Is Climate Change the 21st Century's Most Urgent Environmental Problem?

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INTRODUCTION

Some have argued that the Kyoto Protocol and other schemes for immediately mitigating greenhouse gas (GHG) emissions are justified because human-induced global warming is, in the words of the 42nd U.S. President, William J. Clinton, "the overriding environmental challenge" facing the globe today.[1] Another argument, advanced by those who are more cautious and perhaps less prone to hyperbole, is that the impacts of global warming – on top of myriad other global public health and environmental threats – may prove to be the proverbial "straw that broke the camel's back." They suggest that climate change will overwhelm human and natural systems by increasing the prevalence of climate-sensitive diseases, reducing agricultural productivity in developing countries, raising sea levels, and altering ecosystems, forests, and biodiversity worldwide.[2]

In this paper, we first examine global warming impacts to date – the good, bad and indifferent effects. We next analyze the impacts of global warming into the foreseeable further. Thirdly, we ask whether it is more effective to rely on mitigation (emission reduction) strategies, or on adaptation approaches to climate change impacts. (In this analysis, "adaptation" implies measures, approaches, or strategies that would help cope with, take advantage of, or reduce vulnerability to the impacts of global warming.)

GLOBAL WARMING IMPACTS TO DATE

According to the Intergovernmental Panel on Climate Change (IPCC), over the last century or more, the earth has warmed 0.4 to 0.8 ^{o}C, perhaps due in part to man's influence.[3] Over this period, there have been changes in many climate-sensitive environmental indicators or sectors of the economy — some for the better, others for the worse, and for others, neither better nor worse (good, bad and indifferent changes).

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The Good

For many critical climate-sensitive sectors and indicators, matters have actually improved, especially during the last half century.[4] Global agricultural productivity has never been greater, for instance.

An acre of cropland sustains about twice as many people today as it did in 1900, and it sustains them better. Based on nutrition and affordability of food, people have never been fed better or more cheaply. Between 1961 and 2001, global food supplies per person increased 24 percent, although global population almost doubled.[5] Between 1969-71 and 1998-2000, the number of people in developing countries suffering from chronic hunger declined from 35 percent to 17 percent or, in absolute terms, from 917 million to 799 million despite a 79 percent growth in population in developing countries.[6]

In wealthier countries, deaths due to climate-sensitive infectious and parasitic diseases are now the exception rather than the rule. Such deaths are declining in most developing countries thanks to better nutrition and public-health measures. Accordingly, from 1960 to 2000, the global infant mortality rate dropped by 57 percent, and global life expectancy at birth increased from 50.2 to 66.5 years.[7] However, in the last 10 to 15 years, these improving trends have been reversed in many sub-Saharan African and former communist countries, not because of climate change, but because of increasing poverty, AIDS, and malaria.[8]

Another climate change concern is that severe weather events could become more extreme and, therefore, more destructive. Indeed, increased population and wealth have put more people and property at risk. For example, this factor has contributed to an increase in U.S. property losses from floods and hurricanes over the last century. Significantly, there are no clear trends in losses in terms of the fraction of wealth that these losses represent.[9]

More significant, based upon nine-year averages, U.S. death rates due to hurricanes, tornados, floods, and lightning decreased between 60 and 99 percent, compared with their earlier peaks during this century (overall deaths declined between 46 and 97 percent).[10] Similarly, globally, the average deaths per year from climate and weather related events declined by over 95 percent between the 1930s and 2000-2003, while death rates declined overall by 98.5 percent (see Figure 1).[11]

The Bad

For other climate-sensitive indicators matters have, indeed, worsened. So far, however, human-caused warming has had little to do with these declines.

Consider sea level rise. Mean sea level is rising at a rate of about 0.1 to 0.2 mm per year.[12] While it is not known what fraction, if any, might be due to any human-caused warming, the IPCC's Science Assessment notes that there was no detectable acceleration of sea level rise during the 20th century.[13] Suffice it to say, so far, any accelerated sea level rise due to man-made warming is unlikely to have caused anything other than a minor impact on human or natural systems compared to other environmental stresses (such as development of coastlines, conversion of lands for aquaculture, drainage for other human land uses, sediment diversion due to dam construction, con-

