cyclone shelters; Building codes & practices; Storm & wastewater management; Transport & road infrastructure improvements; Floating houses; Power plant & electricity grid adjustments.	3.5, 3.6, 5.5, 8.2, 8.3, 10.2, 11.7, 23.3, 24.4, 25.7, 26.3, 26.8, Boxes 15-1, 25-1, 25-2, & 25-8
		Technological options: New crop & animal varieties; Indigenous, traditional, & local knowledge, technologies, & methods; Efficient irrigation; Water-saving technologies; Desalinization; Conservation agriculture; Food storage & preservation facilities; Hazard & vulnerability mapping & monitoring; Early warning systems; Building insulation; Mechanical & passive cooling; Technology development, transfer, & diffusion.	7.5, 8.3, 9.4, 10.3, 15.4, 22.4, 24.4, 26.3, 26.5, 27.3, 28.2, 28.4, 29.6, 29.7, Tables 3-3 & 15-1, Boxes 20-5 & 25-2
		Ecosystem-based options: Ecological restoration; Soil conservation; Afforestation & reforestation; Mangrove conservation & replanting; Green infrastructure (e.g., shade trees, green roofs); Controlling overfishing; Fisheries co-management; Assisted species migration & dispersal; Ecological corridors; Seed banks, gene banks, & other *ex situ* conservation; Community-based natural resource management.	4.4, 5.5, 6.4, 8.3, 9.4, 11.7, 15.4, 22.4, 23.6, 23.7, 24.4, 25.6, 27.3, 28.2, 29.7, 30.6, Boxes 15-1, 22-2, 25-9, 26-2, & CC-EA
		Services: Social safety nets & social protection; Food banks & distribution of food surplus; Municipal services including water & sanitation; Vaccination programs; Essential public health services; Enhanced emergency medical services.	3.5, 3.6, 8.3, 9.3, 11.7, 11.9, 22.4, 29.6, Box 13-2

- Establishment of diverse and resilient agricultural systems, and adapting crop and livestock variety mixes to secure food provision. Traditional knowledge may contribute in this area through, for example, identifying indigenous crop and livestock genetic diversity, and water conservation techniques.

Table KR-1 | Examples of hazards/stressors, key vulnerabilities, key risks, and emergent risks.

Polar Regions (Chapter 28)	Loss of multi-year ice and reductions in the spatial extent of summer sea ice (Sections 28.2.5, 28.3.2, 28.4.1)	Indigenous communities that depend on sea ice for traditional livelihoods are vulnerable to this hazard, particularly due to loss of breeding and foraging platforms for marine mammals.	Risk of loss of traditional livelihoods and food sources.	Top-down shifts in food webs
		Ecosystems are vulnerable owing to the shifts in the distribution and timing of ice algal and ocean phytoplankton blooms.	Risk of disruption of synchronized timing of zooplankton ontogeny and availability of prey. Increased variability in secondary production while zooplankton adapt to shifts in timing. Risks also to local marine food webs.	Bottom up shifts in food webs. Potential changes in pelagic and benthic coupling
	Ocean acidification (Sections 28.2.2, 28.3.2)	Tolerance limits of endemic species surpassed. Impacts on exoskeleton formation for some species and alteration of physiological and behavioral properties during larval development	Localized loss of endemic species, local impacts on marine food webs	Localized declines in commercial fisheries. Local declines in fish, shellfish, seabirds, and marine mammals
	Shifts in boundaries of marine eco-regions due to rising water temperature, shifts in mixed layer depth, changes in the distribution and intensity of ocean currents (Sections 28.2.2, 28.3.2)	Marine organisms that are susceptible to spatial shifts are particularly vulnerable.	Risk of changes in the structure and function of marine systems and potentially species invasions	Disputes over international fisheries and shared stocks

Table KR-1 (continued)

	Hazard	Key vulnerabilities	Key risks	Emergent risks
Polar Regions (continued) (Chapter 28)	Declining sea ice, changes in snow and ice timing and state, decreasing predictability of weather (Sections 28.1, 28.4.1)	Many traditional subsistence food sources—especially for indigenous peoples—such as Arctic marine and land mammals, fish, and waterfowl. Various traditional livelihoods are susceptible to these hazards.	Risk of loss of habitats and changes in migration patterns of marine species	Enhancement of risk to food security and basic nutrition—especially for indigenous peoples—from loss of subsistence foods and increased risk to subsistence hunters', herders', and fishers' health and safety in changing ice conditions
	Increased river and coastal flooding and erosion and thawing of permafrost (Sections 28.2.4, 28.3.1, 28.3.4)	Rural and remote communities as well as urban communities in low-lying Arctic areas are exposed. Susceptibility and limited coping capacity of community water supplies due to potential damages to infrastructure.	Community and public health infrastructure damaged resulting in disease from contamination and sea water intrusion	Reduced water quality and quantity may result in increased rates of infection, other medical problems, and hospitalizations.
	Extreme and rapidly changing weather, intense weather and precipitation events, rapid snow and ice melt, changing river and sea ice conditions, permafrost thaw (Section 28.2.4)	People living from subsistence travel and hunting, herding, and fishing, for example indigenous peoples in remote and isolated communities, are particularly susceptible.	Accidents, physical/mental injuries, death, and cold-related exposure, injuries, and diseases	Enhanced risks to safe travel or subsistence hunting, herding, fishing activities affect livelihoods and well-being.
	Diminished sea ice; earlier sea ice melt-out; faster sea ice retreat; thinner, less predictable ice in general; greater variability in snow melt/freeze; ice, weather, winds, temperatures, precipitation (Sections 28.2.5, 28.2.6, 28.4.1)	Livelihoods of many indigenous peoples (e.g., Inuit and Saami) depend upon subsistence hunting and access to and favorable conditions for animals. These livelihoods are susceptible. Also marine ecosystems are susceptible (e.g., marine mammals).	Risk of loss of livelihoods and damage due to, e.g., more difficult access to marine mammals associated with diminishing sea ice (a risk to the Inuit), and loss of access by reindeer to their forage under snow due to ice layers formed by warming winter temperatures and "rain on snow" (a risk to the Saami).	Enhanced risk of loss of livelihoods and culture of increasing numbers of indigenous peoples, exacerbated by increasing loss of lands and sea ice for hunting, herding, fishing due to enhanced petroleum and mineral exploration, and increased maritime traffic

Additional vulnerability of peri-urban areas is on account of the re-constituted institutional arrangements and their structural constraints (Iaquinta and Drescher, 2000). Rapid declines in traditional informal institutions and forms of collective action, and their imperfect replacement with formal state and market institutions, may also increase vulnerability (Pelling and Mustafa, 2010).

In peri-urban areas around Mexico City (Eakin et al., 2013), management of the substantial risk of flooding is led *de facto* by agricultural and water agencies, in the absence of capacity within peri-urban municipalities and despite clear evidence that urban encroachment is a key driver of flood risk. In developed country contexts, suburban–exurban fringe areas often are overlooked in the policy arena that traditionally focuses on rural development and agricultural production, or urban growth and services

(Hanlon et al., 2010). The environmental function of urban agriculture, in particular, in protection against flooding, will increase in the context of climate change (Aubry et al., 2012).

While food production, refrigeration, transport, and processing require large amounts of energy (Pelletier et al., 2011), a major link between food and energy as related to climate change is the competition of bioenergy and food production for land and water (*robust evidence, high agreement*; Section 7.3.2, Box 25-10; Diffenbaugh et al., 2012; Skaggs et al., 2012). Food and crop wastes, and wastewater, may be used as sources of energy, saving not only the consumption of conventional nonrenewable fuels used in their traditional processes, but also the consumption of the water and energy employed for processing or treatment and disposal (Schievano et al., 2009; Oh et al., 2010; Olson, 2012). Examples of this can be found in several countries across all income ranges. For example, sugar cane byproducts are increasingly used to produce electricity or for cogeneration (McKendry, 2002; Kim and Dale, 2004) for economic benefits, and increasingly as an option for greenhouse gas mitigation.

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 leveled against previous IPCC assessments (e.g., Hulme and Mahony, 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; see also Sections 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 utilized (Kuruppu, 2009).

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 (Sections 2.3.3, 2.3.4). Institutional decisions about climate adaptation are taking place within a multi-level governance system (Rosenau, 2005; Kern and Alber, 2008).

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; see also Table 15-1). The challenge will be to collaborate in a way that enables their integration into a shared narrative on future adaptation choices.

Forests and woodlands are principal providers of timber, pulp, bioenergy, water, food, medicines, and recreation opportunities and can play prominent roles in cultural traditions. Forests are the habitat of a large fraction of the Earth's terrestrial plant and animal species, with the highest concentrations and levels of endemism found in tropical regions (Gibson et al., 2011). Climate change and forests interact strongly; air temperature, solar radiation, rainfall, and atmospheric CO_2 concentrations are major drivers of forest productivity and forest dynamics, and forests help control climate through the large amounts of carbon they can remove from the atmosphere or release, through absorption or reflection of solar radiation (albedo), cooling through evapotranspiration, and the production of cloud-forming aerosols (Arneth et al., 2010; Pan et al., 2011; Pielke et al., 2011).

Traditional agriculture preserves soil carbon sinks, supports on-site biodiversity, and uses less fossil fuel than high-input agriculture (Martinez-Alier, 2011) but, due to the typically lower per hectare yields, may require a larger area to be dedicated to cropland. Leaving aside the contested (Searchinger et al., 2008; Plevin et al., 2010) effectiveness of biofuels as a mitigation strategy, there is evidence of their disruptive effect on food security, land tenure, labor rights, and biodiversity in several parts of the world (Obersteiner et al., 2010; Tirado et al., 2010).

Seawater inundation has become a major problem for traditional agriculture in Bangladesh (Rahman et al., 2009), and in low-lying island nations (e.g., Lata and Nunn, 2012).

Ecosystem-based adaptation is increasingly attracting attention…Further work is still needed in order to make reliable quantitative estimates and predictions of the capability of some of these ecosystems to reduce wave, storm surge, and sea level rise impacts and in order to provide reliable cost-benefit analysis of how they compare to other measures based on traditional engineering approaches.

In many parts of the world, small island indigenous communities address climate change consequences based on their own traditional knowledge (Percival, 2008; Langton et al., 2012; Nakashima et al., 2012).

7.5.1.1.4. Indigenous knowledge

Indigenous knowledge (IK) has developed to cope with climate hazards contributing to food security in many parts of the world. Examples in the Americas include Alaska, where the Inuit knowledge of climate variability ensured the source of food to hunters and reduced various risks (Alessa et al., 2008; Ford, 2009; Weatherhead et al., 2010) down to the southern Andes, where the Inca traditions of crop diversification, genetic diversity, raised bed cultivation, agroforestry, weather forecasting, and water harvesting are still used in agriculture (Goodman-Elgar, 2008; Renard et al., 2011; McDowell and Hess, 2012; see also Sections 9.4.3.1, 27.3.4.2). In Africa, weather forecasting, diversity of crops and agropastoralism strategies have been useful in the Sahel (Nyong et al., 2007). Rainwater harvesting has been a common practice in sub-Saharan Africa (Biazin et al., 2012) to cope with dry spells and improve crop productivity, while strategies from agropastoralists in Kenya are related to drought forecasting based on the fauna, flora, moon, winds, and other factors (Speranza et al., 2010). In South Africa, farmers' early warming indicators of wet or dry periods in Namibia based on animals, plants, and climate observations contributed to deal with climatic variability (Newsham and Thomas, 2011). In the same way, in Asia and Australia IK plays an important role to ensure food security of certain groups (Salick and Ross, 2009; Green et al., 2010; Marin, 2010; Speranza et al., 2010; Kalanda-Joshua et al., 2011; Pareek and Trivedi, 2011; Biazin et al., 2012), although IK and the opportunities to implement it can differ according to gender and age in some communities (Rengalakshmi, 2007; Turner and Clifton, 2009; Kalanda-Joshua et al., 2011; see also Section 9.3.5), leading to distinct adaptive capacities and options.

In addition to changes already occurring in climate (seasonal changes, changes in extreme events; IPCC 2012) projected changes beyond historical conditions could reduce the reliance on indigenous knowledge (Speranza et al., 2010; Kalanda-Joshua et al., 2011; McDowell and Hess, 2012) affecting the adaptive capacity of a number of peoples globally (*medium evidence*, *medium agreement*).

Moreover, there is *medium confidence* that some policies and regulations leading to limit the access to territories, promoting sedentarization, the substitution of traditional livelihoods, reduced genetic diversity and harvesting opportunities, as well as loss of transmission of indigenous knowledge, may contribute to limit the adaptation to climate change in many regions (*medium evidence*, *medium agreement*; Nakashina et al., 2012).

