Non-climate scenarios

While the CCIAV studies reported in the TAR typically applied one or more climate scenarios, very few applied contemporaneous scenarios of socio-economic, land-use or other environmental changes. Those that did used a range of sources to develop them. In contrast, AR4 studies which include SRES assumptions may now have several estimates, taking into account different storylines. The role of non-climate drivers such as technological change and regional land-use policy is shown in some studies to be more important in determining outcomes than climate change [2.4.6].

Scenarios of CO_2 concentration are required in some studies, as elevated concentrations can affect the acidity of the oceans and the growth and water use of many terrestrial plants. The observed CO_2 concentration in 2005 was about 380 ppm and was projected in the TAR using the Bern-CC model to rise to the following levels by the year 2100 for the SRES marker scenarios – B1: 540 ppm (range 486-681 ppm); A1T: 575 (506-735); B2: 611 (544-769); A1B: 703 (617-918); A2: 836 (735-1,080); A1FI: 958 (824-1,248) ppm. Values similar to these reference levels are commonly adopted in SRES-based impact studies [2.4.6.2]. Moreover, a multi-stressor approach can reveal important regional dependencies between drivers and their impacts (e.g., the

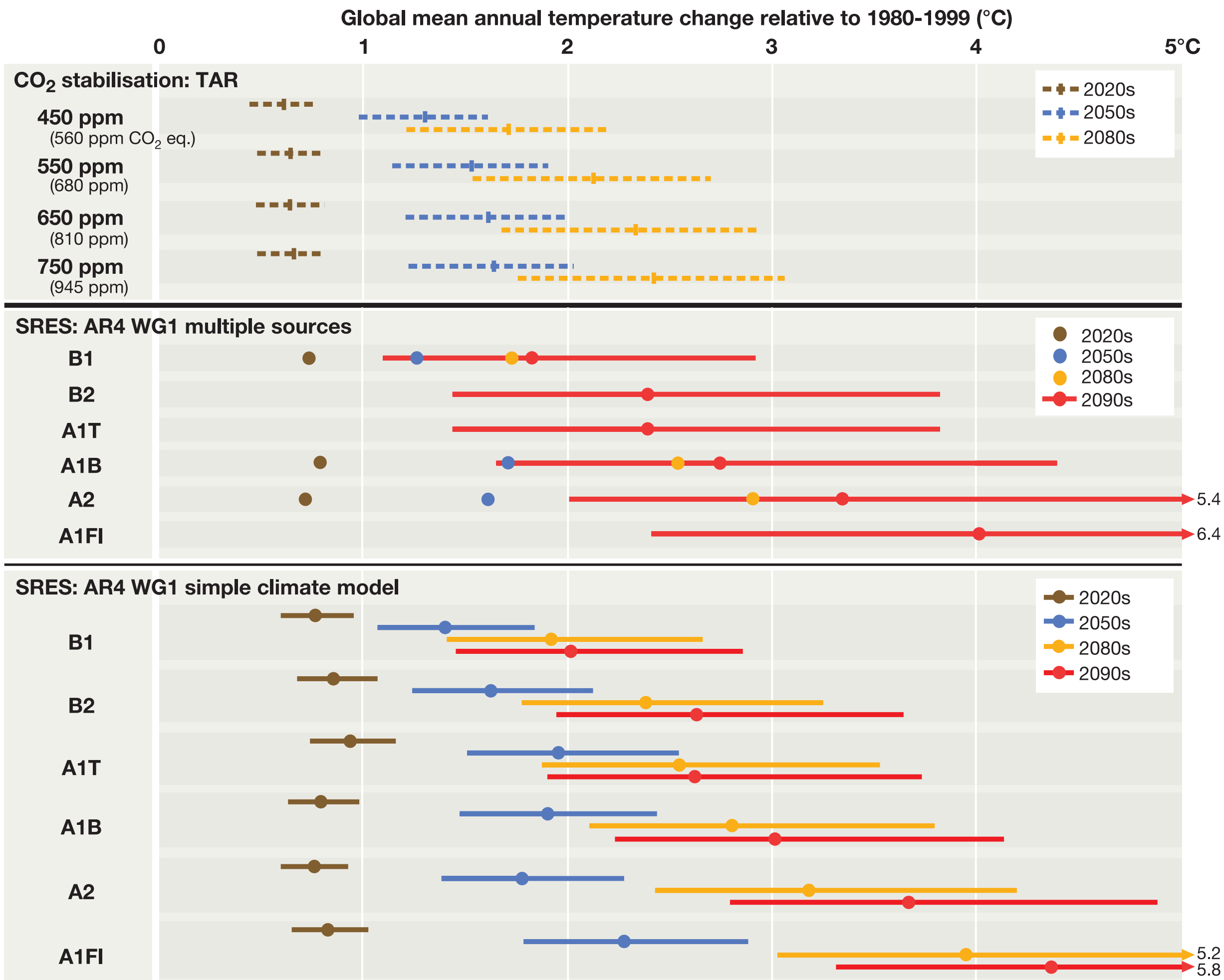

Figure TS.4. *Global temperature changes for selected time periods, relative to 1980-1999, projected for SRES and stabilisation scenarios. To express the temperature change relative to 1850-1899, add 0.5°C. More detail is provided in Chapter 2 [Box 2.8]. Estimates are for the 2020s, 2050s and 2080s, (the time periods used by the IPCC Data Distribution Centre and therefore in many impact studies) and for the 2090s. SRES-based projections are shown using two different approaches.* ***Middle panel:*** *projections from the WGI AR4 SPM based on multiple sources. Best estimates are based on AOGCMs (coloured dots). Uncertainty ranges, available only for the 2090s, are based on models, observational constraints and expert judgement.* ***Lower panel:*** *best estimates and uncertainty ranges based on a simple climate model (SCM), also from WGI AR4 (Chapter 10).* ***Upper panel:*** *best estimates and uncertainty ranges for four CO_2-stabilisation scenarios using an SCM. Results are from the TAR because comparable projections for the 21st century are not available in the AR4. However, estimates of equilibrium warming are reported in the WGI AR4 for CO_2-equivalent stabilisation[11]. Note that equilibrium temperatures would not be reached until decades or centuries after greenhouse gas stabilisation. Uncertainty ranges: middle panel, likely range (> 66% probability); lower panel, range between 19 estimates calculated assuming low carbon-cycle feedbacks (mean - 1 standard deviation) and those assuming high carbon-cycle feedbacks (mean + 1 standard deviation); upper panel, range across seven model tunings for medium carbon-cycle settings.*

[11] Best estimate and likely range of equilibrium warming for seven levels of CO_2-equivalent stabilisation from the WG1 AR4 are: 350 ppm, 1.0°C [0.6–1.4]; 450 ppm, 2.1°C [1.4–3.1]; 550 ppm, 2.9°C [1.9–4.4]; 650 ppm, 3.6°C [2.4–5.5]; 750 ppm, 4.3°C [2.8–6.4]; 1,000 ppm, 5.5°C [3.7–8.3] and 1,200 ppm, 6.3°C [4.2–9.4].

combined effects of extreme weather and air-pollution events on human health). This expansion of scenario scope and application has brought into focus the wide range of potential future impacts and their associated uncertainties [2.2.5, 2.5].

Mitigation/stabilisation scenarios

The SRES storylines assume that no specific climate policies will be implemented to reduce greenhouse gas emissions (i.e. mitigation). Projections of global mean warming during the 21st century for the six SRES scenarios using two different approaches reported by the WGI AR4 (Chapter 10) are depicted in the middle and lower panels of Figure TS-4. Even without assuming explicit climate policies, differences between projections of warming for alternative emissions scenarios by the end of the century can exceed 2°C [B2.8].

CCIAV studies assuming mitigated futures are beginning to assess the benefits (through impacts ameliorated or avoided) of climate policy decisions. Stabilisation scenarios are a type of mitigation scenario describing futures in which emissions reductions are undertaken so that greenhouse gas concentrations, radiative forcing or global average temperature changes do not exceed a prescribed limit. There have been very few studies of the impacts of climate change assuming stabilisation. One reason for this is that relatively few AOGCM stabilisation runs have been completed so far, although the situation is rapidly changing [2.4.6].

Greenhouse gas mitigation is expected to reduce global mean warming relative to baseline emissions, which in turn could avoid some adverse impacts of climate change. To indicate the projected effect of mitigation on temperature during the 21st century, and in the absence of more recent, comparable estimates in the WGI AR4, results from the Third Assessment Report using a simple climate model are reproduced in the upper panel of Figure TS-4. These portray the temperature response for four CO_2-stabilisation scenarios by three dates in the early (2025), mid (2055), and late (2085) 21st century[12] [B2.8].

Large-scale singularities

Very few studies have been conducted on the impacts of large-scale singularities, which are extreme, sometimes irreversible, changes in the Earth system such as an abrupt cessation of the North Atlantic Meridional Overturning Circulation, or rapid global sea-level rise due to Antarctic and/or Greenland ice sheet melting [2.4.7]. Due to incomplete understanding of the underlying mechanisms of these events, or their likelihood, only exploratory studies have been carried out. For example, in terms of exploring the worst-case scenario of abrupt sea-level rise, impact assessments have been conducted for the coastal zone for a 5 m rise, and for a 2.2 m rise by 2100 [2.4.7]. This is the first time these scenarios have been included in any WGII assessment, and the expectation is that many more such studies will become available for assessment in the future.

Probabilistic characterisations

Probabilistic characterisations of future climate and non-climate conditions are increasingly becoming available. A number of studies focused on the climate system have generated probabilistic estimates of climate change, conditional on selected or probabilistic emissions scenarios, the latter being a subject of considerable debate [2.4.8]. Probabilistic futures have been applied in a few CCIAV studies to estimate the risk of exceeding predefined thresholds of impact and the associated timing of such exceedances [2.3.1].

