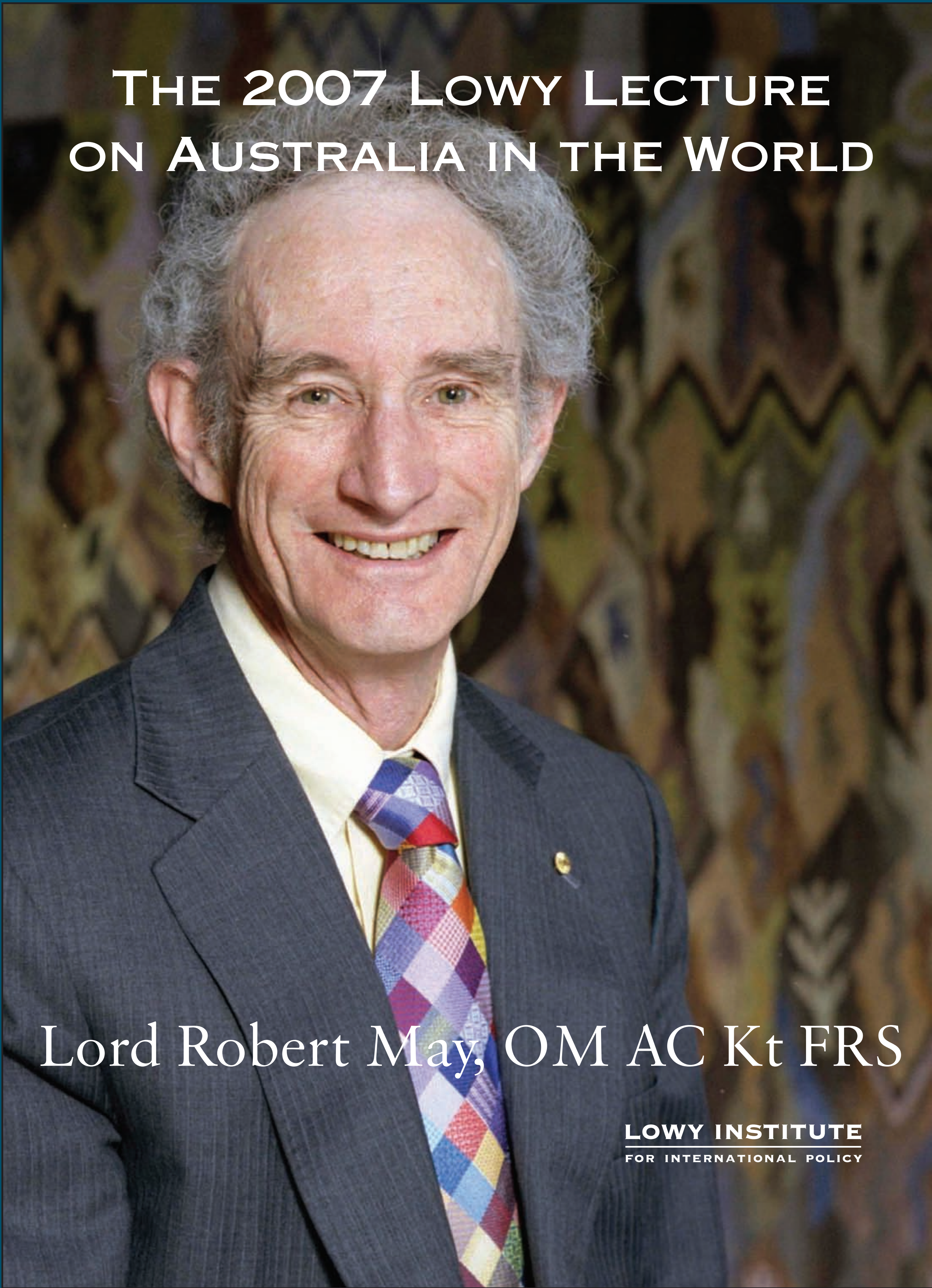
The 2007 Lowy Lecture on Australia in the World



Lord Robert May, OM AC Kt FRS

LOWY INSTITUTE
FOR INTERNATIONAL POLICY

THE THIRD LOWY LECTURE

on Australia in the World – *Relations Among Nations on a Finite Planet* – was given in Sydney on 19 November by Lord May of Oxford. It deals with one of the most urgent problems we face – the consequences for the international system of the range of environmental challenges facing the planet. I cannot think of an issue in my lifetime which has imposed itself on the international agenda with such force or which has been driven so hard, not by political leaders but, first, by scientists, then public opinion. In our 2007 Lowy Institute survey, Australians rated climate change top of the list of potential threats to this country from the outside world.

We could not have asked for a more informed or persuasive lecturer on this subject than Lord May. One of the most distinguished scientists Australia has produced, Robert May holds a BSc and PhD in theoretical physics from Sydney University. He has held chairs of physics at Sydney University, of biology at Princeton University, and of zoology, jointly at Oxford and at Imperial College, London. From 1995 to 2000 he was Chief Scientific Advisor to the British Government and, from 2000 to 2005, President of the Royal Society. His awards include the Crafoord Prize, the Balzan Prize and the Blue Planet Prize.

Among the many honours recognising his accomplishments have been a knighthood in 1996, appointment as a Companion in the Order of Australia in 1998, a Life Peerage in 2001, and membership of the Order of Merit in 2002. He is also, I am proud to say, a member of the Lowy Institute's International Advisory Council.

The Lowy Institute has had a continuing interest in the environment. Our recent work has included papers on the link between security and climate change, the collapse of the region's fisheries stocks and the crisis facing the river systems of Southeast Asia.

But Lord May's lecture takes an even broader view. Informed by his deep scientific and public policy experience, he warns us of the changes that are needed in the way world politics operate as we enter this "post-Metternich age". This is a major contribution to the Lowy Institute's mission of informing and deepening the global debate about international policy.

Allan Gyngell
Executive Director

RELATIONS AMONG NATIONS ON A FINITE PLANET

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ABSTRACT

Much of past human history can be written without too much reference to the effects of the physical environment, much less the results of our own impacts on it. But human numbers combined with their increasing per capita impacts have now grown to the point where their scale rivals the planet's natural biogeochemical processes which created the biosphere and which struggle to maintain it. This essay documents this statement, and suggests some implications for, as it were, the post-Metternich age of relations among nations.