Inherent poor soil quality and human activities have resulted in soil degradation—crusting, sealing, erosion by water and wind, and hardpan formation (Fatondji et al., 2009; Zougmoré et al., 2010). Zaï, a traditional integrated soil and water management practice, can combat land degradation and improve yield and decrease yield variability by concentrating runoff water and organic matter in small pits (20 to 40 cm in diameter and 10 to 15 cm deep) dug manually during the dry season and combined with contour stone bunds to slow runoff.

Transport planners are beginning to reassess maintenance costs and traditional materials—for instance, stiffer binding materials to cope with rising temperatures and softer bitumen for colder regions (Regmi and Hanaoka, 2011).

Mainstreaming adaptation into urban planning and land use management and legal and regulatory frameworks is key to successful adaptation (Lowe et al., 2009; Kehew et al., 2013). It can help planners rethink traditional approaches to land use and infrastructure design based on past trends, and move toward more forward looking risk-based design for a range of future climate conditions (Kithiia, 2010; Solecki et al., 2011; Kennedy and Corfee-Morlot, 2013), as well as reducing administrative cost by building resilience through existing policy channels (Urwin and Jordan, 2008; Benzie et al., 2011; Blanco et al., 2011).

Adelekan, I.O., 2012: Vulnerability to wind hazards in the traditional city of Ibadan, Nigeria. *Environment and Urbanization*, **24(2)**, 597-617.

Whilst having potential, there are complications with using traditional knowledge and farmer perceptions to detect climate trends (Rao et al., 2011; see also Box 18-4).

Table 9-2 | Relevant findings on rural areas from the IPCC Fourth Assessment Report and the International Assessment of Agricultural Science and Technology for Development.

	Finding	Source
Importance of non-climate trends	The significance of climate change needs to be considered in the multi-causal context of its interactions with other non-climate sources of change and stress (e.g., water scarcity, governance structures, institutional and jurisdictional fragmentation, limited revenue streams for public sector roles, resource constraints, or inflexible land use patterns).	W 7.4.2 I 6.7.5
	Different development paths may increase or decrease vulnerabilities to climate-change impacts.	W 7.7
	Neglect by policymakers and underinvestment in infrastructure and services has negatively affected rural areas.	I 1.3.4
	Policy neglect specifically disfavors rural women.	I 1.3.4
	Assessment of climate change impacts on agriculture has to be undertaken against a background of demographic and economic trends in rural areas.	E 5.3.2
	Global numbers of people at risk from hunger will be affected by climate change, but more by socioeconomic trends as captured in the difference between the SRES scenarios.	E 5.6.5
Specific characteristics of smallholder agriculture	Subsistence and smallholder livelihood systems suffer from a number of non-climate stressors, but are also characterized by having certain resilience factors (efficiencies associated with the use of family labor, livelihood diversity to spread risks).	E 5.3.2
	Traditional knowledge of agriculture and natural resources is an important resilience factor.	I 2.1.2, 3.2.2, 3.2.3 E 5.3.2 CC4
	The combination of stressors and resilience factors gives rise to complex and locally specific impacts, resistant to modeling.	E 5.4.7 W 7.2, 7.4, 7.5

Drought could threaten biodiversity and traditional ecosystems particularly in southern Europe, with problems exacerbated by declining water quality.

Traditional knowledge (TK) developed to adapt to past climate variability and change can both be affected by climate change and used and transformed in adaptation (Nyong et al., 2007). Ettenger (2012) discusses how seasonal hunting camps among the Cree of Northern Quebec that were the occasion for intergenerational knowledge transfer have been disrupted by changing bird migrations, while new technologies such as the Internet, GPS, and satellite phones have been integrated into livelihood strategies. Climate change-induced migration can threaten TK transfer (Valdivia et al., 2010; Gilles et al., 2013). Disaster management by central government may undermine decentralization efforts, disfavoring TK transfer (Dekens, 2008).

Lack of access to assets, of which land is an important one, is accepted to be an important factor increasing vulnerability in rural people (McSweeney and Coomes, 2011). The breakdown of traditional land tenure systems increases vulnerability, particularly for those who experience poorer land access as a result (Brouwer et al., 2007; Dougill et al., 2010; Fraser et al., 2011). Those who benefit, for example, wealthier farmers who increased their landholding after privatization in Botswana, remain less vulnerable (Dougill et al., 2010).

Changes in water availability, demand, and quality due to climate change would impact water management and allocation decisions. Traditionally, water managers and users have relied on historical experience when planning water supplies and distribution (Adger et al., 2007; UNFCCC, 2007).

Other mechanisms include elevated occupational exposures to toxic chemical solvents that evaporate faster at higher temperatures (Bennett and McMichael, 2010) and rising temperatures reducing sea ice and increasing risk of drowning in those engaged in traditional hunting and fishing in the Arctic (Ford et al., 2008).

In the longer term, research will need to make the best use of traditional epidemiologic methods, while also taking into account the specific characteristics of climate change. These include the long-term and uncertain nature of the exposure and effects on multiple physical and biotic systems, with the potential for diverse and widespread effects, including high-impact events.

Indigenous, local, and traditional forms of knowledge are a major resource for adapting to climate change (*robust evidence*, *high agreement*). Natural resource dependent communities, including indigenous peoples, have a long history of adapting to highly variable and changing social and ecological conditions. But the salience of indigenous, local, and traditional knowledge will be challenged by climate change impacts. Such forms of knowledge are often neglected in policy and research, and their mutual recognition and integration with scientific knowledge will increase the effectiveness of adaptation. {12.3.3-4}

The assessment in this chapter is based on structured reviews of scientific literature. These were carried out first using searches of scientific databases of relevant studies published from 2000 until 2013, with searches targeted at the core dimensions of culture, indigenous peoples, traditional knowledge, migration, conflict, and transboundary resources. These searches were supplemented by open searches to capture book and other non-journal literature. The comprehensive review in this chapter reflects the dominant findings from the scientific literature that the impacts of climate change on livelihoods, cultures, migration, and conflict are negative, but that some dimensions of human security are less sensitive to climate change and driven by economic and social forces.

Table 12-2 | Cultural dimensions of climate science, policy, impacts, and extreme events in the context of climate change.

Core climate change dimensions	Cultural dimensions	Role in human security	Sources
Climate science and policy	Framing of climate change in a dominant language Global climate change policy implemented at international scales	How concepts and uncertainties are translated, imported, and incorporated can facilitate or hinder adaptation: *Facilitate adaptation*: available explanatory tools; successful translation of climate change impacts; awareness of culture *Hinder adaptation*: lack of trust in science and in policy; policy not recognizing the connection between nature and culture Policy and decision making that is inclusive of cultural perspectives *increases security*.	Ifejika Speranza et al. (2008); Stadel (2008); Jacka (2009); Green et al. (2010); Osbahr et al. (2010); Schroeder (2010); Gero et al. (2011); Kuruppu and Liverman (2011); Roncoli et al. (2011); Sánchez-Cortés and Chavero (2011); McNeely (2012); Rudiak-Gould (2012)
Impacts of environmental conditions, extreme events, and changing natural resource base	Elements of collective understanding such as: • Worldviews • Coupling of nature–culture • Power relations • Heterogeneity within groups and communities	*Facilitate adaptation*: New technologies; livelihood diversification and flexibility; perceptions of resilience; narratives and history about past changes and current conditions; co-management of resources increases adaptive capacity. *Hinder adaptation*: limitations of local knowledge; lack of awareness and understanding of culture constrains action; knowledge and cultural repertoire limited for responding to new challenges; perceptions of resilience Erosion of cultural core potentially *decreases human security*. Institutional responses and resource management will impact human security either negatively or positively.	Nunn (2000); Davidson et al. (2003); Desta and Coppock (2004); Ford et al. (2006, 2008); Furgal and Seguin (2006); Kesavan and Swaminathan (2006); Zamani et al. (2006); Nyong et al. (2007); Tyler et al. (2007); Angassa and Oba (2008); Burningham et al. (2008); Crate (2008); de Sherbinin et al. (2008); King (2008); Gregory and Trousdale (2009); Jacka (2009); Pearce et al. (2009); Berkes and Armitage (2010); Dumaru (2010); Fazey et al. (2010); Hovelsrud and Smit (2010); Hovelsrud et al. (2010a,b); Kalikoski et al. (2010); Kuhlicke (2010); Lefale (2010); Nielsen and Reenberg (2010); Osbahr et al. (2010); Rybråten and Hovelsrud (2010); Valdivia et al. (2010); West and Hovelsrud (2010); Armitage et al. (2011); Gero et al. (2011); Harries and Penning-Rowsell (2011); Kuruppu and Liverman (2011); Marshall (2011); Onta and Resurrection (2011); Roncoli et al. (2011); Adler et al. (2012); Anik and Khan (2012); Eakin et al. (2012); Ford and Goldhar (2012); Gómez-Baggethun et al. (2012); McNeeley (2012); Nursey-Bray et al. (2012); Rudiak-Gould (2012); Sudmeier-Riuex et al. (2012)
Scientific observations, monitoring, models, projections, scenarios	Local, traditional, and indigenous knowledge through observations and experience	*Facilitate adaptation*: mutual integration of traditional, local, and scientific knowledge; climate projections with local relevance; intergenerational knowledge transfers Local knowledge included in climate policy and decision making *increases human security*. Knowledge not included in adaptation planning *decreases human security*.	Orlove et al. (2000, 2010); Ingram et al. (2002); Tàbara et al. (2003); Alcántara-Ayala et al. (2004); Roncoli (2006); Anderson et al. (2007); Forbes (2007); Nyong et al. (2007); Tyler et al. (2007); Vogel et al. (2007); Catto and Parewick (2008); Marfai et al. (2008); Mercer et al. (2009); Pearce et al. (2009); Burns et al. (2010); Frazier et al. (2010); Gearheard et al. (2010); Hovelsrud and Smit (2010); Marin (2010); Mark et al. (2010); Smit et al. (2010); Flint et al. (2011); Huntington (2011); Kalanda-Joshua et al. (2011); Ravera et al. (2011); Sánchez-Cortés and Chavero (2011); Dannevig et al. (2012); Eira et al. (2013)

12.3.2. Indigenous Peoples

There are around 400 million indigenous people worldwide (see Glossary for an inclusive definition), living under a wide range of social, economic, and political conditions and locations (Nakashima et al., 2012). Indigenous peoples represent the world's largest reserve of cultural diversity and the majority of languages (Sutherland, 2003). Climate change poses challenges for many indigenous peoples, including challenges to post-colonial power relations, cultural practices, their knowledge systems, and adaptive strategies. For example, the extensive literature on the Arctic shows that changing ice conditions pose risks in terms of access to food and increasingly dangerous travel conditions (Ford et al., 2008, 2009; Hovelsrud et al., 2011; see also Section 28.4.1). Accordingly, there is a strong research tradition on the impacts of climate change in regions with substantial indigenous populations that focuses on indigenous peoples and their attachment to place. Most studies focus on local, traditional, and rural settings (Cameron, 2012) and hence have been argued to create a knowledge gap regarding new urban indigenous populations. Indigenous peoples are often portrayed in the literature as victims of climate change (Salick and Ross, 2009) and as vulnerable to its consequences (ACIA, 2005). However, traditional knowledge is increasingly being combined with scientific understanding to facilitate a better understanding of the dynamic conditions of indigenous peoples (Huntington, 2011; see also Section 12.3.4).

There is *high agreement* that, historically, indigenous peoples have had a high capacity to adapt to variable environmental conditions. This literature also suggests indigenous peoples also have less capacity to cope with rapidly changing socioeconomic conditions and globalization (Tyler et al., 2007; Crate and Nuttall, 2009). Documented challenges for indigenous cultures to adapt to colonization and globalization may reflect resilience and the determination of indigenous peoples to maintain cultures and identities. Furthermore, historical legacies affect the way that indigenous populations adapt to modern challenges: anthropological research has documented clear linkages between historical colonization and the way the way indigenous peoples respond to current climatic changes (Salick and Ross, 2009; Cameron, 2012; Howitt et al., 2012; Marino, 2012).

Most of the literature in this area emphasizes the significant challenge of maintaining cultures, livelihoods, and traditional food sources under the impacts of climate change (Crate and Nuttall, 2009; Rybråten and Hovelsrud, 2010; Lynn et al., 2013). Examples from the literature show that traditional practices are already under pressure from multiple sources, reducing the ability of such practices to enable effective responses to climate variability (Green et al., 2010). Empirical evidence suggests that the efficacy of traditional practices can be eroded when governments relocate communities (Hitchcock, 2009; McNeeley, 2012; Maldonado et al., 2013); if policy and disaster relief creates dependencies (Wenzel, 2009; Fernández-Giménez et al., 2012); in circumstances of inadequate entitlements, rights, and inequality (Shah and Sajitha, 2009; Green et al., 2010; Lynn et al., 2013); and when there are constraints to the transmission of language and knowledge between generations (Forbes, 2007). Some studies show that current indigenous adaptation strategies may not be sufficient to manage the projected climate changes (Wittrock et al., 2011).

