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VULNERABILITY. EXCERPTS FROM IPCC WORKING GROUP II CONTRIBUTIONS TO THE 4TH ASSESSMENT REPORT OF THE IPCC

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VULNERABILITY. EXCERPTS FROM IPCC WORKING GROUP II CONTRIBUTIONS TO THE 4[TH] ASSESSMENT REPORT OF THE IPCC

Note by the secretariat

1. At its tenth meeting the Board heard a presentation on vulnerability by Dr. Kristie L. Ebi, Executive Director of Working Group II of IPCC (WG II). After the presentation and the ensuing discussion, the Chair considered that [*f]urther discussion of the subject was necessary and the subject would be placed on the agenda for the eleventh meeting of the Board, at which time the Board would also have a technical paper on the subject from the secretariat*[1].

2. Since no further guidance had been provided on the requested paper, the secretariat reverted to IPCC as the authoritative scientific body from which the Board has agreed to seek advice on this issue[2]. Dr. Ebi kindly indicated which paragraphs among the technical summary of WG II contributions to the 4th Assessment Report of IPCC could be the most relevant to guide the Board in its discussion on vulnerability. Thus the present document contains a selection of excerpts from the above mentioned technical summary, a report accepted by WG II of IPCC but not approved in detail[3].

3. The complete technical summary is available at http://ipcc-wg2.gov/download/AR4_WG2_TS.pdf

[1] Report of the tenth meeting of the Adaptation Fund Board, paragraph 123.
[2] Report of the eighth meeting of the Adaptation Fund Board, paragraph 76.
[3] 'Acceptance' of IPCC Reports at a Session of the Working Group or Panel signifies that the material has not been subject to line-by-line discussion and agreement, but nevertheless presents a comprehensive, objective and balanced view of the subject matter.

Technical Summary

Summary of main findings

• Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.

• A global assessment of data since 1970 has shown it is likely that anthropogenic warming has had a discernible influence on many physical and biological systems.

• Other effects of regional climate changes on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers.

• More specific information is now available across a wide range of systems and sectors concerning the nature of future impacts, including for some fields not covered in previous assessments.

• More specific information is now available across the regions of the world concerning the nature of future impacts, including for some places not covered in previous assessments.

• Magnitudes of impact can now be estimated more systematically for a range of possible increases in global average temperature.

• Impacts due to altered frequencies and intensities of extreme weather, climate and sea-level events are very likely to change.

• Some large-scale climate events have the potential to cause very large impacts, especially after the 21st century.

• Impacts of climate change will vary regionally but, aggregated and discounted to the present, they are very likely to impose net annual costs which will increase over time as global temperatures increase.

• Some adaptation is occurring now, to observed and projected future climate change, but on a limited basis.

• Adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions.

• A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to future climate change. There are barriers, limits and costs, but these are not fully understood.

• Vulnerability to climate change can be exacerbated by the presence of other stresses.

• Future vulnerability depends not only on climate change but also on development pathway.

• Sustainable development can reduce vulnerability to climate change, and climate change could impede nations' abilities to achieve sustainable development pathways.
• Many impacts can be avoided, reduced or delayed by mitigation.

• A portfolio of adaptation and mitigation measures can diminish the risks associated with climate change.

Box TS.3. Definitions of Key Terms

Vulnerability is the degree to which the system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes.

For physical systems, (i) climate change is affecting natural and human systems in regions of snow, ice and frozen ground, and (ii) there is now evidence of effects on hydrology and water resources, coastal zones and oceans.

There is more evidence, from a wider range of species and communities in terrestrial ecosystems than reported in the Third Assessment, that recent warming is already strongly affecting natural biological systems. There is substantial new evidence relating changes in marine and freshwater systems to warming. The evidence suggests that both terrestrial and marine biological systems are now being strongly influenced by observed recent warming.

Effects of regional increases in temperature on some managed and human systems are emerging, although these are more difficult to discern than those in natural systems, due to adaptation and non-climatic drivers.

TS.4 Current knowledge about future impacts

Freshwater resources and their management

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).

Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater (high confidence).

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).

Ecosystems

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).

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 preindustrial levels (medium confidence).

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 CO2 (high confidence).

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).

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).

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).

Smallholder and subsistence farmers, pastoralists and artisanal fisherfolk are likely to suffer complex, localised impacts of climate change (high confidence).

Local extinctions of particular fish species are expected at edges of ranges (high confidence).

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).

Experimental research on crop response to elevated CO2 confirms TAR reviews (medium to high confidence). New results suggest lower responses for forests (medium confidence).

Coastal systems and low-lying areas

Coasts are experiencing the adverse consequences of hazards related to climate and sea level (very high confidence).

Coasts are very likely to be exposed to increasing risks in future decades due to many compounding climate-change factors (very high confidence).

The impact of climate change on coasts is exacerbated by increasing human-induced pressures (very high confidence).

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.*

Industry, settlement and society

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].

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).

Vulnerabilities to climate change depend considerably on relatively specific geographical and sectoral contexts (very high confidence).

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.

Health

Climate change currently contributes to the global burden of disease and premature deaths (very high confidence).

Projected trends in climate-change related exposures of importance to human health will have important consequences (high confidence).

Adverse health impacts will be greatest in low-income countries (high confidence).

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 infrequency 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]
• Upto 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 billionin 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 fresh water availability for humans and ecosystems in coastal areas. *** C [3.2, 3.4.2]
• Ground water 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 fresh water systems outweigh the benefits. **D [3.4,3.5]
• Areas in which run off 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 CO2-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]

• 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]
• Forglobalmeantemperatureincreasesofabout1.5to3°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 pecies 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 0.5pHunitsby 2100, with atmosphericCO2 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 CO2 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 urbanized 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 formalaria are foreseen: globally an estimated additional population at risk between 220million (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 kmis 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 SO2 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]

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).

