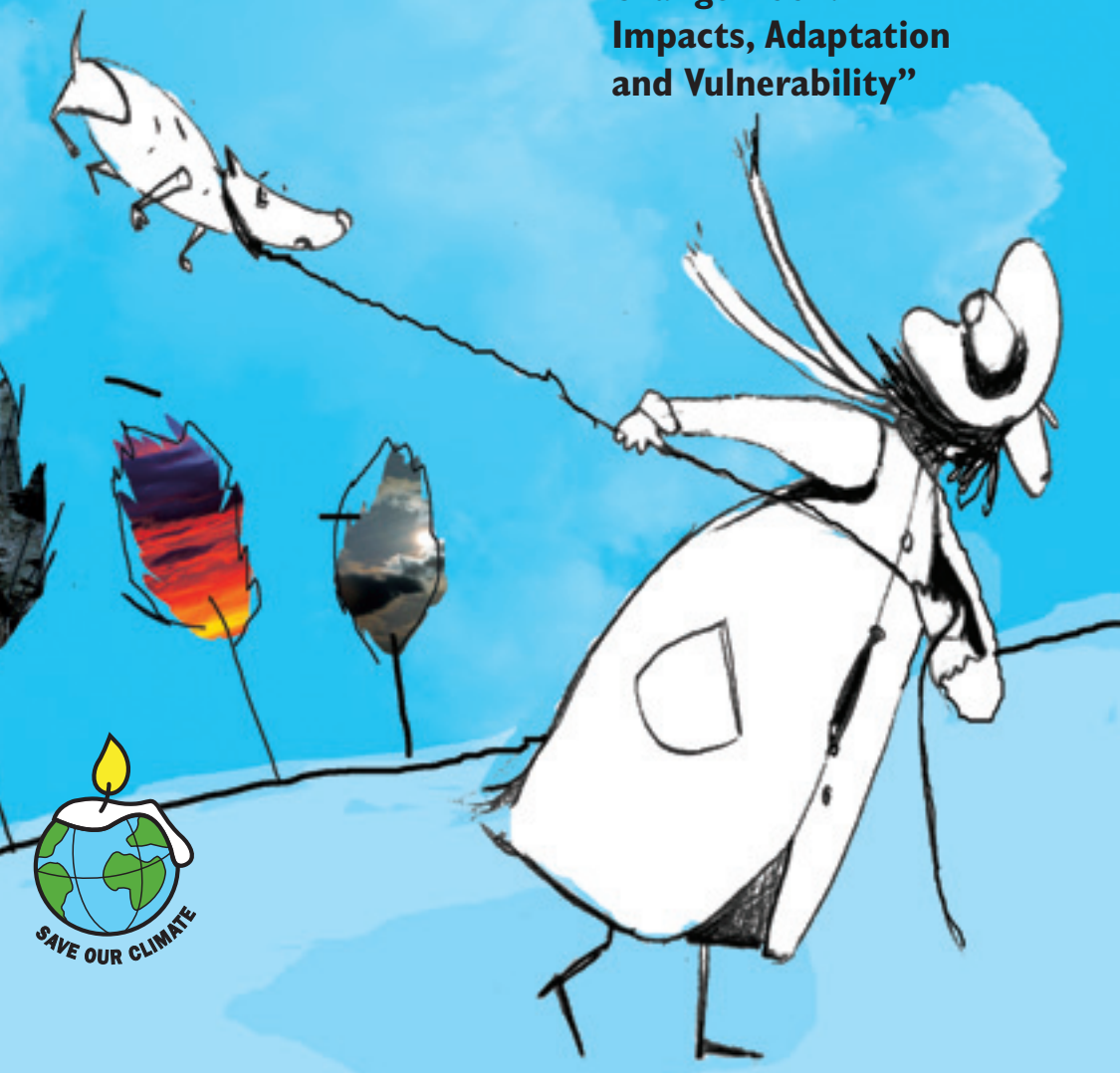
UNEP

How will global warming affect my world?

A simplified guide to the IPCC's "Climate Change 2001: Impacts, Adaptation and Vulnerability"



SAVE OUR CLIMATE

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Foreword

Global warming is already changing the world around us in ways that researchers can measure and quantify. Such changes will become more and more evident with each passing decade. Although cutting greenhouse gas emissions in order to minimize future climate change must be our top priority, we must also prepare to respond to impacts that our past emissions now make inevitable. People everywhere need to understand how climate change is going to affect them and what they can do to cope.

Fortunately, Working Group II of the WMO/UNEP Intergovernmental Panel on Climate Change (IPCC) has assessed what researchers have learned about expected impacts and how to adapt to them. Its findings are presented in a comprehensive publication entitled "Climate Change 2001: Impacts, Adaptation and Vulnerability", which is part of the IPCC's Third Assessment Report. This Report also includes volumes on the causes of climate change and on options for limiting greenhouse emissions.

This simplified guide presents the highly technical findings of Working Group II in everyday language. It is not an official document and has been neither approved nor accepted by the IPCC. Instead, it seeks to make the hundreds of pages of detailed text contained in the volume on "Impacts, Adaptation and Vulnerability" more accessible to a broader audience. I encourage readers seeking further information to refer to the original publications and the IPCC's web site.