Assessments of the cultural implications of climate change for human security illustrate similarities across indigenous peoples. Indigenous peoples have a right to maintain their livelihoods and their connections to homeland and place (Howitt et al., 2012) and it is suggested that the consequences of climate change are challenging this right (Box 12-1; Crate and Nuttall, 2009). Some raise the question whether the Western judicial system can uphold indigenous rights in the face of climate change (Williams, 2012) and that there is a need for justice that facilitates adaptation (Whyte, 2013). In addition, there are uneven societal consequences related to climate change impacts (e.g., use of sea ice: Ford et al., 2008), which add complexity to adaptation in indigenous societies. Heterogeneity within indigenous groups and differentiated exposure to risk has been found in other contexts, for example, in pastoralist groups of the Sahel (Barrett et al., 2001).

Much research on indigenous peoples concludes that lack of involvement in formal, government decision making over resources decreases resilience: the literature recommends further focus on indigenous perceptions of risk and traditional knowledge of change, hazards, and coping strategies and collective responses (Ellemor, 2005; Brown, 2009; Finucane, 2009; Turner and Clifton 2009; Sánchez-Cortés and Chavero, 2011; Maldonado et al., 2013). Though providing economic opportunities, tourism development and industrial activities are particular areas of risk for indigenous peoples when affected populations are not involved in decision making (Petheram et al., 2010). Lack of formal participation in international negotiations may pose risks for indigenous peoples because their perspectives are not heard (Schroeder, 2010). However, there are examples of successful indigenous lobbying and advocacy, as in the case of managing persistent organic pollutants and heavy metals in the Arctic (Selin and Selin, 2008).

12.3.3. Local and Traditional Forms of Knowledge

There is *high agreement* among researchers that involvement of local people and their local, traditional, or indigenous forms of knowledge in decision making is critical for ensuring their security (Ellemor, 2005; Kesavan and Swaminathan, 2006; Burningham et al., 2008; Mercer et al., 2009; Pearce et al., 2009; Anik and Khan, 2012). Such forms of knowledge include categories such as traditional ecological knowledge, indigenous science, and ethnoscience (Nakashima and Roué, 2002). Collectively they are defined as "a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations" (Berkes, 2012, p. 7). In addition to reasserting culture, identity, and traditional values, such forms of knowledge are experiential, dynamic, and highly context dependent, developed through interactions with other forms of knowledge (Ford et al., 2006; Orlove et al., 2010; Sánchez-Cortés and Chavero, 2011; Eira et al., 2013).

The conclusion of many anthropological studies in this area is that there is *robust evidence* that mutual integration and co-production of local and traditional and scientific knowledge increase adaptive capacity and reduce vulnerability (Kofinas, 2002; Oberthür et al., 2004; Anderson et al., 2007; Tyler et al., 2007; Vogel et al., 2007; Marfai et al., 2008; West et al., 2008; Frazier et al., 2010; Armitage et al., 2011; Flint et al., 2011; Ravera et al., 2011; Nakashima et al., 2012; Eira et al., 2013). Local and traditional knowledge about historical changes and adaptation strategies are valuable for evaluating contemporary responses to environmental and social change and policy (Orlove et al., 2000; Desta and Coppock, 2004; Angassa and Oba, 2008; Ford et al., 2008; Lefale, 2010; Osbahr et al., 2010; Fernández-Giménez et al., 2012; Eira et al., 2013). Traditional knowledge contributes to mitigating the impact of natural disasters (Rautela, 2005), maintaining domestic biodiversity (Emperaire and Peroni, 2007) and developing sustainable adaptation and mitigation strategies (Nyong et al., 2007; Adler et al., 2013). A study of Borana indigenous pastoralists, for example, documented how loss of technical and organizational practices contributed to progressive land degradation, erosion of social structures, and poverty (Homann et al., 2008). Local and traditional knowledge is also applied in folk forecasting of weather and has been shown to be mutually reinforcing with scientific forecasts of weather at different time scales (Orlove et al., 2000; Nyong et al., 2007; Tyler et al., 2007; Gearheard et al., 2010; Hovelsrud and Smit, 2010).

Despite recognition in studies of the value of local and traditional knowledge, such knowledge is most often not included in adaptation planning (Tàbara et al., 2003; King et al., 2007; Ifejika Speranza et al., 2008; Huntington, 2011). There are many challenges in managing, utilizing, acknowledging, and incorporating local and traditional knowledge into adaptation practices (Huntington, 2011). Such knowledge is often generated and collected through participatory approaches, an approach that may not be sufficient because of the cultural and social

dynamics of power and interpretation (Roncoli et al., 2011). Local and traditional knowledge itself may have its limits. Some studies suggest that local or traditional knowledge may not be sufficient to provide the proper response to unexpected or infrequent risks or events (Nunn, 2000; Burningham et al., 2008; Kuhlicke, 2010).

There is also concern, documented in many anthropological studies, that indigenous and traditional knowledge is itself under threat. If local or traditional knowledge is perceived to be less reliable because of changing environmental conditions (Ingram et al., 2002; Ford et al., 2006) or because of extreme or new events that are beyond the current local knowledge and cultural repertoire (Valdivia et al., 2010; Hovelsrud et al., 2010a), then community vulnerability, and the vulnerability of local or traditional knowledge itself, may increase (Kalanda-Joshua et al., 2011). New conditions may require new knowledge to facilitate and maintain flexibility and improve livelihoods (see also Homann et al., 2008). Kesavan and Swaminathan (2006) documented how societal and environmental conditions have changed to the point that local knowledge is supplemented with new technologies and new knowledge in coastal communities in India. A study in the Himalayas found that erosion of traditional knowledge occurs through government regulations of traditional building materials and practices (Rautela, 2005). The social cohesion embedded in such practices is weakened because of a move toward concrete construction which changes the reliance on and usefulness of traditional knowledge about wood as a building material (Rautela, 2005).

Table 14-1 | Categories and examples of adaptation options.

Category		Examples of options*
Structural/ physical	Engineered and built environment	Sea walls and coastal protection structures (5.5.2 and 24.4.3.5; Figure 5-5); flood levees and culverts (26.3.3); water storage and pump storage (Section 23.3.4); sewage works (3.5.2.3); improved drainage (24.4.5.5); beach nourishment (5.4.2.1); flood and cyclone shelters (11.7); building codes (Section 8.1.5); storm and waste water management (8.2.4.1); transport and road infrastructure adaptation (8.3.3.6); floating houses (8.3.3.4); adjusting power plants and electricity grids (10.2.2; Table 10-2)
	Technological	New crop and animal varieties (7.5.1.1.1, 7.5.1.1.3, 7.5.1.3; Box 9-3; Table 9-7); genetic techniques (27.3.4.2); traditional technologies and methods (7.5.2, 27.3.4.2, 28.2.6.1, and 29.6.2.1); efficient irrigation (10.3.6 and 22.4.5.7; Box 20-4); water saving technologies (24.4.1.5 and 26.3.3) including rainwater harvesting (8.3.3.4); conservation agriculture (9.4.3.1 and 22.4.5.7); food storage and preservation facilities (22.4.5.7); hazard mapping and monitoring technology (15.3.2.3 and 28.4.1); early warning systems (7.5.1.1, 8.1.4.2, 8.3.3.3, 11.7.3, 15.4.3.2, 18.6.4, 22.2.2.1, 22.3.5.3, and 22.4.5.2); building insulation (8.3.3.3); mechanical and passive cooling (8.3.3.3); renewable energy technologies (29.7.2); second-generation biofuels (27.3.6.2)
	Ecosystem-based[a]	Cross Chapter Box CC-EA, Ecological restoration (5.5.2, 5.5.7, 9.4.3.3, and 27.3.2.2; Box 15-1) including wetland and floodplain conservation and restoration; increasing biological diversity (26.4.3); afforestation and reforestation (Box 22-2); conservation and replanting mangrove forest (15.3.4 and 29.7.2); bushfire reduction and prescribed fire (Section 24.4.2.5; Box 26-2); green infrastructure (e.g., shade trees, green roofs) (8.2.4.5, 8.3.3, 11.7.4, and 23.7.4); controlling overfishing (28.2.5.1 and 30.6.1); fisheries co-management (9.4.3.4 and 27.3.3.1); assisted migration or managed translocation (4.4.2.4, 24.4.2.5, 24.4.3.5, and 25.6.2.3); ecological corridors (4.4.2.4); ex situ conservation and seed banks (4.4.2.5); community-based natural resource management (CBNRM) (22.4.5.6); adaptive land use management (Section 23.6.2)
	Services	Social safety nets and social protection (Box 13-2; 8.3, 17.5.1, and 22.4.5.2); food banks and distribution of food surplus (29.6.2.1); municipal services including water and sanitation (3.5.2.3 and 8.3.3.4); vaccination programs (11.7.1), essential public health services (11.7.2) including reproductive health services (11.9.2) and enhanced emergency medical services (8.3.3.8); international trade (9.3, 9.4, and 23.9.2)
Social	Educational	Awareness raising and integrating into education (11.7, 15.2, and 22.4.5.5); gender equity in education (Box 9-2); extension services (9.4.4); sharing local and traditional knowledge (12.3.4 and 28.4.1) including integrating into adaptation planning (29.6.2.1); participatory action research and social learning (22.4.5.3); community surveys (Section 8.4.2.2); knowledge-sharing and learning platforms (8.3.2.2, 8.4.2.4, 15.2.4.2, and 22.4.5.4); international conferences and research networks (8.4.2.5); communication through media (22.4.5.5)
	Informational	Hazard and vulnerability mapping (11.7.2, 8.4.1.5); early warning and response systems (15.4.2.3 and 22.4.5.2) including health early warning systems (11.7.3, 23.5.1, 24.4.6.5, and 26.6.3); systematic monitoring and remote sensing (15.4.2.1 and 28.6); climate services (2.3.3) including improved forecasts (27.3.4.2); downscaling climate scenarios (8.4.1.5); longitudinal data sets (26.6.2); integrating indigenous climate observations (22.4.5.4, 25.8.2.1, and 28.2.6.1); community-based adaptation plans (5.5.1.4 and 24.4.6.5) including community-driven slum upgrading (8.3.2.2) and participatory scenario development (22.4.4.5)
	Behavioral	Accommodation (5.5.2); household preparation and evacuation planning (23.7.3); retreat (5.5.2) and migration (29.6.2.4), which has its own implications for human health (11.7.4) and human security (12.4.2); soil and water conservation (23.6.2 and 27.3.4.2); livelihood diversification (7.5.1.1, 7.5.2, and 22.4.5.2); changing livestock and aquaculture practices (7.5.1.1); crop-switching (22.3.4.1); changing cropping practices, patterns, and planting dates (7.5.1.1.1, 23.4.1, 26.5.4, and 27.3.4.2; Table 24-2); silvicultural options (25.7.1.2); reliance on social networks (Section 29.6.2.2)
Institutional	Economic	Financial incentives including taxes and subsidies (Box 8-4; 8.4.3 and 17.5.6); insurance (8.4.2.3, 13.3.2.2, 15.2.4.6, 17.5.1, 26.7.4.3, and 29.6.2.2; Box 25-7) including index-based weather insurance schemes (9.4.2 and 22.4.5.2); catastrophe bonds (8.4.2.3 and 10.7.5.1); revolving funds (8.4.3.1); payments for ecosystem services (9.4.3.3 and 27.6.2; Table 27-7); water tariffs (8.3.3.4.1 and 17.5.3); savings groups (8.4.2.3 and 11.7.4; Box 9-4); microfinance (Box 8-3; 22.4.5.2); disaster contingency funds (22.4.5.2 and 26.7.4.3); cash transfers (Box 13-2)
	Laws and regulations	Land zoning laws (22.4.4.2 and 23.7.4); building standards (8.3.2.2, 10.7.5, and 22.4.5.7); easements (27.3.3.2); water regulations and agreements (26.3.4 and 27.3.1.2); laws to support disaster risk reduction (8.3.2.2); laws to encourage insurance purchasing (10.7.6.2); defining property rights and land tenure security (22.4.6 and 24.4.6.5); protected areas (4.4.2.2); marine protected areas (Box CC-CR Chapter 6; 23.6.5 and 27.3.3.2); fishing quotas (23.9.2); patent pools and technology transfer (15.4.3 and 17.5.5)
	Government policies and programs	National and regional adaptation plans (15.2 and 22.4.4.2; Box 23-3) including mainstreaming climate change; sub-national and local adaptation plans (15.2.1.3 and 22.4.4.4; Box 23-3); urban upgrading programs (8.3.2.2); municipal water management programs (8.3.3.4; Box 25-2); disaster planning and preparedness (11.7); city-level plans (8.3.3.3 and 27.3.5.2; Boxes 26-3 and 27-1), district-level plans (26.3.3), sector plans (26.5.4), which may include integrated water resource management (3.6.1 and 23.7.2), landscape and watershed management (4.4.2.3), integrated coastal zone management (2.4.3, 5.5.4.1, and 23.7.1), adaptive management (2.2.1.3 and 5.5.1.4; Box 5-2), ecosystem-based management (6.4.2.1), sustainable forest management (2.3.4), fisheries management (7.5.1.1.3 and 30.6.2.1), and community-based adaptation (5.5.4.1, 8.4, 15.2.2, 21.3.2, 22.4.4.5, 24.5.2, 29.6.2.2, and 29.6.2.3; Tables 5-4 and 8-4; FAQ 15.1)

Notes: These adaptation options should be considered overlapping rather than discrete, and are often pursued simultaneously as part of adaptation plans. Examples given can be relevant to more than one category.

