Evidence for the

Stern Review on the Economics of Climate Change

Submitted by

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Summary

● The fact that (a) the determinants of the capacity to mitigate or adapt to climate change (e.g., access to economic resources, social and human capital, and technological prowess) largely overlap, (b) many factors underlying or related to these determinants are themselves indicators of sustainable development (e.g., per capita income; and various public health and well-being indices such as prevalence of hunger or malaria), and (c) climate change could exacerbate existing climate-sensitive hurdles to sustainable development (e.g., hunger, malaria, water shortage, coastal flooding and threats to biodiversity) specifically faced by many developing countries, allows us to identify and develop integrated strategies and measures to concurrently advance adaptation, mitigation and sustainable development.

● These integrated approaches include enhancing adaptive capacity through either "focused adaptation" (which would focus on reducing vulnerabilities to urgent climate-sensitive risks that hinder sustainable development and would be exacerbated by climate change) or more broadly through sustainable development (by developing and/or nurturing institutions, policies and infrastructure to stimulate economic development, technological change, human and social capital, and reducing climate-sensitive barriers to sustainable development).

● My evidence compares the costs and benefits over the short-to-medium term of using such integrated approaches to reduce climate-sensitive hazards against approaches that rely on mitigation. It relies heavily on the results of recent DEFRA-sponsored studies of the global impacts of climate change through 2085, i.e., the foreseeable future, on several indicators of human and environmental well-being. Regarding human well-being, these studies project changes in the global population at risk (PAR) for malaria, hunger, water shortage, and coastal flooding; with respect to environmental well-being, they estimate changes in the global extent of coastal wetlands, forests and carbon sink capacity.

● These studies allow us to compare the contribution of climate change to the total population at risk (or magnitude of threat) for each of these hazards in 2085. The results indicate that although millions of people will additionally be at risk of malaria, hunger, water shortage and coastal flooding, for the most part, many millions more will be at risk in the absence of any climate change. Consequently, with respect to virtually all indicators of human and environmental well-being addressed by these studies, climate change is unlikely to be the most important environmental problem facing the globe, at least not through the foreseeable future (i.e., 2085). Coastal flooding is the exception to this rule, but its contributions to global mortality, which currently is 0.2 percent of that due to malaria and hunger, should continue to be relatively minor through the foreseeable future.

● DEFRA-sponsored studies, which use the IPCC's scenarios, also show that from the perspective of human well-being, the richest-but-warmest world characterized by the A1FI scenario would probably be superior to the poorer-but-cooler worlds at least through 2085, particularly if one considers the numerous ways GDP per capita advances human well-being. Human well-being would likely be the lowest for the poorest (A2) world. Regarding environmental well-being, matters may be best in the A1FI world for some critical environmental indicators through 2100, but not necessarily for others.

● Assuming that the Kyoto Protocol would reduce climate change in 2085 by 7 percent, it would, at an annual cost of about $165 billion in 2010, reduce total PAR in 2085 by 0.2 percent for malaria, 1.5 percent for hunger, and 18.1 percent for coastal flooding, but it may increase net PAR for water shortage.

● Halting climate change at its 1990 level, on the other hand, would, at a much higher cost, reduce the total population at risk in 2085 by 3 percent for malaria, 21 percent for hunger and up to 93 percent for coastal flooding, but that too might increase the net population at risk for water shortage.

● But the benefits associated with halting climate change — and more — can be obtained at an annual cost of $10–$20 billion through efforts taken now to enhance adaptive capacity through "focused adaptation", i.e., activities focused on reducing vulnerabilities to climate-sensitive problems that are urgent today. Focused adaptation is more effective than mitigation over the foreseeable future because (a) the population at risk for climate-sensitive hazards will, for the most part, continue to be dominated by non-climate change related factors during this period, (b) the technologies, processes, systems, and human and social capital needed to reduce climate-sensitive hazards (such as malaria, hunger, coastal flooding and water shortage) today will also help reduce the same problems in the future whether they are caused by climate change or other factors

● Focused adaptation designed to reduce hunger by increasing food production and consumption per unit of land and water used for agriculture will, in addition to reducing hunger, reduce the most important threats to terrestrial and freshwater biodiversity, namely, diversion of land and water to agricultural uses, while conserving carbon stocks and sinks.

● Not least, co-benefits (or ancillary benefits) of focused adaptation, most of which would flow directly or indirectly from reduced malaria and hunger include better health, increased economic growth, and greater human capital — all key to sustainable development.

● Alternatively, adaptive capacity can also be advanced by broadly advancing sustainable development in developing countries through, for instance, adherence to the Millennium Development Goals (MDGs). Studies by the UN Millennium Project indicate that an additional $150 billion per year could reduce global malaria by 75 percent; hunger, poverty, and lack of access to safe water and sanitation by 50 percent (each); reduce child and maternal mortality by at least 66 percent; provide universal primary education; and reverse growth in AIDS/HIV.

● The resulting sustainable economic development should also help reduce birth rates, which would mitigate climate change and reduce the population exposed to climate change and climate-sensitive risks, thereby reducing impacts, and the demand for adaptation.

- Either approach to increasing adaptive capacity would help solve today's urgent problems sooner and more certainly. Moreover, enhancing adaptive capacity allows adaptation to be proactive as opposed to merely reacting to the effects of climate change after they occur. Equally important, they would increase the ability to deal with tomorrow's problems, whether they are caused by climate change or other factors. None of these claims can be reasonably made on behalf of any mitigation scheme today.

- Increasing adaptive capacity, whether through pursuit of MDGs or through focused adaptation could raise the level at which GHG concentrations might become "dangerous" and/or allow mitigation to be postponed. In either case, the overall cost of mitigation could be reduced, especially if measures are taken in the interim to improve the cost-effectiveness of mitigation technologies.

- Increasing adaptive capacity would also be consistent with helping meet the ultimate objective of the UN Framework Convention on Climate Change, namely, "to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner".

- Accordingly, over the next few decades the focus of climate policy should be to: (a) broadly advance sustainable development, particularly in developing countries since that would generally enhance their adaptive capacity to cope with the many urgent problems they currently face, including many that are climate-sensitive, (b) specifically reduce vulnerabilities to climate-sensitive problems that are urgent today and might be exacerbated by future climate change, and (c) implement "no-regret" emission reduction measures, while (d) concurrently striving to expand the universe of no-regret options through scientific and technological research and development to increase the variety and cost-effectiveness of available mitigation options.

Evidence on Aspects of the Economics of Climate Change

Submitted by

Indur M. Goklany

1. Introduction

1.1 I am an energy and environmental policy analyst with over 30 years experience in the United States working for state and federal governments, think tanks, consulting enterprises, and the private sector. I have participated in the IPCC's activities and deliberations off and on since its founding in 1988 to the present. I was the rapporteur for the Resource Use and Management Subgroup of IPCC's Work Group III for the First Assessment Report, and helped develop the program leading to the Second Assessment Report. I am also an expert reviewer for the IPCC Work Group II's Fourth Assessment Report (currently in preparation).

1.2 I have written extensively on climate change, adaptation, biodiversity, sustainable development, human well-being, technological change, bioengineered crops, and the precautionary principle. Attachment A provides a selected list of relevant publications. I also have Ph.D. and Bachelor of Technology degrees in Electrical Engineering from Michigan State University and the Indian Institute of Technology, Bombay.

