Earth on fire

climate change from a philosophical and ethical perspective

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What will happen?

Scenarios of the future

JØRGEN E. OLESEN

1. Introduction

Climate change is nothing new. In the history of Earth there have been considerable climate changes – from very warm periods to an almost complete freezing of the planet ('snowball Earth'). Over the past half a million years, the biggest climate changes have happened in connection with the coming and going of the ice ages. Nevertheless, life on Earth has survived even though many species have become extinct, especially at the onset of the ice ages. So, history also shows that life on Earth – generally speaking – is pretty robust. However, we should remember that the climate change we currently face is expected to lead to a warmer climate than the Earth has experienced for several million years – and this will take place over just 100 years! We are therefore on the threshold of a new type of climate change which will take place at a speed that surpasses what has previously been seen.

Climate change is undoubtedly one of the biggest challenges faced by mankind. This is not least because of the huge consequences that climate change will have for the world's ecosystems and for our living conditions. At the same time, climate change poses a colossal political problem where democracies around the world risk failing to make the right decisions in time.

The political and democratic problem stems from the fact that people experience only to a very small degree any connection between lifestyle, greenhouse gas emissions, climate change and the effect of the climate change on the living standards of individual citizens. This is because there is both a spatial and a temporal separation between emissions and effects. The world's industrial countries, which emit the largest volumes of greenhouse gases, are generally less vulnerable to the effects of climate change. This is because industrial countries have a higher adaptive capacity than

Box 1. Key terms

In connection with adapting to climate change, a number of terms are used which unfortunately do not always have the same meaning within different scientific disciplines. The IPCC has therefore chosen to define some of these terms. These will be used in this chapter.

Climate describes the 'expected' weather (temperature, precipitation, air humidity etc.). As such, the climate has often been stated as the mean weather over a longer period of time, usually 30 years. With anthropogenic climate change, where the climate changes relatively quickly, it is necessary to use other methods (for example model calculations) to describe both the present and future climate.

Climate change, in the definition of IPCC, refers to a change in the state of the climate over time, regardless of whether this is due to natural variability or the result of human activity. This definition comes from the United Nations Framework Convention on Climate Change (UNFCCC).

Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, 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 the variation to which a system is exposed, its sensitivity and its adaptive capacity.

There have, especially in the study of the relationship between social and environmentally dependent systems (e.g. agriculture and forestry) been different interpretations of the term vulnerability. In such contexts vulnerability can be looked at from different angles: 1) risk or danger, where the angle is the climate impacts and their consequences, 2) a political/economic angle, which looks in particular at how people and society adapt to the changes, and 3) an ecological angle, where the term resilience is often used as an antonym to vulnerability. When assessing vulnerability studies, it is important to be aware of the angle from which vulnerability is defined and interpreted.

many developing countries (see Box 1). Moreover, serious effects will make themselves felt far later (decades to centuries) than the emissions. Therefore it can be very difficult to foster support among the general population (and voters) for the timely adoption of effective measures that are needed to curb greenhouse gas emissions.

The political will to act against climate change will probably only emerge once both politicians and the general population acknowledge that climate change results from greenhouse gas emissions and that these are harmful. Likewise, the will to act assumes that future harmful effects are deemed relevant for decisions being made now. It is therefore important to be able to establish the effects of climate change and their economic consequences. As climate change in one form or another must be regarded as unavoidable, it is crucial that society adapts in the most appropriate way.

2. The effects are already evident

The effects of climate change do not just belong to the future. Climate change is already happening – as are the effects. The global mean temperature has increased by 0.55 °C over the past 30 years. This has led to documented changes in biological and physical systems across all continents. Examples include:

- Increased instability of the ground in areas with permafrost and more rock slides in alpine areas.
- Changes in some Arctic and Antarctic ecosystems, for example for the polar bears (Box 4).
- Increased run-off and earlier spring floods in many rivers which are fed by glaciers and snow.
- Warming of many rivers and lakes with consequences for the food chains and water quality.
- Earlier occurrence of springtime events such as leaf unfolding and bird migration.
- Shift towards the poles in the spread of flora and fauna.
- Change in the distribution area of algae, plankton and fish in the oceans at high latitudes.
- Increased occurrence of algae and zooplankton in lakes at high latitudes (Box 5).
- Incipient bleaching of many coral reefs as a result of rising sea temperatures.

A number of changes have been documented in both natural and human systems, even though it can be difficult to distinguish climate effects from adaptations to other non-climatic trends:

- In northern areas changes are taking place in agricultural and forestry systems involving earlier sowing and growth in the crops as well as changes in the occurrence of windfalls, forest fires and pest infestation.