[a]A number of these would fall under the term "green infrastructure" in some European Commission documents (European Commission, 2009).
*WGII AR5 sections containing representative sample of adaptation options.

Technologies range from more efficient irrigation and fertilization methods, plant breeding for greater drought tolerance, and adjusting planting based on projected yields (Semenov, 2006, 2008; Bannayan and Hoogenboom, 2008) to transfers of traditional technologies such as floating gardens (Irfanullah et al., 2011a,b). Technology options for climate change adaptation include both "hard" and "soft" technologies, and not only new technologies but also indigenous and locally made appropriate technology (Glatzel et al., 2012). For example, traditional construction methods have been identified across the Pacific as a means of adapting to tropical cyclones and floods, including building low aerodynamic houses and the use of traditional roofing material such as sago palm leaves to reduce the hazard of iron roofing being blown away in high winds (see Section 29.6.2.1). Centralized high-technology systems can increase efficiency under normal conditions, but also risk cascading malfunctions in emergencies (Section 15.4.3).

As ideas about adaptation have evolved, there has been a shift in ambition from traditional approaches that emphasize maintaining the status quo to more dynamic and integrative strategies (see also Sections 2.4.3, 14.1, 16.4.2, 20.5). Adaptive management places an emphasis on taking action and then using the lessons learned to inform future actions in order to make better informed, and often incremental, decisions in the face of uncertainty (Sections 2.2.1.3, 14.4). Lempert and Schlesinger (2000) have proposed that adaptation options should be robust against a wide range of plausible climate and societal change futures. Emerging trends in adaptation place an emphasis on the need for more transformational changes, which has a distinct logic that differs from traditional strategies (see Section 14.1).

Consistent with social norms and traditions: 12.3.1, 13.1.2; Moser (2006); O'Brien et al. (2007); Alexander et al. (2011)

Other questions also arise even within a given conceptual framework for considering vulnerability. A system of measurement is usually developed to allow comparisons between different places, social groups, or sectors of activity, although experience repeatedly cautions us to be careful in doing so (Schröter et al., 2005). The challenge is as much of integration across widely differing research domains and traditions (Polksy et al., 2007). Also, a system's vulnerability is not static but can respond rapidly to changes in economic, social, political, and institutional conditions over time (Smit and Pilifosova, 2003; Smit and Wandel, 2006). Much of the effort in relation to estimating social vulnerability is reviewed in Cutter et al. (2009).

Table 14-4 | A selection of examples of actual or potential maladaptive actions from this report.

Broad type of maladaptive action	Examples in AR5
Failure to anticipate future climates. Large engineering projects that are inadequate for future climates. Intensive use of non-renewable resources (e.g., groundwater) to solve immediate adaptation problem	22.3, 22.4.8.5
Engineered defenses that preclude alternative approaches such as EBA	Box CC-EA; 15.2.2
Adaptation actions not taking wider impacts into account	22.4.5.8, 25.4.2, and 26.9.4
Awaiting more information, or not doing so, and eventually acting either too early or too late. Awaiting better "projections" rather than using scenario planning and adaptive management approaches	7.5.1.2.2, 8.5.2, and 16.5.2
Forgoing longer term benefits in favor of immediate adaptive actions; depletion of natural capital leading to greater vulnerability	13.2.1.3; 22.4.5.8; 25.9.1
Locking into a path dependence, making path correction difficult and often too late	16.3.2; FAQ 25.1
Unavoidable ex post maladaptation, e.g., expanding irrigation that eventually will have to be replaced in the distant future	17.5; see also 5 and 6 above
Moral hazard, i.e., encouraging inappropriate risk taking based, e.g., on insurance, social security net, or aid backup	17.5 and 29.8
Adopting actions that ignore local relationships, traditions, traditional knowledge, or property rights, leading to eventual failure	12.3, 12.5.2; 26.9.4
Adopting actions that favor directly or indirectly one group over others leading to breakdown and possibly conflict	13.1.1 and 13.1.4
Retaining traditional responses that are no longer appropriate	21.3.2 and 22.4.5.8
Migration may be adaptive or maladaptive or both depending on context and the individuals involved	26.2.1, 26.8.3, 29.3.3, 29.6.2.4

Note: These examples of maladaptation represent a set of cases found in the report that might help the readers to understand the rich range of circumstances in which maladaptive actions might arise. They do not represent a formal categorization of type of maladaptation.

Some studies warn against the simplistic use of maladaptation to communicate the state of high exposure to risks resulting from certain type of livelihoods. For example, the periodic movement of the nomadic pastoralists following the grass and water is a traditional and effective way of dealing with climate variability (Agrawal and Perrin, 2008), but is increasingly being described by some as maladaptive. More focused studies such as Young et al. (2009) put the breakdown of traditional pastoralism in the Sudan into the wider social and political context that led to restrictions on movement, asset stripping, and escalating violence and was undermined by policies not conducive to mobility.

Irfranullah, H.M., M.A.K. Azad, A.K.M. Kamruzzaman, and M.A. Wahed, 2011b: Floating gardening in Bangladesh: a means to rebuild lives after devastating flood. *Indian Journal of Traditional Knowledge*, **10(1)**, 31-38.

There is a significant increase in the number of planned adaptation responses at the local level in rural and urban communities of developed and developing countries since AR4. Climate adaptation is context dependent and it is uniquely linked to location, making it predominantly a local government and community level of action (Corfee-Morlot et al., 2009; Glaas et al., 2010; Mukheibir et al., 2013). Among these efforts are adaptation plans that utilize local knowledge. Local knowledge- based adaptation is focused primarily on the use of traditional knowledge to increase adaptive capacity at the community level, examples of which are shown in Table 15-1. In addition to raising adaptive capacity, local knowledge often highlights vulnerabilities and impacts that may not be well known, especially when the areas where local knowledge is still held are remote and poorly monitored (e.g., Majule et al., 2013).

Table 15-1 | Application of local knowledge in climate change adaptation.

Location	Sector	Approach and strategy	Adaptive action implemented	Institutions	References
Southern Kimberley, Australia	Water supplies	• Define vulnerabilities • Increase adaptive capacity	• Compile observed changes • Increase monitoring • Manage water resources • Review TEK[a]	Universities; NGOs;[b] United Nations University	Green et al. (2010); Prober et al. (2011); Leonard et al. (2013)
Trinidad, Bolivia and northern central Bolivia	Ecosystems, agriculture	Reduce vulnerability	• Revive "camellones" (earthen platforms) TEK • Reduce erosion • Document local observations	Oxfam International; NGOs; Bolivian government; Food and Agriculture Organization	Oxfam International (2009)
Pinoleville Pomo Nation (California, USA)	Infrastructure	• Mitigation: solar power • Increase adaptive capacity	• Co-design infrastructure • Address insufficient capital • Address water shortages and energy needs	Universities; NGOs; Housing and Urban Development	Shelby et al. (2012); Pinoleville Pomo Nation Housing flyer (2013); Redsteer et al. (2013)
Fiji	Ecosystems and water supply	• Define vulnerabilities • Increase adaptive capacity	• Recognize TEK • Enable adaptive decision making • Enhance community awareness • Participate in development	Australian Agency for International Development; Fiji Department of Environment; University of the South Pacific	Dumaru (2010)
Kenya, Tanzania, Malawi, Zimbabwe, southern Zambia	Agriculture	• Define vulnerabilities • Increase technical capacity • Increase adaptive capacity	• Use drought early warning • Apply TEK • Develop novel reporting • Compile observed changes • Harvest rainwater • Change tilling practices • Use appropriate crop varieties	University of Capetown; University of Nairobi; the United Kingdom's Department for International Development; Canada's International Development Research Centre	Chang'a et al. (2010); Mugabe et al. (2010); Kalanda-Joshua et al. (2011); Majule et al. (2013); Masindel et al. (2013)
Reservation lands (western USA)	Health, water supplies, environment	• Define vulnerabilities and impacts • Increase adaptive capacity	• Compile observed changes • Utilize environmental legislation • Review indigenous knowledge • Analyze local meteorological data • Analyze historical/legal context • Increase monitoring	Universities and affiliated NGOs; tribal offices; federal agency research	Redsteer et al. (2010); Doyle et al. (2013); Gautam et al. (2013)

[a]TEK = Traditional ecological knowledge: adaptive ecological knowledge developed through an intimate reciprocal relationship between a group of people and a particular place over time.

[b]NGO = Nongovernmental organization.

Adaptation practices reflected in the WGII AR5 include agriculture, public health for heat-related risks, disaster risk reduction, water resources, coasts, and urban areas, among others. Options and approaches used in implementation vary widely, ranging from traditional and existing to new and innovative measures. For example, farmers have been adapting to climate change worldwide, and current common practices include altering sowing times, crop cultivars and species, or irrigation and fertilizer control (Fujisawa and Koyabashi, 2010; Lasco et al., 2011; Olesen et al., 2011); reduced tillage practices; and technical measures to more effectively capture rainwater and reduce soil erosion (Thomas et al., 2007; Marongwe et al., 2011; see also Sections 7.5.1, 22.4.5.7, 23.4.1, 24.4.4.5, 27.3.4.2). These have proven to be effective in many cases, while some measures faced other problems; for example, earlier sowing is often prevented by lack of soil workability and frost-induced soil crumbling (Oort, 2012). Furthermore, simple options such as changes in sowing and harvesting dates may become less successful in a more variable climate (Moriondo et al., 2010; see also Section 23.4.1). Adaptation in agriculture is also linked with water management. Adaptation to water scarcity can be improved by taking into account a set of agronomic practices and irrigation such as

deficit irrigation (Geerts and Raes, 2009; see also Section 27.3.4.2). For public health for heat-related risks, major approaches are developing early warning
systems and air pollution control. According to Chapter 11 on Human Health, some studies report that heat wave early warning systems are effective to reduce heat-related mortality, resulting in fewer deaths during heat waves after implementation of the system (e.g., Ebi et al., 2004; Tan et al., 2007; Fouillet et al., 2008). A national assessment attributed the lower death toll to greater public awareness of the health risks of heat, improved health care facilities, and the introduction in 2004 of a heat wave early warning system (Fouillet et al., 2008; see also Section11.7.3).
Mullan (2013) indicated that implementation of adaptation plans are still at an early stage despite the rapid development of strategies and plans that have occurred in OECD countries. In many sectors, adaptation to both environmental conditions and climate change includes accumulating traditional experience and knowledge for adaptation. Furthermore, each country has also developed its own policies and options to prevent, cope with, mitigate, and utilize various environmental changes. As the occurring adaptive actions are usually based on such existing knowledge and options, they are incremental. Research has shown that local governments that have started implementing adaptation plans mostly tend to adopt a reactive or event-driven approach to adaptation relying on technical measures. Often the focus is on climate variability and current weather extremes rather than long- term climate change (Næss et al., 2005; Tompkins, 2005; Wall and Marzall, 2006; Crabbé and Robin, 2006; Storbjörk, 2007; Blanco and Alberti, 2009; Amundsen et al., 2010; Glaas et al., 2010; Anguelovsky and Carmin, 2011; Measham et al., 2011; Preston et al., 2011; Dannevig et al., 2012; Romero-Lankao et al., 2012; Runhaar et al., 2012). Climate adaptation efforts reported on at present are often piecemeal and fragmented approaches, dealing with partial solutions and approaches to climate adaptation, rather than more full-scale implementation (Granberg and Elander, 2007; Blanco and Alberti, 2009; Bulkeley et al., 2009; Amundsen et al., 2010; Burch, 2010; Tompkins et al., 2010; Preston et al., 2011; Dannevig et al., 2012; Mees et al., 2012; Romero-Lankao, 2012; Runhaar et al., 2012). In many cases, these practices have been embedded in existing policies, and thus not necessarily framed or made visible as climate adaptation actions (Tompkins et al., 2010; Berrang- Ford et al., 2011; see Box 25-5). It should be noted that several of these reports on local climate adaptation actions have been taking place without explicit regulative demands for climate adaptation.