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).

In unmanaged environments, multiple, interacting impacts and feedbacks are expected, triggered by changes in climate, but exacerbated by non-climatic factors (high confidence).

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).

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).

Asia

Observations demonstrate that climate change has affected many sectors in Asia in the past decades (medium confidence).

Future climate change is expected to affect agriculture through declining production and reductions in arable land area and food supply for fish (medium confidence).

Climate change has the potential to exacerbate water resource stresses in most regions of Asia (high confidence).

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).

Asian marine and coastal ecosystems are expected to be affected by sea-level rise and temperature increases (high confidence).

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).

Future climate change is likely to continue to adversely affect human health in Asia (high confidence).

Multiple stresses in Asia will be further compounded in the future due to climate change (high confidence).

Australia and New Zealand

Without further adaptation, potential impacts of climate change are likely to be substantial (high confidence).

- As a result of reduced precipitation and increased evaporation, water security problems are very likely to intensify by 2030 in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions [11.4.1].
- Significant loss of biodiversity is projected to occur by 2020 in some ecologically rich sites including the Great Barrier Reef and Queensland Wet Tropics. Other sites at risk include Kakadu Wetlands, south-west Australia, sub-Antarctic islands and the alpine areas of both countries [11.4.2].
- Ongoing coastal development and population growth in areas such as Cairns and south-east Queensland (Australia) and Northland to Bay of Plenty (New Zealand) are projected to exacerbate risks from sea-level rise and increases in the severity and frequency of storms and coastal flooding by 2050 [11.4.5, 11.4.7].

• Risks to major infrastructure are likely to markedly increase. By 2030, design criteria for extreme events are very likely to be exceeded more frequently. These risks include the failure of flood protection and urban drainage/sewerage, increased storm and fire damage, and more heatwaves causing more deaths and more black-outs [11.4.1, 11.4.5, 11.4.7, 11.4.10, 11.4.11].
• Production from agriculture and forestry is projected to decline by 2030 over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. However, in New Zealand, initial benefits to agriculture and forestry are projected in western and southern areas and close to major rivers due to a longer growing season, less frost and increased rainfall [11.4.3, 11.4.4].

Vulnerability is likely to increase in many sectors, but this depends on adaptive capacity.
• Most human systems have considerable adaptive capacity. The region has well-developed economies, extensive scientific and technical capabilities, disaster-mitigation strategies, and biosecurity measures. However, there are likely to be considerable cost and institutional constraints to the implementation of adaptation options (high confidence) [11.5]. Some Indigenous communities have low adaptive capacity (medium confidence) [11.4.8]. Water security and coastal communities are most vulnerable (high confidence) [11.7].
• Natural systems have limited adaptive capacity. Projected rates of climate change are very likely to exceed rates of evolutionary adaptation in many species (high confidence) [11.5]. Habitat loss and fragmentation are very likely to limit species migration in response to shifting climatic zones (high confidence) [11.2.5, 11.5].
• Vulnerability is likely to rise as a consequence of an increase in extreme events. Economic damage from extreme weather is very likely to increase and provide major challenges for adaptation (high confidence) [11.5].
• Vulnerability is likely to be high by 2050 in a few identified hotspots (see Figure TS.12). In Australia, these include the Great Barrier Reef, eastern Queensland, the south-west, Murray-Darling Basin, the Alps and Kakadu; in New Zealand, these include the Bay of Plenty, Northland, eastern regions and the Southern Alps (medium confidence) [11.7].

Europe

For the first time, wide-ranging impacts of changes in current climate have been documented in Europe (very high confidence).

Climate-related hazards will mostly increase, although changes will vary geographically (very high confidence).

Climate change is likely to magnify regional differences in Europe’s natural resources and assets (very high confidence).

Water stress is likely to increase, as well as the number of people living in river basins under high water stress (high confidence).

It is anticipated that Europe’s natural systems and biodiversity will be substantially affected by climate change (very high confidence). The great majority of organisms and ecosystems are likely to have difficulty in adapting to climate change (high confidence).

Nearly all European regions are anticipated to be negatively affected by some future impacts of climate change and these will pose challenges to many economic sectors (very high confidence).

Latin America

Climatic variability and extreme events have been severely affecting the Latin America region over recent years (high confidence).

During the last few decades, important changes in precipitation and increases in temperature have been observed (high confidence).

Under future climate change, there is a risk of significant species extinctions in many areas of tropical Latin America (high confidence).

By the 2020s, the net increase in the number of people experiencing water stress due to climate change is likely to be between 7 and 77 million (medium confidence).

Generalised reductions in rice yields by the 2020s, as well as increases in soybean yields in temperate zones, are likely when CO2 effects are considered (medium confidence).

The expected increases in sea-level rise, weather and climatic variability and extremes are very likely to affect coastal areas (high confidence).

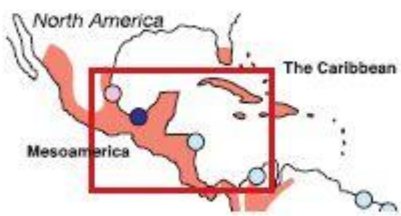

Figure TS.14. *Key hotspots for Latin America, where climate change impacts are expected to be particularly severe. [13.4]*

North America

Climate change is likely to exacerbate other stresses on infrastructure, and human health and safety in urban centres (very high confidence).

Coastal communities and habitats are very likely to be increasingly stressed by climate change impacts interacting with development and pollution (very high confidence).

Warm temperatures and extreme weather already cause adverse human health effects through heat-related mortality, pollution, storm-related fatalities and injuries, and infectious diseases, and are likely, in the absence of effective countermeasures, to increase with climate change (very high confidence).

Climate change is very likely to constrain North America’s already intensively utilised water resources, interacting with other stresses (high confidence).

