Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report

Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability

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Summary for Policymakers

Confidential Second Order Draft for comment by Governments and Experts.

Important Note: This draft is not in its final form. Its content will undergo revision in response to comment. Therefore its contents should not be circulated[1] or published.

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[1] That is, circulation beyond that appropriate for a managed review.

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A. Introduction to the Summary for Policymakers

The aim of this document is to set out the main policy-relevant findings of the Fourth Assessment Report (AR4) of Working Group II (WGII) of the Intergovernmental Panel on Climate Change (IPCC). The WGII AR4 assesses the new knowledge which has emerged since the IPCC Third Assessment (TAR) regarding the understanding of impacts of climate change on natural, managed and human systems, their capacity to adapt and their vulnerability[2].

This Summary for Policymakers is organized under four key headings. These are:

- Current knowledge about present-day impacts
- Current knowledge about future vulnerability and impacts
- Current knowledge about responding to climate change
- Implications for sustainability

A description of the procedures followed in this Assessment by the authors, reviewers and participating governments is given in Appendix 1.

Sources for statements in this Summary are given at the end of each substantive statement and/or paragraph[3]. In the final version sources may be collected together in an Appendix.

B. Current knowledge about present-day impacts

Increases in regional surface temperature changes in all inhabited continents and many sub-continental land areas are likely[4] to be the result of greenhouse gas emissions (IPCC AR4 Working Group I Chapter 9). In this section we summarise current knowledge about how far this may or may not have affected physical, biological and human systems.

Changes in climate are now affecting physical and biological systems on every continent. Effects on human systems, although more difficult to discern due to adaptation and non-climatic drivers, are emerging. Over 99% of observed changes in systems and sectors are consistent with regional temperature trends. Many of the changes are now attributed to temperature increase caused by anthropogenic greenhouse gas emissions.

Observed responses in multiple systems and sectors since 1970 have been attributed to anthropogenic climate change[5] [1.4.2]. The distribution of the sites of the observed system and sector changes, together with the spatial pattern of attributed regional temperature change, is shown in Fig. SPM-1. Some examples of specific changes are shown in Fig. SPM-2.

The main change in **physical systems** is of snow and ice melt (including loss of Arctic sea ice and retreat of parts of the Antarctic and Greenland ice sheets, collapse of ice shelves, retreat of glaciers world-wide, and thawing of permafrost) [1.3.1]. The consequences of this are seen in:

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[2] Definitions of climate change, impact, adaptation and vulnerability are given in Appendix 1.
[3] The example source [3.3.2] refers to Chapter 3, Section 3.2. In the sourcing, F = Figure, T = Table, B = Box and ES = Executive Summary.
[4] Words such as 'virtually certain', 'likely', 'very unlikely and 'exceptionally unlikely' are used in the WGII SPM to express the likelihood of an outcome with precision. The probabilities associated with the likelihood language are shown in Appendix 1.
[5] Formal attribution, using statistical techniques, is carried out in a two-step procedure, first through attribution of the system and sector responses to regional warming and, second, through attribution of the regional warming to anthropogenic climate change.

- accelerated reduction of land-based ice area and mass in most parts of the world (see, for example, Fig. SPM-2(c)), contributing to global sea-level rise and disruption of local water resources in some areas [1.3.1.1; B1.1];
- increasing glacial melt-related floods, ice and rock avalanches in mountain regions, and runoff from snow-covered and glacial basins [1.3.1.1; 1.3.1.4; 1.3.1.5];
- substantial changes in terrestrial and marine flora and fauna in the Arctic and Antarctic [1.3.1.1; 1.3.5].

There is more evidence that an **intensified hydrological cycle** is leading to changes in runoff and streamflow in some regions [1.3.2].

- Runoff into the Arctic Ocean has increased, probably due to a combination of increased precipitation, cryosphere melting and plant responses[6] to higher ambient CO_2 [1.3.2.1; 15.2.1].
- Drought is increasing [IPCC AR4 Working Group I, Chapter 3.3], with drier regions most affected [1.3.2.2].

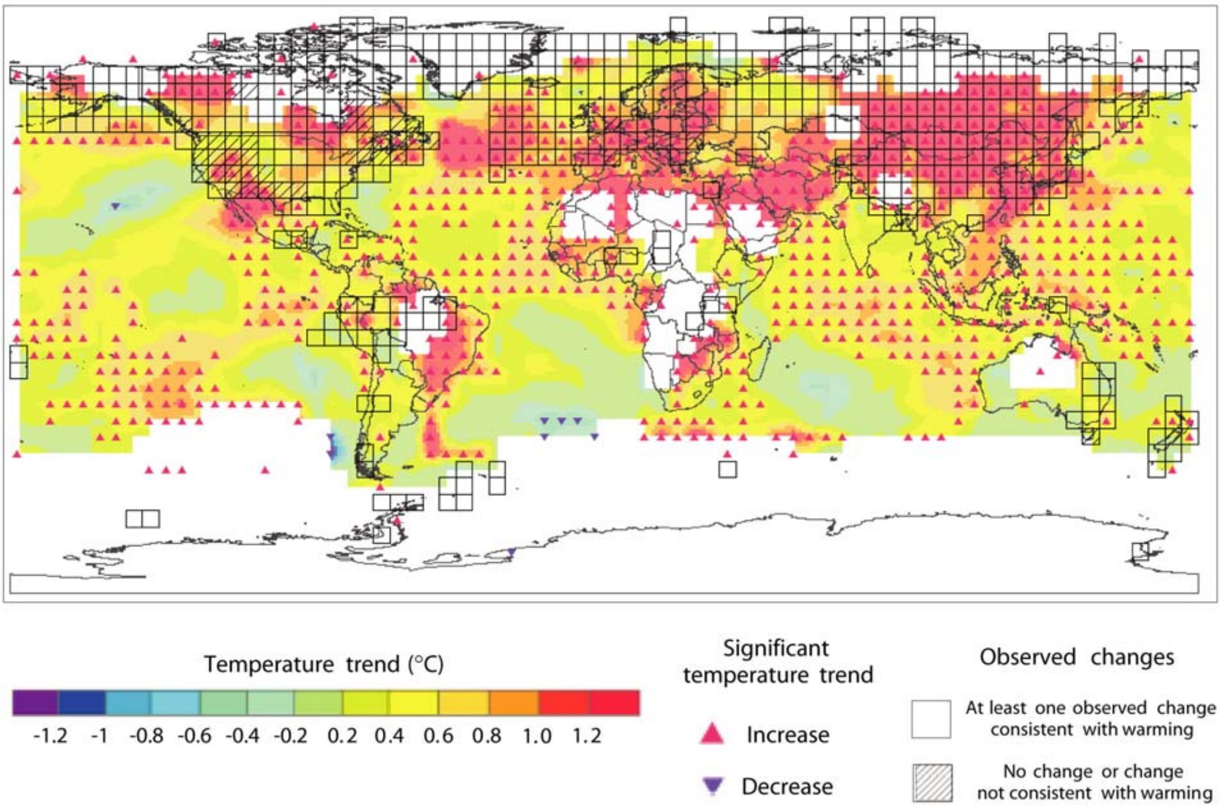


Fig. SPM-1: Observed regional trends in surface air temperature over the period 1973-2002 and observed changes in cryosphere, hydrology, coastal zones, marine, freshwater and terrestrial biological systems with at least 20 years of data in the period. This shows clearly that in most locations where data exist, the change in systems and sectors is consistent with the regional temperature trend. Temperature trends are averaged over 5° by 5° gridboxes; statistically significant temperature changes are marked with triangles. [F1.9]

[6] Increased CO_2 has been observed to suppress transpiration in plants.

Average sea levels are rising about 1.7mm/yr globally [T1.4; 1.3.3]. This is now affecting **coastal zones** in terms of erosion, increased coastal flooding and losses of coastal wetlands and mangrove forests. However, impacts of human activities on coasts have generally been greater than impacts that can be attributed to sea level rise. [T1.4, 1.3.3.1; 1.3.3.2; 1.3.3.5]

Oceans, seas, lakes and rivers around the world are warming, with observed effects on:

- lake chemistry, with concentrations of ions increasing due to weathering [1.3.2.3];
- thermal structure of the oceans, with resultant reduction of sea ice and coastal permafrost, and associated coastal retreat [1.3.1.5; 1.3.1.6]; and,
- the vertical stability of the water column in freshwater lakes [5.4.6.2].