In contrast, local level strategies are more diverse because climate change impacts occur locally and adaptation is context dependent. The scale of community engagement and the approaches used may provide key elements for the success of adaptation programs (Patt and Schröter, 2008; Ensor and Berger, 2009; Ford et al., 2011; Pelling, 2011; Picketts et al., 2012). Methodological guidelines for community adaptation plans and actions fostered by international organizations emphasize strategies focused on the use of local and traditional knowledge to increase adaptive capacity at the community level (IFRC et al., 2009; IISD, 2012; Crane, 2013). Moreover, community adaptation planning has been strengthened through the use of geographic information systems (GIS), modeling, climate change scenarios, ecosystem services, and other scientific research methods applied to foster the ability of the community to design adaptation (Shaw et al., 2009; Bardsley and Sweeney, 2010; IAPAD, 2010). Multilateral development agencies recognize the importance of inclusive approaches for adaptation planning and implementation, but they tend to focus on strengthening the role of local governments (USAID, 2007; OECD, 2009; Bizikova, 2010b; UNDP, 2010b; UN-HABITAT, 2011b; World Bank, 2011a; Abbas et al., 2012).

By the same token, local knowledge-based adaptation is primarily focused on the use of traditional knowledge to increase adaptive capacity at the community level (see Table 15-1 for examples). Local knowledge often

highlights vulnerabilities and impacts that may not be well known owing to the close interactions between climatic and non-climatic stressors associated with structural inequalities to vulnerability in societies (exposure, sensitivity, and adaptive capacity) (Majule et al., 2013). Combining top-down and bottom-up approaches and using low-regret strategies and actions in DRM and in adaptation planning and implementation increase climate resilience, improve livelihoods, reduce development pressures, and strengthen economic and social well-being (Moser and Satterthwaite, 2008; Hallegatte, 2009; Bizikova et al., 2010b; UNDP, 2010b). It can also help alleviate the concerns of limiting the effectiveness of policy interventions, as mentioned in Section 15.2.1.

EWS includes a diversity of approaches. These range from technological advances in systems, satellite information, and climate modeling (UNISDR, 2006; Smith et al., 2009; Bierbaum et al., 2013) to local level early warning based on traditional knowledge needed to develop and inform strategic response options in adaptation planning and implementation. Local knowledge can be complemented with scientific climatic data, research, and planning tools (GIS, modeling, etc.) to strengthen community-based monitoring and vulnerability assessment in disaster risk management and adaptation to climate change (Green and Raygorodetsky, 2010; Kalanda-Joshua et al., 2011; Newsham and Thomas, 2011; Nakashima et al., 2012).

Institutions are composed of tangible formal procedures, laws and regulations and tacit informal values, norms, traditions, codes, and conducts that shape expectations and guide actions among actors and organizations, serving as manifestations of institutions (Ostrom, 1990; Dovers and Hezri, 2010). Adaptation planning and implementation follows formal institutions associated with regulations, policies, and standards created and enforced by government actors but also requires the participation of informal institutions through interactions among stakeholders according to cultural, social, and political conditions in societies (Moser and Satterthwaite, 2008; Carmin et al., 2012). Chapter 14 describes the importance of these institutional frameworks for adaptive capacity. Chapter 16 presents a framework for adaptation, opportunities, and limits, where governance and institutional arrangements are included. This section assesses the literature on how institutional dimensions limit or enable adaptation planning and implementation and what lessons can be learned from these experiences.

Third, the horizontal interplay between actors and policies operating at similar administrative levels is seen as key in institutionalizing climate adaptation. Several international studies have shown that local governments and administrations consist of different professional silos with their own internal norms, values, and priorities and that the institutional rigidity of existing administrative and political sectors creates unfortunate compartmentalization where climate adaptation is seen as the isolated task of a singular sector that may hinder mainstreaming and horizontal coordination across sectors and departments (Mickwitz et al., 2009; Burch, 2010; Roberts, 2010; Storbjörk, 2010; Runhaar et al., 2012; Vammen Larsen et al., 2012; van den Berg and Coenen, 2012; Wilby and Keenan, 2012). Preston et al. (2011) have determined that adaptation plans from Australia, the UK, and the USA largely frame adaptation in a narrow sense overlooking the capacity and institutional challenges involved in the process of mainstreaming in other sectors. Institutional rigidity also takes the form of path dependency where past policies, decisions, habits, and traditions constrain the extent to which systems can learn or adapt to climate change (Garrelts and Lange, 2011; Berkhout, 2012; Runhaar et al., 2012; Preston et al., 2013). Some authors have identified such cultures of reactive management or structural engineered approaches to climate adaptation negatively influencing institutional change (Næss et al., 2005; Harries and Penning-Rowsell, 2011; Measham et al., 2011). Several writers have emphasized the need to facilitate improved cross-sectoral interaction, exchange, and organizational learning to drive institutional change (Berkhout et al., 2006; Crabbé and Robin, 2006; Pelling et al., 2008; Hinkel et al., 2009; Burch, 2010). How cross-sectoral coordination is achieved in practice remains one of the major challenges in transitioning from planning to implementation.

Livelihoods of indigenous peoples in the Arctic have been altered by climate change, through impacts on food security and traditional and cultural values (*medium confidence*). There is emerging evidence of climate change impacts on livelihoods of indigenous people in other regions. {18.4.6, Box 18-5, Table 18-9}

Box 18-5 | Detection, Attribution, and Traditional Ecological Knowledge

Indigenous and local peoples often possess detailed knowledge of climate change that is derived from observations of environmental conditions over many generations. Consequently, there is increasing interest in merging this traditional ecological knowledge (TEK)—also referred to as indigenous knowledge—with the natural and social sciences in order to better understand and detect climate change impacts (Huntington et al., 2004; Parry et al., 2007; Salick and Ross, 2009; Green and Raygorodetsky, 2010; Ford et al., 2011; Diemberger et al., 2012). TEK, however, does not simply augment the sciences, but rather stands on its own as a valued knowledge system that can, together with or independently of the natural sciences, produce useful knowledge for climate change detection or adaptation (Agrawal, 1995; Cruikshank, 2001; Hulme, 2008; Berkes, 2009; Byg and Salick, 2009; Maclean and Cullen, 2009; Wohling, 2009; Ziervogel and Opere, 2010; Ford et al., 2011; Herman-Mercer et al., 2011).

Cases in which TEK and scientific studies both detect the same phenomenon offer a higher level of confidence about climate change impacts and environmental change (Huntington et al., 2004; Laidler, 2006; Krupnik and Ray, 2007; Salick and Ross, 2009; Gamble et al., 2010; Green and Raygorodetsky, 2010; Alexander et al., 2011; Cullen-Unsworth et al., 2012). Evidence is available in particular from Nordic and Mountain peoples, for example, from Peru's Cordillera Blanca mountains (Bury et al., 2010; Carey, 2010; Baraer et al., 2012; Carey et al., 2012b), Tibet (Byg and Salick, 2009), and Canada (Nichols et al., 2004; Laidler, 2006; Krupnik and Ray, 2007; Ford et al., 2009; Aporta et al., 2011). TEK can also inspire scientists to study new issues in the detection of climate change impacts. In one case, experienced Inuit weather forecasters in Baker Lake, Nunavut, Canada, reported that it had become increasingly difficult for them to predict weather, suggesting an increase of weather variability and anomalies in recent years. To test Inuit observations, scientists analyzing hourly temperature data over a 50-year period confirmed that afternoon temperatures fluctuated much more during springtime during the last 20 years—precisely when Inuit forecasters noted unpredictability—than they had during the previous 30 years (Weatherhead et al., 2010).

Despite frequent confluence between TEK and scientific observations, there are sometimes discrepancies between them, indicating uncertainty in the identification of climate change impacts. They can arise because TEK and scientific studies frequently focus on different and distinct scales that make comparison difficult. Local knowledge may fail to detect regional environmental changes while scientific regional or global scale analyses may miss local variation (Wohling, 2009; Gamble et al., 2010). Furthermore, TEK-based observations and related interpretations necessarily need to be viewed within the context of the respective cultural, social, and political backgrounds (Agrawal, 1995). Therefore, a direct translation of TEK into a natural science perspective is often not feasible.

Livelihoods of indigenous people in the Arctic have been identified as among the most severely affected by climate change, including food security aspects, traditional travel and hunting, and cultural values and references (Hovelsrud et al., 2008; Ford et al., 2009; Ford, 2009a,b; Beaumier and Ford, 2010; Pearce et al., 2010; Olsen et al., 2011; Eira, 2012; Crate, 2013; see also Box 18-5, Table 18-9). Impacts of rising temperatures, increased variability, and weather extremes on crops and livestock of indigenous people in highlands were reported from Tibet Autonomous Region, China (Byg and Salick, 2009), and the Andes of Bolivia (McDowell and Hess, 2012).

However, in developing countries, particularly in Africa, where traditional knowledge could potentially moderate this uncertainty, it is often not recognized as a reference point for managing climate risks and emerging threats. In Kenya, the importance of indigenous knowledge, given increased uncertainty and climate- related risks, has compelled national agencies such as the Kenyan Meteorological Agencies and vulnerable groups such as the indigenous communities commonly known as rainmakers to form strategic reciprocal links. By working closely together to calibrate their forecasts and test the efficacy of the results against climate change impacts on agricultural productivity, the two groups have been able to demonstrate the benefits of Western science and traditional knowledge systems to increase effectiveness (Ziervogel and Opere, 2010). In integrating different kinds of knowledge, participatory processes, which call for a deliberative form of decision making among stakeholders, are well suited to the governance culture necessary for effective adaptation and mitigation. However, findings in the literature regarding the effectiveness of participatory processes are mixed. For example, though some scholars have argued that deliberative democracy methods can bring diverse stakeholders and kinds of knowledge (e.g., lay, expert, and indigenous) together thus putting in place a more communicative model of science delivery (Benn et al., 2009), empirical research shows that stakeholder participation does not always lead to consensus (Rowe and Frewer, 2004; Bell et al., 2011; also see Salter et al., 2010).

Common problems with institutional arrangements for adaptively managing natural resources include a frequent incompatibility of current governance structures with many of those that may be necessary for promoting social and ecological resilience. For example, some major tenets of traditional management styles have "in many cases operated through exclusion of users and the top-down application of scientific knowledge in rigid programmes" (Tompkins and Adger, 2004, p. 10).

Indigenous

- Livelihoods and lifestyles of indigenous peoples, pastoralists, and fisherfolk, often dependent on natural resources, are highly sensitive to climate change and climate change policies, especially those that marginalize their knowledge, values, and activities. [9.3, 11.3, 12.3, 14.2, 22.4, 25.8, 26.8, 28.2]

Indigenous peoples in both Australia and New Zealand have higher than average exposure to climate change due to a heavy reliance on climate-sensitive primary industries and strong social connections to the natural environment, and face additional constraints to adaptation (*medium confidence*). [25.2, 25.3, 25.5 to 25.8, Boxes 25-1, 25-2, 25-5, and 25-8]

Already, accelerated rates of change in permafrost thaw, loss of coastal sea ice, sea level rise, and increased intensity of weather extremes are forcing relocation of some indigenous communities in Alaska (*high confidence*). In the Arctic and Antarctic, some marine species will shift their ranges in response to changing ocean and sea ice conditions (*medium confidence*). Climate change will increase the vulnerability of terrestrial ecosystems to invasions by non-indigenous species (*high confidence*). [6.3, 6.5, 28.2 to 28.4]

Mitigation efforts focused on land acquisition for biofuel production show preliminary negative impacts for the poor in many developing countries, and particularly for indigenous people and (women) smallholders. [9.3, 13.3, 22.6]

Some indigenous communities are changing seasonal migration and hunting patterns to adapt to changes in temperature.

The production of information with non-scientific sources such as indigenous knowledge or stakeholder views is also enriching climate change research. This trend has led to the merging of relevant global programs of the international councils for science and for social science (ICSU and ISSC) under the umbrella "Future Earth" (see also ISSC and UNESCO, 2013). This expanded scientific focus combined with increased practice and experience with adaptation creates a new opportunity space for evaluating policy options and their risks in the search for climate resilient development pathways (Figure 1-5) (Sections 2.1, 2.4.3, 20.2, 20.3.3). Human and social-ecological systems can build resilience through adaptation, mitigation, and sustainable development.

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

Narratives of climate change have evolved over time and invariably represent uncertainty and risk (Hamblyn, 2009) being characterized as tools for analysis, communication, and engagement (Cohen, 2011; Jones et al., 2013; Westerhoff and Robinson, 2013) by: Exploring responses at an individual/institutional level to an aspect of adaptation, and communicating 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 (Section2.5.2).