INTRODUCTION

Regis DeBray's *Revolution in the Revolution* has a memorable opening paragraph[1]:

> "We are never completely contemporaneous with our present. History advances in disguise; it appears on stage wearing the mask of the preceding scene, and we tend to lose the meaning of the play… The blame, of course, is not history's, but lies in our vision, encumbered with memory and images learned in the past. We see the past superimposed on the present, even when the present is a revolution."

The "revolution" I have in mind is not DeBray's romanticised struggle at the barricades, but rather the fact that the scale and scope of human activities are now of such magnitude as to rival the natural processes which built the biosphere on our finite planet.

Of course humans have, from their beginnings, had impacts on their environment which changed it – prompting reactions to that change.

These are the terms in which the biological and cultural evolution of *Homo sapiens* is written, no less than for any other organism. Thus our hunter-gatherer ancestors were almost certainly responsible for the extinction of the Pleistocene megafauna, more completely after their relatively abrupt arrival in the New World than in the Old World where we originated. Indeed entire histories of our species can be written in terms of human-induced environmental change and our reactions to that change: McNeil's[2] *Plagues and Peoples*, Diamond's[3] *Guns, Germs and Steel.*

Humanity's global impact today is, however, on a scale which no other single species has ever reached. In what follows, I will first document this claim. I will then outline implications for actions we need to be taking, emphasising that the situation is serious but not hopeless. Finally, I will indicate some of the problems, and indeed paradoxes, that such need for cooperative activity among nation states must confront.

THE GLOBAL SCALE OF HUMANITY'S IMPACTS

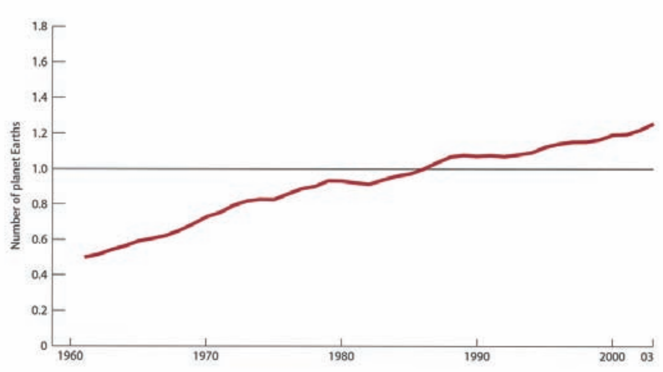
Overview

In 1986, a group at Stanford University[4] estimated that humans now take to their own use, directly or indirectly, between 25 % and 50 % of all green stuff that grows on land each year ("net terrestrial primary productivity"). This estimate is necessarily imprecise, but it accords with a very recent study, using satellite imagery, which finds 40 % of the Earth's land surface – from poles to equator – being modified by human use, mainly for agriculture.

All living things are, to a good approximation, made up of atoms of hydrogen, carbon and oxygen in the proportions 2:1:1. To a second approximation, for every 1,000 carbon atoms there are roughly 10 of nitrogen and one of phosphorus. And half the elements in the Periodic Table are also important, albeit in much smaller quantities. Given these fundamental proportions, I find it astonishing that more than half the atoms of nitrogen, and also of phosphorus, incorporated into green plants today come from artificial fertilisers (produced with a fossil-fuel energy subsidies) rather than the natural biogeochemical cycles which constructed, and which struggle to maintain, the biosphere.

The Worldwide Fund for Nature, WWF, has presented estimates,[5] country by country, of humanity's "ecological footprint" (EF) at current levels of consumption. The EF for a given country is defined as the biologically productive area required to produce the food and wood people consume, to give room for infrastructure, and to absorb the carbon dioxide emitted from burning fossil fuels. Thus estimated, the EF is expressed in "area units". Any such estimate is necessarily imprecise (the carbon dioxide factor arguably more so than other components), but on the other hand it is conservative in that other factors, such as requirements for natural ecosystem services to handle pollutants, are excluded. Having estimated individual countries' EF, the WWF adds them up to get the overall global EF, as shown in Figure 1. The observed increase over time derives partly from population growth, and partly from increases in the average footprint per person.

Fig. 1: HUMANITY'S ECOLGICAL FOOTPRINT, 1961-2003



The WWF also estimates the total EF that individual countries, and thence the planet, could maintain sustainably (the "biological capacity", BC). Here the figures depend, to a degree, on assumptions about the footprints of future crops and energy sources. Figure 1 suggests we passed the point where humanity's actual EF exceeds the sustainable level – a milestone of milestones – around two decades ago. I again emphasise the ineluctable uncertainties in any such estimates of footprints. Even so, I believe Figure 1 is indicative.

The planet's biological capacity, BC, ultimately depends on the number of people multiplied by the average per capita footprint. It could thus correspond to more people each casting a smaller footprint, or alternatively to fewer people with larger footprints.

Population Growth

The past 70 years have seen an astonishing and unprecedented tripling of the human population, to around 6.5 billion today.[6] To put this in perspective, the total number of humans ever to have lived is estimated at less than 100 billion. For most of our few hundred thousand year history, we were hunter-gatherers, with the global population probably between 5 and 20 million. The first big change began around 10,000 years ago, with the beginning of settled agriculture, followed by the first cities and recorded history. The subsequent rapid growth in human numbers slowed somewhat as infectious diseases which could not be maintained at low population densities now became established, acquired from domestic or other animals (some 300 such infections, including smallpox, measles and others, can be recognised; endemic measles, for example, requires population aggregations of 300,000 or more).[7] The Scientific-Industrial Revolution in the West, beginning in the seventeenth century, saw another marked surge. Even so, mortality rates in industrial cities such as Liverpool in the mid-1800's were not much better than for hunter-gatherers, with roughly one of two dying before the age of 5.

The last 70 years have been really different, as basic scientific understanding of the transmission and treatment of infectious disease has been achieved and applied in simple measures of primary health care. Put briefly, global average live expectancy at birth 50 years ago was 46 years; today it is 64.[8] The main factor in this change is that the difference in life expectancy between developed and developing countries 50 years ago was 26 years; today it is 12 years. This is still a disappointing difference. Even so, as a result of enlightenment science, a child born in a poor country today is – at least in terms of life expectancy – better off than one born 150 years ago in the industrialising centres of the Western world.[9]

Birth rates are now slowing, but the "momentum of population growth" – the fact that in most developing countries there are currently a lot more young people than older ones – means that we will see population increase by half as much again, to around 9 billion, by 2050.