Klaus Töpfer
Executive Director
United Nations Environment Programme

About the IPCC

The Intergovernmental Panel on Climate Change was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The IPCC does not conduct new research. Instead, its mandate is to make policy-relevant assessments of the existing worldwide literature on the scientific, technical and socio-economic aspects of climate change. Most of this expert literature has appeared in peer-reviewed publications.

The IPCC has produced a series of assessment reports, special reports, technical papers and methodologies that have become standard works of reference for climate change policymakers, experts, and students. The Panel is organized into three Working Groups: Working Group I focuses on the science of the climate system; Working Group II on impacts, vulnerability and adaptation; and Working Group III on mitigation, a term used to describe human interventions to reduce new greenhouse gas emissions.

The IPCC's First Assessment Report was completed in 1990 and helped to inspire the intergovernmental talks that led to the 1992 United Nations Framework Convention on Climate Change. Its Second Assessment Report was published in 1996 and played a role in the Kyoto Protocol negotiations. The 2001 Third Assessment Report concentrated on new findings since 1995 and paid special attention to what is known about climate change at the regional level.

Introduction

Look closely and you will see the effects of climate change.

Scientists have documented climate-induced changes in some 100 physical and 450 biological processes. In the Russian Arctic, higher temperatures are melting the permafrost, causing the foundations of five-story apartment buildings to slump. Worldwide, the rain, when it falls, is often more intense. Floods and storms are more severe, and heat waves are becoming more extreme. Rivers freeze later in the winter and melt earlier. Trees flower earlier in spring, insects emerge faster and birds lay eggs sooner. Glaciers are melting. The global mean sea level is rising.

Even if we reduce our greenhouse gas emissions dramatically today, these trends will continue for decades or centuries to come.

The rate of climate change expected over the next 100 years is unprecedented in human history. Throughout geologic time the average global temperature has usually varied by 5°C over intervals of millions of years. Now scientists believe that the temperature of the Earth's surface – which has already risen by 0.6°C since the late 1800s – is likely to rise by another 1.4 to 5.8°C during the course of the 21st century.

Such an unusually rapid rate of change would affect fundamental Earth systems upon which our very lives depend – including ocean circulation and the hydrological, carbon and nutrient cycles. It would disrupt the natural and managed ecosystems that provide us with water, food and fiber. It would add to existing environmental stresses such as desertification, declining water quality, stratospheric ozone depletion, urban air pollution and deforestation.

Researchers have been investing a great deal of effort in analyzing just how climate change will influence the natural environment and human society. The cause-and-effect linkages are often complex and the timing uncertain. But while much more research is needed, we understand today in greater detail than ever before what is happening – and what may occur next – in every region of the world. We also know more than before about how we can adapt to the expected impacts and assist those people who are the most vulnerable.

This booklet summarizes the most recent assessment of this growing knowledge by the Intergovernmental Panel on Climate Change (IPCC).

The natural world

The polar regions will warm fastest

Observed changes

- Arctic air temperatures increased by about 5°C in the 20th century – ten times faster than the global-mean surface temperature – while Arctic sea-surface temperatures rose by 1°C over the past 20 years.
- In the Northern Hemisphere, spring and summer sea-ice cover decreased by about 10 to 15% from the 1950s to the year 2000; sea-ice extent in the Nordic seas has shrunk by 30% over the last 130 years.
- Arctic sea-ice thickness declined by about 40% during late summer and early autumn in the last three decades of the 20th century.
- Alaska's boreal forests have been expanding northward by some 100 kilometers for every one degree celsius of temperature rise.
- Precipitation has increased over the Antarctic; the Antarctic Peninsula has experienced a marked warming trend over the past 50 years, while the rest of the continent also seems to have warmed.
- Surface waters of the Southern Ocean have warmed and become less saline; the water flowing from the Atlantic into the Arctic Ocean has also warmed, and the water in the Beaufort Sea has become less saline.
- The major seal breeding grounds in the Bering Sea have seen fur-seal pup numbers fall by half between the 1950s and the 1980s.

The 21st century

Both the Arctic and the Antarctic are expected to continue warming. More sea ice will disappear; in the Arctic, this will allow ships to move safely through wide expanses of ocean formerly blocked by ice. Most of the Antarctic will warm more slowly, with the largest changes likely to occur later in the century.

Across vast expanses of the Arctic, forest will replace tundra. Many plant and animal species will either migrate, flourish under new habitat conditions or decline. Walruses, polar bears, seals and other marine mammals that rely on ice floes for resting, feeding and breeding will be particularly threatened. Populations of krill and other small organisms will decline as the ice recedes, with large consequences for fish, whales and other marine mammals. Due to the importance of krill in many food chains, the entire marine food web may be adversely affected.

Indigenous people who have lived in the frozen North for centuries will be most directly affected. Their knowledge of where and when to hunt, fish and gather food plants is already becoming less reliable as sea-ice dwindles, land-ice melts, and birds, fish, plants and animals change their seasonal distribution and location.

People living in modern towns or settlements in the far north will also be affected as the permafrost – the frozen layer of soil and water just beneath the Earth's surface – continues to thaw. This will cause the terrain to subside and damage buildings, pipelines, roads and other infrastructure.