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; see also Section 12.3.3).

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; see also Table 15-1). The challenge will be to collaborate in a way that enables their integration into a shared narrative on future adaptation choices.

Much of the observed adaptation practice deals with the coastal hazards of erosion and flooding (Hanak and Moreno, 2012). In many parts of the world, small island indigenous communities address climate change consequences based on their own traditional knowledge (Percival, 2008; Langton et al., 2012; Nakashima et al., 2012). Long- term adaptation to sea level rise has been confined to a few major projects such as the Venice Lagoon project, the Thames Estuary 2100 project (Box 5-1), and the Delta Programme, Netherlands (Norman, 2009).

For example, neither scientific climate knowledge alone nor indigenous knowledge alone is considered sufficient for coastal adaptation (Sales, 2009; Dodman and Mitlin, 2011; Bormann et al., 2012). Finally, since coastal systems are complex, diverse, and dynamic, their governance requires experimentation and learning by doing (Jentoft, 2007).

Climate change may endanger harvests of marine species with spiritual and aesthetic importance to indigenous cultures, raising ethical questions about cultural preservation (e.g., Nuttall, 1998). In coastal communities, losing the aesthetic values of marine ecosystems may harm local economies: better water quality and fewer harmful algal blooms are related to higher shellfish landings and real estate prices (Jin et al., 2008).

Indigenous knowledge is an important resource in climate risk management and is important for food security in many parts of the world. Climate changes may be reducing reliance on indigenous knowledge in some locations but also some policies and regulation may be limiting the contribution that indigenous knowledge can make to effective climate adaptation (*medium evidence*, *medium agreement*; Section 7.5.1.1.4).

Deak and Bucht (2011) analyze past hydrological structures in Lund, Sweden, and use the concept of indigenous blue infrastructure to question current storm water management in the urban core. Cities in California have a range of flood management methods but Hanak and Lund (2012) suggest that they will also require forward-looking reservoir operation planning and floodplain mapping, less restrictive rules for raising local funds, and improved public information on flood risks.

Ecosystem based adaptation has relevance for many chapters (see Box CC-EA). Ecosystem-based adaptation in urban areas as part of the climate change adaptation strategy seeks to move beyond a focus on street trees and parks to a more detailed understanding of the ecology of indigenous ecosystems, and how biodiversity and ecosystem services can reduce the vulnerability of ecosystems and people. Strategies to achieve biodiversity goals (developing corridors for species migration, enlarging core conservation areas, identifying areas for improved matrix management to enhance ecological viability) can have adaptation co- benefits.

Frequently Asked Questions

FAQ 9.1 | What is distinctive about rural areas in the context of climate change impacts, vulnerability, and adaptation?

Nearly half of the world's population, approximately 3.3 billion people, lives in rural areas, and 90% of those people live in developing countries. Rural areas in developing countries are characterized by a dependence on agriculture and natural resources; high prevalence of poverty, isolation, and marginality; neglect by policymakers; and lower human development. These features are also present to a lesser degree in rural areas of developed countries, where there are also closer interdependencies between rural and urban areas (such as commuting), and where there are also newer forms of land use such as tourism and recreational activities (although these also generally depend on natural resources).

The distinctive characteristics of rural areas make them uniquely vulnerable to the impacts of climate change because:

- Greater dependence on agriculture and natural resources makes them highly sensitive to climate variability,

  extreme climate events, and climate change.

- Existing vulnerabilities caused by poverty, lower levels of education, isolation, and neglect by policymakers can

  all aggravate climate change impacts in many ways.

  Conversely, rural people in many parts of the world have, over long time scales, adapted to climate variability, or at least learned to cope with it. They have done so through farming practices and use of wild natural resources (often referred to as indigenous knowledge or by similar terms), as well as through diversification of livelihoods and through informal institutions for risk-sharing and risk management. Similar adaptations and coping strategies can, given supportive policies and institutions, form the basis for adaptation to climate change, although the effectiveness of such approaches will depend on the severity and speed of climate change impacts.

Table 9-2 | Relevant findings on rural areas from the IPCC Fourth Assessment Report and the International Assessment of Agricultural Science and Technology for Development.

	Finding	Source
Importance of non-climate trends	The significance of climate change needs to be considered in the multi-causal context of its interactions with other non-climate sources of change and stress (e.g., water scarcity, governance structures, institutional and jurisdictional fragmentation, limited revenue streams for public sector roles, resource constraints, or inflexible land use patterns).	W 7.4.2 I 6.7.5
	Different development paths may increase or decrease vulnerabilities to climate-change impacts.	W 7.7
	Neglect by policymakers and underinvestment in infrastructure and services has negatively affected rural areas.	I 1.3.4
	Policy neglect specifically disfavors rural women.	I 1.3.4
	Assessment of climate change impacts on agriculture has to be undertaken against a background of demographic and economic trends in rural areas.	E 5.3.2
	Global numbers of people at risk from hunger will be affected by climate change, but more by socioeconomic trends as captured in the difference between the SRES scenarios.	E 5.6.5
Specific characteristics of smallholder agriculture	Subsistence and smallholder livelihood systems suffer from a number of non-climate stressors, but are also characterized by having certain resilience factors (efficiencies associated with the use of family labor, livelihood diversity to spread risks).	E 5.3.2
	Traditional knowledge of agriculture and natural resources is an important resilience factor.	I 2.1.2, 3.2.2, 3.2.3 E 5.3.2 CC4
	The combination of stressors and resilience factors gives rise to complex and locally specific impacts, resistant to modeling.	E 5.4.7 W 7.2, 7.4, 7.5
Impacts on agriculture and agricultural trade	In low-latitude regions, temperature increases of 1–2°C are likely to have negative impacts on yields of major cereals. Further warming has increasingly negative impacts in all regions.	E 5.4.2
	Increases in global mean temperatures (GMTs) of 2–3°C might lead to a small rise or decline (10–15%) in food (cereals) prices, while GMT increases in the range of 5.5°C or more might result in an increase in food prices of, on average, 30%.	E 5.6.1
Forestry	Loss of forest resources through climate change may affect 1.2 billion poor and forest-dependent people, including through impacts on non-timber forest products.	E 5.4.5
Valuation	Robust valuation of climate change impact on human settlements is difficult, and social and environmental costs are poorly captured by monetary metrics: non-monetary valuation methods should be explored.	W 7.4.3, 7.5 I 8.2.5
Adaptation	The need and the capacity to adapt vary considerably from region to region, and from farmer to farmer.	I 1.3.3
	Adaptation actions can be effective in achieving their specific goals, but they may have other (positive or negative) effects, including resource competition.	I 6.7.5
	Diversification of agricultural and non-agricultural livelihood strategies is an important adaptation trend, but requires institutional support and access to resources.	E 5.5.1, 5.5.2
	The effectiveness of adaptation efforts is likely to vary significantly between and within regions, depending on geographic location, vulnerability to current climate extremes, level of economic diversification and wealth, and institutional capacity.	I 6.8
	Multi-stakeholder processes are increasingly important with respect to climate change adaptation.	I 7.5.3
Links between adaptation and mitigation	Mitigation and adaptation policies are in many cases, and certainly for agriculture, closely linked.	K 18.4.3, 18.7.1 E 5.4.1, 5.4.2, 5.6.5 W 7.1, 7.7

Sources: W = Wilbanks et al. (2007); E = Easterling et al. (2007); I = McIntyre et al. (2009); K = Klein et al. (2007); CC4 = Cross-Chapter Case Study C4 "Indigenous knowledge for adaptation to climate change" in AR4 (Parry et al., 2007).

There is also a rich specialized literature on the impacts of shrinking sea ice and changing seasonal patterns of ice formation and melt on indigenous peoples in the Arctic (Ford, 2009; Beaumier and Ford, 2010; see also Section 28.2.5.1.7).

Frequently Asked Questions

FAQ 9.2 | What will be the major climate change impacts in rural areas across the world?

The impacts of climate change on patterns of settlement, livelihoods, and incomes in rural areas will be complex and will depend on many intervening factors, so they are hard to project. These chains of impact may originate with extreme events such as floods and storms, some categories of which, in some areas, are projected with *high confidence* to increase under climate change. Such extreme events will directly affect rural infrastructure and may cause loss of life. Other chains of impact will run through agriculture and the other ecosystems (rangelands, fisheries, wildlife areas) on which rural people depend. Impacts on agriculture and ecosystems may themselves stem from extreme events like heat waves or droughts, from other forms of climate variability, or from changes in mean climate conditions such as generally higher temperatures. All climate-related impacts will be mediated by the vulnerability of rural people living in poverty, isolation, or with lower literacy, and so forth, but also by factors that give rural communities resilience to climate change, such as indigenous knowledge, and networks of mutual support.

Given the strong dependence in rural areas on natural resources, the impacts of climate change on agriculture, forestry, and fishing, and thus on rural livelihoods and incomes, are *likely* to be especially serious. Secondary (manufacturing) industries in these areas, and the livelihoods and incomes that are based on them, will in turn be substantially affected. Infrastructure (e.g., roads, buildings, dams, and irrigation systems) will be affected by extreme events associated with climate change. These climate impacts may contribute to migration away from rural areas, though rural migration already exists in many different forms for many non-climate-related reasons. Some rural areas will also experience secondary impacts of climate policies—the ways in which governments and others try to reduce net greenhouse gas emissions such as encouraging the cultivation of biofuels or discouraging deforestation. These secondary impacts may be either positive (increasing employment opportunities) or negative (landscape changes, increasing conflicts for scarce resources).

Research on climate change impacts in rural North America has largely focused on the effects on agricultural production and on indigenous populations, many of whom rely directly on natural resources. Developed countries in Europe will be less affected than the developing world (Tol et al., 2004), with most of the climate sensitive sectors located in rural areas.

Market integration is seen as reducing the capacity of indigenous or smallholder systems for dealing with climate risk in Bolivia (Valdivia et al., 2010), Honduras (McSweeney and Coomes, 2011), Mexico (Eakin, 2005), Mozambique (Eriksen and Silva, 2009; Silva et al., 2010), and in the Sahel (Fraser et al., 2011) by variously accelerating socioeconomic stratification and reducing crop diversity. On the other hand, distance from large markets is seen as increasing vulnerability of rainfed mixed crop/livestock areas in sub- Saharan Africa (Jones and Thornton, 2009) and the Peruvian Altiplano (Sietz et al., 2011). Each case needs to be analyzed within its complexity, considering interactions among all the factors that can affect vulnerability (Rivera-Ferre et al., 2013a). Regarding the scale of farms, some authors suggest that small-scale farming increases the vulnerability of communities in rural areas (Gbetibouo et al., 2010b; Bellon et al., 2011) although their resilience (stemming from factors such as indigenous knowledge, family labor, livelihood diversification) should not be underestimated.

But while some authors emphasize the need for local responses and indigenous knowledge to reduce vulnerability (Valdivia et al., 2010), and call for an integration of local knowledge into climate policies (Nyong et al., 2007; Brugger and Crimmins, 2012), Bellon et al. (2011) state that local knowledge is too local, and in some contexts gathering information from further away is important.

There is now *high confidence* that public decision making for adaptation can be strengthened by understanding the decision making of rural people in context, and in particular considering examples of autonomous adaptation and the interplay between informal and formal institutions (Bryan et al., 2009; Eakin and Patt, 2011; Adhikari and Taylor, 2012; Naess, 2012). Adaptation can also build upon local and indigenous knowledge for responding to weather events and a changing climate as has been observed in Samoa (Lefale, 2010; see Chapter 29), the Solomon Islands (Rasmussen et al., 2009; see Chapter 29), Namibia (Newsham and Thomas, 2011), Canada (Nakashima et al., 2011; see Chapter 24), the Indo-Gangetic Plains (Rivera-Ferre et al., 2013b), and Australia (Green et al., 2010).

Box 9-4 | Factors Influencing Uptake and Utility of Climate Forecasts in Rural Africa

The IPCC *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX) identified the use of forecasts as a risk management measure (IPCC, 2012). So far the uptake of weather and climate information has been suboptimal (Vogel and O'Brien, 2006). In Africa annual climate information (e.g., seasonal forecasts) is more used than climate change scenarios for agricultural development (Ziervogel and Zermoglio, 2009), although attempts to use longer-term climate projections for crop forecasting and livestock farming have been examined (Boone et al., 2004; Challinor, 2009). The potential for improved prediction and effective timely dissemination of such information has been noted in different sectors, including water managers (Ziervogel et al., 2010a) and disaster planners (Tall et al., 2012), as well as farmers (both arable and pastoral) (Klopper et al., 2006; Archer et al., 2007; Bryan et al., 2009).