Observed responses in **marine and freshwater biological systems** to rising water temperatures include:

- bleaching of coral reefs [1.3.4.1; B6.1];
- poleward extension in distributions of many marine plankton and fish species [1.3.4.2; 15.ES]; and,
- altered ecology of warming lakes and rivers, including altered abundance and productivity, community composition, phenology, distribution and migration. [1.3.4.4; 1.3.4.5; T1.7]

Ocean acidification due to increasing atmospheric levels of CO_2 is occurring, with an increase in hydrogen ion concentration of 30% since 1800 [1.ES]. Because this issue has only recently been identified, little is known at present about the implications for ocean or coastal biology, although there are concerns about the implications for calcifying organisms [6.4.2.2].

In **terrestrial biological systems**, responses to warming have occurred in a wide array of species:

- changes in floral and faunal abundance, both increases and decreases (see examples in Fig. SPM-2b) [1.3.5.4; 1.3.5.7];
- changes in behaviour, such as in avian migration patterns [1.3.5.2; 15.4.2];
- earlier onset of spring events and lengthening of the growing season in high and high mid-latitudes (see Fig. SPM-2b) [1.3.5.2; T1.9];
- increases in global net primary productivity (c. 6 % since about 1980) due to elevated atmospheric CO_2 concentrations [1.3.6.2].

Effects are not yet strongly apparent in **human systems** because of adaptation and non-climate drivers. [1.3] Exceptions include:

- Some changes in higher latitude agriculture such as earlier planting in response to earlier spring seasons [1.3.6.1; T1.11].
- In Arctic settlements, subsidence of buildings and highways due to thawing permafrost and changes in indigenous livelihoods [1.3.1.5; 1.3.1.8; 15.5].
- Emerging evidence of effects on human health including changes in seasonal production of pollens which cause allergenic diseases [1.3.7.5; 8.2.7], and increased duration and frequency of heatwaves [1.3.7.3; T8.1; 10.2.3.1].

Global economic losses from weather-related disasters have risen substantially since the 1970s [1.3.8.5]. During the same period, global temperatures have risen and the magnitude of some extremes, such as the intensity of tropical cyclones, has increased [1.3.8.3]. However, because of increases in exposed value (due to changes in wealth and property/population distribution), the contribution of these weather-related trends to increased losses is at present not known [1.3.8.4].

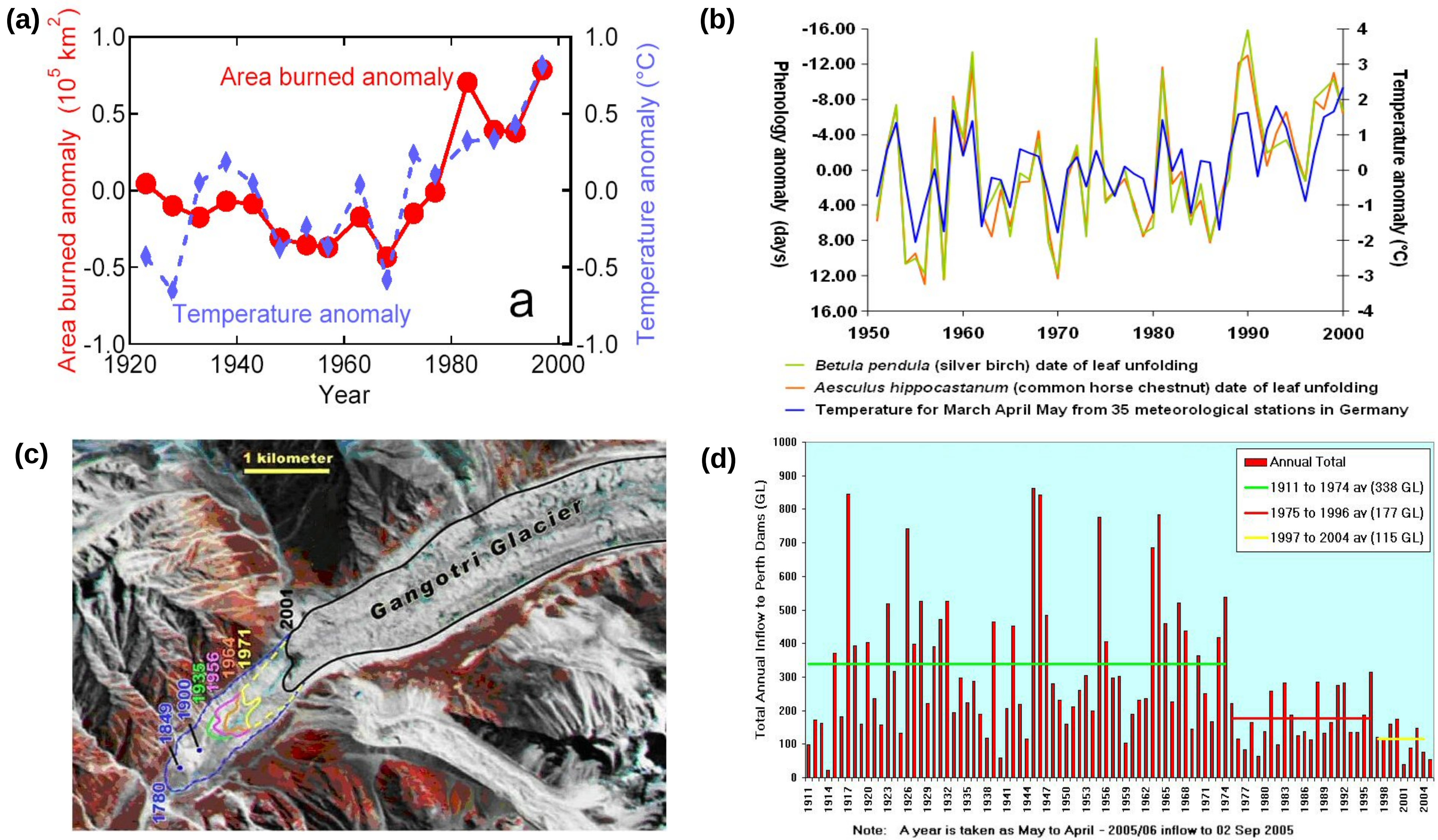


Fig SPM-2: Observed changes in selected systems and sectors: (a) Canadian forest fires 1920-2000 [1.3.6.2; F14.1(g)]. The area burned has increased by around 70,000 km^2 per annum since the 1920s. (b) Spring temperatures and date of leaf unfolding in Germany [F1.4]. On average, spring temperatures are 1-1.5^{o}C warmer now than in the 1950s, and trees are coming into leaf around 4 days earlier. (c) Retreat of the Gangotri Glacier, Indian Himalayas [1.3.1.1; F10.6]. This glacier has been receding since 1780, more rapidly since 1971. In the last 25 years, the glacier has receded by 850 m. (d) Changes in yearly streamflow into the Perth, Australia, water supply [1.3.2; F11.4]. Since the mid-twentieth century, there has been a 50% drop in the annual inflows to reservoirs supplying the city of Perth.

C. Current knowledge about future vulnerability and impacts

Magnitudes of impact can now be estimated for a range of potential increases in global mean temperature

Global effects have been estimated for a range of global temperature changes[7]. For ecosystems and food security, two of the issues mentioned in Article 2 of the UNFCCC, the following effects are estimated:

Up to 1°C:	Some ecosystem shifts; some increases in global agricultural production potential, but reduced yields at lower latitudes [4.4.10; T4.2; F4.4; 5.4.2.2; F5.2; 19.3.2].
For 1 to 2°C:	About one-quarter of species lost from current range; further increases in global agricultural production potential but further yield reductions at lower latitudes [T4.2; 5.4.2.2; 19.3.2].
For 2 to 3°C:	Most of tundra and about half of boreal forest area disappears; about one-third of species lost from current range; global agricultural production potential peaks but further yield reductions at lower latitudes suggest large increases in numbers of people at risk of hunger [T4.2; 5.4.2.2; T19.2].
For 3 to 4°C:	Global decreases in agricultural production potential; large numbers additionally at risk of hunger [F5.2; T20.2; T20.3].
For 4 to 5°C:	Decreases in agricultural production potential at higher latitudes, as well as further decreases at lower latitudes. [F5.2]
For 5 to 6 °C:	Widespread species extinction. [T19.2]