TS.4 Current knowledge about future impacts

This section summarises the main projected impacts in each system and sector (Section TS.4.1) and region (Section TS.4.2) over this century,[13] judged in terms of relevance for people and the environment. It assumes that climate change is not mitigated, and that adaptive capacity has not been enhanced by climate policy. All global temperature changes are expressed relative to 1990 unless otherwise stated.[14] The impacts stem from changes in climate and sea-level changes associated with global temperature change, and frequently reflect projected changes in precipitation and other climate variables in addition to temperature.

TS.4.1 Sectoral impacts, adaptation and vulnerability

A summary of impacts projected for each sector is given in Box TS.5.

Freshwater resources and their management

The impacts of climate change on freshwater systems and their management are mainly due to the observed and projected increases in temperature, evaporation, sea level and precipitation variability (very high confidence).
More than one-sixth of the world's population live in glacier- or snowmelt-fed river basins and will be affected by a decrease in water volume stored in glaciers and snowpack, an increase in the ratio of winter to annual flows, and possibly a reduction in low flows caused by decreased glacier extent or melt-season snow water storage [3.4.1, 3.4.3]. Sea-level rise will extend areas of salinisation of groundwater and estuaries, resulting in a decrease in freshwater availability for humans and ecosystems in coastal areas [3.2, 3.4.2]. Increased precipitation intensity and variability is projected to increase the risk of floods and droughts in many areas [3.3.1]. Up to 20% of the world's population live in river basins that are likely to be affected by increased flood hazard by the 2080s in the course of global warming [3.4.3].

[12] WRE stabilisation profiles were used in the TAR, and a description is given in the TAR Synthesis Report.
[13] Unless otherwise stated.
[14] To express the temperature change relative to pre-industrial (about 1750) levels, add 0.6°C.

The number of people living in severely stressed river basins is projected to increase significantly from 1.4-1.6 billion in 1995 to 4.3-6.9 billion in 2050, for the SRES A2 scenario (medium confidence).
The population at risk of increasing water stress for the full range of SRES scenarios is projected to be: 0.4-1.7 billion, 1.0-2.0 billion and 1.1-3.2 billion, in the 2020s, 2050s and 2080s, respectively [3.5.1]. In the 2050s (A2 scenario), 262-983 million people are likely to move into the water-stressed category [3.5.1]. Water stress is projected to decrease by the 2050s on 20-29% of the global land area (considering two climate models and the SRES scenarios A2 and B2) and to increase on 62-76% of the global land area [3.5.1].

Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater (high confidence).
Many of these areas (e.g., Mediterranean Basin, western USA, southern Africa, north-eastern Brazil, southern and eastern Australia) will suffer a decrease in water resources due to climate change (see Figure TS.5) [3.4, 3.7]. Efforts to offset declining surface water availability due to increasing precipitation variability will be hampered by the fact that groundwater recharge is likely to decrease considerably in some already water-stressed regions [3.4.2], where vulnerability is often exacerbated by the rapid increase of population and water demand [3.5.1].

Higher water temperatures, increased precipitation intensity and longer periods of low flows are likely to exacerbate many forms of water pollution, with impacts on ecosystems, human health, and water system reliability and operating costs (high confidence).
These pollutants include sediments, nutrients, dissolved organic carbon, pathogens, pesticides, salt and thermal pollution [3.2, 3.4.4, 3.4.5].

Climate change affects the function and operation of existing water infrastructure as well as water management practices (very high confidence).
Adverse effects of climate on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land-use change and urbanisation [3.3.2, 3.5]. Globally, water demand will grow in the coming decades, primarily due to population growth and increased affluence. Regionally, large changes in irrigation water demand as a result of climate change are likely [3.5.1]. Current water management practices are very likely to be inadequate to reduce the negative impacts of climate change on water-supply reliability, flood risk, health, energy and aquatic ecosystems [3.4, 3.5]. Improved incorporation of current climate variability into water-related management is likely to make adaptation to future climate change easier [3.6].

Adaptation procedures and risk management practices for the water sector are being developed in some countries and regions (e.g., Caribbean, Canada, Australia, Netherlands, UK, USA, Germany) that recognise the uncertainty of projected hydrological changes (very high confidence).
Since the IPCC Third Assessment, uncertainties have been evaluated and their interpretation has improved, and new methods (e.g., ensemble-based approaches) are being developed for their characterisation [3.4, 3.5]. Nevertheless, quantitative projections of changes in precipitation, river flows and water levels at the river-basin scale remain uncertain [3.3.1, 3.4].

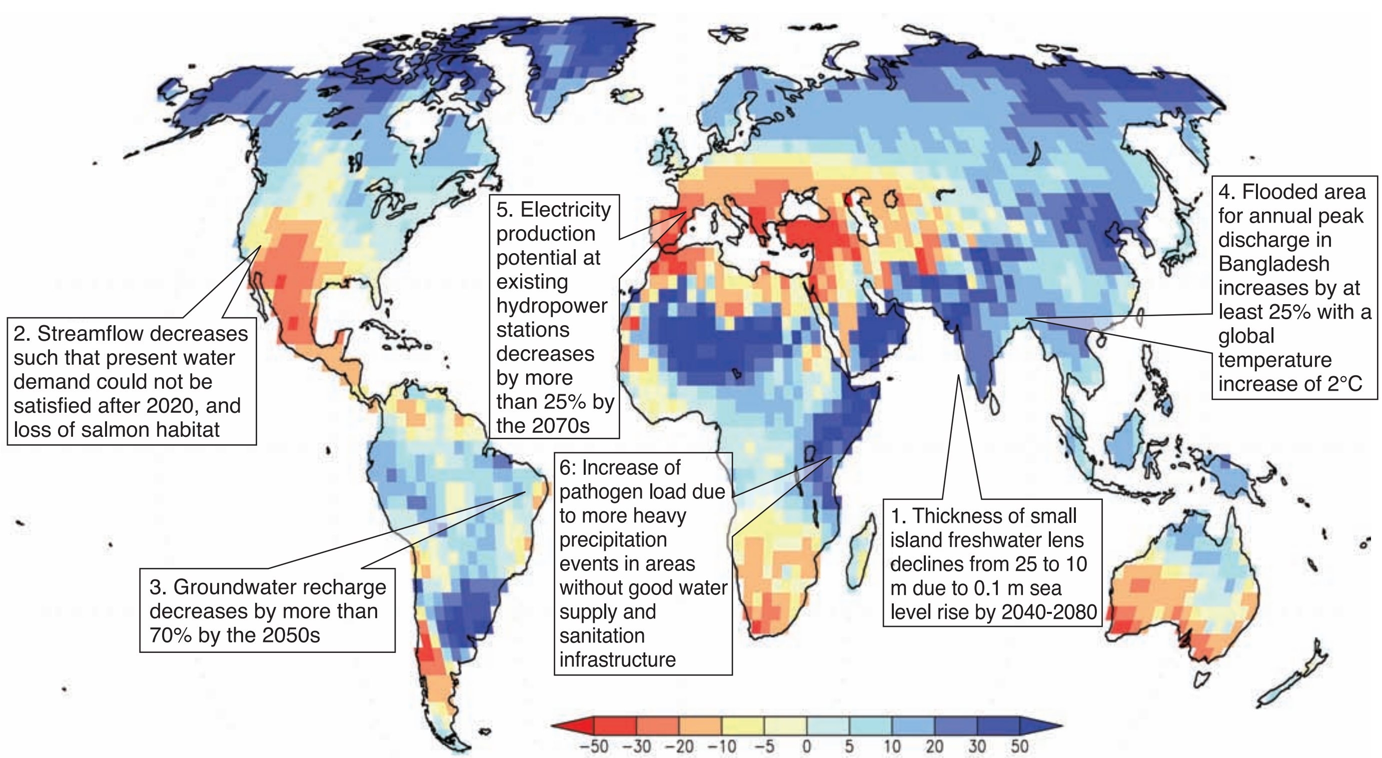

Figure TS.5. *Illustrative map of future climate change impacts on freshwater which are a threat to the sustainable development of the affected regions. Background shows ensemble mean change of annual runoff, in percent, between the present (1981-2000) and 2081-2100 for the SRES A1B emissions scenario; blue denotes increased runoff, red denotes decreased runoff. [F3.2]*

The negative impacts of climate change on freshwater systems outweigh its benefits (high confidence).

All IPCC regions show an overall net negative impact of climate change on water resources and freshwater ecosystems. Areas in which runoff is projected to decline are likely to face a reduction in the value of the services provided by water resources. The beneficial impacts of increased annual runoff in other areas is likely to be tempered in some areas by negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risks (see Figure TS.5) [3.4, 3.5].

Ecosystems

Records of the geological past show that ecosystems have some capacity to adapt naturally to climate change [WGI AR4 Chapter 6; 4.2], but this resilience[15] has never been challenged by a large global human population and its multi-faceted demands from and pressures on ecosystems [4.1, 4.2].

The resilience of many ecosystems (their ability to adapt naturally) is likely to be exceeded by 2100 by an unprecedented combination of change in climate, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification), and other global change drivers (e.g., land-use change, pollution, over-exploitation of resources) (high confidence).

Ecosystems are very likely to be exposed to atmospheric CO_2 levels much higher than in the past 650,000 years, and global mean temperatures at least as high as those in the past 740,000 years [WGI AR4 Chapter 6; 4.2, 4.4.10, 4.4.11]. By 2100, ocean pH is very likely to be lower than during the last 20 million years [4.4.9]. Extractive use from and fragmentation of wild habitats are very likely to impair species' adaptation [4.1.2, 4.1.3, 4.2, 4.4.5, 4.4.10]. Exceedance of ecosystem resilience is very likely to be characterised by threshold-type responses, many irreversible on time-scales relevant to human society, such as biodiversity loss through extinction, disruption of species' ecological interactions, and major changes in ecosystem structure and disturbance regimes (especially wildfire and insects) (see Figure TS.6). Key ecosystem properties (e.g., biodiversity) or regulating services (e.g., carbon sequestration) are very likely to be impaired [4.2, 4.4.1, 4.4.2 to 4.4.9, 4.4.10, 4.4.11, F4.4, T4.1].