Average Ecological Footprint

How about trends in the average person's patterns of consumption, and consequent impacts on the environment?

(i) Energy Consumption. The energy requirements of our hunter-gatherer ancestors were minimal – essentially those needed to maintain basic metabolic processes (BMP). By contrast, the average inhabitant of the globe today uses energy subsidies amounting to around14 times what would be required simply to maintain BMP. There are, of course, big differences among countries, with some more than three times this average amount, but essentially no-one is living the life of a hunter-gatherer. Of all these energy subsidies (in 2001) 80 % ultimately came from burning fossil fuels (gas, oil, coal), 10 % from biomass, 7 % nuclear fusion, and 3 % renewables (hydro, geothermal, solar, etc.).[10]

Such energy subsidies have helped wash away hierarchies of servitude, as helpful devices substitute for human labour at home, work, and marketplace. But we now realise the inputs of the gas carbon dioxide,

CO_2, into the atmosphere, resulting from burning fossil fuels, are causing serious climate change.

The climate on our planet, over its billions of years of existence, has varied a lot – from times when the entire planet may have been enveloped by snow and ice ("snowball Earth"), to times when tropical animals inhabited the polar regions. Even over the hundred-thousand years or so of *Homo sapiens'* tenancy, ice ages have come and gone. The most recent 8,000 years or so, since the beginnings of agriculture and the first cities, however, have been unusually steady. Over this time, ice-core records show clearly that levels of CO_2 in the atmosphere have been around 280 parts per million (ppm), give or take 10 ppm. CO_2 is, of course, the principal "greenhouse gas" in the atmosphere, and the density of this "blanket" plays a crucial, if complex, role in determining Earth's climate. Some have indeed argued that the beginnings of agriculture, and the subsequent development of cities and civilisations, is not a coincidence, but is a consequence of this unusual steadiness over many millennia.

Be this is it may, things began to change with the advent of the Industrial Revolution, which may be said to have begun with James Watts' development of the steam engine around 1780. As industrialisation began to drive up the burning of fossil fuels in the developed world, CO_2 levels rose. At first the rise was slow. It took about a century and a half to reach 315 ppm, moving outside the multi-millennial envelope. Accelerating during the twentieth century, levels reached 330 ppm by the mid-1970s, 360 ppm by the 1990s, 380 ppm today. This change of magnitude by 20 ppm over only a decade has not been seen since the most recent ice age ended, ushering in the Holocene epoch, around 10,000 years ago. And if current trends continue, by about 2050 atmospheric CO_2 levels will have reached at least 500ppm, roughly double pre-industrial levels.[11]

There are long time lags involved here, which are not easily appreciated by those unfamiliar with physical systems. Once in the atmosphere, the characteristic "residence" time of a CO_2 molecule is a century. And the time taken for the oceans' expansion to come to equilibrium with a given level of greenhouse warming is several centuries; it takes a very long time for water-expanding heat to reach abyssal depths. It is worth noting that the last time our planet settled to greenhouse gas levels as high as 500 ppm was some 20-40 million years ago, when sea-levels were around 300 feet higher than today. The Dutch Nobelist, Paul Crutzen, has suggested that we should recognise that we are now entering a new geological epoch, the Anthropocene, which began around 1780, when industrialisation began to change the geochemical history of our planet.

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Such increases in the concentrations of the greenhouse gases which blanket our planet will cause global warming, albeit with the time lags just noted. In their most recent report[11] in February 2007, the Intergovernmental Panel on Climate Change (IPCC), which brings together the world's top climate scientists from 169 countries, estimates that this warming will be in the range of 1.1 to 6.4^{0}C by 2100, with the likelihood of settling at 2.0 to 2.8^{0}C. This assumes that we will manage to stabilise greenhouse gas concentrations at around 450-550 ppm by that date, which could be optimistic. Things get much worse at higher concentrations. This would be the warmest period on earth for at least the last 100,000 years. Many people find it hard to grasp the significance of such a seemingly small change, given that temperatures can differ from one day to the next by 10^0C. But there is a huge difference between daily fluctuations, and global averages sustained year on year. The difference in average global temperature between today and the depths of the last ice age is only around 5^0C.

There do remain significant uncertainties about the timescales and magnitudes of some important and nonlinear processes associated with climate change (nonlinear means, roughly, doubling the cause does not simply double the effect; huge, and often irreversible, "tipping points" can occur, and occur abruptly). For instance, as the polar ice-caps melt, surface reflectivity is altered – dazzling white ice or snow giving way to dark oceans – causing more warming and fast melting; the timescale for the ice-cap to disappear entirely (a few decades? a century? longer?) is unclear. Such melting or collapse of ice sheets would eventually threaten land which today is home to 1 in every 20 people. As northern permafrost thaws, large amounts of methane gas are released, further increasing global warming; methane is a more efficient greenhouse gas than CO_2. Unfortunately, essentially all these uncertainties go in the direction of making things worse. It is worth noting that the IPCC's predictions, under sensible pressures for conservatism, have consistently underestimated the rate of climate change.

Seeking to emphasise the scientific consensus on the reality and causes of climate change, in the summer of 2005 The Royal Society (on the occasion of the G8 Summit in the UK) took the unprecedented step of producing a brief statement[12] on the science of climate change, signed by the Science Academies of all the G8 countries – USA, Japan, Germany, France, UK, Italy, Canada, Russia – along with China, India, and Brazil. This statement called on the G8 nations to "Identify cost-effective steps that can be taken now to contribute to substantial and long-term reduction in net global greenhouse gas emission [and to] recognise that delayed action will increase the risk of adverse environmental effects and will likely incur a greater cost”.