- Changes in health-related risks, for example the occurrence of heat-related deaths in Europe (see Box 2) and a greater incidence of allergenic pollens at the mid and high latitudes in the northern hemisphere.
- Certain human activities in the Arctic (e.g. hunting and moving across snow and ice) as well as winter sports in low-lying alpine areas.

There are also indications that climate change is affecting other natural and human systems. Even though these changes are described in the literature, they are still not documented trends which can be ascribed to anthropogenic climate change.

- Buildings in mountain areas are subject to an increased risk of flooding from melting glaciers. Governments and other authorities have in several places initiated the construction of dams and ducts to mitigate the risk.

Heatwave over Europe in 2003 — Box 2

From June to August 2003, many parts of Europe suffered a serious heatwave with summer temperatures 3-5 °C above normal over much of southern and central Europe. The highest temperatures were recorded at the beginning of August when the maximum temperature for several days running was 35-40 °C. The average summer temperature was way above normal, which shows that it was an extremely unusual phenomenon under normal climate conditions. However, the phenomenon is consistent with the combined increase in both mean temperature and temperature variability that is expected as a result of climate change. As such, the 2003 heatwave simply represents what can be expected to be normal for central and southern Europe towards the end of the twenty-first century. Consequently, the heatwave in 2003 has been taken by many as a sign of what is to come.

The heatwave was accompanied by a significant shortfall in precipitation, and the resulting drought led to a loss of productivity of 30 per cent for agricultural and forestry production in large parts of Europe. This obviously reduced agricultural production and increased costs. It has been estimated that total losses amounted to EUR 11 billion within agriculture and forestry. The warm and dry conditions also resulted in many very large forest fires, especially in Portugal. Several large rivers (e.g., the Po, Rhine, Donau and Loire) had record low streamflows, affecting river navigation and the use of the river water for cooling and irrigation. The Alpine glaciers melted at extremely high rates, which helped to prevent even lower rates of flow in the Rhine and Donau. In large towns and cities, the heatwave from June to August led to excessive mortality of more than 35,000 people, especially among senior citizens. Many of these large towns and cities have now introduced emergency plans to prevent a repeat of this in future.

- In the Sahel in Africa, warmer and drier conditions have led to a shorter growing season with devastating consequences for the crops. In southern Africa, a longer dry season and more uncertain rainfall has led to changes in patterns of crop cultivation.
- Rising sea levels, increased settlement and urban development have led to a loss of wetlands and mangroves as well as increased damage from flooding along the coasts in many areas.

Effects depend on the extent of the warming

It probably does not come as any surprise to learn that the greater the extent of the global warming, the greater the consequences. However, it is only since the publication of the IPCC's Fourth Assessment Report that an overall picture has been presented of the consequences across various sectors and across the world's continents. Examples of this are given in Figure 1 where the expected effects are shown for a number of areas which are deemed to be relevant for people and the environment.

Figure 1 shows the effects in relation to a rise in the global mean temperature. However, only a few of the most serious consequences of global warming can solely and directly be ascribed to temperature changes. Most of the effects are associated with changes in patterns of rainfall or the increased frequency of extreme weather phenomena such as storms, heatwaves, droughts and torrential rain. In coastal areas, the rising sea levels also play a big role.

Figure 1 illustrates what could happen during the present century. Far more serious effects are likely in the following centuries. These effects will, in particular, be associated with significant rises in the sea level, leading to the large-scale displacement of people, economic activities and infrastructure away from the present coastlines. This will both be extremely expensive and will pose social, cultural and political challenges of as yet unseen dimensions. It is expected that parts at least of the Greenland ice sheet and possibly the ice cap in West Antarctica will melt in the coming centuries with temperature increases of 1-4 °C, leading to sea level rises of 4-6 metres or more. This is on top of the sea level rises resulting from the fact that water expands when warmed.

3. Water resources

The availability of clean and ample drinking water is regarded as a human right. At the same time, water is fundamental to agricultural production. Of total agricultural production, 40 per cent comes from irrigated farming, but

