SPM

Summary for Policymakers

Drafting Authors:
Christopher B. Field (USA), Vicente R. Barros (Argentina), Michael D. Mastrandrea (USA), Katharine J. Mach (USA), Mohamed A.-K. Abdrabo (Egypt), W. Neil Adger (UK), Yury A. Anokhin (Russian Federation), Oleg A. Anisimov (Russian Federation), Douglas J. Arent (USA), Jonathon Barnett (Australia), Virginia R. Burkett (USA), Rongshuo Cai (China), Monalisa Chatterjee (USA/India), Stewart J. Cohen (Canada), Wolfgang Cramer (Germany/France), Purnamita Dasgupta (India), Debra J. Davidson (Canada), Fatima Denton (Gambia), Petra Döll (Germany), Kirstin Dow (USA), Yasuaki Hijioka (Japan), Ove Hoegh-Guldberg (Australia), Richard G. Jones (UK), Roger N. Jones (Australia), Roger L. Kitching (Australia), R. Sari Kovats (UK), Joan Nymand Larsen (Iceland), Erda Lin (China), David B. Lobell (USA), Iñigo J. Losada (Spain), Graciela O. Magrin (Argentina), José A. Marengo (Brazil), Anil Markandya (Spain), Bruce A. McCarl (USA), Roger F. McLean (Australia), Linda O. Mearns (USA), Guy F. Midgley (South Africa), Nobuo Mimura (Japan), John F. Morton (UK), Isabelle Niang (Senegal), Ian R. Noble (Australia), Leonard A. Nurse (Barbados), Karen L. O'Brien (Norway), Taikan Oki (Japan), Lennart Olsson (Sweden), Michael Oppenheimer (USA), Jonathan T. Overpeck (USA), Joy J. Pereira (Malaysia), Elvira S. Poloczanska (Australia), John R. Porter (Denmark), Hans-O. Pörtner (Germany), Michael J. Prather (USA), Roger S. Pulwarty (USA), Andy Reisinger (New Zealand), Aromar Revi (India), Patricia Romero-Lankao (Mexico), Oliver C. Ruppel (Namibia), David E. Satterthwaite (UK), Daniela N. Schmidt (UK), Josef Settele (Germany), Kirk R. Smith (USA), Dáithí A. Stone (Canada/South Africa/USA), Avelino G. Suarez (Cuba), Petra Tschakert (USA), Riccardo Valentini (Italy), Alicia Villamizar (Venezuela), Rachel Warren (UK), Thomas J. Wilbanks (USA), Poh Poh Wong (Singapore), Alistair Woodward (New Zealand), Gary W. Yohe (USA)

This Summary for Policymakers should be cited as:

IPCC, 2014: Summary for policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

Contents

ASSESSING AND MANAGING THE RISKS OF CLIMATE CHANGE

Human interference with the climate system is occurring,[1] and climate change poses risks for human and natural systems (Figure SPM.1). The assessment of impacts, adaptation, and vulnerability in the Working Group II contribution to the IPCC's Fifth Assessment Report (WGII AR5) evaluates how patterns of risks and potential benefits are shifting due to climate change. It considers how impacts and risks related to climate change can be reduced and managed through adaptation and mitigation. The report assesses needs, options, opportunities, constraints, resilience, limits, and other aspects associated with adaptation.

Climate change involves complex interactions and changing likelihoods of diverse impacts. A focus on risk, which is new in this report, supports decision making in the context of climate change and complements other elements of the report. People and societies may perceive or rank risks and potential benefits differently, given diverse values and goals.

Compared to past WGII reports, the WGII AR5 assesses a substantially larger knowledge base of relevant scientific, technical, and socioeconomic literature. Increased literature has facilitated comprehensive assessment across a broader set of topics and sectors, with expanded coverage of human systems, adaptation, and the ocean. See Background Box SPM.1.[2]

Section A of this summary characterizes observed impacts, vulnerability and exposure, and adaptive responses to date. Section B examines future risks and potential benefits. Section C considers principles for effective adaptation and the broader interactions among adaptation, mitigation,

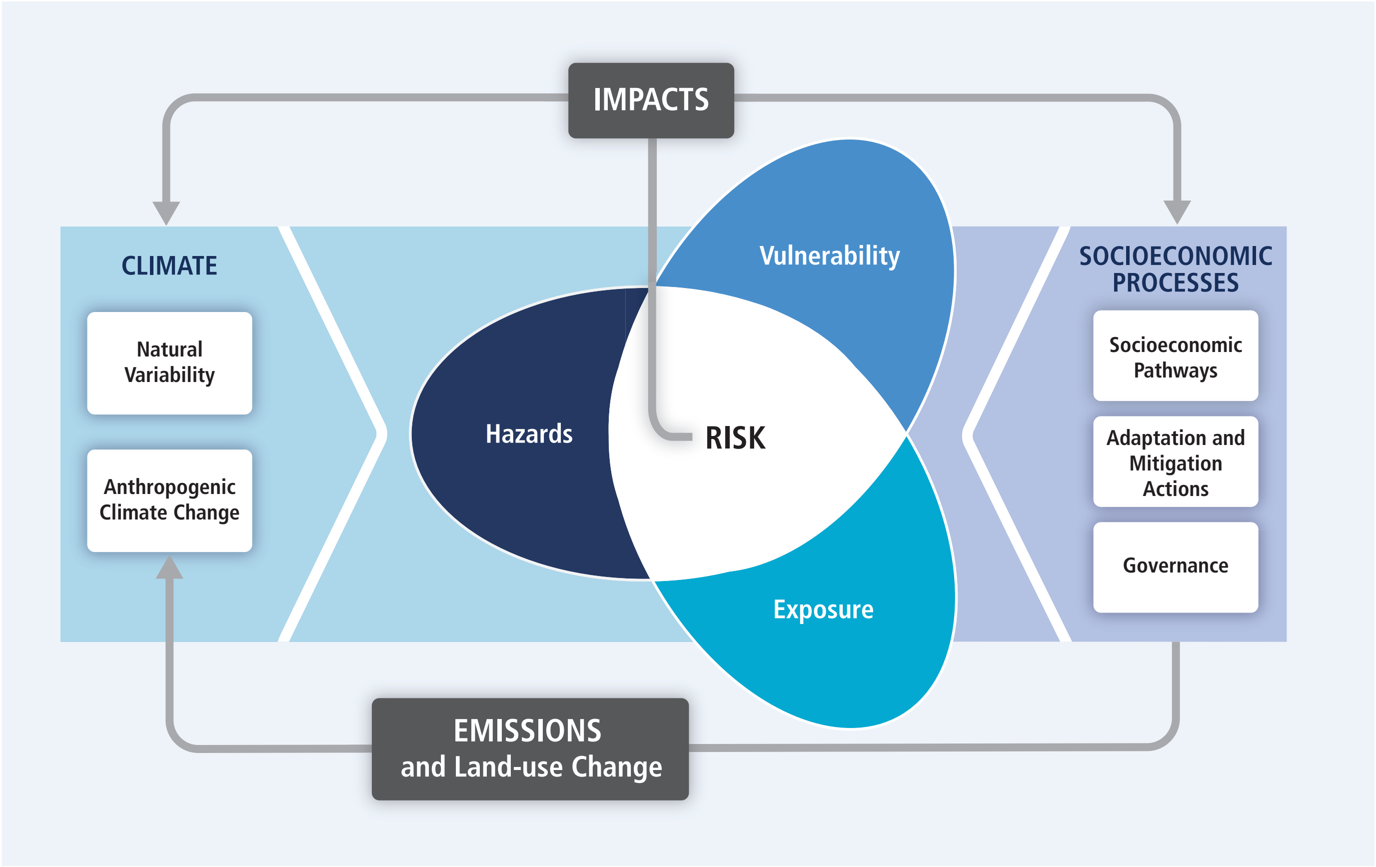


Figure SPM.1 | Illustration of the core concepts of the WGII AR5. Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability. [19.2, Figure 19-1]

---

[1] A key finding of the WGI AR5 is, "It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century." [WGI AR5 SPM Section D.3, 2.2, 6.3, 10.3-6, 10.9]

[2] 1.1, Figure 1-1

Background Box SPM.1 | Context for the Assessment

For the past 2 decades, IPCC's Working Group II has developed assessments of climate-change impacts, adaptation, and vulnerability. The WGII AR5 builds from the WGII contribution to the IPCC's Fourth Assessment Report (WGII AR4), published in 2007, and the *Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (SREX), published in 2012. It follows the Working Group I contribution to the AR5 (WGI AR5).[3]

The number of scientific publications available for assessing climate-change impacts, adaptation, and vulnerability more than doubled between 2005 and 2010, with especially rapid increases in publications related to adaptation. Authorship of climate-change publications from developing countries has increased, although it still represents a small fraction of the total.[4]

The WGII AR5 is presented in two parts (Part A: Global and Sectoral Aspects, and Part B: Regional Aspects), reflecting the expanded literature basis and multidisciplinary approach, increased focus on societal impacts and responses, and continued regionally comprehensive coverage.

and sustainable development. Background Box SPM.2 defines central concepts, and Background Box SPM.3 introduces terms used to convey the degree of certainty in key findings. Chapter references in brackets and in footnotes indicate support for findings, figures, and tables.

A: OBSERVED IMPACTS, VULNERABILITY, AND ADAPTATION IN A COMPLEX AND CHANGING WORLD

A-1. Observed Impacts, Vulnerability, and Exposure

In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. Evidence of climate-change impacts is strongest and most comprehensive for natural systems. Some impacts on human systems have also been attributed[5] to climate change, with a major or minor contribution of climate change distinguishable from other influences. See Figure SPM.2. Attribution of observed impacts in the WGII AR5 generally links responses of natural and human systems to observed climate change, regardless of its cause.[6]

In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality (*medium confidence*). Glaciers continue to shrink almost worldwide due to climate change (*high confidence*), affecting runoff and water resources downstream (*medium confidence*). Climate change is causing permafrost warming and thawing in high-latitude regions and in high-elevation regions (*high confidence*).[7]

Many terrestrial, freshwater, and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances, and species interactions in response to ongoing climate change (*high confidence*). See Figure SPM.2B. While only a few recent species extinctions have been attributed as yet to climate change (*high confidence*), natural global climate change at rates slower than current anthropogenic climate change caused significant ecosystem shifts and species extinctions during the past millions of years (*high confidence*).[8]

Based on many studies covering a wide range of regions and crops, negative impacts of climate change on crop yields have been more common than positive impacts (*high confidence*). The smaller number of studies showing positive impacts relate mainly to

---

[3] 1.2-3
[4] 1.1, Figure 1-1
[5] The term *attribution* is used differently in WGI and WGII. Attribution in WGII considers the links between impacts on natural and human systems and observed climate change, regardless of its cause. By comparison, attribution in WGI quantifies the links between observed climate change and human activity, as well as other external climate drivers.
[6] 18.1, 18.3-6
[7] 3.2, 4.3, 18.3, 18.5, 24.4, 26.2, 28.2, Tables 3-1 and 25-1, Figures 18-2 and 26-1
[8] 4.2-4, 5.3-4, 6.1, 6.3-4, 18.3, 18.5, 22.3, 24.4, 25.6, 28.2, 30.4-5, Boxes 4-2, 4-3, 25-3, CC-CR, and CC-MB

Background Box SPM.2 | Terms Central for Understanding the Summary[9]

Climate change: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term *hazard* usually refers to climate-related physical events or trends or their physical impacts.

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.

Impacts: 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.

Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard (see Figure SPM.1). In this report, the term *risk* is used primarily to refer to the risks of climate-change impacts.

Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Transformation: A change in the fundamental attributes of natural and human systems. Within this summary, transformation could reflect strengthened, altered, or aligned paradigms, goals, or values towards promoting adaptation for sustainable development, including poverty reduction.

Resilience: The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

high-latitude regions, though it is not yet clear whether the balance of impacts has been negative or positive in these regions (*high confidence*). Climate change has negatively affected wheat and maize yields for many regions and in the global aggregate (*medium confidence*). Effects on rice and soybean yield have been smaller in major production regions and globally, with a median change of zero across all available data, which are fewer for soy compared to the other crops. Observed impacts relate mainly to production aspects of food security rather than access

[9] The WGII AR5 glossary defines many terms used across chapters of the report. Reflecting progress in science, some definitions differ in breadth and focus from the definitions used in the AR4 and other IPCC reports.

SPM

Background Box SPM.3 | Communication of the Degree of Certainty in Assessment Findings[10]

The degree of certainty in each key finding of the assessment is based on the type, amount, quality, and consistency of evidence (e.g., data, mechanistic understanding, theory, models, expert judgment) and the degree of agreement. The summary terms to describe evidence are: *limited*, *medium*, or *robust*; and agreement: *low*, *medium*, or *high*.

Confidence in the validity of a finding synthesizes the evaluation of evidence and agreement. Levels of confidence include five qualifiers: *very low*, *low*, *medium*, *high*, and *very high*.

The likelihood, or probability, of some well-defined outcome having occurred or occurring in the future can be described quantitatively through the following terms: *virtually certain*, 99–100% probability; *extremely likely*, 95–100%; *very likely*, 90–100%; *likely*, 66–100%; *more likely than not*, >50–100%; *about as likely as not*, 33–66%; *unlikely*, 0–33%; *very unlikely*, 0–10%; *extremely unlikely*, 0–5%; and *exceptionally unlikely*, 0–1%. Unless otherwise indicated, findings assigned a likelihood term are associated with *high* or *very high confidence*. Where appropriate, findings are also formulated as statements of fact without using uncertainty qualifiers.

Within paragraphs of this summary, the confidence, evidence, and agreement terms given for a bold key finding apply to subsequent statements in the paragraph, unless additional terms are provided.

or other components of food security. See Figure SPM.2C. Since AR4, several periods of rapid food and cereal price increases following climate extremes in key producing regions indicate a sensitivity of current markets to climate extremes among other factors (*medium confidence*).[11]

At present the worldwide burden of human ill-health from climate change is relatively small compared with effects of other stressors and is not well quantified. However, there has been increased heat-related mortality and decreased cold-related mortality in some regions as a result of warming (*medium confidence*). Local changes in temperature and rainfall have altered the distribution of some water-borne illnesses and disease vectors (*medium confidence*).[12]

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]

Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability (*very high confidence*). Impacts of such climate-related extremes include alteration of ecosystems, disruption of food production and water supply, damage to infrastructure and settlements, morbidity and mortality, and consequences for mental health and human well-being. For countries at all levels of development, these impacts are consistent with a significant lack of preparedness for current climate variability in some sectors.[14]

Climate-related hazards exacerbate other stressors, often with negative outcomes for livelihoods, especially for people living in poverty (*high confidence*). Climate-related hazards affect poor people's lives directly through impacts on livelihoods, reductions in crop

[10] 1.1, Box 1-1
[11] 7.2, 18.4, 22.3, 26.5, Figures 7-2, 7-3, and 7-7
[12] 11.4-6, 18.4, 25.8
[13] 8.1-2, 9.3-4, 10.9, 11.1, 11.3-5, 12.2-5, 13.1-3, 14.1-3, 18.4, 19.6, 23.5, 25.8, 26.6, 26.8, 28.4, Box CC-GC
[14] 3.2, 4.2-3, 8.1, 9.3, 10.7, 11.3, 11.7, 13.2, 14.1, 18.6, 22.3, 25.6-8, 26.6-7, 30.5, Tables 18-3 and 23-1, Figure 26-2, Boxes 4-3, 4-4, 25-5, 25-6, 25-8, and CC-CR

