

The state of major ecosystems



ALL ECOSYSTEMS from the local to the global are under threat from the pressures of human resource extraction and pollution, driven by population, consumption and technology.

Ecosystems are important not just from an aesthetic or ethical point of view; they play roles that are crucial to human survival and prosperity. Wetlands purify water and assimilate waste. Forests stimulate local rainfall and prevent erosion and floods. Coral reefs and mangroves protect coasts from erosion. In all their variety, ecosystems both constitute and harbor the biological diversity that makes up the stuff of life.

BIODIVERSITY

Biodiversity is an immense resource, built up over 3.5 billion years of evolution. It embraces not only the number of species on Earth, but the range of habitats and genetic diversity within species as well. It is of enormous importance to humans. Of the 270 000 known plants, some 3 000 are exploited for food, and between 25 000 and 50 000 more are used in traditional medicine. Wild plants are potential sources of new medicines and of material for genetic engineering. Biodiversity is a major attraction for tourism, and not least a lasting source of human aesthetic pleasure¹.

Estimates of the total number of species on Earth vary wildly. Around 1.75 million species have been scientifically described. More than half of these are insects, while vertebrates – including fish, birds, mammals, reptiles and amphibians – make up only 2.5 percent².

But the real number is certainly far higher. Most recent estimates fall in the 7 to 20 million range, though a widely acceptable working estimate, used by the United Nations Environment Programme's *Global Biodiversity Assessment* of 1995, is 13.6 million³.

Most ecologists believe that we are currently undergoing a mass extinction driven by human activities. Since 1600, 484 animal and 654 plant species are known to have become extinct through human actions. But these are only the tip of a vast iceberg. Since most species are as yet undescribed, the majority of current extinctions are going unrecorded – species are dying out before we even learn of their existence⁴.

Projections of future losses vary widely, from 2 to 25 percent of all species over the next 25 years. But even the low end of this range is 1 000 times the background rate of extinction⁵.

The total extinction of a species is drastic and at present irreversible. But local extinctions are serious, and far more common. Species are disappearing from more and more locations, where they can no longer play the distinctive ecological, economic and aesthetic roles they once filled.

Data on species are far from complete, but countries and taxonomic groups with more complete information have a higher share of species threatened, so it is quite likely that as more data become available, the percentage judged to be under threat will rise⁶.

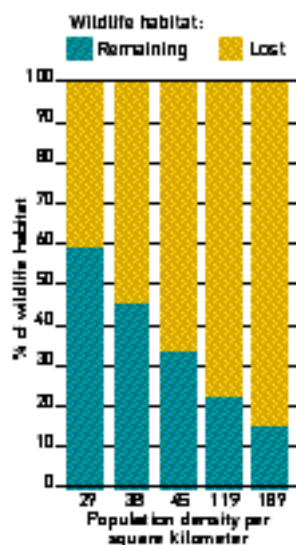
The prospects for the coming decades look gloomy. Forests are the home of between 50 and 90 percent of all land species in the world. If tropical deforestation continues at present rates for the next 30 years, it is estimated that 5 to 11 percent of forest species will eventually be lost⁷.

Wildlife habitat is becoming increasingly fragmented by human activities – making way for

Natural extinctions

The Earth's biodiversity has been devastated by mass extinctions in the past. Up to 90 percent of species were lost in the great extinctions marking the end of the Permian and Cretaceous periods. And there has always been an ongoing natural attrition. The average lifetime of a species in the fossil record is 5 to 10 million years. Between one and three species per year became extinct through natural processes in pre-human times.

MORE PEOPLE, LESS WILDLIFE 50 countries in Africa and Asia, 1990



Source: IUCN; WRI.

cities, farms and roads. Fragmentation lowers the size of individual populations, reducing their genetic variability, and making them more vulnerable to extinction. Human barriers also make it difficult for animals and plants to migrate in response to environmental change.

At the same time, global warming will be shifting present temperature zones generally polewards and uphill. Species will have a greater need to migrate but will encounter human barriers blocking their way. Some species which prefer cold temperatures will see their natural habitats disappear completely.

Meanwhile genetic engineering – unless it is rigorously controlled – may introduce new genes which could spread to wildlife with unforeseeable consequences. There is no doubt that genes from existing commercial crops can pass to wild relatives, and even with rigorous control measures, it is unlikely that accidental transfers could be prevented indefinitely⁸. The extent to which this is likely to have negative impacts on the environment and biological diversity is still not known.