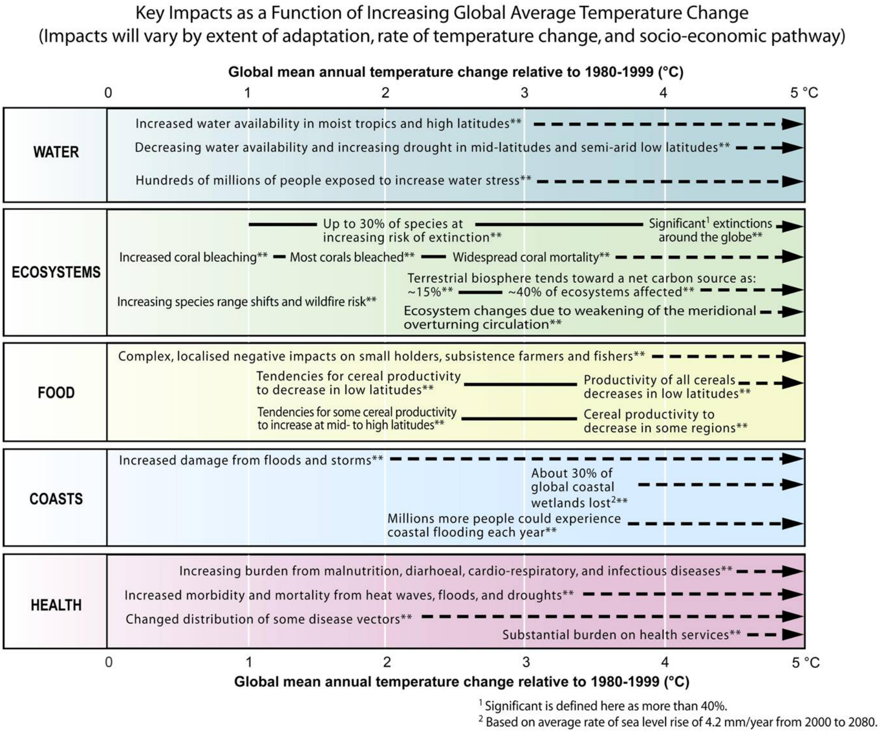


Figure 1. Illustration of how different degrees of global warming during the twenty-first century will affect various resources, ecosystems and human health. The solid lines show where the effects are calculated to take place, and the dashed lines show that the effects continue and are reinforced by increasing temperatures. Adaptation to climate change is not included in these estimates (Parry et al. 2007).

worldwide agriculture accounts for 80 per cent of total freshwater consumption. In addition, water plays a role in many different contexts which will be affected by climate change, for example river navigation, hydroelectric power, cooling of thermal power plants and private and industrial uses.

More than a sixth of the world's population live on floodplains where much of the water comes from melting glaciers and snow. Here, global warming will initially lead to increased streamflow in rivers and thereby greater possibilities for agricultural irrigation. In the long term, the consequences will be smaller volumes of water stored in the glaciers and snow, resulting in bigger differences between summer and winter streamflow in the rivers with an increased risk of both flooding and drought.

By the middle of the twenty-first century, the annual run-off in the rivers and the availability of water is expected to have increased by 10-40 per cent in the high latitudes and in certain tropical regions. The run-off will correspondingly fall by 10-30 per cent in certain dry areas at medium latitudes (e.g. southern Europe, South Africa and Australia) as well as in the dry tropics, which are at present among the most water-stressed areas. Increased drought will often be linked to greatly increased summer temperatures, and the effect of this can be illustrated by the heatwave over Europe in 2003 (see Box 2).

The size of the drought-struck area is also likely to grow. At the same time, the risk of very heavy rainfall increases, increasing the risk of flooding. The effect of more extensive flooding can be illustrated with the widespread flooding along the River Elbe in 2002 (see Box 3).

There are a number of options available for adapting to changes to a river's water flow, the frequency of flooding and to more frequent drought. As human society is so dependent on water, most of these methods are already known by the authorities and private organisations handling water

Major flooding along the River Elbe in 2002 — Box 3

On 10 August 2002, a large low-pressure system moved slowly in across central and eastern Europe. The storm had started several days earlier above the British Isles and then swung south where it gathered large volumes of humid air from the warm Mediterranean. While gradually making its way over the central part of the continent, it released its humidity in the form of sustained and heavy rain. In some places, almost 250 millimetres of rain fell over a four-day period.