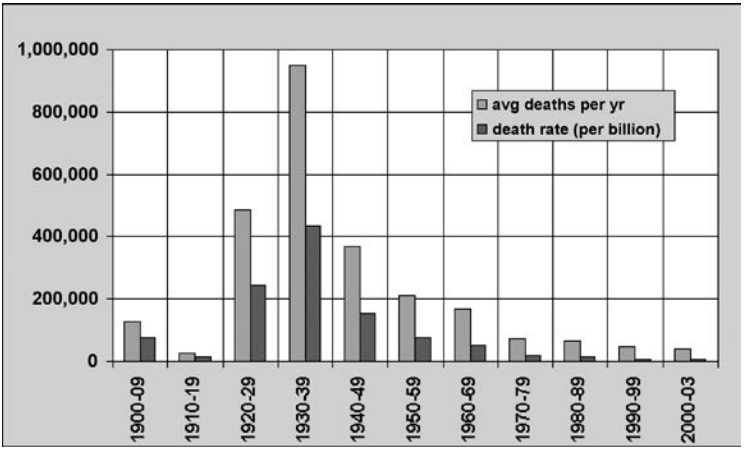

Figure 1. Global deaths and death rates from climate–related disasters (includes deaths from drought; extreme temperature; famine; flood; slides; wave/surge; wild fires; wind storm), 1900–2003. Sources: Emergency Disasters Data Base (2004), McEvedy & Jones (1978), and FAO (2004).

struction of seawalls, and subsidence owing to water, oil and gas extraction).[14]

Agricultural demand for water – probably the largest threat to freshwater species – continues to increase.[15] Meanwhile, threats to terrestrial biodiversity – primarily the conversion of habitat to agricultural uses[16] – have not diminished. Forested area declined by 124 million hectares (306 million acres) in tropical and subtropical nations between 1990 and 2000.[17] This decline, which occurred largely because increases in food demand outstripped increases in agricultural yields in those nations, is unrelated to global warming. During the same period, forest cover in the rest of the world (mainly wealthy nations) expanded by 28 million hectares (69 million acres) primarily because technology-based, high yield agriculture has reduced the demand for cropland in those countries.

The Indifferent

As the higher latitudes have become warmer, spring has arrived earlier since the 1960s. As a result, we observe "earlier breeding or first singing of birds, earlier arrival of migrant birds, earlier appearance of butterflies, earlier choruses and spawning in amphibians, earlier shooting and flowering of plants.[18] This has been accompanied by later arrival of autumn and autumn colours in some places.

A meta-analysis of trends for 99 species of birds, butterflies and alpine herbs, found significant range shifts averaging 6.1 km per decade towards the poles.[19] It also found a significant mean advancement of spring events by 2.3 days per decade based on data for 172 species of shrubs, herbs, trees, birds, butterflies and amphibians.[20] Clearly, there have been changes, but are these changes adverse?

The Finnish branch of the World Wildlife Fund notes, for example, that:

> Thanks to the warming trend, the growing season has grown .... At the same time the spring migration of birds, including finches, larks, wagtails, and swifts, has begun an average of ten days earlier than before.
>
> The warmer temperatures have brought new, more southerly species of butterflies to Finland. Many existing types of butterflies have extended their habitats further north.[21]

According to the Royal Society for the Protection of Birds, some birds in the U.K. have also become more abundant, possibly due to milder winters.[22] Similarly, the ranges of 15 butterfly species in the U.K. have expanded substantially since the 1970s, "almost certainly" because of warming (whether or not human-induced).[23] Butterflies also appear earlier in the year and some have been able to spawn an extra generation during the summer. In addition, some moths, crickets and dragonflies have migrated into the U.K. [24]

With respect to vegetation, a study of the earliest flowering dates of 385 wildflower species in the United Kingdom shows that on average they bloomed more than 4.5 days earlier in the 1990s compared to their 1954 to1990 average, with 16 percent blooming significantly earlier, while 3 percent bloomed significantly later. One plant bloomed fully 55 days earlier.[25] Similarly, the ranges of flowering plants and mosses seem to have expanded in the parts of Antarctica that have warmed.[26] Soil invertebrates have also advanced with changes in vegetation.[27]

Obviously, warming (whether due to man's activities or nature's machinations) seems to have a measurable impact on the distribution and abundance of species, but it is far from clear whether these changes are beneficial or detrimental. More importantly, the major current threats to species come from habitat modification and loss, water diversions, and invasive species, perhaps in that order, rather from climate change.

