International environmental governance

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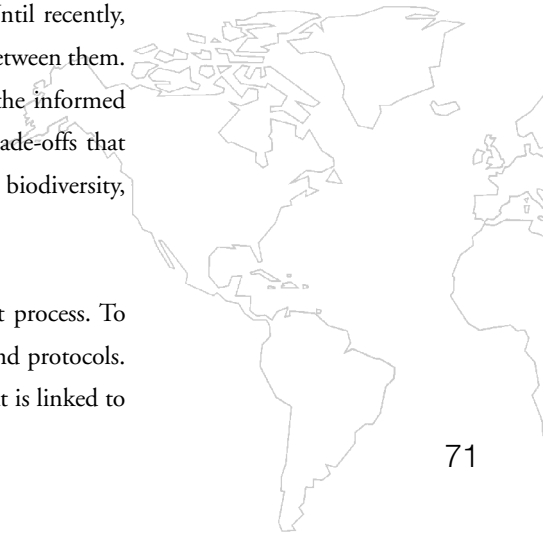
There are international conventions for stratospheric ozone depletion, climate change, biodiversity and desertification. There are no conventions for air quality, water or forestry, though we do have a good deal of regional or national legislation on each of these. The problem is that with a number of different conventions and legislative structures covering the various environmental themes, we tend to think through the policies for one while neglecting the implications for another, so there is some degree of dysfunctionality in the way we approach the policy process at both national and international levels. Whether in the United Kingdom, within Europe or in developing countries, one department looks at climate change, another at biodiversity, a different one at forestry, and yet another at water.

We have to recognize that we have multiple environmental issues to deal with, of which climate change is but one, though it is the one that the world is focused on at present. As climate begins to change, it will have an effect on the radiation budget of the atmosphere and the stratosphere, which in turn has an affect on stratospheric ozone, and stratospheric ozone in turn has an affect on the Earth's climate, particularly in the polar regions. Equally, a changing climate has an effect on biodiversity and ecosystems, and as we change our ecosystems we modify the exchange of energy and chemicals between the atmosphere, the ocean and the land, so that it feeds back again on the climate system. There is no question that climate change has a significant effect on forests and in turn these affect the climate. Climate change clearly affects water, land albedo and desertification, and it has an impact on air quality. In other words, we cannot look at climate change in isolation from these other environmental issues, which are also issues of development and national security.

The tendency to isolation is also one of the fundamental problems of assessment. Until recently, even the scientists tended to look at each of these issues separately rather than at the links between them. But if we do not look at them in a much more holistic way we will probably not have the informed policies that we need. We can miss out the synergies and, even worse, there could be trade-offs that we don't understand – policies that will be good for climate change may well be bad for biodiversity, for example.



Not all the areas of environmental concern actually have an international assessment process. To look at three: stratospheric ozone, climate change and biodiversity all have conventions and protocols. There is an assessment process embedded within stratospheric ozone, and we have one that is linked to

but not embedded in the climate change process (the Intergovernmental Panel on Climate Change – IPCC), but there is no assessment process linked with biodiversity. Instead it has a number of rather poor ad hoc processes.

Science in policy making

While science can only ever be one of the many necessary inputs to decision making, comprehensive scientific programmes at the national and international level are absolutely essential to inform public policy. We have some pretty strong programmes in general for the natural sciences: climate change, biodiversity, or stratospheric ozone depletion. But we have underinvested in the social sciences – the behavioural issues linked to the environment. Too many people think we can solve the climate issue through technology combined with policy. But if we don't understand people, individual and community behaviour, the private sector and governments – and how they make their decisions – we will miss out. Technology is crucial, but so are the behavioural issues.

We have good international coordination of some of the international programmes that relate to biodiversity, climate change and ecosystems, such as the World Climate Research Programme, the International Geosphere-Biosphere Programme and the international human DIVERSITAS programme addressing biodiversity, though the latter – which is indeed a social science programme – is pretty weak.

A further weakness is that we have inadequate private- and public-sector funding. Provided that there is open, transparent, independent peer review of the research – whether funded in a collaborative way between the public and private sectors or just by the private sector – we really should be promoting far more public-private partnerships. And then it is absolutely crucial to bring everything together – the scientific, the technical and the economic – through the best experts from all stakeholder groups: universities, government laboratories, the private sector and the NGOs. Indigenous and local knowledge also needs to be integrated with modern scientific knowledge, though here the difficulty is that little of it is written down, and what is written down is not peer reviewed.

One of the big challenges is how to bring together the various types of research. Of course effective communication is absolutely crucial, though this is something that we tend to be rather bad at. Most scientists talk in jargon, so for politicians and the media in general we are pretty incomprehensible.

What is an assessment?

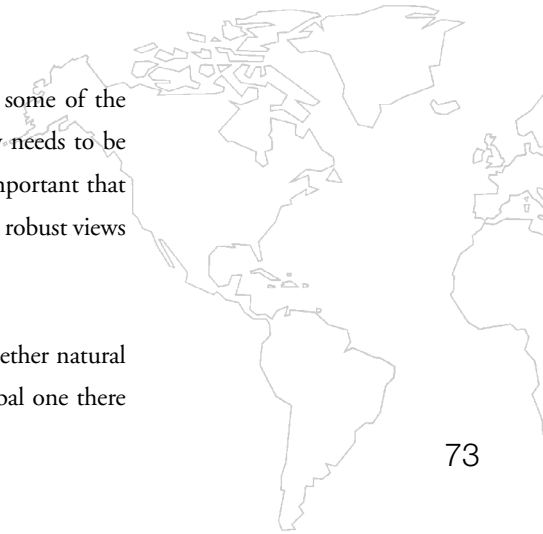
An assessment is more than a review. It is a critical evaluation, an expert judgement of what constitutes robust knowledge and of what is uncertain. Its aim is to reduce complexity, especially for ministers, and to add value. And if it is to have an impact it must be demand-driven, not supply-driven. The users of the assessment have an important role in defining its scope, alongside, of course, the academic community.