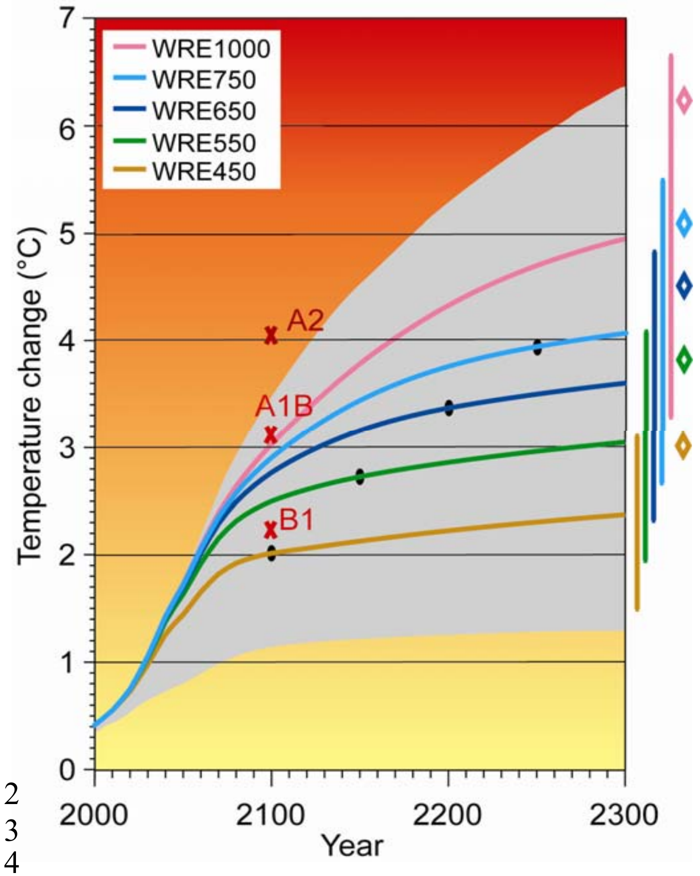
In addition to these, other key vulnerabilities have been identified which might significantly affect the livelihood of people or the ecosystems they depend on. These are summarised in Fig. SPM-3.

The size and character of such impacts is likely to vary greatly according to the level and nature of future socio-economic development [T20.2]. The few studies that have been carried out, using scenarios based on IPCC SRES, indicate that levels of development are likely to affect the amount of impact as much as does the magnitude of climate change, at least with respect to human welfare and economic development as measured by, for example, the number of people at risk from flooding, water shortage, hunger and disease. [20.6.1; T20.2]

An illustration is given in Fig. SPM-4, which shows that:

a) There is a substantial difference between the estimated additional millions at risk of flooding under the A2 SRES scenario than under the B2 or A1FI scenarios, primarily because many more millions of poor people live in flood prone areas in the A2 scenario; and
b) Adaptation can often reduce these impacts substantially, as will be discussed in the following section. When spending on coastal protection is assumed to evolve pro rata with GDP, this decreases substantially the numbers estimated to be additionally at risk of flooding.

[7] All references to temperature changes in this Summary for Policymakers are with respect to pre-industrial (c. 1750) temperatures.



Ecosystems	Food (changes in production potential, pp)	Sustainable Development (water stress, flooding, human health)	Weather Extremes	Large Scale Singular Events
Widespread species extinctions ●	Further global pp decreases +/○	Out-migration may be the only option in many regions ○/●	Frequency of hot days much greater, many locations untenable without adaptation	Considerable weakening ● and shutdown of MOC ○/+
Most mountain glaciers disappear ●	Decreases in pp at higher latitudes +/○	Too expensive to protect many from flooding ○/● Up to one-third of the population water stressed ○	Further increased frequency and intensity of fire, drought and storms ●	
Most tundra and c. half boreal forest disappear ○ c. one-third of species lost from current range ○ all coral reefs bleached ●	Global pp decreases + Larger numbers at risk of hunger ○ Global pp peaks + Risk of hunger increases at lower latitudes ○	1 billion newly water stressed ○ Increased risk to human health ○	Heat wave frequency increases rapidly ● Increased frequency and intensity of drought ●	Triggering of widespread deglaciation in Greenland and disintegration of WAI ○/●
c. one-quarter of species lost from current range ○ Most of world's coral reefs bleached ●	Global increases in pp + Increases in pp at higher latitudes ○/+ Decreases in pp at lower latitudes +	Many at risk from coastal flooding ● Increased water stress in some regions ● Flooding by SLR ●	Increased heat stress and heat waves, especially in continental areas ● Increases in severe storms ○/●	Localised deglaciation in Greenland and local disintegration of WAI ●

Fig. SPM-3: Some global impacts projected for global temperature changes relative to pre-industrial temperatures. NB impacts may also be affected by the rate of change which is not indicated here; and adaptation has the capacity to reduce or avoid impacts (see later discussion).
Confidence levels: ● High confidence ○ Medium confidence + Low confidence. Confidence estimates cannot be made for each statement. For definitions see Appendix 1. Sources: 3.2, 3.5, T4.2, F5.2, 5.4, 5.6, T19.2, 20.2 and 20.6.
The key on the left, taken from the Third Assessment Synthesis Report, is for guidance only and provides an indication of temperature changes (relative to pre-industrial temperatures) up to 2300 under various SRES and stabilization scenarios. A2, A1B and B1 are projected temperature changes under SRES scenarios. Temperature changes for stabilization scenarios are estimated using a simple climate model for the WRE stabilization profiles. Warming continues after the time at which CO2 concentration is stabilized (indicated by black spots), but at a much diminished rate. It is assumed that emissions of gases other than CO2 follow the SRES A1B projection until the year 2100 and are constant thereafter. This scenario was chosen as it is the middle of the range of SRES scenarios. The shaded area illustrates the effect of a range of climate sensitivity across the five stabilization cases. The coloured bars on the right hand side show uncertainty for each stabilization case at the year 2300. The diamonds on the right hand side show the average equilibrium (very long term) warming for each CO2 stabilization level. Source: Fig. SPM-6 in the Third Assessment Synthesis Report adjusted with temperature changes relative to pre-industrial levels. West Antarctic Ice sheet (WAI), Meridional Overturning Circulation (MOC), Sea Level Rise (SLR) [The revised version of this draft will aim to use AR4 data on projected temperature changes rather than from the TAR]

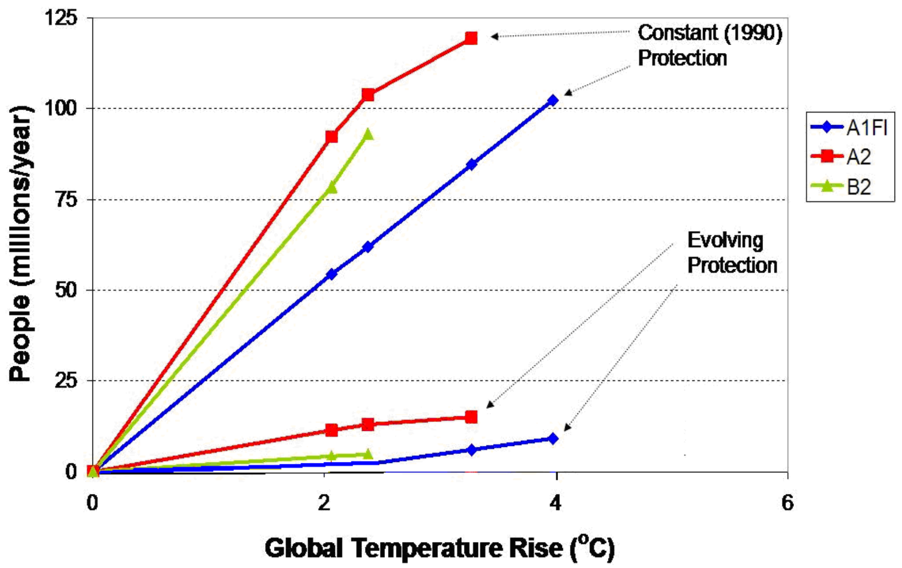


Fig. SPM-4: Global number of additional people estimated to be flooded in coastal areas in the 2080s due to climate change under three SRES scenarios, and with constant and evolving protection [F6.3]. In evolving protection, spending increases at the same rate as GDP. Constant protection assumes no changes from 1990 levels.

Some sectors and systems are especially vulnerable

A summary of the main impacts expected in each sector/system is given in Box SPM-1.