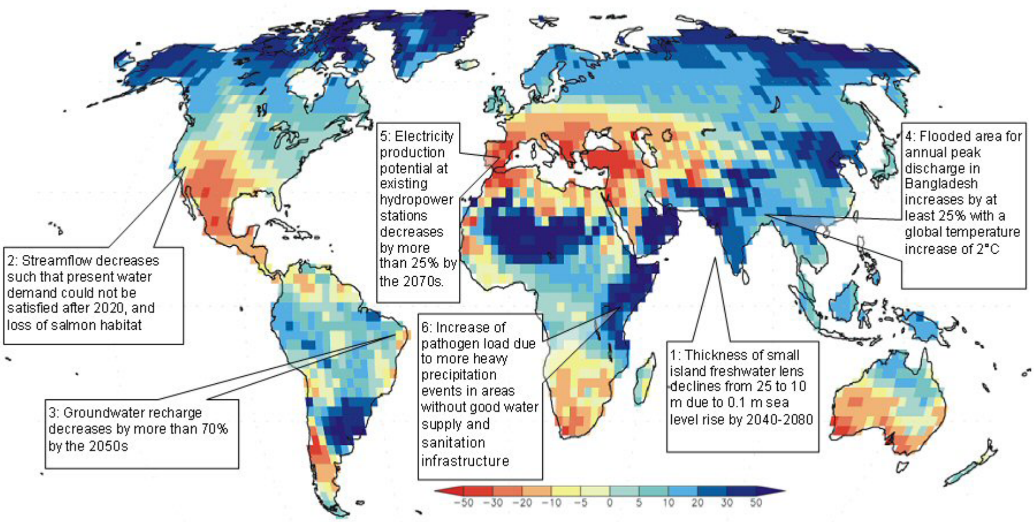
The flooding started in the Czech Republic, where the Vltava River, one of the main tributaries of the Elbe, caused flooding in the medieval towns of Cesky Krumlov and Ceske Budejovice. The next victim further downstream was the low-lying districts in Prague. The flood wave continued into the Elbe and, on 15 August, caused widespread flooding in Dresden. While the flood wave moved further down the Elbe, the river burst its banks in Wittenberg, Dessau and other towns in Saxony. The high water levels finally reached the mouth of the Elbe on 24 August. Even though most flooding was seen along the Elbe, the streamflow increased considerably in the Danube, which led to flooding in many towns in Austria and Slovakia.

When the Elbe and the Danube burst their banks, fertile farmland was flooded along the rivers, destroying crops which were about to be harvested. The muddy flood water which swept across low-lying areas forced many businesses along the river to stop production and trade, and bridges, roads and other infrastructure was extensively damaged or destroyed. Private homes and other property were also to a large extent lost in the flooding waters. If the damage from all the floods in central and eastern Europe is put together, the financial losses from the floods in August 2002 amount to approximately EUR 15 billion.

resources in many countries around the world. The possibilities open to us for managing changes in water supplies basically fall under the following points:

- *Political instruments* such as 'regional strategic water plans', which consolidate and document the initiatives which the authorities and other players can implement to adapt to climate change.
- *Technological and structural instruments* such as new water reservoirs and implementing programmes designed to ensure the renewal of groundwater to safeguard water supplies in the long term as a way of countering the increasing frequency of droughts.
- *Risk sharing and spreading* in the form of insurance policies against extreme climate events and which are made available to poor and vulnerable societies.
- *Changes in use, activity and place* covers measures for overcoming climate change, e.g. special zones along rivers to protect the population from the risk of flooding. This also includes a large number of initiatives to boost the efficient use of water (especially in farming) and water-saving methods (in industry and in private and public housing).

Figure 2. Illustration of how the effects of climate change on freshwater resources affect the possibility for sustainable development in various regions (Parry et al. 2007). The background map shows the estimated difference in annual run-off (in per cent) between the present (1981-2000) and future (2081-2100) climate for the SRES A1B emissions scenario. The blue colours show increasing run-off, the red declining run-off.



4. Ecosystems

Climate change will have serious consequences for the world's ecosystems. However, it is important to remember that, globally, ecosystems already have to contend with considerable impacts of human activities. In the areas which are at the moment bearing the brunt of deforestation, agricultural expansion and pollution, it is expected that these effects and not climate change will be largely responsible for the loss of biodiversity over the next 50 years. However, climate change will exacerbate the situation and lead to further species loss. On the other hand, climate change will be the dominant driving force for changes in places which are not affected to the same extent by human activities. This applies, for example, to areas with tundra and polar ice (see Box 4), coniferous forests at high latitudes, certain areas with Mediterranean vegetation, deserts, savannahs and tropical rainforests.

Natural world in the Arctic is the loser — Box 4

For thousands of years, the fauna and flora in the Arctic region have adapted to the extreme living conditions, and many species are directly dependent on ice and snow. Polar bears live almost exclusively from hunting seals on the sea ice, and when this disappears during the summer, the bears are unable to find anything to eat. This is already happening, with hundreds of polar bears becoming stranded on Svalbard because the ice melts too rapidly. On land the polar bears are unable to find sufficient food, and this means that the polar bear population will shrink considerably with climate change.

There will be similar problems on land as the tundra gradually becomes overgrown with trees and bushes. This will obviously benefit the species which can spread northwards. However, it will threaten the Arctic species, which will likewise move north. But they are far more restricted because the animals and plants can migrate no further than to the edge of the Arctic Ocean, and the species which depend on the ice have nowhere to go once it disappears during the summer.