1.3 I am currently Assistant Director, Science and Technology Policy, Office of Policy Analysis, at the US Department of the Interior, which manages 20 percent of U.S. surface area, all its Outer Continental Shelf, and their biological, water and mineral resources. This evidence, however, is submitted in an individual capacity. I do not represent any agency, group or institution.

1.4 I am grateful for the opportunity to submit evidence for the Stern Review.

2. Scope of Evidence

2.1 My evidence addresses the issue of the appropriate balance of resources that should be expended on mitigation and adaptation with regard to climate change, and how they might shift with the passage of time. In doing this, I will, among other things, also address the following issues: (a) Is climate change likely to be the most important environmental issue facing the globe in the foreseeable future? (b) Whether and, if so, for how long, would a richer-but-warmer-world be better off than poorer-but-cooler-worlds? (c) Co-benefits from different adaptation approaches. (d) The relative costs and benefits in the medium and long term of allocating resources to mitigation rather than to adaptation. (d) Trends in global deaths and death rates due to extreme weather events. Finally, I will identify strategies and approaches that would simultaneously advance sustainable development, and the capacity to adapt to or mitigate climate change.

3. Sources of Estimates for the Impacts of Climate Change

3.1 My evidence draws heavily upon two sets of analyses of the global impacts of climate change that were funded by DEFRA (and its predecessor, DETR). Along with the authors of these studies, I will assume — optimistically, I believe — that socio-economic scenarios are not credible beyond 2085 and, therefore, 2085 is at the limit of the foreseeable future. Neither set of studies considered low-probability but potentially high-consequence outcomes such as a shut down of the thermohaline circulation. They are deemed unlikely to occur during this century (see, e.g., Nicholls and Lowe 2004).

3.2 With respect to estimating impacts of climate change on human well-being, both sets of studies focused on four climate-sensitive hazards to human health and safety, namely, malaria, hunger, water shortage and coastal flooding. Accordingly, so will I for the most part.

3.3 With respect to environmental impacts, I will, like the second set of studies, focus on habitat loss and terrestrial carbon sink capacity.

3.4 The first set of DEFRA-sponsored studies, whose results appeared in the peer-reviewed literature between 1999 and 2002 (Parry and Livermore 1999, Parry et al. 2001, Arnell et al. 2002), was based on a scenario that predated the IPCC's Special Report on Emission Scenarios (SRES 2000). This set formed the basis of claims by several advocates of stronger greenhouse gas (GHG) controls, e.g., Sir David King (2004), that, unless curbed, climate change would place additional millions at risk of diseases such as malaria, hunger, water shortage and coastal flooding.

3.5 The second set of DEFRA-sponsored studies, also called the "Fast Track Assessment" (FTA) used the SRES scenarios to project future climate change and estimate its global impacts to 2085. Results from the FTA were reported in a special issue of *Global Environmental Change: Part A* (volume 14, issue 1, pp. 1-99, 2004).

3.6 Among the shortcomings of these studies is their tendency to overestimate climate change impacts because they do not fully consider the increase in society's adaptive capacity that should occur because of advances in levels of economic and technological development that the SRES assumes will come with passage of time (Goklany 2005a, 2005b, 2005c). Adaptive capacity is a key determinant of impacts, or damages, due to climate change because the greater that capacity, the greater society's ability to: (a) forestall or reduce some impacts through a combination of "spontaneous" (or "autonomous") adaptations and proactive adaptations, and (b) cope with any residual impacts through reactive adaptations. Nevertheless, despite this tendency to overestimate, my evidence, for the most part, adopts the results from these studies.

4. SRES Scenarios

4.1 Table 1 summarizes the dominant characteristics of the "storylines" associated with the scenarios used by the FTA, and corresponding estimates in 2085 of atmospheric CO_2 concentrations and climate change — the latter represented by increases in globally averaged temperature (Arnell et al., 2004). The columns in this, and most subsequent, tables are arranged from left to right in the order of decreasing CO_2 concentrations (and global temperature changes), that is, A1FI, A2, B2 and B1. This table indicates that A1FI would be the richest-but-warmest world while A2 would be the poorest-but-most-populous world.

Table 1
Characteristics and assumptions for the various scenarios

	Scenario			
	A1FI	A2	B2	B1
Population in 2085 (billions)	7.9	14.2	10.2	7.9
GDP growth factor, 1990-2100	525-550	243	235	328
GDP/capita in 2100				
Industrialized countries	$107,300	$46,200	$54,400	$72,800
Developing countries	$66,500	$11,000	$18,000	$40,200
Technological change	Rapid	Slow	Medium	Medium
Energy use	Very high	High	Medium	Low
Energy technologies	fossil intensive	regionally diverse	"dynamics as usual"	high efficiency
Land use change	Low-medium	Medium-high	Medium	High
CO_2 concentration in 2085	810	709	561	527
Global temp change (^oC) in 2085	4.0	3.3	2.4	2.1

Sources: Arnell et al. (2004), Tables 1, 6, 7; Arnell (2004), Table 1.

5. Is climate change likely to be the most important environmental problem facing the globe over the foreseeable future?

5.1 I will attempt to answer this question in the broader context of climate-sensitive hazards and threats that have frequently been cited as causes for concern regarding climate change (see, e.g., King 2004, Parry et al. 2001, Parry 2004). Specifically, with respect to hazards to human health and safety, I will look at the contribution of climate change to the total population at risk (PAR) for malaria, hunger, water shortage, coastal flooding and habitat loss over the foreseeable future. With respect to environmental well-being, I will look at various measures of habitat loss and terrestrial sink capacity.

5.2 Table 2, based on Parry et al. (2004), shows the FTA's estimates of the global population at risk (PAR) for hunger in 2085 both with and without climate change (CC) for each scenario, assuming CO_2 effects are fully operative. In this table and henceforth, PAR in the absence of climate change is denoted by P_0, and the increase in PAR due to climate change by ΔPAR. The total PAR (TPAR) with climate change is the sum of P_0 and ΔPAR.

Table 2
Global population at risk (PAR) in 2085 for hunger with and without further climate change

		Baseline 1990	A1FI 2085	A2 2085	B2 2085	B1 2085
P_0 (no climate change)	millions	798-872	105	767	90	233
ΔPAR (because of CC only)	millions	NA	28	-28 to -9	-11 to +5	10
Total PAR with climate change	*millions*	798 to 872	*133*	*739 to 758*	*79 to 95*	*243*

NOTE: Table is based on results that assume direct CO_2 effects are fully operative (see Section 5.4).
Source: Parry et al. (2004).

5.3 Table 2 indicates that through 2085, the ΔPAR for hunger due to climate change under each scenario is relatively small compared to the contribution of other non-climate-change-related factors. That is, climate change is not as important as the other factors contributing to hunger, at least through the foreseeable future. Most of the population at risk of hunger will be in developing countries. Secondly, eliminating climate change would, at best, reduce TPAR by 21 percent (under the A1FI scenario). At worst, it might increase the total population at risk (under the A2 and, possibly, B2 scenarios). Thirdly, TPAR is not largest under the warmest scenario (A1FI), nor is it smallest under the coolest scenario (B1).[1] Fourthly, under each scenario, TPAR will be lower in 2085 than it was in 1990.