So what are some of the critical features of an assessment? Assessments must be open, transparent and representative, and they have to be legitimate with respect to all the stakeholders you are trying to influence. The process is as important as the results: if you get it wrong, you won't have stakeholder confidence and the results won't be used. Success requires a very bureaucratic approach, with well-defined principles and procedures about how the peer review will be done and by whom, and how the resulting documents will be accepted and approved. The review is an essential part of the process – without it, research and assessments are worthless – and it is not unusual to have an assessment reviewed twice. This is a huge amount of work involving governments, the academic community and the public sector.

Whether you want to influence governments, the private sector or civil society, they must be involved in helping to define what they want to assess. With regard to maximizing the potential for influence, I would argue (even though many academics would disagree) that assessments should be policy relevant but not policy prescriptive. They should not be normative and should not make recommendations. The private sector and governments tend not to listen if you tell them what to do, so options for action are far more powerful than recommendations. The 'if... then...' approach generally has the greatest success, and of course it must be evidence based.

It is interesting trying to differentiate the evidence from the ideological positions of some of the authors involved in assessments. Different authors present different views, and every view needs to be taken into account, even if it is supported by only 10 per cent of the literature. So it is important that policy makers understand what is robust and what is not, while bearing in mind that the less robust views have to be understood and taken into account.

The best experts in the world need to be balanced across the disciplines – bringing together natural sciences with social sciences and technologies, and if the issue is an international or a global one there



must be expertise from both developed and developing countries. It is absolutely crucial that the experts are there in their individual capacity, not representing their government, the private sector or an NGO.

Assessments should be holistic in scope. They should cover risk assessment and clearly define and separate it from risk management: the key issue is to communicate the risk in terms of probabilities. We are fairly good at identifying where the uncertainties lie – an essential element of any assessment – but the implications for policy formulation (or risk management) are much trickier to pin down. I have already said we need to use both traditional and institutional knowledge, which must come into play on the local and global scale as appropriate. For many climate change issues, for example, you can take a global perspective to bring together information leading to a mitigation strategy. But when it comes to water resource management or biological diversity, then it has to be a very local perspective – at least at a watershed or regional level – and communications with local stakeholders are absolutely crucial.

Key characteristics

An assessment must be multi-thematic, bringing together the environment, technological, social and economic perspectives. It must be multi-spacial, using a consistent framework from the local to the global. It must be multi-temporal, examining what we can learn from the past and identifying a likely or plausible future. There should be multiple sponsors and maximized stakeholder involvement. Indigenous and institutional knowledge need to be integrated, and scientific knowledge, technologies, institutions and policies must all come under scrutiny.

What sort of assessments have we done? The International Ozone Assessments began in 1981 and have continued until the present. They have been intergovernmental, with governments approving their broad scope, and have undergone expert peer review (with no governmental involvement). These have been unbelievably influential on both national and international policy formulation, and also with respect to the private sector. Understanding the links between what we were doing, putting chlorine and bromine into the atmosphere, and the ultimate effect of an increase in skin cancer, captured the attention of the public and the policy makers alike. I shall return to the ozone assessments later.

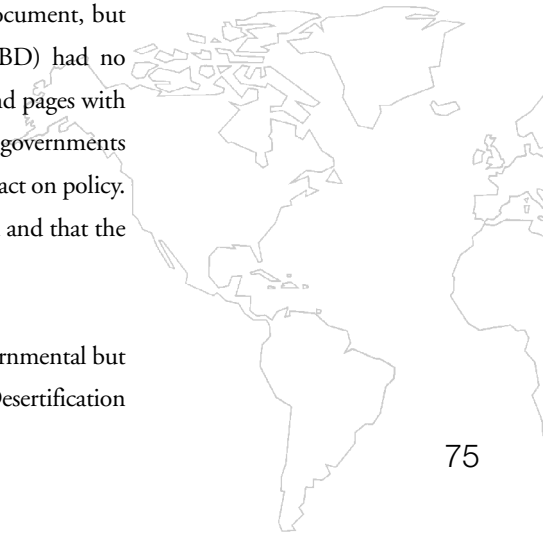
The IPCC started in 1988 and is on-going. The chairmanship of Burt Bolin really set up the IPCC in the right way. It started off very simply: our first working group on the science of climate change involved

only about 40 people, whereas more recent working groups probably brought about 300 people to the table. But it has always been intergovernmental, with governments approving the scope of each of the working groups. There are three working groups – one on the science of the climate system, one on impacts and adaptation, and one on economics and technological issues. There is also a synthesis report that integrates the knowledge of the three. This worked very well in the *Third Assessment Report* (I am biased about this one because I chaired it). Unfortunately the *Fourth Assessment Report* involved far less integration of the three groups, not because of the scientists but because the governments – largely led by the United States of America and China – did not want a full synthesis.