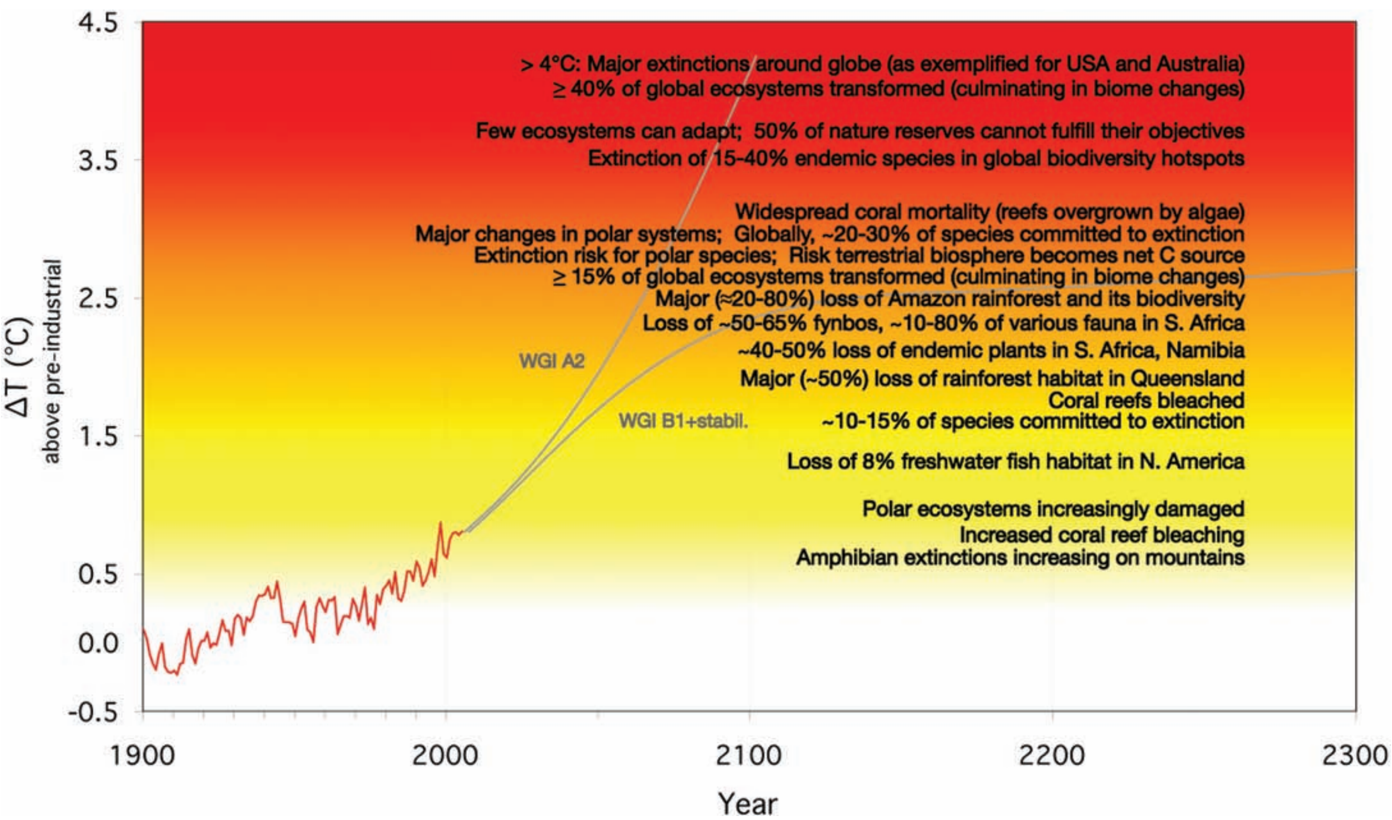

Figure TS.6. Compendium of projected risks due to critical climate change impacts on ecosystems for different levels of global mean annual temperature rise, ΔT, relative to pre-industrial climate, used as a proxy for climate change. The red curve shows observed temperature anomalies for the period 1900-2005 [WGI AR4 F3.6]. The two grey curves provide examples of the possible future evolution of global average temperature change (ΔT) with time [WGI AR4 F10.4] exemplified by WGI simulated, multi-model mean responses to (i) the A2 radiative forcing scenario (WGI A2) and (ii) an extended B1 scenario (WGI B1+stabil.), where radiative forcing beyond 2100 was kept constant at the 2100 value [WGI AR4 F10.4, 10.7]. White shading indicates neutral, small negative, or positive impacts or risks; yellow indicates negative impacts for some systems or low risks; and red indicates negative impacts or risks that are more widespread and/or greater in magnitude. Illustrated impacts take into account climate change impacts only, and omit effects of land-use change or habitat fragmentation, over-harvesting or pollution (e.g., nitrogen deposition). A few, however, take into account fire regime changes, several account for likely productivity-enhancing effects of rising atmospheric CO_2 and some account for migration effects. [F4.4, T4.1]

[15] *Resilience* is defined as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt naturally to stress and change.

The terrestrial biosphere is likely to become a net carbon source by 2100, thus amplifying climate change, given continued greenhouse gas emissions at or above current rates and other unmitigated global changes, such as land-use changes (high confidence).

Several major terrestrial carbon stocks are vulnerable to climate change and/or land-use impacts [F4.1, 4.4.1, F4.2, 4.4.5, 4.4.6, 4.4.10, F4.3]. The terrestrial biosphere currently serves as a variable, but generally increasing, carbon sink (due to CO_2-fertilisation, moderate climate change and other effects) but this is likely to peak before mid-century and then tend towards a net carbon source, thus amplifying climate change [F4.2, 4.4.1, 4.4.10, F4.3, 4.4.11], while ocean buffering capacity begins saturating [WGI AR4, e.g., 7.3.5]. This is likely to occur before 2100, assuming continued greenhouse gas emissions at or above current rates and unmitigated global change drivers including land-use changes, notably tropical deforestation. Methane emissions from tundra are likely to accelerate [4.4.6].

Roughly 20 to 30% (varying among regional biotas from 1% to 80%) of species assessed so far (in an unbiased sample) are likely to be at increasingly high risk of extinction as global mean temperatures exceed 2 to 3°C above pre-industrial levels (medium confidence).

Global losses of biodiversity are of key relevance, being irreversible [4.4.10, 4.4.11, F4.4, T4.1]. Endemic species richness is highest where regional palaeo-climatic changes have been muted, indicating that endemics are likely to be at a greater extinction risk than in the geological past [4.4.5, 4.4.11, F4.4, T4.1]. Ocean acidification is likely to impair aragonite-based shell formation in a wide range of planktonic and shallow benthic marine organisms [4.4.9, B4.4]. Conservation practices are generally ill-prepared for climate change, and effective adaptation responses are likely to be costly to implement [4.4.11, T4.1, 4.6.1]. Although links between biodiversity intactness and ecosystem services remain quantitatively uncertain, there is high confidence that the relationship is qualitatively positive [4.1, 4.4.11, 4.6, 4.8].

Substantial changes in structure and functioning of terrestrial and marine ecosystems are very likely to occur with a global warming of 2 to 3°C above pre-industrial levels and associated increased atmospheric CO_2 (high confidence).

Major biome changes, including emergence of novel biomes, and changes in species' ecological interactions, with predominantly negative consequences for goods and services, are very likely by, and virtually certain beyond, those temperature increases [4.4]. The previously overlooked progressive acidification of oceans due to increasing atmospheric CO_2 is expected to have negative impacts on marine shell-forming organisms (e.g., corals) and their dependent species [B4.4, 6.4].

Food, fibre and forest products

In mid- to high-latitude regions, moderate warming benefits cereal crop and pasture yields, but even slight warming decreases yields in seasonally dry and tropical regions (medium confidence).

Modelling results for a range of sites find that, in temperate regions, moderate to medium increases in local mean temperature (1 to 3°C), along with associated CO_2 increase and rainfall changes, can have small beneficial impacts on crop yields. At lower latitudes, especially the seasonally dry tropics, even moderate temperature increases (1 to 2°C) are likely to have negative yield impacts for major cereals, which would increase the risk of hunger. Further warming has increasingly negative impacts in all regions (medium to low confidence) (see Figure TS.7) [5.4].

Climate change increases the number of people at risk of hunger marginally, with respect to overall large reductions due to socio-economic development (medium confidence).

Compared with 820 million undernourished today, SRES scenarios of socio-economic development, without climate change, project 100-240 million undernourished for the SRES A1, B1 and B2 scenarios (770 million under the A2 scenario) in 2080 (medium confidence). Scenarios with climate change project 100-380 million undernourished for the SRES A1, B1 and B2 scenarios (740-1,300 million under the A2 scenario) in 2080 (low to medium confidence). The ranges here indicate the extent of effects of the exclusion and inclusion of CO_2 effects in the scenarios. Climate change and socio-economics combine to alter the regional distribution of hunger, with large negative effects on sub-Saharan Africa (low to medium confidence) [5.4, T5.6].

Projected changes in the frequency and severity of extreme climate events have significant consequences on food and forestry production, and food insecurity, in addition to impacts of projected mean climate (high confidence).

Recent studies indicate that increased frequency of heat stress, droughts and floods negatively affects crop yields and livestock beyond the impacts of mean climate change, creating the possibility for surprises, with impacts that are larger, and occur earlier, than predicted using changes in mean variables alone [5.4.1, 5.4.2]. This is especially the case for subsistence sectors at low latitudes. Climate variability and change also modify the risks of fires, pest and pathogen outbreaks, negatively affecting food, fibre and forestry (high confidence) [5.4.1 to 5.4.5, 5.ES].