It will be particularly hard on the high Arctic zone. Here the plants will seldom grow more than 5-10 centimetres tall. The high Arctic constitutes a relatively narrow border between the low Arctic to the south and the Arctic Ocean to the north. Many of the species from the high Arctic tundra will thus become extinct or decline significantly in number and extent. The warmer winter climate will mean periods of thawing during the winter. This will form crusts of ice in the snow, which will make it hard or impossible for musk and other herbivores to feed on the vegetation. There is therefore considerable risk that they will disappear from large areas.

During climate change, the northern coniferous forests with a naturally low biodiversity will slowly develop into deciduous forest areas with a potentially higher biodiversity. The tropical rainforests, which are home to much of the world's biodiversity, will, on the other hand, be particularly sensitive to changes in rainfall volumes. If the rainforests become drier, as some climate models predict, many species will not be able to survive, which will lead to huge species loss.

The temperature of the world's oceans is expected to increase, affecting the distribution of sea ice. In addition, the sensitivity to nutrient loading will increase in many places, which can lead to an increased risk of hypoxia in coastal areas (see Box 5). The tropical coral reefs are particularly vulnerable, and these are enormously significant for the oceans' biodiversity and for fishing by local populations. Predictions based on the climate models show that the majority of the coral reefs will be in the danger zone by 2050.

Increasing temperatures are not alone in affecting life in the oceans. The increased CO_2 concentration in the atmosphere also impacts the oceans directly, because they absorb large volumes of atmospheric CO_2. This leads to ocean acidification, and during the twenty-first century, the pH could fall by 0.3 to 0.4 units. This may not sound like very much, but it represents an increase in the hydrogen ion concentration of between 100 and 250 per cent. This can have major consequences for the marine fauna and flora, including the coral reefs, but these effects are still poorly understood.

Several attempts have been made to calculate how many species risk becoming extinct as a result of climate change. The calculations are based on models which are still subject to considerable uncertainty, and the results vary greatly. According to the most pessimistic predictions, between 15 and 37 per cent of all the world's species risk becoming extinct as a result of global warming.

5. Agriculture, forestry and food security

Climate change comes on top of the major challenge which agriculture has in the twenty-first century of securing food for an ever growing and more prosperous global population at the same time as having to preserve the available soil and water resources. Projections of present developments show that global food production must be doubled over the next 50 years in order to meet demand. Doubts are now being raised about whether this will be possible. Climate change exacerbates this challenge by reducing the quality of the soil and the availability of water in many of the world's agricultural regions and by increasing temperature and rainfall variability.

Climate change has already affected agriculture and food production worldwide. At the same time, the patterns of precipitation have changed. Worldwide there is more extensive drought, especially in the subtropics. In Europe it is most evident around the Mediterranean, where the growing incidence of drought has led to growing pressure on irrigation systems. In parts of southern France and Italy, this has resulted in a reduction in the size of irrigated areas and in changes in crop rotation in favour of less water-consuming crops. Northern Europe on the other hand has seen an increase in precipitation. This has also had consequences for the aquatic environment (see Box 5).

Warmer climate leads to more oxygen depletion — Box 5

Oxygen depletion, or hypoxia, is unfortunately a recurring phenomenon in many lakes, inlets and coastal waters worldwide. In Europe, oxygen depletion in the Baltic Sea in particular has spurred extensive EU regulation with the aim of reducing the leaching of nutrients into the aquatic environment. Billions of euros have been invested in reducing emissions of nitrogen and phosphorus, but it has not yet been sufficiently well implemented to ensure a healthy aquatic environment.

Oxygen depletion occurs when oxygen consumption on the sea or lake bed exceeds supply. When the water column is stratified or characterised by pycnoclines, the water at the bottom is separated from the water above and is not supplied with oxygen from the atmosphere. This results in limited amounts of oxygen at the bottom of the water column available for organisms during summer. Most oxygen is consumed on the sea bed during the decomposition of algae and other organic materials which sink down from above. Nutrients and light stimulate the production of algae, but it is the weather which determines the extent of the oxygen depletion. Oxygen depletion has serious consequences and, in addition to high fish mortality, causes long-term damage to vegetation and all marine life.

The regulations which have been implemented in the EU have led to large reductions in the release of nutrients to the marine environment, but climate change is unfortunately having the opposite effect. Warmer sea water can contain less oxygen, and higher temperatures lead to higher oxygen consumption on the sea bed. In inlets and coastal waters in particular, this means that the oxygen is used faster during periods with clear stratification or well-defined pycnoclines. Climate change may also result in increased precipitation and consequently more run-off, especially during the winter. This in turn results in more leaching of nutrients and stronger stratification in coastal waters. In combination, this exacerbates the hypoxia, and it may therefore be necessary to impose more regulations via the aquatic environment plans.