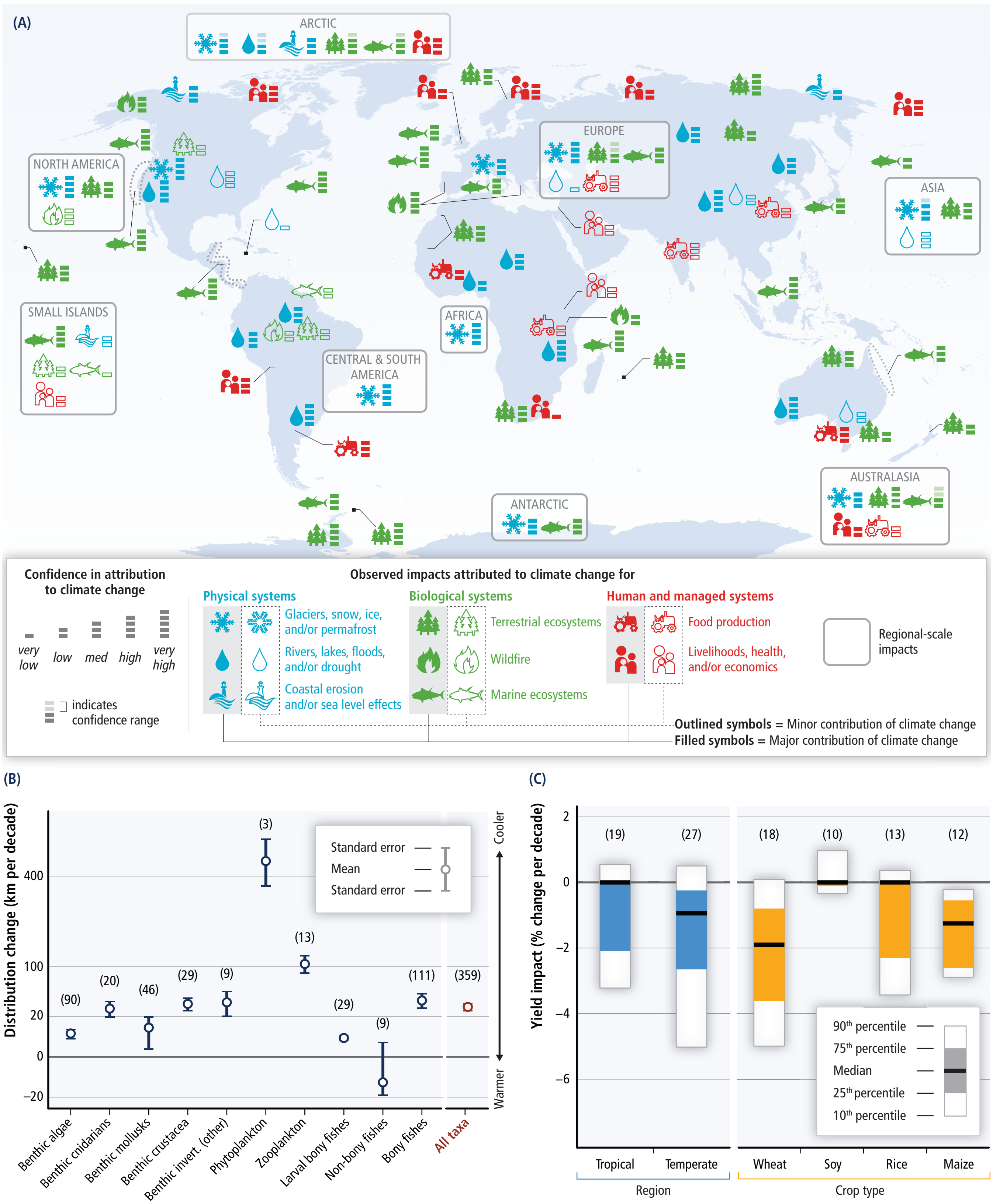


Figure SPM.2 | Widespread impacts in a changing world. (A) Global patterns of impacts in recent decades attributed to climate change, based on studies since the AR4. Impacts are shown at a range of geographic scales. Symbols indicate categories of attributed impacts, the relative contribution of climate change (major or minor) to the observed impact, and confidence in attribution. See supplementary Table SPM.A1 for descriptions of the impacts. (B) Average rates of change in distribution (km per decade) for marine taxonomic groups based on observations over 1900–2010. Positive distribution changes are consistent with warming (moving into previously cooler waters, generally poleward). The number of responses analyzed is given within parentheses for each category. (C) Summary of estimated impacts of observed climate changes on yields over 1960–2013 for four major crops in temperate and tropical regions, with the number of data points analyzed given within parentheses for each category. [Figures 7-2, 18-3, and MB-2] yields, or destruction of homes and indirectly through, for example, increased food prices and food insecurity. Observed positive effects for poor and marginalized people, which are limited and often indirect, include examples such as diversification of social networks and of agricultural practices.[15]

Violent conflict increases vulnerability to climate change (*medium evidence*, *high agreement*). Large-scale violent conflict harms assets that facilitate adaptation, including infrastructure, institutions, natural resources, social capital, and livelihood opportunities.[16]

A-2. Adaptation Experience

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.

Adaptation is becoming embedded in some planning processes, with more limited implementation of responses (*high confidence*). Engineered and technological options are commonly implemented adaptive responses, often integrated within existing programs such as disaster risk management and water management. There is increasing recognition of the value of social, institutional, and ecosystem-based measures and of the extent of constraints to adaptation. Adaptation options adopted to date continue to emphasize incremental adjustments and co-benefits and are starting to emphasize flexibility and learning (*medium evidence*, *medium agreement*). Most assessments of adaptation have been restricted to impacts, vulnerability, and adaptation planning, with very few assessing the processes of implementation or the effects of adaptation actions (*medium evidence*, *high agreement*).[17]

Adaptation experience is accumulating across regions in the public and private sector and within communities (*high confidence*). Governments at various levels are starting to develop adaptation plans and policies and to integrate climate-change considerations into broader development plans. Examples of adaptation across regions include the following:

- In Africa, most national governments are initiating governance systems for adaptation. Disaster risk management, adjustments in technologies and infrastructure, ecosystem-based approaches, basic public health measures, and livelihood diversification are reducing vulnerability, although efforts to date tend to be isolated.[18]
- In Europe, adaptation policy has been developed across all levels of government, with some adaptation planning integrated into coastal and water management, into environmental protection and land planning, and into disaster risk management.[19]
- In Asia, adaptation is being facilitated in some areas through mainstreaming climate adaptation action into subnational development planning, early warning systems, integrated water resources management, agroforestry, and coastal reforestation of mangroves.[20]
- In Australasia, planning for sea level rise, and in southern Australia for reduced water availability, is becoming adopted widely. Planning for sea level rise has evolved considerably over the past 2 decades and shows a diversity of approaches, although its implementation remains piecemeal.[21]
- In North America, governments are engaging in incremental adaptation assessment and planning, particularly at the municipal level. Some proactive adaptation is occurring to protect longer-term investments in energy and public infrastructure.[22]
- In Central and South America, ecosystem-based adaptation including protected areas, conservation agreements, and community management of natural areas is occurring. Resilient crop varieties, climate forecasts, and integrated water resources management are being adopted within the agricultural sector in some areas.[23]

---

[15] 8.2-3, 9.3, 11.3, 13.1-3, 22.3, 24.4, 26.8
[16] 12.5, 19.2, 19.6
[17] 4.4, 5.5, 6.4, 8.3, 9.4, 11.7, 14.1, 14.3-4, 15.2-5, 17.2-3, 21.3, 21.5, 22.4, 23.7, 25.4, 26.8-9, 30.6, Boxes 25-1, 25-2, 25-9, and CC-EA
[18] 22.4
[19] 23.7, Boxes 5-1 and 23-3
[20] 24.4-6, 24.9 Box CC-TC
[21] 25.4, 25.10, Table 25-2, Boxes 25-1, 25-2, and 25-9
[22] 26.7-9
[23] 27.3

SPM

- In the Arctic, some communities have begun to deploy adaptive co-management strategies and communications infrastructure, combining traditional and scientific knowledge.[24]
- In small islands, which have diverse physical and human attributes, community-based adaptation has been shown to generate larger benefits when delivered in conjunction with other development activities.[25]
- In the ocean, international cooperation and marine spatial planning are starting to facilitate adaptation to climate change, with constraints from challenges of spatial scale and governance issues.[26]

A-3. The Decision-making Context

Climate variability and extremes have long been important in many decision-making contexts. Climate-related risks are now evolving over time due to both climate change and development. This section builds from existing experience with decision making and risk management. It creates a foundation for understanding the report's assessment of future climate-related risks and potential responses.

Responding to climate-related risks involves decision making in a changing world, with continuing uncertainty about the severity and timing of climate-change impacts and with limits to the effectiveness of adaptation (*high confidence*). Iterative risk management is a useful framework for decision making in complex situations characterized by large potential consequences, persistent uncertainties, long timeframes, potential for learning, and multiple climatic and non-climatic influences changing over time. See Figure SPM.3. Assessment of the widest possible range of potential impacts, including low-probability outcomes with large consequences, is central to understanding the benefits and trade-offs of alternative risk management actions. The complexity of adaptation actions across scales and contexts means that monitoring and learning are important components of effective adaptation.[27]

Adaptation and mitigation choices in the near term will affect the risks of climate change throughout the 21st century (*high confidence*). Figure SPM.4 illustrates projected warming under a low-emission mitigation scenario and a high-emission scenario [Representative Concentration Pathways (RCPs) 2.6 and 8.5], along with observed temperature changes. The benefits of adaptation and mitigation occur over different but overlapping timeframes. Projected global temperature increase over the next few decades is similar across emission scenarios (Figure SPM.4B).[28] During this near-term period, risks will evolve as socioeconomic trends interact with the changing climate. Societal

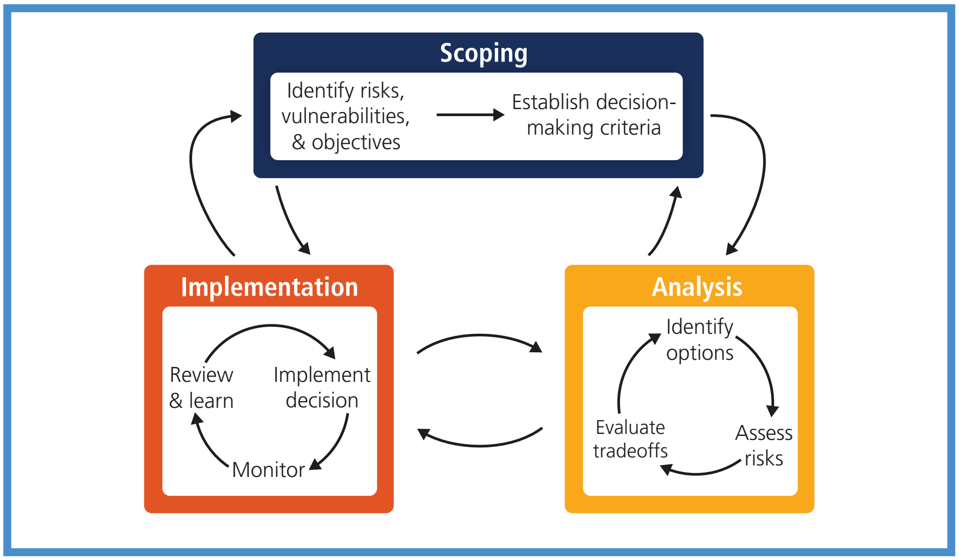


Figure SPM.3 | Climate-change adaptation as an iterative risk management process with multiple feedbacks. People and knowledge shape the process and its outcomes. [Figure 2-1]

[24] 28.2, 28.4
[25] 29.3, 29.6, Table 29-3, Figure 29-1
[26] 30.6
[27] 2.1-4, 3.6, 14.1-3, 15.2-4, 16.2-4, 17.1-3, 17.5, 20.6, 22.4, 25.4, Figure 1-5
[28] WGI AR5 11.3

SPM

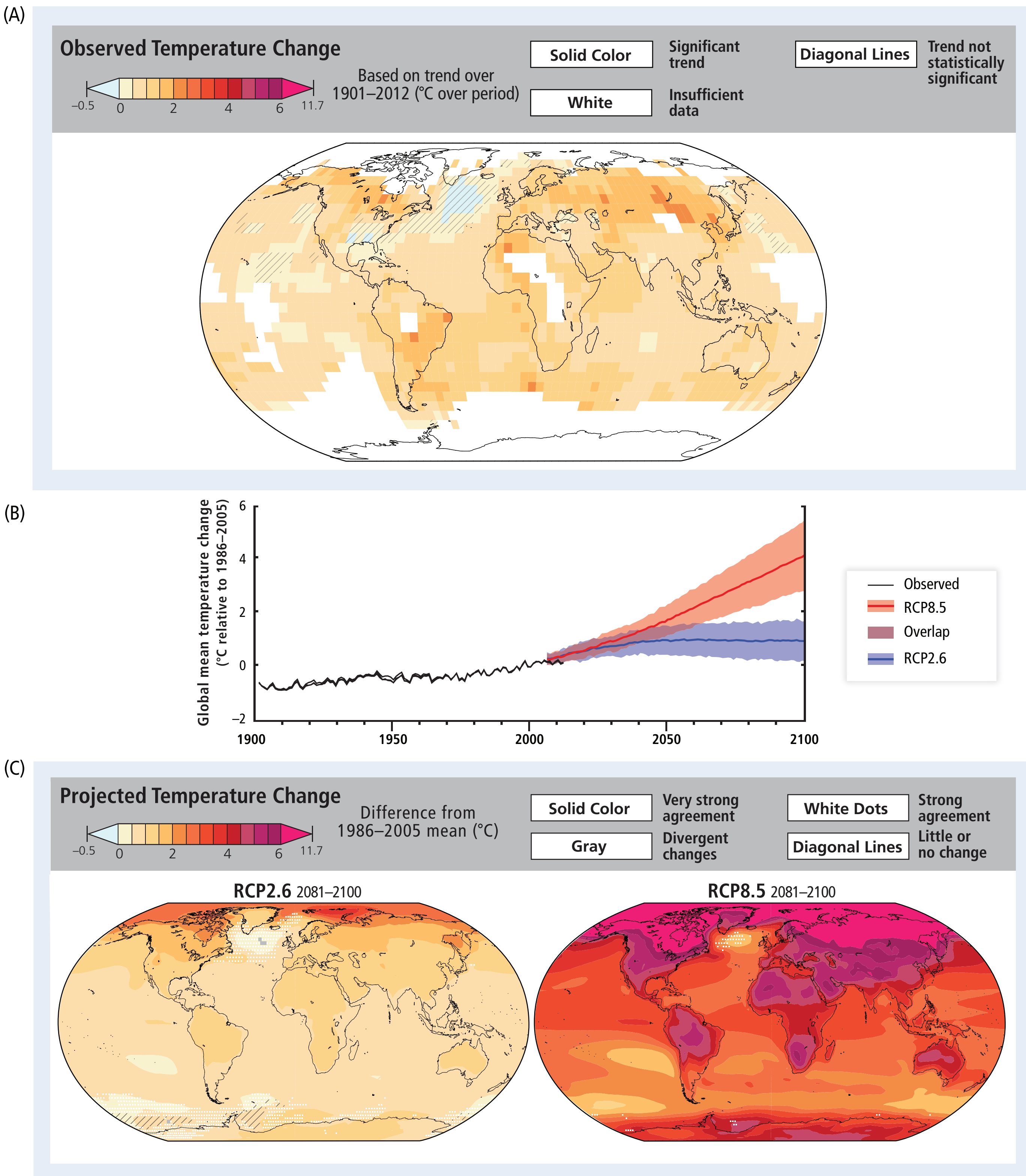


Figure SPM.4 | Observed and projected changes in annual average surface temperature. This figure informs understanding of climate-related risks in the WGII AR5. It illustrates temperature change observed to date and projected warming under continued high emissions and under ambitious mitigation.

Figure SPM.4 Technical Details

(A) Map of observed annual average temperature change from 1901–2012, derived from a linear trend where sufficient data permit a robust estimate; other areas are white. Solid colors indicate areas where trends are significant at the 10% level. Diagonal lines indicate areas where trends are not significant. Observed data (range of grid-point values: –0.53 to 2.50°C over period) are from WGI AR5 Figures SPM.1 and 2.21. (B) Observed and projected future global annual average temperature relative to 1986–2005. Observed warming from 1850–1900 to 1986–2005 is 0.61°C (5–95% confidence interval: 0.55 to 0.67°C). Black lines show temperature estimates from three datasets. Blue and red lines and shading denote the ensemble mean and ±1.64 standard deviation range, based on CMIP5 simulations from 32 models for RCP2.6 and 39 models for RCP8.5. (C) CMIP5 multi-model mean projections of annual average temperature changes for 2081–2100 under RCP2.6 and 8.5, relative to 1986–2005. Solid colors indicate areas with very strong agreement, where the multi-model mean change is greater than twice the baseline variability (natural internal variability in 20-yr means) and ≥90% of models agree on sign of change. Colors with white dots indicate areas with strong agreement, where ≥66% of models show change greater than the baseline variability and ≥66% of models agree on sign of change. Gray indicates areas with divergent changes, where ≥66% of models show change greater than the baseline variability, but <66% agree on sign of change. Colors with diagonal lines indicate areas with little or no change, where <66% of models show change greater than the baseline variability, although there may be significant change at shorter timescales such as seasons, months, or days. Analysis uses model data (range of grid-point values across RCP2.6 and 8.5: 0.06 to 11.71°C) from WGI AR5 Figure SPM.8, with full description of methods in Box CC-RC. See also Annex I of WGI AR5. [Boxes 21-2 and CC-RC; WGI AR5 2.4, Figures SPM.1, SPM.7, and 2.21]

responses, particularly adaptations, will influence near-term outcomes. In the second half of the 21st century and beyond, global temperature increase diverges across emission scenarios (Figure SPM.4B and 4C).[29] For this longer-term period, near-term and longer-term adaptation and mitigation, as well as development pathways, will determine the risks of climate change.[30]

Assessment of risks in the WGII AR5 relies on diverse forms of evidence. Expert judgment is used to integrate evidence into evaluations of risks. Forms of evidence include, for example, empirical observations, experimental results, process-based understanding, statistical approaches, and simulation and descriptive models. Future risks related to climate change vary substantially across plausible alternative development pathways, and the relative importance of development and climate change varies by sector, region, and time period (*high confidence*). Scenarios are useful tools for characterizing possible future socioeconomic pathways, climate change and its risks, and policy implications. Climate-model projections informing evaluations of risks in this report are generally based on the RCPs (Figure SPM.4), as well as the older IPCC *Special Report on Emission Scenarios* (SRES) scenarios.[31]

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.[32]

B: FUTURE RISKS AND OPPORTUNITIES FOR ADAPTATION

This section presents future risks and more limited potential benefits across sectors and regions, over the next few decades and in the second half of the 21st century and beyond. It examines how they are affected by the magnitude and rate of climate change and by socioeconomic choices. It also assesses opportunities for reducing impacts and managing risks through adaptation and mitigation.