Disturbances such as wildfire and insect outbreaks are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons, and to interact with changing land use and development affecting the future of wildland ecosystems (high confidence).

Polar Regions

There is a growing evidence of the impacts of climate change on ecosystems in both polar regions (high confidence).

The continuation of hydrological and cryospheric changes will have significant regional impacts on Arctic freshwater, riparian and near-shore marine systems (high confidence).

The retreat of Arctic sea ice over recent decades has led to improved marine access, changes in coastal ecology/biological production, adverse effects on many ice-dependent marine mammals, and increased coastal wave action (high confidence).

Warming of areas of the northern polar oceans has had a negative impact on community composition, biomass and distribution of phytoplankton and zooplankton (medium confidence).

Small Islands

Small islands have characteristics which make them especially vulnerable to the effects of climate change, sea-level rise and extreme events (very high confidence).

Sea-level rise is likely to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening the vital infrastructure that supports the socio-economic well-being of island communities (very high confidence).

There is strong evidence that under most climate-change scenarios, water resources in small islands are likely to be seriously compromised (very high confidence).

Climate change is likely to heavily impact coral reefs, fisheries and other marine-based resources (high confidence).
On some islands, especially those at higher latitudes, warming has already led to the replacement of some local species (high confidence).

It is very likely that subsistence and commercial agriculture on small islands will be adversely affected by climate change (high confidence).

New studies confirm previous findings that the effects of climate change on tourism are likely to be direct and indirect, and largely negative (high confidence).

There is growing concern that global climate change is likely to impact human health, mostly in adverse ways (medium confidence).

Latitude	Region and system at risk	Impacts and vulnerability
High	Iceland and isolated Arctic islands of Svalbard and the Faroe Islands: Marine ecosystem and plant species	• The imbalance of species loss and replacement leads to an initial loss in diversity. Northward expansion of dwarf-shrub and tree-dominated vegetation into areas rich in rare endemic species results in their loss. • Large reduction in, or even a complete collapse of, the Icelandic capelin stock leads to considerable negative impacts on most commercial fish stocks, whales and seabirds.
	High-latitude islands (Faroe Islands): Plant species	• Scenario I (temperature increase 2°C): species most affected by warming are restricted to the uppermost parts of mountains. For other species, the effect will mainly be upward migration. • Scenario II (temperature decrease 2°C): species affected by cooling are those at lower altitudes.
Mid	Sub-Antarctic Marion Islands: Ecosystem	• Changes will directly affect the indigenous biota. An even greater threat is that a warmer climate will increase the ease with which the islands can be invaded by alien species.
	Five islands in the Mediterranean Sea: Ecosystems	• Climate change impacts are negligible in many simulated marine ecosystems. • Invasion into island ecosystems becomes an increasing problem. In the longer term, ecosystems will be dominated by exotic plants irrespective of disturbance rates.
	Mediterranean: Migratory birds (pied flycatchers: *Ficedula hypoleuca*)	• Reduction in nestling and fledgling survival rates of pied flycatchers in two of the southernmost European breeding populations.
	Pacific and Mediterranean: Sim weed (*Chromolaena odorata*)	• Pacific islands at risk of invasion by sim weed. • Mediterranean semi-arid and temperate climates predicted to be unsuitable for invasion.
Low	Pacific small islands: Coastal erosion, water resources and human settlements	• Accelerated coastal erosion, saline intrusion into freshwater lenses and increased flooding from the sea cause large effects on human settlements. • Lower rainfall coupled with accelerated sea-level rise compounds the threat on water resources; a 10% reduction in average rainfall by 2050 is likely to correspond to a 20% reduction in the size of the freshwater lens on Tarawa Atoll, Kiribati.
	American Samoa, fifteen other Pacific, islands: Mangroves	• 50% loss of mangrove area in American Samoa; 12% reduction in mangrove area in fifteen other Pacific islands.
	Caribbean (Bonaire, Netherlands Antilles): Beach erosion and sea-turtle nesting habitats	• On average, up to 38% (±24% standard deviation) of the total current beach could be lost with a 0.5 m rise in sea level, with lower narrower beaches being the most vulnerable, reducing turtle nesting habitat by one-third.
	Caribbean (Bonaire, Barbados): Tourism	• The beach-based tourism industry in Barbados and the marine-diving-based ecotourism industry in Bonaire are both negatively affected by climate change through beach erosion in Barbados and coral bleaching in Bonaire.

Table TS.2. *Range of future impacts and vulnerabilities in small islands [B16.1]. These projections are summarised from studies using a range of scenarios including SRES and Third Assessment Report sea-level rise projections.*

Box TS.6. The main projected impacts for regions

Africa

• The impacts of climate change in Africa are likely to be greatest where they co-occur with a range of other stresses (e.g., unequal access to resources [9.4.1]; enhanced food insecurity [9.6]; poor health management systems [9.2.2, 9.4.3]). These stresses, enhanced by climate variability and change, further enhance the vulnerabilities of many people in Africa. ** D [9.4]

• An increase of 5 to 8% (60 to 90 million ha) of arid and semi arid land in Africa is projected by the 2080s under a range of climate change scenarios. ** N [9.4.4]

•Declining agricultural yields are likely due to drought and land degradation, especially in marginal areas. Changes in the length of growing period have been noted under various scenarios. In the A1FI SRES scenario, which has an emphasis on globally integrated economic growth, areas of major change include the coastal systems of southern and eastern Africa. Under both the A1 and B1 scenarios, mixed rain-fed, semi-arid systems are shown to be heavily affected by changes in climate in the Sahel. Mixed rain-fed and highland perennial systems in the Great Lakes region in East Africa and in other parts of East Africa are also heavily affected. In the B1 SRES scenario, which assumes development within a framework of environmental protection, the impacts are, however, generally less, but marginal areas (e.g., the semi-arid systems) become more marginal, with the impacts on coastal systems becoming moderate. ** D [9.4.4]