Climate change impacts on the following systems and sectors are expected to have the greatest implications for sustainability and development:

- The **cryosphere,** which would be severely affected by ice melt and reductions in seasonal snow cover [15.4.1.2];
- **Ecosystems,** where climate change could lead to major ecosystem shifts [4.4];
- **Coastal areas,** which would be threatened by sea level rise [6.4];
- **Water resources**, which would become more scarce for most people; and [3.4]
- **Agricultural food production**, which would be likely to increase in global potential at least for small amounts of warming, but which is also likely to decrease in those areas where food security is low at the present day [5.4.2].

Sub-Saharan Africa, small islands and polar areas are the regions most at risk.

A summary of the main impacts expected in each region is given in Box SPM-2.

Two sources of risk can be identified: exposure and intrinsic vulnerability:

- Polar regions are likely to experience large impacts because of exposure to higher than average projected rates of warming [15.3.2; 15.ES].
- Sub-Saharan Africa is likely to experience large impacts from climate change, due to high levels of intrinsic vulnerability stemming from heavy dependence on rain-fed agriculture, propensity to drought, and relatively low levels of adaptive capacity [9.1; 9.2.2; 9.ES].
- Small islands are likely to experience large impacts due to the combination of high exposure (e.g., sea level rise and storm surge) and high vulnerability (e.g., lack of infrastructure) [16.2.1; 16.4].

All areas, even the most developed, have vulnerable regions, communities and sectors.

- Even in high-income economies, vulnerable locations, economic activities and sectors of society exist [7.2; 8.ES; 8.7; B8.1]. This is demonstrated by the impacts of some recent extreme events such as the hot summer of 2003 in Western Europe and Hurricane Katrina in the southern U.S. in 2005 [7.2; B7.1; 8.ES; 8.2.1; 8.2.2; 14.5.2].

- In general, it appears that the most vulnerable include:
  - Those already under stress (because they are, for example, poor or marginalised or weakened by over-exploitation) [17.3.2; B17.5];
  - Those with low adaptive capacity [17.2; 17.3.2; B17.7; 18.3]; and,
  - Women, young children and the elderly (particularly in primary-resource dependent and poorer economies) [B8.1; B17.6].

- Over the past 5 years, the completion of many more studies has improved the coverage of knowledge for regions and sectors about which little was previously known. There remain major regional and sectoral information gaps, but it is possible now to estimate the severity of projected impacts across regions and sectors. Fig. SPM-5 is a summary of findings.

	Africa	Asia	Latin Am.	A & NZ	Europe	North Am.	Polar reg.	Small Is.
Water resources	9.4.1	10.4.2	13.4.2 13.4.3	11.4.1	12.4.1	F3.7 F14.1a	15.4.1	F3.7
Marine ecosystems	4.4.9 5.4.6	4.4.9 5.4.6	4.4.9 5.4.6	4.4.9 5.4.6	4.4.9 5.4.6	4.4.9 5.4.6	4.4.9 5.4.6	4.4.9 5.4.6
Forest ecosystems	4.4.5	T4.2 10.4.4	13.4.1	T11.4	12.4.4.	14.4.2	4.4.5	16.4.4 B16.1
Grassland ecosystems	4.4.3	10.4.4	T4.2	T11.4	12.4.4	4.4.3	4.4.6	
Lakes, rivers and wetlands	4.4.8	10.4.3		T11.4	12.4.5	14.4.1	15.4.1	
Coastal ecosystems	9.4.6	10.4.3	T13.5	T11.4 T4.2	12.4.2	14.4.3	4.4.6 15.4.7	16.4.2
Birds, amphibians and terrestrial mammals	T4.2 4.4.3			T11.1	12.4.6	14.4.2	4.4.6 B4.4	B16.1
Commercial agriculture	9.4.4	10.4.1	13.ES 13.4.2	11.4.3	12.4.7	14.4.4	15.4.2	16.4.3
Subsistence agriculture	9.4.4	10.4.1					15.4.2	16.4.3
Livestock	F5.6 9.4.4	10.4.1	13.4.2	11.4.3	T12.7	5.4.3		
Forestry	F5.6	F5.6	F5.6	11.4.4	F5.6	14.4.4	15.4.2	
Coastal settlements	9.4.6	10.4.3	13.4.4 T13.5	11.4.5	12.4.2	14.4.3	15.4.7 15.7.1	16.4.2
Urban areas and megacities	T9.2 9.4.8	10.4.3	13.4.5	11.4.7	T12.7	14.4.5 14.4.6	15.7.1	16.4.5
Human health: heat stress	T9.2	10.4.5	13.4.5	11.4.11	12.4.11	14.4.5		16.4.5
Human health: Vector-borne diseases	9.4.3	10.4.5	13.4.5	11.4.11	12.4.11	14.4.5	15.4.6	16.4.5
Energy demand: Increased demand shown -ive	T9.2	10.4.6	13.4.5	11.4.10	12.4.8	14.4.8	15.ES	
Transport	T9.2	10.4.6		11.ES	12.4.8	14.4.8	15.ES 15.7.1	16.4.7
Construction industry	T9.2					14.4.8	15.7.1	
Tourism	9.4.7	10.5.6	13.ES	11.4.9 11.6	12.4.9	14.4.7		16.4.6

Estimated impact of climate change:

Negative: Strongly negative ↑ Weakly negative

Positive: Strongly positive ↑ Weakly positive

Neutral

N/A or no information

Fig. SPM-5: Regional/sectoral strength of the estimated impact of climate change. This reflects the extent of exposure as well as the capacity to adapt. Negative or positive represents changes in potential productivity in a given system or sector, not necessarily human wellbeing. Numbers are sources in the chapters of the full Assessment. Impacts are estimated for c. 2050, assume that climate changes have not been significantly reduced by emissions reductions, and that adaptive capacities in different regions and systems/sectors are broadly commensurate with a development pathway along a line similar to that of the past half century. Am. = America; A & NZ = Australia and New Zealand; reg. = Regions; Is. = Islands.

Box SPM-1 Main expected impacts for systems and sectors

WATER

- The hydrological cycle is likely to intensify. There is already evidence of increases in the number of very wet and very dry areas. [3.4.3]
- Simulation of precipitation change by climate models remains uncertain. This has implications for adaptation procedures which need to be developed based on projections of changes, for example in river discharge or groundwater. [3.ES; 3.3.1, 3.4.1]
- Semi-arid and arid river basins are most vulnerable to water stress. Climate-induced changes in runoff for these basins are projected to be high. [3.5.1] Management adaptation will be essential to avoid strong negative impacts. [3.6]
- Reduction in transpiration from plants due to direct physiological effects of rising CO_2 may lead to greater increases or smaller decreases in runoff compared to those expected from climate change alone. [3.ES; 3.4.1]
- Projected increases in summer drying over mid-latitude continental interiors and hence drought risk would lead to adverse impacts on crop yields, water resource quantity and quality, and risk of forest fire. [3.4.3]
- Climate change is very likely to have a strong impact on saltwater intrusion in coastal areas, and on salinization of groundwater. Where relative sea-level rise occurs, it will adversely affect groundwater aquifers. [3.2.1; 3.4.2; 3.4.4]
- In many aquifers, spring recharge is expected to retreat towards winter, and summer recharge is expected to decline dramatically. [3.1; 3.4.2]
- The thickness of small island freshwater lens in the Indian Ocean declines from 25 to 10 m with a 10 cm rise in sea level by 2040-2080 [3.4.2; F3.7]

ECOSYSTEMS

- Terrestrial ecosystems provide a net global carbon sink until ~2030 (0.5-1.0°C warming), but a likely net source by ~2100 under SRES A2 and B1 scenarios [4.4.1, F4.2]. Sequestration by expanding taiga [4.4.5] may be offset by albedo change and CH_4 losses from tundra [4.4.6]; that of tropical forests depends on their persistence under socio-economic pressures [4.4.5, 4.4.10]. Nutrient (mainly nitrogen) constraints on CO_2 fertilization are a key uncertainty in terrestrial carbon sink projections [4.4.1, 4.4.10, 4.8].
- Forest expansion is projected in North America with <2°C warming [4.4.10, F4.4, T4.3], while other vulnerable (e.g. tropical) ecosystems are likely to experience severe impacts, including some biodiversity loss [4.4.10, 4.4.11, T4.2].
- Amazon forests, China's taiga and 77% of Canadian tundra are at risk of degradation, and Australian Kakadu wetlands of inundation with >3°C warming [T4.2, 4.4.1, F4.2, 4.4.10, F4.4], with ~25% global biodiversity loss possible [4.4.11].
- Wildfires could increase globally, causing replacement of forests and woodlands by an up to 50% savanna and grassland expansion [4.4.10, F4.4, T4.3]. Alien invasive species and pest interactions remain key uncertainties [4.4].
- Ocean acidification through direct CO_2 effects (previously unrecognized) are likely to impact calcifying organisms (e.g. cold-water corals) and aragonite shell forming organisms (e.g. stony corals) severely [4.4.9, B4.5].
- Massive loss of corals due to bleaching is expected over the next 50 years [B4.5, 4.4.9]. Annual coral bleaching is expected between 2030 and 2050 for the Great Barrier Reef, due to climate change and other pressures [B4.5, 4.4.9].
- Ocean biota will move polewards more rapidly than those on land, where many plant species will lag behind warming [4.4.5, 4.4.9]. Oceanic productivity is expected to decline at low and increase at high latitudes [4.4.9].
- The productive sea ice biome could contract by 42% (Arctic) and 17% (Antarctic) by 2050 under IS92a [4.4.9]. Ice dependent species such as polar bears will lose their habitat and be pushed towards extinction [4.4.6, B4.4].