B-1. Key Risks across Sectors and Regions

Key risks are potentially severe impacts relevant to Article 2 of the United Nations Framework Convention on Climate Change, which refers to "dangerous anthropogenic interference with the climate system." Risks are considered key due to high hazard or high vulnerability of societies and systems exposed, or both. Identification of key risks was based on expert judgment using the following specific criteria: large magnitude,

[29] WGI AR5 12.4 and Table SPM.2
[30] 2.5, 21.2-3, 21.5, Box CC-RC
[31] 1.1, 1.3, 2.2-3, 19.6, 20.2, 21.3, 21.5, 26.2, Box CC-RC; WGI AR5 Box SPM.1
[32] 11.3, 12.6, 21.3-5, 25.3-4, 25.11, 26.2

Assessment Box SPM.1 | Human Interference with the Climate System

Human influence on the climate system is clear.[33] Yet determining whether such influence constitutes "dangerous anthropogenic interference" in the words of Article 2 of the UNFCCC involves both risk assessment and value judgments. This report assesses risks across contexts and through time, providing a basis for judgments about the level of climate change at which risks become dangerous.

Five integrative reasons for concern (RFCs) provide a framework for summarizing key risks across sectors and regions. First identified in the IPCC Third Assessment Report, the RFCs illustrate the implications of warming and of adaptation limits for people, economies, and ecosystems. They provide one starting point for evaluating dangerous anthropogenic interference with the climate system. Risks for each RFC, updated based on assessment of the literature and expert judgments, are presented below and in Assessment Box SPM.1 Figure 1. All temperatures below are given as global average temperature change relative to 1986–2005 ("recent").[34]

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.

2) **Extreme weather events**: Climate-change-related risks from extreme events, such as heat waves, extreme precipitation, and coastal flooding, are already moderate (*high confidence*) and high with 1°C additional warming (*medium confidence*). Risks associated with some types of extreme events (e.g., extreme heat) increase further at higher temperatures (*high confidence*).

3) **Distribution of impacts**: Risks are unevenly distributed and are generally greater for disadvantaged people and communities in countries at all levels of development. Risks are already moderate because of regionally differentiated climate-change impacts on crop production in particular (*medium* to *high confidence*). Based on projected decreases in regional crop yields and water availability, risks of unevenly distributed impacts are high for additional warming above 2°C (*medium confidence*).

4) **Global aggregate impacts**: Risks of global aggregate impacts are moderate for additional warming between 1–2°C, reflecting impacts to both Earth's biodiversity and the overall global economy (*medium confidence*). Extensive biodiversity loss with associated loss of ecosystem goods and services results in high risks around 3°C additional warming (*high confidence*). Aggregate economic damages accelerate with increasing temperature (*limited evidence*, *high agreement*), but few quantitative estimates have been completed for additional warming around 3°C or above.

5) **Large-scale singular events**: With increasing warming, some physical systems or ecosystems may be at risk of abrupt and irreversible changes. Risks associated with such tipping points become moderate between 0–1°C additional warming, due to early warning signs that both warm-water coral reef and Arctic ecosystems are already experiencing irreversible regime shifts (*medium confidence*). Risks increase disproportionately as temperature increases between 1–2°C additional warming and become high above 3°C, due to the potential for a large and irreversible sea level rise from ice sheet loss. For sustained warming greater than some threshold,[35] near-complete loss of the Greenland ice sheet would occur over a millennium or more, contributing up to 7 m of global mean sea level rise.

high probability, or irreversibility of impacts; timing of impacts; persistent vulnerability or exposure contributing to risks; or limited potential to reduce risks through adaptation or mitigation. Key risks are integrated into five complementary and overarching reasons for concern (RFCs) in Assessment Box SPM.1.

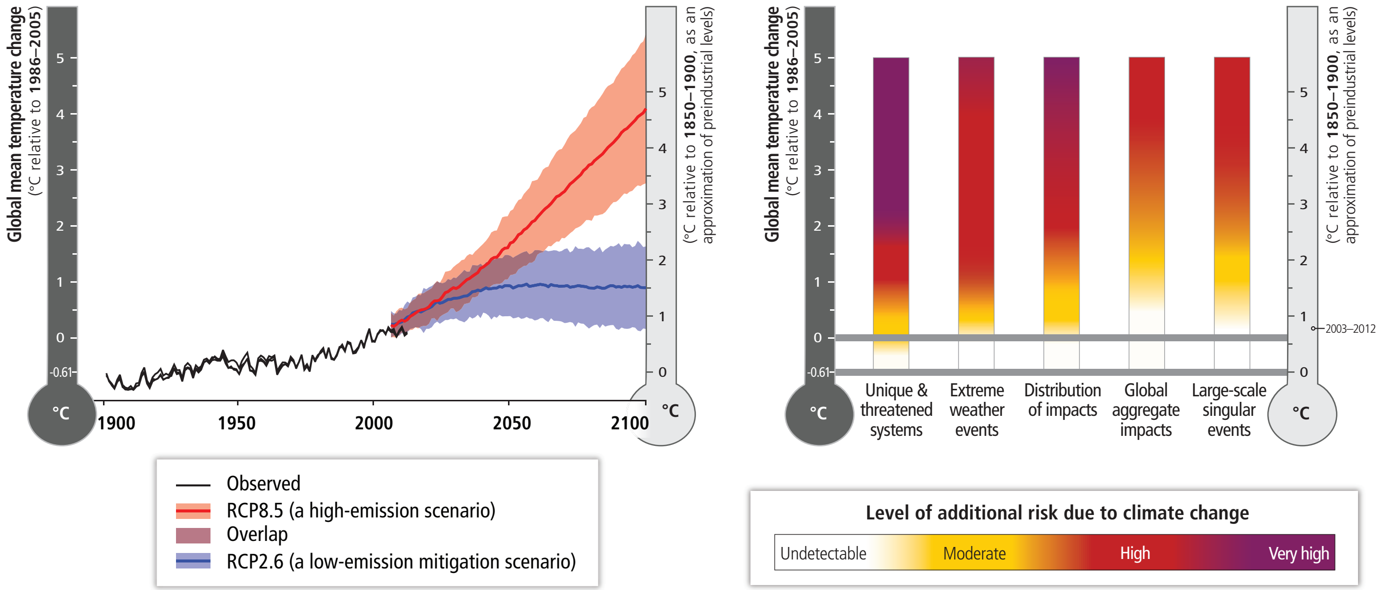
The key risks that follow, all of which are identified with *high confidence*, span sectors and regions. Each of these key risks contributes to one or more RFCs.[36]

[33] WGI AR5 SPM, 2.2, 6.3, 10.3-6, 10.9

[34] 18.6, 19.6; observed warming from 1850–1900 to 1986–2005 is 0.61°C (5–95% confidence interval: 0.55 to 0.67°C). [WGI AR5 2.4]

[35] Current estimates indicate that this threshold is greater than about 1°C (*low confidence*) but less than about 4°C (*medium confidence*) sustained global mean warming above preindustrial levels. [WGI AR5 SPM, 5.8, 13.4-5]

[36] 19.2-4, 19.6, Table 19-4, Boxes 19-2 and CC-KR



Assessment Box SPM.1 Figure 1 | A global perspective on climate-related risks. Risks associated with reasons for concern are shown at right for increasing levels of climate change. The color shading indicates the additional risk due to climate change when a temperature level is reached and then sustained or exceeded. Undetectable risk (white) indicates no associated impacts are detectable and attributable to climate change. Moderate risk (yellow) indicates that associated impacts are both detectable and attributable to climate change with at least *medium confidence*, also accounting for the other specific criteria for key risks. High risk (red) indicates severe and widespread impacts, also accounting for the other specific criteria for key risks. Purple, introduced in this assessment, shows that very high risk is indicated by all specific criteria for key risks. [Figure 19-4] For reference, past and projected global annual average surface temperature is shown at left, as in Figure SPM.4. [Figure RC-1, Box CC-RC; WGI AR5 Figures SPM.1 and SPM.7] Based on the longest global surface temperature dataset available, the observed change between the average of the period 1850–1900 and of the AR5 reference period (1986–2005) is 0.61°C (5–95% confidence interval: 0.55 to 0.67°C) [WGI AR5 SPM, 2.4], which is used here as an approximation of the change in global mean surface temperature since preindustrial times, referred to as the period before 1750. [WGI and WGII AR5 glossaries]

i) Risk of death, injury, ill-health, or disrupted livelihoods in low-lying coastal zones and small island developing states and other small islands, due to storm surges, coastal flooding, and sea level rise.[37] [RFC 1-5]

ii) Risk of severe ill-health and disrupted livelihoods for large urban populations due to inland flooding in some regions.[38] [RFC 2 and 3]

iii) Systemic risks due to extreme weather events leading to breakdown of infrastructure networks and critical services such as electricity, water supply, and health and emergency services.[39] [RFC 2-4]

iv) Risk of mortality and morbidity during periods of extreme heat, particularly for vulnerable urban populations and those working outdoors in urban or rural areas.[40] [RFC 2 and 3]

v) Risk of food insecurity and the breakdown of food systems linked to warming, drought, flooding, and precipitation variability and extremes, particularly for poorer populations in urban and rural settings.[41] [RFC 2-4]

vi) Risk of loss of rural livelihoods and income due to insufficient access to drinking and irrigation water and reduced agricultural productivity, particularly for farmers and pastoralists with minimal capital in semi-arid regions.[42] [RFC 2 and 3]

vii) Risk of loss of marine and coastal ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide for coastal livelihoods, especially for fishing communities in the tropics and the Arctic.[43] [RFC 1, 2, and 4]

viii) Risk of loss of terrestrial and inland water ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide for livelihoods.[44] [RFC 1, 3, and 4]

Many key risks constitute particular challenges for the least developed countries and vulnerable communities, given their limited ability to cope.

---

[37] 5.4, 8.2, 13.2, 19.2-4, 19.6-7, 24.4-5, 26.7-8, 29.3, 30.3, Tables 19-4 and 26-1, Figure 26-2, Boxes 25-1, 25-7, and CC-KR
[38] 3.4-5, 8.2, 13.2, 19.6, 25.10, 26.3, 26.8, 27.3, Tables 19-4 and 26-1, Boxes 25-8 and CC-KR
[39] 5.4, 8.1-2, 9.3, 10.2-3, 12.6, 19.6, 23.9, 25.10, 26.7-8, 28.3, Table 19-4, Boxes CC-KR and CC-HS
[40] 8.1-2, 11.3-4, 11.6, 13.2, 19.3, 19.6, 23.5, 24.4, 25.8, 26.6, 26.8, Tables 19-4 and 26-1, Boxes CC-KR and CC-HS
[41] 3.5, 7.4-5, 8.2-3, 9.3, 11.3, 11.6, 13.2, 19.3-4, 19.6, 22.3, 24.4, 25.5, 25.7, 26.5, 26.8, 27.3, 28.2, 28.4, Table 19-4, Box CC-KR
[42] 3.4-5, 9.3, 12.2, 13.2, 19.3, 19.6, 24.4, 25.7, 26.8, Table 19-4, Boxes 25-5 and CC-KR
[43] 5.4, 6.3, 7.4, 9.3, 19.5-6, 22.3, 25.6, 27.3, 28.2-3, 29.3, 30.5-7, Table 19-4, Boxes CC-OA, CC-CR, CC-KR, and CC-HS
[44] 4.3, 9.3, 19.3-6, 22.3, 25.6, 27.3, 28.2-3, Table 19-4, Boxes CC-KR and CC-WE

SPM

Increasing magnitudes of warming increase the likelihood of severe, pervasive, and irreversible impacts. Some risks of climate change are considerable at 1 or 2°C above preindustrial levels (as shown in Assessment Box SPM.1). Global climate change risks are high to very high with global mean temperature increase of 4°C or more above preindustrial levels in all reasons for concern (Assessment Box SPM.1), and include severe and widespread impacts on unique and threatened systems, substantial species extinction, large risks to global and regional food security, and the combination of high temperature and humidity compromising normal human activities, including growing food or working outdoors in some areas for parts of the year (*high confidence*). The precise levels of climate change sufficient to trigger tipping points (thresholds for abrupt and irreversible change) remain uncertain, but the risk associated with crossing multiple tipping points in the earth system or in interlinked human and natural systems increases with rising temperature (*medium confidence*).[45]

The overall risks of climate change impacts can be reduced by limiting the rate and magnitude of climate change. Risks are reduced substantially under the assessed scenario with the lowest temperature projections (RCP2.6 – low emissions) compared to the highest temperature projections (RCP8.5 – high emissions), particularly in the second half of the 21st century (*very high confidence*). Reducing climate change can also reduce the scale of adaptation that might be required. Under all assessed scenarios for adaptation and mitigation, some risk from adverse impacts remains (*very high confidence*).[46]

B-2. Sectoral Risks and Potential for Adaptation

Climate change is projected to amplify existing climate-related risks and create new risks for natural and human systems. Some of these risks will be limited to a particular sector or region, and others will have cascading effects. To a lesser extent, climate change is also projected to have some potential benefits.