Climate change is expected to lead to increasing productivity of agricultural crops at medium high and high latitudes with temperature increases of up to 1-3 °C. Temperature increases above this level will probably result in reduced yields. At low latitudes, especially the dry tropics and subtropics, crop yields will fall with even small increases in temperature (1-2 °C), which will increase the risk of famine in many places. Globally, calculations indicate that food production will increase with temperature increases of 1-3 °C, but that above this level food production will fall. However, most of these calculations do not take account of many of the negative effects which increasing climate variability and more flooding and drought have for agricultural production. The consequences therefore might well be declining food supplies and food availability, especially in developing countries at low latitudes (see Box 8).

At the global level it is expected that commercial timber production will increase slightly with climate change in the short and medium term. However, there will be considerable regional variations to this general trend. Around the Mediterranean, the big challenge will be a far higher incidence of forest fires in future. In northern Europe, forestry is dominated by long production times of, depending on the tree species, between 50 and 180 years. In this context, climate change poses a significant challenge because the trees and forests we are planting today must be able to grow and remain stable in the climate of the next many decades. One example is the Norway spruce which will see a decline in southern Scandinavia as high winter temperatures result in forest die-back in Norway spruce plantations. A higher incidence of heavy storms poses a particular threat to forests. Monocultural conifer plantations are particularly liable to storm damage. Many countries are therefore in the process of converting their forestry operations to 'multi-species plantings', where several species of trees of different ages are grown together. This results in greater stability in the face of changes in climatic conditions while also increasing the richness and diversity of life in the forests.

Climate change will lead to considerable regional changes in the distribution and production of fish species, and in many places it is expected to have negative consequences for aquaculture and fisheries. Fish populations depend on a complex interplay between various parts of the marine food chain, and biological production will be affected by the climate at all levels. It is therefore hard to predict exactly what the consequences will be for the fisheries. European fishery areas will see the widespread influx of species from southern areas, whereas some of the native species will move further north.

6. Agriculture

The cool temperate areas (e.g. Scandinavia) will be favoured by the expected effects of climate change on agricultural production potential. However, exploiting this potential assumes that cultivation methods are properly adapted. It is especially in terms of agriculture's environmental impact that this adaptation will need to be planned and managed. This is because intensive farming in these areas discharges significant volumes of fertilisers and pesticides to the surrounding environment.

Sea level rise will, in certain places, lead to flooding or to so high groundwater levels that farming will become impossible. This is likely to be the case along some inlets as well as rivers with a very small height of fall. In some places, the problem can be solved through building dykes, although this may have a negative impact on the natural world. Alternatively, these areas must be abandoned for agricultural purposes. In some regions, in particular along estuaries, salt water intrusion will threaten groundwater quality for both drinking water and irrigation purposes.

Worldwide, approx. 40 per cent of food production comes from irrigated farmland, and about 80 per cent of the world's freshwater consumption is used for irrigation. Climate change is accompanied by more drought in many places during the summer, increasing the need for irrigation. This will have serious implications for groundwater levels and the streamflow in rivers and streams. More efficient irrigation methods and better water consumption regulation is therefore required.

The changes in crop growing conditions and the more extreme rainfall resulting from climate change are expected to lead to greater discharges of phosphorus and nitrogen to the aquatic environment. However, considerable uncertainty still surrounds the size of these changes, but the consequences are probably a higher risk of algae blooms in the aquatic environment (see Box 5). At the same time, rising temperatures are expected to lead to more crop protection problems and thus to greater pesticide use (see Box 6).

7. Coasts

Life along the costs will never be the same. The patterns of winds and storms will change, and in many cases it will lead to more intense storms and hurricanes. Sea levels in the oceans will rise, and a walk along the beach will often include sights of ruins of old buildings, shipyards and quays surrounded by rising water. Along other coasts, which are now dominated by

Greater pesticide use in agriculture **Box 6.**

Most problems with crop infestation are closely related to the host crop and the climate. The extent and nature of the disease and pest problems will therefore change once climate change means that new crops have to be cultivated. Higher temperatures will reduce the generation times of both diseases and pests, and milder winters may also increase survival rates for both pests and their natural predators. Higher temperatures will also see the emergence of new weed species in northern Europe, for example *Redroot amaranth*, which is a serious weed in the maize fields of Central America.