The IPCC has had excellent expert government and peer review of the summaries for policy makers, a process that typically takes four, five or six days, and results in an approved 20-page summary (boiled down from around a thousand pages). Many in the academic community think it inappropriate to involve governments in approval of a document written by experts, but I would argue vehemently that this is part of the process. Only when governments read and approve these documents on a word-by-word basis will they begin to inform policy. Simultaneously, of course, the scientists maintain ownership because, while the document may undergo changes, the academics are there to ensure that there is no distortion. The IPCC has undoubtedly been influential on the policy process, albeit limited in the United States, though here, too, it is starting to penetrate. Some of the big multinationals are using it, as are some individual states such as California and New York. The religious right, amazingly, is also starting to use it, arguing that climate change is a serious moral and ethical issue.

The Global Biodiversity Assessment was a brilliant non-governmental expert review document, but it was totally supply driven. Realizing that the Convention on Biological Diversity (CBD) had no international assessment process, a bunch of us simply got together and did one – a thousand pages with over a thousand contributing scientists. It was a superb academic document, but because the governments did not ask for it and it had no appropriate mandate in the convention, it had almost no impact on policy. It was a valuable lesson: do not do supply-driven assessments; make sure that there is a need and that the user community has asked for one.

So when we did the Millennium Ecosystem Assessment a few years later, it was non-governmental but tied to the intergovernmental process (e.g. CBD; United Nations Convention to Combat Desertification



– UNCCD; Ramsar Convention on Wetlands). It underwent both expert and informal governmental review, and there was a broad range of stakeholders on the board of directors, including users and scientists. It was also multi-scale, from local to global. But there were relatively few governments involved, which was its biggest weakness, and it has taken a number of years to catch on. It is, however, beginning to have an impact. The UK government, for instance, has started to put together a policy arguing that the country should take an ecosystem approach both in the management of natural ecosystems and with regard to the implications of infrastructure such as roads. Its main weakness is that it was non-governmental.

Our latest major assessment is the International Assessment of Agricultural Science and Technology for Development. This was intergovernmental but with a multi-stakeholder bureau. The bureau was made up of 60 people, 30 governments, 30 members of civil society, six from the private sector, six NGOs, six producer groups, four consumer groups, and eight international organizations dealing with agriculture. It was sponsored by seven international agencies (World Bank, Food and Agriculture Organization, United Nations Environment Programme, United Nations Educational, Scientific and Cultural Organization, United Nations Development Programme, World Health Organization and Global Environment Facility) and had reasonably significant amounts of money from governments and a little from the private sector. It underwent three expert and government reviews. The plenary approved the scope as well as the summaries for decision makers and the synthesis report. It was multi-thematic, multi-temporal and multi-scale, including a global and five sub-global assessments.

Did it work? It was an incredible social experiment, with a bureau that effectively went all the way from the private sector through to the NGOs and covered some contentious issues – transgenics and trade, for example. These are far more contentious than anything we had touched upon in the IPCC or Millennium Ecosystem Assessments. There were people in the room that would not usually even begin to talk to each other: Pesticide Action Network, Greenpeace, Monsanto... So it was an incredible experience and I shall detail some of the results later on.

Assessment governance structures

So what are the pros and cons of different governance structures? The pro for the non-governmental one is that it is typically driven by scientists, but this carries the downside of little buy-in by the other stakeholders. The Global Biodiversity Assessment is a perfect example of that. The Millennium

Ecosystem Assessment made greater effort to involve all users, but it still lacked true government buy-in. The intergovernmental approach, such as the IPCC, gets good buy-in from governments – even though some still walk away, as the United States did from this one – but can have a more limited impact with other stakeholders. The hybrid – the agricultural assessment – has everybody on board but is a real challenge given the range of views. Nonetheless I would always argue for the hybrid. The transaction costs are huge but at least it brings everybody to the table, even if they then walk away: the private sector turned its back on the agricultural assessment three months before its finish because we were not saying very positive things about pesticides or transgenics.

In the last two years there have been seven major international assessments: the *Millennium Ecosystem Assessment*; the *2006 Scientific Assessment of Ozone Depletion*; the Consultative Group on International Agricultural Research (CGIAR) *Comprehensive Assessment of Water Management*; the *IPCC Fourth Assessment Report*, the fourth *Global Environment Outlook*; the *Assessment of Agricultural Science and Technology*; and the upcoming Organisation for Economic Co-operation and Development's *Environmental Outlook 2008*.

In the next six months some 40 people will be coming together to do a synthesis of all these global assessments. I think they are basically saying the same thing, and that what is now needed is to focus on policy implications that cut across all the different conventions and international organizations. So our synthesis is to spend only five or 10 pages on the scientific interlinkages, and 20 to 30 on the policy implications, what types of policies will have positive synergies across the various issues, and where there are significant trade-offs.

Assessment findings

Of course the most successful assessments are driven by scientific research, and an assessment is only as good as the knowledge base in the literature. Assessments do not try to add new knowledge. Rather they synthesize existing knowledge.