Extensive research has taken place to assess factors influencing uptake and utility of climate forecasts, including mapping of dissemination through stakeholder networks (Ziervogel and Downing, 2004), and user needs (Ziervogel, 2004). Such studies have shown that various factors affect dissemination and use, including stakeholder involvement in the process (usually higher when participatory processes had taken place) (Roncoli et al., 2009; Peterson et al., 2010); effects of user wealth, risk aversion, and presentational parameters, such as the position of forecast parameter categories, and the size of probability categories (Millner and Washington, 2011); and the legitimacy, salience, access, understanding, and capacity to respond (Hansen et al., 2011). Gender differences have been observed in preferred dissemination channels (Archer, 2003; Naab and Korenteng, 2012).

There are promising signs for the integration of scientific-based seasonal forecasts with indigenous knowledge systems (Speranza et al., 2010; Ziervogel et al., 2010b). Ensuring improved validity and utility of seasonal forecasts will require collaboration of researchers, data providers, policy developers, and extension workers (Coe and Stern, 2011), as well as with end users. Additional opportunities to benefit rural communities come from expanding the use of seasonal forecast information for coordinating input and credit supply, food crisis management, trade, and agricultural insurance (Hansen et al., 2011). For more information on climate information and services, and the history, politics, and practice of this area, see Section 2.4.1.

In many countries, race and ethnicity are powerful markers of health status and social disadvantage…Indigenous peoples who depend heavily on local resources, and live in parts of the world where the climate is changing quickly, are generally at greater risk of economic losses and poor health. Studies of the Inuit people, for example, show that rapid warming of the Canadian Arctic is jeopardizing hunting and many other day-to-day activities, with implications for livelihoods and well-being (Ford, 2009).

Frequently Asked Questions

FAQ 12.2 | Can lay knowledge of environmental risks help adaptation to climate change?

Lay knowledge about the environment and climate is deeply rooted in history, and encompasses important aspects of human life. Lay knowledge is particularly pertinent in cultures with an intimate relationship between people and the environment. For many indigenous and rural communities, for example, livelihood activities such as herding, hunting, fishing, or farming are directly connected to and dependent on climate and weather conditions. These communities thus have critical knowledge about dealing with environment changes and associated societal conditions. In regions around the world, such knowledge is commonly used in adapting to environmental conditions and is directly relevant to adaptation to climate change.

Various governments are presently engaged in planning to move settlements as part of adaptation strategies, either because of the assessment of new risks or to justify existing resettlement programs (de Sherbinin et al., 2011; Biermann, 2012). Scientific literature on these policies most often portrays resettlement as a failure of adaptation and a policy of last resort (Barnett and Webber, 2010; Fernando et al., 2010; Hugo, 2011). Most practice to date, learning from other resettlement programs, demonstrates negative social outcomes for those resettled, often analyzed as breaches in individual human rights (Bronen, 2011; Johnson, 2012; Arnall, 2013). There are some documented examples of settlements that are already planning for their own relocation, such as five indigenous communities in Alaska that have experienced increased erosion, loss of sea ice cover, and flooding over the past decades (Bronen, 2010). These settlements have undertaken planning for relocation and have received government funding for these processes. Bronen (2010) and Bronen and Chapin (2013) conclude that while the relocations are feasible, there are significant perceptions of cultural loss and related studies report psychological stress and community dislocation (Cunsolo- Wilcox et al., 2012, 2013). The studies argue that legitimacy and success depend on incorporating cultural and psychological factors in the planning processes (Bronen and Chapin, 2013). There is significant resistance to relocation, even where such options are well planned and have robust justifications, as demonstrated by Marino (2012) for relocation in Alaska.

- Climate change will exacerbate multidimensional poverty in most developing countries, including high mountain states, countries at risk from sea level rise, and countries with indigenous peoples. Climate change will also create new poverty pockets in countries with increasing inequality, in both developed and developing countries. {13.2.2}
- Mitigation efforts focused on land acquisition for biofuel production show preliminary negative impacts on the lives of poor people, such as dispossession of farmland and forests, in many developing countries, particularly for indigenous peoples and (women) smallholders. {13.3.1.4}

The AR4 identified poor and indigenous peoples in North America (Field et al., 2007) and in Africa (Boko et al., 2007) as highly vulnerable. Vulnerability, or the propensity or predisposition to be adversely affected (IPCC, 2012a) by climatic risks and other stressors (see also Glossary), emerges from the intersection of different inequalities, and uneven power structures, and hence is socially differentiated (Sen, 1999; Banik, 2009; IPCC, 2012a). Vulnerability is often high among indigenous peoples, women, children, the elderly, and disabled people who experience multiple deprivations that inhibit them from managing daily risks and shocks (Eriksen and O'Brien, 2007; Ayers and Huq, 2009; Boyd and Juhola, 2009; Barnett and O'Neill, 2010; O'Brien et al., 2010; Petheram et al., 2010) and may present significant barriers to adaptation.

Mountain environments (McDowell and Hess, 2012). Indigenous Aymara farmers in highland Bolivia face land scarcity, pervasive poverty, climate change, and lack of infrastructure due in part to racism and institutional marginalization. The retreat of the Mururata glacier causes water shortages 1 , compounded by the increased water requirements of cash crops on smaller and smaller "minifundios" and market uncertainties 2 . High temperatures amplify evaporation, and flash floods coupled with delayed rainfall cause irrigation canals to collapse 3 . The current policy environment makes it difficult to access loans and obtain land titles 4 , pushing many farmers onto downward livelihood trajectories 5 while those who can afford it invest in fruit and vegetable trees at higher altitudes 6 . Sustained access to land, technical assistance, and irrigation infrastructure would be effective policy responses to enhance well-being 7 .

Finally, weather events and climate also erode *social and cultural assets*. In some contexts, climatic and non-climatic stressors and changing trends disrupt informal social networks of the poorest, elderly, women, and women-headed households, preventing mobilization of labor and reciprocal gifts (Osbahr et al., 2008; Buechler, 2009) as well as formal social networks, including social assistance programs (Douglas et al., 2008). Indigenous peoples (see Chapter 12) witness their cultural points of reference disappearing (Ford, 2009; Bell et al., 2010; Green et al., 2010).

Diverse indigenous groups in Russia have changed their livelihoods as result of Soviet legacy and climate change; for example, many Viliui Sakha have abandoned cow- keeping due to youth out-migration, growing access to consumer goods, and seasonal changes in temperature, rainfall, and snow (Crate, 2013).

Inequality and disproportionate effects of climate-related impacts also occur along the axes of *indigeneity and race*. Disproportionate climate impacts are documented for Afro-Latinos and displaced indigenous groups in urban Latin America (Hardoy and Pandiella, 2009), and indigenous peoples in the Russian North (Crate, 2013) and the Andes (Andersen and Verner, 2009; Valdivia et al., 2010; McDowell and Hess, 2012; Sietz et al., 2012). See Chapter 12 for impacts on indigenous cultures. In the USA, low-income people of color are more affected by climate-related disasters (Sherman and Shapiro, 2005; Morello-Frosch et al., 2009; Lynn et al., 2011) as demonstrated in the case of low- income African American residents of New Orleans after Hurricane Katrina (Elliott and Pais, 2006).

Impacts on social and cultural assets have received little attention. Exceptions address losses of social identity and cultural connections with land and sea among indigenous populations threatened by sea level rise and potential relocation (Green et al., 2010) and conflicts between ethnic and/or religious groups (Adano et al., 2012; see also Chapter 12). Poor households with limited social networks will be worst off, including in places such as Nepal (Menon, 2009) and Indonesia (Skoufias et al., 2011a).

Toward the end of the century, the risk of heat stress may become acute in parts of Africa, particularly the Sahel, and the Indian sub-continent, potentially preventing people from practicing agriculture (Patricola and Cook, 2010; Dunne et al., 2013). In the glacier-dependent Himalayan region, excessive runoff and flooding will threaten livelihoods (Xu et al., 2009). Relocation would represent a critical threshold for indigenous groups, due to sea level rise for the Torres Strait Islanders between Australia and Papua New Guinea (Green et al., 2010) and permafrost degradation and higher and seasonally erratic precipitation for the Viliui Sakha in the Russian North (Crate, 2013).

Concerns include threats to the poor (Ghazoul et al., 2010; Phelps et al., 2010; Börner et al., 2011; Larson, 2011; McDermott et al., 2011; Van Dam, 2011; Mahanty et al., 2012; Neupane and Shrestha, 2012) and indigenous peoples (Shankland and Hasenclever, 2011).

The expansion of bioenergy, and biofuels in particular, increases the corporate power of international actors over governments and local actors with harmful effects on national food and agricultural policies (Dauvergne and Neville, 2009; Glenna and Cahoy, 2009; Hollander, 2010; Mol, 2010; Fortin, 2011; Jarosz, 2012), further marginalizing smallholders (Ariza-Montobbio et al., 2010; De Schutter, 2011; Neville and Dauvergne, 2012) and indigenous peoples (Montefrio, 2012; Obidzinski et al., 2012; Manik et al., 2013; Montefrio and Sonnenfeld, 2013). There is growing apprehension that increased competition for scarce land undermines women's access to land and their ability to benefit economically from biofuel investment (Arndt et al., 2011; Chu, 2011; Molony, 2011; Behrman et al., 2012; Julia and White, 2012; Perch et al., 2012). Concerns differ somewhat among regions, with the greatest risk for negative outcomes for smallholders in Africa (Daley and Englert, 2010; Borras et al., 2011b).

Improved information for adaptation can benefit from efforts to combine indigenous and scientific knowledge (Section 12.3).

However, providing information does not mean that users will be able to make effective use of it, and this information will often have to be tailored or translated to the individual context (Webb and Beh, 2013). Efficacy of scientific knowledge can be improved by calibration with indigenous knowledge (Section

20.4.2). There are also opportunities for technology transfer and innovation to be enhanced through information technologies (Section 20.4.3).

Table 14-1 | Categories and examples of adaptation options.