5.4 On the other hand, if CO_2 effects are ignored, then climate change would exacerbate TPAR under each scenario, although ΔPAR would still be less than P_0 for all but the A1FI scenario (Parry et al. 2004). However, the possibility of such an outcome should be tempered by: (a) the low probability that CO_2 effects would be zero, and (b) the high probability that declines in agricultural yield, and therefore TPAR for hunger, are exaggerated because the adaptive responses used in the FTA were based on currently available technologies, not on technologies that would be available in the future or any technologies developed to specifically cope with the negative impacts of climate change (Parry et al., 2004, p. 57). These overestimates are likely to be most pronounced for the A1FI world because, as shown in Table 1, that scenario has the highest levels of economic and technological development, both of which should increase agricultural yields (Goklany 2005b, 2005c).

5.5 Table 2 shows that in comparing outcomes under various scenarios, it is not sufficient to examine only the impacts of climate change. One should also include the impacts of non-climate-change-related factors. Otherwise, based merely on an examination of ΔPAR, one could conclude, erroneously, that with respect to hunger, A2 is the best of the four scenarios and A1FI the worst. But, in fact, based on total PAR, A2 would be the worst, and A1FI the best. This also illustrates that efforts focused on minimizing the consequences of climate change to the exclusion of other societal objectives may not be the most effective method of advancing human welfare.

5.6 The magnitudes of ΔPAR shown in Table 2 are disproportionately large compared to changes in yield due to climate change because small changes in yield lead to large swings in food prices (Goklany

[1] Notably, the results following from Table 2 (and subsequent tables) are unaffected whether impacts are measured in terms of absolute numbers or as a proportion of total population (Goklany 2005b).

2003). For example, the 21 percent increase in PAR in 2085 due to climate change under A1FI is the result of a less than 2 percent drop in the yield. This means that because of climate change, agricultural productivity will increase by 0.80 percent per year between 1990 and 2085 rather than 0.82 percent in the absence of climate change. This suggests that a modest, but sustained increase in agricultural R&D for the next several decades, could more than compensate for any declines in agricultural productivity due to climate change, particularly if the additional investment is targeted toward solving developing countries' current agricultural problems that might be further exacerbated by warming (Goklany 2003).

5.7 Table 3, constructed using Arnell (2004), shows the FTA's estimates of the global population at risk (PAR) for water shortage in 2085 both with and without climate change (CC) for each scenario.

Table 3
Global population at risk (PAR) in 2085 for water shortage, with and without climate change

		Baseline 1990	**A1FI 2085**	**A2 2085**	**B2 2085**	**B1 2085**
P_0, no climate change	millions	1,368	2,859	8,066	4,530	2,859
ΔPAR due to climate change		NA	-1,192	- 2,100 to 0	- 937 to 104	-634
Total PAR with climate change	*millions*	*NA*	*1,667*	*5,966-8,066*	*3,593-4,634*	*2,225*

PAR is measured as the number of people inhabiting countries where available water supplies are less than 1,000 m^3 per person per year. Source: Arnell (2004).

5.8 Table 3 indicates that, just as for hunger, climate change is not as important as the other factors contributing to water shortage, at least through the foreseeable future.

5.9 Table 3 affirms that if the objective is to improve human well-being with respect to water shortage, one should attempt minimize TPAR rather than ΔPAR (all else being equal).

5.10 Eliminating climate change might increase the total population at risk for water shortage under all scenarios except, possibly, the B2 scenario. This illustrates one of the shortcomings of emission reduction strategies, namely, they indiscriminately eliminate the positive as well as the negative impacts of climate change. On the other hand, adaptation approaches will allow societies to selectively capture the benefits of climate change while reducing, if not eliminating, its costs. Notably, the total population at risk (TPAR) for water shortage in 2085 is smallest under the warmest scenario (A1FI).

5.11 With respect to malaria, — a surrogate for other climate-sensitive infectious and parasitic diseases — Arnell et al. (2002), based on a DEFRA-sponsored study which used a scenario that predated the SRES, indicates that the global population at risk in the absence of climate change (P_0) would double from 4,410 million in 1990 to 8,820 million in 2085, while ΔPAR would be between 256 million and 323 million.[2] In other words, no more than 3.5 percent of the total PAR in 2085 can be attributed to climate change (Goklany 2005a).

[2] As part of the FTA, van Lieshout et al. (2004) provided estimates for ΔPAR for malaria. However, they neglected to provide information for either P_0 or TPAR. Hence, the FTA's results for malaria could not be used to estimate the importance of climate change relative to non-climate-change-related factors.

5.12 Table 4, based on Nicholls (2004), shows the FTA's estimates of the global population at risk (PAR) for coastal flooding in 2085 both with and without climate change (CC) for each scenario. For this table, PAR is measured as the average number of people who experience flooding each year by storm surge. These estimates assume that the coastal population grows twice as fast as the general population (or, if populations are projected to drop, it drops at half the pace of the general population), and "evolving" protection with a 30-year lag time. The low and high end of the ranges for PAR for each entry in the table assume low and high subsidence due to non-climate change related human causes, respectively.

Table 4
Global population at risk (PAR) in 2085 for coastal flooding, with and without climate change

		Baseline 1990	**A1FI 2085**	**A2 2085**	**B2 2085**	**B1 2085**
PAR, no sea level rise (SLR)	millions	10	1-3	30-74	5-35	2-5
ΔPAR because of SLR alone	millions	NA	10-42	50-277	27-66	3-34
TOTAL PAR		*10*	*11-45*	*80-351*	*32-101*	*5-39*

Source: Nicholls (2004).

5.13 Table 4 shows that, in contrast to the other climate-sensitive hazards discussed above, the contribution of climate change to TPAR for coastal flooding would substantially exceed that of non-climate-change-related factors. Eliminating climate change could reduce TPAR by as much as 93 percent in 2085 (under the A1FI scenario)

5.14 In terms of the human impacts at the global level, as measured by the number of annual fatalities or the burden of disease, hunger and malaria outrank coastal flooding. According to *The World Health Report 2002*, malaria was responsible for 1.12 million deaths in 2001. It attributes an additional 3.24 million deaths to underweight.[3] By contrast, weather-related floods, waves, surges and wind storms caused fewer than 8,000 fatalities per year from 2000-2004 (EM-DAT 2005), or 0.2 percent of deaths due to malaria and underweight.

5.15 Table 5, based on Levy et al. (2004) and Nicholls (2004), provides projections from the FTA for three specific ecological indicators under different scenarios, namely, the net biome productivity (a measure of the terrestrial biosphere's net carbon sink capacity), the area of cropland (a crude measure of the amount of habitat converted to human use which is perhaps the single largest threat to global terrestrial biodiversity; Goklany, 1998), and the global loss of coastal wetlands relative to 1990 levels.

[3] This estimate excludes an estimated 0.51 million people who died from malaria which were attributed to underweight in the report (WHO 2002).

Table 5

Ecological indicators under different scenarios, 2085-2100

		Baseline 1990	**A1FI**	**A2**	**B2**	**B1**
Global temperature increase (ΔT) (in 2085)	° C	*0*	4.0	3.3	2.4	2.1
Global population (in 2085)	billions	*5.3*	7.9	14.2	10.2	7.9
GDP/capita, global average (in 2085)	$/cap	*3.8*	52.6	13.0	20.0	36.6
CO_2 concentration (in 2100)	ppm	*353*	970	856	621	549
Net Biome Productivity with climate change (in 2100)	Pg C/yr	*0.7*	5.8	5.9	3.1	2.4
Area of cropland with climate change (in 2100)	% of global land area	*11.6%*	5.0%	NA	13.7%	7.8%
Global losses of coastal wetlands in 2085						
Losses due SLR alone	% of current area	*NA*	5 - 20%	3 - 14%	3 - 15%	4 - 16%
Losses due to other causes	% of current area	*NA*	32 - 62%	32 - 62%	11 - 32%	11 - 32%
Combined losses	% of current area	*NA*	35 - 70%	35 - 68%	14 - 42%	14 - 42%

Sources: Arnell et al. (2004); Nicholls (2004); Levy et al. (2004)

5.16 Table 5 shows that net biome productivity, a measure of the terrestrial sink capacity, is projected to increase under climate change, at least through the 21st century, mainly due to the increase in productivity due to higher atmospheric CO_2 concentrations and, to a lesser extent, a reversal of deforestation under the high CO_2 scenarios (i.e., A1FI and A2). Secondly, the area of cropland is expected to be least under the A1FI, the warmest scenario, which should lead to the lowest habitat loss (all else being equal). Thirdly, although sea level rise (SLR) is projected to add substantially to the loss of coastal wetlands, total losses will be dominated by non-climate-change-related factors through at least the 21st century.