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(ii) Food and Water. Another problem is food. Global food production has doubled over the past 30-40 years, but this Green Revolution – a combination of breeding more efficient crops, and farming more intensively (more fertiliser, more water, and consequently more energy subsidies) – shows signs of flattening out. We could not feed today’s population with yesterday’s agriculture. But it is not clear that we can feed tomorrow’s 9 billion with today’s agriculture, much less do it sustainably. The first wave of products created with new “gene-splicing” technologies, which enable far more precise genetic manipulation than previous crop breeding methods, were (in contrast with the Green Revolution) oriented to agribusiness rather than the consumer. Unfortunately, this has led to a demonisation of “GM crops” by many well-intentioned but ill-informed NGOs. One thing we need is a second wave of products, aimed at creating a Doubly Green Revolution, with crops adapted to their environment – drought resistant, salt tolerant, nitrogen fixing, etc – instead of having the environment modified to suit the crops by using fossil-fuel energy subsidies.

Food production also needs water. Lots of it. As human numbers have grown, and living standards risen (water use per capita has doubled over the past century), we have arrived at the point where roughly 30 countries, with 500 million people, are in "water deficit", consuming more water than rain and rivers supply. Projections, necessarily uncertain, suggest that by 2025 these numbers will have increased to 50 countries, with 3 billion people. Global demand for water is estimated to exceed global supply around 2040-2060.[13] Currently agriculture accounts for roughly 70 % of global water use, industry 20 %, and domestic 10 %.

As more mouths need to be fed, and the Green Revolution plateaus, climate change compounds tomorrow's problems. Of course, there will be winners and losers; agriculture will be helped in some places. But, as recently emphasised in a Royal Society study,[14] equatorial regions will be badly affected. In particular, "Africa is consistently predicted to be among the worst hit areas across a range of future climate change scenarios". This echoes the disconnect between two central themes in global politics. On the one hand, solemn promises have been made to increase aid and support development in Africa. On the other hand, the lack of effective agreement on measures to curb greenhouse gas emissions means that increasing amounts of aid will be spent on tackling the consequences of climate change.

(iii) Other Species – and Ecosystem Services. Moving beyond concern for ourselves, how about the other living things – plants and non-human animals – that share the planet with us? Seen through a wider-angle lens, the impending diminution of the planet's diversity of plant and animal species, which derives from human impacts, could be an even greater threat than climate change.

Currently around 1.5 to 1.6 million distinct species of plants and multicellular animals have been named and recorded. Even this number – analogous to the number of books in the British Library – is uncertain to within around 10 %, because the majority of species are invertebrate animals of one kind or another, for many of which the records are still on file cards in separate museums and other institutions (this causes problems with "synonyms" – the same species being separately named and recorded on two or more different occasions). We know even less about how many species in total actually exist on Earth today. Plausible estimates[15] range around 5-10 million, and some experts would argue for higher or lower numbers; either way, the number remaining to be discovered exceeds the total number so far identified by us. Given this lamentable ignorance, we clearly cannot say much about the actual number of species that are likely to become extinct this century. We can note that the IUCN Red Data Books[16] in 2004, using specific and sensible criteria, estimate 20 % of recorded mammal species are threatened with extinction, and likewise 12 % of birds and 4 % of reptiles and of fish. However, when these figures are re-expressed in terms of the number of species whose status has been evaluated (as distinct from dividing the number known to be threatened by the total number known – however slightly – to science), the corresponding numbers for mammals and birds do not change much, but leap to 61 % of reptiles and 26 % of fish. This says a lot about how much attention reptiles and fish have received. The corresponding numbers for the majority of plant species (dicots and monocots) are respectively 4 % and 1 % of known species, which contrasts with 74 % and 68 % of those evaluated. Most dramatic are the two numbers for the most numerous group of species, namely insects: 0.06 % of all known species are threatened, versus 73 % of those actually evaluated. The same pattern holds true for other invertebrate groups. For these small things, which arguably run the world, we know too little to make any rough estimate of the proportions that have either become extinct or are threatened with it.

Perhaps surprisingly, we can nevertheless say some relatively precise things about current and likely future rates of extinction in relation to the average rate seen over the roughly 550 million year sweep of the fossil record.[17, 18] Humans have much greater emotional resonance with furry and feathery creatures than with other species, and mammals and birds consequently have been relatively well studied. Over the previous century, documented extinctions within these two groups have been at a rate roughly 1,000 times greater than that seen in the fossil record. And four different lines of argument suggest a further rough upswing of extinction rates, by a factor of around 10, over the coming centuries.[19] So, if mammals and birds are typical (and there is no reason to suppose they are not), we are looking at an acceleration in extinction rates which is of the magnitude which characterised the Big Five mass extinction events in the fossil record, one of which did in the dinosaurs. There is, however, a crucial difference between the Sixth Wave of mass extinction on whose breaking tip we stand and the previous Big Five. All the earlier extinctions stemmed from external environmental events. The Sixth, set to unfold over the next several centuries (seemingly long to us, but a blink of the eye in geological terms), derives directly from human impacts.

The main causes of extinction have been habitat loss, overexploitation, and the arrival of "alien" species. Often two, or all three, combine. But an increasing number of recent studies show clearly that the effects of climate change are compounding these more direct effects of human activities. The UK Treasury's *Review on the Economics of Climate* Change,[20] led by Nicholas Stern, notes that "Ecosystems will be particularly vulnerable to climate change, with around 15-40 % of species potentially facing extinction after only

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2°C of warming. And ocean acidification, a direct result of rising carbon dioxide levels, will have major effects on marine ecosystems, with possible adverse consequences on fish stocks."

The UN-sponsored Millennium Ecosystem Assessment (MEA), published in 2005, integrated ecological studies with economic and social considerations, and concluded that approximately two-thirds of the ecosystem services that support life on Earth – such as fresh water, fisheries, air and water regulation, pollinators for crops, along with the regulation of regional climate, pests, and certain kinds of natural hazards – are being degraded and/or used unsustainably. Table 1 gives an outline account of these MAE findings.[21]

The way economists conventionally calculate gross domestic products (GDP) takes little or no account of the role of such ecosystem services. Thus an oil tanker going aground, and wreaking havoc on the region's biota, will typically make a positive contribution to conventional GDP (clean-up costs are a plus; environmental damage usually deemed not assessable). A recent attempt to assess the "GDP-equivalent" of the totality of the planet's ecosystem services arrives at the guesstimate that such services have a value roughly equal to global GDP as conventionally assessed.[22] Any calculation of this kind is beset with many uncertainties, and some would argue that you simply cannot put a price upon services which are essential to life. But I find it helpfully indicative.