Simulations suggest rising relative benefits of adaptation with low to moderate warming (medium confidence), although adaptation may stress water and environmental resources as warming increases (low confidence).

There are multiple adaptation options that imply different costs, ranging from changing practices in place to changing locations of food, fibre and forest activities [5.5.1]. Adaptation effectiveness varies from only marginally reducing negative impacts to changing a negative impact into a positive one. On average, in cereal-cropping systems, adaptations such as changing varieties and planting times enable avoidance of a 10 to 15% reduction in yield, corresponding to 1 to 2°C local temperature increases. The benefit from adapting tends to increase with the degree of climate change [F5.2]. Changes in policies and institutions are needed to facilitate adaptation. Pressure to cultivate marginal land or to adopt unsustainable cultivation practices may increase land degradation and resource use, and endanger biodiversity of both wild and domestic species

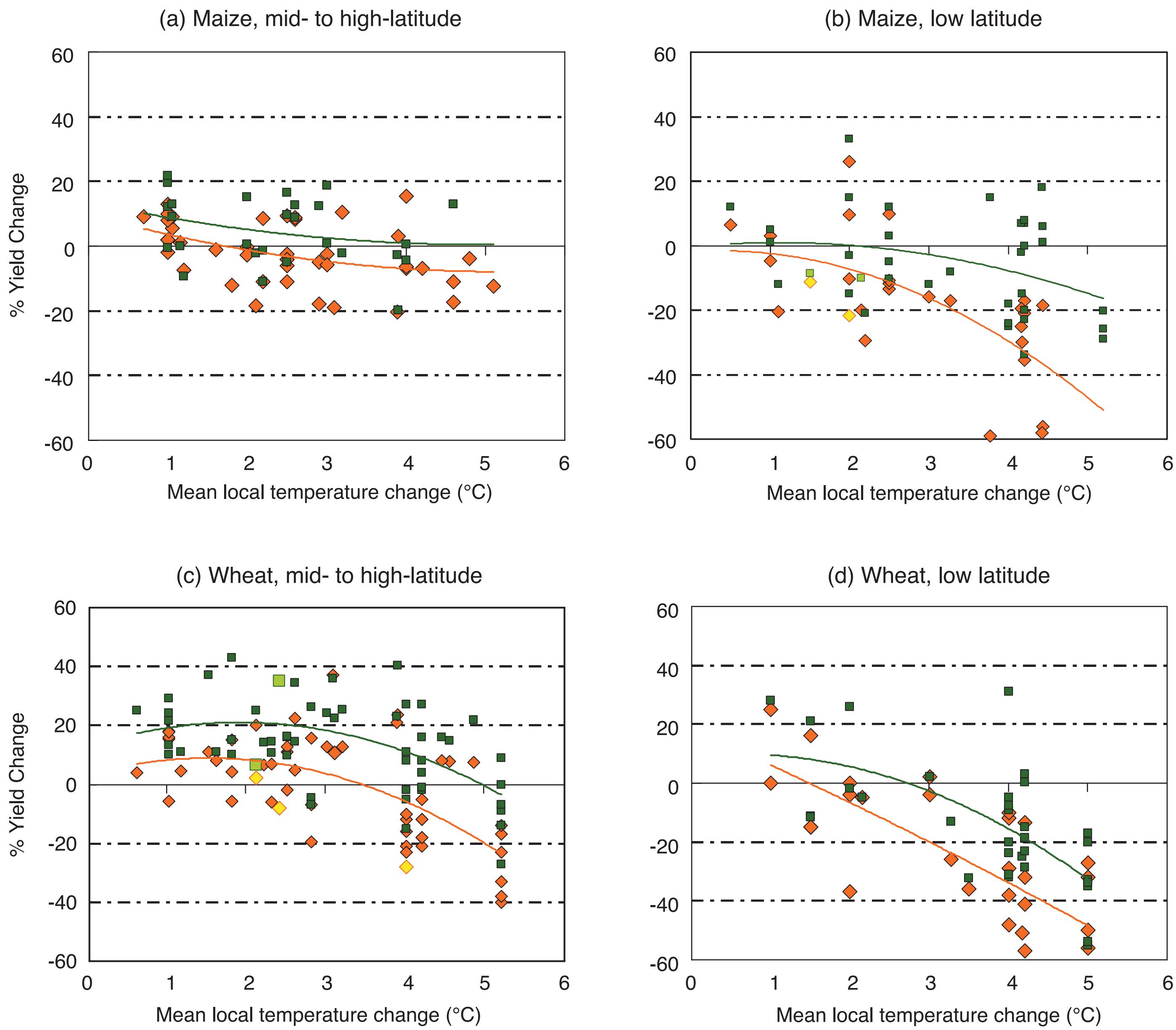

Figure TS.7. *Sensitivity of cereal yield to climate change for maize and wheat. Responses include cases without adaptation (orange dots) and with adaptation (green dots). The studies on which this figure is based span a range of precipitation changes and CO_2 concentrations, and vary in how they represent future changes in climate variability. For instance, lighter-coloured dots in (b) and (c) represent responses of rain-fed crops under climate scenarios with decreased precipitation. [F5.4]*

[5.4.7]. Adaptation measures should be integrated with development strategies and programmes, country programmes and poverty-reduction strategies [5.7].

Smallholder and subsistence farmers, pastoralists and artisanal fisherfolk are likely to suffer complex, localised impacts of climate change (high confidence).
These groups, whose adaptive capacity is constrained, are likely to experience negative effects on yields of tropical crops, combined with a high vulnerability to extreme events. In the longer term, there are likely to be additional negative impacts of other climate-related processes such as snowpack decrease especially in the Indo-Gangetic Plain, sea-level rise, and a spread in the prevalence of human diseases affecting agricultural labour supply (high confidence) [5.4.7].

Globally, forestry production is estimated to change only modestly with climate change in the short and medium term (medium confidence).
The change in global forest product outputs ranges from a modest increase to a slight decrease, although regional and local changes are likely to be large [5.4.5.2]. Production increase is likely to shift from low-latitude regions in the short term, to high-latitude regions in the long term [5.4.5].

Local extinctions of particular fish species are expected at edges of ranges (high confidence).
It is likely that regional changes in the distribution and productivity of particular fish species will continue and local extinctions will occur at the edges of ranges, particularly in freshwater and diadromous species (e.g., salmon, sturgeon). In

some cases, ranges and productivity are likely to increase [5.4.6]. Emerging evidence suggests concern that the Meridional Overturning Circulation is slowing down, with potentially serious consequences for fisheries [5.4.6].

Food and forestry trade is projected to increase in response to climate change, with increased food-import dependence of most developing countries (medium to low confidence). While the purchasing power for food is likely to be reinforced in the period to 2050 by declining real prices, it would be adversely affected by higher real prices for food from 2050 to 2080 due to climate change [5.6.1, 5.6.2]. Exports of temperate-zone food products to tropical countries are likely to rise [5.6.2], while the reverse is likely in forestry in the short term [5.4.5].

Experimental research on crop response to elevated CO_2 confirms TAR reviews (medium to high confidence). New results suggest lower responses for forests (medium confidence). Recent reanalyses of free-air carbon dioxide enrichment (FACE) studies indicate that, at 550 ppm CO_2, yields increase under unstressed conditions by 10 to 20% over current concentrations for C3 crops, and by 0 to 10% for C4 crops (medium confidence). Crop model simulations under elevated CO_2 are consistent with these ranges (high confidence) [5.4.1]. Recent FACE results suggest no significant response for mature forest stands and confirm enhanced growth for young tree stands [5.4.1]. Ozone exposure limits CO_2 response in both crops and forests [B5.2].

Coastal systems and low-lying areas

Since the TAR, our understanding of the implications of climate change for coastal systems and low-lying areas (henceforth referred to as 'coasts') has increased substantially, and six important policy-relevant messages emerge.

Coasts are experiencing the adverse consequences of hazards related to climate and sea level (very high confidence). Coasts are highly vulnerable to extreme events, such as storms, which impose substantial costs on coastal societies [6.2.1, 6.2.2, 6.5.2]. Annually, about 120 million people are exposed to tropical cyclone hazards. These killed 250,000 people from 1980 to 2000 [6.5.2]. Throughout the 20th century, the global rise of sea level contributed to increased coastal inundation, erosion and ecosystem losses, but the precise role of sea-level rise is difficult to determine due to considerable regional and local variation due to other factors [6.2.5, 6.4.1]. Late 20th century effects of rising temperature include loss of sea ice, thawing of permafrost and associated coastal retreat at high latitudes, and more frequent coral bleaching and mortality at low latitudes [6.2.5].

Coasts are very likely to be exposed to increasing risks in future decades due to many compounding climate-change factors (very high confidence). Anticipated climate-related changes include: an accelerated rise in sea level of 0.2 to 0.6 m or more by 2100; further rise in sea surface temperatures of 1 to 3°C; more intense tropical and extra-tropical cyclones; generally larger extreme wave and storm surges; altered precipitation/runoff; and ocean acidification [WG1 AR4 Chapter 10; 6.3.2]. These phenomena will vary considerably at regional and local scales, but the impacts are virtually certain to be overwhelmingly negative [6.4, 6.5.3]. Coastal wetland ecosystems, such as salt marshes and mangroves, are very likely threatened where they are sediment-starved or constrained on their landward margin [6.4.1]. The degradation of coastal ecosystems, especially wetlands and coral reefs, has serious implications for the well-being of societies dependent on coastal ecosystems for goods and services [6.4.2, 6.5.3]. Increased flooding and the degradation of freshwater, fisheries and other resources could impact hundreds of millions of people, and socio-economic costs for coasts are virtually certain to escalate as a result of climate change [6.4.2, 6.5.3].