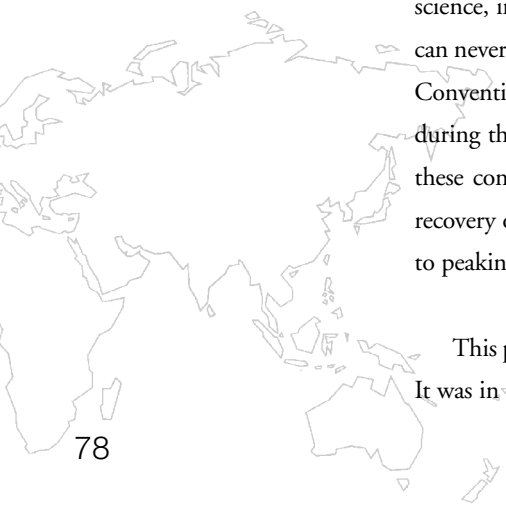
Stratospheric ozone

In the 1970s we had a theory that chlorine and bromine destroyed stratospheric ozone, but there were no observations to prove it, let alone link cause and effect. We effectively began to do ozone assessments in

1981, but it was a few years before data on the Antarctic ozone hole, gathered at the Halley Bay research station by Joe Farman and the British Antarctic Survey, revealed the extent of the problem. In 1987 we got the Montreal Protocol, which put a freeze on the growth trend of the long-lived CFCs (11, 12, 113, 114 and 115) and imposed a 50 per cent cut on the industrialized countries but no obligations on developing countries. Our 1989 assessment explained how human activities – putting chlorine and bromine in the stratosphere – were destroying stratospheric ozone, leading to the London Amendments (1990) for the gradual phase-out of CFCs. Then we realized that we could actually see downward seasonal ozone trends. The mistake we had been making was to take all the ground-based observational data from the Dobson stations and look for an annual global average, so we had failed to notice that ozone thinning was a function of latitude and season – exactly what the theory said it should be. An assessment of these findings quickly led to the Copenhagen Amendment (1992) for faster phase-out. We then actually started to see increases in ultraviolet radiation at ground level, findings that came out in our 1994 assessment, and led to the Vienna Adjustment which put caps on other ozone-depleting substances. We also at that time started to see that ozone losses are as significant in the Arctic as in the Antarctic. By the time of our 1998 assessment, we were able to report a detectable reduction of ozone-depleting chemicals in the lower atmosphere. This one led to the Beijing Amendment, with new controls and trade limits. By 2002 we were able to assess the time period involved in ozone recovery.

This was fundamentally excellent research brought together in a series of international assessments, each one leading to new regulations, such that all long-lived CFCs and bromofluorocarbons have been banned, as have most short-lived compounds. There can be a superb linkage between good academic science, international assessment, international agreement and effective policy for change. Obviously we can never be absolutely sure what would have been the effect of stratospheric chlorine without the Vienna Convention, the Montreal Protocol and its amendments, but it would have been going off the scale during the next couple of decades. Each amendment has done a little more to bring down the levels of these compounds in the atmosphere, and the most recent – the Beijing Amendment – aims for total recovery of the ozone layer. All the ozone-destroying compounds have either peaked or are close enough to peaking for the ozone layer largely to have recovered in around 50 years time.

This process raises an interesting question about how much evidence you need before you take action. It was in 1974 that Sherwood Rowland and Mario Molina postulated that chlorine and bromine would



destroy stratospheric ozone. It took 10 years to get a convention and two more to get a protocol, with effective amendments following on. But with long-lived substances like these halocarbons, it meant that enough chlorine and bromine had built up in the stratosphere for it to take decades to return to normal, even after a 100 per cent ban on emissions. So in one way the ozone story is a phenomenal success story. In other ways you could argue that we waited too long.

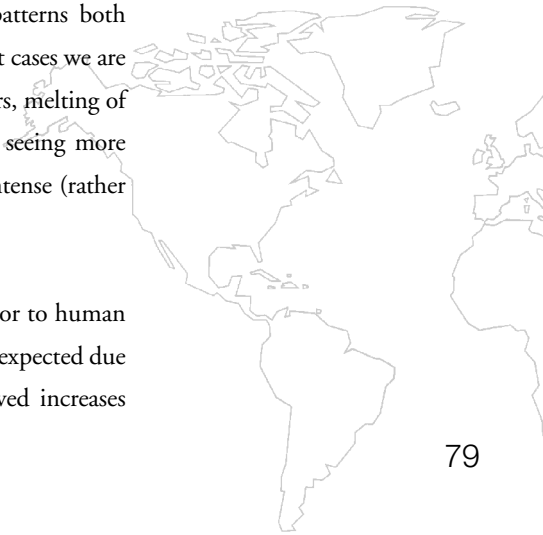
Climate change and ecosystems

Climate change and ecosystem degradation are highly integrated issues. They are environmental and developmental issues of course: both undermine environmental sustainability, poverty alleviation and the livelihoods of the poor. They cause significant problems for human health and threaten security at the personal, national and regional level. Climate change and ecosystem degradation put further stress on a highly stressed world. We have recently seen how fragile even a country which is relatively stable, such as Kenya, can be. Ecosystem degradation and climate change can push a country or a region that is on the borders of conflict into conflict. These are issues of both inter- and intra-generational equity. Developing countries and the poor are the most vulnerable, but with both climate change and ecosystem degradation it is largely the actions of the industrialized world that have caused the problem, and clearly the actions of today will affect future generations.