The rest of humanity will be affected indirectly but significantly, notably through sea-level rise (see below). In addition, the polar regions are key drivers of global weather patterns, and the changes caused by global warming could cause these regions to magnify the greenhouse effect in a number of ways. For example, warming dries out tundra which then dies and decomposes, giving off additional carbon dioxide (CO_2) and methane (CH_4).

The polar regions also drive the oceans' circulation. When ocean water freezes, it sheds its salt. The water under the ice becomes saltier and thus heavier, falls to the ocean bottom and creates the momentum that drives the oceans' main currents. But when sea ice and glaciers melt, the upper layers of seawater become less salty; this reduces the amount of very salty water available to sink to the bottom and weakens its driving effect on the global ocean circulation. In a worst-case scenario, this might slow or even stop worldwide ocean circulation in future centuries. This would have substantial impact on regional climates – by shutting off the "Gulf Stream" that warms northern Europe, for example – and could reduce the supply of nutrients available to marine life.

What can be done?

Unfortunately, polar regions are highly vulnerable to climate change, and their natural and human systems have a low capacity for adapting. Indigenous communities with traditional life-styles will have only limited opportunities to respond to the expected changes. Technologically developed communities, however, are likely to adapt their infrastructure and transport means to the new conditions and take advantage of new trade and commercial opportunities.

New rainfall patterns will threaten water supplies

Observed changes

- Precipitation over many mid- to high-latitude land areas in the Northern Hemisphere has become more and more intense.
- Rainfall has generally declined in the tropics and subtropics of both hemispheres; when rain does fall, it is frequently so heavy that it causes erosion and flooding.
- In large parts of Eastern Europe, European Russia, Central Canada and California, peak stream flows have advanced from spring to winter, since more precipitation falls as rain rather than snow, thus reaching rivers more rapidly than before.

- In Africa's large catchment basins of Niger, Lake Chad and Senegal, total available water has decreased by 40 - 60%.
- Desertification has been exacerbated by lower average annual rainfall, runoff and soil moisture, especially in southern, northern and western Africa.
- Increased summer drying and the associated risk of drought have been observed in a few continental areas, including Central Asia and the Sahel.
- Some observations of tropical cyclones show an increase in both mean precipitation and in extremes.

The 21st century

Rainfall patterns will continue to change around the world. Computer models consistently project that, as warming progresses, the temperate regions as well as Southeast Asia will receive more precipitation.

In general, global warming should accelerate the hydrological cycle. Warmer air causes more water to evaporate. A warmer atmosphere can hold more water vapor, so more water is available to fall back to Earth when it rains or snows. As a result, extreme precipitation events should become more frequent and intense, leading to worse flooding. The Rhine floods of 1996 and 1997, the Chinese floods of 1998, the East European floods of 1998 and 2002, and the Mozambique and European floods of 2000 all point to a changing hydrological regime.

Meanwhile, Central Asia, the Mediterranean region, the Sahel and many other regions in Africa, Australia and New Zealand are expected to receive considerably less rain. In addition, increased evaporation in these regions will lead to drier conditions, with a higher probability of drought.

In many countries the consequences of less precipitation and more evaporation will be greater stress on freshwater supplies. In addition, countries that rely on run-off from mountains may suffer as glaciers retreat and snow accumulation reduces. Water shortages could affect critically important food production. Conflicts over water, particularly in river and lake basins shared by more than one country, could well escalate.

Besides changing the distribution of precipitation, climate change will also affect the quality of freshwater supplies. Algae and plants grow more prolifically in warmer conditions; when they decompose, higher levels of nutrients collect in the water. Meanwhile, more intense rains will flush more pollutants from the surrounding land and from overflowing waste facilities. In regions where rainfall declines, pollutants will be more highly concentrated in the remaining available water.

Water quality will be also affected by sea-level rise. More salty water will find its way into coastal aquifers and estuaries, making freshwater brackish and eventually unsafe. This will have severe impacts in some areas, particularly low-lying islands and atolls that rely on underground water for their fresh-

water supplies. Seawater intrusion will also affect the surface freshwater supplies of communities living within estuaries.

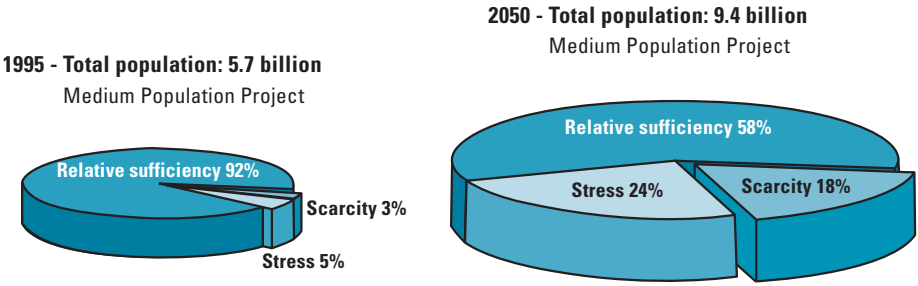
With one third of the world's population living in countries that already lack enough water, and with populations and demand set to grow dramatically, freshwater supplies may be one our greatest vulnerabilities in a climate change world.

What can be done?

The impacts of flooding can be reduced through improved land-use management. Many human activities are inappropriate in flood-prone lowlands; housing, for example, should not be developed on vulnerable riverbanks and flood plains.