When one species dies out, another may evolve to fill the niche it left vacant. The problem now is that most human-induced extinctions happen because we are progressively occupying or polluting more and more niches and habitats, leaving less and less ecological space for other species.

The *Global Biodiversity Assessment* found that the major threat to biodiversity was habitat loss, fragmentation and degradation, due to the need for land for farms, dwellings, industry, services, transport and leisure. Of those species that are threatened, habitat loss affects 44 percent of the bird species, 55 percent of the fishes, 68 percent of the reptiles, and 75 percent of the mammals⁹.

Other direct pressures are overexploitation of species for commercial gain, for subsistence or for sport. The introduction of alien species, pollution and climate change are all major threats.

Population is a major indirect cause underlying most of these threats¹⁰. Population density is closely linked with most forms of habitat loss. A sample of 50 non-desert countries in Asia and Africa where wildlife habitat loss has been estimated showed that the percentage loss tends to be highest where population density is highest. The top 20 percent of countries, ranked in terms of habitat loss, had lost an average of 85 percent of their original wildlife habitat. Their average population density was 189 people per square kilometer. The 20 percent with lowest population density had lost an average of only 41 percent of their wildlife habitat – and their average population density was only 29 people per square kilometer¹¹.

As always there are many other indirect causes of loss of biodiversity: inappropriate technology, short-term thinking, and failure of markets to factor in environmental costs and benefits.

Governments are gradually moving to give wider areas protected status, but progress is slow. Globally, in 1997, only 6.4 percent of the land area was protected. To protect the full range of species, large areas are needed, but 88 percent of protected areas in 1997 were smaller than 100 000 hectares – a square with sides of about 32 kilometers¹².

FORESTS

In the mid-1990s forests covered about one third of the world's land area – probably around half the original extent before human intervention¹³. We are continuing to lose forests at the rate of some 112 million hectares each decade, an area twice the size of Kenya or France¹⁴.

As with many kinds of environmental indicator, a country's forest cover usually follows a U-shaped curve. It declines during the earlier stages of development, then as population slows in growth and becomes more urban, it stabilizes and may eventually begin to rise again.

So each year, while developing countries are deforesting some 13.7 million hectares – an annual loss of 0.61 percent – developed countries are actually increasing their forested area at the rate of almost 1 million hectares per year¹⁵.

Among developing countries, India and China have almost come to the end of their period of deforestation and have begun to reverse forest loss. Some of the fastest rates of deforestation are found in middle-income developing countries with strong commercial logging interests (Indonesia 2.4 percent, the Philippines 3.5 percent, Thailand 2.6 percent).

Overall, deforestation in developing countries may now be slowing down. According to estimates

by the Food and Agriculture Organization of the United Nations (FAO), the annual loss in 1990-95 was 1.7 million hectares a year lower than in the 1980s. Against this, there was massive damage from forest fires in the late 1990s. In 1998 alone more than 6 million hectares were burned in Indonesia, Brazil and Russia¹⁶.

Deforestation data reveal only the net loss of forest converted to other uses. They say nothing about the quality of the remaining forest – its health and biodiversity. Logged-over forests still count as forest, since they can in theory regrow, but destructive logging methods mean that secondary forest is often impoverished. Plantations also count as forest, though they are usually made up of a single species with all competing weeds and shrubs cleared from the ground.

Increasingly, natural forests are fragmented into smaller areas which can no longer support the full range of species. Only three areas of very extensive natural “frontier forest” remain on Earth – in Canada/Alaska, in Russia and in the Amazon basin. Some 39 percent of this remaining extent is threatened, mostly by logging, mining and roads. Some 76 countries have lost all their frontier forest¹⁷.

Perhaps not surprisingly, the more people there are in any given area, the less forest. A number of studies have found a strong correlation between population density and deforestation rates at national level¹⁸.

A recent report by the United Nations Population Fund (UNFPA) divided developing countries for which data exist into two groups of 37, according to the speed of deforestation. In the group suffering faster deforestation – with an average loss of 1.8 percent of forests per year in 1980-90 – population density was 89 people per square kilometer. In the group with slower deforestation population density was just 34 per square kilometer, and the average deforestation rate was only 0.5 percent¹⁹.