Summary

Despite any warming, by virtually any climate-sensitive measure of human well-being, human welfare has improved over the last century.[28] While some credit for increasing agricultural and forest productivity is probably due to higher carbon dioxide concentrations and higher wintertime temperatures, most of these improvements are due to technological progress driven by market — and science — based economic growth, technology, and trade.[29] Such progress has also reduced human vulnerability to the effects of climate change.[30] As a result, technological progress has so far had a greater impact on the climate-sensitive measures than has climate change itself.[31]

On the other hand, matters may actually have deteriorated for some climate-sensitive environmental indicators, such as the loss of habitat and forests, and threats to biodiversity. However, so far, climate change (human-induced or not), while contributing to change, seems to be responsible for little, if any, of this deterioration.

On the basis of current evidence, it is difficult to sustain the notion that climate change is the greatest threat to public health or the environment today. But what about the future?

THE FUTURE WITH AND WITHOUT GLOBAL WARMING

How important is global warming, relative to other factors that might affect public health and the environment into the "foreseeable future"? Table 1 puts climate change impacts in perspective. This table is based, for the most part, on a set of impact studies sponsored by the U.K. Department of Environment, Food, and Rural Affairs (DEFRA). Many of these studies have been incorporated into the IPCC's 2001 Third Assessment Report (TAR). Because the DEFRA-sponsored assessments did not provide an estimate of future forest cover in the absence of climate change, it was necessary to rely on other studies reported by the IPCC for that estimate.

Analysts involved in the DEFRA studies recognized that socioeconomic projections are "not credible" beyond the 2080s.[32] Table 1, therefore, reflects this concession to reality. Although the TAR states that between 1990 and 2100, global temperature might increase from 1.4 to 5.8^{o}C, it also notes that "on time scales of a few decades, the current observed rate of warming...suggests that anthropogenic warming is likely to lie in the range of 0.1 to 0.2^{o}C per decade over the next few decades."[33]

The scenarios employed in the DEFRA-sponsored impact assessments are based on globally-averaged temperature increases of slightly more than 0.3^{o}C per decade;[34] therefore, they may overestimate likely impacts to the 2080s.

Column 3 in Table 1 provides estimates of various public health and environmental risks, or factors related to those risks, under baseline conditions in the 2080s (i.e., in the absence of global warming). Column 4 provides the changes in risks or risk-related factors in the 2080s due to the imposition of global warming, above and beyond baseline conditions. Finally, column 5 provides estimates of reductions in total risks, or risk-related factors, due to full implementation of the Kyoto Protocol, assuming that the Protocol would reduce temperature change between 3 to 7 percent by 2100.[35] The Kyoto Protocol, thus, would reduce the impacts of global warming by less than 7 percent for all risk categories except coastal flooding. For the latter, it is assumed that the Protocol will decrease the impact of climate change by about three times that.[36]

The data in Table 1 indicate that:

- In the absence of warming, (that is, in the "baseline" case), global cereal production would increase by 123 percent — from 1,800 megatons in 1990 to 4,012 megatons in the 2080s — in response to the additional food demand of a larger and wealthier global population[37]. Such an increase is plausible provided: 1) agricultural technology continues to enhance productivity, 2) sufficient investments are made in the agricultural sector and related infrastructure, and 3) trade continues to move food from surplus areas to deficit areas.[38]

Due to global warming, agricultural production may decline in poor countries, but may increase in wealthy countries, resulting in a net decline in global production of 100 megatons to 160 megatons (i.e., 2 to 4 percent of total production in the absence of warming) in 2080. Thus, downturns in economic growth (which would inhibit investments in the agriculture and infrastructure), slower technological change, or less voluntary trade of food supplies are more likely to create a future food crisis than any potential global warming.[39] Notably, the Kyoto Protocol would result in a marginal improvement in production of less than 0.3% in the 2080s.