Freshwater resources

Freshwater-related risks of climate change increase significantly with increasing greenhouse gas concentrations (*robust evidence*, *high agreement*). The fraction of global population experiencing water scarcity and the fraction affected by major river floods increase with the level of warming in the 21st century.[47]

Climate change over the 21st century is projected to reduce renewable surface water and groundwater resources significantly in most dry subtropical regions (*robust evidence*, *high agreement*), intensifying competition for water among sectors (*limited evidence*, *medium agreement*). In presently dry regions, drought frequency will *likely* increase by the end of the 21st century under RCP8.5 (*medium confidence*). In contrast, water resources are projected to increase at high latitudes (*robust evidence*, *high agreement*). Climate change is projected to reduce raw water quality and pose risks to drinking water quality even with conventional treatment, due to interacting factors: increased temperature; increased sediment, nutrient, and pollutant loadings from heavy rainfall; increased concentration of pollutants during droughts; and disruption of treatment facilities during floods (*medium evidence*, *high agreement*). Adaptive water management techniques, including scenario planning, learning-based approaches, and flexible and low-regret solutions, can help create resilience to uncertain hydrological changes and impacts due to climate change (*limited evidence*, *high agreement*).[48]

Terrestrial and freshwater ecosystems

A large fraction of both terrestrial and freshwater species faces increased extinction risk under projected climate change during and beyond the 21st century, especially as climate change interacts with other stressors, such as habitat modification, over-

[45] 4.2-3, 11.8, 19.5, 19.7, 26.5, Box CC-HS

[46] 3.4-5, 16.6, 17.2, 19.7, 20.3, 25.10, Tables 3-2, 8-3, and 8-6, Boxes 16-3 and 25-1

[47] 3.4-5, 26.3, Table 3-2, Box 25-8

exploitation, pollution, and invasive species (*high confidence*). Extinction risk is increased under all RCP scenarios, with risk increasing with both magnitude and rate of climate change. Many species will be unable to track suitable climates under mid- and high-range rates of climate change (i.e., RCP4.5, 6.0, and 8.5) during the 21st century (*medium confidence*). Lower rates of change (i.e., RCP2.6) will pose fewer problems. See Figure SPM.5. Some species will adapt to new climates. Those that cannot adapt sufficiently fast will decrease in abundance or go extinct in part or all of their ranges. Management actions, such as maintenance of genetic diversity, assisted species migration and dispersal, manipulation of disturbance regimes (e.g., fires, floods), and reduction of other stressors, can reduce, but not eliminate, risks of impacts to terrestrial and freshwater ecosystems due to climate change, as well as increase the inherent capacity of ecosystems and their species to adapt to a changing climate (*high confidence*).[49]

Within this century, magnitudes and rates of climate change associated with medium- to high-emission scenarios (RCP4.5, 6.0, and 8.5) pose high risk of abrupt and irreversible regional-scale change in the composition, structure, and function of terrestrial and freshwater ecosystems, including wetlands (*medium confidence*). Examples that could lead to substantial impact on climate are the boreal-tundra Arctic system (*medium confidence*) and the Amazon forest (*low confidence*). Carbon stored in the terrestrial biosphere (e.g., in peatlands, permafrost, and forests) is susceptible to loss to the atmosphere as a result of climate change, deforestation, and ecosystem degradation (*high confidence*). Increased tree mortality and associated forest dieback is projected to occur in many regions over the 21st century, due to increased temperatures and drought (*medium confidence*). Forest dieback poses risks for carbon storage, biodiversity, wood production, water quality, amenity, and economic activity.[50]

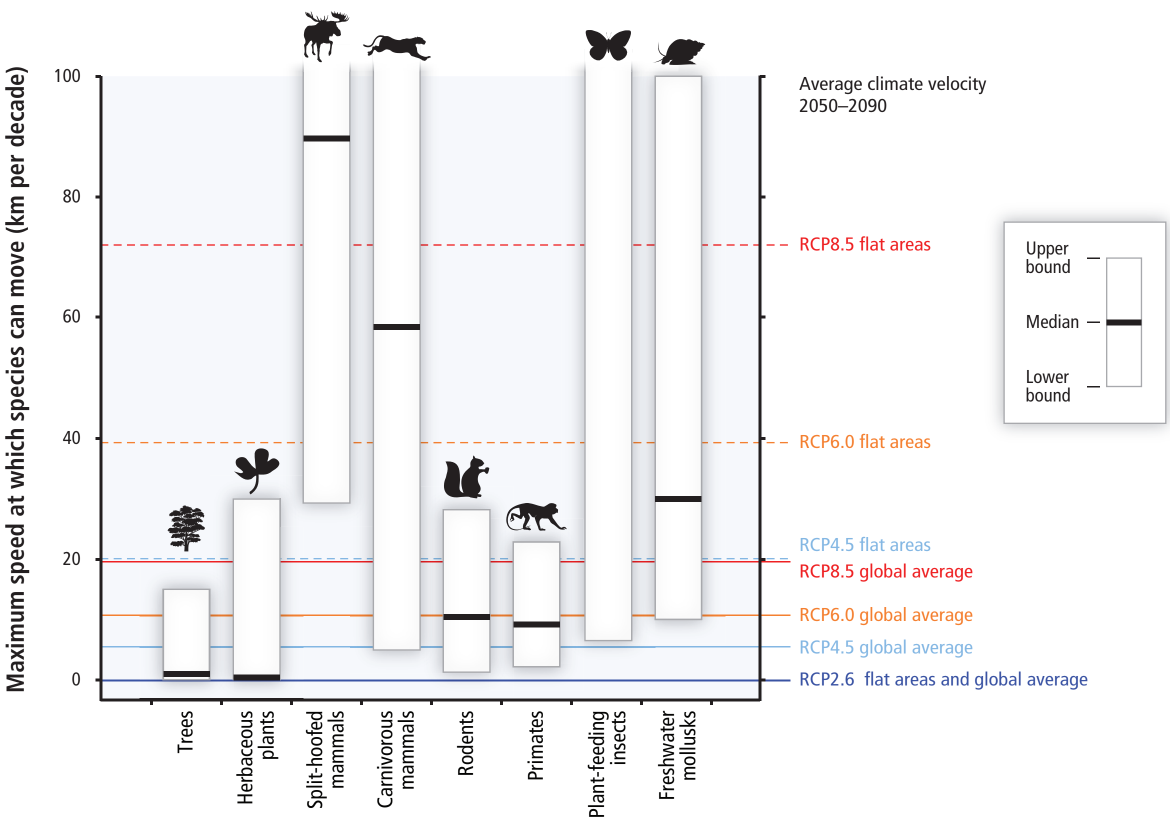


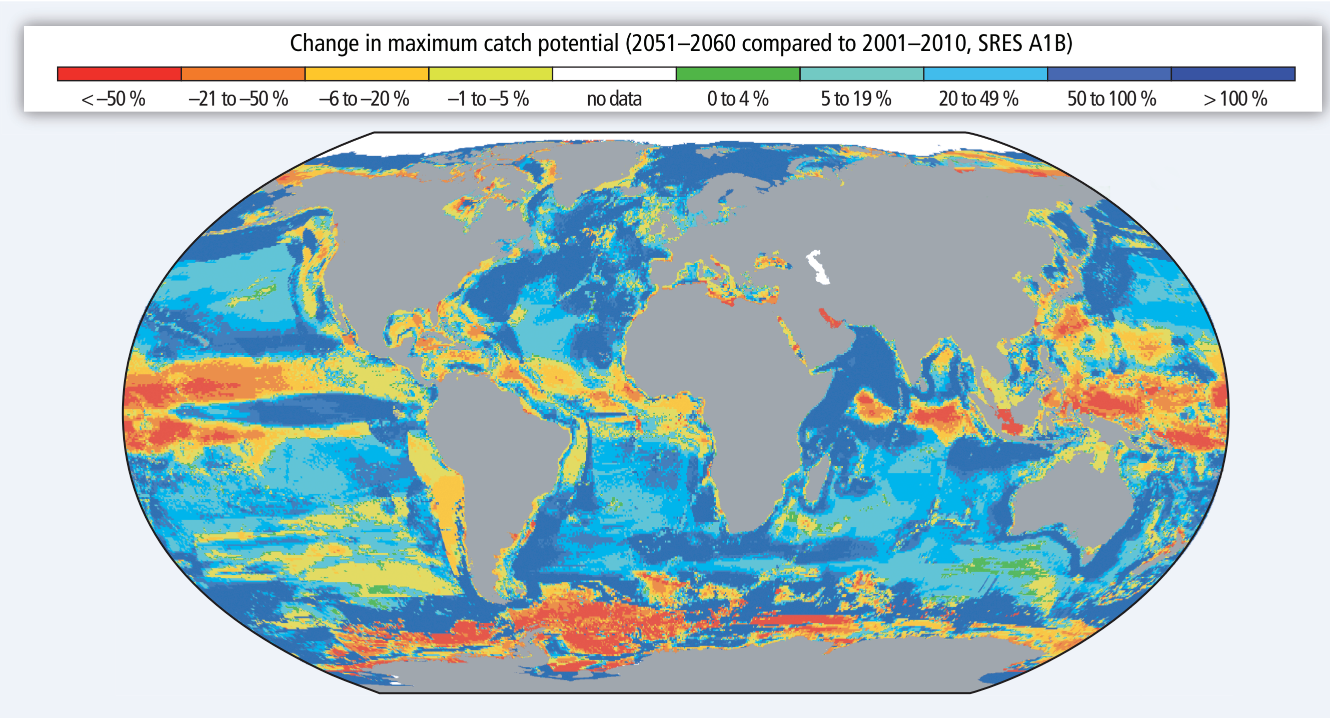
Figure SPM.5 | Maximum speeds at which species can move across landscapes (based on observations and models; vertical axis on left), compared with speeds at which temperatures are projected to move across landscapes (climate velocities for temperature; vertical axis on right). Human interventions, such as transport or habitat fragmentation, can greatly increase or decrease speeds of movement. White boxes with black bars indicate ranges and medians of maximum movement speeds for trees, plants, mammals, plant-feeding insects (median not estimated), and freshwater mollusks. For RCP2.6, 4.5, 6.0, and 8.5 for 2050–2090, horizontal lines show climate velocity for the global-land-area average and for large flat regions. Species with maximum speeds below each line are expected to be unable to track warming in the absence of human intervention. [Figure 4-5]

[48] 3.2, 3.4-6, 22.3, 23.9, 25.5, 26.3, Table 3-2, Table 23-3, Boxes 25-2, CC-RF, and CC-WE; WGI AR5 12.4

[49] 4.3-4, 25.6, 26.4, Box CC-RF

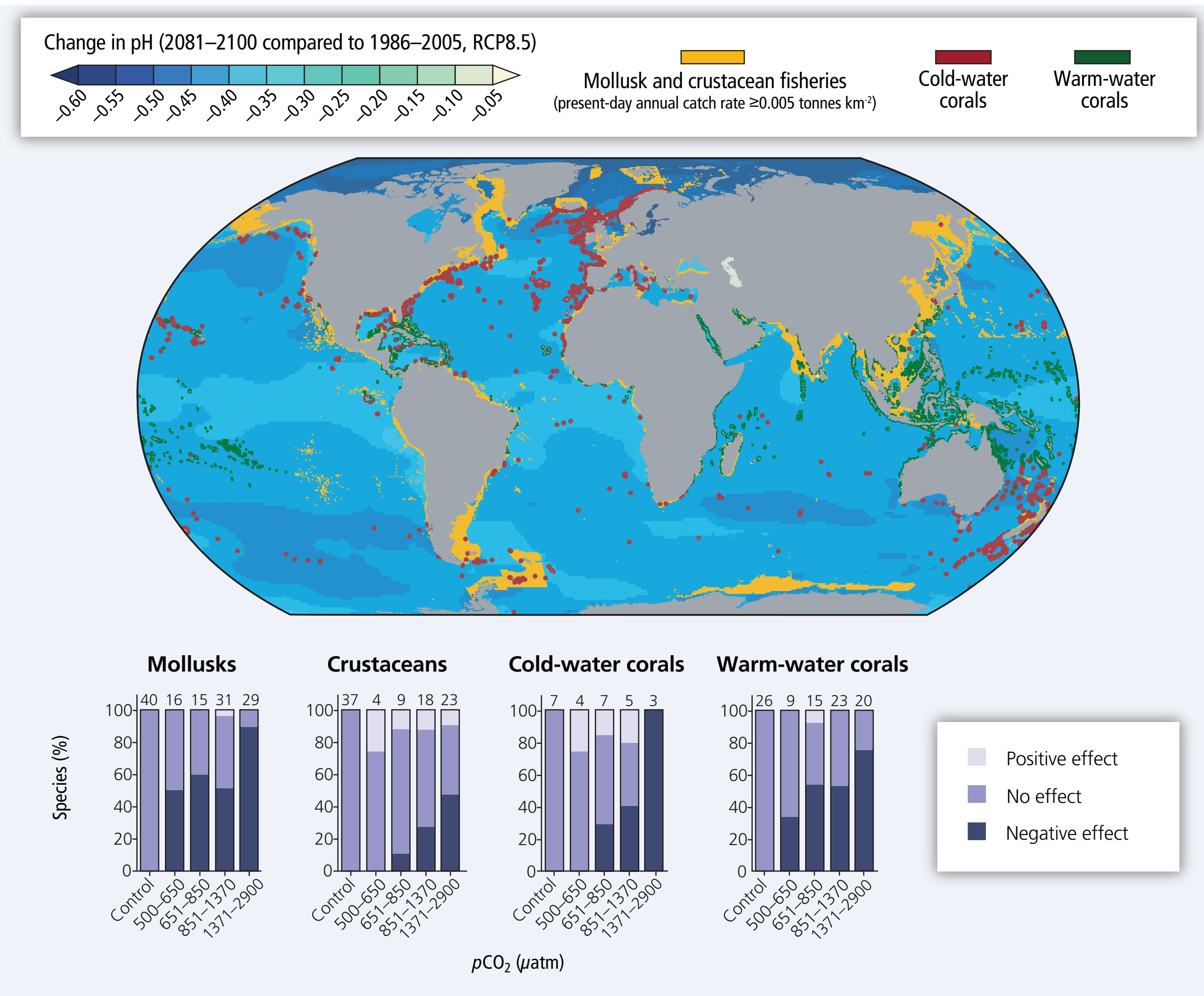
[50] 4.2-3, Figure 4-8, Boxes 4-2, 4-3, and 4-4

(A)



Change in maximum catch potential (2051–2060 compared to 2001–2010, SRES A1B)
< –50 %
–21 to –50 %
–6 to –20 %
–1 to –5 %
no data
0 to 4 %
5 to 19 %
20 to 49 %
50 to 100 %
> 100 %

(B)



Change in pH (2081–2100 compared to 1986–2005, RCP8.5)
–0.60
–0.55
–0.50
–0.45
–0.40
–0.35
–0.30
–0.25
–0.20
–0.15
–0.10
–0.05
Mollusk and crustacean fisheries
(present-day annual catch rate ≥0.005 tonnes km-2)
Cold-water corals
Warm-water corals
Mollusks
Crustaceans
Cold-water corals
Warm-water corals
Species (%)
40 16 15 31 29
37 4 9 18 23
7 4 7 5 3
26 9 15 23 20
0
20
40
60
80
100
Control
500–650
651–850
851–1370
1371–2900
pCO2 (µatm)
Positive effect
No effect
Negative effect

Figure SPM.6 | Climate change risks for fisheries. (A) Projected global redistribution of maximum catch potential of ~1000 exploited fish and invertebrate species. Projections compare the 10-year averages 2001–2010 and 2051–2060 using SRES A1B, without analysis of potential impacts of overfishing or ocean acidification. (B) Marine mollusk and crustacean fisheries (present-day estimated annual catch rates ≥0.005 tonnes km^{-2}) and known locations of cold- and warm-water corals, depicted on a global map showing the projected distribution of ocean acidification under RCP8.5 (pH change from 1986–2005 to 2081–2100). [WGI AR5 Figure SPM.8] The bottom panel compares sensitivity to ocean acidification across mollusks, crustaceans, and corals, vulnerable animal phyla with socioeconomic relevance (e.g., for coastal protection and fisheries). The number of species analyzed across studies is given for each category of elevated CO_2. For 2100, RCP scenarios falling within each CO_2 partial pressure (pCO_2) category are as follows: RCP4.5 for 500–650 μatm (approximately equivalent to ppm in the atmosphere), RCP6.0 for 651–850 μatm, and RCP8.5 for 851–1370 μatm. By 2150, RCP8.5 falls within the 1371–2900 μatm category. The control category corresponds to 380 μatm. [6.1, 6.3, 30.5, Figures 6-10 and 6-14; WGI AR5 Box SPM.1]

Coastal systems and low-lying areas

Due to sea level rise projected throughout the 21st century and beyond, coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding, and coastal erosion (*very high confidence*). The population and assets projected to be exposed to coastal risks as well as human pressures on coastal ecosystems will increase significantly in the coming decades due to population growth, economic development, and urbanization (*high confidence*). The relative costs of coastal adaptation vary strongly among and within regions and countries for the 21st century. Some low-lying developing countries and small island states are expected to face very high impacts that, in some cases, could have associated damage and adaptation costs of several percentage points of GDP.[51]

Marine systems

Due to projected climate change by the mid 21st century and beyond, global marine-species redistribution and marine-biodiversity reduction in sensitive regions will challenge the sustained provision of fisheries productivity and other ecosystem services (*high confidence*). Spatial shifts of marine species due to projected warming will cause high-latitude invasions and high local-extinction rates in the tropics and semi-enclosed seas (*medium confidence*). Species richness and fisheries catch potential are projected to increase, on average, at mid and high latitudes (*high confidence*) and decrease at tropical latitudes (*medium confidence*). See Figure SPM.6A. The progressive expansion of oxygen minimum zones and anoxic "dead zones" is projected to further constrain fish habitat. Open-ocean net primary production is projected to redistribute and, by 2100, fall globally under all RCP scenarios. Climate change adds to the threats of over-fishing and other non-climatic stressors, thus complicating marine management regimes (*high confidence*).[52]

For medium- to high-emission scenarios (RCP4.5, 6.0, and 8.5), ocean acidification poses substantial risks to marine ecosystems, especially polar ecosystems and coral reefs, associated with impacts on the physiology, behavior, and population dynamics of individual species from phytoplankton to animals (*medium* to *high confidence*). Highly calcified mollusks, echinoderms, and reef-building corals are more sensitive than crustaceans (*high confidence*) and fishes (*low confidence*), with potentially detrimental consequences for fisheries and livelihoods. See Figure SPM.6B. Ocean acidification acts together with other global changes (e.g., warming, decreasing oxygen levels) and with local changes (e.g., pollution, eutrophication) (*high confidence*). Simultaneous drivers, such as warming and ocean acidification, can lead to interactive, complex, and amplified impacts for species and ecosystems.[53]

Food security and food production systems

For the major crops (wheat, rice, and maize) in tropical and temperate regions, climate change without adaptation is projected to negatively impact production for local temperature increases of 2°C or more above late-20th-century levels, although individual locations may benefit (*medium confidence*). Projected impacts vary across crops and regions and adaptation scenarios, with about 10% of projections for the period 2030–2049 showing yield gains of more than 10%, and about 10% of projections showing yield losses of more than