The reason for the link with population density is straightforward. The land needed for farming depends on the total population, the consumption of agricultural products per person, and the amount of land needed to produce each unit of consumption. If population or consumption increase, and yield improvements do not compensate fully, then the farm area must expand.

Land is also needed for dwellings, industry, roads, leisure and so on. These are partly a function of population, but also depend on many other things such as standards of residential space, the share of people living in high-rise buildings, the size of gardens, or the level of car ownership. Generally, non-farm land requirements per person rise in line with income.

Of course, many other factors drive deforestation today, from government policies on timber royalties and protected areas, to the numbers of landless people.

COASTAL ENVIRONMENTS

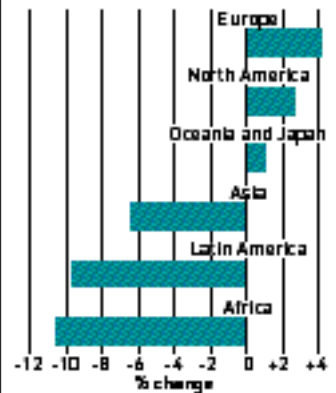
A very high proportion of human population and activity is located on or near coasts. Coastal areas have always been important for trade, sea transport and defence, and contain some of the densest concentrations of human population and activities on Earth today. Nearly two fifths of the world’s population live within 150 kilometers of a coastline. In rapidly developing regions such as China, tens of millions of people have moved to coastal cities in search of work in the last two decades²⁰.

A recent assessment found that over half the world’s coastlines are at risk from coastal development and just over one third are at high risk. Nearly three quarters of the world’s marine protected areas are similarly threatened²¹. In addition, human activities over a vast inland area have an impact on the coast and coastal water. Much of the water pollution and sediment eroded from whole watersheds are transported to the sea.

Coral reefs

The world has an estimated 255 000 square kilometers of near-surface coral reefs, which constitute one of the richest resources of biodiversity on the planet. The Great Barrier Reef alone has more than 700 species of coral, 1 500 species of fish and more than 4 000 species of mollusc. The

CHANGES IN FOREST AREA, 1980-95



Source: FAO.

Between 1980 and 1995 Africa lost 10.5 percent of its forest cover, Latin America 9.7 percent, and Asia 6.4 percent. But developed areas managed to increase their forest cover; Europe by around 4 percent.

Mangroves

Mangroves are estimated to cover 18 million hectares of the Earth's tropical coastlines, around one quarter of the total.

Mangroves host unique species, and are important nurseries for commercial marine species.

No comprehensive survey has yet been made, but it is estimated that around half of all tropical mangroves have been destroyed. The Philippines, Puerto Rico, Kenya and Liberia have lost over 70 percent. The major direct pressures are cutting for fuelwood and timber; habitat conversion for coastal development or aquaculture (often shrimp farming); and damming of rivers which alters water salinity. Population growth and concentration, as well as tourism and resource consumption in and around coastal areas, are important direct and indirect causes of these pressures.

net primary productivity of reefs is higher even than that of tropical forests, and 20 times higher than that of the open ocean²².

Reefs are a major source of livelihood, providing 20 to 25 percent of the fish catch of developing countries, and serving as a major tourist attraction in many countries dependent on tourist income. Overall, reefs have been calculated to provide resources and services worth about US\$375 billion per year.

Yet reefs are among the most seriously threatened habitats on Earth. The status of world reefs has never been comprehensively evaluated, but it is believed that around 10 percent have already been degraded beyond recovery, and another 30 percent are expected to degrade seriously within the next two decades²³. A recent study estimated that 58 percent of the world's reefs are potentially threatened by human activity, almost half of these seriously so. In Southeast Asia, which has a very high level of coral and fish diversity, more than 80 percent are potentially at risk²⁴.

The threats to coral reefs are many. Overfishing pushes fish stocks below their maximum sustainable yield. Destructive fishing practices like cyanide poisoning or dynamite blasting kill or damage many species. In many areas reefs are directly plundered for specimens of fish, shell and coral, and even construction materials. Tourist divers and their boats damage corals.

Water pollution from industry, sewage and fertilizer, and sediment eroded from deforested or badly farmed areas, all wash into the sea, reducing light levels and physically smothering corals. Finally there is evidence that episodes of coral bleaching – when corals lose their symbiotic algae – have been rising in severity and frequency as sea temperatures increase with global warming.

