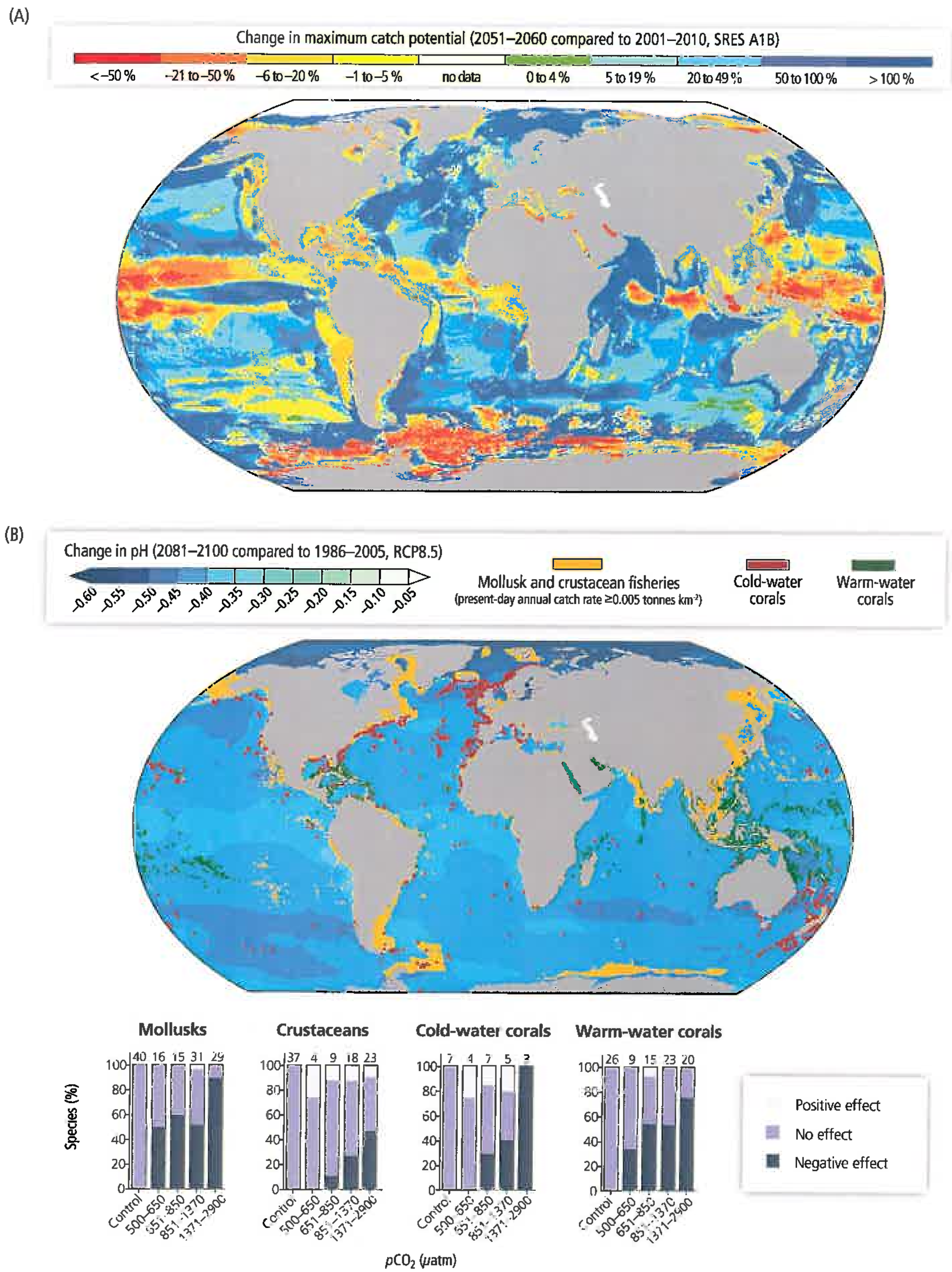
(A)
Change in maximum catch potential (2051–2060 compared to 2001–2010, SRES A1B)
< –50 %
–21 to –50 %
–6 to –20 %
–1 to –5 %
no data
0 to 4 %
5 to 19 %
20 to 49 %
50 to 100 %
> 100 %
(B)
Change in pH (2081–2100 compared to 1986–2005, RCP8.5)
–0.60
–0.55
–0.50
–0.45
–0.40
–0.35
–0.30
–0.25
–0.20
–0.15
–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 (%)
0
20
40
60
80
100
40 16 15 31 29
37 4 9 18 23
7 4 7 5 2
26 9 15 23 20
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