Table 1: Projected Climate Change Impact in the 2080s, Compared to Other Environmental & Public Health Problems

Climate-Sensitive Sector/Indicator	**Year**	**Impact/Effect**		
		Baseline (B) in the 2080s, includes impacts of environmental problems other than climate change	*Impacts of climate change (ΔCC) in the 2080s, on top of the baseline*	*Impacts of Kyoto Protocol in 2080s, relative to baseline+ΔCC**
Global Agricultural (cereal) Production	2080s	4,012 million metric tons (MMT), vs 1,800 MMT in 1990	production would drop 2% to 4%; and could be substantially redistributed from developing to developed countries	increase net global production by 0.1% to 0.3%
Falciparum Malaria (population at risk, PAR)	2080s	8.82 billion at risk by the 2080s, vs. 4.41 billion in 1990	increase PAR by 0.26 to 0.32 billion (or 2.9% to 3.7%)	reduce total PAR by 0.2% to 0.3%
Water Resources(population in countries where available resources use >20%)	2085	6.46 billion, vs. 1.75 billion in 1990	impact of PAR of -2.39 billion to +1.06 billion (or -27.0% to 14.1%)	impact total PAR from reducing it by 1.0% to increasing it by 4.1%
Global Forest Area	2050s-2080s	decrease 25-30(+)% by 2050, relative to 1990	increase by 5%, relative to 1990	reduce the increase in global forest area by 0.4%

Table 1: Projected Climate Change Impact in the 2080s, Compared to Other Environmental & Public Health Problems

Table 1 (continue):

Climate-Sensitive Sector/Indicator	**Year**	**Impact/Effect**		
		Baseline (B) in the 2080s, includes impacts of environmental problems other than climate change	*Impacts of climate change (ΔCC) in the 2080s, on top of the baseline*	*Impacts of Kyoto Protocol in 2080s, relative to baseline+ΔCC**
Sea Level Rise (SLR)	2080s	Varies	~40-41 cm (or 20 inches), relative to 1990	reduce SLR by <1.4 inches
Costal Flooding (PAR)	2080s	0.013 billion	increase PAR by 0.081 billion (or 623%)	reduce total PAR by 18.1% (0.017 billion)
Coastal Wetlands (Area)	2080s	decline of 40% relative to 1990	decline of 12% relative to 1990	reduce the decline by 0.8% , relative to 1990 level
Storms	2080s	unknown	unknown whether magnitudes or frequencies of occurence will increase or decrease in any specific area	unknown

Sources: Parry et al. (1999) and IPCC (200lb) for agriculture; Arnell et al. (2002) and Goklany (2000), based on Solomon et al. (1996), for forest cover; Arnell et al. (2002) and IPCC (200lb) for Falciparum malaria; Arnell et al. (2002) for coastal flooding; Arnell (1999) for water resources.

**Assumes that the Kyoto Protocol, if implemented, would reduce climate change and its impacts by 7% by the late 21st Century. See text.*

- The population at risk (PAR) from malaria, one of the most common and dreaded climate-sensitive infectious diseases, might essentially double in the absence of global warming, from 4.41 billion in 1990 to 8.82 billion in 2080.[40] With global warming, the numbers at risk of contracting malaria might increase by 0.26 to 0.32 billion in the 2080s (equivalent to an increase of between 2.9 and 3.7 percent over the 2080 baseline).[41] However, an increase in the numbers at risk does not necessarily translate into an increased number of cases of malaria, or an increase in its prevalence.[42] The Kyoto Protocol would reduce the total numbers at risk of contracting malaria by less than 0.3 percent in the 2080s, as well.

- The number of people living in countries which experience water stress (defined as countries using more that 20 percent of their available water resources) would increase from 1.75 billion in 1990 to 6.46 billion under the baseline (no climate change) case in the 2080s.[43] This number is projected to increase by as much as 1.1 billion or possibly *decrease* by nearly 2.4 billion, depending on the precise climate model employed to estimate future climate change.[44] The impact of the Kyoto Protocol for this risk category would be minimal into the 2080s, ranging from a 1 percent decrease in PAR to a 4 percent *increase*.

- Agricultural and other human needs may increase the demand on land, because (the world's population will be larger and probably wealthier). In the absence of warming, forest cover may decline by 25-30 percent by the middle of this century, putting enormous pressure on global biodiversity.[45] On the other hand, if land use does not change after 1990, then by the 2080s global forest area may *increase* 5 percent over 1990 levels due to global warming alone.[46]

- Sea level may rise about 40 cm from 1990 to 2080.[47] As a result, the population at risk of coastal flooding is expected to increase by 623 percent — from 0.013 billion under the baseline to 0.094 billion. The Kyoto Protocol could reduce the total PAR from coastal flooding by about 18 percent. Sea level rise could also lead to a loss of coastal wetlands, but such losses due to other human activities are expected to dominate at least into the 2080s.