Climate change

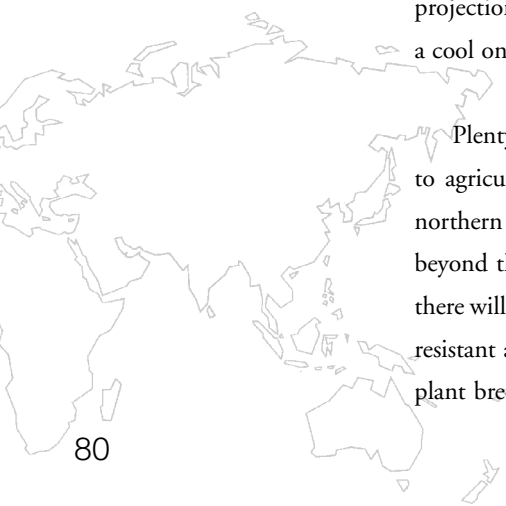
We know that climate change is happening and there is absolutely no doubt that it is due to human activity. Atmospheric carbon dioxide has increased by 30 to 35 per cent. We are already seeing warmer temperatures and future warming is inevitable. We are seeing changing precipitation patterns both spacially and temporally. Some areas are becoming wetter; some are becoming drier. In most cases we are seeing more heavy precipitation. We are seeing higher sea levels, retreating mountain glaciers, melting of the Greenland ice cap, and reduced Arctic sea ice in both extent and thickness. We are seeing more frequent extreme weather events (heat waves, floods, droughts), and we are seeing more intense (rather than more frequent) cyclonic events such as the hurricanes in the Atlantic.

The big debate has surrounded whether these changes are due to natural phenomena or to human activity. When we plot observed temperatures against simulations of what might have been expected due to natural phenomena such as solar radiation and volcanic activity, we find that observed increases



simply don't fit the simulations – whether as a global mean, over land or over sea, and over each of the continents. When, however, we simulate the changes you might expect with the added influence of anthropogenic greenhouse gases, the simulation matches observed temperature change. It was this type of information that led the IPCC in its *Fourth Assessment Report* to say with more than 90 per cent certainty that most of the observed temperature change in the last 50 years has been due to human activity: an increase in greenhouse gases largely resulting from combustion practices and deforestation. The crucial issue is what will happen in the future. Relative to 1990, one predicts a rise of anything from a low of 1.1°C to a high of 6.4°C, with land areas warming more than the oceans, and high latitudes warming more than the tropics. So to what degree should one adopt a precautionary approach with this type of information?

We project future changes based on plausible assumptions of demographic, economic, technological, socio-political, and indeed behavioural change. Probabilistic scenarios are not easy to do but, given a range of scenarios, it is reasonable to take the average as a best estimate. On that basis, what we expect doesn't look good – it would suggest something like a 3°C change over the next 100 years. We all know that the summer of 2003 was hot, with some 20,000 to 30,000 people in Europe dying in the heat wave – typically old people who could not get out of the high temperatures at night (it was a night-time phenomenon). There was a similar experience in the United States more than a decade ago when 600 people died. This was a socio-economic issue, particularly affecting poor people and the elderly who did not have air conditioning. As with Hurricane Katrina in New Orleans, it is always the poor and disadvantaged that suffer most from these types of events. But based on the projections, the summer temperatures of 2003 will seem like a very average summer in the 2040s and a cool one by the 2060s.



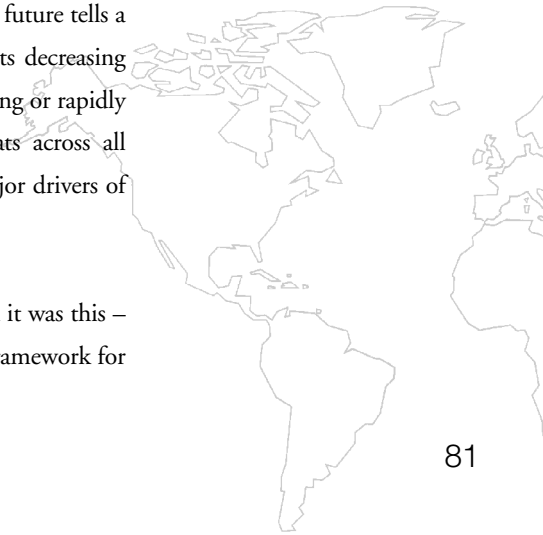
Plenty of people living in the United Kingdom might welcome warmer temperatures. With respect to agriculture, there might be opportunities for an extended growing season. High latitudes in the northern hemisphere are likely to experience increased productivity, at least with a rise of 2 or 3°C. But beyond that, we would project falls in yields in many developed regions. Of course this assumes that there will be no significant breakthrough in developing drought-resistant, temperature-tolerant, salinity-resistant and pest-resistant plants – all of which might be feasible, but can we do it with conventional plant breeding or will we need transgenics? Will transgenics live up to their promise? Even if they do

make the breakthrough, will the public accept them in light of environmental and human health considerations? These are real issues, so our projections make no assumptions about developing crops to be more climate resilient.

A moderate rise in temperatures may have some advantages for the developed world, but in many developing countries temperatures are already beyond what is required for maximum yield for most cereals, so even a slight warming will result in decreased productivity. With regard to water, we are already seeing glaciers melting all over the world – a serious environmental issue but an equally serious developmental one, as hundreds of millions of people depend on run-off from glaciers. We will see significant decreases in water in the southern Mediterranean, the northern and southern parts of Africa and in many parts of Asia. Sea-level rise will have adverse effects in low-lying delta areas, and obviously in the small island states.

Ecosystems

The five major threats to biological diversity and ecosystem function are climate change, habitat change, invasive species, overexploitation and pollution, especially by nitrogen and phosphorus. The Millennium Ecosystem Assessment looked at a number of ecological systems including forestry, drylands and the marine environment, and assessed to what extent the five main threat factors have been drivers of biodiversity loss over the last 100 years. The results were varied. Boreal forest diversity, for example, has suffered little from habitat alteration, whereas this has been a major driver of loss in tropical forests and temperate grasslands. Climate change, as you might expect, has not been a significant threat in the last hundred years to most ecological systems (with the exception of the polar regions). But the future tells a very different story. In only one ecosystem type (temperate forests) is one of these threats decreasing (habitat alteration). In all other ecosystems, the five major threats have an ongoing, increasing or rapidly increasing impact, with climate change and pollution the most rapidly growing threats across all ecosystems. If we don't get to grips with climate change or pollution, these will be the major drivers of change over the next century.