5.17 Conclusion. With respect to virtually all the indicators of human and environmental well-being addressed in the foregoing, climate change is unlikely to be the most important problem facing the globe, at least through the foreseeable future. Coastal flooding is the exception to this rule but its contributions to global mortality and burden of disease are relatively minor compared to malaria and hunger.

5.18 Implications. If the objective of policy is to improve human and/or environmental well-being as opposed to reducing damages from climate change as an end in itself, the opportunities to improve well-being are greater if we focus on reducing today's urgent climate-sensitive problems (e.g., malaria, hunger, water shortage and habitat loss). Moreover, measures, systems and processes that would accomplish this would also reduce damages from climate change due to the same problems, whether they occur now or in the future. The issue, of course, is whether one can capitalize on these opportunities more economically than through emission reductions. This is addressed in Section 7.

6. Is the richer-but-warmer (A1FI) world worse than poorer-but-cooler (A2, B1 and B2) worlds?

6.1 Table 6 ranks the four SRES scenarios for each indicator of human and environmental well-being examined in the foregoing.[4] The rankings are based on the total impact in the 2085-2100 period assuming that climate change and its impacts will occur per the FTA's projections. In the ranking scheme, "1" indicates the best level of well-being while "4" indicates the worst. If two scenarios have approximately the same level of well-being then they would split their ranking. For example, scenarios A1FI and B1 share top ranking for carbon sink strength. Accordingly, their joint ranking is indicated as 1.5.

Table 6:
Ranking of scenarios per each indicator of well-being, 2085-2100, assuming climate change

Indicator	A1FI	A2	B2	B1
Indicators of Human Well-Being				
GDP/capita	1	4	3	2
Hunger (PAR in 2085)	2	4	1	3
Water stress (PAR in 2085)	1	4	3	2
Coastal flooding (PAR in 2085)	2	4	3	1
Indicators of environmental quality				
Terrestrial carbon sink strength (in 2100)	1.5	1.5	3	4
Cropland area (in 2100)	1	NA	3	2
Coastal wetland area (in 2085)	3.5	3.5	1.5	1.5

Sources; Table 1, 2, 3, 4 and 5.

6.2 Table 6 assumes that the relative ranking of the scenarios with respect to GDP per capita (a surrogate for per capita wealth or income) will be maintained despite any climate change. This is likely because the gaps in GDP per capita from one scenario to the next are quite large (see Tables 1 and 5) and the impacts of climate change are relatively small through 2085-2100. The other entries in Table 6 suggest that any drop in the GDP per capita due to climate change will be largest for the A2 world and least for the A1FI world (because these scenarios are likely to result in the smallest and largest amount of

[4] This table excludes malaria, since the results for the FTA reported in van Lieshout et al. (2004) provided data for ΔPAR but not enough information to estimate TPAR, which makes it impossible to use their results to estimate the impacts of malaria on well-being. See, e.g., Section 5.5.

climate change impacts on human well-being). Hence, if there is any re-ordering of the ranks for GDP per capita, it would probably be due to B2 and B1 trading places.

6.3 Among the indicators of human well-being (HWB) noted on Table 6, GDP per capita should be given greater weight because it's a surrogate for numerous, and more appropriate, HWB indicators (e.g., life expectancy, mortality rates, access to safe water and sanitation, and level of educational attainment; Goklany 2001a, 2005c). Moreover, as noted earlier, impacts analyses have a general tendency to underestimate changes in adaptive capacity as a function of both economic development and technological progress (or time). Accordingly, Table 6 suggests that human well-being in 2085 would, in the aggregate, be highest for the A1FI scenario and lowest for A2.

6.4 Applying the same logic and considerations, it would seem that HWB should be somewhat better under B1 than B2. Notably, these aggregate rankings would stay the same whether climate changes or not, or whether the rankings are based on PAR in terms of absolute numbers or the proportion of global population.

6.5 With respect to environmental well-being, based on the strength of the terrestrial carbon sink and cropland area, environmental quality would be superior under the A1FI scenario than under either the B1 or B2 scenarios through 2100, but these rankings would apparently be reversed for coastal wetlands, at least through 2085 — "apparently," because that could be an artifact of the assumption that subsidence should/would be lower under the B1 and B2 scenarios than the A1FI scenario despite the latter's greater adaptive capacity (Goklany 2005b).

6.6 Conclusion. From the perspective of human well-being, the richest-but-warmest world characterized by the A1FI scenario would probably be superior to the poorer-but-cooler worlds at least through 2085, particularly if one considers the numerous ways GDP per capita advances human well-being. Human well-being would likely be the lowest for the poorest (A2) world. With respect to environmental well-being, matters may be best in the A1FI world for some critical environmental indicators through 2100, but not necessarily for others.

6.7 Implications. This conclusion casts doubt on a key premise implicit in all calls to take actions now that would go beyond "no-regret" policies in reducing GHG emissions,[5] namely, a richer-but-warmer world will, before too long, necessarily be worse for the globe than a poorer-but-cooler world. But the above analysis suggests this is unlikely, at least until after the 2085-2100 period.

6.8 Assuming that it takes 50 years to replace the energy infrastructure, that means we have at least 30 years (= 2085-50-2005) before embarking on a GHG reduction program that goes beyond "no-regrets" provided, in the interim, we use this time gainfully.

7. Costs and benefits of mitigation and adaptation approaches to reducing the damages of climate change in the short-to-medium term

[5] "No-regret" policies or actions are those can be justified on their own merits without reference to climate change or are not associated with measures that would advance sustainable development or adaptive capacities (through focused or broad adaptation; see Section 7).

7.1 Table 7 is based on the results of DEFRA-sponsored studies reported in Arnell et al. (2002) and Arnell (1999). It provides estimates of the percent reduction in total global populations at risk (TPAR) in the year 2085 for malaria, hunger, water shortage and coastal flooding under four mitigation scenarios, namely, the Kyoto Protocol (KP), stabilization of greenhouse gas concentrations at 750 ppm in 2250, stabilization at 550 ppm in 2150, and "no climate change".

Table 7
Percent reduction in the total global population at risk (TPAR) in 2085 under various mitigation scenarios. Sources: Goklany (2005a), based on Arnell (1999) and Arnell et al. (2002).