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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

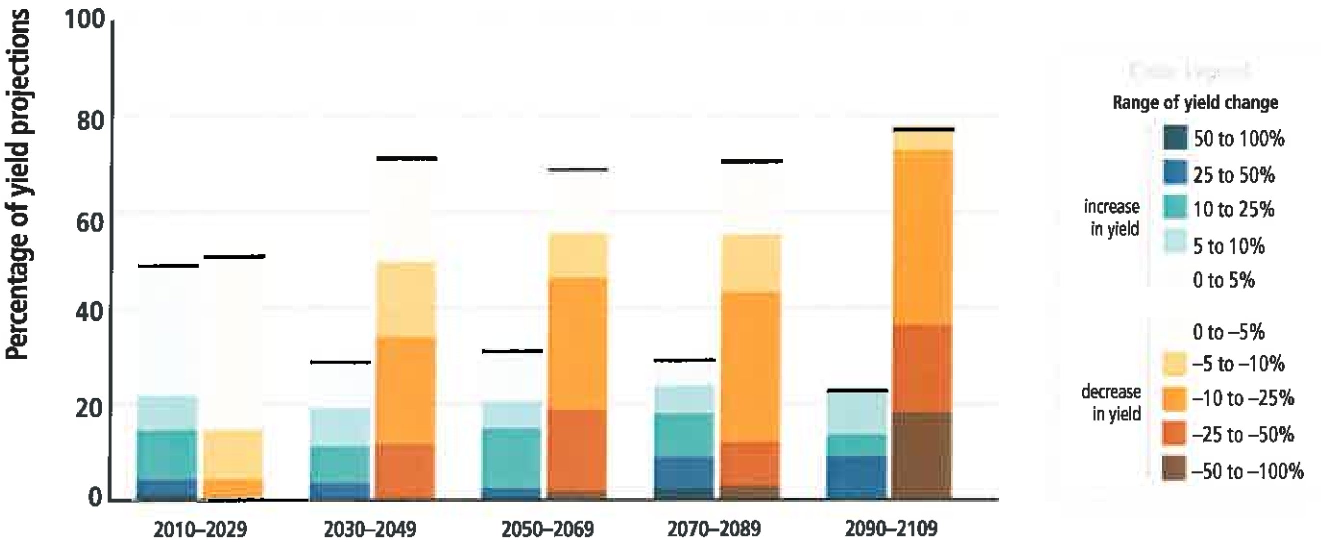

Figure SPM.7 | Summary of projected changes in crop yields, due to climate change over the 21st century. The figure includes projections for different emission scenarios, for tropical and temperate regions, and for adaptation and no-adaptation cases combined. Relatively few studies have considered impacts 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

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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

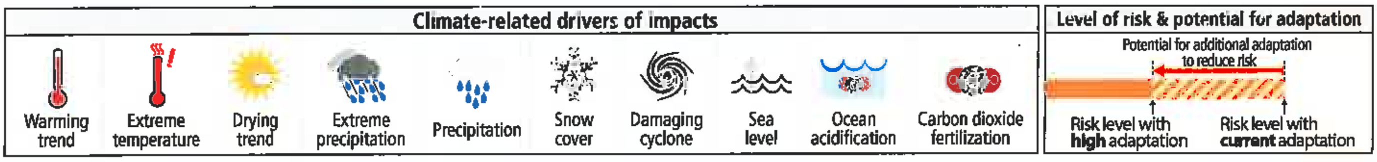
Risks will vary through time across regions and populations, dependent on myriad factors including the extent of adaptation and mitigation. A selection of key regional risks identified with *medium* to *high confidence* is presented in Assessment Box SPM.2. For extended summary of regional risks and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

Assessment Box SPM.2 | Regional Key Risks

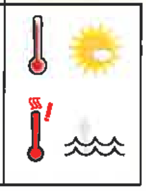
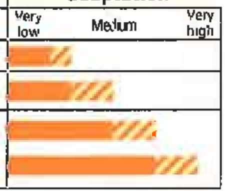
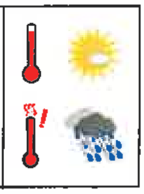
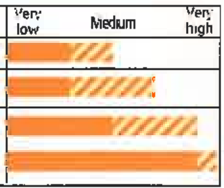
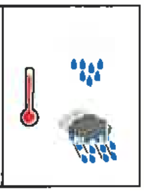
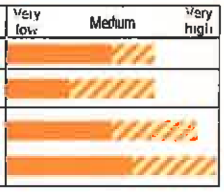
The accompanying Assessment Box SPM.2 Table 1 highlights several representative key risks for each region. Key risks have been identified based on assessment of the relevant scientific, technical, and socioeconomic literature detailed in supporting chapter sections. Identification of key risks was based 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	