As with all environmental damage, these pressures have many indirect causes ranging from technologies for fishing, construction, agriculture and sewage, to changes in incomes and shifts in tastes and leisure habits.

Population factors are important indirect causes. Rising population contributes to increased demand for fish and construction materials. The speed with which urban population growth outpaces improvements in sewage treatment affects levels of water pollution. The rising demand for food of growing populations increases the pressure to use more fertilizer on farmland, much of which gets leached out by rain and washed into rivers, lakes and seas.

MARINE ENVIRONMENTS

Human response to any environmental problem depends on how visible it is, how good our data and our understanding of its causes are, and how directly the problem impacts on people in a position to do something about it.

Of all ecological zones, marine environments are the least visible, the least studied and the least understood. Because of this they are probably the most at risk. The sea's surface is reflective and few venture below it to check what is happening. Baseline data of pristine conditions have not been compiled, and most marine species have yet to be described. Changes due to human activity are therefore hard to document.

But we do have reasonably good data about fish catches, and these reveal disturbing trends in the ecology of the oceans. Assessments made in 1999 found that 44 percent of major fish stocks are already exploited to their maximum sustainable yield. Another 16 percent are overfished, which means that future catches will fall unless remedial action is taken. And 6 percent are depleted, with falling production. Only 34 percent still have room for growth in production²⁵.

Fisheries pass through a sequence of phases over time. From an undeveloped phase, they enter a developing phase where catches increase rapidly, and then a mature phase where the maximum sustainable yield is reached. If the maximum sustainable yield is overshot, a senescent phase follows when yields are stagnant or declining. According to a 1997 assessment, as recently as 1960 only a very small percentage of fisheries were mature, none were senescent, and half were still undeveloped. By 1994, 35 percent were senescent, showing declining yields, 25 percent were mature, and only 40 percent were still in the developing phase²⁶.

These phases correspond to states of the underlying ecology and the human response to

growing shortages. At the maximum sustainable yield the population of the target species is plentiful and can be sustained indefinitely. But good resource management is in short supply, so the maximum sustainable yield is usually overshot and the target fish population begins to decline. Collapses have hit major fisheries. The Peruvian anchovy fishery collapsed in the 1970s. Catches of cod, hake and haddock in the Northwest Atlantic were at their peak in 1965, at 2.27 million tons. After this they declined and levelled off at around 1 million throughout the 1980s, but in the 1990s they fell precipitously, reaching 126 000 tons in 1997²⁷.

Fishers are now shifting rapidly across the spectrum of species and areas, altering the underlying ecology in ways that we can only catch glimpses of. Many of our preferred fish are top-level predators. As these are overfished, their prey may have population explosions, which in turn reduce populations of the fish they feed on and so on down the food chain. Recent research by Daniel Pauly and colleagues shows that the fishing effort since 1950 has been moving down the food chain at the rate of about one whole level per century. But this shift does not bring respite for the top predators, as they are left with little to eat²⁸.

Fish increasingly fail to grow to full size, and may not reach reproductive age. There has been a very considerable drop in the average size of fish caught, from about 100 centimeters in the early 1980s to just over 40 centimeters in 1997²⁹.

In the absence of effective fishery management at national, regional and global levels, it is likely that the ecology of the oceans will be even more drastically altered by human intervention.

Fishing is not the only source of ocean problems. Alien species from ships' ballast tanks are being spread to areas where they compete with indigenous species. "Red tides" – planktonic blooms of toxic marine algae which can kill fish and cause amnesia, paralysis and death in humans – are on the increase.

There are now around 50 known "dead zones" with no or low oxygen. Most of these have appeared over the last half century, and are blamed on excess influx of nitrogen and phosphorus from farming and sewage. The dead zone in the Gulf of Mexico is 4 144 square kilometers and has doubled in size since 1993³⁰.

The direct causes of these marine trends are complex. Species are being overexploited through overfishing, collecting and resource extraction. Ecosystems are being physically altered by coastal development, blast fishing and so on.