FOOD, FIBRE AND FOREST PRODUCTS (FFF)

- In temperate regions, moderate increases in temperature (1 to 3ºC), with associated CO_2 increase and rainfall changes, can have small beneficial impacts on crops. In tropical regions, even moderate temperature increases are likely to have negative yield impacts for major cereals. Short-term adaptations may enable avoidance of a 10-15% reduction in yield. [F5.2]
- The role of pests has become clearer since the TAR. In the FFF sectors, the poleward spread of diseases and pests, which were previously found at lower latitudes, is observed now and is projected to continue. The magnitude of the overall effect is unknown, but is likely to be highly regionalized. [5.ES; 5.4.1.4; 5.4.2.1]
- Warming and increased frequency of heat waves and droughts in Mediterranean, semi-arid and arid pastures will reduce livestock productivity and mortality whereas in some humid and temperate grasslands a moderate incremental warming will increase pasture productivity and reduce the need for housing and for feed concentrates. [5.ES; 5.4.3.1; 5.4.3.2; T5.2]
- Global forest products output may rise with climate change with large regional differences. Production in some traditional forest production regions may decline as new ones benefit. [5.ES; 5.4.5.1]
- Regional changes in the distribution and productivity of 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 will increase. [5.ES; 5.4.6.2]
- Trade flows are foreseen to rise significantly with climate change; export of temperate zone food products to tropical countries is likely to increase whereas there is likely to be greater export of forest products from tropical and sub-tropical regions to temperate regions. [5.ES; 5.4.5; T5.6; 5.6.3]

COASTAL SYSTEMS AND LOW-LYING AREAS

- Key vulnerabilities in coastal zones exist for (i) human communities in low-lying areas, especially where there are constraints on adaptation, particularly densely-populated megadeltas and atolls; (ii) coastal areas subject to multiple natural and human-induced stresses, e.g., subsidence or sediment starvation, such as many deltaic, estuarine and small island coasts; (iii) coastal areas already experiencing adverse effects of temperature rise, including ice-bound coasts and coral reefs; and (iv) coastal areas exposed to significant extreme water levels (e.g., Bay of Bengal, the US Gulf and East Coast and the Caribbean, Rio de la Plata). [T6.6]
- All coastal ecosystems are particularly vulnerable especially saltmarshes, mangroves, and corals. This is exacerbated where human infrastructure precludes onshore migration. [6.2; 6.4.1.4; 6.4.1.5]
- The greatest increase in vulnerability is expected on the coastal strips of South and SE Asia, and urbanized coastal locations around Africa, where the combination of coastal topography, numbers of people, poverty and lack of adaptive capacity combine to enhance exposure to risk. [6.4.2.2] Most small islands are also highly vulnerable. [6.4.3; T6.5]
- Increases in coastal flooding depend on the magnitude of sea-level rise (SLR) and climate change, the socio-economic scenario, and most particularly the degree of protection upgrade. If defences are not upgraded, impacts could be roughly 100 million people flooded per year under the SRES A1FI and A2 scenarios by 2080, while enhanced upgrade allowing for sea-level rise leads to almost negligible impacts. [6.5.3; F6.3]
- For a 65-cm SLR by 2100, costs and impacts are estimated to be greater in developing than in developed countries, with 30 times more people displaced, 12 times the area of land inundated, and flood protection costing three times more in developing than in developed countries. [6.5.3; F6.4]

INDUSTRY, SETTLEMENT AND SOCIETY

- Vulnerabilities of industry, infrastructures, settlements, and society are greater in certain high-risk locations, particularly coastal and riverine areas subject to flooding and areas whose economies are closely linked with climate-sensitive resources, such as agroprocessing, water resources, and tourism. [7.ES; 7.4, 7.5]
- In terms of annual regional GDP and/or capital formation, costs of extreme weather events – many of which are likely to become more intense and/or more frequent with climate change, - can range from several percent in larger, more developed and diversified regions to more than 25% in smaller, less developed, less diversified, and/or more natural resource dependent regions. [7.ES; 7.5]
- In most parts of the world and most segments of populations, lifestyles are likely to change as a result of climate change. Net valuations of benefits vs. costs will vary, but they are more likely to be negative if climate change is substantial and rapid rather than if it is moderate and gradual. [7.ES; 7.4; 7.6]
- Poor communities and households are especially vulnerable to climate change because they tend to be located in relatively high-risk areas and to have limited access to services and other resources for coping. They are likely to be impacted at lower levels and rates of climate change than the relatively wealthy. [7.ES; 7.4.5; 7.4.6]
- With increased catastrophe loss costs, the private insurance sector is likely to increase prices and withdraw coverage from situations at highest risk, leaving an increased role for governments and individuals as risk bearers. [7.ES; 7.4.2]
- Climate change is likely in many areas to increase pressures on governmental infrastructures and institutional capacities and to raise social equity concerns. [7.ES; 7.4.5; 7.6.5]
- Urban water supply infrastructures are vulnerable, especially in coastal areas, to sea level rise and reduced regional precipitation. Together or singly, these may increase saline intrusion to rivers and aquifers used for water supply. [7.4.3]

HEALTH

- For low-income populations, projected changes in climate by 2030 under a range of emissions scenarios are expected to increase rates of mortality from climate change, principally due to increases in malnutrition and diarrhoeal diseases. [8.4.1.1; 8.7]
- Increases in heat waves are likely to lead to increases in heat-related deaths. [8.4.1.3; 8.7]
- Extreme rainfall events test the integrity of water management systems and increase the risk of outbreaks of water-borne disease. [8.2.7] The impacts of flooding are particularly severe in areas of environmental degradation, and where basic public infrastructure, including sanitation and hygiene, is lacking. [8.ES; 8.2.2; 8.7]
- Increases in ground-level ozone concentration could increase respiratory and cardiovascular morbidity and mortality. [8.ES; 8.4.1.4; 8.7; T8.6]
- Increases in mean temperature could facilitate the spread of malaria and dengue fever along the current edges of their geographic distribution in some regions, and increase the length of the transmission season for malaria, although the magnitude of the effect is thought to be smaller than previously estimated. [8.2; 8.4.4; 8.4.1.2; 8.7]
- Increases in daily temperature will increase numbers of cases of food poisoning in temperate regions; warmer seas may contribute to increased cases of human shellfish and reef-fish poisoning (ciguatera) in tropical regions [8.ES; 8.2.4].
- There are important prerequisites for adaptation that are currently not met in many parts of the world, e.g., access to primary health care and basic education. [8.ES; 8.6]
- There has been progress in the design and implementation of climate-health warning systems, established to reduce effects of weather extremes as well as for the seasonal prediction of infectious diseases. Limited evidence suggests that such systems can be effective. [B8.5; 8.6.1; 8.6.2]

Box SPM-2 Main expected impacts for regions

AFRICA

- Impacts of climate change are likely to be greatest where they co-occur with a range of other stresses (e.g., unequal access to resources [9.4.1]; food insecurity [9.6]; poor health management systems [9.2.2; 9.4.3]).
- The proportion of the African population at risk of water scarcity could increase from 47% in 2000 to 65% in 2025, when c. 370 million African people may experience increased water stress based on a range of SRES and other scenarios [9.ES; 9.4.1].
- Substantial losses of potential agricultural land are projected for sub-Saharan Africa by the 2080s under a range of SRES scenarios [9.ES; 9.4.4].
- Changes in the primary production of large lakes will have important impacts on local food supplies. For example, Lake Tanganyika currently provides 25-40% of animal protein intake for the population of the surrounding countries and, on the basis of observed and palaeoclimate records, it is expected that climate change will reduce catches by around 30%. [9.ES; 9.4.5]
- Mangroves could degrade due to sea level rise, changes in salinity and sedimentation, coastal fisheries may be adversely affected. [9.4.6]
- Recent initial assessments show that despite water deficits that may arise with climate change, efficient water utilisation and adaptation through drip irrigation could save water and therefore offset some water losses [9.5.1; T9.3].