Climate-Sensitive Hazard	**% Reduction in total PAR* in 2085**			
	Due to the Kyoto Protocol (KP)	*Assuming stabil-ization at750 ppmv*	*Assuming stabil-ization at550 ppmv*	*Assuming no climate change*
Malaria	0.2%	1.3%	0.4%	3.2%
Hunger	1.5%	16.6%	9.7%	21.1%
Water shortage§	-4.1% to 0.8%			-58.6% to 11.8%
Coastal flooding	18.1%	62.8%	80.1%	86.2%

* Total PAR = (PAR without climate change) + (PAR due to climate change). §A negative sign indicates that emission reductions will increase TPAR. Reductions in water shortage are estimated as the net change in the global population under greater water stress using Arnell (1999). By contrast, Arnell et al. (2002) emphasized the estimates of only the population experiencing greater stress.

7.2 This table assumes, optimistically, that in 2085 the Kyoto Protocol would reduce climate change by 7 percent, which would reduce the impacts of climate change on malaria, hunger and water shortage by a like amount, and the impacts of coastal flooding by thrice that (Goklany 2003).

7.3 By 2085, the Protocol would, at an annual cost of 0.5 percent of the GDP of Annex I nations in 2010 (equivalent to about $165 billion in 2003 US$, market exchange rates; Goklany 2005a), reduce total PAR by 0.2 percent for malaria, 1.5 percent for hunger, and 18.1 percent for coastal flooding. In the near term, however, mitigation would provide virtually no benefits. And through the foreseeable future, there is no certainty that mitigation would not, in fact, increase total PAR for water shortage (see also Table 3).

7.4 On the other hand, measures implemented today and focused on reducing current vulnerabilities to these climate-sensitive hazards would through the foreseeable future provide at least as much benefit as would stabilization at 550 ppm, but at less than a tenth of the cost of the Kyoto Protocol:

- Malaria's current global death toll of about a million/yr can be reduced by 75 percent at an additional cost of $3 billion/yr (UN Millennium Project 2005a). These expenditures may have to be doubled by 2085 to keep pace with the projected increase in the global population at risk in the absence of climate change (see Section 5.11).

- An additional \$5 billion annual investment in agricultural R&D should raise productivity sufficiently to not only erase any climate-change-caused deficit in agricultural production in 2085 (which would eliminate ΔPAR) but also reduce P_0 (the PAR in the absence of climate change) (see also Section 5.6; Goklany 2003, 2005a).
- An annual investment of \$1 billion per year is sufficient to protect coastal areas against a 0.5 meter sea level rise in 2100 (IPCC 1996). Notably, the DEFRA-sponsored studies on which Table 7 is based project that global sea level will rise by 0.41 meters by 2085.

7.5 Such **focused adaptation** measures — so-called, because they focus on reducing damages from specific climate-sensitive hazards — include:

- For malaria: indoor residual (home) spraying with insecticides, insecticide-treated bednets, improved case management, more comprehensive antenatal care, and development of safe, effective and cheap vaccine(s) (WHO 1999, UNMP 2005a).
- For hunger: R&D targeted toward solving the developing world's current agricultural problems that might worsen with climate change, e.g., growing crops in poor climatic or soil conditions (such as drought, highly saline or acidic soils); developing cultivars for conditions likely to prevail in the future regardless of the accuracy of climate models, e.g., higher CO_2 and temperature conditions; high yield, low impact cultivars and agronomic practices so that more crops are produced per unit of land and water; reducing losses at each stage of agricultural and food production – from pre-harvest to post-harvest to end-use (Goklany 1998, 2005c).
- For coastal flooding: early warning systems, evacuation plans, protective structures, and orderly retreat (IPCC 2001).
- For water shortage: institution of transferable property rights to water, water pricing, development of drought resistant crops and more cost-effective methods of precision agriculture (Goklany 2003, 2005c).

7.6 Focused adaptation will not only reduce present-day climate-sensitive problems, it will also help reduce these problems in the future, whether they are caused by climate change or other factors. This is because the technologies, practices, systems, and human and social capital devised to cope with these problems today will aid societies cope with these problems in the future.

7.7 Framing adaptation merely as an approach to reduce ΔPAR, as is done in the *Government Response to the Economics of Climate Change* (House of Lords 2005, pp. 7, 23), is a fatally flawed approach to analyzing and developing climate change policy. Adaptation is correctly viewed to include not only reactive measures to respond to the effects of climate change but also measures that would, by building adaptive capacity, reduce climate-sensitive problems which, however, are not necessarily caused by climate change (Goklany 2005c). Focused adaptation is consistent with this view.

7.8 Because focused adaptation acts on both P_0 and ΔPAR (i.e., the climate change and non-climate-change related components of TPAR), it can, as shown in Section 7.4, provide greater benefits in the foreseeable future than either mitigation or adaptation specifically keyed to react to the impacts of climate change (both of which act only on ΔPAR).[6]

7.9 Focused adaptation can also be proactive since it can be implemented without detailed knowledge of the impacts of climate change (Goklany 2005c).

7.10 Focused adaptation will start to provide a steady stream of benefits in the very near term, while the benefits of mitigation will not be significant until decades have elapsed (because of the inertia of the climate system).

7.11 As the case of water shortage illustrates, mitigation would indiscriminately reduce all impacts of climate change, whether they are positive or negative. But adaptation can capture the positive aspects of climate change, while reducing its negatives.

7.12 While the impacts of global warming are uncertain, there is no doubt that malaria, hunger, water shortages and coastal flooding are currently real and urgent problems. Thus, focused adaptation is far more likely to deliver benefits than is mitigation.

7.13 Not least, co-benefits (or ancillary benefits) of focused adaptation, most of which would flow directly or indirectly from reduced malaria and hunger include better health, increased economic growth, and greater human capital (Goklany 2001a, 2002a, 2005c).

7.14 In addition, measures such as those listed in Section 7.5 to reduce hunger and water shortage would enhance agricultural productivity per unit of land and water. In turn, that would:

- Reduce human demand for agricultural land and water, which is the greatest current threat to both terrestrial and freshwater biodiversity.
- Aid mitigation by limiting land under cultivation which would reduce losses of carbon stores and sinks, and the socioeconomic costs of reserving land for conservation or carbon sequestration.

Notably, the general strategy and many measures outlined above for the demand for food by the productivity of the food and agricultural sector are generically applicable to forestry and would have similar co-benefits with respect to conserving biodiversity and aiding mitigation (Goklany 2005c).

7.15 Focused adaptation would advance sustainable development through all the avenues listed in Sections 7.6 through 7.14.

7.16 The conclusion that focused adaptation is for the foreseeable future superior in terms of both global benefits and global costs is robust to the choice of discount rates, including a zero discount rate.

7.17 The fact that (a) the determinants of adaptive and mitigative capacities[7] (e.g., availability of technological options, and access to economic resources, social capital and human capital) largely overlap, (b) many factors underlying or related to these determinants are themselves indicators of sustainable development (e.g., per capita income; and various public health, education and research indices), and (c) climate change could exacerbate existing climate-sensitive hurdles to sustainable

[6] Mitigation may be accompanied by some "co-benefits" (Goklany 2005d)

[7] "Mitigative capacity" is the capacity to mitigate greenhouse gas concentrations in the atmosphere (IPCC 2001, Yohe 2001).

development (e.g., hunger, malaria, water shortage, coastal flooding and threats to biodiversity) faced specifically by many developing countries, allow us to identify and develop integrated approaches to formulating strategies and measures to concurrently advance adaptation, mitigation and sustainable development (Goklany 2005c). These approaches range from broadly moving sustainable development forward (by developing and/or nurturing institutions, policies and infrastructure to stimulate economic development, technological change, human and social capital, and reducing specific barriers to sustainable development) to focused adaptation (which would reduce specific vulnerabilities to urgent climate-sensitive risks that hinder sustainable development and would be exacerbated by climate change).