• Current stress on water in many areas of Africa is likely to be enhanced by climate variability and change. Increases in runoff in East Africa (possibly floods) and decreases in runoff and likely increased drought risk in other areas (e.g., southern Africa) are projected by the 2050s. Current water stresses are not only linked to climate variations, and issues of water governance and water-basin management must also be considered in any future assessments of water in Africa. ** D [9.4.1]

• Any changes in the primary production of large lakes are likely to have important impacts on local food supplies. For example, Lake Tanganyika currently provides 25 to 40% of animal protein intake for the population of the surrounding countries, and climate change is likely to reduce primary production and

possible fish yields by roughly 30% [9.4.5, 3.4.7, 5.4.5]. The interaction of human management decisions, including over-fishing, is likely to further compound fish offtakes from lakes. ** D [9.2.2]
•Ecosystems in Africa are likely to experience major shifts and changes in species range and possible extinctions (e.g.,fynbos and succulent Karoo biomes in southern Africa). * D [9.4.5]
• Mangroves and coral reefs are projected to be further degraded,with additional consequences for fisheries and tourism.**D [9.4.5]
• Towards the end of the21stcentury, projected sea-level rise will affect low lying coastal areas with large populations. The cost of adaptation will exceed 5 to 10%of GDP. ** D [B9.2, 9.4.6, 9.5.2]

Asia

• A 1mrise in sea level would lead to a loss of almost half of the man grove area in the Mekong River delta (2,500 km2), while approximately 100,000 ha of cultivated land and aquaculture area would become salt marsh. * N [10.4.3]
• Coastal areas, especially heavily populated megadelta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from the rivers. For a 1 m rise in sea level, 5,000 km2 of Red River delta, and 15,000 to 20,000 km2 of Mekong River delta are projected to be flooded, which could affect 4 million and 3.5 to 5 million people, respectively. *N[10.4.3]
• Tibetan Plateau glaciers of under 4 km in length are projected to disappear with a temperature increase of 3° C and no change in precipitation. ** D [10.4.4]
•If current warming rates are maintained, Himalayan glaciers could decay at very rapid rates, shrinking from the present 500,000km2 to 100,000 km2 by the 2030s. ** D [10.6.2]
• Around 30%ofAsian coral reefs are expected to be lost in the next 30 years, compared with 18%globally under the IS92a emissions scenario, but this is due to multiple stresses and not to climate change alone. ** D [10.4.3]
• It is estimated that under the full range of SRES scenarios, 120 million to1.2 billion and 185 to 981 million people will experience increased water stress by the 2020s and the 2050s, respectively. ** D [10.4.2]
• The per capita availability of fresh water in India is expected to drop from around1,900m3 currently to 1,000m3 by 2025 in response to the combined effects of population growth and climate change [10.4.2.3]. More intense rain and more frequent flash floods during the monsoon would result in a higher proportion of runoff and a reduction in the proportion reaching the groundwater. ** N [10.4.2]
• It is projected that crop yields could increase upto 20% in East and South East Asia, while they could decrease upto 30% in Central and South Asia by the mid-21st century. Taken together and considering the influence of rapid population growth and urbanisation, the risk of hunger is projected to remain very high in several developing countries. * N [10.4.1]
• Agricultural irrigation demand in arid and semi-arid regions of East Asia is expected to increase by 10% for an increase in temperature of 1°C. ** N [10.4.1]
• The frequency and extent of forest fires in northern Asia are expected to increase in the future due to climate change and extreme weather events that would likely limit forest expansion. * N [10.4.4]

Australia and New Zealand

• The most vulnerable sectors are natural ecosystems, water security and coastal communities.**C[11.7]
• Many ecosystems are likely to be altered by 2020, even under medium emissions scenarios [11.4.1]. Among the most vulnerable are the Great Barrier Reef, south-western Australia, Kakadu Wetlands, rain forests and alpine areas [11.4.2]. This is virtually certain to exacerbate existing stresses such as invasive species and habitat loss, increase the probability of species extinctions, and cause a reduction in ecosystem services for tourism, fishing, forestry and water supply. * N [11.4.2]

• Ongoing water security problems are very likely to increase by 2030 in southern and eastern Australia and, in New Zealand, in Northland and some eastern regions, e.g., a 0 to 45% decline in runoff in Victoria by 2030 and a 10 to 25%reduction in river flow in Australia's Murray-Darling Basin by 2050. ** D [11.4.1]
• Ongoing coastal development is very likely to exacerbate risk to lives and property from sea level rise and storms. By2050,there is very likely to be loss of high-value land, faster road deterioration, degraded beaches, and loss of items of cultural significance.*** C [11.4.5, 11.4.7, 11.4.8]
• Increased fire danger is likely with climate change; for example, in south-east Australia the frequency of very high and extreme fire danger days is likely to rise 4 to 25%by 2020 and 15 to 70%by 2050. ** D [11.3.1]
•Risks to major infrastructure are likely to increase. Design criteria for extreme events are very likely to be exceeded more frequently by 2030. Risks include failure of floodplain levees and urban drainage systems, and flooding of coastal towns near rivers. ** D [11.4.5, 11.4.7]
•Increased temperatures and demographic change are likely to increase peak energy demand in summer and the associated risk of black-outs. ** D [11.4.10]
•Production from agriculture and forestry by 2030 is projected to decline over much of southern and eastern Australia, and over parts of eastern New Zealand, due to increased drought and fire. However, in New Zealand, initial benefits are projected in western and southern areas and close to major rivers due to a longer growing season, less frost and increased rainfall. ** N [11.4]
• In the south and west of NewZealand, growth rates of economically important plantation crops(mainly *Pinus radiata*) are likely to increase with CO2-fertilisation, warmer winters and wetter conditions. ** D [11.4.4]
• Increased heat related deaths for people eaged over 65 are likely, with an extra 3, 200 to 5,200 deaths on average per year by2050 (allowing for population growth and ageing, but assuming no adaptation). ** D [11.4.11]