Table 1 : Global Status of Ecosystem Services
(Millennium Ecosystem Assessment, 2005)[21]

Service	Status [a]	Notes
Provisioning Services		
Food: crops	+	substantial production increase
: livestock	+	substantial production increase
: capture fisheries	–	declining production due to overharvest
: aquaculture	+	substantial production increase
: wild foods	–	declining production
Fibre: timber	+/–	forest loss in some regions, growth in others
: cotton, hemp, silk	+/–	declining production of some fibres, growth in others
: wood fuel	–	declining production
Genetic resources	–	lost through extinction and crop genetic resource loss
Biochemicals, natural medicines, pharmaceuticals	–	lost through extinction, overharvest
Fresh water	–	unsustainable use for drinking, industry, and irrigation; amount of hydro energy unchanged, but dams increase ability to use that energy
Regulating Services		
Air quality regulation	–	decline in ability of atmosphere to cleanse itself
Climate regulation: global	+	net source of carbon sequestration since mid-century
: regional and local	–	preponderance of negative impacts
Water regulation	+/–	varies depending on ecosystem change and location
Erosion regulation	–	increased soil degradation
Water purification and waste treatment	–	declining water quality
Disease regulation	+/–	varies depending on ecosystem change
Pest regulation	–	natural control degraded through pesticide use
Pollination	– [b]	apparent global decline in abundance of pollinators
Natural hazard regulation	–	loss of natural buffers (wetlands, mangroves)
Cultural Services		
Spiritual and religious values	–	rapid decline in sacred groves and species
Aesthetic values	–	decline in quantity and quality of natural lands
Recreation and ecotourism	+/–	more areas accessible but many degraded

Footnote:
a: + means enhanced, – means degraded, in the senses defined in the main text.
b: the evaluation here is of "low to medium certainty"; all other trends are "medium to high certainty"

IMPLICATIONS FOR ACTION

Having set out, in some detail, the unprecedentedly global nature of the environmental problems confronting us, I now briefly sketch solutions. The problems are not, in principle, intractable. The overarching difficulty, however, is that – greenhouse gases do not recognise their country of origin once in the atmosphere – effective action requires all nations to engage cooperatively. I will conclude by discussing this.

Population Growth

Some time in the past year or so – the data are unavoidably a bit imprecise – we passed an important turning-point in human history: global fertility rates fell below replacement levels. That is, the average female had less than (only just less than) one female child. Nevertheless, global population will continue to grow, although slowing down, to around 9 billion by 2050, driven by the previously noted "momentum of population growth". This slow transition to some steady population, provided current trends continue, is remarkable. But the overall figure masks huge variations among countries. In some European countries the decline in birth rates is already causing problems with the old outnumbering the young, whilst in other countries populations continue to grow apace. In particular, Africa currently accounts for one-seventh of the world population; if current trends persist, by 2050 it will be one-quarter.

Halting the growth in human numbers is a prerequisite to our achieving a sustainable ecological footprint. So one priority is educating and empowering women, particularly in those cultures and places where this is not current practice. In the words of the United Nation's Millennium Development Goals, we need to "achieve universal primary education" and "promote gender equality and empower women". Although other factors obviously enter, experience suggests these are primary factors in decreasing growth of the global population.

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In this context, UNICEF estimates that 700 million women (two-thirds of all those married or in stable unions) use some method of contraception. Contraceptive use increased 20% between 1990 and 2000, in both the developed and the developing world. In sub-Saharan Africa, contraceptive use doubled between 1990 and 2000, but from a low base of 16%. Most unfortunately, in my view, religious beliefs or other ideological prejudices prompt some major international organisations to oppose contraception, forbidding distribution of condoms or even advice about fertility control. This is a particularly pernicious feature of some programmes directed against HIV/AIDS.

Arguably, the main factor producing lower birth rates and smaller families is a combination of better infant survival and higher living standards, which themselves are entwined. The former derives from better, science-based primary health care (one study finds that income growth explains only 10-25% of increasing life expectancy,[23] another finds a decline in infant mortality owing only 5% to income growth as against 21% to better education).[24] But higher living standards are associated with economic growth. So we have the difficulty that declining population growth, which reduces future ecological footprints, derives in part from factors which increase footprints.

Average Ecological Footprint

So, is it possible to reduce our per capita impacts on the environment without sacrificing the amenities the developed world enjoys, and without denying the aspirations of the developing world? Most importantly, can we solve the problem of climate change by decoupling "economic growth" from the CO_2 emissions associated with energy production?

One thing is clear. The magnitude of the problem we face is such that there is no "silver bullet", no single technological fix. Rather, a wide range of actions must be pursued. I think these can be divided broadly into four categories.[25]

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First, we can adapt to change: stop building on flood plains; start thinking more deliberately about coastal defences and flood protection, recognising that some areas should, in effect, be given up. In Holland, one quarter of which lies below sea-level, there are already plans for houses designed to float on seasonally flooded areas. Second, we can reduce inputs of CO_2 by reducing wasteful energy consumption. There are studies, for example, both in the US and in the UK, which demonstrate we can design housing which consumes less than half current energy levels without significantly reducing living standards. Third, we could capture some of the CO_2 emitted in burning fossil fuels, at the source, and sequester it (burying it on land or under the seabed, which, amongst other things, requires safety and environmental problems to be addressed). Fourth, we could move much more quickly toward renewable sources of energy, which do not put greenhouse gases into the atmosphere. These include geothermal, wind, wave, and water energy; solar energy (from physics-based or biology-based devices); fission (which, despite its problems, surely, must play a play a role in the medium-term); fusion (a realistic long-term possibility) and biomass (assuming that the carbon dioxide you put into the atmosphere was carbon dioxide you took out when you grew the fuel). Some of these "renewables" are already being used, others are more futuristic.[26] In total, they currently account for only 3% of world energy production.