Why do we care? Ecosystem health has major consequences for human well-being, and it was this – the link between ecosystem health and human well-being – that provided the conceptual framework for the Millennium Ecosystem Assessment. We separated ecosystem services into four blocks:

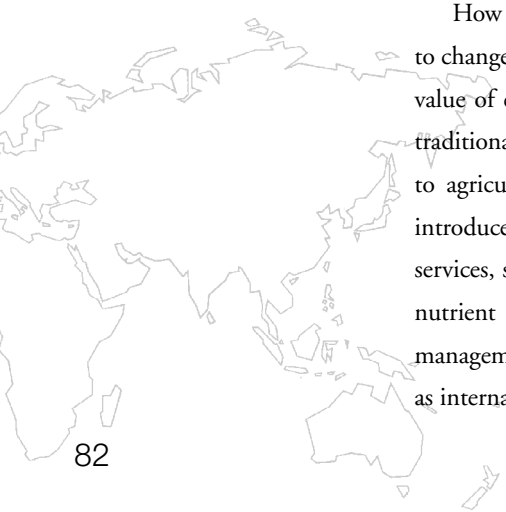
- Provisioning: food, fresh water, wood and fibre, fuel etc.
- Regulating: of climate, flood, disease and water purification.
- Cultural: aesthetic, spiritual, educational and recreational.
- And supporting the above: nutrient cycling, soil formation, primary production etc.

And we looked at the five major constituents of human well-being, as follows:

- Security: personal safety, access to resources, security from disasters.
- Basic material requirements: adequate livelihoods, sufficient nutritious food, shelter, access to goods.
- Health: strength, feeling well, access to clean air and water.
- Good social relations: social cohesion, mutual respect, ability to help others.
- And relevant to all of the above: freedom of choice and action.

Of course we have insufficient knowledge to measure these links in a strictly quantitative sense, but the framework enabled us to see where certain ecosystem services have been maximized at the expense of others. We realized, for example, that human development has mainly focused on maximizing the provisioning services – food, water and fuel – and that this has been undermining the regulating, cultural and supporting services, which in turn has undermined many of the constituents of human well-being. It is this type of analysis that – even without strict quantification – is slowly but surely influencing policy formulation in some countries.

How do we move to sustainable ecosystems? We have to put a value on them, and therefore we need to change the economic background to decision making. We need to make sure that we understand the value of ecosystem services that sell in the market place – the provisioning services – and those that traditionally have no market value – the regulating and cultural services. We need to remove subsidies to agriculture, fisheries and energy that cause harm to people and the environment. We need to introduce payments to landowners in return for managing their lands in ways that protect ecosystem services, such as water quality and carbon storage. We need to establish market mechanisms to reduce nutrient releases and carbon emissions in the most cost-effective way. We need to improve policy management, and we need to integrate decision making across different departments and sectors, as well as international institutions. We must include sound management of ecosystem services in all planning



decisions. Whether building a road, or planning an agricultural project or a water scheme, we need to make absolutely sure that we understand those ecosystem services when we make planning decisions. And we need to bring stakeholders – particularly marginalized groups – into the planning and implementation of projects. Of course we need additional protected areas, but first we must turn most of the existing 'paper parks' into real protected areas. We need to exchange knowledge, including that of local and indigenous groups. We need much more environmentally friendly technology, and obviously we need to move to a low-carbon economy. We need to influence behaviour through public education on why and how to reduce the exploitation of threatened ecosystem services, through establishing reliable certification systems to give people the choice to buy sustainably harvested products, and by giving all stakeholders access to information about ecosystems and decisions affecting their services.

Mitigating climate change

If we want to limit climate change to a 2°C temperature rise, then staying below atmospheric carbon concentrations of 400 parts per million (ppm) will give us a 50/50 chance. If we let concentrations rise to 550ppm then we have a 50/50 chance of limiting change to a 3°C temperature rise. The European and UK position is to try to stick at 2°C – a great aspirational goal and I strongly applaud it. However, the chances of stabilizing at 400 or even 450ppm CO_2 equivalent are very remote. So while our policy should be to aim at stabilizing at 2°C, we should be ready to adapt to a rise of at least 4°C, and we should put the planning in place now.

Stern concluded in his report that if we did nothing to reduce emissions, there would be a 50 per cent probability of exceeding a 5°C rise, and I fully agree with him. For Europe, this would probably mean summer temperatures of 8-10°C higher than normal, and for northern Canada it would probably mean summer temperatures of 10-15°C higher than normal, so really very significant warming. Stern estimated that this would be at an annual cost of anything from 5 to 20 per cent of GDP. If we were to achieve the 550ppm trajectory, with a 50 per cent chance of exceeding a 3°C rise in temperature, the cost would be around 1 per cent of GDP annually. Looking at the 450ppm trajectory, mitigation costs would be at about 3 per cent of GDP. But even then, we would only have a 50 per cent chance of keeping the temperature increase at 2°C, so we need to think about adapting to something higher.