Ocean pollution is rising inexorably. Although dumping at sea is now better policed and oil spillages are less common, more than three quarters of marine pollution originates on land, where marine-related controls are absent. Pollution from runoff and rivers includes sewage, industrial effluents, fertilizers, pesticides and herbicides. Air pollution is the source of one third of marine pollutants. Some of the most harmful organic molecules accumulate at the boundary layer between sea and air where the early stages of many species develop as plankton, causing mortality, deformity and chromosomal abnormalities³¹.

Finally, atmospheric and climatic changes threaten the sea. Rising temperatures have been implicated in coral bleaching, while the thinning ozone layer allows in higher levels of ultraviolet radiation which depresses the productivity of phytoplankton, the basis of almost all life at sea³².

Behind these direct causes lie indirect ones. Fishing is driven by the level of demand for marine products. The demand, in turn, is determined by the absolute size of the human population, the level of income, and the proportion available to spend on fish.

It is not just the total level of demand, however, but the way in which it is being met that does the harm. The technologies of modern fishing – radar, sonar, global positioning systems – allow a terrifying efficiency in tracking down and catching every last stock. Modern net designs practically vacuum the sea and sea bottom clean of living organisms. There is a very high level of by-catch of unwanted species, or juveniles that would be illegal to land. These amount to about one quarter of the catch, and are simply discarded at sea.

Misguided fishery policy based on short-term political advantage has been a major factor preventing timely adaptation. In most countries the fishing industry has been subsidized for electoral

Shifting ground in fishing

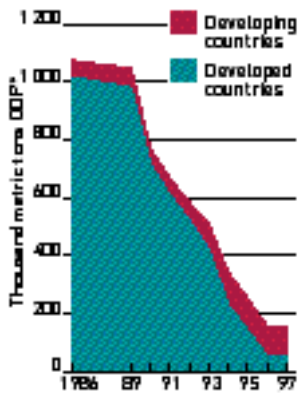
Fishermen respond to the decline in a target species by moving to other fishing areas or other species of fish, and the sequence starts again.

Area shifting has been seen in Atlantic fisheries for favored species like cod, haddock and hake. When Northwest Atlantic fisheries began to decline after 1965, fishing effort shifted to the Northeast and Southeast. As the Southeast in turn showed signs of decline, attention was turned to the Southwest³³.

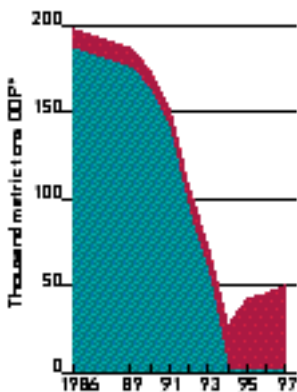
Species shifting has been seen in the case of whaling. As humpback whale populations declined in the first decades of this century, whalers began to take more blue whales. As these, in turn, declined, sperm and fin whales bore the brunt of the catch. When these too were overhunted, blue and minke whales were targeted. Eventually every whale species was so severely hit that commercial whaling had to be halted³⁴.

RAPID RESPONSE

CFC production



Halon production



* ODP = ozone-depleting potential

Source: UNEP.

The Montreal Protocol on Substances that Deplete the Ozone Layer was in place in 1987 and, as a result, by 1997 production of CFCs had been slashed by 85 percent and halons by 75 percent – although halon production in China has increased considerably since 1993.

reasons, creating excess capacity. This artificially lowers the price of marine fish and thereby increases the demand. Even after scientists start warning that maximum sustainable yields are being exceeded, politicians rarely act decisively or adequately for fear of alienating voters in fishing constituencies. As a result, collapse of fisheries with massive job losses becomes more likely.

ATMOSPHERE AND CLIMATE

Perhaps the most dramatic and threatening of all the signs of our deepening environmental impact are the changes we are working in the Earth's atmosphere, altering its composition and chemistry, and affecting the Earth's climate.

Ozone

The most immediate threat is the thinning of the ozone layer. Ozone losses pose serious threats to human health, by increasing rates of skin cancer, and by affecting biological productivity in plankton and some plants.

Although ozone losses have not progressed as far as was predicted in the mid-1990s, they are still serious. Total column ozone losses between 1979 and 1994-97 averaged 5 percent all year round in southern mid-latitudes. In northern mid-latitudes losses varied from 2.8 percent in summer to 5.4 percent in winter/spring³⁵.