Reforming land management practices can also reduce the impact of drought in the world's drylands. Local communities need to be fully engaged in such efforts. Both hi-tech (satellite imagery and communications) and traditional solutions (terracing steep slopes, water conservation) should be promoted. New investments in reservoirs and other infrastructure can help. Supply and demand management can be improved through regulations, technologies, incentives and, above all, education about water conservation. Climate change concerns should be included in integrated water resource management.

Figure 1. World population in freshwater scarcity, stress, and relative sufficiency in 1995 and 2050



Note: Pie size is proportional to the world population in the designated year.

Source: T. Garner-Outlaw and R. Engelman, 1997. *Sustaining Water, Easing Scarcity: A second Update*. Population Action International. Washingon, D.C. As cited in "Protecting our Planet-Securing our Future", p 38. UNEP, NASA and World Bank, 1998.

Wildlife and ecosystems will face additional stress

Observed changes

- In the Alps, some plant species have been migrating upwards by one to four meters per decade; some plants previously found only on mountaintops have now disappeared.
- Butterflies, dragonflies, moths, beetles and other insects are now living at higher latitudes and altitudes, where previously it was too cold for them to survive; migratory birds arrive earlier in the spring and depart later in the autumn, and many birds and amphibians are reproducing earlier.
- Cold- and cool-water fish are losing suitable habitat; warm-water fish are expanding their ranges in both the northern and southern hemispheres.
- Some bird species in Europe, North America, and Latin America are breeding earlier in the season; in Europe, egg-laying has advanced over the last 23 years; in the UK, 20 of 65 species, including long-distant migrants, advanced their egg-laying dates by an average of eight days between 1971 and 1995.
- Remarkable species such as the tiny golden frog living in Costa Rica's misty forests are becoming extinct because their habitat has become drier.
- Changes in climatic variables have increased the frequency and intensity of pest and disease outbreaks as the related organisms shift their ranges poleward or to higher elevations.
- Across Europe, the growing season in controlled mixed-species gardens lengthened by 10.8 days from 1959 to 1993; separate studies of 46 plant and tree species in the US show that they are flowering earlier because of higher spring temperatures.
- Almost two thirds of the glaciers in the Himalayan and Tienshan mountains have retreated in the past decade; Andean glaciers have also receded dramatically in the past several decades.

The 21st century

Climate shapes the geographic distribution of plant and animal species around the globe. Many plants, for example, can successfully reproduce and grow only within a narrow temperature range and in response to the right amounts and seasonal distribution of precipitation.

As the century progresses, plants, animals, birds, insects, reptiles, amphibians, fish and even fungi and microbes will have to adapt to new climatic conditions. Some species will prosper while others will decline or die off. Some animals and insects will simply move to more suitable environments; others will find that human settlements or natural barriers block their way. Many plant species

will be unable to migrate with the necessary speed and would require human intervention to cope. Many cold- and cool-water fish may run out of habitat, and disappear, much to the alarm of local fishing communities.

As a result of climatic stress, most species that today are critically endangered – some 25% of mammals and 12% of birds are already at significant risk – may become extinct in the next few decades. However, climate change is only one of a long list of pressures on wildlife. Other pressures include deforestation and other land-use changes, hunting and the wildlife trade, pollution, extreme climate events, wildlife diseases, collisions with human structures, and war and other civil conflicts. The greatest stress of all is habitat conversion and degradation, which affects nearly 89% of all threatened birds and 83% of all threatened mammals.

As individual species migrate or die off, the composition of ecosystems and food chains will change. The expected rate of change over the coming 100 years would be far more rapid that any experienced by natural systems for thousands – if not millions – of years.

Meanwhile, many plants may respond positively to rising atmospheric concentrations of carbon dioxide, growing faster while using less water. Higher temperatures, however, accelerate the evaporation of soil moisture and the decay of soil organic matter, leading to changes in the mix of nutrients. In many instances, these effects could slow plant growth while increasing their release of CO_2 into the atmosphere.

Rising atmospheric CO_2 levels will affect plants in other ways as well. For example, they will diminish the protein content of wheat and rice the quality of many forage species. Wild plants have not yet been studied in depth; however, it is likely that many of these species would also decline in quality, affecting the wild animals and other creatures that rely on them for nourishment.

Global warming may further exacerbate the negative impacts on plant growth and production by promoting the spread of pests and diseases. Other expected effects include greater leaching of nutrients from the soils during intense rains, greater erosion due to stronger winds and more wildfires in drier regions.

Such dramatic changes are likely to have important implications for human society, which relies on many goods and services provided by natural ecosystems. The services provided by wildlife include pollination, natural pest control, seed dispersal and recreation, amongst many others. Wetlands contribute to flood control, nutrient cycling and water detoxification, while forests provide wood-fuel, food, fiber and much more. The value of such products and services is enormous.

What can be done?

Most conservation programmes today focus on parks and protected areas. But strategies for adapting to climate change are relevant to the entire natural world. Monitoring systems can help to detect trends driven by climate change and thus identify options for adapting to them. In conservation planning, it may be necessary to accept that certain genotypes, species and ecosystems can no longer be conserved in a particular area or region due to changed conditions and that the focus should be on strengthening the resilience of biodiversity as a whole.