- It is unclear whether the frequencies and magnitudes of storms, such as tornados, hurricanes, and cyclones, will increase or decrease.[48]

Thus, with the exception of coastal flooding, the impacts of climate change into the foreseeable future are secondary to the impacts of other agents of change built into the baseline case. Moreover, for the most part, the impacts of global warming would seem to be within the "noise level" of these baseline problems.

Consequently, stabilizing GHG concentrations immediately — even if feasible — would, unfortunately, do little over the next several decades to solve the bulk of the problems frequently invoked to justify actions to reduce humanity's role in warming. Land and water conversion will continue almost unabated, with little or no reduction in the threats to forests, biodiversity, and carbon stores and sinks. Food production would not be markedly increased or decreased. Populations at risk of malaria would not be affected much, nor would the numbers of people at risk of water stress. The reductions in risks due to the Kyoto Protocol would be relatively trivial, at least until the 2080s, with respect to all risk categories — with the possible exception of coastal flooding.

Nevertheless, climate change could be the proverbial "last straw". Moreover, the relatively large reductions in the population at risk from coastal flooding might arguably, by itself or in conjunction with reductions in other risk categories, justify the Kyoto Protocol (or other mitigation schemes).

DEALING WITH GLOBAL WARMING IMPACTS ON THE ENVIRONMENT AND PUBLIC HEALTH

There are several approaches to address potential climate change impacts on climate-sensitive environmental and public health problems. Policy makers can: (1) reduce the size of the "last straw" (reduce climate change), (2) reduce the cumulative "load", (3) increase resilience (strengthen the camel's back), or (4) share the burden (redistribute the load among more camels). These approaches need not be mutually exclusive, of course.[49]

Focusing on the Last Straw

The most common approach is to focus almost exclusively on the last straw by reducing or eliminating it. This is equivalent to reducing or eliminating human contribution to climate change, i.e., mitigating greenhouse gasses (GHGs). However, as Table 1 shows, this would accomplish little except in the case of coastal flooding, because it would leave untouched the major share of the total risk burden.

Reducing the Cumulative Burden

Another approach would be to lighten the total burden on the camel's back before it breaks. This is tantamount to reducing the cumulative environmental burden before global warming causes significant and, possibly, irreparable damage.

Consider malaria, for instance. Under the first approach, mitigation, one would, at most, reduce the population at risk from malaria in the 2080s by 2.9 to 3.7% (260 to 320 million people). Keep in mind that this is the maximum effect, achievable only if all climate change impacts could be eliminated — an impossible mission. By contrast, under the second approach, one would attempt to reduce the total PAR from malaria, whether it was the 4.41 billion in 1990 or the projected 9.14 billion in the 2080s. This approach has several advantages.

First, even a small reduction in the baseline population at risk (PAR without climate change impacts) could provide greater aggregate public-health benefits, than would a large reduction in the relatively minor increase in PAR due to climate change. Assuming that annual cases and deaths due to malaria are proportional to the PAR, reducing the base rate for malaria by a mere 0.3 percent per year between 1990 and 2085 would compensate entirely for any increases due to climate change

Second, resources employed to reduce the base rate would provide substantial benefits to humanity decades before any significant benefits are realized from limiting climate change. About one million Africans currently die from malaria every year. This death toll can be cut in half at a cost of between $380 million to $1.25 billion.[50] Humanity would be better served if such sums were spent now to reduce malaria in the near future, rather than on limiting climate change only to curb a relatively minor share of the potential increase in malaria decades from now. Moreover, the benefits of reducing malaria in Africa today are real and far more certain than any benefits resulting from eliminating climate change.

Third, the technologies developed and public-health measures implemented to reduce the base rate would themselves serve to limit additional cases due to climate change when, and if, they occur

Fourth, reducing the baseline rate would serve as an insurance policy against adverse impacts of climate change, whether that change is due to anthropogenic or natural causes or if the changes occur more rapidly than currently projected. In effect, by reducing the baseline today, one would also help solve the cumulative malaria problem of tomorrow, regardless of its cause.

Fifth, because of the inertia of the climate system, it is unrealistic to think that future climate change could be completely eliminated. Moreover, the difficulties in ratifying the Kyoto Protocol because of its socioeconomic impacts, indicates that even a freeze in emissions is unrealistic, despite the fact that such a freeze would not halt further climate change.