The immediate cause was human emissions of ozone-depleting chemicals. The role of population and consumption in their growth was extremely small. The major cause was technological change – the introduction and rapid spread of chlorofluorocarbons (CFCs) from the 1930s on. Between 1940 and 1970 production grew at 20 percent a year, far outstripping the growth of population and consumption combined.

The ozone problem gave us one of the most encouraging examples of rapid response to a perceived environmental problem. The seminal paper documenting the ozone thinning was published in 1985. Within just two years the world had an international treaty to limit and reduce production of ozone-depleting chemicals.

By and large the treaty has been working well. Global production of CFCs fell by almost 90 percent between 1986 and 1995. As a result, atmospheric concentrations of ozone-depleting chemicals peaked in 1994 and are now slowly declining, though illegal production and trade in CFCs are growing problems³⁶.

Global warming

In the case of ozone-destroying chemicals rapid response was possible because producers were few, CFCs were not central to our industrial way of life, and economical substitutes were already available. Prospects for similar rapid response on the major greenhouse gases are much less rosy.

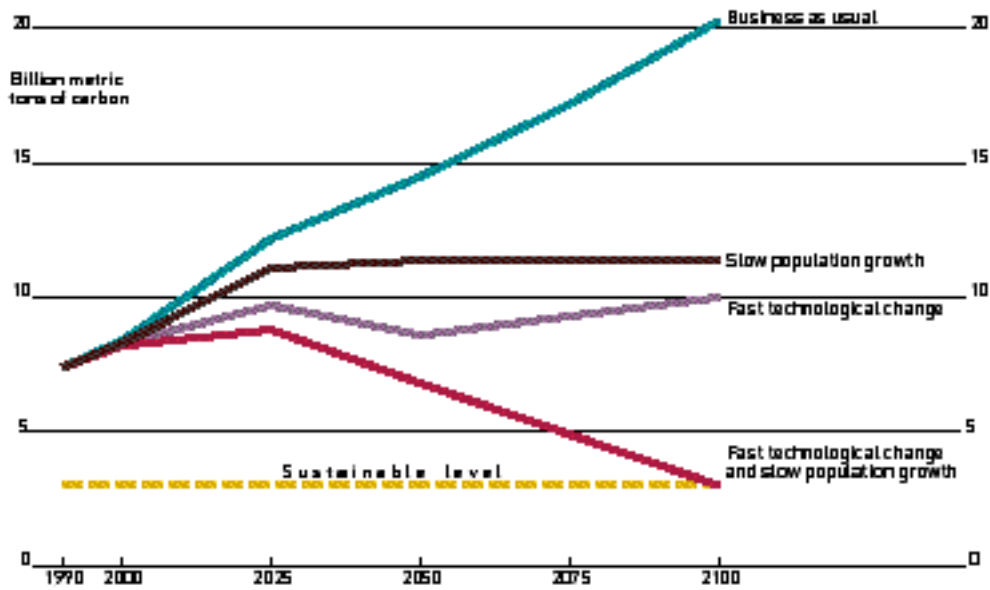
Over the past century, the global mean surface air temperature has increased by between 0.3 and 0.6 degrees centigrade. Linked to this warming, the sea level has risen by between 10 and 25 centimeters. Atmospheric concentrations of carbon dioxide (CO₂) have increased by more than 20 percent, and methane by 145 percent over pre-industrial levels³⁷.

The climate models used by the Intergovernmental Panel on Climate Change (IPCC) predict that over the coming century average world temperature will rise by 1 to 3.5 degrees centigrade and sea level by 15 to 95 centimeters over 1990 levels. The central estimates suggest a warming of 2 degrees and a sea-level rise of 45 to 50 centimeters by 2100. The rate of warming will be faster than any seen over the whole of human history.

The potential impacts are grave. The range of certain diseases and their insect carriers will increase. The range of malaria transmission will spread. If the upper range temperatures are reached, the number of malaria cases could increase by between 10 and 16 percent by the latter half of the 21st century³⁸.

Extreme weather events such as droughts and floods may increase in frequency. Between 200 and 250 million people currently live below the annual storm surge level on the coasts, liable to

POPULATION TRENDS AND CO₂ EMISSIONS*



Source: Independent Commission on Population and Quality of Life.

* This figure expresses CO₂ emissions as elemental carbon. 1 ton elemental carbon = 3.664 tons CO₂.

