Economic and Other Policy Implications

10. Economic and Other Policy Implications

Introduction

10.1 Climate and Economy

10.1.1 Hunger
10.1.2 Life Expectancy and Disease
10.1.3 Poverty
10.1.4 Extreme Weather Events
10.1.5 Water Shortages

10.2 Projected Impacts and Damages from Global Warming

10.2.1 Determining Adaptive Capacity
10.2.2 Future Adaptive Capacities
10.2.3 IPCC Errors

10.3 Biofuels
10.4 War and Social Unrest

Introduction

The Intergovernmental Panel on Climate Change (IPCC) claims CO₂-induced global warming is already occurring and "climate change currently contributes to the global burden of disease and premature deaths" (IPCC, 2007-II, p. 393). While the IPCC recognizes climate change could "bring some benefits to health, including fewer deaths from cold," it says those benefits must be weighed against "the negative effects of rising temperatures worldwide, especially in developing countries" (ibid.). Policy proposals aimed at mitigating climate change have been justified by the claim that the net costs of action for present and future populations would exceed that of inaction.

According to the IPCC narrative, the well-being of the vast majority of humanity should have deteriorated due to anthropogenic climate change. But in fact, human well-being has in aggregate never been better than it is currently. This is partly because the IPCC's projections of future impacts severely underestimate the ability of humans to cope with and adapt to climate change, a topic we also addressed in Chapter 9.

For the 2009 report of the Nongovernmental International Panel on Climate Change (NIPCC), Idso and Singer (2009) addressed some of these issues in sections 9.4 and 9.5 of the report's final chapter on "human health effects." Section 9.4 of that report explained how "the aerial fertilization effect of the increase in the air's CO₂ content that is expected to occur by the year 2050 would boost crop yields by the amounts required to prevent mass starvation in many parts of the globe, without a large-scale encroachment on the natural world" (p. 698). Section 9.5 described the unintended consequences of increased use of biofuels - ethanol, biodiesel, and methanol - which the IPCC encouraged as a way to reduce greenhouse gas emissions. "Biofuels may have some advantages over gasoline and diesel fuels, but they are more expensive to produce and can supply only a small part of the world's total transportation energy needs. Because they compete with food crops and nature for land and nutrients, expanding the use of biofuels could negatively affect human health and natural ecosystems" (p. 701).

This chapter significantly expands Idso and Singer's earlier work. It shows how real-world data

on human well-being (e.g., hunger, disease, poverty, and deaths from droughts, floods, and other extreme weather events) contradict claims about the impacts of warming in the twentieth century. It present results from impact assessments cited by IPCC (2007-II) and co-written by several of its contributors that reveal climate change should be a minor player among the factors that determine human well-being worldwide through the foreseeable future. New research on the economics and ecology of biofuels is presented, as well as some research and commentary on the role climate change might play in matters of war and social unrest.

References

Idso, C.D. and Singer, S.F. 2009. *Climate Change Reconsidered: 2009 Report of the Nongovernmental International Panel on Climate Change (NIPCC)*. Chicago, IL: The Heartland Institute.

IPCC. 2007-II. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Edited by M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson. Cambridge, UK: Cambridge University Press.

10.1. Climate and Economy

One of the fundamental rationales behind the desire to control greenhouse gas emissions is the frequent claim that CO_2 -induced global warming will negatively affect livelihoods and reduce well-being in the developing world. However, as shown in the material below, decades-long empirical trends of climate-sensitive measures of human well-being reveal improvement, notwithstanding the historic increase in atmospheric CO_2 concentrations or any climate change.

10.1.1. Hunger

Proponents of greenhouse gas controls frequently claim global warming will reduce crop productivity in the developing world, thereby exacerbating hunger and famine (e.g., Freeman and Guzman, 2009). Idso and Singer (2009) rebutted this claim, citing a series of studies showing that important food crops benefit from higher CO₂ concentrations (pp. 696–697). This, coupled with technological advances, has increased crop productivity and production dramatically during the latter half of the twentieth century in least developed countries (LDCs) as well as globally, as is shown in Figure 10.1.1.