ASIA

- For a 1 m rise in sea level, half million ha^2 of Red River delta and 15,000 to 20,000 km^2 of Mekong River delta are projected to be flooded. [10.4.3.2]
- Around 30% of Asian coral reefs are expected to be lost in the next 30 years, compared with 18% globally, under IS92a, but this is due to multiple stresses and not to climate change alone. [10.4.3.2]
- The per capita availability of freshwater in India is expected to drop from around 1900 m^3 currently to 1000 m^3 by 2025. [10.4.2.3]
- If current warming rates are maintained, Himalayan glaciers could decay at very rapid rates, shrinking from the present 500,000 km^2 to 100,000 km^2 by the 2030s. [10.6.2]
- Substantial decreases in crop yields have been suggested in parts of Asia, with expected yield losses as high as 30% for the SRES A1FI scenario by the 2080s. [10.4.1.1]
- Agricultural irrigation demand in arid and semi-arid regions of Asia will increase by 10% or more for an increase in temperature of 1^oC. [10.4.1.2]

AUSTRALIA AND NEW ZEALAND

- Among the most vulnerable ecosystems are those of the Great Barrier Reef, south-western Australia, Kakadu wetlands, rainforests, coasts and alpine areas [F11.6]. There is likely to be substantial loss of biodiversity. [11.4.2]
- Future declines in water supply are likely for much of southern and eastern Australia and in areas distant from major rivers in eastern New Zealand. A 10-25% reduction in river flow is likely in Australia's Murray-Darling Basin by 2050 under SRES A1 and B1 scenarios. [11.4.1.1]
- Ongoing coastal development is very likely to exacerbate risk to lives and property from sea level rise and storms. There is very likely to be loss of high-value land, faster road deterioration, degraded beaches, social and economic trauma. [11.ES; 11.4.5]
- Increased fire risk in Australia and eastern New Zealand is likely: in SE Australia the frequency of fire risk days is expected to increase by 4-25% by 2020 and 15-70% by 2050 based on the full range of SRES scenarios [11.3.1].
- Up to about 2050, enhanced growing conditions from higher CO_2, longer growing seasons and less frost risk are likely to be beneficial for agriculture, horticulture and forestry over much of New Zealand and Tasmania. The impacts are likely to become negative for warming in excess of 2-4°C where there are reductions in rainfall. [11.ES; 11.4.3; 11.4.4]

EUROPE

- By the 2080s, annual runoff is projected to increase by up to 50 % in northern Europe, and decrease by up to 60% in south-eastern Europe, with summer low flows reduced by up to 80% under the IS92a emissions scenario. [T12.2]
- Under the A1FI scenario, by the 2080s, up to 2.5 million people each year are expected to be affected by coastal flooding. [12.4.2]
- Lowest river flows shift from winter to summer in Eastern-central Europe, and decrease by up to 50% under the SRES A1 emissions scenario by 2080. [12.4.1]
- Up to 50% of European flora could become vulnerable, endangered, critically endangered or extinct by the end of the 21st century under four SRES emissions scenarios [12.ES; 12.4.6].
- By 2050, crops are expected to show a northward expansion in area. Climate-related increases in crop yield are only expected in Northern Europe; largest reductions are expected in the Mediterranean, the southwest Balkans and the South of European Russia. [12.ES; 12.4.7.1]
- Small Alpine glaciers 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 [12.ES; 12.4.3].

LATIN AMERICA

- There is a projected reduction of rice yields after the year 2010, and an increase in soybean yields when direct CO_2 effects are considered under the full range of SRES and incremental scenarios. [13.ES; 13.4.2]
- Cattle productivity is expected to decline in response to increasing temperatures. [13.ES; 13.4.2]
- In 2025 between 30 and 90 million people will suffer from the lack of adequate water supplies and for 2055, between 100 and 180 millions, depending on the SRES scenario considered. [13.ES; 13.4.3]
- Any future reductions in rainfall due to climate change in arid and semi-arid regions of Argentina and Brazil would lead to severe water shortages. [13.4.3]
- In the future, sea level rise, weather and climatic variability and extremes modified by global warming are expected to have impacts on: (i) low-lying areas (e.g., in El Salvador, Guyana, Uruguay), (ii) buildings and tourism, (e.g., in Uruguay); (iii) coastal morphology (e.g., in Peru); (iv) mangroves (e.g., in Brazil, Ecuador, Colombia, Venezuela); (v) availability of drinking water in the Pacific coast of Costa Rica and Ecuador. Sea level rise alone will affect: (i) Mesoamerican coral reefs, and the (ii) location of fish stocks in the south-east Pacific. [13.ES; 13.4.4]

NORTH AMERICA

- Population growth, rising property values and continued investment increase coastal vulnerability. Any increase in destructiveness of coastal storms could 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. [14.ES; 14.2.3; 14.4.3]
- Vulnerability to climate change will 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. [14.ES; 14.2.6]
- Warming will probably reduce snowpack at moderate elevations in the western cordillera by the mid 21st century. Earlier snowmelt and winter rain events will likely increase peak winter flows and flooding, while summer flows decrease. Supply and demand mismatches will complicate water management in heavily used watersheds. [14.ES; 14.2.4; 14.4.1]
- Greatest impacts on forests will likely be through changing disturbances from pests, diseases, and fire. Warmer summers could extend the season of high fire risk by 10-30%, and increase the area burned by 74-118% in Canada by 2100. [B14.1; 14.4.4]
- Continued investments in adaptation in response to historical experience rather than projected future conditions may increase vulnerability of many sectors to climate change. [14.5.2]

POLAR REGIONS

- Annually-averaged sea ice area is projected to reduce by 20-30% by 2080-2100, depending on emissions scenario. [15.3.3]
- Northern Hemisphere permafrost is projected to reduce by 20-35% by 2050. The depth of seasonal thawing is likely to increase by 15-25% in most areas by 2050, and by 50% and more in northernmost locations under the full range of SRES scenarios. [15.3.4]
- Models project replacement of 11% of Arctic tundra by forest by 2100, given encroachment is actually as fast as in the models, whilst tundra is expected to replace 14-23% of polar desert by 2080 under SRES A2. [15.4.2.2]
- Geographic patterns of habitat use by migratory aquatic birds and mammals will be affected by climate change, with implications for predators such as seals and polar bears, the latter being pushed towards extinction [15.2.2.1; 15.4.3.2].
- Projected hydrological changes will influence productivity and distribution of aquatic species, especially fish. Warming of lake waters is likely to lead to reductions in fish stock, especially such species as lake trout, which prefer colder waters. [15.4.1.3]
- The climatic barriers that hitherto have protected polar species from competition will be lowered and loss of some of these species can be expected. [15.6.3]

SMALL ISLANDS

- Many port facilities e.g., Suva, Fiji, and Apia, Samoa, could 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 1/50 year cyclone [16.4.7].
- Without adaptation, agricultural economic costs from climate change could 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 and B2 scenarios [16.4.3].
- Climate change is expected to have significant impacts on tourism destination selection. Surveys show that, in some islands, 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. [16.ES; 16.4.6]
- With climate change, increased numbers of introductions and enhanced colonization by alien species are likely to occur on middle and high latitude islands. These changes are already evident on some islands [16.4.4].
- In small islands, energy is mainly from imported fossil fuels. To enhance resilience, many islands have already embarked on initiatives to ensure renewable energy sources constitute a significant percentage of the energy mix. 16.ES; [16.4.7]
- Use of insurance as an adaptation strategy for small islands has many constraints, including the size of the risk pool, lack of availability of financial instruments and services for risk management. [16.ES; 16.5.4]

D. Current knowledge about responding to climate change

Some adaptation is occurring now, but capacity varies.