The impact of climate change on coasts is exacerbated by increasing human-induced pressures (very high confidence). Utilisation of the coast increased dramatically during the 20th century and this trend is virtually certain to continue through the 21st century. Under the SRES scenarios, the coastal population could grow from 1.2 billion people (in 1990) to between 1.8 billion and 5.2 billion people by the 2080s, depending on future trends in coastward migration [6.3.1]. Hundreds of millions of people and major assets at risk at the coast are subject to additional stresses by land-use and hydrological changes in catchments, including dams that reduce sediment supply to the coast [6.3]. Three key hotspots of societal vulnerability are: (i) deltas (see Figure TS.8), especially the seven Asian megadeltas with a collective population already exceeding 200 million; (ii) low-lying coastal urban areas, especially those prone to subsidence; and (iii) small islands, especially coral atolls [6.4.3].

Adaptation for the coasts of developing countries is virtually certain to be more challenging than for coasts of developed countries (high confidence). Developing countries already experience the most severe impacts from present coastal hazards [6.5.2]. This is virtually certain to continue under climate change, even allowing for optimum adaptation, with Asia and Africa most exposed [6.4.2, B6.6, F6.4, 6.5.3]. Developing countries have a more limited adaptive capacity due to their development status, with the most vulnerable areas being concentrated in exposed or sensitive settings such as small islands or deltas [6.4.3]. Adaptation in developing countries will be most challenging in these vulnerable 'hotspots' [6.4.3].

Adaptation costs for vulnerable coasts are much less than the costs of inaction (high confidence). Adaptation costs for climate change are virtually certain to be much lower than damage costs without adaptation for most developed coasts, even considering only property losses and human deaths [6.6.2, 6.6.3]. As post-event impacts on coastal businesses, people, housing, public and private social institutions, natural resources and the environment generally go unrecognised in disaster cost accounting, it is virtually certain that the full benefits of adaptation are even larger [6.5.2, 6.6.2]. Without action, the highest sea-level scenarios combined with other climate change (e.g., increased storm intensity) are about as likely as not to make some low-lying islands and other low-lying areas

Figure TS.8. *Relative vulnerability of coastal deltas as indicated by estimates of the population potentially displaced by current sea-level trends to 2050 (extreme >1 million; high 1 million to 50,000; medium 50,000 to 5,000) [B6.3]. Climate change would exacerbate these impacts.*

(e.g., in deltas and megadeltas) uninhabitable by 2100 [6.6.3]. Effective adaptation to climate change can be integrated with wider coastal management, reducing implementation costs among other benefits [6.6.1.3].

The unavoidability of sea-level rise, even in the longer term, frequently conflicts with present-day human development patterns and trends (high confidence).
Sea-level rise has substantial inertia and will continue beyond 2100 for many centuries [WG1 AR4 Chapter 10]. Breakdown of the West Antarctic and/or Greenland ice sheets would make this long-term rise significantly larger. For Greenland, the temperature threshold for breakdown is estimated to be about 1.1 to 3.8°C above today's global average temperature. This is likely to happen by 2100 under the A1B scenario [WG1 AR4 Chapter 10]. This questions both the long-term viability of many coastal settlements and infrastructure (e.g., nuclear power stations) across the globe and the current trend of increasing human use of the coastal zone, including a significant coastward migration. This issue presents a challenge for long-term coastal spatial planning. Stabilisation of climate is likely to reduce the risks of ice sheet breakdown, and reduce but not stop sea-level rise due to thermal expansion [B6.6]. Hence, since the IPCC Third Assessment it has become virtually certain that the most appropriate response to sea-level rise for coastal areas is a combination of adaptation to deal with the inevitable rise, and mitigation to limit the long-term rise to a manageable level [6.6.5, 6.7].

Industry, settlement and society

Virtually all of the world's people live in settlements, and many depend on industry, services and infrastructure for jobs, well-being and mobility. For these people, climate change adds a new challenge in assuring sustainable development for societies across the globe. Impacts associated with this challenge will be determined mainly by trends in human systems in future decades as climate conditions exacerbate or ameliorate stresses associated with non-climate systems [7.1.1, 7.4, 7.6, 7.7].

Inherent uncertainties in predicting the path of technological and institutional change and trends in socio-economic development over a period of many decades limit the potential to project future prospects for industry, settlements and society involving *considerable* climate change from prospects involving relatively little climate change. In many cases, therefore, research to date has tended to focus on *vulnerabilities to impacts* rather than on *projections of impacts* of change, saying more about what could happen than about what is expected to happen [7.4].

Key vulnerabilities of industry, settlements and society are most often related to (i) climate phenomena that exceed thresholds for adaptation, related to the rate and magnitude of climate change, particularly extreme weather events and/or abrupt climate change, and (ii) limited access to resources (financial, human, institutional) to cope, rooted in issues of development context (see Table TS.1) [7.4.1, 7.4.3, 7.6, 7.7].

Findings about the context for assessing vulnerabilities are as follows.

Climate change vulnerabilities of industry, settlement and society are mainly to extreme weather events rather than to gradual climate change, although gradual changes can be associated with thresholds beyond which impacts become significant (high confidence).
The significance of gradual climate change, e.g., increases in the mean temperature, lies mainly in variability and volatility, including changes in the intensity and frequency of extreme events [7.2, 7.4].

Climate driven phenomena	Evidence for current impact/vulnerability	Other processes/stresses	Projected future impact/vulnerability	Zones, groups affected
a) Changes in extremes				
Tropical cyclones, storm surge	Flood and wind casualties and damages; economic losses; transport, tourism; infrastructure (e.g., energy, transport); insurance [7.4.2, 7.4.3, B7.2, 7.5].	Land use/population density in flood-prone areas; flood defences; institutional capacities.	Increased vulnerability in storm-prone coastal areas; possible effects on settlements, health, tourism, economic and transportation systems, buildings and infrastructure.	Coastal areas, settlements, and activities; regions and populations with limited capacities and resources; fixed infrastructure; insurance sector.
Extreme rainfall, riverine floods	Erosion/landslides; land flooding; settlements; transportation systems; infrastructure [7.4.2, regional chapters].	Similar to coastal storms plus drainage infrastructure.	Similar to coastal storms plus drainage infrastructure.	Similar to coastal storms.
Heat- or cold-waves	Effects on human health; social stability; requirements for energy, water and other services (e.g., water or food storage); infrastructure (e.g., energy transportation) [7.2, B7.1, 7.4.2.2, 7.4.2.3].	Building design and internal temperature control; social contexts; institutional capacities.	Increased vulnerabilities in some regions and populations; health effects; changes in energy requirements.	Mid-latitude areas; elderly, very young, and/or very poor populations.
Drought	Water availability; livelihoods, energy generation, migration, transportation in water bodies [7.4.2.2, 7.4.2.3, 7.4.2.5].	Water systems; competing water uses; energy demand; water demand constraints.	Water-resource challenges in affected areas; shifts in locations of population and economic activities; additional investments in water supply.	Semi-arid and arid regions; poor areas and populations; areas with human-induced water scarcity.
b) Changes in means				
Temperature	Energy demands and costs; urban air quality; thawing of permafrost soils; tourism and recreation; retail consumption; livelihoods; loss of meltwater [7.4.2.1, 7.4.2.2, 7.4.2.4, 7.4.2.5].	Demographic and economic changes; land-use changes; technological innovations; air pollution; institutional capacities.	Shifts in energy demand; worsening of air quality; impacts on settlements and livelihoods depending on meltwater; threats to settlements/infrastructure from thawing permafrost soils in some regions.	Very diverse, but greater vulnerabilities in places and populations with more limited capacities and resources for adaptation.
Precipitation	Agricultural livelihoods; saline intrusion; water infrastructures; tourism; energy supplies [7.4.2.1, 7.4.2.2, 7.4.2.3].	Competition from other regions/sectors; water resource allocation.	Depending on the region, vulnerabilities in some areas to effects of precipitation increases (e.g., flooding, but could be positive) and in some areas to decreases (see drought above).	Poor regions and populations.
Sea-level rise	Coastal land uses: flood risk, waterlogging; water infrastructures [7.4.2.3, 7.4.2.4].	Trends in coastal development, settlements and land uses.	Long-term increases in vulnerabilities of low-lying coastal areas.	Same as above.

Table TS.1. *Selected examples of current and projected climate-change impacts on industry, settlement and society and their interaction with other processes [for full text, see 7.4.3, T7.4]. Orange shading indicates very significant in some areas and/or sectors; yellow indicates significant; pale brown indicates that significance is less clearly established.*

Aside from major extreme events, climate change is seldom the main factor in considering stresses on sustainability (very high confidence).
The significance of climate change (positive or negative) lies in its interactions with other sources of change and stress, and its impacts should be considered in such a multi-cause context [7.1.3, 7.2, 7.4].

Vulnerabilities to climate change depend considerably on relatively specific geographical and sectoral contexts (very high confidence).
They are not reliably estimated by large-scale (aggregate) modelling and estimation [7.2, 7.4].

Climate change impacts spread from directly impacted areas and sectors to other areas and sectors through extensive and complex linkages (very high confidence).
In many cases, total impacts are poorly estimated by considering only direct impacts [7.4].

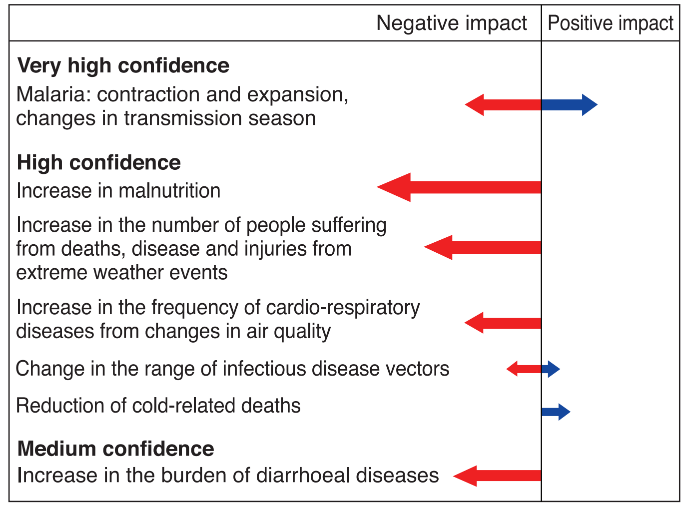

Figure TS.9. *Direction and magnitude of change of selected health impacts of climate change.*

Health

Climate change currently contributes to the global burden of disease and premature deaths (very high confidence).
Human beings are exposed to climate change through changing weather patterns (for example, more intense and frequent extreme events) and indirectly through changes in water, air, food quality and quantity, ecosystems, agriculture and economy. At this early stage the effects are small, but are projected to progressively increase in all countries and regions [8.4.1].