[51] 5.3-5, 8.2, 22.3, 24.4, 25.6, 26.3, 26.8, Table 26-1, Box 25-1
[52] 6.3-5, 7.4, 25.6, 28.3, 30.6-7, Boxes CC-MB and CC-PP
[53] 5.4, 6.3-5, 22.3, 25.6, 28.3, 30.5, Boxes CC-CR, CC-OA, and TS.7

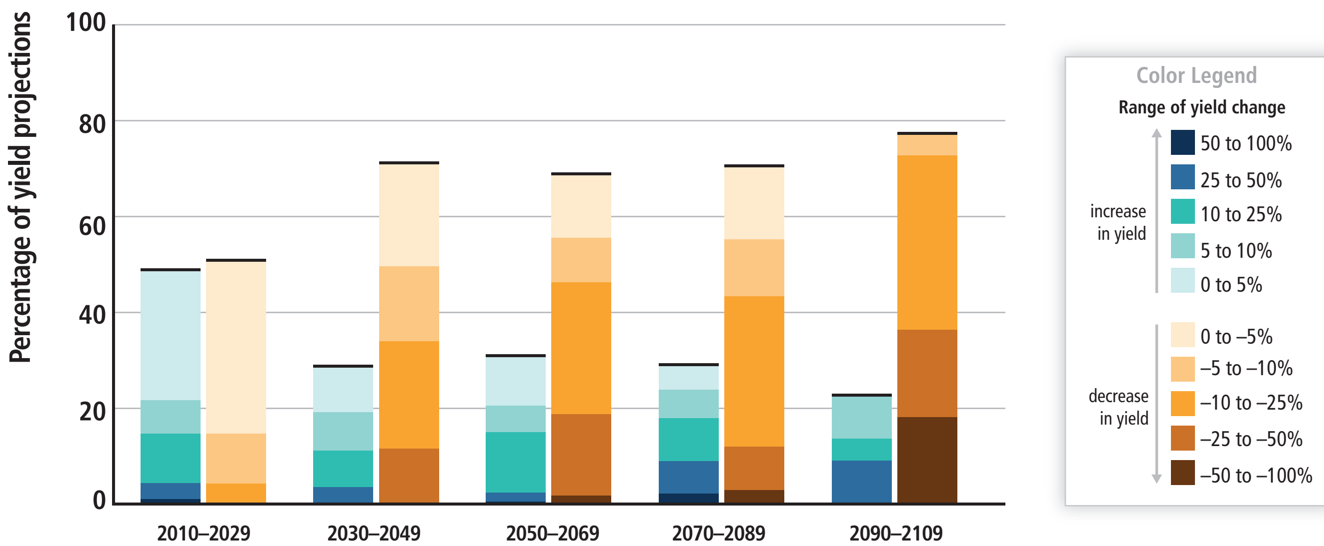


Figure SPM.7 | Summary of projected changes in crop yields, due to climate change over the 21st century. The figure includes projections for different emission scenarios, for tropical and temperate regions, and for adaptation and no-adaptation cases combined. Relatively few studies have considered impacts on cropping systems for scenarios where global mean temperatures increase by 4°C or more. For five timeframes in the near term and long term, data (n=1090) are plotted in the 20-year period on the horizontal axis that includes the midpoint of each future projection period. Changes in crop yields are relative to late-20th-century levels. Data for each timeframe sum to 100%. [Figure 7-5]

25%, compared to the late 20th century. After 2050 the risk of more severe yield impacts increases and depends on the level of warming. See Figure SPM.7. Climate change is projected to progressively increase inter-annual variability of crop yields in many regions. These projected impacts will occur in the context of rapidly rising crop demand.[54]

All aspects of food security are potentially affected by climate change, including food access, utilization, and price stability (*high confidence*). Redistribution of marine fisheries catch potential towards higher latitudes poses risk of reduced supplies, income, and employment in tropical countries, with potential implications for food security (*medium confidence*). Global temperature increases of ~4°C or more above late-20th-century levels, combined with increasing food demand, would pose large risks to food security globally and regionally (*high confidence*). Risks to food security are generally greater in low-latitude areas.[55]

Urban areas

Many global risks of climate change are concentrated in urban areas (*medium confidence*). Steps that build resilience and enable sustainable development can accelerate successful climate-change adaptation globally. Heat stress, extreme precipitation, inland and coastal flooding, landslides, air pollution, drought, and water scarcity pose risks in urban areas for people, assets, economies, and ecosystems (*very high confidence*). Risks are amplified for those lacking essential infrastructure and services or living in poor-quality housing and exposed areas. Reducing basic service deficits, improving housing, and building resilient infrastructure systems could significantly reduce vulnerability and exposure in urban areas. Urban adaptation benefits from effective multi-level urban risk governance, alignment of policies and incentives, strengthened local government and community adaptation capacity, synergies with the private sector, and appropriate financing and institutional development (*medium confidence*). Increased capacity, voice, and influence of low-income groups and vulnerable communities and their partnerships with local governments also benefit adaptation.[56]

[54] 7.4-5, 22.3, 24.4, 25.7, 26.5, Table 7-2, Figures 7-4, 7-5, 7-6, 7-7, and 7-8
[55] 6.3-5, 7.4-5, 9.3, 22.3, 24.4, 25.7, 26.5, Table 7-3, Figures 7-1, 7-4, and 7-7, Box 7-1
[56] 3.5, 8.2-4, 22.3, 24.4-5, 26.8, Table 8-2, Boxes 25-9 and CC-HS

Rural areas

Major future rural impacts are expected in the near term and beyond through impacts on water availability and supply, food security, and agricultural incomes, including shifts in production areas of food and non-food crops across the world (*high confidence*). These impacts are expected to disproportionately affect the welfare of the poor in rural areas, such as female-headed households and those with limited access to land, modern agricultural inputs, infrastructure, and education. Further adaptations for agriculture, water, forestry, and biodiversity can occur through policies taking account of rural decision-making contexts. Trade reform and investment can improve market access for small-scale farms (*medium confidence*).[57]

Key economic sectors and services

For most economic sectors, the impacts of drivers such as changes in population, age structure, income, technology, relative prices, lifestyle, regulation, and governance are projected to be large relative to the impacts of climate change (*medium evidence*, *high agreement*). Climate change is projected to reduce energy demand for heating and increase energy demand for cooling in the residential and commercial sectors (*robust evidence*, *high agreement*). Climate change is projected to affect energy sources and technologies differently, depending on resources (e.g., water flow, wind, insolation), technological processes (e.g., cooling), or locations (e.g., coastal regions, floodplains) involved. More severe and/or frequent extreme weather events and/or hazard types are projected to increase losses and loss variability in various regions and challenge insurance systems to offer affordable coverage while raising more risk-based capital, particularly in developing countries. Large-scale public-private risk reduction initiatives and economic diversification are examples of adaptation actions.[58]

Global economic impacts from climate change are difficult to estimate. Economic impact estimates completed over the past 20 years vary in their coverage of subsets of economic sectors and depend on a large number of assumptions, many of which are disputable, and many estimates do not account for catastrophic changes, tipping points, and many other factors.[59] With these recognized limitations, the incomplete estimates of global annual economic losses for additional temperature increases of ~2°C are between 0.2 and 2.0% of income (±1 standard deviation around the mean) (*medium evidence*, *medium agreement*). Losses are *more likely than not* to be greater, rather than smaller, than this range (*limited evidence*, *high agreement*). Additionally, there are large differences between and within countries. Losses accelerate with greater warming (*limited evidence*, *high agreement*), but few quantitative estimates have been completed for additional warming around 3°C or above. Estimates of the incremental economic impact of emitting carbon dioxide lie between a few dollars and several hundreds of dollars per tonne of carbon[60] (*robust evidence*, *medium agreement*). Estimates vary strongly with the assumed damage function and discount rate.[61]

Human health

Until mid-century, projected climate change will impact human health mainly by exacerbating health problems that already exist (*very high confidence*). Throughout the 21st century, climate change is expected to lead to increases in ill-health in many regions and especially in developing countries with low income, as compared to a baseline without climate change (*high confidence*). Examples include greater likelihood of injury, disease, and death due to more intense heat waves and fires (*very high confidence*); increased likelihood of under-nutrition resulting from diminished food production in poor regions (*high confidence*); risks from lost work capacity and reduced labor productivity in vulnerable populations; and increased risks from food- and water-borne diseases (*very high confidence*) and

---

[57] 9.3, 25.9, 26.8, 28.2, 28.4, Box 25-5

[58] 3.5, 10.2, 10.7, 10.10, 17.4-5, 25.7, 26.7-9, Box 25-7

[59] 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]

[60] 1 tonne of carbon = 3.667 tonne of CO_2

[61] 10.9

vector-borne diseases (*medium confidence*). Positive effects are expected to include modest reductions in cold-related mortality and morbidity in some areas due to fewer cold extremes (*low confidence*), geographical shifts in food production (*medium confidence*), and reduced capacity of vectors to transmit some diseases. But globally over the 21st century, the magnitude and severity of negative impacts are projected to increasingly outweigh positive impacts (*high confidence*). The most effective vulnerability reduction measures for health in the near term are programs that implement and improve basic public health measures such as provision of clean water and sanitation, secure essential health care including vaccination and child health services, increase capacity for disaster preparedness and response, and alleviate poverty (*very high confidence*). By 2100 for the high-emission scenario RCP8.5, the combination of high temperature and humidity in some areas for parts of the year is projected to compromise normal human activities, including growing food or working outdoors (*high confidence*).[62]

Human security

Climate change over the 21st century is projected to increase displacement of people (*medium evidence*, *high agreement*). Displacement risk increases when populations that lack the resources for planned migration experience higher exposure to extreme weather events, in both rural and urban areas, particularly in developing countries with low income. Expanding opportunities for mobility can reduce vulnerability for such populations. Changes in migration patterns can be responses to both extreme weather events and longer-term climate variability and change, and migration can also be an effective adaptation strategy. There is *low confidence* in quantitative projections of changes in mobility, due to its complex, multi-causal nature.[63]

Climate change can indirectly increase risks of violent conflicts in the form of civil war and inter-group violence by amplifying well-documented drivers of these conflicts such as poverty and economic shocks (*medium confidence*). Multiple lines of evidence relate climate variability to these forms of conflict.[64]

The impacts of climate change on the critical infrastructure and territorial integrity of many states are expected to influence national security policies (*medium evidence*, *medium agreement*). For example, land inundation due to sea level rise poses risks to the territorial integrity of small island states and states with extensive coastlines. Some transboundary impacts of climate change, such as changes in sea ice, shared water resources, and pelagic fish stocks, have the potential to increase rivalry among states, but robust national and intergovernmental institutions can enhance cooperation and manage many of these rivalries.[65]

Livelihoods and poverty

Throughout the 21st century, climate-change impacts are projected to slow down economic growth, make poverty reduction more difficult, further erode food security, and prolong existing and create new poverty traps, the latter particularly in urban areas and emerging hotspots of hunger (*medium confidence*). Climate-change impacts are expected to exacerbate poverty in most developing countries and create new poverty pockets in countries with increasing inequality, in both developed and developing countries. In urban and rural areas, wage-labor-dependent poor households that are net buyers of food are expected to be particularly affected due to food price increases, including in regions with high food insecurity and high inequality (particularly in Africa), although the agricultural self-employed could benefit. Insurance programs, social protection measures, and disaster risk management may enhance long-term livelihood resilience among poor and marginalized people, if policies address poverty and multidimensional inequalities.[66]

B-3. Regional Key Risks and Potential for Adaptation

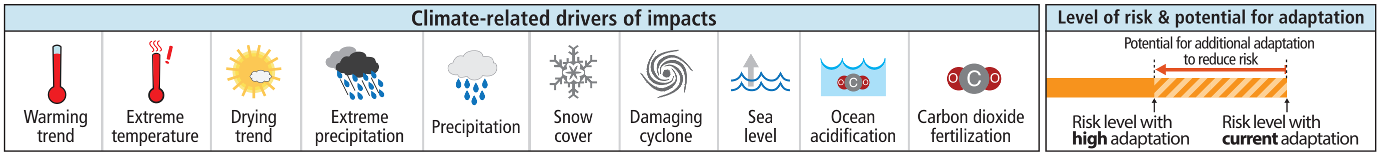
Risks will vary through time across regions and populations, dependent on myriad factors including the extent of adaptation and mitigation. A selection of key regional risks identified with *medium* to *high confidence* is presented in Assessment Box SPM.2. For extended summary of regional risks and potential benefits, see Technical Summary Section B-3 and WGII AR5 Part B: Regional Aspects.

Assessment Box SPM.2 | Regional Key Risks

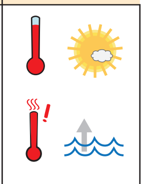
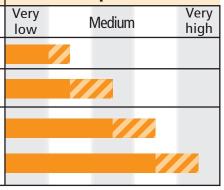
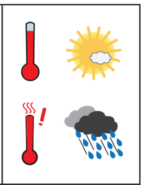
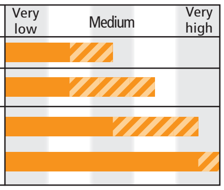
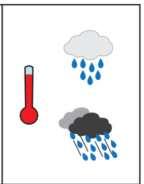
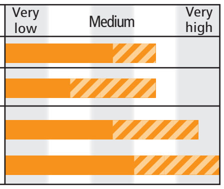
The accompanying Assessment Box SPM.2 Table 1 highlights several representative key risks for each region. Key risks have been identified based on assessment of the relevant scientific, technical, and socioeconomic literature detailed in supporting chapter sections. Identification of key risks was based on expert judgment using the following specific criteria: large magnitude, high probability, or irreversibility of impacts; timing of impacts; persistent vulnerability or exposure contributing to risks; or limited potential to reduce risks through adaptation or mitigation.

For each key risk, risk levels were assessed for three timeframes. For the present, risk levels were estimated for current adaptation and a hypothetical highly adapted state, identifying where current adaptation deficits exist. For two future timeframes, risk levels were estimated for a continuation of current adaptation and for a highly adapted state, representing the potential for and limits to adaptation. The risk levels integrate probability and consequence over the widest possible range of potential outcomes, based on available literature. These potential outcomes result from the interaction of climate-related hazards, vulnerability, and exposure. Each risk level reflects total risk from climatic and non-climatic factors. Key risks and risk levels vary across regions and over time, given differing socioeconomic development pathways, vulnerability and exposure to hazards, adaptive capacity, and risk perceptions. Risk levels are not necessarily comparable, especially across regions, because the assessment considers potential impacts and adaptation in different physical, biological, and human systems across diverse contexts. This assessment of risks acknowledges the importance of differences in values and objectives in interpretation of the assessed risk levels.

Assessment Box SPM.2 Table 1 | Key regional risks from climate change and the potential for reducing risks through adaptation and mitigation. Each key risk is characterized as very low to very high for three timeframes: the present, near term (here, assessed over 2030–2040), and longer term (here, assessed over 2080–2100). In the near term, projected levels of global mean temperature increase do not diverge substantially for different emission scenarios. For the longer term, risk levels are presented for two scenarios of global mean temperature increase (2°C and 4°C above preindustrial levels). These scenarios illustrate the potential for mitigation and adaptation to reduce the risks related to climate change. Climate-related drivers of impacts are indicated by icons.