7.18 A co-benefit of these approaches is that, based on empirical evidence, economic development should reduce birth rates, thereby mitigating all manner of population-related environmental and natural resource problems and reducing population exposure to risks related to those problems, including climate-sensitive problems such as hunger (see Table 2), water shortage (see Table 3) and malaria (see Section 5.11) (Goklany 2005c).

7.19 One way to broadly advance sustainable development — and adaptive and mitigative capacities — would be through striving to meet the Millennium Development Goals (MDGs).

7.20 Such an approach, which I label **broad adaptation**, would subsume focused adaptation because it is broader in scope, and provides the same qualitative advantages as listed in Sections 7.6 through 7.16 for focused adaptation, while providing substantially larger benefits. Specifically for the MDGs, these benefits include halving global poverty, hunger, lack of access to safe water and sanitation; reducing child and maternal mortality by 66% or more; universal primary education; and reversing growth in malaria, AIDS/HIV, and other major diseases.

7.21 The additional annual cost to the richest countries of attaining the Millennium Development Goals (MDGs) by 2015 is pegged at about $143 billion (in 2003 US$) in 2010, according to the UN Millennium Project (2005b). That is somewhat below the cost of the barely-effective Kyoto Protocol, and less than the cost of stabilization at either 750 or 550 ppm.

7.22 Table 8 compares the costs and benefits of the Kyoto Protocol, stabilization at 550 ppm, focused adaptation and the MDGs. In this table, for focused adaptation I have arbitrarily tripled the cost estimate provided in Section 7.4 for protecting coastal areas through 2085 against a sea level rise of 0.5 m. The table assumes that, consistent with IPCC (1996), such protection would reduce total PAR for coastal flooding by at least as much as would halting climate change. This level of protection (and associated cost) has also been grafted on to the MDG column because these goals do not explicitly address coastal flooding.

7.23 <u>Conclusions</u>. Table 8 indicates that either focused or broad adaptation would, over the next several decades, deliver much greater benefits at lower costs than would any mitigation scheme.

7.24 Increasing adaptive capacity, whether through pursuit of MDGs or through focused adaptation could raise the level at which GHG concentrations might become “dangerous” and/or allow mitigation to be postponed. In either case, the overall cost of mitigation could be reduced, especially if measures are taken in the interim to improve the cost-effectiveness of mitigation technologies.

Table 8: Comparing Benefits and Costs Associated with Mitigation, Focused Adaptation and Broad Adaptation (as exemplified by the Millennium Development Goals, MDGs). Sources: Updated from Goklany (2005a). For costs, IPCC (2001), World Bank (2005) and UN Millennium Project (2005a, 2005b); for reduction in risks, Table 7, World Bank (2002), UN Millennium Project (2005a, 2005b) .

Risk factor	**Dependence of risk factor on climate change (CC)**	**Reduction in Total PAR[a]**			
		Due to Kyoto Protocol (in 2085)	**Due to a halt in CC (in 2085)**	**Focused adaptation (in 2085)**	**Due to MDGs (in 2015)**
Malaria[b,c]	Yes	0.2%	3%	75%[f]	75%[f,h]
Hunger[b,c]	Yes	2%	21%	>21%[d]	50%
Water shortage	Yes	-4 to +1%	-59 to +12%	+	Not addressed explicitly
Coastal flooding[c]	Yes	18%	86%	>86%[g]	>86%[g]
Poverty[b,c]	Indirect	Unknown sign, but small	Unknown sign	++[b,e]	50%
Child mortality rate[b,c]	Indirect	Small +	+[e]	++[b,e]	67%
Maternal mortality rate[b,c]	Indirect	Small +	+[e]	++[b,e]	75%
Lack of access to safe water[c]	No	No effect	No effect	No effect	50%
Lack of access to sanitation[c]	No	No effect	No effect	No effect	50%
Lack of primary education[b,c]	No	Minor +[e]	Small +[e]	+[b,e]	100%
AIDS, TB[b,c]	No	No effect	Zero to small +[e]	+[b,e]	++
Annual costs		**~ $165 billion in 2010**	**>> cost of Kyoto Protocol**	**~$10-20 billion/yr**	**~$145 billion in 2010**

NOTES: (a) + denotes a positive reduction in P, while ++ denotes a larger positive reduction. (b) Reductions in malaria and/or hunger should directly or indirectly reduce risks associated with each other, poverty, child and maternal mortality rates, educability, AIDS and TB. (c) Risks associated with these categories should decline with economic development. (d) Assumes $5 billion extra per year for agricultural R&D. (e) Indirect improvements because hunger/malaria would be reduced under focused adaptation. (f) Assumes $6 billion per year would reduce malaria by three-quarters (see Section 7.4). (g) Assumes $3 billion per year spent on coastal protection, which is thrice the estimate for protection against a 0.5 meter sea level rise per IPCC (1996) (see Section 7.4). (h) The 75% reduction exceeds the formally adopted MDG, but it is the target established by the UNMP task force (UNMP 2005a).

7.25 Implication: Consistency with UNFCCC's ultimate objective. Either adaptation approach would be consistent with the UN Framework Convention on Climate Change's objectives outlined in Article 2, namely, "to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner" (Goklany 2003). First, either would reduce emissions. Second, by limiting habitat loss, they would also limit loss of wildlife corridors and fragmentation of habitat (see Section 7.14). And if anything can aid "ecosystems to adapt more naturally to climate change", it would be limiting habitat fragmentation and conserving corridors. That would help species migrate and disperse, with less need for human intervention. Third, either approach would reduce threats to food production. Finally, they would also contribute to sustainable economic development, particularly in developing nations where employment is usually heavily dependent on the agricultural sector (see Section 7.15 through 7.18; Goklany 2005c).

8. Additional issues relevant to adaptation and mitigation

8.1 This section discusses various additional issues relevant to mitigation and adaptation. While mitigation and adaptation are not — nor should they be — mutually exclusive (see Section 9), much of the following discussion compares the two as if they are.

8.2 Conference on Avoiding Dangerous Climate Change. The UK Government Response to the House of Lords Select Committee on Economic Affairs' Report on the Economics of Climate Change makes much about the February 2005 Exeter conference on "Avoiding Climate Change" (see pp. 7 and 12 of that response). As a participant at that conference, I must note that there was no consensus report produced by that conference, although there was a Chairman's report, the details of which were not fully discussed and drew protests from some participants. The conference did provide much information on what is possible, but much less information on what is probable and in what time frame.

8.3 Which is better insurance — adaptation or mitigation? Some have argued for mitigation as an insurance policy. Table 8 shows that in the short-to-medium term, mitigation would, as an insurance policy, carry a hefty premium if it goes beyond "no-regret" actions. On the other hand, enhancing adaptive capacity will, by addressing urgent and larger existing problems, pay handsome dividends whether or not climate changes. In that respect, these adaptive approaches are better than a climate insurance policy which would pay off only if human-induced climate change is a fact. And if climate changes, either adaptive approach will help reduce attendant risks much more contemporaneously with incurred costs than is possible through mitigation.

8.4 Which is more precautionary — adaptation or mitigation? Some have invoked the precautionary principle as an argument for going beyond no-regret actions to mitigate GHG emissions. Table 8, however, indicates that in the short-to-medium term the precautionary principle would be better-served by addressing today those urgent climate-related hurdles to sustainable development that could be aggravated by future climate change, especially if that leads to some near-term mitigation, advances mitigative and adaptive capacities, and is complemented by efforts to: (a) implement no-regret mitigation actions, and (b) expand and improve the cost-effectiveness of mitigation options (through greater investments in science and technology) so that in the future, mitigation, if and when it becomes necessary, is more affordable and effective (Goklany 2003).