An important study by Pacala and Socolow[27] suggests that, in principle, we could stabilise greenhouse gas concentrations at around 500ppm by 2050. They present a scheme of some 15 "stabilisation wedges", each one of which would, if implemented now and rising linearly, save 25 billion tonnes of carbon emissions over the next 50 years. All 15 wedges are based on proven technologies. They fall into three broad categories: energy demand, energy supply, and capture and sequestration of CO_2 emissions. They include such various targets as: more efficient buildings; better vehicle fuel use; carbon capture; wind power; solar power; nuclear power (at twice current levels); stopping tropical deforestation and planting new trees. Pacala and Socolow estimate that any 7 of the 15, if implemented promptly and strenuously, could result in the eventual CO_2 load in the atmosphere being held below 500ppm. Not one of these wedges is easy or uncontroversial. But the scheme does illustrate that we could get there, if we put our minds to it.

Notice that the wedge corresponding to reducing deforestation, and eventually halting it and reforesting, could also contribute to maintaining biodiversity and ecosystem services, as well as helping with water supplies by protecting watersheds. At the same time, given the pressures for logging and forest clearing (with 1-2% of the planet's tropical forest currently disappearing each year), this wedge underlines the difficulties.

What about the economic costs of such actions? In his report[20] on "The Economics of Climate Change" for the UK Government, Nicholas Stern estimated that the effects of climate change under a "business as usual" scenario for greenhouse gas emissions would, over the next two centuries, lie in the range of a 5-7% reduction of global GDP or "personal consumption". If indirect impacts on the environment and human health (sometimes called "non-market" impacts, and not usually included in such calculations, despite their obvious relevance) are included these figures rise to 11-14% or more.

for a century once it gets there). So projected plans need to focus on the growing total load, which is related to, but ultimately more important than, emissions in any one year. Once a target level of greenhouse gas concentration is set, you can get there steadily by taking significant action early; if you start too slowly you will require dramatically – perhaps infeasibly – large efforts later. Stern chooses a target of 450-

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Stabilisation of greenhouse gas concentrations, whatever the level, requires that annual emissions be reduced to a level where they can be balanced by the Earth's natural capacity to remove them from the atmosphere (keep in mind that a molecule of CO_2 typically remains in the atmosphere

550ppm, regarding higher levels as corresponding eventually to dangerously high temperature rises. He estimates the economic costs of stabilising at this level by 2050 as ranging from a cost of 5% of global GDP to a gain of 2%, with a best guess of a cost of around 1%. It looks like a good bet to me.

An important ingredient of Stern's work is the rate at which the future is discounted. In effect, Stern's assumptions recognise, amongst other things, the long time-lags in the Earth's atmospheric system (mentioned earlier), which undercut simplistic but conventional economic arguments for heavier discount rates. His conclusions have been criticised by some[28] who believe that global GDP must inexorably increase, and thus ask why not defer action until things get really bad, by which time we will all be much richer. To put it mildly, I think such criticism smacks of scholasticism, failing to appreciate the nonlinear complexities of this problem.[29]

In short, the problems outlined above are, in principle, solvable. And they are solvable with current, or reasonably foreseeable, technologies. We could plot a path to an ecological footprint for humanity in our finite planet, at or below the sustainable level indicated in Figure 1. But will we do it?

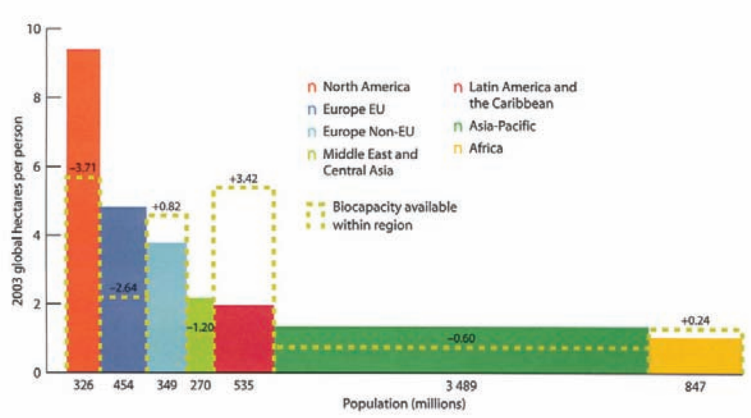
PROBLEMS & PARADOXES

Such global problems require a globally cooperative response. This is obvious for the major challenge of climate change. It is also true for other problems, such as continuing population growth combined with pressures on water supplies and other resources, increasingly leading to conflicts and mass movements of people which cannot be ignored. All this roils together with rapid and continuing advances in information technology, which simultaneously makes things better and worse: better because we can more easily and effectively coordinate action, once motivated to do so: worse because in such a global village the massive inequities between groups are clearly exposed.

Ideally, we need people – from individuals to nation states – to act cooperatively, but to do so in equitable proportions. In broad terms, we can talk of three worlds: rich, poor, and transitional. In 2000, the rich (or developed, OECD) world comprised 13 % of the world's population, with 51 % of global GDP, consuming 51 % of all energy generated.[30] The corresponding figures for the countries in transition were 20 % of population, 25 % of GDP, 26 % of energy, and for the remaining poor 67 %, 24 %, 23 %. The rich 13 % of the world's population were responsible for 48 % of all CO_2 emissions in 2000. Focussing a bit more finely, in 2003 the average inhabitant of the USA put 5.5 tonnes of carbon into the atmosphere, compared with 2.2 for Europe, 0.7 for China, 0.2 for India, and lower levels for many developing countries.

Figure 2 shows the ecological footprint (the height of the coloured rectangles), as defined earlier, for the average inhabitant of each of seven regions of the world, along with the number of people in each region (the width of the rectangles).[31] It will be seen that the average North American's footprint is twice that of an inhabitant of the European Union, and more than six times that for "Asia-Pacific" (which is mostly China and India). On the other hand, the sheer number of people in the Asia-Pacific region means its total ecological footprint exceeds that of North America. Both region's ecological footprints exceed their sustainable biological capacity (SBC). Interesting ethical paradoxes arise if we pursue

Fig. 2: ECOLOGICAL FOOTPRINT AND BIOCAPACITY BY REGION, 2003



these questions at the level of individual countries: in 2003 the average inhabitant of Australia had a footprint of 6.6 area units, in a country whose per capita SBC is 12.4; the corresponding figures for the average inhabitant of Egypt are 1.4 and 0.5. Who is the more virtuous, the average Australian living within the country's sustainable limits, or the Egyptian casting roughly one-fifth the Australian's footprint but greatly exceeding the country's SBC?