Africa

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Compounded stress on water resources facing significant strain from overexploitation and degradation at present and increased demand in the future, with drought stress exacerbated in drought-prone regions of Africa (*high confidence*) [22.3-4]	• Reducing non-climate stressors on water resources • Strengthening institutional capacities for demand management, groundwater assessment, integrated water-wastewater planning, and integrated land and water governance • Sustainable urban development		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	
Reduced crop productivity associated with heat and drought stress, with strong adverse effects on regional, national, and household livelihood and food security, also given increased pest and disease damage and flood impacts on food system infrastructure (*high confidence*) [22.3-4]	• Technological adaptation responses (e.g., stress-tolerant crop varieties, irrigation, enhanced observation systems) • Enhancing smallholder access to credit and other critical production resources; Diversifying livelihoods • Strengthening institutions at local, national, and regional levels to support agriculture (including early warning systems) and gender-oriented policy • Agronomic adaptation responses (e.g., agroforestry, conservation agriculture)		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	
Changes in the incidence and geographic range of vector- and water-borne diseases due to changes in the mean and variability of temperature and precipitation, particularly along the edges of their distribution (*medium confidence*) [22.3]	• Achieving development goals, particularly improved access to safe water and improved sanitation, and enhancement of public health functions such as surveillance • Vulnerability mapping and early warning systems • Coordination across sectors • Sustainable urban development		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	

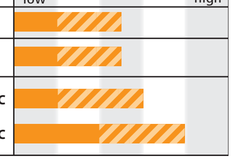
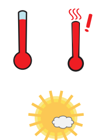
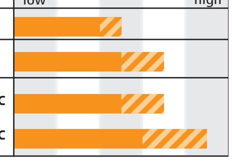
[62] 8.2, 11.3-8, 19.3, 22.3, 25.8, 26.6, Figure 25-5, Box CC-HS
[63] 9.3, 12.4, 19.4, 22.3, 25.9
[64] 12.5, 13.2, 19.4
[65] 12.5-6, 23.9, 25.9
[66] 8.1, 8.3-4, 9.3, 10.9, 13.2-4, 22.3, 26.8

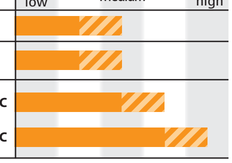
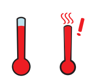
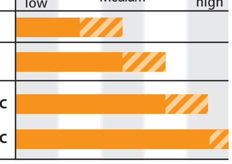
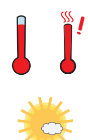
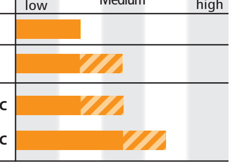
Continued next page →

SPM

Assessment Box SPM.2 Table 1 (continued)

Continued next page →

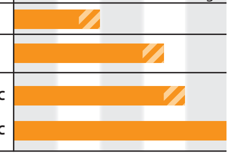
Europe				
Key risk	**Adaptation issues & prospects**	**Climatic drivers**	**Timeframe**	**Risk & potential for adaptation**
Increased economic losses and people affected by flooding in river basins and coasts, driven by increasing urbanization, increasing sea levels, coastal erosion, and peak river discharges (*high confidence*) [23.2-3, 23.7]	Adaptation can prevent most of the projected damages (*high confidence*). • Significant experience in hard flood-protection technologies and increasing experience with restoring wetlands • High costs for increasing flood protection • Potential barriers to implementation: demand for land in Europe and environmental and landscape concerns		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low / Medium / Very high 
Increased water restrictions. Significant reduction in water availability from river abstraction and from groundwater resources, combined with increased water demand (e.g., for irrigation, energy and industry, domestic use) and with reduced water drainage and runoff as a result of increased evaporative demand, particularly in southern Europe (*high confidence*) [23.4, 23.7]	• Proven adaptation potential from adoption of more water-efficient technologies and of water-saving strategies (e.g., for irrigation, crop species, land cover, industries, domestic use) • Implementation of best practices and governance instruments in river basin management plans and integrated water management		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low / Medium / Very high 
Increased economic losses and people affected by extreme heat events: impacts on health and well-being, labor productivity, crop production, air quality, and increasing risk of wildfires in southern Europe and in Russian boreal region (*medium confidence*) [23.3-7, Table 23-1]	• Implementation of warning systems • Adaptation of dwellings and workplaces and of transport and energy infrastructure • Reductions in emissions to improve air quality • Improved wildfire management • Development of insurance products against weather-related yield variations		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low / Medium / Very high 

Asia				
Key risk	**Adaptation issues & prospects**	**Climatic drivers**	**Timeframe**	**Risk & potential for adaptation**
Increased riverine, coastal, and urban flooding leading to widespread damage to infrastructure, livelihoods, and settlements in Asia (*medium confidence*) [24.4]	• Exposure reduction via structural and non-structural measures, effective land-use planning, and selective relocation • Reduction in the vulnerability of lifeline infrastructure and services (e.g., water, energy, waste management, food, biomass, mobility, local ecosystems, telecommunications) • Construction of monitoring and early warning systems; Measures to identify exposed areas, assist vulnerable areas and households, and diversify livelihoods • Economic diversification		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low / Medium / Very high 
Increased risk of heat-related mortality (*high confidence*) [24.4]	• Heat health warning systems • Urban planning to reduce heat islands; Improvement of the built environment; Development of sustainable cities • New work practices to avoid heat stress among outdoor workers		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low / Medium / Very high 
Increased risk of drought-related water and food shortage causing malnutrition (*high confidence*) [24.4]	• Disaster preparedness including early-warning systems and local coping strategies • Adaptive/integrated water resource management • Water infrastructure and reservoir development • Diversification of water sources including water re-use • More efficient use of water (e.g., improved agricultural practices, irrigation management, and resilient agriculture)		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low / Medium / Very high 

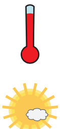
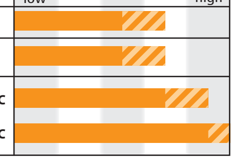
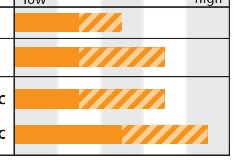
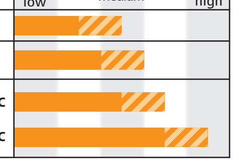
Assessment Box SPM.2 Table 1 (continued)

Continued next page →

Australasia

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Significant change in community composition and structure of coral reef systems in Australia (*high confidence*) [25.6, 30.5, Boxes CC-CR and CC-OA]	• Ability of corals to adapt naturally appears limited and insufficient to offset the detrimental effects of rising temperatures and acidification. • Other options are mostly limited to reducing other stresses (water quality, tourism, fishing) and early warning systems; direct interventions such as assisted colonization and shading have been proposed but remain untested at scale.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low / Medium / Very high 
Increased frequency and intensity of flood damage to infrastructure and settlements in Australia and New Zealand (*high confidence*) [Table 25-1, Boxes 25-8 and 25-9]	• Significant adaptation deficit in some regions to current flood risk. • Effective adaptation includes land-use controls and relocation as well as protection and accommodation of increased risk to ensure flexibility.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low / Medium / Very high 
Increasing risks to coastal infrastructure and low-lying ecosystems in Australia and New Zealand, with widespread damage towards the upper end of projected sea-level-rise ranges (*high confidence*) [25.6, 25.10, Box 25-1]	• Adaptation deficit in some locations to current coastal erosion and flood risk. Successive building and protection cycles constrain flexible responses. • Effective adaptation includes land-use controls and ultimately relocation as well as protection and accommodation.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low / Medium / Very high 

North America

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Wildfire-induced loss of ecosystem integrity, property loss, human morbidity, and mortality as a result of increased drying trend and temperature trend (*high confidence*) [26.4, 26.8, Box 26-2]	• Some ecosystems are more fire-adapted than others. Forest managers and municipal planners are increasingly incorporating fire protection measures (e.g., prescribed burning, introduction of resilient vegetation). Institutional capacity to support ecosystem adaptation is limited. • Adaptation of human settlements is constrained by rapid private property development in high-risk areas and by limited household-level adaptive capacity. • Agroforestry can be an effective strategy for reduction of slash and burn practices in Mexico.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low / Medium / Very high 
Heat-related human mortality (*high confidence*) [26.6, 26.8]	• Residential air conditioning (A/C) can effectively reduce risk. However, availability and usage of A/C is highly variable and is subject to complete loss during power failures. Vulnerable populations include athletes and outdoor workers for whom A/C is not available. • Community- and household-scale adaptations have the potential to reduce exposure to heat extremes via family support, early heat warning systems, cooling centers, greening, and high-albedo surfaces.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low / Medium / Very high 
Urban floods in riverine and coastal areas, inducing property and infrastructure damage; supply chain, ecosystem, and social system disruption; public health impacts; and water quality impairment, due to sea level rise, extreme precipitation, and cyclones (*high confidence*) [26.2-4, 26.8]	• Implementing management of urban drainage is expensive and disruptive to urban areas. • Low-regret strategies with co-benefits include less impervious surfaces leading to more groundwater recharge, green infrastructure, and rooftop gardens. • Sea level rise increases water elevations in coastal outfalls, which impedes drainage. In many cases, older rainfall design standards are being used that need to be updated to reflect current climate conditions. • Conservation of wetlands, including mangroves, and land-use planning strategies can reduce the intensity of flood events.		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low / Medium / Very high 

SPM

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
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	Very low / Medium / Very high
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	Very low / Medium / Very high
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	Very low / Medium / Very high Long term 2°C: not available Long term 4°C: not available

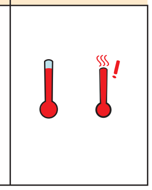
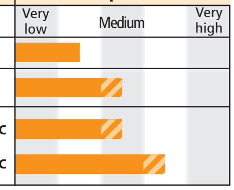
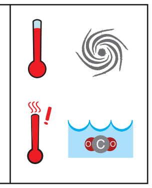
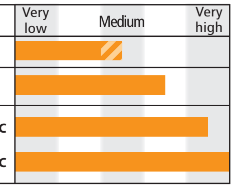
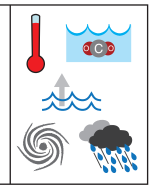
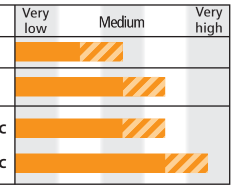
Polar Regions

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Risks for freshwater and terrestrial ecosystems (*high confidence*) and marine ecosystems (*medium confidence*), due to changes in ice, snow cover, permafrost, and freshwater/ocean conditions, affecting species´ habitat quality, ranges, phenology, and productivity, as well as dependent economies [28.2-4]	• Improved understanding through scientific and indigenous knowledge, producing more effective solutions and/or technological innovations • Enhanced monitoring, regulation, and warning systems that achieve safe and sustainable use of ecosystem resources • Hunting or fishing for different species, if possible, and diversifying income sources		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	Very low / Medium / Very high
Risks for the health and well-being of Arctic residents, resulting from injuries and illness from the changing physical environment, food insecurity, lack of reliable and safe drinking water, and damage to infrastructure, including infrastructure in permafrost regions (*high confidence*) [28.2-4]	• Co-production of more robust solutions that combine science and technology with indigenous knowledge • Enhanced observation, monitoring, and warning systems • Improved communications, education, and training • Shifting resource bases, land use, and/or settlement areas		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	Very low / Medium / Very high
Unprecedented challenges for northern communities due to complex inter-linkages between climate-related hazards and societal factors, particularly if rate of change is faster than social systems can adapt (*high confidence*) [28.2-4]	• Co-production of more robust solutions that combine science and technology with indigenous knowledge • Enhanced observation, monitoring, and warning systems • Improved communications, education, and training • Adaptive co-management responses developed through the settlement of land claims		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	Very low / Medium / Very high

Small Islands

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Loss of livelihoods, coastal settlements, infrastructure, ecosystem services, and economic stability (*high confidence*) [29.6, 29.8, Figure 29-4]	• Significant potential exists for adaptation in islands, but additional external resources and technologies will enhance response. • Maintenance and enhancement of ecosystem functions and services and of water and food security • Efficacy of traditional community coping strategies is expected to be substantially reduced in the future.		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	Very low / Medium / Very high
The interaction of rising global mean sea level in the 21st century with high-water-level events will threaten low-lying coastal areas (*high confidence*) [29.4, Table 29-1; WGI AR5 13.5, Table 13.5]	• High ratio of coastal area to land mass will make adaptation a significant financial and resource challenge for islands. • Adaptation options include maintenance and restoration of coastal landforms and ecosystems, improved management of soils and freshwater resources, and appropriate building codes and settlement patterns.		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	Very low / Medium / Very high

Assessment Box SPM.2 Table 1 (continued)

The Ocean				
Key risk	**Adaptation issues & prospects**	**Climatic drivers**	**Timeframe**	**Risk & potential for adaptation**
Distributional shift in fish and invertebrate species, and decrease in fisheries catch potential at low latitudes, e.g., in equatorial upwelling and coastal boundary systems and sub-tropical gyres (*high confidence*) [6.3, 30.5-6, Tables 6-6 and 30-3, Box CC-MB]	• Evolutionary adaptation potential of fish and invertebrate species to warming is limited as indicated by their changes in distribution to maintain temperatures. • Human adaptation options: Large-scale translocation of industrial fishing activities following the regional decreases (low latitude) vs. possibly transient increases (high latitude) in catch potential; Flexible management that can react to variability and change; Improvement of fish resilience to thermal stress by reducing other stressors such as pollution and eutrophication; Expansion of sustainable aquaculture and the development of alternative livelihoods in some regions.		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	
Reduced biodiversity, fisheries abundance, and coastal protection by coral reefs due to heat-induced mass coral bleaching and mortality increases, exacerbated by ocean acidification, e.g., in coastal boundary systems and sub-tropical gyres (*high confidence*) [5.4, 6.4, 30.3, 30.5-6, Tables 6-6 and 30-3, Box CC-CR]	• Evidence of rapid evolution by corals is very limited. Some corals may migrate to higher latitudes, but entire reef systems are not expected to be able to track the high rates of temperature shifts. • Human adaptation options are limited to reducing other stresses, mainly by enhancing water quality, and limiting pressures from tourism and fishing. These options will delay human impacts of climate change by a few decades, but their efficacy will be severely reduced as thermal stress increases.		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	
Coastal inundation and habitat loss due to sea level rise, extreme events, changes in precipitation, and reduced ecological resilience, e.g., in coastal boundary systems and sub-tropical gyres (*medium* to *high confidence*) [5.5, 30.5-6, Tables 6-6 and 30-3, Box CC-CR]	• Human adaptation options are limited to reducing other stresses, mainly by reducing pollution and limiting pressures from tourism, fishing, physical destruction, and unsustainable aquaculture. • Reducing deforestation and increasing reforestation of river catchments and coastal areas to retain sediments and nutrients • Increased mangrove, coral reef, and seagrass protection, and restoration to protect numerous ecosystem goods and services such as coastal protection, tourist value, and fish habitat		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	

C: MANAGING FUTURE RISKS AND BUILDING RESILIENCE

Managing the risks of climate change involves adaptation and mitigation decisions with implications for future generations, economies, and environments. This section evaluates adaptation as a means to build resilience and to adjust to climate-change impacts. It also considers limits to adaptation, climate-resilient pathways, and the role of transformation. See Figure SPM.8 for an overview of responses for addressing risk related to climate change.

C-1. Principles for Effective Adaptation

Adaptation is place- and context-specific, with no single approach for reducing risks appropriate across all settings (*high confidence*). Effective risk reduction and adaptation strategies consider the dynamics of vulnerability and exposure and their linkages with socioeconomic processes, sustainable development, and climate change. Specific examples of responses to climate change are presented in Table SPM.1.[67]

Adaptation planning and implementation can be enhanced through complementary actions across levels, from individuals to governments (*high confidence*). National governments can coordinate adaptation efforts of local and subnational governments, for example by protecting vulnerable groups, by supporting economic diversification, and by providing information, policy and legal frameworks, and financial support (*robust evidence*, *high agreement*). Local government and the private sector are increasingly recognized as critical to progress in adaptation, given their roles in scaling up adaptation of communities, households, and civil society and in managing risk information and financing (*medium evidence*, *high agreement*).[68]

A first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability (*high confidence*). Strategies include actions with co-benefits for other objectives. Available strategies and actions can increase resilience across a range of possible future climates while helping to improve human health, livelihoods, social and economic well-being, and

[67] 2.1, 8.3-4, 13.1, 13.3-4, 15.2-3, 15.5, 16.2-3, 16.5, 17.2, 17.4, 19.6, 21.3, 22.4, 26.8-9, 29.6, 29.8

[68] 2.1-4, 3.6, 5.5, 8.3-4, 9.3-4, 14.2, 15.2-3, 15.5, 16.2-5, 17.2-3, 22.4, 24.4, 25.4, 26.8-9, 30.7, Tables 21-1, 21-5, & 21-6, Box 16-2