Solutions can include creating networks of reserves with connecting corridors to provide dispersal and migration routes for plants and animals. Captive breeding programmes for animals, seed banks and botanical gardens for plants as well as translocation programmes for both can play a critical role. Some natural pest control, pollination and seed dispersal services provided by wildlife can be replaced by human management and appropriate technologies.

Coordinated strategies for land-use, landscape values and water supplies can simultaneously promote human needs and conservation goals. Similarly, integrated coastal fisheries management could reduce the pressure on some coastal fisheries. Efforts to enhance sustainable agriculture and rural development could make biodiversity more resilient. Conserving wood-fuel, for example by introducing efficient stoves and biogas and other forms of renewable energy, could reduce pressures on forests and thus protect biodiversity.

The sea level will rise as ocean waters warm

Observed changes

- Vast expanses of the oceans have warmed over the past 50 years; globally, sea-surface temperatures have risen in line with land temperatures.
- The global mean sea level has risen by 10 - 20 cm during the 20th century – ten times faster than the rate for the previous three thousand years.
- More water is evaporating from the sea surface; this has likely resulted in total atmospheric water vapor increasing by several percent per decade over many regions of the Northern Hemisphere.
- Seventy per cent of sandy shorelines have retreated over the past 100 years; 20 - 30 percent are stable, while less than 10 percent are advancing.
- Seawater is seeping into freshwater aquifers and intruding into estuaries in low-lying coastal areas around the world, particularly on low-lying islands.

The 21st century

Climate change is expected to cause further increases in sea surface temperature and in the mean global sea level – a further 9 to 88 cm by the year 2100. It will also lead to

reduced ice cover and to changes in salinity, wave conditions and ocean circulation.

These impacts will have a strong influence on freshwater supplies, weather patterns and storms over the oceans and coastal regions. Many coastal areas will experience more flooding, accelerated erosion, loss of wetlands and mangroves and seawater intrusion into freshwater supplies.

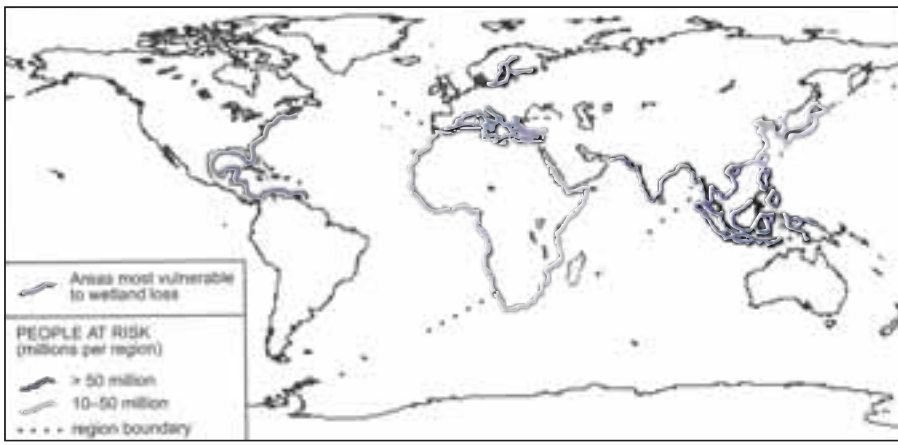
The extent and severity of storm impacts, including storm-surge floods and shore erosion, will worsen as a result of sea-level rise and other climate change impacts.

The consequences for highly diverse and productive coastal ecosystems, such as coral reefs, atolls, reef islands, salt marshes, and mangrove forests, will depend on the rate of sea-level rise relative to sediment supply and the ecosystems' natural growth rates. Other variables include the possibility for ecosystems to migrate inland, changes in sea temperatures and storminess and pressure from human activities in coastal zones.

Future sea surface warming would place greater stress on coral reefs and result in a greater frequency of marine diseases.

People living along the coasts and on low islands will be most directly affected by sea-level rise and by economic impacts on fisheries, property and infrastructure, recreation facilities and so forth.

Figure 2. People at risk from a 44 cm sea-level rise by the 2080s, assuming 1990s level of flood protection



Source: R. Nicholls, Middlesex University in the U.K. Meteorological Office. 1997. *Climate Change and Its Impacts: A Global Perspective*. Brittanic Crown Copyright. As cited in "Protecting our Planet-Securing our Future", p51. UNEP, NASA and World Bank, 1998.

What can be done?

The emphasis on adaptation strategies for coastal zones is shifting away from "hard" protective structures (such as seawalls) towards "soft" protective measures such as strengthening beaches and other natural barriers and making a managed retreat inland. Programmes for enabling coastal and marine areas to adapt can work best if developed in tandem with land-use plans and other national policies. Specific options include promoting flood- and salt-tolerant crops, strengthening emergency procedures and developing disaster-mitigation plans.

People and Society

New environmental conditions could affect food security

The effects of global warming on agriculture will vary widely both from region to region and from place to place. Changes in local and regional temperatures, precipitation, soil moisture, sunshine and cloudiness, and extreme events such as storms and hail will all have an influence. Other important variables will include the species and cultivar (variety) being farmed, soil properties, pests and pathogens and air quality.

In general, the temperate mid-latitudes are expected to receive more rain with global warming. However, mid-continental areas such as the US grain belt and vast areas of Asia are likely to dry, as will much of Australia. Less rain, warmer temperatures and greater evapotranspiration could reduce agricultural yields by a third or more in these areas. Even though increased CO_2 concentrations can stimulate crop growth and yield, these benefits may not always overcome the adverse effect of excessive heat and drought.