All this is, however, part of a larger problem, namely how did cooperative associations among humans evolve, leading eventually to the complex societies of today? At first glance, the answer seems easy. You pay some small cost to gather a much larger cooperative benefit. For example, a prairie dog takes a personal risk in giving an alarm call, but all colony members benefit and, by taking turns as alarm giver, each individual's group benefit exceeds the occasional risk. But any such arrangement is immediately vulnerable to cheats who enjoy the benefits without paying the risk-taking dues. In evolutionary terms, such cheats have a selective advantage, and it is unclear how such observed cooperative phenomena can arise or be maintained. Darwin recognised this as his most important unsolved problem.

Following work on "kin selection" by Hamilton[32] and others a century after Darwin, we now understand how such cooperative associations can evolve and be maintained in relatively small groups of sufficiently closely related individuals. These conditions could apply to humans when we were small bands of hunter-gatherers. But for large aggregations of essentially unrelated individuals, as developed once agriculture appeared and cities began, the origin of cooperative associations – with group benefits which exceed the "cost of membership" – remains as puzzling today as it was for Darwin.

The problem has been much explored, in the scholarly literature, employing a variety of metaphors: the Tragedy of the

Commons;[33] the Free-Rider problem; the Prisoner's Dilemma;[34] and others. The Tragedy of the Commons for example, considers a "commons", where all inhabitants of a village can graze their cattle. Left unregulated, each individual will add stock, until the commons is overgrazed. If some socially responsible individuals limit themselves, they will be economically disadvantaged in the short run, whilst still suffering the long-run degradation of the commons by their less inhibited neighbours. The analogy with climate change is obvious. This is a good metaphor, despite its historical inaccuracy. A more concrete and specific example is the recent decline in voluntary uptake of childhood measles-mumps-rubella (MMR) vaccination in the UK, as individual parents avoided a putative (but non-existent, or at least undetectably tiny) risk, implicitly replying on others' children to be vaccinated to provide herd immunity; enough parents having made this choice, we are now seeing a rise in the incidence of measles (with a risk of serious consequences for roughly 1 case in 1,000).

Despite a literature running to thousands of papers on these metaphors in learned journals, along with much "thick description" of real societies in many countries, I do not believe there is any agreed explanation for the evolution and maintenance of cooperative behaviour in human societies. Moreover – focussing narrowly on metaphors such as the Tragedy of the Commons or the Prisoner's Dilemma – despite the amount of published work there are essentially no studies exploring circumstances where costs and benefits vary among the players, as they clearly do in the real world of climate change.

My personal opinion – and this is pure speculation – goes as follows. The attribute which primarily distinguishes *H. sapiens* from other animals is our conscious desire to understand the world around us and our place in it. The first stirrings of this search are shrouded in magic and mysticism, whose enigmatic traces remain in the caves at Altamira, in stone circles, and other such reminders. Once we move out of the mists of pre-history, we find stories of dreamtime, creation myths, ceremonies and initiation rites, spirits and gods, with a unifying theme that all seek simultaneously to help explain the external world and also to provide a "stabilisation matrix" for a cohesive society. There are, moreover, some striking and unexplained similarities in belief systems and rituals from different times and places. Conscience, a simple word for a complex concept which helps foster behaviour in accord with society's professed norms, has been memorably defined by H. L. Mencken as "the inner voice which warns us that somebody might be looking". And how helpful it is if that somebody is an all-seeing, all-knowing, supernatural entity.

Common to these conjectured "stabilising forces" in essentially all earlier societies are hierarchical structures, serving and interpreting the divine being or pantheon, along with unquestioning respect for authority. In such systems, faith trumps evidence. I think I was eight years old when I first encountered, and was disturbed by, the biblical injunction, relating to the doubting St Thomas: "blessed is he that seeth not, yet believeth".

But if indeed this is broadly the explanation for how cooperative behaviour has evolved and been maintained in human society, it could be Bad News. Because though such authoritarian systems seem to be good at preserving social coherence and an orderly society, they are, by the same token, not good at adapting to change. Diamond's book, *"Collapse: How Societies Choose to Fail or Survive"*, provides striking examples.[35]

Emerging in Western Europe in the seventeenth century, the Enlightenment cut against these values, offering a questioning, fact-based, experimental, analytic approach to understanding the world and humankind's place in it. By so doing, it created today's world. The emerging and still accelerating understanding of physical, and more recently biological, systems has resulted in longer, healthier lives, liberated by energy subsidies and informed by easily accessible information about anything and everything. But, as we have seen, these well-intended actions have also produced adverse unintended consequences. Many people and institutions have always found such questioning, attended by unavoidable uncertainties, less comfortable than the authoritarian certitudes of dogma or revelation.

I think this helps explain why fundamentalist forces are again on the march, West and East. Surveying this phenomenon, Debora MacKenzie[36] has suggested that – in remarkably similar ways across countries and cultures – many people are scandalised by "pluralism and tolerance of other faiths, non-traditional gender roles and sexual behaviour, reliance on human reason rather than divine revelation, and democracy, which grants power to people rather than God." She adds that in the US evangelical Christians have successfully fostered a belief that science is anti-religious, and that a balance must be restored, citing a survey which found 37% of Americans (many of them not evangelicals) wanted Creationism taught in schools. Fundamentalist sects of Islam offer a complex but ultimately similar threat to science according to Sardar,[37] Ruthven,[38] Masood[39] and others, who note that a rise in literalist religious thinking in the Islamic world in recent decades has seriously damaged science and free enquiry there, seeing the Koran as the font of all knowledge.

From this viewpoint, what we are seeing is not Huntington's "Clash of Civilizations", but rather a revival of an older clash between dogmatic, faith-based belief systems and the open-minded, experimental, questioning spirit of the Enlightenment. Thus, according to Julian Baggini,[40] we find Pope John Paul II in 2004 encouraging his successor-to-be, then

Cardinal Ratzinger, "to challenge a world 'marked by both a wide spread relativism and the tendency to a facile pragmatism' by boldly proclaiming the truth of the church". Implementing this agenda, Pope Benedict has recently drawn a clear distinction between the Orthodox churches and Protestants, who lack a "sacramental priesthood … and a Eucharistic Mystery".[41] This disconcertingly harks back to Pope Boniface VIII, whose similar edicts in 1378 led to the Reformation, and eventually – as an unintended consequence to end all unintended consequences – the Enlightenment. It is not likely, however, that today's revivals of dogmatic intolerance, in both West and East, will have such fortunate, if unintended consequences.