Europe

• The probability of an extreme winter precipitation exceeding two standard deviations above normal is expected to increase by up to a factor of five in parts of the UK and northern Europe by the 2080s with a doubling of CO2. ** D [12.3.1]
• By the2070s, annual runoff is projected to increase in northern Europe, and decrease by upto 36% in southern Europe, with summer low flows reduced by up to 80%under IS92a. ** D [12.4.1, T12.2]
• The percentage of river-basin area in the severewater stress category (withdrawal/availability higher than 0.4) is expected to increase from 19%today to 34 to 36%by the 2070s. ** D [12.4.1]
• The number of additional people living in water stressed watersheds in the seventeen western Europe countries is likely to increase from 16 to 44 million based on HadCM3 climate under the A2 and B1 emission scenarios, respectively, by the 2080s. ** D[12.4.1]
• Under A1FI scenarios, by the 2080s an additional 1.6million people each year are expected to be affected by coastal flooding. ** D [12.4.2]
• By the 2070s, hydro power potential for the whole of Europe is expected to decline by 6%, with strong regional variations from a 20 to 50% decrease in the Mediterranean region to a 15 to 30% increase in northern and eastern Europe. ** D [12.4.8]
• A large percentage of the European flora could become vulnerable, endangered, critically endangered or extinct by the end of the 21st century under a range of SRES scenarios. *** N [12.4.6]
• By 2050, crops are expected to show a northward expansion in area [12.4.7.1]. The greatest increases in climate-related crop yields are expected in northern Europe (e.g., wheat: +2 to +9%by 2020, +8 to +25%by 2050, +10 to +30%by 2080), while the largest reductions are expected in the south (e.g., wheat: +3 to +4%by 2020, −8 to +22%by 2050, −15 to +32% by 2080).*** C [12.4.7]

• Forested area is likely to increase in the north and decrease in the south. A redistribution of tree species is expected, and an elevation of the mountain tree line. Forest-fire risk is virtually certain to greatly increase in southern Europe. ** D [12.4.4]
• Most amphibian (45 to 69%) and reptile (61 to 89%) species are virtually certain to expand their range if dispersal were unlimited. However, if species were unable to disperse, then the range of most species (>97%) would become smaller, especially in the Iberian Peninsula and France. ** N [12.4.6]
• Small Alpine glaciers in different regions will disappear, while larger glaciers will suffer a volume reduction between 30% and 70% by 2050 under a range of emissions scenarios, with concomitant reductions in discharge in spring and summer. *** C [12.4.3]
• Decreased comfort of the Mediterranean region in the summer, and improved comfort in the north and west, could lead to a reduction in Mediterranean summer tourism and an increase in spring and autumn. ** D [12.4.9]
• Rapid shut down of Meridional Overturning Circulation (MOC), although assigned a low probability, is likely to have wide spread severe impacts in Europe, especially in western coastal areas. These include reductions in crop production with associated price increases, increased cold-related deaths, winter transport disruption, population migration to southern Europe and a shift in the economic centre of gravity. * N [12.6.2]

Latin America

• Over the next 15 years, inter-tropical glaciers are very likely to disappear, reducing water availability and hydro-power generation in Bolivia, Peru, Colombia and Ecuador. *** C [13.2.4]
• Any future reductions in rainfall in arid and semi-arid regions of Argentina, Chile and Brazil are likely to lead to severe water shortages. ** C [13.4.3]
• By the 2020s between 7 million and 77 million people are likely to suffer from a lack of adequate water supplies, while for the second half of the century the potential water availability reduction and the increasing demand, from an increasing regional population, would increase these figures to between 60 and 150 million. ** D [13.ES, 13.4.3]
• In the future, anthropogenic climate change (including changes in weather extremes) and sea-level rise are very likely to have impacts on ** N [13.4.4]:
- low-lying areas (e.g., in El Salvador, Guyana, the coast of Buenos Aires Province in Argentina);
- buildings and tourism(e.g., in Mexico and Uruguay);
- coastal morphology (e.g., in Peru);
- mangroves (e.g., in Brazil, Ecuador, Colombia, Venezuela);
- availability of drinking water in the Pacific coast of Costa Rica and Ecuador.
• Seasurfacetemperatureincreasesduetoclimatechangeareprojectedtohaveadverseeffectson**N[13.4.4]:
- Mesoamerican coral reefs (e.g., Mexico, Belize, Panama);
- the location of fish stocks in the south-east Pacific (e.g., Peru and Chile).
• Increases of 2° C and decreases in soil water would lead to a replacement of tropical forest by savannas in eastern Amazonia and in the tropical forests of central and southern Mexico, along with replacement of semi-arid by arid vegetation in parts of northeast Brazil and most of central and northern Mexico. ** D [13.4.1]
• In the future, the frequency and intensity of hurricanes in the Caribbean Basin are likely to increase.*D [13.3.1]
• As a result of climate change, rice yields are expected to decline after the year 2020, while increases in temperature and precipitation in south-eastern South America are likely to increase soybean yields if CO2 effects are considered. * C [13.4.2]