The logic of reducing the cumulative burden applies to other climate-sensitive problems and sectors where factors unrelated to climate change are expected to dominate for the next several decades. As the data in Table 1 indicate, these problems and sectors include agriculture, food security, water, forests, ecosystems, and biodiversity.

Increasing Resilience and Reducing Vulnerability

Yet another approach to dealing with the last straw is to strengthen the camel's back to enable it to carry a heavier load. This calls for policies that improve resilience and reduce vulnerability.

It is generally acknowledged that poorer countries have the greatest vulnerability to climate change, not because their climates are expected to change the most, but because they lack the resources to adapt adequately to change. But their expected difficulty of coping with climate change is only one manifestation of a deeper overarching problem, namely poverty.

If we look around at the world today, we find that almost every indicator of human or environmental well-being improves with wealth (see Figure 2).[51] This is true whether or not the indicator is climate-sensitive. Poorer countries have less food available per capita (they are hungrier and more malnourished); their air and water are more polluted; and they have poorer access to education, sanitation and safe water.

Because they are more prone to death and disease from malaria and other infectious and parasitic diseases, they have higher mortality rates and lower life expectancies.[52]

Citizens of developing nations are more vulnerable to any adversity because they lack the fiscal and human-capital resources needed to create, acquire, and use new and existing technologies to cope with that adversity. As a consequence, economic growth, by enhancing technological change, would make society more resilient and less vulnerable to adversity in general, and to climate change in particular.

Focusing on enhancing economic growth should be complemented by efforts to bolster the institutions that underpin society's ability and desire to develop, improve, and utilize newer and cleaner technologies. These institutions include providing greater protections for property rights and contracts, enforcing the rule of law, providing honest and accountable government and bureaucracies, and supporting freer and open trade.[53]

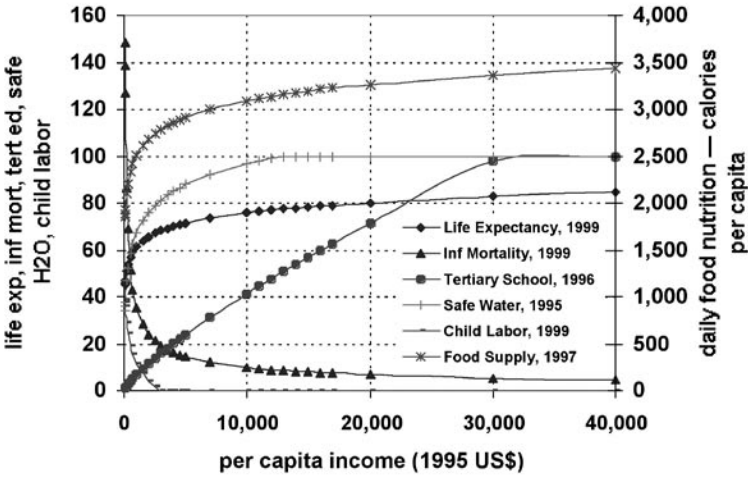

Figure 2. Human well-being vs. economic development, 1990s. Source: Goklany, "Affluence, Technology and Well-being," Case Western Reserve Law Review 53: 369-390 (2002).

Sharing the Burden

Climate change might create regional winners and losers. In particular, it could redistribute agricultural production, with developing countries producing less and developed countries producing more. That would aggravate the problem of hunger in the former.

However, imbalances in production are not a new problem. Nor is a new solution needed. Currently, poor countries consume about 10 percent more grain than they produce.[54] Their future dependence on food imports might increase because their demand for food is expected to grow faster than their agricultural productivity. Such imbalances have traditionally been solved, by and large, through trade. Freer trade would work just as well in the future whether the imbalance is caused by climate change or another factor.

In effect, trade is akin to helping solve the problem of the "last straw" by sharing the burden amongst more camels. However, developing countries would need the wherewithal to purchase food surpluses produced elsewhere. This is yet another reason for increasing economic growth, particularly in the non-food sectors of poor countries.[55]

MITIGATION OR ADAPTATION?

In 2010, the cost of the Kyoto Protocol to the developed countries for whom the Protocol was designed is estimated at between 0.1 and 2.0 percent of their cumulative GDP.[56] Let us assume that the cost be 0.5 percent of their combined GDP. Using their combined GDP for 2000 as an example, Kyoto's costs would have amounted to $125 billion in 1995 U.S. dollars.[57] By the 2080s, net benefits from these expenditures would include a reduction of only 17 million (17 percent) in the population at risk from coastal flooding. For the other climate sensitive risk categories listed in Table 1, however, the Protocol's benefits would be trivial compared to the increase in baseline PARs.