In the tropics, many crops are already near their maximum temperature tolerance, and farmers are often unable to irrigate because water supplies are inadequate. Where dryland agriculture relies solely on rain – as in sub-Saharan Africa – yields would decrease generally with even minimal increases in temperature. More extremes and a shift in precipitation zones could worsen food security in Africa.

While climate change could be linked to local or regional food shortages, the world as a whole would still grow enough food to satisfy demand if global temperatures rise by less than 2.5° C.

What can be done?

In temperate regions, initiatives by individual farmers to adapt should suffice to prevent losses to both crops and livestock and could even lead to gains. In the tropics, the efforts of farmers will prevent some losses but not all.

Farmers can adapt by making appropriate changes in planting dates, cultivar selection, and pest and disease control strategies. More expensive and organized efforts – such as changing land-use allocations and investing in irrigation infrastructure – can further prevent climate-induced losses. Monitoring climate and the projected changes would provide a greater lead-time for preparing solutions.

Environmental changes will harm human health

The World Health Organization (WHO) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". Global climate change will have a wide

range of affects on human health as so defined. Overall, the negative effects are expected to outweigh the positive ones.

New patterns of heat waves and cold snaps, floods and droughts, and local pollution and allergens would affect health directly. Indirect effects will result from changes to ecological and social systems. Such impacts will include changes in infectious diseases, freshwater supplies, local food production, population movements and economic activities.

Studies of the health impacts associated with climate variability (particularly those related to El Niño events) have provided new evidence of the sensitivity of human welfare and health to climate, particularly regarding vector- and water-borne diseases such as dengue and cholera.

The increased frequency and intensity of heat waves could lead to more deaths and serious illnesses, especially amongst the elderly and urban poor. Hotter conditions would be exacerbated by greater humidity and urban air pollution. Studies suggest that a number of US cities would experience an average of several hundred extra deaths each summer.

More frequent and intense storms, floods, droughts and cyclones will also harm human health. These natural hazards can lead directly to death, injury and mental stress. Indirect effects would result from the loss of shelter, contamination of water supplies, reduced food supplies, heightened risk of infectious disease epidemics (such as diarrhea and respiratory disease), damage to health services infrastructure and the displacement of people. In recent years, major climate-related disasters have had serious consequences for human health, including Hurricane Mitch, which devastated Central America in 1998, as well as floods in China, Bangladesh, Europe, Venezuela and Mozambique.

Climate change will undermine air quality in cities. Higher temperatures (possibly accompanied by more ultraviolet radiation) will promote the formation of surface ozone, a pollutant that harms human respiratory health as well as plants.

Higher temperatures and changes in precipitation and climate variability would alter, and in some cases extend, the geographic range and seasonality of vector-borne diseases.

Climate change may affect the marine environment in ways that would worsen the risk of biotoxin poisoning from consuming fish and shellfish. Biotoxins associated with warmer waters, such as ciguatera in the tropics, could extend their range to higher latitudes. Warmer seas will also encourage more toxic algal blooms, which can be linked to human poisoning. Declining water quantity and quality would cause more cases of diarrhea.

With some 790 million people currently undernourished, changes in food supply resulting from climate change could affect

the nutrition and health of the poor in some regions. Isolated areas with poor access to markets will be particularly vulnerable to local problems with the food supply.

Undernourishment is a fundamental cause of stunted physical and intellectual development in children, low productivity in adults and increased susceptibility to infectious diseases. Climate change would exacerbate these conditions in the developing world, particularly in the tropics.

What can be done?

Negative health impacts can be lessened through a range of social, institutional, technological and behavioral adaptations. Whatever happens with the climate, public health programmes, services, and surveillance systems around the world need to be strengthened. Public education, vaccination and other preventative measures, good personal hygiene and certain cultural and behavioral changes should all be encouraged. The WHO-led Global Health Watch can also play an important role.

Settlements and infrastructure will need to adapt

Flooding, landslides, melting permafrost and sea-level rise will pose widespread risks to human settlements as the climate changes. Snow and rainfall will be heavier, causing more severe and frequent floods and mudflows. Coastal storm surges made more destructive by higher temperatures and sea-level rise will increasingly threaten coastal communities. While people living along riverbanks and seacoasts face clear risks, urban flooding due to intense precipitation could be a problem in all regions. This is especially true where old-fashioned storm-water drains and water distribution and sewage systems are already running near capacity or are poorly maintained.

Also at greater risk will be squatter and other informal urban settlements, where many people live close together under poor shelter, with little or no access to safe water, sanitary and public health services and other resources. There is little they can do to avoid floods and landslides or escape disaster when it strikes.

Tropical cyclones (also known as hurricanes or typhoons) and tornadoes may become more destructive in a warmer world and pose the next most serious threat after flooding. Other risks include windstorms, droughts and wildfires, all of which are expected to increase. Heat waves will cause more illness and death and encourage more energy use as people turn on their air conditioning systems. Energy supplies will be further affected when winds and storms damage power lines. In some regions dwindling water supplies will undermine hydropower generation.