There is growing evidence that adaptation to climate change is already taking place [17.ES]. This is in response either to observed climate changes or in anticipation of expected impacts. For example:

- In the Maldive islands, construction of coastal defences and planned abandonment of the lowest islands [B16.4].
- In Canada, Inuit hunters have navigated new travel and hunting routes to adapt to changing ice and wildlife conditions, despite decreasing ice stability and safety [15.6.1; B17.7].
- In Nepal, projects to prevent the outburst flooding from new or expanding glacial lakes [B17.1].

Planned adaptation is much more prevalent in developed than in developing countries [7.6.2]. There are significant differences in adaptive capacity between rich and poor in society, based on wealth, housing quality and location, level of education, mobility etc. [7.6.2; 17.3.3].

Adaptive capacity varies between systems and sectors, with industrial sectors having greater capacity to manage climate impacts (although location and access to infrastructure influence sensitivity to disruption) [7.4.2]. Natural systems which are largely unmanaged, such as marine and polar environments, have the lowest adaptive capacity [19.4.1; T19.2].

Many potential current adaptations are effective and consistent with sustainable development; that is, they can protect against both climate variability now and future climate change (and hence are sometimes termed 'no regrets' strategies) [17.2; 17.4.2; 20.3]. Examples include types of flood protection and coastal defence (such as the Thames Barrier to protect the Greater London area, UK) which are designed for current flood risk as well as future sea-level rise. [17.2.2]

Adaptive capacity can be enhanced, but there are limits and costs.

Adaptive capacity can be increased by co-ordinating adaptation measures (sometimes termed 'mainstreaming') into development planning at the international, regional or national level; for example, by including measures to reduce vulnerability in existing disaster preparedness programmes. National Adaptation Programs of Action have the potential to direct effective adaptation, but initial evidence suggests they are limited in their inclusiveness of knowledge. [17.4.1]

Initial experience of adaptation shows that early adaptation is effective for avoiding damage, provided that projections of future climate change are sufficiently accurate [17.4.2.4]. Delayed adaptation, perhaps due to uncertainty, may lead to greater subsequent costs [19.4.1; T19.2]. For very large temperature increases, adaptation may not be possible due to technological limitations or excessive cost. [17.4.2]

The array of potential adaptive responses is very large, ranging from purely technological (e.g. sea defences), to managerial (e.g., altering farm practices), to policy (e.g., planning regulations). A selection of these is given in Table SPM-1.

Table SPM-1 Some adaptation options

	Agriculture, forestry	Water Supply	Human Health	Settlement/Other
Drying/ Drought	*Crops* : new drought-resistant varieties, intercropping [T17.2]; crop residue retention [5.5.1]; weed management [5.5.1]; irrigation [5.5] and hydroponic farming [T17.2]; water harvesting [5.5.1] *Livestock*: supplementary feeding; change in stocking rate; altered grazing and rotation of pasture [5.5.1] *Social:* Improved extension services [T17.2]; debt relief [T17.2]; diversification of income [5.5]	Rainwater harvesting and storage [T17.2] Leak reduction [T17.2] Water demand management through metering etc. [T17.2] Soil moisture conservation e.g. through mulching [T17.2] Desalination of sea water [3.6] Increased storage capacity for groundwater [3.6] Education for sustainable water use [3.6]	Use of indigenous knowledge [8.6] Grain storage and provision of emergency feeding stations [7.6] Provision of safe water and sanitation [8.6] Strengthening of public institutions and health systems [8.6.1] Public education and awareness campaigns [8.6.1.2]	*Government*: assistance programmes [7.6.4]; enhancement of community development practices [7.6.4]; institutional development [7.6.4] *Public and private sector*: investment in increased resilience [7.6.3]
Increased rainfall/ Flooding	*Crops* : Alternative crops [T17.2]; adjustment of harvesting schedule [5.5] *Social*: Improved extension services [T17.2]	Enhanced implementation of protection measures: • Flood forecasting and warning • Regulation through planning legislation and zoning • Insurance • Relocation [3.6.2]	Early warning systems [8.6.1.2]; disaster preparedness planning; effective post-event emergency relief [8.6]	*Government:* Emergency warning systems [7.6.6] *Public and private sector*: risk assessment [7.6]; relocation of settlements and activities [7.6]; changing land use in vulnerable areas [7.6]; high levels of protection for critical infrastructure [7.6]
Warming	*Crops*: new heat-resistant varieties [5.5]; altered timing of cropping activities [5.5]; pest control and surveillance of crops [5.5] *Livestock*: Housing and shade provision; change to heat-tolerant breeds [5.5.1] *Forestry:* Fire management through altered stand layout, landscape planning; dead timber salvaging, clearing undergrowth [5.5.1]. Insect control through prescribed burning, non-chemical pest control [5.5.1] *Social*: Diversification of income [5.5]	Water demand management through metering etc. [T17.2] Education for sustainable water use [3.6]	International surveillance systems for disease emergence [8.6] Strengthening of public institutions and health systems [8.6.1.5] National and regional heat warning systems [T17.2. 8.6.1.2] Retrofitting of air conditioning and installation in new buildings [8.6.2] Measures to reduce urban heat island effects, e.g., through creating green spaces [8.6.2] Retraining front-line health workers [8.6.1] Adjusting clothing and activity levels; increasing fluid intake [8.6.1]	*Government*: Assistance programmes for vulnerable segments of society [7.6.4]; institutional development [7.6.4] *Insurance industry:* New coverages (weather derivatives, crop insurance); expanded property insurance [7.6.2]; risk reduction [7.6.2] *Construction:* Changes in building design [7.6.1]; new construction techniques [7.6] *Energy sector*: diversification of supply sources; technological change [7.6.1] *Tourism*: investment in snow-making equipment; beach enhancement; development of new destinations [7.6.2]
Wind speed/ Storminess	*Crops* : Wind-resistant crops (e.g. vanilla) [T17.2] *Forestry* : change in harvesting schedule; change in forest layout [5.5]	Coastal defence design and implementation [T17.2] to protect water supply against contamination [8.6]	Early warning systems [T17.2]; disaster preparedness planning; effective post-event emergency relief [8.6]	*Government:* emergency warning systems [7.6] *Construction*: Coastal defence design and implementation [T17.2]; changes in building design [7.6.1]; revised building codes [7.6.2] *Insurance*: Expanded property insurance [7.6.2]; risk management [7.6.1] *Individual*: Relocation [T17.2] Remittances from overseas [7.6.2]

Even with substantial investments in adaptation, evidence suggests that there are significant barriers and limits that reduce effectiveness. Informational and cognitive limits are currently the most severe, but there are also technological, financial, physical/ecological, social/cultural, and institutional factors. For some developing countries, availability of resources is particularly important [17.4.2].

Less is known about the costs and benefits of different adaptive strategies. The choice of optimal measures, whether low cost or with high benefit-cost ratios, is highly dependent on local attributes, as well as on the climate and socio-economic scenarios used [17.ES].

- Costs of protection against sea level rise are estimated to be less than 0.2% GDP except in the most exposed nations, but the estimates are highly sensitive to assumptions about land values, levels of protection, and whether or not changes in storm surge are taken into account [17.2.3.1; F17.2].
- Changing planting dates for some major crops (maize, soybean and wheat) has the potential to reduce the impact of climate change by between 4% in Asia and 11% in the Americas [T17.2]. This assumes perfect adaptation by farmers – slowness or failure to adapt could reduce this potential by 10-16% [17.2.3.1].

Impacts can be reduced or delayed by emissions control

A small number of impact assessments have now been completed for stabilisation scenarios. These provide a preliminary indication of damages avoided for different amounts of emissions reduction.

For emissions pathways leading to stabilisation at about 2200, the impacts in about 2080 have been estimated as follows [18.4.3; T20.4]:

- At stabilisation levels below 450 ppm[8] CO_2: most major impacts on human welfare would be avoided; but some major impacts on ecosystems are likely to occur.
- At 550 ppm: some, but not all, major impacts on human welfare would be avoided; major impacts on ecosystems would occur.
- At 750 ppm: major impacts on human welfare would not be avoided.

Adaptation and mitigation are potentially complementary response measures to climate change

Adaptation and mitigation efforts are more effective when they are applied together and not in isolation:

- Adaptation strategies can reduce vulnerability to changes in climate at the local and regional level and over short time scales, thus reducing the impact [18.ES; B18.1].
- Mitigation acts on a global level over longer time scales due to the inertia of the climate system, slowing the rate of climate change and thus delaying the date of impact and its magnitude [18.ES; B18.1].
- Most of the benefits of mitigation will not be realised until after 2040, requiring adaptation to address near-future impacts [18.ES].
- Without mitigation, eventually the increasing magnitude of climate change would significantly diminish the effectiveness of adaptation [18.ES; 18.4.1].