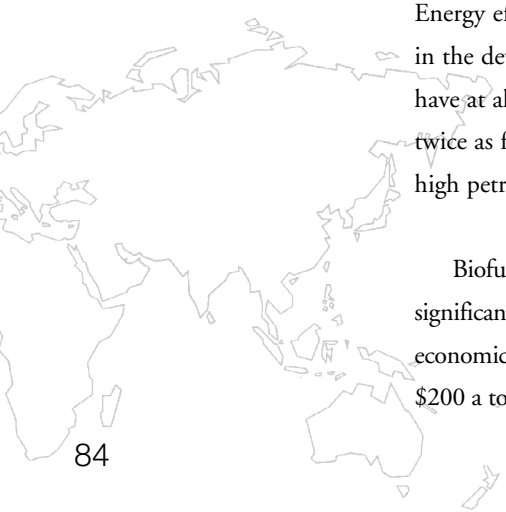
There is no such thing as business as usual, but if we project what could happen in the future without taking time or change into consideration, we can expect something like a 60 per cent increase in greenhouse gas emissions over the next 50 years. So in order to get onto a pathway for stabilization at 500 to 550ppm, we would need a 60 per cent decrease in emissions by developed countries (relative to 2002 emissions levels) and an increase of only 60 per cent by developing countries instead of the predicted 140 per cent increase under a 'do nothing' scenario.

Have we got the technological options to achieve this? Absolutely: more efficient energy production and use, fuel switching, renewable energy, carbon capture and storage, nuclear fission, improved management of our forests and agricultural soils. We already have a huge amount of technological capability to start to move onto the 500 to 550ppm pathway, but there are also certain pre-commercial activities, like carbon capture and storage, integrated gasification combined cycle, and second and third generation biofuels, that require investment and research to bring them to market as soon as possible.

It is absolutely crucial that we get a price on carbon, whether it is $20 a tonne, $50 a tonne or $100 a tonne. We need to work across all sectors, and even the modest carbon price of $20 a tonne can start to stimulate reductions right across these sectors. By the time you get to $100 a tonne, you can get very significant reductions.

There are many combinations of technologies that could get us onto the 550ppm trajectory, and it will vary regionally, but the one thing that is critical across the board is carbon capture and storage. Energy efficiency is a major driver, though there is likely to be a rebound effect. If you give someone in the developing world a gadget that is twice as efficient as the one they've got (or indeed might not have at all) they will probably use it twice as much. In fact if you gave the average person a car that is twice as fuel efficient as their current one, they probably wouldn't use it twice as much but, given the high petrol prices, they would certainly use it more.

Biofuels (bioethanol from sugar and maize, or biodiesel from palm oil, soy or rape seed) usually play a significant role in mitigation scenarios. But they are rarely economic. The only place that has made it really economic was Brazil when oil prices went above $50 a barrel and they could produce sugar for less than $200 a tonne. But in most other places, especially Europe and North America, biofuels have been heavily



subsidized. And of course there are some really serious questions regarding the environment. Do biofuels really reduce greenhouse gas emissions? As a fuel, bioethanol from sugar cane clearly does, but if its cultivation leads to tropical deforestation it actually causes an increase in emissions. Is there a loss in biodiversity? Every time you expand into a pristine area you lose biodiversity and risk soil and water degradation. There are also serious questions about social sustainability: the use of maize for biofuels has clearly contributed to food price increases, and there has been involuntary displacement of small farmers by large-scale plantations in certain parts of the world. Here in the United Kingdom, I think we have to ask ourselves whether we can truly source biofuels at the level we need under the Renewable Transport Fuel Obligation (RTFO) and the European Directive that are environmentally and socially sustainable.

Summary of the major mitigation challenges

We need a global regulatory framework involving all major emitters including the United States, China and India. It must be equitable: in other words China and India should not be under the same obligations as the United States. It must be long term: if we only have an agreement for five years after Kyoto it will send the wrong signal to the private sector, which needs to know that there will be a long-term market for low-carbon technology. If we keep the clean development mechanism that we have under the Kyoto Protocol, we need to expand the range of eligible activities, including avoided deforestation, green investment schemes, energy efficiency standards, and exploring a sectoral and programmatic approach.

A key priority will be to quantify impacts and assess costs and benefits. We have to realize that on average there are more costs than benefits, but we should exploit the benefits and minimize the costs. Investment in adaptation to reduce the negative impacts of climate change will help here, but we have to accept that whatever we do there will be some residual damage. And we have to accept that the cost of both adaptation and residual damage will be lower than the cost of inaction. Mitigation costs will vary depending on whether we are looking at an agricultural system, a water system or coastal zoning infrastructure, and we need to do a great deal of work to understand the impact sector by sector and region by region.

On the same basis, we need to establish the physical, behavioural and technological limits to adaptation – a long-term framework within a long-term goal. These would include, for example, the physical limits to adaptation on small low-lying islands, the behavioural constraints that influence

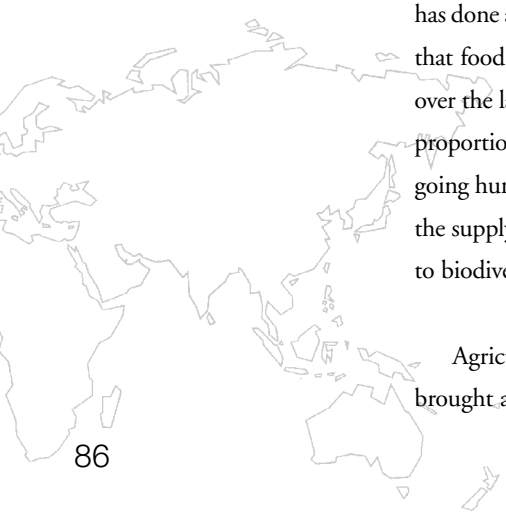
where we live and why, e.g. New Orleans, and the technological limits to the flood defences that can be constructed, e.g. the Thames Barrier in London.