Building, roads, railways, ports and industrial development – particularly when based

on coasts, riverbanks, hills, or permafrost – may suffer more damage. They will more often require repairs, reconstruction or relocation.

The social fabric and infrastructure of many cities may face greater stress as people migrate away from vulnerable areas towards population centers. As shanty-towns further encircle urban centers there will be higher risks that disease will spread. Urban pollution and fire risks may worsen under global warming conditions.

In general, regions whose main income derives from primary industries such as agriculture, forestry, and fisheries are more vulnerable than those that do not rely so much on natural resources.

What can be done?

Human settlements are expected to be among the sectors that will more easily adapt to climate change. Key strategies for land-use, sustainable building development and transport systems will need to include policies and management practices that anticipate the future climate regime. Planners should consider climate change projections when building settlements or infrastructure – locating industrial and urban waste sites, for example, away from flood-prone areas.

Strengthening environmental planning and management for a climate change world could involve rolling out new tools for pollution control, focusing on demand management and waste reduction, encouraging mixed-use zoning and greener transport systems (particularly for pedestrians and cyclists) and conducting capacity studies and environmental audits. Many cities are already using a combination of these strategies to develop their "Local Agenda 21". These agendas deal with a list of urban problems that could closely interact with future climate change.

Extreme weather events will boost costs

The costs of extreme weather events have been growing rapidly. Since 1960, the number of global weather-related disasters has increased four-fold, real economic losses seven-fold and insured losses twelve-fold. Real losses are estimated to have risen from US$3.9 billion per year in the 1950s to US$40 billion per year in the 1990s.

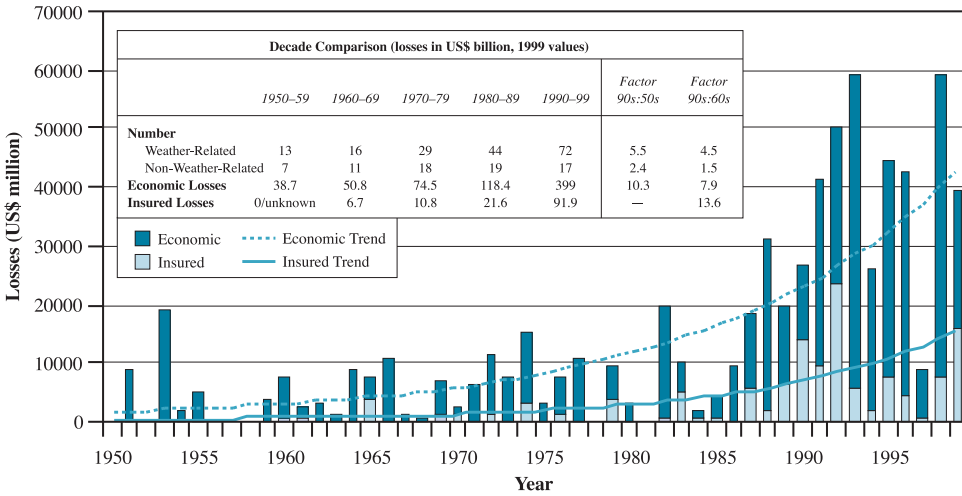
Part of the rise in disaster losses can be explained by the explosive growth in human population, inappropriate land-use planning (such as building on floodplains or areas vulnerable to erosion or coastal storms), the expanding financial value of homes and infrastructure and the availability of insurance. But climate change and worsening weather extremes such as winds, floods and droughts can also be expected to play a role.

Recent history has shown that weather-related losses can overwhelm insurance companies, which may respond by hiking

premiums and withdrawing coverage from vulnerable sectors and regions. This can lead to higher demand for publicly funded compensation and relief.

Developing countries are most vulnerable to natural disasters. For many of them, weather-related risks could become uninsurable, premium prices could rise substantially, or insurance would become nonexistent or harder to obtain. Countries already hard-pressed to provide the essentials of food, safe water and shelter have little leeway for absorbing the extra costs of natural disasters. Internal migration will likely add to the total costs.

Figure 3. Cost trend for catastrophic events



Source: "Climate Change 2001: Impacts, Adaptation and Vulnerability", p.42. IPCC, Cambridge University Press, 2001.

What can be done?

The damage caused by extreme events can be reduced through careful and consistent planning. Useful tools range from effective land-use planning to municipal codes mandating that buildings be designed to resist high winds and ground subsidence to comprehensive coastal-management strategies to early-warning systems such as those already enforced in many hurricane-prone areas.

The insurance industry can contribute by seeking creative solutions for spreading risks, hence keeping insurance coverage available and affordable. Developing countries will need more extensive access to insurance. Technology transfer and the widespread introduction of micro-financing schemes and development banking could also help.

Conclusion: get ready to adapt

Today's international debate on climate change is focused on the challenge of reducing greenhouse gas emissions. This makes sense: unless we start cutting emissions soon, atmospheric concentrations of heat-trapping gases will continue to rise, making the impacts described above that much more likely and severe.

But this does not mean that we should not already plan how to adapt to a warmer world. Planning for adaptation can and should complement efforts to reduce emissions, and an early start would reduce the overall costs. This is especially true when it comes to many large and expensive decisions, such as what kind of building or road to construct, where to locate a new nature reserve, or when to replace or relocate a power plant. Many investment and planning decisions being taken today could strongly influence the costs of adaptation in the coming decades and the options available to future generations. In some cases advance planning can ensure that efforts to adapt achieve great benefits at low or even no cost.