For these reasons, neither adaptation nor mitigation alone is likely to be able effectively to alleviate the impacts of climate change. But together they can. This suggests the value of a portfolio or mix of strategies which would include mitigation, adaptation, technological development (to enhance both adaptation and mitigation) and scientific research (on climate science, impacts, adaptation). [18.ES; 18.4].

[8] ppm = parts per million, a widely-used measure of the concentration of gases (here carbon dioxide) in the atmosphere. Impact studies published so far only consider changes in atmospheric concentrations of CO_2, and not other radiatively-actives gases.

E. Implications for Sustainability

Aggregate effects of climate change at global and regional levels will be negative, especially in the context of multiple stresses

- The impacts of global mean temperature changes up to 2^{o}C above pre-industrial levels are likely to be mixed, positive at higher latitudes and negative at lower latitudes. The net global effect of global temperature increases 2-3^{o}C above pre-industrial levels is expected to be negative, with increasing damages at higher magnitudes of climate change. [F5.2; T19.2]

- Estimates of the social costs of carbon[9] have a very wide range. For recent peer-reviewed studies, the mean estimate was $43 per tonne of carbon, with a standard deviation of $83/tC. The cost will rise over time, at an estimated rate of 2-3% per annum. [20.ES; 20.6.2]

- The impacts of climate change are expected to be greatest where they occur in the context of multiple stresses from other sources such as poverty, unequal access to resources, food insecurity, and environmental degradation (Fig. SPM- 6). [9.2.2; 20.3.1]

- Climate change is likely to impede the achievement of Millennium Development Goals (such as reduction of poverty and improvement of equity), particularly in Africa and parts of Asia. [B8.2; 9.7.1.1; 20.7.1]

- Climate change will affect future sustainable development, making it more difficult to achieve. The corollary is that sustainable development may be an effective means of reducing/avoiding negative aspects of climate change impacts, and building adaptive capacity. The challenge is to understand and exploit the complementarities between sustainable development and adaptive capacity. [20.3.3; 20.8.1; 20.8.3]

[9] The Social Cost of Carbon is the economic concept used to measure the marginal global damage cost, per tonne of carbon emitted.

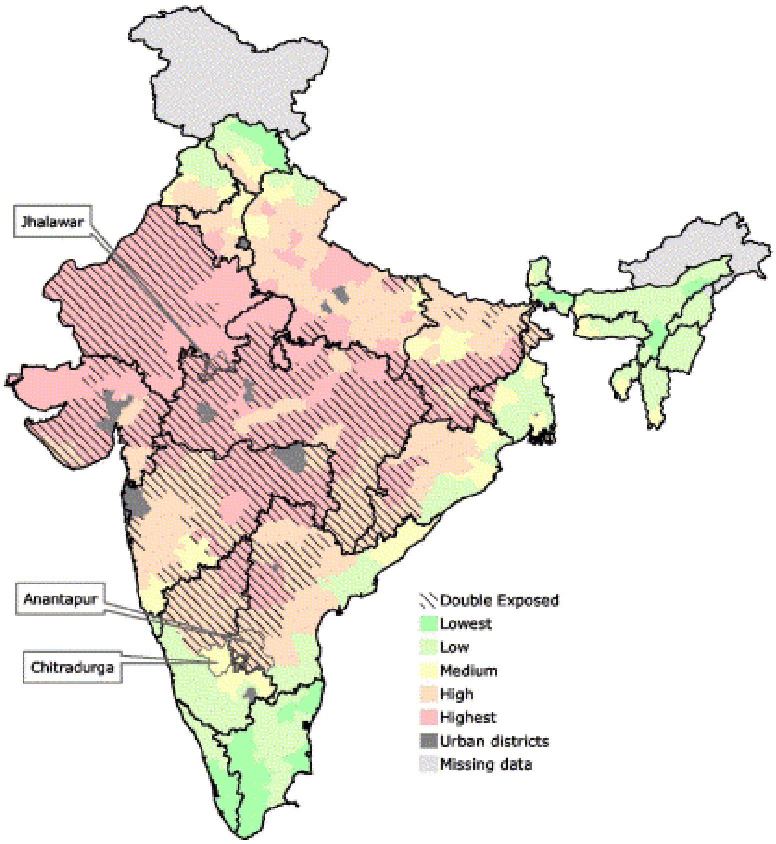


Fig. SPM-6. Climate impacts in the context of other stresses. Districts in India that rank highest in terms of both climate change vulnerability and globalization vulnerability are depicted to be double exposed (with hatching). A combination of biophysical, socioeconomic and technological conditions is considered to influence the capacity to adapt to changing environmental and economic conditions. The biophysical factors include soil quality and depth and groundwater availability, whereas socioeconomic factors consist of measures of literacy, gender equity, and the percentage of farmers and agricultural wage labourers in a district. Technological factors include availability of irrigation and the quality of infrastructure. Together, these factors provide an indication of which districts are most likely to be able to adapt to drier conditions and variability in the Indian monsoons, as well as respond to import competition and export opportunities resulting from liberalized agricultural trade. The results of this mapping show higher degrees of adaptive capacity in districts located along the Indo-Gangetic Plains (except in the state of Bihar), and lower capacity in the interior parts of the country, particularly in the states of Bihar, Rajasthan, Madhya Pradesh, Maharashtra, Andhra Pradesh, and Karnataka. [B17.5]

Appendix 1

Supplementary information for the Working Group II Fourth Assessment Summary for Policymakers

A1.1 Definitions of key terms

Climate change is a statistically significant variation in either the mean state of the climate or in its variability over an extended period (typically decades or longer). This definition includes climate changes due to natural causes, and so differs from that of the United Nations Framework Convention on Climate Change where climate change is "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

Climate change impacts are the consequences of climate change on natural and human systems.

Adaptation is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

A1.2 Procedures followed in this Assessment by the authors, reviewers and participating governments

The IPCC Fourth Assessment is intended to be a balanced assessment of current knowledge. Its emphasis is on new knowledge acquired since the IPCC Third Assessment (2001). This requires a survey of all relevant published literature, including non-English language and 'grey' literature such as government and NGO reports.

In total, the WGII AR4 involved 47 Co-ordinating Lead Authors (CLAs), 127 Lead Authors (LAs), and 47 Review Editors (REs), drawn from 74 countries. In addition there were 214 Contributing Authors and 837 Expert Reviewers.

Each chapter in the Working Group II Fourth Assessment had a writing team of 2 to 4 CLAs and 6 to 9 LAs. Led by the CLAs, it was the responsibility of this writing team to produce the drafts and finished version of the chapter. Where necessary, they could recruit Contributing Authors to assist in their task. Three drafts of each chapter were produced prior to the production of the final version. Drafts were reviewed in two separate cycles of revision, by experts and by governments. It was the duty of the REs (2 to 3 per chapter) to ensure that the review comments were properly addressed by the authors.

The authors and review editors were selected by the Co-Chairs and Vice-Chairs of WGII from the lists of experts nominated by governments. Due regard was paid to the need to balance the writing team with proper representation from developing and developed countries, and Economies in Transition. Chapters were sent out for review by experts who included all those nominated by governments but who were not yet included in the assessment, together with scientists and researchers identified by the

WGII Co-Chairs and Vice Chairs from their knowledge of the literature and the global community of research.

A1.3 Communication of Uncertainty in the Working Group II AR4

A set of terms to describe uncertainties in current knowledge is common to all parts of the IPCC Fourth Assessment.

Description of likelihood

Likelihood refers to a probabilistic assessment of some well defined outcome having occurred or occurring in the future, and may be based on quantitative analysis or an elicitation of expert views. In the Summary for Policymakers, when authors evaluate the likelihood of certain outcomes, the associated meanings are:

Terminology	**Likelihood of the occurrence/ outcome**
Virtually certain	>99% probability of occurrence
Very likely	90 to 99% probability
Likely	66 to 90% probability
About as likely as not	33 to 66% probability
Unlikely	10 to 33% probability
Very unlikely	1 to 10% probability
Exceptionally unlikely	<1% probability

Description of confidence

Authors have assigned a confidence level to some statements in the Summary for Policymakers, on the basis of their assessment of current knowledge, as follows:

Terminology	**Degree of confidence in being correct**
Very high confidence	At least 9 out of 10 chance of being correct
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than a 1 out of 10 chance