• The number of additional people at risk of hunger under the SRESA2 emissions scenario is likely to attain 5,26 and 85 million in 2020, 2050 and 2080, respectively, assuming little or no CO2 effects. * D [13.4.2]
• Cattle productivity is very likely to decline in response to a 4°C increase in temperatures. **N[13.ES,13.4.2]
• The Latin American region, concerned with the potential effects of climate variability and change, is trying to implement some adaptation measures such as:
- the use of climate forecasts in sectors such as fisheries (Peru) and agriculture (Peru, north-eastern Brazil);
- early-warning systems for flood in the Rio de la Plata Basin based on the 'Centro Operativo de Alerta Hidrológico'.
• The region has also created new institutions to mitigate and prevent impacts from natural hazards, such as the Regional Disaster Information Center for Latin America and the Caribbean, the International Centre for Research on El Niño Phenomenon in Ecuador, and the Permanent Commission of the South Pacific. *** D [13.2.5]

North America

• Population growth, rising property values and continued investment increase coastal vulnerability. Any increase in destructiveness of coastal storms is very likely to lead to dramatic increases in losses from severe weather and storm surge, with the losses exacerbated by sea-level rise. Current adaptation is uneven, and readiness for increased exposure is poor. *** D [14.2.3, 14.4.3]
• Sea-level rise and the associated increase in tidal surge and flooding have the potential to severely affect transportation and infrastructure along the Gulf, Atlantic and northern coasts. A case study of facilities at risk in New York identified surface road and rail lines, bridges, tunnels, marine and airport facilities and transit stations. *** D [14.4.3, 14.4.6, 14.5.1, B14.3]
• Severe heat waves, characterized by stagnant, warm air masses and consecutive nights with high minimum temperatures, are likely to increase in number, magnitude and duration in cities where they already occur, with potential for adverse health effects. Elderly populations are most at risk. ** D [14.4.5]
• By mid-century, daily average ozone levels are projected to increase by 3.7 ppb across the eastern USA ,with the most polluted cities today experiencing the greatest increases. Ozone-related deaths are projected to increase by 4.5%from the 1990s to the 2050s. * D [14.4.5]
• Projected warming in the western mountains by the mid 21st century is very likely to cause large decreases in snow pack, earlier snow melt, more winter rain events, increased peak winter flows and flooding, and reduced summer flows *** D [14.4.1].
• Reduced water supplies coupled with increases in demand are likely to exacerbate competition for over-allocated water resources. *** D [14.2.1, B14.2]
• Climate change in the first several decades of the 21st century is likely to increase forest production, but with high sensitivity to drought, storms, insects and other disturbances. ** D [14.4.2, 14.4.4]
• Moderate climate change in the early decades of the century is projected to increase aggregate yields of rain-fed agriculture by 5 to 20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilised water resources. ** D [14.4]
• By the second half of the 21st century, the greatest impacts on forests are likely to be through changing disturbances from pests, diseases and fire. Warmer summer temperatures are projected to extend the annual window of high fire risk by 10 to 30%, and increase area burned by 74 to 118% in Canada by 2100. *** D [14.4.4, B14.1]

• Present rates of coastal wetland loss are projected to increase with accelerated relative sea-level rise, in part due to structures preventing landward migration. Salt-marsh biodiversity is expected to decrease in north-eastern marshes. ** D [14.4.3]
• Vulnerability to climate change is likely be concentrated in specific groups and regions, including indigenous peoples and others dependent on narrow resource bases, and the poor and elderly in cities. ** D [14.2.6, 14.4.6]
• Continued investment in adaptation in response to historical experience rather than projected future conditions is likely to increase vulnerability of many sectors to climate change [14.5]. Infrastructure development, with its long lead times and investments, would benefit from incorporating climate-change information. *** D [14.5.3, F14.3]

Polar Regions

• By the end of the century, annually averaged Arctic sea-ice extent is projected to show a reduction of 22 to 33%, depending on emissions scenario; and in Antarctica, projections range from a slight increase to a near-complete loss of summer sea ice. ** D [15.3.3]
• Over the next hundred years there will important reductions in thickness and extent of ice from Arctic glaciers and ice caps, and the Greenland ice sheet ***, as a direct response to climate warming; in Antarctica, losses from the Antarctic Peninsula glaciers will continue ***, and observed thinning in part of the West Antarctic ice sheet, which is probably driven by oceanic change, will continue **. These contributions will form a substantial fraction of sea-level rise during this century. *** D [15.3.4, 15.6.3; WGI AR4 Chapters 4, 5]
• Northern Hemisphere permafrost extent is projected to decrease by 20 to 35% by 2050. The depth of seasonal thawing is likely to increase by 15 to 25% in most areas by 2050, and by 50% or more in northernmost locations under the full range of SRES scenarios. ** D [15.3.4]
• In the Arctic, initial permafrost thaw will alter drainage systems, allowing establishment of aquatic communities in areas formerly dominated by terrestrial species ***. Further thawing will increasingly couple surface drainage to the groundwater, further disrupting ecosystems. Coastal erosion will increase. ** D [15.4.1]
• By the end of the century, 10 to 50% of Arctic tundra will be replaced by forest, and around 15 to 25% of polar desert will be replaced by tundra. * D [15.4.2]
• In both polar regions, climate change will lead to decreases in habitat (including sea ice) for migratory birds and mammals [15.2.2, 15.4.1], with major implications for predators such as seals and polar bears ** [15.2, 15.4.3]. Changes in the distribution and abundance of many species can be expected. *** D [15.6.3]
• The climatic barriers that have hitherto protected polar species from competition will be lowered, and the encroachment of alien species into parts of the Arctic and Antarctic are expected. ** D [15.6.3, 15.4.4, 15.4.2]
• Reductions in lake and river ice cover are expected in both polar regions. These will affect lake thermal structures, the quality/quantity of under-ice habitats and, in the Arctic, the timing and severity of ice jamming and related flooding. *** N [15.4.1]
• Projected hydrological changes will influence the productivity and distribution of aquatic species, especially fish. Warming of freshwaters is likely to lead to reductions in fish stock, especially those that prefer colder waters. ** D [15.4.1]