Future CO₂ emissions can be considerably reduced, compared to the business-as-usual scenario, by more rapid shifts to low-carbon and renewable energy sources, and by slower population growth.

annual flooding. Sea-level rise combined with population growth could double this total by 2020³⁹. The impacts of climate change could have far-reaching consequences for social stability.

The historical record shows that major shifts in climate can occur over very short periods when major ocean currents are affected. The Gulf Stream which warms Western Europe, for example, is driven partly by the sinking of cold saline waters in the Arctic. Increased melting of the Arctic ice cap is now reducing Arctic salinity, which could result in a reduction or shutdown of the Gulf Stream.

For each of the gases that cause global warming – such as CO₂, methane and nitrous oxide – emissions are the product of population, multiplied by consumption per person, multiplied by emissions per unit of consumption. In the case of methane emissions, the population element is very significant. Rice paddies and livestock are among the most important human-induced sources. Between 1961 and 1985 population growth accounted for 69 percent of the increase in livestock numbers in developing countries, whereas changes in meat and milk consumption per person accounted for only 31 percent. As so often happens, technology – the productivity of livestock – worked to reduce the livestock numbers needed for any given level of production⁴⁰.

In the case of CO₂ emissions, population was a lesser but still significant element, accounting for just over one third of the increase in emissions between 1965 and 1989⁴¹. Again, however, at issue is the unit of analysis. If population is counted as households rather than as individuals, its unit contribution to CO₂ will be much greater.

All projections of future global warming made by the IPCC depend on assumptions about population, consumption and technology. The technology element is the result of two factors: energy efficiency (the amount of energy used per dollar of GDP) and carbon intensity (the amount of carbon emitted per unit of energy used). Carbon intensity depends on the share of energy production due to fossil fuels, and on the relative shares of gas, oil and coal in fossil-fuel use (gas produces the least carbon and coal the most).

The IPCC has produced several alternative scenarios, but each scenario varies several factors at once, making it impossible to get an idea of the potential impact of different policies affecting population, or consumption, or technology.

However, a study for the Independent Commission on Population and Quality of Life used the IPCC's raw data to develop policy-oriented scenarios which showed the potential impacts of changes in economic growth, technology and population growth taken separately. Although these factors do interact, the exercise provides at least a rough idea of the possible gains⁴².

The IPCC used three population projections – medium-low (7.8 billion people by 2050), medium (10 billion) and medium-high (12.5 billion). The central IPCC scenario (IS92a) projected direct greenhouse gas emissions equivalent to 14.5 billion tons of carbon by the year 2050. Applying the low population projection while leaving everything else unchanged would result in emissions of only 11.4 billion tons of carbon. The “savings” of 3.1 billion tons are equivalent to half the total emissions from fossil fuels in 1990, and more than twice the level of 1990 carbon emissions from deforestation.

Thus population measures could have a very large potential impact on global warming. Achieving the low population projection rather than the medium could, over the next 50 years, have more than twice the impact on greenhouse gas emissions as halting all deforestation at today's rates. It would be equivalent to more than doubling today's energy efficiency, or replacing more than half of today's fossil-fuel use with renewable energy.

However, this reduction would not be enough. To achieve the level of emissions that the IPCC suggests is sustainable, we would also need to achieve rapid shifts in energy efficiency and in the transition to renewable energy. The Independent Commission on Population and Quality of Life study suggested that a combination of slow population growth and fast but achievable technological change could bring total greenhouse gas emissions down to the more or less sustainable level of 3.2 billion tons of carbon equivalent by 2100. A further study, done by the International Institute for Applied Systems Analysis in 1997, found a similar level of benefit from slower population growth⁴³.

These studies omit possible feedback effects – for example, slower population growth might result in faster economic growth. Nevertheless they show clearly that measures to slow population growth could make a major contribution to reducing future growth of greenhouse gas emissions.

There are many other policy opportunities available which would not only reduce greenhouse gas emissions, but also bring other benefits. They include energy efficiency measures which would save money, or shifting tax and subsidy regimes so that “bads” like fossil-fuel use are discouraged, and “goods” like renewable energy are encouraged.

The sinks and reservoirs for greenhouse gases can also be boosted, for example by increased tree planting or improved forest management. These would bring other benefits in regulating local climates, slowing soil erosion and reducing flooding.