It is likely that warmer temperatures will aggravate plant protection problems for the agricultural sector, and increase the need for pesticides. This may lead to an increase in the spreading of pesticides beyond the fields and contribute to the increased biodiversity loss.

marshes or mangroves, only remnants of these ecosystems will be found. This will particularly be the case where the coast prevents these ecosystems from retreating or where they will be robbed of the necessary sediment.

Towards the end of the twenty-first century, land on which many millions of people depend worldwide is expected to be flooded as a result of rising sea levels. The greatest risk affects the densely populated and low-lying areas with little space for adaptation and which are already now threatened by tropical storms. The threat is particularly great for the populations in the mega-deltas in Asia and Africa and for the small Pacific islands. By 2050, the sea level is expected to have risen by about 45 centimetres, leading to the loss of 15,000 square kilometres of land in Bangladesh which will affect 11 per cent of the country's population.

In Europe, many large cities have grown up along the coast or along rivers which will be affected by sea level rises, and a lot of tourism is dependent on the coastal zone. Many densely populated and low-lying areas in the world are protected by dykes. This is true, for example, of the Netherlands, where much of the country already lies below sea level. Elsewhere, coastlines are protected against erosion by other means (for example beach nourishment by pumping up sand). These measures will have to become more widespread in future to protect coastlines, while in many areas it will probably be relevant to allow the coastline to move back. Throughout much of the world, sandy beaches along many coastlines have been pushed back during the twentieth century. There are complex reasons for this, but climate change is likely to be partially responsible, and there is no doubt that this will be a growing trend in future.

8. Infrastructure under pressure

In town and cities, climate change will bring about both benefits and disadvantages. In some places, temperature increases will reduce the need for heating, while in others it will increase the need for air-conditioning. It will therefore be necessary to insulate buildings more effectively against both heat and cold. It may also be necessary to decide new building standards so that buildings can better withstand violent storms and higher wind speeds. Generally, the disadvantages are expected to outweigh the benefits.

Roads, bridges, tunnels and railways will be vulnerable to heavier precipitation, higher groundwater levels, higher temperatures and falling trees. The infrastructure will be affected very differently by climate change, but the life-spans of such investments are often 50 to 100 years. It is therefore necessary to take climate change into account in the case of renovation and new construction work. Increasingly heavy rainfall also results in more frequent and more extensive flooding of land and basements. This is exacerbated in towns and cities by increasing built-up areas so that larger volumes of rainwater have to be carried away via the sewer systems. Drain and sewer dimensions therefore need to be enlarged during renovation and construction work, while new urban layouts are also required to accommodate reservoirs where rain water can be stored before being carried away in the sewers and streams.

9. Health

Climate change is expected to affect the health and well-being of millions of people worldwide, and for populations with low adaptive capacity the effects will generally be negative:

- Higher incidence of malnourishment, affecting children's growth and development.
- Increased mortality, illness and injury from heatwaves, flooding, storms, fires and droughts.
- Higher incidence of diarrhoea.
- Increasing frequency of cardiovascular disease as a result of higher levels of ozone in the air in towns and cities.
- Changed distribution of certain infectious diseases (e.g. malaria) due to changed living conditions for the disease vectors.

However, climate change will also have positive effects, for example fewer cold-related deaths. Generally, the favourable effects are again overshad-

More allergies in northern Europe **Box 7**

The effects of climate change on health in northern Europe will probably be indirect. Already, significantly larger amounts of pollen have been observed, and the pollen season now starts several weeks earlier. This may partly explain the increase in the prevalence and incidence of allergies. Climate change means that new plant species will thrive in northern Europe, and here ambrosia artemisiifolia poses a particular risk for people with pollen allergies.

Ambrosia artemisiifolia is a plant which originally comes from North America where it is called *common ragweed*. It is thus an invasive species which has spread to many European countries. It is also found in northern Europe but is not yet common here as it flowers too late in the year to be able to produce viable seed. However, a warmer climate will mean that the plant can produce viable seeds resulting in the propagation of Ambrosia artemisiifolia in northern Europe, causing a new weed problem. Ambrosia artemisiifolia poses serious problems for people suffering from pollen allergies as the pollen season is very long (six to eight weeks); in areas where the plant grows, it is responsible for about half of all asthma attacks.

owed by the harmful effects at a global level. Moreover, there will be a number of additional side effects from climate change which also affect health, for example changes in the composition and timing of allergenic pollen (see Box 7).

10. More expensive insurance

Climate change will increase the insurance burden as a result of more frequent and stronger storms, more intense rainfall and more flooding. This is one of the reasons why new buildings should not be constructed on low-lying areas near rivers, lakes and inlets. It may well become more expensive and possibly even impossible to insure such properties in future. And the insurance premiums will not solely depend on developments in the individual countries. If the large international reinsurance companies become liable for claims elsewhere in the world, it can affect the local insurance company's ability to reinsure climate-sensitive risks.