8.5 Is it fairer to expend resources on adaptation or mitigation? Table 8 shows that resources expended in the short-to-medium term on mitigation that goes beyond no-regrets could be put to better use in reducing current risks and vulnerabilities (see also Schelling 1995; Dowlatabadi 1997; Goklany 2000, 2003, 2005a; Tol and Dowlatabadi 2001, Lomborg 2004). Focused and broad adaptation would provide benefits in both the short and the long term. On the other hand, the major share of the benefits of mitigation are likely to occur in the longer term. It might, therefore, be more equitable, especially to present generations, to expend resources on the adaptive strategies now and defer purely mitigation actions for a few years until they can better pay for themselves, especially since future generations are, according to the IPCC's scenarios (see Table 1), likely to be wealthier, have greater access to technology and human capital, and should, therefore, be able to solve many of their problems with relatively greater ease (Goklany 1992, 2000, 2003).

8.6 Adaptation is unfair because those adapting are not the ones responsible for climate change. Some claim that adaptation could be "unfair" since those doing the adapting are "not always responsible for causing climate change" (Dang et al. 2003, p. S84) and that responsible parties should compensate those who are not. However, before assigning responsibility, one has to first determine who is "responsible" and for what. On that score, while it is possible to assign greenhouse gas (GHG) emissions to nations based on where the act of burning a ton of coal, for instance, physically occurs, we should be cognizant that GHG emissions are the effluvia of civilization and all its activities. It is not only energy consumption that contributes to it, but land clearance, crop production, animal husbandry, trade, tourism, and so forth. Moreover, because of the globalized economy, which sustains today's civilization, economic activity in one country helps provide livelihoods and incomes for many inhabitants of other countries, and vice versa. In fact, a substantial portion of economic growth in developing countries is attributable to trade (Goklany 1995), and remittances and tourism from developed countries. Without such economic activities, U.S. emissions, for example, might be lower, but so would jobs and incomes elsewhere (e.g., in India or Bangladesh). Thus, the improvements in human well-being that have occurred in many developing countries (particularly since World War II) are partly due to the GHG-fueled economic growth in developed countries (Goklany 2002b).

8.7 Greenhouse gas fueled economic growth also enabled today's rich societies to invest in research and development that helped, for instance, raise crop yields worldwide, develop new and more effective medicines (e.g., for HIV/AIDS), provide aid in times of famine or other natural disasters, provide funding for reducing TB and malaria, create and support the Internet, and other items now considered by some to be global public goods (ODS 2003). Also, absent such economic growth, the sum of human capital worldwide would have been much less — consider, for instance, the millions of non-Americans who have been cycled through universities in the US who, then, have gone back to help in their native countries' economic and technological development. Thus, all countries indulge in or benefit from activities that lead to global warming (GW). Hence, before determining responsibility and/or compensation one should try to estimate whether direct and indirect costs of GW will, in fact, exceed direct and indirect benefits.

8.8 It might be argued that if the actions of A produce both benefits and harms to B, A should compensate B for the harms, but she cannot subtract the benefits in escaping responsibility (because, after all, B did not solicit A to undertake the actions in question). This would be disingenuous because benefits are nothing but negative harms, and should, therefore, necessarily be subtracted in estimating net harm to B. Also, if B insists on not subtracting benefits from the compensation package, he loses his moral claim for any compensation. In other words, one can't insist on compensation on one hand, and be a free rider on the other.

8.9 Some might also argue that one should not take indirect effects of GHG-producing activities into consideration: only direct effects should be considered. But the notion of assigning responsibility (or demanding compensation) for climate change is itself based on indirect (and inadvertent) outcomes. After all, developed countries did not emit GHG emissions with express intent to harm anyone. There has to be symmetry in these matters.

8.10 Let's assume for the sake of argument that one can indeed estimate the fraction of global warming caused by the USA (for instance), the next step is to estimate the net harm that has been caused to, say, Bangladesh (ignoring for now issues such as whether today's generation should be liable for damages incurred by previous generations). To make such estimates, it is not sufficient to know the direct impacts of climate change on Bangladesh, but also the indirect consequences of all GHG producing activities. This involves developing answers to questions such as: had there been no GHG producing activities in developed countries, what would have been Bangladesh's level of human well-being? What would be its life expectancy (which is currently 62 years and was about 35 years in 1945) had there been no GHG emissions in the interim? What about its hunger and malnutrition rates? How many Bangladeshis were saved in the 1960s and 1970s because of food aid from the developed countries? How much of the past increase in Bangladesh's agricultural productivity is due to higher CO_2 levels, or indirectly due to efforts that were possible because developed countries were wealthy enough to support/stimulate them? Assuming in the future, agricultural productivity declines due to climate change, how do you subtract out past benefits from future harms? These are just a small sample of issues that have to be addressed before assigning responsibility to various actors for climate change.

8.11 Adaptation is unfair because it lets those responsible for climate change off the hook. Some regard adaptation as inherently inequitable because, arguably, it might let off the hook those "responsible" for climate change. Even if one could assign responsibility for climate change, it does not follow that it would be more fair if developed nations were to expend resources on ambitious mitigation measures now based partly on the premise that it would reduce future climate change risks for developing nations, when the same resources would, in the short-to-medium term, provide greater and faster benefits to precisely those nations by reducing existing — and generally larger — climate-sensitive risks and vulnerabilities (see Table 8).

8.12 Adaptation is of little use in reducing threats to biodiversity and ecosystems. Among the many misconceptions about adaptation is that it is of limited utility in reducing threats to biodiversity and natural systems. However, as noted in Sections 7.14 and 7.25, several actions available today would reduce pressures on terrestrial and freshwater biodiversity while also reducing hunger and advancing sustainable development.

8.13 Global trends in deaths and death rates due to extreme events. Climate change could change the frequencies, magnitudes and spatial and temporal distributions of extreme weather events. Accordingly, to estimate trends in the consequences of extreme events one ought to look at cumulative death (and death rates) at a global level due to all types of extreme events instead of looking for trends for each of the types of events.

8.14 Figure 1, based on data from EM-DAT, the International Disaster Database maintained by the Office of Foreign Disaster Aid and Center for Research on the Epidemiology of Disasters at the Université Catholique de Louvain, Brussels, Belgium, shows aggregate global trends in deaths and death rates between 1900 and 2004 for "weather-related extreme events", namely, droughts, extreme temperatures (both extreme heat and extreme cold), floods, landslides, waves and surges, wild fires and wind storms of different types (e.g., hurricanes, cyclones, tornados, typhoons, etc.).[8] It indicates that both death and death rates have trended downward since the 1920s. Comparing the 1920s to the 2000-2004 period, the annual number of deaths has declined from 485,200 to 19,400, a 96 percent decline, while the death rate per million has declined from 241.8 to 3.1, a decline of 98.7 percent.[9]