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[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

Assessment Box SPM.2 Table 1 (continued)

Continued next page →

Europe

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation (Very low – Medium – Very high)
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	
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	
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	

Asia

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation (Very low – Medium – Very high)
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	
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	
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	

Assessment Box SPM.2 Table 1 (continued)

Continued next page →

Australasia

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
				Very low — Medium — Very high
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	

North America

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
				Very low — Medium — Very high
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	

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

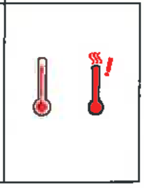
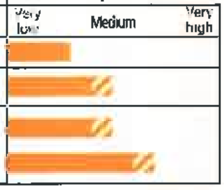
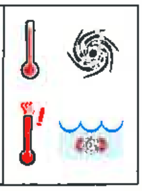
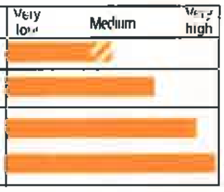
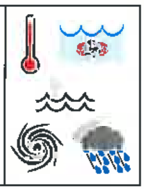
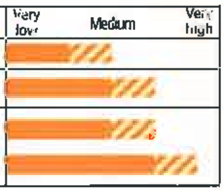
Polar Regions

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

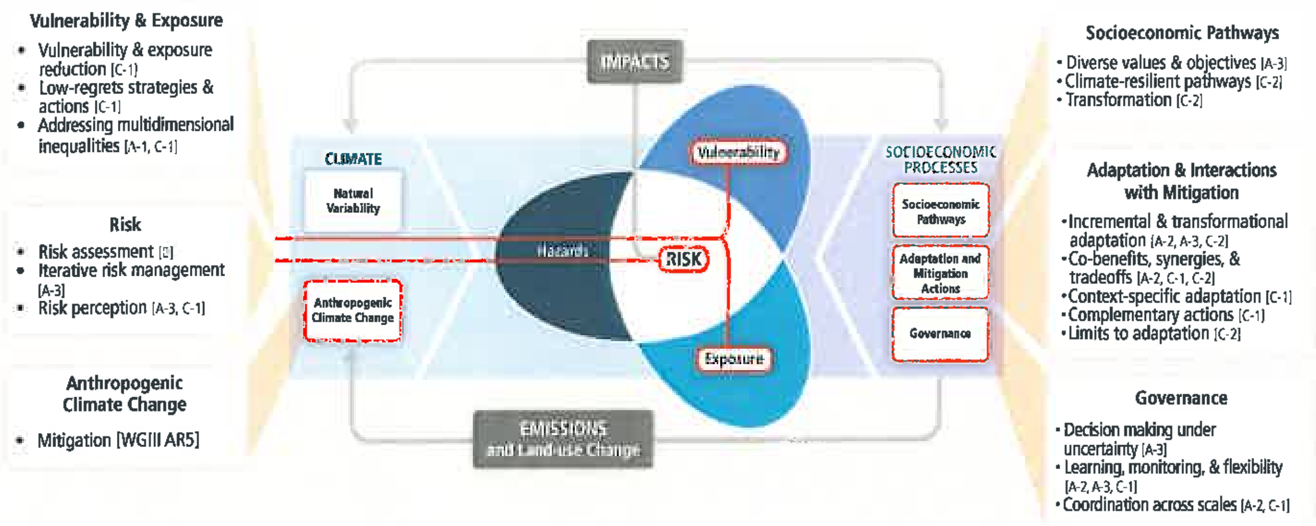


Figure SPM.8 | The solution space. Core concepts of the WGII AR5, illustrating overlapping entry points and approaches, as well as key considerations, in managing risks related to climate change, as assessed in this report and presented throughout this SPM. Bracketed references indicate sections of this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