Projected trends in climate-change related exposures of importance to human health will have important consequences (high confidence).
Projected climate-change related exposures are likely to affect the health status of millions of people, particularly those with low adaptive capacity, through:

- increases in malnutrition and consequent disorders, with implications for child growth and development;
- increased deaths, disease and injury due to heatwaves, floods, storms, fires and droughts;
- the increased burden of diarrhoeal disease;
- mixed effects on the range (increases and decreases) and transmission potential of malaria in Africa;
- the increased frequency of cardio-respiratory diseases due to higher concentrations of ground-level ozone related to climate change;
- the altered spatial distribution of some infectious-disease vectors.

This is illustrated in Figure TS.9 [8.2.1, 8.4.1].

Adaptive capacity needs to be improved everywhere (high confidence).
Impacts of recent hurricanes and heatwaves show that even high-income countries are not well prepared to cope with extreme weather events [8.2.1, 8.2.2].

Adverse health impacts will be greatest in low-income countries (high confidence).
Studies in temperate areas (mainly in industrialised countries) have shown that climate change is projected to bring some benefits, such as fewer deaths from cold exposure. Overall it is expected that these benefits will be outweighed by the negative health effects of rising temperatures worldwide, especially in developing countries. The balance of positive and negative health impacts will vary from one location to another, and will alter over time as temperatures continue to rise. Those at greater risk include, in all countries, the urban poor, the elderly and children, traditional societies, subsistence farmers, and coastal populations [8.1.1, 8.4.2, 8.6.1, 8.7].

Current national and international programmes and measures that aim to reduce the burdens of climate-sensitive health determinants and outcomes may need to be revised, reoriented and, in some regions, expanded to address the additional pressures of climate change (medium confidence).
This includes the consideration of climate-change related risks in disease monitoring and surveillance systems, health system planning, and preparedness. Many of the health outcomes are mediated through changes in the environment. Measures implemented in the water, agriculture, food and construction sectors can be designed to benefit human health [8.6, 8.7].

Economic development is an important component of adaptation, but on its own will not insulate the world's population from disease and injury due to climate change (very high confidence).
Critically important will be the manner in which economic growth occurs, the distribution of the benefits of growth, and factors that directly shape the health of populations, such as education, health care, and public health infrastructure [8.3.2].

Box TS.5. The main projected impacts for systems and sectors[16]

Freshwater resources and their management

- Water volumes stored in glaciers and snow cover are very likely to decline, reducing summer and autumn flows in regions where more than one-sixth of the world's population currently live. ** N [3.4.1]
- Runoff and water availability are very likely to increase at higher latitudes and in some wet tropics, including populous areas in East and South-East Asia, and decrease over much of the mid-latitudes and dry tropics, which are presently water-stressed areas. ** D [F3.4]
- Drought-affected areas will probably increase, and extreme precipitation events, which are likely to increase in frequency and intensity, will augment flood risk. Increased frequency and severity of floods and droughts will have implications for sustainable development. ** N [WGI AR4 SPM; 3.4]
- Up to 20% of the world's population live in river basins that are likely to be affected by increased flood hazard by the 2080s in the course of global warming. * N [3.4.3]
- Many semi-arid areas (e.g., Mediterranean Basin, western USA, southern Africa and north-eastern Brazil) will suffer a decrease in water resources due to climate change. *** C [3.4, 3.7]
- The number of people living in severely stressed river basins is projected to increase from 1.4-1.6 billion in 1995 to 4.3-6.9 billion in 2050, for the A2 scenario. ** N [3.5.1]
- Sea-level rise will extend areas of salinisation of groundwater and estuaries, resulting in a decrease in freshwater availability for humans and ecosystems in coastal areas. *** C [3.2, 3.4.2]
- Groundwater recharge will decrease considerably in some already water-stressed regions ** N [3.4.2], where vulnerability is often exacerbated by the rapid increase in population and water demand. *** C [3.5.1]
- Higher water temperatures, increased precipitation intensity and longer periods of low flows exacerbate many forms of water pollution, with impacts on ecosystems, human health, and water system reliability and operating costs. ** N [3.2, 3.4.4, 3.4.5]
- Uncertainties have been evaluated and their interpretation has improved and new methods (e.g., ensemble-based approaches) are being developed for their characterisation *** N [3.4, 3.5]. Nevertheless, quantitative projections of changes in precipitation, river flows and water levels at the river-basin scale remain uncertain. *** D [3.3.1, 3.4]
- Climate change affects the function and operation of existing water infrastructure as well as water management practices *** C [3.6]. Adaptation procedures and risk management practices for the water sector are being developed in some countries and regions that recognise the uncertainty of projected hydrological changes. *** N [3.6]
- The negative impacts of climate change on freshwater systems outweigh the benefits. ** D [3.4, 3.5]
- Areas in which runoff is projected to decline will face a reduction in the value of services provided by water resources *** C [3.4, 3.5]. The beneficial impacts of increased annual runoff in other areas will be tempered by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risks. ** N [3.4, 3.5]

Ecosystems

- The following ecosystems are identified as most vulnerable, and are virtually certain to experience the most severe ecological impacts, including species extinctions and major biome changes. On continents: tundra, boreal forest, mountain and Mediterranean-type ecosystems. Along coasts: mangroves and salt marshes. And in oceans: coral reefs and the sea-ice biomes. *** D [4.4, see also Chapters 1, 5, 6, 14, 15; WGI AR4 Chapters 10, 11]
- Initially positive ecological impacts, such as increased net primary productivity (NPP), will occur in ecosystems identified as least vulnerable: savannas and species-poor deserts. However, these positive effects are contingent on sustained CO_2-fertilisation, and only moderate changes in disturbance regimes (e.g., wildfire) and in extreme events (e.g., drought). • D [4.4.1, 4.4.2, B4.2, 4.4.3, 4.4.10, 4.4.11]
- For global mean temperature increases up to 2°C,[17] some net primary productivity increases are projected at high latitudes (contingent to a large degree on effective migration of woody plants), while an NPP decline (ocean and land) is likely at low latitudes. ** D [4.4.1, 4.4.9, 4.4.10]

[16] In the text of Boxes TS.5 and TS.6, the following conventions are used:

Relationship to the TAR		Confidence in a statement	
C	*Confirmation*	***	*Very high confidence*
D	*Development*	**	*High confidence*
R	*Revision*	*	*Medium confidence*
N	*New*	•	*Low confidence*

[17] Temperature thresholds/sensitivities in the Ecosystems section (only) are given relative to pre-industrial climate and are a proxy for climate change including precipitation changes. In other sections temperature changes are relative to 1990 as indicated in the first paragraph of Section TS.4.

- Projected carbon sequestration by poleward taiga expansion • D [4.4.5, F4.3] is as likely as not to be offset by albedo changes, wildfire, and forest declines at taiga's equatorial limit ** N/D [4.4.5, F4.3], and methane losses from tundra. * N [4.4.6]
- Tropical forest sequestration, despite recently observed productivity gains, is very likely to depend on land-use change trends *** D [4.2, 4.3, 4.4.10], but by 2100 is likely to be dominated by climate-change impacts, especially in drier regions. ** D [4.4.5, 4.4.10, F4.3]
- Amazon forests, China's taiga, and much of the Siberian and Canadian tundra are very likely to show major changes with global mean temperatures exceeding 3°C ** D [T4.2, 4.4.1, F4.2, 4.4.10, F4.4]. While forest expansions are projected in North America and Eurasia with <2°C warming [4.4.10, F4.4, T4.3], tropical forests are likely to experience severe impacts, including biodiversity losses. * D [4.4.10, 4.4.11, T4.1]
- For global mean temperature increases of about 1.5 to 3°C, the low-productivity zones in sub-tropical oceans are likely to expand by about 5% (Northern) and about 10% (Southern Hemisphere), but the productive polar sea-ice biomes are very likely to contract by about 40% (Northern) and about 20% (Southern Hemisphere). ** N [4.4.9]
- As sea-ice biomes shrink, dependent polar species, including predators such as penguins, seals and polar bears, are very likely to experience habitat degradation and losses. *** D [4.4.6]
- Loss of corals due to bleaching is very likely to occur over the next 50 years *** C [B4.5, 4.4.9], especially for the Great Barrier Reef, where climate change and direct anthropogenic impacts such as pollution and harvesting are expected to cause annual bleaching (around 2030 to 2050) followed by mass mortality. ** D [B4.4, 4.4.9]
- Accelerated release of carbon from vulnerable carbon stocks, especially peatlands, tundra frozen loess ('yedoma'), permafrost soils, and soils of boreal and tropical forests is virtually certain. *** D/N [F4.1, 4.4.1, 4.4.6, 4.4.8, 4.4.10, 4.4.11]
- An intensification and expansion of wildfires is likely globally, as temperatures increase and dry spells become more frequent and more persistent. ** D/N [4.4.2, 4.4.3, 4.4.4, 4.4.5]
- Greater rainfall variability is likely to compromise inland and coastal wetland species through shifts in the timing, duration and depth of water levels. ** D [4.4.8]
- Surface ocean pH is very likely to decrease further, by as much as 0.5 pH units by 2100, with atmospheric CO_2 increases projected under the A1FI scenario. This is very likely to impair shell or exoskeleton formation by marine organisms requiring calcium carbonate (e.g., corals, crabs, squids, marine snails, clams and oysters). ** N [4.4.9, B4.5]