• For Arctic human communities, it is virtually certain that there will be both negative and positive impacts, particularly through changing cryospheric components, on infrastructure and traditional indigenous ways of life. ** D [15.4]
• In Siberia and North America, there may be an increase in agriculture and forestry as the northern limit for these activities shifts by several hundred kilometres by 2050 [15.4.2]. This will benefit some communities and disadvantage others following traditional lifestyles. ** D [15.4.6]
• Large-scale forest fires and outbreaks of tree killing insects, which are triggered by warm weather, are characteristic of the boreal forest and some forest tundra areas, and are likely to increase. ** N [15.4.2]
• Arctic warming will reduce excess winter mortality, primarily through a reduction in cardiovascular and respiratory deaths and in injuries. *** N [15.4.6]
• Arctic warming will be associated with increased vulnerability to pests and diseases in wildlife, such as tick-borne encephalitis, which can be transmitted to humans. ** N [15.4.6]
• Increases in the frequency and severity of Arctic flooding, erosion, drought and destruction of permafrost, threaten community, public health and industrial infrastructure and water supply. *** N [15.4.6]
• Changes in the frequency, type and timing of precipitation will increase contaminant capture and increase contaminant loading to Arctic freshwater systems. Increased loadings will more than offset the reductions that are expected to accrue from global emissions of contaminants. ** N [15.4.1]
• Arctic human communities are already being required to adapt to climate change. Impacts to food security, personal safety and subsistence activities are being responded to via changes in resource and wildlife management regimes and shifts in personal behaviours (e.g., hunting, travelling). In combination with demographic, socio-economic and lifestyle changes, the resilience of indigenous populations is being severely challenged. *** N [15.4.1, 15.4.2, 15.4.6, 15.6]

Small Islands

• Sea-level rise and increased sea-water temperature are projected to accelerate beach erosion, and cause degradation of natural coastal defences such as mangroves and coral reefs. It is likely that these changes would, in turn, negatively impact the attraction of small islands as premier tourism destinations. According to surveys, it is likely that, in some islands, up to 80% of tourists would be unwilling to return for the same holiday price in the event of coral bleaching and reduced beach area resulting from elevated sea surface temperatures and sea-level rise. ** D [16.4.6]
• Port facilities at Suva, Fiji, and Apia, Samoa, are likely to experience overtopping, damage to wharves and flooding of the hinterland following a 0.5 m rise in sea level combined with waves associated with a 1 in 50-year cyclone. *** D [16.4.7]
• International airports on small islands are mostly sited on or within a few kilometres of the coast, and the main (and often only) road network runs along the coast. Under sea-level rise scenarios, many of them are likely to be at serious risk from inundation, flooding and physical damage associated with coastal inundation and erosion. *** D [16.4.7]
• Coastal erosion on Arctic islands has additional climate sensitivity through the impact of warming on permafrost and massive ground ice, which can lead to accelerated erosion and volume loss, and the potential for higher wave energy. *** D [16.4.2]
• Reduction in average rainfall is very likely to reduce the size of the freshwater lens. A 10% reduction in average rainfall by 2050 is likely to correspond to a 20% reduction in the size of the freshwater lens on Tarawa Atoll, Kiribati. In general, a reduction in physical size resulting from land loss accompanying sea-level rise could reduce the thickness of the freshwater lens on atolls by as much as 29%. *** N [16.4.1]

• Without adaptation, agricultural economic costs from climate change are likely to reach between 2-3%and 17-18%of 2002 GDP by 2050, on high terrain (e.g., Fiji) and low terrain (e.g., Kiribati) islands, respectively, under SRES A2 (1.3°C increase by 2050) and B2 (0.9°C increase by 2050). ** N [16.4.3]
• With climate change, increased numbers of introductions and enhanced colonisation by alien species are likely to occur on mid- and high-latitude islands. These changes are already evident on some islands. For example, in species-poor sub- Antarctic island ecosystems, alien microbes, fungi, plants and animals have been causing a substantial loss of local biodiversity and changes to ecosystem function. ** N [16.4.4]
• Outbreaks of climate-sensitive diseases such as malaria, dengue, filariasis and schistosomiasis can be costly in lives and economic impacts. Increasing temperatures and decreasing water availability due to climate change is likely to increase burdens of diarrhoeal and other infectious diseases in some small-island states. ** D [16.4.5]
• Climate change is expected to have significant impacts on tourism destination selection ** D [16.4.6]. Several small-island countries (e.g., Barbados, Maldives, Seychelles, Tuvalu) have begun to invest in the implementation of adaptation strategies, including desalination, to offset current and projected water shortages. *** D [16.4.1]
• Studies so far conducted on adaptation on islands suggest that adaptation options are likely to be limited and the costs high relative to GDP. Recent work has shown that, in the case of Singapore, coastal protection would be the least-cost strategy to combat sea-level rise under three scenarios, with the cost ranging from US$0.3-5.7 million by 2050 to US$0.9-16.8 million by 2100. ** D [16.5.2]
• Although adaptation choices for small islands may be limited and adaptation costs high, exploratory research indicates that there are some co-benefits which can be generated from pursuing prudent adaptation strategies. For example, the use of waste-to-energy and other renewable energy systems can promote sustainable development, while strengthening resilience to climate change. In fact, many islands have already embarked on initiatives aimed at ensuring that renewables constitute a significant percentage of the energy mix. ** D [16.4.7, 16.6]

TS.4.5 Especially affected systems, sectors and regions

Some systems, sectors and regions are likely to be especially affected by climate change.
Regarding systems and sectors, these are as follows.
• Some ecosystems especially
- terrestrial: tundra, boreal forest, mountain, mediterranean-type ecosystems;
- along coasts: mangroves and salt marshes;
- in oceans: coral reefs and the sea-ice biomes. [4.ES, 4.4, 6.4]
• Low-lying coasts, due to the threat of sea-level rise [6.ES].
• Water resources in mid-latitude and dry low-latitude regions, due to decreases in rainfall and higher rates of evapotranspiration [3.4].
• Agriculture in low-latitude regions, due to reduced water availability [5.4, 5.3].
• Human health, especially in areas with low adaptive capacity [8.3].
Regarding regions, these are as follows.
• The Arctic, because of high rates of projected warming on natural systems [15.3].
• Africa, especially the sub-Saharan region, because of current low adaptive capacity as well as climate change [9.ES, 9.5].
• Small islands, due to high exposure of population and infrastructure to risk of sea-level rise and increased storm surge [16.1, 16.2].