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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
	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
Adaptation including incremental & transformational adjustments	Structural/physical	***Engineered & built-environment options***: Sea walls & coastal protection structures; Flood levees; Water storage; Improved drainage; Flood & cyclone shelters; Building codes & practices; Storm & wastewater management; Transport & road infrastructure improvements; Floating houses; Power plant & electricity grid adjustments.	3.5-6, 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]

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[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]

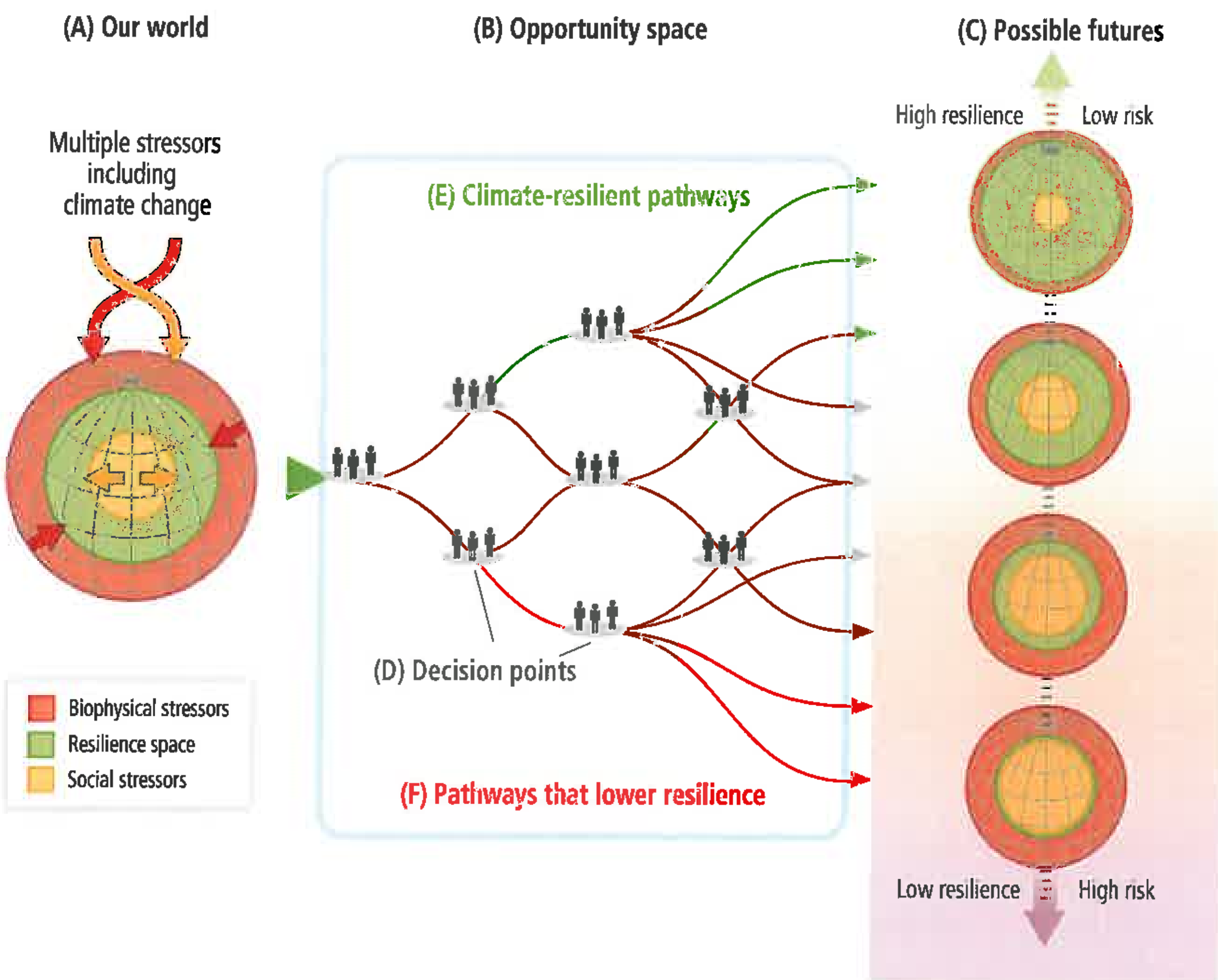

Figure SPM.9 | Opportunity space and climate-resilient pathways. (A) Our world [Sections A-1 and B-1] is threatened by multiple stressors that impinge on resilience from many directions, represented here simply as biophysical and social stressors. Stressors include climate change, climate variability,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

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]

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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]

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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]