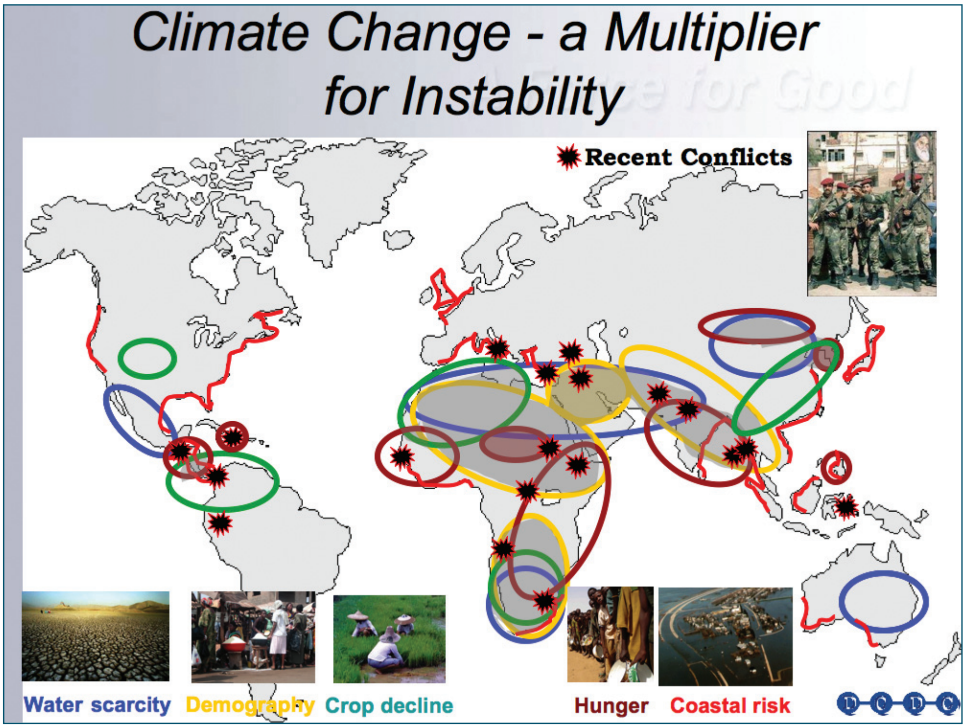
WHAT WE ARE SEEING IS NOT HUNTINGTON'S "CLASH OF CIVILIZATIONS", BUT RATHER A REVIVAL OF AN OLDER CLASH BETWEEN DOGMATIC, FAITH-BASED BELIEF SYSTEMS AND THE OPEN-MINDED, EXPERIMENTAL, QUESTIONING SPIRIT OF THE ENLIGHTENMENT.

The really unfortunate thing is that none of these fundamentalist beliefs are grounded on, or representative of, the contemporary mainstream of the religions they profess to serve. Fundamentalist Christianity is widely considered as irrelevant to modern theology as it is to modern science. The extremist views and acts of fundamentalist Islam find little sanction in the Koran. Karen Armstrong[42] suggests that "to fight the secular enemy, fundamentalists reduce complex faiths to streamlined ideologies and, above all, try to recast old mythical tales as modern, literal truths." In so doing, they tend to lose the compassion that is the mark of mature religious beliefs.

Ahead of us lie dangerous times. There are unprecedented problems, global in scale and scope that ultimately derive from the finiteness of our planet: climate change, shortages of water and other resources, new and re-emerging diseases, loss of biological diversity and ecosystem services and more. Arguably these problems already underlie conflicts – Rwanda, Darfur, others (Figure 3, below)[46] – which are exacerbated by tribalism and dogmatic intolerance.

Not the least of our difficulties is that too many in positions of power tend still to see the world in terms of yesterday's "Great Game" among nations. Thus Kissinger has suggested that the geopolitics of twenty-first century Asia will be a replay of nineteenth century Europe, jockeying for position with wars being "politics by other means".

I think nothing could be further from the truth. Tomorrow's struggles among nations will be in a resource-limited world, where the real need is for cooperation to



address global environmental changes, in ways that recognise current inequities. Where conflicts persist, they are increasingly likely to be driven in large part by needs for water or other necessities, although often wearing a cloak of ideology. The global information environment will make counter-terrorism more difficult, diminishing the traditional advantage of the "hard power" of technically advanced actors. Overall, in the words of David Kilcullen, the Australian-born former Chief Strategist in the US State Department Office for Counterterrorism, it will be a world where people "don't get pushed into rebellion by their ideology. They get pulled in by their social networks [and perceived problems]".[43] This points away from expenditures which emphasise "shock and awe", and back to an older wisdom of classical counter-insurgency doctrine which says that 80 % of effort should be non-military. By contrast, according to George Packer, in Iraq and Afghanistan civilian agencies have received 1.4 % of the total money expended by the US.[44]

Coming closer to home the implications, as sketched in the Lowy Institute Paper 16 by Hugh White,[45] are "that Australia does indeed need to move beyond the 'Defence of Australia' as the central organising principle of defence policy, and focus instead on maximising its military capacity to protect its interests in the stability of its region."

CODA

Ultimately, the challenge is to achieve a sustainable future for everyone.

Easter Island offers a cautionary tale, on a micro-scale, of what could happen if we fail this challenge. The initial colonisers, the brilliant Melanesian voyagers, flourished. Individual villages, each with their own massive stone icons, existed in apparent harmony. But as forests shrank, boat-building materials became scarcer, and an economy based heavily on fishing deteriorated. In his book *Collapse*,[35] Jared Diamond wonders what they said as the cut down the last trees. Did they say "it's jobs not trees", or "we need more research", or did "I will if you will" give way to "I won't if you won't". We will never know. What we do know is that, far from attempting to solve their tragedy of the commons and strive for cooperation, they dissipated their energy pulling down each others' iconic statues, presumably driven by what we might call an upsurge of fundamentalist intolerance.

This is not a happy story. Probably the Easter Islanders did not fully understand the impacts they were having on their island universe. We have no such excuse.

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