• Asian megadeltas, such as the Ganges-Brahmaputra and the Zhujiang, due to large populations and high exposure to sea-level rise, storm surge and river flooding [T10.9, 10.6].
Within other areas, even those with high incomes, some people can be particularly at risk (such as the poor, young children and the elderly) and also some areas and some activities [7.1, 7.2, 7.4].

Key vulnerabilities

Key vulnerabilities are found in many social, economic, biological and geophysical systems.

Increasing levels of climate change will result in impacts associated with an increasing number of key vulnerabilities, and some key vulnerabilities have been associated with observed climate change.

Key systems or groups at risk	Prime criteria for 'key vulnerability'	Global average temperature change above 1990 (0°C, 1°C, 2°C, 3°C, 4°C, 5°C)
Global social systems		
Food supply	Distribution, magnitude	Productivity decreases for some cereals in low latitudes ** Productivity increases for some cereals in mid/high latitudes ** Cereal productivity decreases in some mid/high latitude regions ** Global production potential increases to around 3°C, decreases above this * **a**
Aggregate market impacts and distribution	Magnitude, distribution	Net benefits in many high latitudes; net costs in many low latitudes * **b** Benefits decrease, while costs increase. Net global cost * **b**
Regional system		
Small islands	Irreversibility, magnitude, distribution, low adaptive capacity	Increasing coastal inundation and damage to infrastructure due to sea-level rise **
Indigenous, poor or isolated communities	Irreversibility, distribution, timing, low adaptive capacity	Some communities already affected ** **c** Climate change and sea-level rise adds to other stresses **. Communities in low-lying coastal and arid areas are especially threatened ** **d**
Global biological systems		
Terrestrial ecosystems and biodiversity	Irreversibility, magnitude, low adaptive capacity, persistence, rate of change, confidence	Many ecosystems already affected *** c. 20-30% species at increasingly high risk of extinction * Major extinctions around the globe ** Terrestrial biosphere tends toward a net carbon source **
Marine ecosystems and biodiversity	Irreversibility, magnitude, low adaptive capacity, persistence, rate of change, confidence	Increased coral bleaching ** Most corals bleached ** Widespread coral mortality **
Geophysical systems		
Greenland ice sheet	Magnitude, irreversibility, low adaptive capacity, confidence	Localised deglaciation (already observed due to local warming), extent would increase with temperature *** **e** Commitment to wide-spread ** or near-total * deglaciation, 2-7 m sea-level rise[14] over centuries to millennia * **e** Near-total deglaciation ** **e**
Meridional Overturning Circulation	Magnitude, persistence, distribution, timing, adaptive capacity, confidence	Variations including regional weakening (already observed but no trend identified) **f** Considerable weakening **. Commitment to large-scale and persistent change including possible cooling in northern high-latitude areas near Greenland and north-west Europe •, highly dependent on rate of climate change.
Risks from extreme events		
Tropical cyclone intensity	Magnitude, timing, distribution	Increase in Cat. 4-5 storms */**, with impacts exacerbated by sea-level rise Further increase in tropical cyclone intensity */**
Drought	Magnitude, timing	Drought already increasing * **g** Increasing frequency / intensity drought in mid-latitude continental areas ** **h** Extreme drought increasing from 1% land area to 30% (A2 scenario) * **i** Mid-latitude regions affected by poleward migration of Annular Modes seriously affected ** **j**

Table TS.8. *Table of selected key vulnerabilities. The key vulnerabilities range from those associated with societal systems, for which the adaptation potential is the greatest, to those associated with biophysical systems, which are likely to have the least adaptive capacity. Adaptation potential for key vulnerabilities resulting from extreme events is associated with the affected systems,* *most of which are socio-economic. Information is presented where available on how impacts may change at larger increases in global mean temperature (GMT). All increases in GMT are relative to circa 1990. Most impacts are the result of changes in climate, weather and/or sea level, not of temperature alone. In many cases climate change impacts are marginal or synergistic on top of other existing and possibly increasing stresses. Criteria for key vulnerabilities are given in Section TS 5.3. For full details refer to the corresponding text in Chapter 19. Confidence symbol legend: *** very high confidence, ** high confidence, * medium confidence, • low confidence. Sources for left hand column are T19.1. Sources for right hand column are T19.1, and are also found in Tables TS.3 and TS.4, with the exception of: **a**: 5.4.2, 5.6; **b**: 20.6, 20.7; **c**: 1.3, 11.4.8, 14.2.3, 15.4.5; **d**: 3.4, 6.4, 11.4; **e**: 19.3.5, T19.1; **f**: 19.3.5, 12.6; **g**: 1.3.2, 1.3.3, T19.1; **h**: WGI 10.3.6.1; **i**: WGI AR4 10.3.6.1; **j**: WGI AR4 10.3.5.6.*

TS.5.4 Perspectives on climate change and sustainability

Future vulnerability depends not only on climate change but also on development pathway.

Vulnerability to climate change can be exacerbated by the presence of other stresses.

Climate change will very likely impede nations' abilities to achieve sustainable development pathways, as measured, for example, as long-term progress towards the Millennium Development Goals.