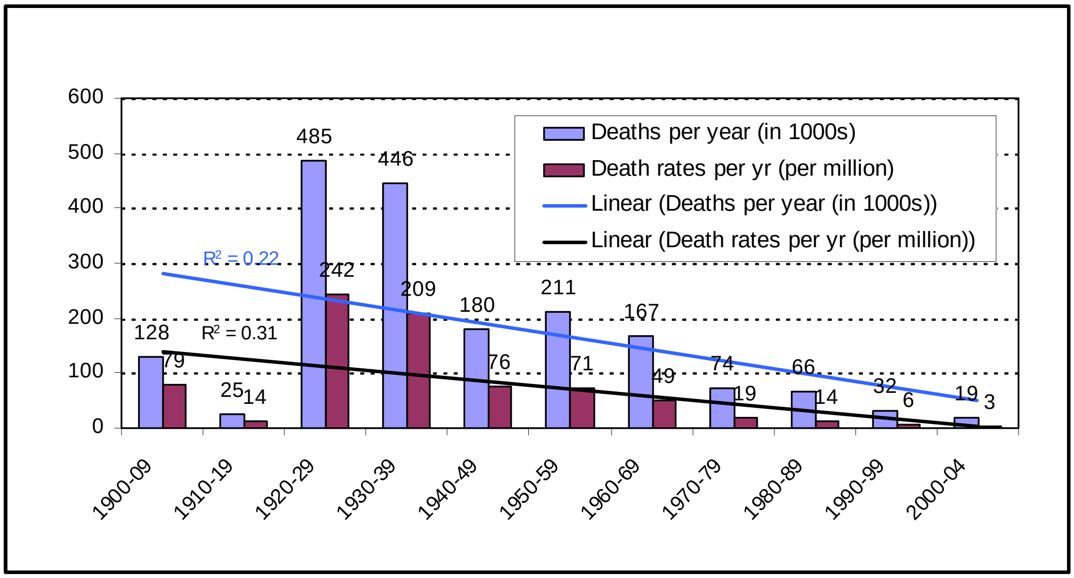

Figure 1: Global Death and Death Rates Due to Extreme Events, 1900-2004. Sources; EM-DAT (2005); McEvedy and Jones (1978); WRI (2005).

8.14 The 19,400 annual deaths due to all weather-related extreme events accounts for 0.03 percent of global deaths. [In 2002 a total of 57.0 million people died worldwide from all causes, including 2.8

[8] EM-DAT contains data on the occurrence and effects of over 12,800 mass disasters in the world from 1900 to present. The data are compiled from various sources, including UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies. For a disaster to be entered into the database one or more of the following criteria must be met: (a) at least 10 people must have been reported killed, (b) at least 100 people must have been reported as affected, (c) a state of emergency must have been declared, or (d) there should have been a call for international assistance. Figure 1 is constructed using data the following sources: (1) For deaths, EM-DAT (2005). (2) For population from 1900-1925, McEvedy & Jones (1978). (3) For population from 1950-2004, World Resources Institute (2005). (4) For population from 1926-1949, estimates were based on interpolation for each year using the 1925 estimate from McEvedy and Jones and the 1950 WRI estimate, assuming exponential population growth. Death estimates, in particular, are approximate and more likely to be in error as we go further into the past. Although EM-DAT is not quite complete, it should have captured the major natural disasters, particularly in recent years.

[9] These numbers include 45,755 deaths due to the 2003 heat wave in Europe.

million from HIV/AIDS, 1.8 million from diarrhoeal diseases, 1.3 million from malaria and 129,000 from other tropical diseases (WHO 2004).]

8.15 Trends in global deaths and death rates are generally consistent with US trends for floods, tornadoes, hurricanes, and lightning over the last several decades (Goklany 2000).

8.16 By contrast, trends in property losses in the US (measured in constant dollars) due to floods and hurricanes (individually) due to extreme events have gone up. However, when the losses are measured in terms of the wealth at risk, there are no obvious trends up or down (from the 1920s through 2004; Goklany, in preparation). This suggests that the increasing magnitude of losses in constant dollars is due as much (or more) to socio-economic factors than to any climate change (Goklany 2000, Pielke and Landsea 1998, Landsea et al. 1999, Downton et al. 2005).

8.17 Recent disasters due to extreme meteorological events (e.g., the 2003 heat wave in Europe, and Hurricanes Katrina and Rita) argue for improvements in adaptive capacity, including human and social capacity, to help cope with such challenges. Mitigation efforts, such as the Kyoto Protocol, for instance, would have accomplished virtually nothing in terms of reducing damage to life and property.

9. A climate change policy for the near and medium term

9.1 In the near-to-medium term, because of the inertia of the climate system, the benefits of mitigation are relatively small compared to its costs (see Tables 7 and 8). On the other hand, increasing adaptive capacity would improve well-being relatively rapidly while also reducing current and future damages from climate change.

9.2 In the near-to-medium term, the impacts of climate change on human and environmental well-being are for most indicators relatively small compared to the impacts of non-climate change related factors (Section 5.17). Therefore, greater improvements in well-being are possible during this period through advances in adaptive capacity (either through broad advances in sustainable development or focused adaptation).

9.3 In the long term, however, the adverse impacts of climate change should grow while the impact of non-climate change related factors may diminish. Therefore, sooner or later mitigation is inevitable.

9.4 The issue, consequently, isn't whether adaptation or mitigation should be the sole approach to deal with climate change. Clearly, both approaches are necessary.

9.5 The issue, in fact, is one of the magnitude and relative balance of resources expended on these approaches, and how they might shift with the passage of time.

9.6 Regardless of when mitigation becomes necessary, "no regret" actions should be taken without further ado. Such actions include, as a general rule, removal of subsidies which contribute to greenhouse gas emissions, e.g., subsidies that lead to greater use of energy, fertilizer and land.

9.7 Through 2085, climate change is projected neither to be the most important environmental problem facing the globe nor to significantly diminish human or environmental well-being (Section 6).

Therefore, if it takes 50 years to replace the energy infrastructure, that means we have at least 30 years (= 2085-50-2005) before selecting hard and fast targets for an ambitious GHG reduction program that goes beyond "no-regrets".

9.8 With aggressive adaptation efforts (such as those outlined in Section 7) it should be possible to buy even more time. Increasing adaptive capacity, whether through pursuit of MDGs or through focused adaptation, could raise the level at which GHG concentrations might become "dangerous" and/or allow mitigation to be postponed. In either case, the net present value cost of mitigation would be reduced. In the interim, we should strive to make mitigation more cost-effective so that, if or when mitigation becomes necessary, net costs would be lower even if emission reductions have to be more drastic.

9.9 Conclusion. In the near-to-medium term, we should pursue a broad adaptive strategy based on advancing sustainable development. Secondly, we should take focused adaptation measures now to reduce vulnerability to today's urgent climate-sensitive risks — hunger, malaria, water shortages, coastal flooding, extreme events, and pressures on biodiversity — that could be exacerbated by warming. Together, these efforts would improve human and environmental well-being and enhance adaptive capacity of developing countries, which, it ought to be remembered, are most vulnerable to climate change. This can be accomplished more broadly by striving to augment economic resources, human capital, and the propensity for technological change. That would also advance sequestration and enhance mitigative capacity. Thirdly, we should ensure that "no-regret" mitigation measures are implemented while constantly expanding the universe of such measures through R&D designed to improve their cost-effectiveness. Finally, we should continue to advance knowledge of climate change science, economics and responses to better evaluate and determine trade-offs and synergies between adaptation and mitigation, and continue to monitor trends to provide advance warning should the adverse impacts of warming occur faster, or threaten to be more severe or more likely than is currently projected

9.10 Such a climate policy would solve some of most critical problems facing the world today and tomorrow while preparing it to address the uncertain problems of the day after tomorrow, of which climate change is but one among many.

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