SPM

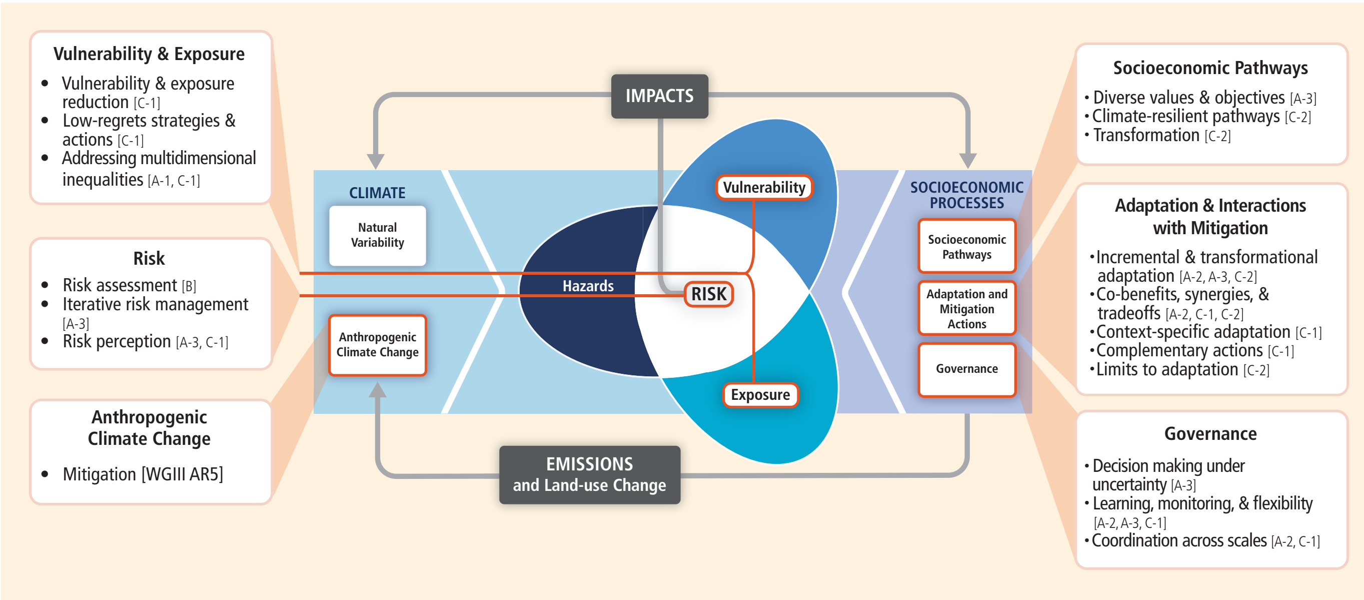


Figure SPM.8 | The solution space. Core concepts of the WGII AR5, illustrating overlapping entry points and approaches, as well as key considerations, in managing risks related to climate change, as assessed in this report and presented throughout this SPM. Bracketed references indicate sections of this summary with corresponding assessment findings.

environmental quality. See Table SPM.1. Integration of adaptation into planning and decision making can promote synergies with development and disaster risk reduction.[69]

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]

Decision support is most effective when it is sensitive to context and the diversity of decision types, decision processes, and constituencies (*robust evidence*, *high agreement*). Organizations bridging science and decision making, including climate services, play an important role in the communication, transfer, and development of climate-related knowledge, including translation, engagement, and knowledge exchange (*medium evidence*, *high agreement*).[71]

Existing and emerging economic instruments can foster adaptation by providing incentives for anticipating and reducing impacts (*medium confidence*). Instruments include public-private finance partnerships, loans, payments for environmental services, improved resource pricing, charges and subsidies, norms and regulations, and risk sharing and transfer mechanisms. Risk financing mechanisms in the public and private sector, such as insurance and risk pools, can contribute to increasing resilience, but without attention to major design challenges, they can also provide disincentives, cause market failure, and decrease equity. Governments often play key roles as regulators, providers, or insurers of last resort.[72]

Constraints can interact to impede adaptation planning and implementation (*high confidence*). Common constraints on implementation arise from the following: limited financial and human resources; limited integration or coordination of governance; uncertainties

[69] 3.6, 8.3, 9.4, 14.3, 15.2-3, 17.2, 20.4, 20.6, 22.4, 24.4-5, 25.4, 25.10, 27.3-5, 29.6, Boxes 25-2 and 25-6
[70] 2.2-4, 9.4, 12.3, 13.2, 15.2, 16.2-4, 16.7, 17.2-3, 21.3, 22.4, 24.4, 24.6, 25.4, 25.8, 26.9, 28.2, 28.4, Table 15-1, Box 25-7
[71] 2.1-4, 8.4, 14.4, 16.2-3, 16.5, 21.2-3, 21.5, 22.4, Box 9-4
[72] 10.7, 10.9, 13.3, 17.4-5, Box 25-7

Table SPM.1 | 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. [14.2-3, 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, 13.1-3, 14.2-3, 22.4
	Poverty alleviation	Improved access to & control of local resources; Land tenure; Disaster risk reduction; Social safety nets & social protection; Insurance schemes.	8.3-4, 9.3, 13.1-3
	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, 13.1-3, 22.3-4, 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.	8.2-4, 11.7, 14.3, 15.4, 22.4, 24.4, 26.6, 28.4, Box 25-1, Table 3-3
Adaptation including incremental & transformational adjustments	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, 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, 8.1-4, 22.4, 23.7-8, 27.3, Box 25-8
	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.	3.5-6, 5.5, 8.2-3, 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, 29.6-7, Boxes 20-5 & 25-2, Tables 3-3 & 15-1
		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, 23.6-7, 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.	3.5-6, 8.3, 9.3, 11.7, 11.9, 22.4, 29.6, Box 13-2
	Institutional	***Economic options***: Financial incentives; Insurance; Catastrophe bonds; Payments for ecosystem services; Pricing water to encourage universal provision and careful use; Microfinance; Disaster contingency funds; Cash transfers; Public-private partnerships.	8.3-4, 9.4, 10.7, 11.7, 13.3, 15.4, 17.5, 22.4, 26.7, 27.6, 29.6, Box 25-7
		Laws & regulations: Land zoning laws; Building standards & practices; Easements; Water regulations & agreements; Laws to support disaster risk reduction; Laws to encourage insurance purchasing; Defined property rights & land tenure security; Protected areas; Fishing quotas; Patent pools & technology transfer.	4.4, 8.3, 9.3, 10.5, 10.7, 15.2, 15.4, 17.5, 22.4, 23.4, 23.7, 24.4, 25.4, 26.3, 27.3, 30.6, Table 25-2, Box CC-CR
		National & government policies & programs: National & regional adaptation plans including mainstreaming; Sub-national & local adaptation plans; Economic diversification; Urban upgrading programs; Municipal water management programs; Disaster planning & preparedness; Integrated water resource management; Integrated coastal zone management; Ecosystem-based management; Community-based adaptation.	2.4, 3.6, 4.4, 5.5, 6.4, 7.5, 8.3, 11.7, 15.2-5, 22.4, 23.7, 25.4, 25.8, 26.8-9, 27.3-4, 29.6, Boxes 25-1, 25-2, & 25-9, Tables 9-2 & 17-1
	Social	***Educational options***: Awareness raising & integrating into education; Gender equity in education; Extension services; Sharing indigenous, traditional, & local knowledge; Participatory action research & social learning; Knowledge-sharing & learning platforms.	8.3-4, 9.4, 11.7, 12.3, 15.2-4, 22.4, 25.4, 28.4, 29.6, Tables 15-1 & 25-2
		Informational options: Hazard & vulnerability mapping; Early warning & response systems; Systematic monitoring & remote sensing; Climate services; Use of indigenous climate observations; Participatory scenario development; Integrated assessments.	2.4, 5.5, 8.3-4, 9.4, 11.7, 15.2-4, 22.4, 23.5, 24.4, 25.8, 26.6, 26.8, 27.3, 28.2, 28.5, 30.6, Table 25-2, Box 26-3
		Behavioral options: Household preparation & evacuation planning; Migration; Soil & water conservation; Storm drain clearance; Livelihood diversification; Changed cropping, livestock, & aquaculture practices; Reliance on social networks.	5.5, 7.5, 9.4, 12.4, 22.3-4, 23.4, 23.7, 25.7, 26.5, 27.3, 29.6, Table SM24-7, Box 25-5
Transformation	Spheres of change	***Practical***: Social & technical innovations, behavioral shifts, or institutional & managerial changes that produce substantial shifts in outcomes.	8.3, 17.3, 20.5, Box 25-5
		Political: Political, social, cultural, & ecological decisions & actions consistent with reducing vulnerability & risk & supporting adaptation, mitigation, & sustainable development.	14.2-3, 20.5, 25.4, 30.7, Table 14-1
		Personal: Individual & collective assumptions, beliefs, values, & worldviews influencing climate-change responses.	14.2-3, 20.5, 25.4, Table 14-1

about projected impacts; different perceptions of risks; competing values; absence of key adaptation leaders and advocates; and limited tools to monitor adaptation effectiveness. Another constraint includes insufficient research, monitoring, and observation and the finance to maintain them. Underestimating the complexity of adaptation as a social process can create unrealistic expectations about achieving intended adaptation outcomes.[73]

Poor planning, overemphasizing short-term outcomes, or failing to sufficiently anticipate consequences can result in maladaptation (*medium evidence*, *high agreement*). Maladaptation can increase the vulnerability or exposure of the target group in the future, or the vulnerability of other people, places, or sectors. Some near-term responses to increasing risks related to climate change may also limit future choices. For example, enhanced protection of exposed assets can lock in dependence on further protection measures.[74]

Limited evidence indicates a gap between global adaptation needs and the funds available for adaptation (*medium confidence*). There is a need for a better assessment of global adaptation costs, funding, and investment. Studies estimating the global cost of adaptation are characterized by shortcomings in data, methods, and coverage (*high confidence*).[75]

Significant co-benefits, synergies, and trade-offs exist between mitigation and adaptation and among different adaptation responses; interactions occur both within and across regions (*very high confidence*). Increasing efforts to mitigate and adapt to climate change imply an increasing complexity of interactions, particularly at the intersections among water, energy, land use, and biodiversity, but tools to understand and manage these interactions remain limited. Examples of actions with co-benefits include (i) improved energy efficiency and cleaner energy sources, leading to reduced emissions of health-damaging climate-altering air pollutants; (ii) reduced energy and water consumption in urban areas through greening cities and recycling water; (iii) sustainable agriculture and forestry; and (iv) protection of ecosystems for carbon storage and other ecosystem services.[76]

C-2. Climate-resilient Pathways and Transformation

Climate-resilient pathways are sustainable-development trajectories that combine adaptation and mitigation to reduce climate change and its impacts. They include iterative processes to ensure that effective risk management can be implemented and sustained. See Figure SPM.9.[77]

Prospects for climate-resilient pathways for sustainable development are related fundamentally to what the world accomplishes with climate-change mitigation (*high confidence*). Since mitigation reduces the rate as well as the magnitude of warming, it also increases the time available for adaptation to a particular level of climate change, potentially by several decades. Delaying mitigation actions may reduce options for climate-resilient pathways in the future.[78]

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]

---

[73] 3.6, 4.4, 5.5, 8.4, 9.4, 13.2-3, 14.2, 14.5, 15.2-3, 15.5, 16.2-3, 16.5, 17.2-3, 22.4, 23.7, 24.5, 25.4, 25.10, 26.8-9, 30.6, Table 16-3, Boxes 16-1 and 16-3

[74] 5.5, 8.4, 14.6, 15.5, 16.3, 17.2-3, 20.2, 22.4, 24.4, 25.10, 26.8, Table 14-4, Box 25-1

[75] 14.2, 17.4, Tables 17-2 and 17-3

[76] 2.4-5, 3.7, 4.2, 4.4, 5.4-5, 8.4, 9.3, 11.9, 13.3, 17.2, 19.3-4, 20.2-5, 21.4, 22.6, 23.8, 24.6, 25.6-7, 25.9, 26.8-9, 27.3, 29.6-8, Boxes 25-2, 25-9, 25-10, 30.6-7, CC-WE, and CC-RF

[77] 2.5, 20.3-4

[78] 1.1, 19.7, 20.2-3, 20.6, Figure 1-5

[79] 1.1, 11.8, 13.4, 16.2-7, 17.2, 20.2-3, 20.5-6, 25.10, 26.5, Boxes 16-1, 16-3, and 16-4

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]

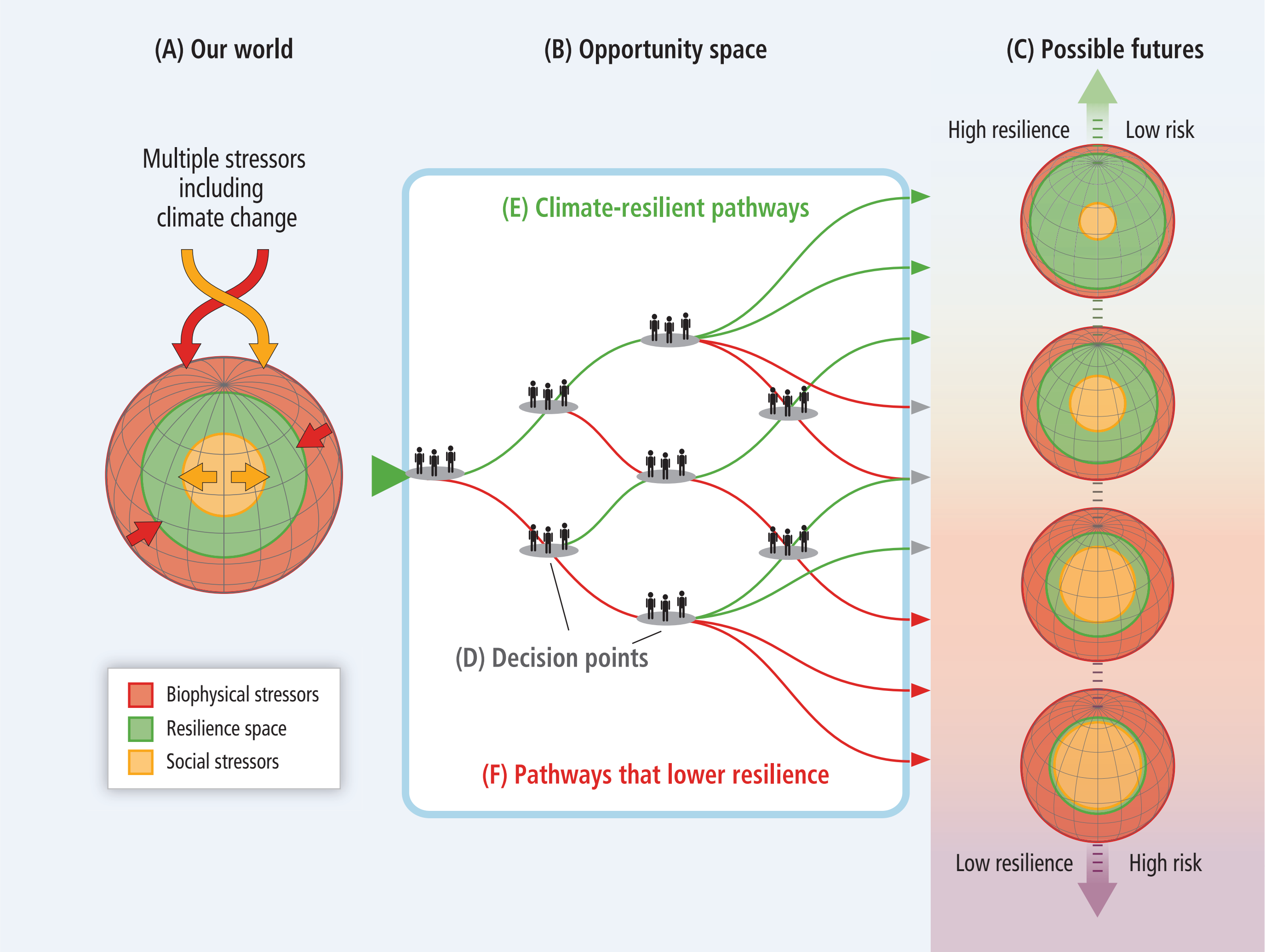


Figure SPM.9 | Opportunity space and climate-resilient pathways. (A) Our world [Sections A-1 and B-1] is threatened by multiple stressors that impinge on resilience from many directions, represented here simply as biophysical and social stressors. Stressors include climate change, climate variability, 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.

[80] 1.1, 2.1, 2.5, 8.4, 14.1, 14.3, 16.2-7, 20.5, 22.4, 25.4, 25.10, Figure 1-5, Boxes 16-1, 16-4, and TS.8

SPM

SUPPLEMENTARY MATERIAL

Table SPM.A1 | Observed impacts attributed to climate change reported in the scientific literature since the AR4. These impacts have been attributed to climate change with *very low*, *low*, *medium*, or *high confidence*, with the relative contribution of climate change to the observed change indicated (major or minor), for natural and human systems across eight major world regions over the past several decades. [Tables 18-5, 18-6, 18-7, 18-8, and 18-9] Absence from the table of additional impacts attributed to climate change does not imply that such impacts have not occurred.