By contrast, the cost of stabilizing GHG concentrations would be greater, but so would the benefits. Stabilization at 450 ppm (20 percent higher than current levels), for instance, is estimated to cost a few trillion dollars between now and the end of the century. Despite the considerable costs, and regardless of which mitigation regime is imposed, the formidable baseline problems indicated in Table 1 would be virtually undiminished for all risk categories except coastal flooding. Moreover, one should expect that some residual impacts of global warming would persist.

Interestingly, some studies suggest that temperature increases of the order of 1-2^{o}C might, in fact, result in *net benefits* for agricultural and timber production.[58] Consistent with these assessments, the IPCC report also suggests that a small (1-2^{o}C) increase might possibly produce a net economic benefit to the world but an increase in excess of 2^{o}C could have negative economic consequences.[59] Therefore, the costs of any mitigation may have to be shouldered for several decades before one can be confident that they would create net benefits. This problem is magnified because of the inertia of the climate system, which magnifies the time lag between when emissions reductions are initiated, and noticeable effects on the impacts of global warming would be observed.

On the other hand, instead of mitigation-based approaches, we could employ a set of adaptation strategies based upon principles two through four outlined above for dealing with the last straw, and targeted to each of the risk categories in Table 1. These strategies would enhance adaptability and/or reduce vulnerability to both the impacts of warming and the other global changes included in the baseline. They also would have the added advantage that the benefits would be observed sooner after the costs were experienced. For example:

- The global cost estimate for protecting against a 50 cm sea level rise by 2100 is about $1 billion a year,[60] or less than 0.005 percent of the overall global economic product.[60] Compared to the Protocol and any other mitigation approach, this is orders of magnitude cheaper, and would also provide greater reductions in the PAR from coastal flooding into the 2080s and beyond.

- Over a period of 95 years, a 20 percent increase in global agricultural research funding, (which in the mid-1990s stood at $33 billion per year including $12 billion in developing countries) ought to more than erase the entire 4 percent reduction in agricultural production due to global warming.[61] This would be substantially more than the trivial portion that the Protocol would restore.
- No less important, to the extent the additional research funding increases sustainable agricultural productivity beyond the quantity needed to replace the shortfall, it would reduce the human demand for land. In fact, increasing agricultural productivity would not only reduce conversion of wild land to new cropland, but it could return existing cropland back to nature. Increasing agricultural productivity is the single most effective method of preventing habitat loss and fragmentation, and conserving global forests, terrestrial biodiversity and carbon stocks and sinks.[62]
- Similarly, the above increases in agricultural research, if targeted appropriately, would also help to increase the amount of food that can be produced by one unit of water. Because agriculture is responsible for 85 percent of the freshwater consumed globally, each 1 percent reduction in agricultural water consumption allows consumption for other sectors to increase by 5.7 percent. This would not only reduce the population at risk from water stress but also would decrease pressures on fresh water species.
- Annual expenditures of between $380 million and the $1.25 billion could reduce the current death toll from malaria by 50 percent or, about 1 million people per year according to the World Health Organization. This would be far more effective in reducing death and disease from malaria than either full implementation of the Kyoto Protocol or even halting climate change altogether. As previously noted, methods developed to prevent or treat baseline malaria problems (that is, problems resulting in the absence of global warming) can be used to address similar problems resulting from climate change.

Thus, over the next 75 years, the above set of adaptation measures would cumulatively cost much less, and deliver greater benefits, than either the Kyoto Protocol or other more ambitious mitigation schemes.

Advocates of immediate greenhouse gas controls, might argue, however, that regardless of the urgency of climate change during the next several decades, unless GHG emission reductions commence now those reductions may come too late to do any good. They claim the inertia of the climate and energy systems argue for immediate action.

Certainly we would want to take all "no-regrets" actions — actions that produce added benefits greater then added costs, after accounting for opportunity costs.[63] But as the data displayed in Table 1 indicate, even if it takes 50 years to completely replace existing energy systems with new ones, we could nevertheless wait 25 years or more before initiating heroic measures to control greenhouse gas emissions.[64]

Meanwhile, we could implement the strategies outlined above, which would deliver benefits for people living today, while enhancing our ability to address future problems that climate change may cause or exacerbate. These strategies could be complemented by developing more cost-effective mitigation and adaptation technologies that could be implemented when they are needed.