Food, fibre and forest products

- In mid- to high-latitude regions, moderate warming benefits cereal crops and pasture yields, but even slight warming decreases yields in seasonally dry and tropical regions *. Further warming has increasingly negative impacts in all regions [F5.2]. Short-term adaptations may enable avoidance of a 10 to 15% reduction in yield. */• D [F5.2, 5.4]
- Climate change will increase the number of people at risk of hunger marginally, with respect to overall large reductions due to socio-economic development. ** D [5.6.5, T5.6]
- Projected changes in the frequency and severity of extreme climate events, together with increases in risks of fire, pests, and disease outbreak, will have significant consequences on food and forestry production, and food insecurity, in addition to impacts of projected mean climate. ** D [5.4.1 to 5.4.5]
- Smallholder and subsistence farmers, pastoralists and artisanal fisherfolk will suffer complex, localised impacts of climate change. ** N [5.4.7]
- Global food production potential is likely to increase with increases in global average temperature up to about 3°C, but above this it is very likely to decrease. * D [5.6]
- Globally, forestry production is estimated to change only modestly with climate change in the short and medium term. Production increase will shift from low-latitude regions in the short term, to high-latitude regions in the long term. * D [5.4.5]
- Local extinctions of particular fish species are expected at edges of ranges. ** N [5.4.6]
- Food and forestry trade is projected to increase in response to climate change, with increased food-import dependence of most developing countries. */• N [5.6.1, 5.6.2, 5.4.5]
- Experimental research on crop response to elevated CO_2 confirms TAR conclusions * C. New free-air carbon dioxide enrichment (FACE) results suggest a lower response for forests. * D [5.4.1]

Coastal systems and low-lying areas

- Coasts are very likely to be exposed to increasing risks due to climate change and sea-level rise and the effect will be exacerbated by increasing human-induced pressures on coastal areas. *** D [6.3, 6.4]
- It is likely that corals will experience a major decline due to increased bleaching and mortality due to rising sea-water temperatures. Salt marshes and mangroves will be negatively affected by sea-level rise. *** D [6.4]

- All coastal ecosystems are vulnerable to climate change and sea-level rise, especially corals, salt marshes and mangroves. *** D [6.4.1]
- Corals are vulnerable to thermal stress and it is very likely that projected future increases in sea surface temperature (SST) of about 1 to 3°C in the 21st century will result in more frequent bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals. *** D [B6.1, 6.4.1]
- Coastal wetlands, including salt marshes and mangroves, are sensitive to sea-level rise, with forecast global losses of 33% given a 36 cm rise in sea level from 2000 to 2080. The largest losses are likely to be on the Atlantic and Gulf of Mexico coasts of the Americas, the Mediterranean, the Baltic, and small-island regions. *** D [6.4.1]
- Ocean acidification is an emerging issue with potential for major impacts in coastal areas, but there is little understanding of the details. It is an urgent topic for further research, especially programmes of observation and measurement. ** D [6.2.3, 6.2.5, 6.4.1]
- Coastal flooding in low-lying areas is very likely to become a greater risk than at present due to sea-level rise and more intense coastal storms, unless there is significant adaptation [B6.2, 6.4.2]. Impacts are sensitive to sea-level rise, the socio-economic future, and the degree of adaptation. Without adaptation, more than 100 million people could experience coastal flooding each year by the 2080s due to sea-level rise alone, with the A2 world likely to have the greatest impacts. *** N [F6.2]
- Benefit-cost analysis of responses suggests that it is likely that the potential impacts will be reduced by widespread adaptation. It also suggests that it is likely that impacts and protection costs will fall disproportionately on developing countries. ** C [F6.4, 6.5.3]
- Key human vulnerabilities to climate change and sea-level rise exist where the stresses on natural low-lying coastal systems coincide with low human adaptive capacity and/or high exposure and include: ** D [6.4.2, 6.4.3]
    - deltas, especially Asian megadeltas (e.g., the Ganges-Brahmaputra in Bangladesh and West Bengal);
    - low-lying coastal urban areas, especially areas prone to natural or human-induced subsidence and tropical storm landfall (e.g., New Orleans, Shanghai);
    - small islands, especially low-lying atolls (e.g., the Maldives).
- Regionally, the greatest increase in vulnerability is very likely to be to be in South, South-East and East Asia, and urbanised coastal locations around Africa, and small-island regions. The numbers affected will be largest in the megadeltas of Asia, but small islands face the highest relative increase in risk. ** D [6.4.2]
- Sea-level rise has substantial inertia compared with other climate change factors, and is virtually certain to continue beyond 2100 for many centuries. Stabilisation of climate could reduce, but not stop, sea-level rise. Hence, there is a commitment to adaptation in coastal areas which raises questions about long-term spatial planning and the need to protect versus planned retreat. *** D [B6.6]

Industry, settlement and society

- Benefits and costs of climate change for industry, settlement and society will vary widely by location and scale. Some of the effects in temperate and polar regions will be positive and others elsewhere will be negative. In the aggregate, however, net effects are more likely to be strongly negative under larger or more rapid warming. ** N [7.4, 7.6, 15.3, 15.5]
- Vulnerabilities of industry, infrastructures, settlements and society to climate change are generally greater in certain high-risk locations, particularly coastal and riverine areas, those in areas prone to extreme weather events, and areas whose economies are closely linked with climate-sensitive resources, such as agricultural and forest product industries, water demands and tourism; these vulnerabilities tend to be localised but are often large and growing. For example, rapid urbanisation in most low- and middle-income nations, often in relatively high-risk areas, is placing an increasing proportion of their economies and populations at risk. ** D [7.1, 7.4, 7.5]
- Where extreme weather events become more intense and/or more frequent with climate change, the economic costs of those events will increase, and these increases are likely to be substantial in the areas most directly affected. Experience indicates that costs of major events can range from several percent of annual regional GDP and income in very large regions with very large economies, to more than 25% in smaller areas that are affected by the events. ** N [7.5]
- Some poor communities and households are already under stress from climate variability and climate-related extreme

events; and they can be especially vulnerable to climate change because they tend to be concentrated in relatively high-risk areas, to have limited access to services and other resources for coping, and in some regions to be more dependent on climate-sensitive resources such as local water and food supplies. ** N [7.2, 7.4.5, 7.4.6]

- Growing economic costs from weather-related extreme events are already increasing the need for effective economic and financial risk management. In those regions and locations where risk is rising and private insurance is a major risk management option, pricing signals can provide incentives for adaptation; but protection may also be withdrawn, leaving increased roles for others, including governments. In those regions where private insurance is not widely available, other mechanisms for risk management will be needed. In all situations, poorer groups in the population will need special help in risk management and adaptation. ** D [7.4.2]
- In many areas, climate change is likely to raise social equity concerns and increase pressures on governmental infrastructures and institutional capacities. ** N [7.ES, 7.4.5, 7.6.5]
- Robust and reliable physical infrastructures are especially important to climate-related risk management. Such infrastructures as urban water supply systems are vulnerable, especially in coastal areas, to sea-level rise and reduced regional precipitation; and large population concentrations without infrastructures are more vulnerable to impacts of climate change. ** N [7.4.3 to 7.4.5]

Health

- The projected relative risks attributable to climate change in 2030 show an increase in malnutrition in some Asian countries ** N [8.4.1]. Later in the century, expected trends in warming are projected to decrease the availability of crop yields in seasonally dry and tropical regions [5.4]. This will increase hunger, malnutrition and consequent disorders, including child growth and development, in particular in those regions that are already most vulnerable to food insecurity, notably Africa. ** N [8.4.2]
- By 2030, coastal flooding is projected to result in a large proportional mortality increase; however, this is applied to a low burden of disease so the aggregate impact is small. Overall, a two- to three-fold increase in population at risk of flooding is expected by 2080. ** N [8.4.1]
- Estimates of increases of people at risk of death from heat differ between countries, depending on the place, ageing population, and adaptation measures in place. Overall, significant increases are estimated over this century. ** D [T8.3]
- Mixed projections for malaria are foreseen: globally an estimated additional population at risk between 220 million (A1FI) and 400 million (A2) has been estimated. In Africa, estimates differ from a reduction in transmission in south-east Africa in 2020 and decreases around the Sahel and south-central Africa in 2080, with localised increases in the highlands, to a 16-28% increase in person-months of exposure in 2100 across all scenarios. For the UK, Australia, India and Portugal, some increased risk has been estimated. *** D [T8.2]
- In Canada, a northward expansion of the Lyme-disease vector of approximately 1,000 km is estimated by the 2080s (A2) and a two- to four-fold increase in tick abundance by the 2080s also. In Europe, tick-borne encephalitis is projected to move further north-eastward of its present range but to contract in central and eastern Europe by the 2050s. * N [T8.2]
- By 2030 an increase in the burden of diarrhoeal diseases in low-income regions by approximately 2-5% is estimated ** N [8.4.1]. An annual increase of 5-18% by 2050 was estimated for Aboriginal communities in Australia ** N [T8.2]. An increase in cases of food poisoning has been estimated for the UK for a 1-3°C temperature increase. * N [T8.2]
- In eastern North America under the A2 climate scenario, a 4.5% increase in ozone-related deaths is estimated. A 68% increase in average number of days/summer exceeding the 8-hour regulatory standard is projected to result in a 0.1-0.3% increase in non-accidental mortality and an average 0.3% increase in cardiovascular disease mortality. In the UK, large decreases in days with high particulates and SO_2 and a small decrease in other pollutants have been estimated for 2050 and 2080, but ozone will have increased ** N [T8.4]. The near-term health benefits from reducing air-pollution concentrations (such as for ozone and particulate matter), as a consequence of greenhouse gas reductions, can be substantial. ** D [8.7.1, WGIII AR4]
- By 2085 it is estimated that the risk of dengue from climate change increases to include 3.5 billion people. * N [8.4.1.2]
- Reductions in cold-related deaths due to climate change are projected to be greater than increases in heat-related deaths in the UK. ** D [T8.3]

TS.4.2 Regional impacts, adaptation and vulnerability

A summary of impacts projected for each region is given in Box TS.6.