Yet another advantage is that many adaptation measures will help people whether or not the climate changes. For example, adapting to current climate risks such as droughts and storms will offer immediate benefits to today's most vulnerable people as well as benefits that will be appreciated by future generations. Similarly, adaptation measures can be incorporated into programmes that address existing non-climate stresses, such as biodiversity loss. The more we strengthen our societies today, and the more we work towards a healthier natural environment, the better prepared and more resilient our world will be in the future.

Of course, both natural and social systems will adapt spontaneously to some degree. Such adaptation, however, will not be sufficient for many regions and sectors. And even planned adaptation will not succeed in addressing all impacts. Some unique and vulnerable natural and social systems (such as indigenous communities) may be irreparably harmed if the climate changes beyond a certain threshold. Risks related to extreme weather events and unlikely-but-possible large-scale singular events, such as the collapse of the West Antarctic ice sheet or the shutdown of the so-called Gulf Stream, may be particularly difficult to respond to.

A major challenge facing us today is that there are still many uncertainties about climate change impacts and our options for adapting to them. There are simply too many variables – such as population growth, the economy, technology, and environmental stress – that, like the climate, will change over time. How do we distinguish cause and effect? What will be the overall consequence as the various individual impacts accumulate and interact over time?

Figure 4. Types and examples of adaptation to climate change

		Anticipatory	Reactive
Natural Systems			• Changes in length of growing season • Changes in ecosystem composition • Wetland migration
Human Systems	*Private*	• Purchase of insurance • Construction of house on stilts • Redesign of oil-rigs	• Changes in farm practices • Changes in insurance premiums • Purchase of air-conditioning
Human Systems	*Public*	• Early-warning systems • New building codes, design standards • Incentives for relocation	• Compensatory payments, subsidies • Enforcement of building codes • Beach nourishment

Source: "Climate Change 2001: Impacts, Adaptation and Vulnerability", p.885. IPCC, Cambridge University Press, 2001.

To gain a better understanding of how global warming will affect human and natural systems and how we can minimize the negative consequences, the IPCC will continue assessing key findings and uncertainties in all areas of climate change research. Its Fourth Assessment Report, to be released in 2007, will highlight our improved understanding of how the climate system works and of how to adapt to climate change and build sustainable economies. The IPCC's assessment of vulnerabilities and impacts will draw on this knowledge and other relevant findings to paint a more detailed picture of future climate change, particularly at the regional level.

The IPCC's new assessment will also address growing concerns over humanity's access to freshwater supplies and focus on how climate impacts and adaptation strategies can interact with biodiversity loss, desertification, ozone depletion and other harmful trends. This more integrated approach will give decision-makers more useful, policy-relevant information on how to adapt to future climate change and achieve other internationally agreed goals on environment and development.

While the research challenges are immense, understanding and adapting to climate change should be seen as a vital priority. The majority of climate change impacts will be borne by future generations. Fortunately, there is much that today's generation can do to minimize their risks and to ease their task of adapting to a climate change world.

Conclusion: get ready to adapt

Regional scenarios

Africa

Over the next century, East Africa could receive more rain while southern Africa will probably become a great deal drier. Food and water shortages are likely to increase throughout most of Africa, as will floods and storms. Desertification will remain a major threat in arid and semi-arid regions.

Asia

While northern and mid-latitude Asia will enjoy dramatic advances in crop production in a warmer world, South and Southeast Asia's many developing countries will see food production drop due to intolerably high temperatures and declines in rainfall and water supply. In arid and semi-arid Asia, higher temperatures and more evaporation will reduce rice yields dramatically.

Australia and New Zealand

Further reduction of scarce water resources and higher temperatures for crops already growing near their maximum heat tolerance will affect food production in arid Australia. New Zealand, which is cooler and wetter, could benefit at least initially from warmer temperatures, particularly in its more southerly regions.

Europe

A changing climate will dry out the south and boost agricultural production in central and northern areas. The Arctic landscape will change permanently as ice and permafrost melt, the tundra dries and forests migrate north. The region's key vulnerabilities will be water and land resources, semi-natural ecosystems and forests, and agriculture and fisheries.

Latin America

The Amazonian rainforests will dry out. This will encourage the spread of wildfires in the expanding areas of disturbed forests and threaten the continent's rich biological diversity. If, as seems likely, El Niño events become more frequent in a warmer world, the climate will dry in northern Amazonia, northeastern Brazil and the Peruvian-Bolivian Altiplato. Andean glaciers would retreat further, while Mexico's droughts would become more frequent.

North America

Floods, droughts, storms and landslides are expected to increase in frequency, severity and duration. There will be fewer cold snaps in winter, more very hot days in summer, more coastal erosion and emergencies from higher seas and bigger storms, and heavier rain and snow. The Great Plains in the US and the Canadian Prairies may face increased drought, but North American food production will rise overall in a warmer world.

Small Island States

The tens of thousands of small islands scattered across the world's oceans are particularly vulnerable to climate change. Many rise up only one or two metres above sea level. In addition to rising seas, risks include more savage storms, big reductions in rainfall in some parts of the ocean, and intolerably high temperatures.

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