	Africa
Snow & Ice, Rivers & Lakes, Floods & Drought	• Retreat of tropical highland glaciers in East Africa (*high confidence*, major contribution from climate change) • Reduced discharge in West African rivers (*low confidence*, major contribution from climate change) • Lake surface warming and water column stratification increases in the Great Lakes and Lake Kariba (*high confidence*, major contribution from climate change) • Increased soil moisture drought in the Sahel since 1970, partially wetter conditions since 1990 (*medium confidence*, major contribution from climate change) [22.2-3, Tables 18-5, 18-6, and 22-3]
Terrestrial Ecosystems	• Tree density decreases in western Sahel and semi-arid Morocco, beyond changes due to land use (*medium confidence*, major contribution from climate change) • Range shifts of several southern plants and animals, beyond changes due to land use (*medium confidence*, major contribution from climate change) • Increases in wildfires on Mt. Kilimanjaro (*low confidence*, major contribution from climate change) [22.3, Tables 18-7 and 22-3]
Coastal Erosion & Marine Ecosystems	• Decline in coral reefs in tropical African waters, beyond decline due to human impacts (*high confidence*, major contribution from climate change) [Table 18-8]
Food Production & Livelihoods	• Adaptive responses to changing rainfall by South African farmers, beyond changes due to economic conditions (*very low confidence*, major contribution from climate change) • Decline in fruit-bearing trees in Sahel (*low confidence*, major contribution from climate change) • Malaria increases in Kenyan highlands, beyond changes due to vaccination, drug resistance, demography, and livelihoods (*low confidence*, minor contribution from climate change) • Reduced fisheries productivity of Great Lakes and Lake Kariba, beyond changes due to fisheries management and land use (*low confidence*, minor contribution from climate change) [7.2, 11.5, 13.2, 22.3, Table 18-9]
	Europe
Snow & Ice, Rivers & Lakes, Floods & Drought	• Retreat of Alpine, Scandinavian, and Icelandic glaciers (*high confidence*, major contribution from climate change) • Increase in rock slope failures in western Alps (*medium confidence*, major contribution from climate change) • Changed occurrence of extreme river discharges and floods (*very low confidence*, minor contribution from climate change) [18.3, 23.2-3, Tables 18-5 and 18-6; WGI AR5 4.3]
Terrestrial Ecosystems	• Earlier greening, leaf emergence, and fruiting in temperate and boreal trees (*high confidence*, major contribution from climate change) • Increased colonization of alien plant species in Europe, beyond a baseline of some invasion (*medium confidence*, major contribution from climate change) • Earlier arrival of migratory birds in Europe since 1970 (*medium confidence*, major contribution from climate change) • Upward shift in tree-line in Europe, beyond changes due to land use (*low confidence*, major contribution from climate change) • Increasing burnt forest areas during recent decades in Portugal and Greece, beyond some increase due to land use (*high confidence*, major contribution from climate change) [4.3, 18.3, Tables 18-7 and 23-6]
Coastal Erosion & Marine Ecosystems	• Northward distributional shifts of zooplankton, fishes, seabirds, and benthic invertebrates in northeast Atlantic (*high confidence*, major contribution from climate change) • Northward and depth shift in distribution of many fish species across European seas (*medium confidence*, major contribution from climate change) • Plankton phenology changes in northeast Atlantic (*medium confidence*, major contribution from climate change) • Spread of warm water species into the Mediterranean, beyond changes due to invasive species and human impacts (*medium confidence*, major contribution from climate change) [6.3, 23.6, 30.5, Tables 6-2 and 18-8, Boxes 6-1 and CC-MB]
Food Production & Livelihoods	• Shift from cold-related mortality to heat-related mortality in England and Wales, beyond changes due to exposure and health care (*low confidence*, major contribution from climate change) • Impacts on livelihoods of Sámi people in northern Europe, beyond effects of economic and sociopolitical changes (*medium confidence*, major contribution from climate change) • Stagnation of wheat yields in some countries in recent decades, despite improved technology (*medium confidence*, minor contribution from climate change) • Positive yield impacts for some crops mainly in northern Europe, beyond increase due to improved technology (*medium confidence*, minor contribution from climate change) • Spread of bluetongue virus in sheep and of ticks across parts of Europe (*medium confidence*, minor contribution from climate change) [18.4, 23.4-5, Table 18-9, Figure 7-2]

Continued next page →

Table SPM.A1 (continued)

Asia	
Snow & Ice, Rivers & Lakes, Floods & Drought	• Permafrost degradation in Siberia, Central Asia, and Tibetan Plateau (*high confidence*, major contribution from climate change) • Shrinking mountain glaciers across most of Asia (*medium confidence*, major contribution from climate change) • Changed water availability in many Chinese rivers, beyond changes due to land use (*low confidence*, minor contribution from climate change) • Increased flow in several rivers due to shrinking glaciers (*high confidence*, major contribution from climate change) • Earlier timing of maximum spring flood in Russian rivers (*medium confidence*, major contribution from climate change) • Reduced soil moisture in north-central and northeast China (1950–2006) (*medium confidence*, major contribution from climate change) • Surface water degradation in parts of Asia, beyond changes due to land use (*medium confidence*, minor contribution from climate change) [24.3-4, 28.2, Tables 18-5, 18-6, and SM24-4, Box 3-1; WGI AR5 4.3, 10.5]
Terrestrial Ecosystems	• Changes in plant phenology and growth in many parts of Asia (earlier greening), particularly in the north and east (*medium confidence*, major contribution from climate change) • Distribution shifts of many plant and animal species upwards in elevation or polewards, particularly in the north of Asia (*medium confidence*, major contribution from climate change) • Invasion of Siberian larch forests by pine and spruce during recent decades (*low confidence*, major contribution from climate change) • Advance of shrubs into the Siberian tundra (*high confidence*, major contribution from climate change) [4.3, 24.4, 28.2, Table 18-7, Figure 4-4]
Coastal Erosion & Marine Ecosystems	• Decline in coral reefs in tropical Asian waters, beyond decline due to human impacts (*high confidence*, major contribution from climate change) • Northward range extension of corals in the East China Sea and western Pacific, and of a predatory fish in the Sea of Japan (*medium confidence*, major contribution from climate change) • Shift from sardines to anchovies in the western North Pacific, beyond fluctuations due to fisheries (*low confidence*, major contribution from climate change) • Increased coastal erosion in Arctic Asia (*low confidence*, major contribution from climate change) [6.3, 24.4, 30.5, Tables 6-2 and 18-8]
Food Production & Livelihoods	• Impacts on livelihoods of indigenous groups in Arctic Russia, beyond economic and sociopolitical changes (*low confidence*, major contribution from climate change) • Negative impacts on aggregate wheat yields in South Asia, beyond increase due to improved technology (*medium confidence*, minor contribution from climate change) • Negative impacts on aggregate wheat and maize yields in China, beyond increase due to improved technology (*low confidence*, minor contribution from climate change) • Increases in a water-borne disease in Israel (*low confidence*, minor contribution from climate change) [7.2, 13.2, 18.4, 28.2, Tables 18-4 and 18-9, Figure 7-2]
Australasia	
Snow & Ice, Rivers & Lakes, Floods & Drought	• Significant decline in late-season snow depth at 3 of 4 alpine sites in Australia (1957–2002) (*medium confidence*, major contribution from climate change) • Substantial reduction in ice and glacier ice volume in New Zealand (*medium confidence*, major contribution from climate change) • Intensification of hydrological drought due to regional warming in southeast Australia (*low confidence*, minor contribution from climate change) • Reduced inflow in river systems in southwestern Australia (since the mid-1970s) (*high confidence*, major contribution from climate change) [25.5, Tables 18-5, 18-6, and 25-1; WGI AR5 4.3]
Terrestrial Ecosystems	• Changes in genetics, growth, distribution, and phenology of many species, in particular birds, butterflies, and plants in Australia, beyond fluctuations due to variable local climates, land use, pollution, and invasive species (*high confidence*, major contribution from climate change) • Expansion of some wetlands and contraction of adjacent woodlands in southeast Australia (*low confidence*, major contribution from climate change) • Expansion of monsoon rainforest at expense of savannah and grasslands in northern Australia (*medium confidence*, major contribution from climate change) • Migration of glass eels advanced by several weeks in Waikato River, New Zealand (*low confidence*, major contribution from climate change) [Tables 18-7 and 25-3]
Coastal Erosion & Marine Ecosystems	• Southward shifts in the distribution of marine species near Australia, beyond changes due to short-term environmental fluctuations, fishing, and pollution (*medium confidence*, major contribution from climate change) • Change in timing of migration of seabirds in Australia (*low confidence*, major contribution from climate change) • Increased coral bleaching in Great Barrier Reef and western Australian reefs, beyond effects from pollution and physical disturbance (*high confidence*, major contribution from climate change) • Changed coral disease patterns at Great Barrier Reef, beyond effects from pollution (*medium confidence*, major contribution from climate change) [6.3, 25.6, Tables 18-8 and 25-3]
Food Production & Livelihoods	• Advanced timing of wine-grape maturation in recent decades, beyond advance due to improved management (*medium confidence*, major contribution from climate change) • Shift in winter vs. summer human mortality in Australia, beyond changes due to exposure and health care (*low confidence*, major contribution from climate change) • Relocation or diversification of agricultural activities in Australia, beyond changes due to policy, markets, and short-term climate variability (*low confidence*, minor contribution from climate change) [11.4, 18.4, 25.7-8, Tables 18-9 and 25-3, Box 25-5]
North America	
Snow & Ice, Rivers & Lakes, Floods & Drought	• Shrinkage of glaciers across western and northern North America (*high confidence*, major contribution from climate change) • Decreasing amount of water in spring snowpack in western North America (1960–2002) (*high confidence*, major contribution from climate change) • Shift to earlier peak flow in snow dominated rivers in western North America (*high confidence*, major contribution from climate change) • Increased runoff in the midwestern and northeastern US (*medium confidence*, minor contribution from climate change) [Tables 18-5 and 18-6; WGI AR5 2.6, 4.3]
Terrestrial Ecosystems	• Phenology changes and species distribution shifts upward in elevation and northward across multiple taxa (*medium confidence*, major contribution from climate change) • Increased wildfire frequency in subarctic conifer forests and tundra (*medium confidence*, major contribution from climate change) • Regional increases in tree mortality and insect infestations in forests (*low confidence*, minor contribution from climate change) • Increase in wildfire activity, fire frequency and duration, and burnt area in forests of the western US and boreal forests in Canada, beyond changes due to land use and fire management (*medium confidence*, minor contribution from climate change) [26.4, 28.2, Table 18-7, Box 26-2]
Coastal Erosion & Marine Ecosystems	• Northward distributional shifts of northwest Atlantic fish species (*high confidence*, major contribution from climate change) • Changes in musselbeds along the west coast of US (*high confidence*, major contribution from climate change) • Changed migration and survival of salmon in northeast Pacific (*high confidence*, major contribution from climate change) • Increased coastal erosion in Alaska and Canada (*medium confidence*, major contribution from climate change) [18.3, 30.5, Tables 6-2 and 18-8]
Food Production & Livelihoods	• Impacts on livelihoods of indigenous groups in the Canadian Arctic, beyond effects of economic and sociopolitical changes (*medium confidence*, major contribution from climate change) [18.4, 28.2, Tables 18-4 and 18-9]

Continued next page →

SPM

Table SPM.A1 (continued)

	Central and South America
Snow & Ice, Rivers & Lakes, Floods & Drought	• Shrinkage of Andean glaciers (*high confidence*, major contribution from climate change) • Changes in extreme flows in Amazon River (*medium confidence*, major contribution from climate change) • Changing discharge patterns in rivers in the western Andes (*medium confidence*, major contribution from climate change) • Increased streamflow in sub-basins of the La Plata River, beyond increase due to land-use change (*high confidence*, major contribution from climate change) [27.3, Tables 18-5, 18-6, and 27-3; WGI AR5 4.3]
Terrestrial Ecosystems	• Increased tree mortality and forest fire in the Amazon (*low confidence*, minor contribution from climate change) • Rainforest degradation and recession in the Amazon, beyond reference trends in deforestation and land degradation (*low confidence*, minor contribution from climate change) [4.3, 18.3, 27.2-3, Table 18-7]
Coastal Erosion & Marine Ecosystems	• Increased coral bleaching in western Caribbean, beyond effects from pollution and physical disturbance (*high confidence*, major contribution from climate change) • Mangrove degradation on north coast of South America, beyond degradation due to pollution and land use (*low confidence*, minor contribution from climate change) [27.3, Table 18-8]
Food Production & Livelihoods	• More vulnerable livelihood trajectories for indigenous Aymara farmers in Bolivia due to water shortage, beyond effects of increasing social and economic stress (*medium confidence*, major contribution from climate change) • Increase in agricultural yields and expansion of agricultural areas in southeastern South America, beyond increase due to improved technology (*medium confidence*, major contribution from climate change) [13.1, 27.3, Table 18-9]
	Polar Regions
Snow & Ice, Rivers & Lakes, Floods & Drought	• Decreasing Arctic sea ice cover in summer (*high confidence*, major contribution from climate change) • Reduction in ice volume in Arctic glaciers (*high confidence*, major contribution from climate change) • Decreasing snow cover extent across the Arctic (*medium confidence*, major contribution from climate change) • Widespread permafrost degradation, especially in the southern Arctic (*high confidence*, major contribution from climate change) • Ice mass loss along coastal Antarctica (*medium confidence*, major contribution from climate change) • Increased river discharge for large circumpolar rivers (1997–2007) (*low confidence*, major contribution from climate change) • Increased winter minimum river flow in most of the Arctic (*medium confidence*, major contribution from climate change) • Increased lake water temperatures 1985–2009 and prolonged ice-free seasons (*medium confidence*, major contribution from climate change) • Disappearance of thermokarst lakes due to permafrost degradation in the low Arctic. New lakes created in areas of formerly frozen peat (*high confidence*, major contribution from climate change) [28.2, Tables 18-5 and 18-6; WGI AR5 4.2-4, 4.6, 10.5]
Terrestrial Ecosystems	• Increased shrub cover in tundra in North America and Eurasia (*high confidence*, major contribution from climate change) • Advance of Arctic tree-line in latitude and altitude (*medium confidence*, major contribution from climate change) • Changed breeding area and population size of subarctic birds, due to snowbed reduction and/or tundra shrub encroachment (*medium confidence*, major contribution from climate change) • Loss of snow-bed ecosystems and tussock tundra (*high confidence*, major contribution from climate change) • Impacts on tundra animals from increased ice layers in snow pack, following rain-on-snow events (*medium confidence*, major contribution from climate change) • Increased plant species ranges in the West Antarctic Peninsula and nearby islands over the past 50 years (*high confidence*, major contribution from climate change) • Increased phytoplankton productivity in Signy Island lake waters (*high confidence*, major contribution from climate change) [28.2, Table 18-7]
Coastal Erosion & Marine Ecosystems	• Increased coastal erosion across Arctic (*medium confidence*, major contribution from climate change) • Negative effects on non-migratory Arctic species (*high confidence*, major contribution from climate change) • Decreased reproductive success in Arctic seabirds (*medium confidence*, major contribution from climate change) • Decline in Southern Ocean seals and seabirds (*medium confidence*, major contribution from climate change) • Reduced thickness of foraminiferal shells in southern oceans, due to ocean acidification (*medium confidence*, major contribution from climate change) • Reduced krill density in Scotia Sea (*medium confidence*, major contribution from climate change) [6.3, 18.3, 28.2-3, Table 18-8]
Food Production & Livelihoods	• Impact on livelihoods of Arctic indigenous peoples, beyond effects of economic and sociopolitical changes (*medium confidence*, major contribution from climate change) • Increased shipping traffic across the Bering Strait (*medium confidence*, major contribution from climate change) [18.4, 28.2, Tables 18-4 and 18-9, Figure 28-4]
	Small Islands
Snow & Ice, Rivers & Lakes, Floods & Drought	• Increased water scarcity in Jamaica, beyond increase due to water use (*very low confidence*, minor contribution from climate change) [Table 18-6]
Terrestrial Ecosystems	• Tropical bird population changes in Mauritius (*medium confidence*, major contribution from climate change) • Decline of an endemic plant in Hawai'i (*medium confidence*, major contribution from climate change) • Upward trend in tree-lines and associated fauna on high-elevation islands (*low confidence*, minor contribution from climate change) [29.3, Table 18-7]
Coastal Erosion & Marine Ecosystems	• Increased coral bleaching near many tropical small islands, beyond effects of degradation due to fishing and pollution (*high confidence*, major contribution from climate change) • Degradation of mangroves, wetlands, and seagrass around small islands, beyond degradation due to other disturbances (*very low confidence*, minor contribution from climate change) • Increased flooding and erosion, beyond erosion due to human activities, natural erosion, and accretion (*low confidence*, minor contribution from climate change) • Degradation of groundwater and freshwater ecosystems due to saline intrusion, beyond degradation due to pollution and groundwater pumping (*low confidence*, minor contribution from climate change) [29.3, Table 18-8]
Food Production & Livelihoods	• Increased degradation of coastal fisheries due to direct effects and effects of increased coral reef bleaching, beyond degradation due to overfishing and pollution (*low confidence*, minor contribution from climate change) [18.3-4, 29.3, 30.6, Table 18-9, Box CC-CR]