Africa

Agricultural production in many African countries and regions will likely be severely compromised by climate change and climate variability. This would adversely affect food security and exacerbate malnutrition (very high confidence).
Agricultural yields and dependence on natural resources constitute a large part of local livelihoods in many, but not all, African countries. Agriculture is a major contributor to the current economy of most African countries, averaging 21% and ranging from 10% to 70% of GDP with indications that off-farm income augments the overall contribution of agriculture in some countries [9.2.2, 9.4.4]. Agricultural losses are shown to be possibly severe for several areas (e.g., the Sahel, East Africa and southern Africa) accompanied by changes in length of growing periods impacting mixed rain-fed, arid and semi-arid systems under certain climate projections. In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020. At the local level, many people are likely to suffer additional losses to their livelihood when climate change and variability occur together with other stressors (e.g., conflict) [9.2.2, 9.6.1].

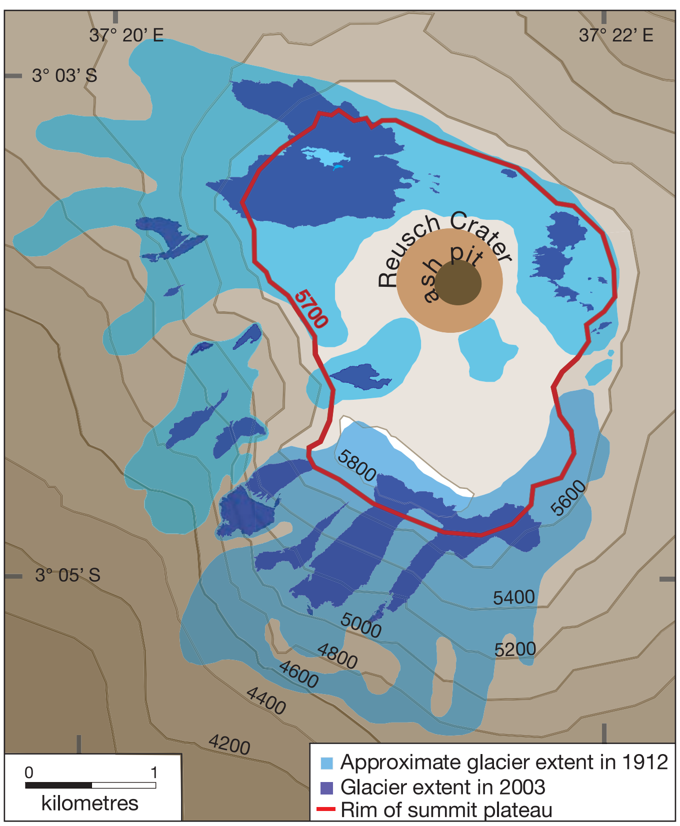

Figure TS.10. *Changes in the Mt. Kilimanjaro ice cap and snow cover over time. Decrease in surface area of Kilimanjaro glaciers from 1912 to 2003. [F9.2]*

Climate change and variability are likely to result in species loss, extinctions and also constrain the 'climate spaces' and ranges of many plants and animals (high confidence).
Changes in a variety of ecosystems are already being detected, particularly in southern African ecosystems, at a faster rate than anticipated as a result of a variety of factors, including the influence of climate, e.g., mountain ecosystems [9.4.5, 4.4.2, 4.4.3, 4.4.8].

In unmanaged environments, multiple, interacting impacts and feedbacks are expected, triggered by changes in climate, but exacerbated by non-climatic factors (high confidence).
Impacts on Kilimanjaro, for example, show that glaciers and snow cover have been retreating as a result of a number of interacting factors (e.g., solar radiation, vegetation changes and human interactions), with a decrease in glacier surface area of approximately 80% between 1912 and 2003 (see Figure TS.10). The loss of 'cloud forests', e.g., through fire, since 1976 has resulted in a 25% annual reduction of water sources derived from fog (equivalent to the annual drinking water supply of 1 million people living around Mt. Kilimanjaro) [9.4.5].

Lack of access to safe water, arising from multiple factors, is a key vulnerability in many parts of Africa. This situation is likely to be further exacerbated by climate change (very high confidence).
By 2020, some assessments project that between 75 and 250 million people are estimated to be exposed to increased water stress due to climate change. If coupled with increased demand, this will adversely affect livelihoods and exacerbate water-related problems. Some assessments, for example, show severe increased water stress and possible increased drought risk for parts of northern and southern Africa and increases in runoff in East Africa. Water access is, however, threatened not only by climate change [9.4.1] but also by complex river-basin management (with several of Africa's major rivers being shared by several countries), and degradation of water resources by abstraction of water and pollution of water sources [9.4.1].

Attributing the contribution of climate change to changes in the risk of malaria remains problematic (high confidence).
Human health, already compromised by a range of factors, could also be further negatively impacted by climate change and climate variability (e.g., in southern Africa and the East African highlands). The debate on climate change attribution and malaria is ongoing and this is an area requiring further research [9.4.3, 8.2.8, 8.4.1].

Africa is one of the most vulnerable continents to climate variability and change because of multiple stresses and low adaptive capacity. The extreme poverty of many Africans, frequent natural disasters such as droughts and floods, and agriculture which is heavily dependent on rainfall, all contribute. Cases of remarkable resilience in the face of multiple stressors have, however, been shown (high confidence).
Africa possesses many examples of coping and adaptation strategies that are used to manage a range of stresses including climate extremes (e.g., droughts and floods). Under possible increases in such stresses, however, these strategies are likely to

be insufficient to adapt to climate variability and change, given the problems of endemic poverty, poor institutional arrangements, poor access to data and information, and growing health burdens [9.2.1, 9.2.2., 9.2.5].

Asia

Observations demonstrate that climate change has affected many sectors in Asia in the past decades (medium confidence).
Evidence of impacts of climate change, variability and extreme events in Asia, as predicted in the Third Assessment, has emerged. The crop yield in most countries of Asia has been observed to be declining, probably partly attributable to rising temperatures. As a likely consequence of warming, the retreat of glaciers and thawing of permafrost in boreal Asia have been unprecedented in recent years. The frequency of occurrence of climate-induced diseases and heat stress in Central, East, South and South-East Asia has increased with rising temperatures and rainfall variability. Observed changes in terrestrial and marine ecosystems have become more pronounced [10.2.3].

Future climate change is expected to affect agriculture through declining production and reductions in arable land area and food supply for fish (medium confidence).
Projected surface warming and shifts in rainfall in most countries of Asia will induce substantial declines in agricultural crop productivity as a consequence of thermal stress and more severe droughts and floods [10.4.1]. The decline in agricultural productivity will be more pronounced in areas already suffering from increasing scarcity of arable land, and will increase the risk of hunger in Asia, particularly in developing countries [10.4.1]. Subsistence farmers are at risk from climate change. Marginal crops such as sorghum and millet could be at the greatest risk, both from a drop in productivity and from a loss of crop genetic diversity [10.4.1]. In response to climate change, it is expected that changes will occur in fish breeding habitats and food supply for fish, and ultimately the abundance of fish populations [10.4.1].

Climate change has the potential to exacerbate water-resource stresses in most regions of Asia (high confidence).
The most serious potential threat arising from climate change in Asia is water scarcity. Freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease due to climate change which, along with population growth and increasing demand arising from higher standards of living, could adversely affect more than a billion people by the 2050s [10.4.2]. Changes in seasonality of runoff due to rapid melting of glaciers and in some areas an increase in winter precipitation could have significant effects on hydropower generation and on crop and livestock production [10.4.2].

Increases in temperature are expected to result in more rapid recession of Himalayan glaciers and the continuation of permafrost thaw across northern Asia (medium confidence).
If current warming rates are maintained, Himalayan glaciers could decay at very rapid rates (Figure TS.11). Accelerated glacier melt would result in increased flows in some river systems for the next two to three decades, resulting in increased flooding, rock avalanches from destabilised slopes, and disruption of water resources. This would be followed by a decrease in flows as the glaciers recede [10.6.2]. Permafrost degradation can result in ground subsidence, alter drainage characteristics and infrastructure stability, and can result in increased emissions of methane [10.4.4].

Asian marine and coastal ecosystems are expected to be affected by sea-level rise and temperature increases (high confidence).
Projected sea-level rise could result in many additional millions of people being flooded each year [10.4.3.1]. Sea-water intrusion could increase the habitat of brackish-water fisheries but significantly damage the aquaculture industry [10.4.1]. Overall, sea-level rise is expected to exacerbate already declining fish productivity in Asia [10.4.1]. Arctic marine fisheries would be greatly influenced by climate change, with some species, such as cod and herring, benefiting at least for modest temperature increases, and others, such as the northern shrimp, suffering declining productivity [10.4.1].

Climate change is expected to exacerbate threats to biodiversity resulting from land-use/cover change and population pressure in most parts of Asia (high confidence).
Increased risk of extinction for many flora and fauna species in Asia is likely as a result of the synergistic effects of climate change and habitat fragmentation [10.4.4]. Threats to the ecological stability of wetlands, mangroves and coral reefs around Asia would also increase [10.4.3, 10.6.1]. The frequency and extent of forest fires in northern Asia is expected to increase in the future due to climate change and extreme weather events that could likely limit forest expansion [10.4.4].

Figure TS.11. *Projected future changes in the northern Asia permafrost boundary under the SRES A2 scenario for 2100. [F10.5]*