CONCLUSION

Assessments of present-day and future impacts of human-induced climate change indicate that it is not now, nor is it likely to be in the foreseeable future (i.e., into the 2080s), as significant as other environmental and public health problems facing the globe. Nevertheless, it has been argued, global warming could be the proverbial "straw that broke the camel's back," particularly for natural ecosystems and biodiversity.

But there is more than one way to solve the problem posed by the "last straw." Reducing or eliminating the last straw — reducing or eliminating climate change — does little good, however, if the camel's back bends or breaks in the meantime. Instead of focusing just on the last straw — the camel's back may also be saved more economically in other ways.

A better approach is to reduce today's urgent public health and environmental threats (such as malaria, water stress, hunger, and habitat loss) that might be exacerbated by climate change. As we have seen, this would provide greater, more cost-effective and quicker benefits to both humanity and the rest of nature.

We should also strengthen the camel's back so that it can withstand a heavier burden, regardless of how or why the load is generated. The basic reasons as to why some societies are less resilient and more vulnerable to climate change effects are precisely the same reasons why they are also less resilient and more vulnerable to adversity, in general — they have insufficient economic development and a lower propensity towards technological change.[65]

Not surprisingly, poorer countries with less ability to develop, afford, and use new technologies have higher rates of hunger; poorer public health services; greater incidence of infectious and parasitic diseases; less access to education, safe water and sanitation. Therefore, they have greater mortality rates and lower life expectancies. Accordingly, we should strengthen the institutions that drive both economic growth and technological change. Not coincidentally, many of these institutions nurture, foster and reinforce each other. This approach would enhance these societies' abilities to cope not only with climate change, but adversity in general, regardless of its cause, or whether it's man-made or not.[66]

In addition, we should make it possible to share the burden among numerous "camels". Because climate change would create regional winners and losers, the burden could be spread more evenly through trade. Thus, shortfalls in agricultural production induced by climate change in some countries could be addressed through trade with others that would experience gains in agricultural production. Trade, moreover, has the added benefits of stimulating both economic growth and technological change. It particular, it allows societies everywhere to gain from innovations and inventions made elsewhere in the world, without having to "reinvent wheels."[67]

Policies based on these alternative approaches, all of which rely on improving adaptability and reducing vulnerability, are superior to the single-minded pursuit of reductions in climate change, at least into the foreseeable future. Into the 2080s, they would provide greater benefits, far sooner and far more economically than would be achieved by efforts which focus on mitigation.

Indeed, by reducing vulnerability and increasing adaptability, we might increase the level to which greenhouse gas concentrations might rise before they need to be stabilized in order to avoid dangers to humanity and nature (the stated goal of the UN Framework Convention on Climate Change). This would further reduce the costs of addressing climate change.[68]

Despite the inertia inherent in both the climate and energy systems, we have at least two to three decades before we need to embark on socially and economically costly efforts to reduce GHG emissions that would go beyond "no-regrets" actions.[69] In the interim, we should focus on:

1) solving today's urgent problems while creating the means to address future potential problems due to climate change
2) improving our understanding of the impacts of climate change so that we can distinguish between the possible and the probable
3) increasing information regarding the trade-offs and synergies between adaptation and mitigation
4) reducing barriers to implementing no-regret technologies, whether they are related to mitigation or adaptation (such as eliminating needless subsidies for energy and natural resource uses)
5) undertaking efforts to expand the portfolio of no-regret actions[70] through greater R&D into more cost-effective mitigation and adaptation technologies.

Such a multifaceted and holistic approach would help improve the lives of people living today, without compromising our ability to address future challenges, whether caused by human-induced climate change, another agent of global change, or something else entirely.

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62. Byerlee and Echeverria (2002).
63. Goklany, (1998); Goklany (1999a).
64. "No regret" actions are actions that would be undertaken for economic or environmental reasons unrelated to climate change, would be implemented in any case. Examples of no-regret actions include elimination of subsidies, replacement of inefficient processes or appliances, or replacement of coal with natural gas in order to reduce air pollution.
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70. If they are not costly in a socio-economic sense, they are, almost by definition, no-regret actions.

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