We need very strict targets for developed countries in order to stimulate the low-carbon economy, and we need to bring developing countries in gradually. We need robust carbon markets that view carbon as a commodity just like rice and wheat. We need to further develop technology. We need to adapt. We need to bring deforestation in. It is not an energy issue alone. We also need to think about how to bring aviation and shipping – currently not part of the equation – into the system.

Food security

We currently have a major issue with rising food prices: rice has almost doubled in price in the last two years and maize prices have also gone up significantly. Rapid increase in demand in developing countries, especially China, has a lot to do with it, but it is not the amount of food that counts, it is the type of food. A growing demand for meat is putting pressure on grains as livestock feed. We have had some poor harvests in Australia, Europe and North America, so have less stock than normal. The increased use of biofuels – especially maize in the United States – is taking up land that was originally being used for food crops. High energy prices are pushing up agricultural input costs, and some large exporting countries have become very myopic in the use of export bans. Speculation on the commodity market has also played its part.

But is this temporary, or are we going to see more of it in the future? Overall, the agricultural sector has done a superb job. Total food production has exceeded the global rate of demographic change, meaning that food production per capita has increased. Food prices are at an all-time low despite having doubled over the last year, which has effectively brought them back to where they were in the mid-1980s. And the proportion of the world's population that is undernourished has fallen. Yet we still have 850 million people going hungry every day. Uneven distribution is the main problem: there is plenty of food in the world but the supply system isn't working. In addition, however, increased productivity has done significant damage to biodiversity, soils and water, and we now have the major contributing factor of climate change.



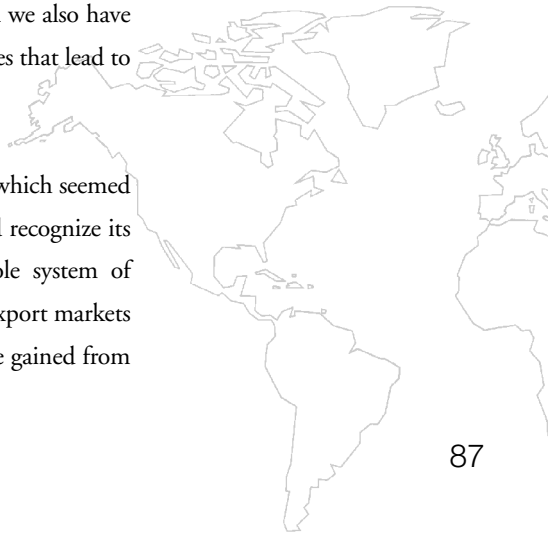
Agricultural productivity has almost doubled in parts of Asia and the Pacific, and this is what has brought a lot of people out of poverty and hunger in China. But in sub-Saharan Africa, production has

actually gone down over the last 20 years, bringing increased hunger and poverty. Even in India, where the Green Revolution was considered a major success, we still have 50 per cent of children under five suffering from malnutrition. So while the Green Revolution had significant successes at one level, we certainly have not solved the problem.

So what are the challenges?

We need to double our production in the next 25 to 50 years. We need to make food more nutritious and we need to make it more affordable. We need the agricultural sector to feed the world, to enhance rural livelihoods in developing countries and to stimulate economic growth, but it must not be done with an exclusively production-oriented focus. It must recognize food safety standards and be both environmentally and socially sustainable. There are plenty of problems: there is less labour available due to HIV/AIDS; there are endemic disease problems in Africa (malaria, cholera); rural-to-urban migration is taking people off the land; there is less water available for irrigation as demand from other sectors grows; climate change is making the arid and semi-arid areas yet drier; and there is competition for land from biofuels, roads and expanding cities. This results in major land policy conflicts in many parts of the world where there are neither individual nor community property rights. We have lost biodiversity due to mono-cropping, which undermines the genetic base for much of agriculture. There are increasing levels of acid deposition in many developing countries that have not yet got the industrial standards of Europe or North America. It is of course self-evident that agriculture has an impact on climate change and climate change an impact on agriculture. The extensification of agricultural systems leads to unsustainable forestries which leads to biodiversity loss which also leads to a loss of the genetic base, and we also have significant loss of fertility, bad irrigation systems, and other poor land-management practices that lead to the loss of organic matter in the soils, in turn leading to salinization and erosion.

After the Second World War, the only thing that mattered in Europe was production, which seemed fine at the time. But we now have to look at agriculture as a multi-functional activity, and recognize its economic, social and environmental dimensions. We have to think through the whole system of marketing and trade, which is currently neither environmentally nor socially sustainable. Export markets have created environmental problems, and while many people – including the poor – have gained from the trade system, the poorest of the poor have not.



Environment on the Edge

The academic community has helped produce some outstanding knowledge. Scientific assessments have been the corner stones of work at the national and international level to bring about policy changes regarding ozone and climate, and they are starting to get people to rethink biodiversity at a local and national level. International assessments such as the agricultural assessment are starting to turn people's minds towards what sort of revolution we need in the agricultural sector to move away from a production focus to what I would call a sustainability focus. We still have fragmented policies around the world, but slowly and surely, led by the academic community, policy is beginning to recognize the interconnectivity of all these issues.

We are moving in the right direction. But we have a long way to go: business as usual – whether it is in climate change or biodiversity or agriculture – will not work. We need a paradigm shift in all of them.

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