Category		Examples of options*
Structural/ physical	Engineered and built environment	Sea walls and coastal protection structures (5.5.2 and 24.4.3.5; Figure 5-5); flood levees and culverts (26.3.3); water storage and pump storage (Section 23.3.4); sewage works (3.5.2.3); improved drainage (24.4.5.5); beach nourishment (5.4.2.1); flood and cyclone shelters (11.7); building codes (Section 8.1.5); storm and waste water management (8.2.4.1); transport and road infrastructure adaptation (8.3.3.6); floating houses (8.3.3.4); adjusting power plants and electricity grids (10.2.2; Table 10-2)
	Technological	New crop and animal varieties (7.5.1.1.1, 7.5.1.1.3, 7.5.1.3; Box 9-3; Table 9-7); genetic techniques (27.3.4.2); traditional technologies and methods (7.5.2, 27.3.4.2, 28.2.6.1, and 29.6.2.1); efficient irrigation (10.3.6 and 22.4.5.7; Box 20-4); water saving technologies (24.4.1.5 and 26.3.3) including rainwater harvesting (8.3.3.4); conservation agriculture (9.4.3.1 and 22.4.5.7); food storage and preservation facilities (22.4.5.7); hazard mapping and monitoring technology (15.3.2.3 and 28.4.1); early warning systems (7.5.1.1, 8.1.4.2, 8.3.3.3, 11.7.3, 15.4.3.2, 18.6.4, 22.2.2.1, 22.3.5.3, and 22.4.5.2); building insulation (8.3.3.3); mechanical and passive cooling (8.3.3.3); renewable energy technologies (29.7.2); second-generation biofuels (27.3.6.2)
	Ecosystem-based[a]	Cross Chapter Box CC-EA, Ecological restoration (5.5.2, 5.5.7, 9.4.3.3, and 27.3.2.2; Box 15-1) including wetland and floodplain conservation and restoration; increasing biological diversity (26.4.3); afforestation and reforestation (Box 22-2); conservation and replanting mangrove forest (15.3.4 and 29.7.2); bushfire reduction and prescribed fire (Section 24.4.2.5; Box 26-2); green infrastructure (e.g., shade trees, green roofs) (8.2.4.5, 8.3.3, 11.7.4, and 23.7.4); controlling overfishing (28.2.5.1 and 30.6.1); fisheries co-management (9.4.3.4 and 27.3.3.1); assisted migration or managed translocation (4.4.2.4, 24.4.2.5, 24.4.3.5, and 25.6.2.3); ecological corridors (4.4.2.4); ex situ conservation and seed banks (4.4.2.5); community-based natural resource management (CBNRM) (22.4.5.6); adaptive land use management (Section 23.6.2)
	Services	Social safety nets and social protection (Box 13-2; 8.3, 17.5.1, and 22.4.5.2); food banks and distribution of food surplus (29.6.2.1); municipal services including water and sanitation (3.5.2.3 and 8.3.3.4); vaccination programs (11.7.1), essential public health services (11.7.2) including reproductive health services (11.9.2) and enhanced emergency medical services (8.3.3.8); international trade (9.3, 9.4, and 23.9.2)
Social	Educational	Awareness raising and integrating into education (11.7, 15.2, and 22.4.5.5); gender equity in education (Box 9-2); extension services (9.4.4); sharing local and traditional knowledge (12.3.4 and 28.4.1) including integrating into adaptation planning (29.6.2.1); participatory action research and social learning (22.4.5.3); community surveys (Section 8.4.2.2); knowledge-sharing and learning platforms (8.3.2.2, 8.4.2.4, 15.2.4.2, and 22.4.5.4); international conferences and research networks (8.4.2.5); communication through media (22.4.5.5)
	Informational	Hazard and vulnerability mapping (11.7.2, 8.4.1.5); early warning and response systems (15.4.2.3 and 22.4.5.2) including health early warning systems (11.7.3, 23.5.1, 24.4.6.5, and 26.6.3); systematic monitoring and remote sensing (15.4.2.1 and 28.6); climate services (2.3.3) including improved forecasts (27.3.4.2); downscaling climate scenarios (8.4.1.5); longitudinal data sets (26.6.2); integrating indigenous climate observations (22.4.5.4, 25.8.2.1, and 28.2.6.1); community-based adaptation plans (5.5.1.4 and 24.4.6.5) including community-driven slum upgrading (8.3.2.2) and participatory scenario development (22.4.4.5)
	Behavioral	Accommodation (5.5.2); household preparation and evacuation planning (23.7.3); retreat (5.5.2) and migration (29.6.2.4), which has its own implications for human health (11.7.4) and human security (12.4.2); soil and water conservation (23.6.2 and 27.3.4.2); livelihood diversification (7.5.1.1, 7.5.2, and 22.4.5.2); changing livestock and aquaculture practices (7.5.1.1); crop-switching (22.3.4.1); changing cropping practices, patterns, and planting dates (7.5.1.1.1, 23.4.1, 26.5.4, and 27.3.4.2; Table 24-2); silvicultural options (25.7.1.2); reliance on social networks (Section 29.6.2.2)
Institutional	Economic	Financial incentives including taxes and subsidies (Box 8-4; 8.4.3 and 17.5.6); insurance (8.4.2.3, 13.3.2.2, 15.2.4.6, 17.5.1, 26.7.4.3, and 29.6.2.2; Box 25-7) including index-based weather insurance schemes (9.4.2 and 22.4.5.2); catastrophe bonds (8.4.2.3 and 10.7.5.1); revolving funds (8.4.3.1); payments for ecosystem services (9.4.3.3 and 27.6.2; Table 27-7); water tariffs (8.3.3.4.1 and 17.5.3); savings groups (8.4.2.3 and 11.7.4; Box 9-4); microfinance (Box 8-3; 22.4.5.2); disaster contingency funds (22.4.5.2 and 26.7.4.3); cash transfers (Box 13-2)
	Laws and regulations	Land zoning laws (22.4.4.2 and 23.7.4); building standards (8.3.2.2, 10.7.5, and 22.4.5.7); easements (27.3.3.2); water regulations and agreements (26.3.4 and 27.3.1.2); laws to support disaster risk reduction (8.3.2.2); laws to encourage insurance purchasing (10.7.6.2); defining property rights and land tenure security (22.4.6 and 24.4.6.5); protected areas (4.4.2.2); marine protected areas (Box CC-CR Chapter 6; 23.6.5 and 27.3.3.2); fishing quotas (23.9.2); patent pools and technology transfer (15.4.3 and 17.5.5)
	Government policies and programs	National and regional adaptation plans (15.2 and 22.4.4.2; Box 23-3) including mainstreaming climate change; sub-national and local adaptation plans (15.2.1.3 and 22.4.4.4; Box 23-3); urban upgrading programs (8.3.2.2); municipal water management programs (8.3.3.4; Box 25-2); disaster planning and preparedness (11.7); city-level plans (8.3.3.3 and 27.3.5.2; Boxes 26-3 and 27-1), district-level plans (26.3.3), sector plans (26.5.4), which may include integrated water resource management (3.6.1 and 23.7.2), landscape and watershed management (4.4.2.3), integrated coastal zone management (2.4.3, 5.5.4.1, and 23.7.1), adaptive management (2.2.1.3 and 5.5.1.4; Box 5-2), ecosystem-based management (6.4.2.1), sustainable forest management (2.3.4), fisheries management (7.5.1.1.3 and 30.6.2.1), and community-based adaptation (5.5.4.1, 8.4, 15.2.2, 21.3.2, 22.4.4.5, 24.5.2, 29.6.2.2, and 29.6.2.3; Tables 5-4 and 8-4; FAQ 15.1)

Notes: These adaptation options should be considered overlapping rather than discrete, and are often pursued simultaneously as part of adaptation plans. Examples given can be relevant to more than one category.

[a] A number of these would fall under the term "green infrastructure" in some European Commission documents (European Commission, 2009).
*WGII AR5 sections containing representative sample of adaptation options.

Technology options for climate change adaptation include both "hard" and "soft" technologies, and not only new technologies but also indigenous and locally made appropriate technology (Glatzel et al., 2012). For example,

traditional construction methods have been identified across the Pacific as a means of adapting to tropical cyclones and floods, including building low aerodynamic houses and the use of traditional roofing material such as sago palm leaves to reduce the hazard of iron roofing being blown away in high winds (see Section 29.6.2.1). Centralized high-technology systems can increase efficiency under normal conditions, but also risk cascading malfunctions in emergencies (Section 15.4.3).

Linking indigenous and conventional climate observations can add value, for example, in western Kenya, where scientists have worked with local rainmakers to develop consensus forecasts (Section 22.4.5.4).

Indigenous communities are those populations that have cultural and historical ties to specific homelands. They are generally distinct from politically dominant populations (Battiste, 2008). Because of these characteristics, they are particularly vulnerable to climate change impacts. When assessing indigenous vulnerability and developing CCA strategies and resilience to climate change, the following issues need to be examined and addressed: the relationship of indigenous peoples to land, the degree of migration or displacement of indigenous communities (Miron, 2008), and their adaptive capacity. Vulnerability and challenges to adaptation for indigenous people are discussed broadly in Chapters 13, 27, and 28.

Finally, in the chapter on Polar Regions, Anisimov et al. (2007) noted that indigenous groups have developed resilience through sharing resources in kinship networks that link hunters with office workers, and even in the cash sector of the economy. However, they concluded that such responses may be constrained by social, cultural, economic, and political factors. For all of these regions, adaptation constraints are linked to governance systems and the quality of national institutions as well as limited scientific capacity and ongoing development challenges (e.g., poverty, literacy, and civil and political rights).

The unique and threatened systems with strongest detection and attribution evidence cover the Arctic, warm-water coral reefs, and mountains. In the Arctic, climate change has played a major role in observed impacts on glaciers, permafrost, the tundra, marine ecosystems, and livelihoods of indigenous peoples (at least *medium confidence*), reflecting large-scale changes across both natural and human systems and across the physical and ecological sub-regions. Evidence for the detection and attribution of shrinkage and recession of glaciers comes from all continents, while evidence for attribution of coral bleaching spans a similarly broad area of the tropical oceans (see Figure 18-5).

Indigenous people throughout the Arctic are impacted by these changes (Eira, 2012; Crate, 2013; see also Section 18.4.6). In summary, several indicators of the ongoing regime shift in the entire Arctic land-sea socio-ecological system can be interpreted as a warning sign for a large-scale singular event (Post et al., 2009; CAFF, 2010; Callaghan et al., 2010; AMAP, 2011; Duarte et al., 2012b; Figure 18-3; Tables 18-5, 18-7 to 18-9; Section 28.2).

1. *The Arctic*, where indigenous people (Crowley, 2011) are projected to be exposed to the disruption, and possible destruction of, their hunting and food sharing culture (see Chapter 28). Risk arises from a combination of sea ice loss and the concomitant local extinctions of the animals dependent on the ice (Johannessen and Miles, 2011). Thawing ground also disrupts land transportation, buildings, and infrastructure while exposure of coastal settlements to storms also increases due to loss of sea ice. Arctic ecosystems are broadly at risk (Kittel et al., 2011).

Table 19-4 | A selection of the hazards, key vulnerabilities, key risks, and emergent risks identified in various chapters in this report (Chapters 4, 6, 7, 8, 9, 11, 13, 19, 22, 23, 24, 25, 26, 27, 28, 29, and 30). Key risks are determined by hazards interacting with vulnerability and exposure of human systems and of ecosystems or species. The table underscores the complexity of risks determined by various climate-related hazards, non-climatic stressors, and multifaceted vulnerabilities. The examples show that underlying phenomena, such as poverty or insecure land tenure arrangements, unsustainable and rapid urbanization, other demographic changes, failure in governance and inadequate governmental attention to risk reduction, and tolerance limits of species and ecosystems that often provide important services to vulnerable communities, generate the context in which climatic change–related harm and loss can occur. The table illustrates that current global megatrends (e.g., urbanization and other demographic changes) in combination and in specific development contexts (e.g., in low-lying coastal zones) can generate new systemic risks in their interaction with climate hazards that exceed existing adaptation and risk management capacities, particularly in highly vulnerable regions, such as dense urban areas of low-lying deltas. Roman numerals correspond with key risks listed in Section 19.6.2.1. A representative set of lines of sight is provided from across WGI AR5 and WGII AR5. See Section 19.6.2.1 for a full description of the methods used to select these entries.

No.	Hazard	Key vulnerabilities	Key risks	Emergent risks
i	Sea level rise, coastal flooding including storm surges (WGI AR5 Sections 3.7 and 13.5; WGI AR5 Table 13.5; Sections 5.4.3, 8.1.4, 8.2.3, 8.2.4, 13.1.4, 13.2.2, 24.4, 24.5, 26.7, 26.8, 29.3.1, and 30.3.1; Boxes 25-1, 25-7)	High exposure of people, economic activity, and infrastructure in low-lying coastal zones, Small Island Developing States (SIDS), and other small islands Urban population unprotected due to substandard housing and inadequate insurance. Marginalized rural population with multidimensional poverty and limited alternative livelihoods Insufficient local governmental attention to disaster risk reduction	Death, injury, and disruption to livelihoods, food supplies, and drinking water Loss of common-pool resources, sense of place and identity, especially among indigenous populations in rural coastal zones	Interaction of rapid urbanization, sea level rise, increasing economic activity, disappearance of natural resources, and limits of insurance; burden of risk management shifted from the state to those at risk, leading to greater inequality

However, in developing countries, particularly in Africa, where traditional knowledge could potentially moderate this uncertainty, it is often not recognized as a reference point for managing climate risks and emerging threats. In Kenya, the importance of indigenous knowledge, given increased uncertainty and climate- related risks, has compelled national agencies such as the Kenyan Meteorological Agencies and vulnerable groups such as the indigenous communities commonly known as rainmakers to form strategic reciprocal links. By working closely together to calibrate their forecasts and test the efficacy of the results against climate change impacts on agricultural productivity, the two groups have been able to demonstrate the benefits of Western science and traditional knowledge systems to increase effectiveness (Ziervogel and Opere, 2010). In integrating different kinds of knowledge, participatory processes, which call for a deliberative form of decision making among stakeholders, are well suited to the governance culture necessary for effective adaptation and mitigation. However, findings in the literature regarding the effectiveness of participatory processes are mixed. For example, though some scholars have argued that deliberative democracy methods can bring diverse stakeholders and kinds of knowledge (e.g., lay, expert, and indigenous) together thus putting in place a more communicative model of science delivery (Benn et al., 2009), empirical research shows that stakeholder participation does not always lead to consensus (Rowe and Frewer, 2004; Bell et al., 2011; also see Salter et al., 2010).

Effective use of innovations depends on more than idea and/or technology development alone. Unless the innovations, the skills required to use them, and the institutional approaches appropriate to deploy them are effectively transferred from providers to users, effects of innovations—however promising—are minimized (IPCC, 2012). Challenges in putting science and technology to use for sustainable development have received considerable attention (e.g., Nelson and Winter, 1982; Patel and Pavit, 1995; National Research Council, 1999; International Council for Science, 2002; Kristjanson et al., 2009). These studies emphasize the wide range of contexts that shape both barriers and potentials and the importance of "co-production" of knowledge, integrating general scientific knowledge with other forms of knowledge (e.g., local, indigenous, practical knowledge, experience, and expertise). If obstacles related to intellectual property rights can be overcome, however, the growing power of the information technology revolution could accelerate the transfer of technologies and other innovations (linked with local knowledge) in ways that would be very promising for strengthening local resilience (Wilbanks and Wilbanks, 2010).

HERITAGE
RESEARCH