11. Economic consequences

A number of estimates of the net economic costs of global damage caused by anthropogenic climate change are now available. It is expressed as the current value of future net benefits minus costs. Estimates show that the costs of climate change for 2005 amounted to approx. USD 12 per tonne of CO_2 emitted. However, the estimates vary considerably in the various studies, and it is likely that the harmful effects globally are underestimated. Generally, the studies indicate that the net costs of climate change are significant and increasing with time.

Every country will be affected by climate change. The most vulnerable, i.e. the poorest countries and populations, will suffer most, even though they have contributed least to the causes of climate change (see Box 8). The costs of extreme weather events (flooding, drought and storms) are already increasing, even in rich countries. It is no longer possible to imagine that climate change can be avoided for the next 50 years, but it is still possible to minimise the negative economic consequences of the changes – for example by providing better information, improving planning and investing

The poorest are the hardest hit — Box 8

Climate change is affecting the world's population as a whole, but its effects are particularly significant for livelihoods in the world's poorest countries. Vulnerability to climate change depends on the available resources, information and technologies as well as on the stability and effectiveness of national and local institutions. This means that the possibility of achieving sustainable development will be more negatively affected in developing countries and among indigenous peoples than in the developed world. Climate change can make it harder for these populations to meet their basic needs, both in the short and long term. It will therefore become even harder for developing countries to lift themselves out of situations with high levels of poverty and low economic growth and to move towards eradicating poverty and ensuring sustainable development. In this way, climate change increases the difference between rich and poor, and inequality worldwide.

Some of the most serious consequences of climate change are expected in Africa. This continent is also most vulnerable to climate change, and adaptive capacity is often low because of a combination of underdevelopment, poverty and scarce resources. A quarter of Africa's population – approximately 200 million people, primarily in eastern and southern Africa – are already experiencing water shortages. This figure is expected to rise by 75-200 million people by 2020, and by as many as 350-600 million people by 2050. This will obviously affect farming and consequently food security and incomes in rural areas. When water becomes an ever scarcer resource, it can lead to conflict, for example between people who need water for their households and those who need water for irrigation purposes and industrial production. In many cases there will also be conflicts between countries and regions about the right to water, which can potentially lead to armed conflict and war.

in more climate-resistant crops and infrastructure. Making the necessary adaptations will cost billions of dollars each year just in the developing countries, and climate change will consequently increase the pressure on the world's sparse resources.

References

Bates B, Kundzewicz ZW, Wu S & Palutikof J (2008): *Climate change and water*. Intergovernmental Panel on Climate Change.

Caldeira K & Wickett M (2003): Anthropogenic carbon and ocean pH. *Nature* 425, p. 365.

Cassman KG, Dobermann A, Walters DT & Yang H (2003): Meeting cereal demand while maintaining natural resources and improving environmental quality. *Annual Review of Environment and Resources* 28, pp. 315-358.

Gilland B (2002): World population and food supply. *Food Policy* 27, pp. 47-63.

Eakin H & Luers AL (2006): Assessing the vulnerability of social-environmental systems. *Annual Review of Environmental Resources* 31, pp. 365-394.

Fink AH, Brücher T, Krüger A, Leckebusch GC, Pinto JG & Ulbrich U (2004): The 2003 European summer heat waves and drought – Synoptic diagnosis and impact. *Weather* 59, pp. 209-216.

Mueller M (2003): Damages of the Elbe flood 2002 in Germany – a review. *Geophysical Research Abstracts* 5, p. 12992.

Parry ML, Canziani OF, Palutikof JP, van der Linden PJ & Hanson CE (2007): *Climate change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge.

Philander, SG (2008). *Encyclopedia of global warming and climate change*. SAGE.

Petrie G (2002): Flooding in Middle Europe observed from space. *Geoinformatics* 5(7), pp. 6-9.

Schär C, Vidale PL, Lüthi D, Frei C, Häberli C, Liniger MA & Appenzeller C (2004): The role of increasing temperature variability in European summer heatwaves. *Nature* 427, pp. 332-336.

Schär C & Jendritzky G (2004): Climate change: Hot news from summer 2003. *Nature* 432, pp. 559-560.

Stern N (2007): *The economics of climate change: The Stern review*. Cambridge University Press, Cambridge. p. 602.

Tubiello FN, Soussana JF, Howden SM (2007): Crop and pasture response to climate change. *Proceedings of the National Academy of Science* 104, pp. 19686-19690.