Because of the increase in agricultural



Figure 10.1.1. Cereal yield and production, 1961-2008, for Least Developed Countries (LDCs) and globally. Source: Food and Agricultural Organization (2010a).

productivity and trade in agricultural and food inputs and outputs, the portion of the developing world's population suffering from chronic hunger has been declining for decades. From 1969–1971 to 2003– 2005, it declined from 33 percent to 16 percent (FAO, 2009a). However, it has started to rise once again, at least temporarily (see Figure 10.1.2; FAO, 2009a). It increased to about 17 percent in 2008 and 19 percent in 2009 before being projected to decline to 16 percent once again in 2010. But as shown in Figure 10.1.1 (which goes only through 2008), neither productivity nor production has declined. Therefore, the recent increase in hunger cannot be a result of any loss of productivity or production due to global warming.

The Food and Agricultural Organization (FAO) ascribes the increase in hunger to a surge in food prices, the global economic slowdown, insufficient investment in agriculture, and biofuel production that has diverted crops from food to fuel production (FAO, 2009a; 2009b). Ironically, concern over global warming is responsible for the mandates and subsidies that drive biofuel production. In addition, as spending on global warming has increased, investments in agriculture have dropped.

10.1.2. Life Expectancy and Diseases

While the IPCC claims death and disease have increased due to the modest global warming of the twentieth century driven by economic development and energy use, actual data on life expectancy and the incidence of diseases tell a different story. Average life expectancies around the world have increased from 31 years in 1900 to 47 years in the early 1950s and 69 years today (Goklany, 2007; World Bank, 2010a). For developing countries, life expectancies increased from twenty-five to thirty years in 1900 to forty-one years in the early 1950s and sixty-nine years at present (Goklany, 2009a; World Bank, 2010a).

For Sub-Saharan Africa, life expectancy increased from 40.9 years in 1960 to 52.1 years in 2008. In virtually every country, health-adjusted life expectancies currently exceed unadjusted life expectancies from just a few decades ago (Goklany 2007). ["Health-adjusted" life expectancy is the life expectancy adjusted downward to partially discount the numbers of years of life an average person would spend in a disabled or diseased condition.] In other words, people in developing countries are not only living longer, they are also healthier.



Figure 10.1.2. Percent of developing world population suffering from chronic hunger, 1969/71-2010. Source: Food and Agricultural Organization (2010b).

Meanwhile, the ranges of the most critical climate-sensitive infectious diseases have shrunk. Malaria accounts for about 75 percent of the global burden of disease from vector-borne diseases and therefore serves as a good surrogate for the latter (IPCC, 2001). As indicated in Figure 10.1.3, the area in which malaria due to *Plasmodium falciparum* – the deadliest of the four protozoan parasites that cause malaria – is endemic has been reduced substantially since 1900 (Gething et al., 2010).

Endemic/stable malaria is estimated to have covered 58 percent of the world's land surface around 1900 but only 30 percent by 2007. *P. falciparum* malaria is today restricted largely to developing countries in the tropics. Equally important, its endemicity has fallen by one or more classes in more than two-thirds of the current range of stable transmission. See Figure 10.1.3c.

Gething et al. (2010) note:

[O]f the 66 million km² of the Earth's surface thought to have sustained stable/endemic malaria in 1900, 12%, 18% and 57% had exhibited proportional decreases in the reproductive number of up to one, between one and two, and greater than two orders of magnitude, respectively; 11% had shown no evidence of change; and 2% had shown evidence of an increase in the reproductive number by 2007.

Figure 10.1.3 does not show the rebound in malaria in many developing areas that occurred in the 1980s and 1990s because of a combination of poor policies (such as cessation of indoor spraying of DDT in many countries partly due to a reluctance of developed countries' aid programs to support DDT use), development of resistance to drugs and insecticides, and a deterioration of public health infrastructure in many African countries coincident with a period in which their economies deteriorated and AIDS was ascendant (Goklany, 2007). Since then, however, matters have improved substantially. According to the World Health Organization's World Malaria Report 2010, estimated deaths from malaria in Africa declined from 900.000 in 2000 to 709.000 in 2009 (WHO 2010, 61). Globally, the number of malaria deaths over the same period fell from 985,000 to 781.000.



Figure 10.1.3. Changing global malaria endemicity since 1900. (a) Pre-intervention endemicity (approximately 1900). (b) Contemporary endemicity for 2007. (c) Change in endemicity class between 1900 and 2007. Negative values denote a reduction in endemicity, positive values an increase. Source: Gething et al. (2010).

10.1.3. Poverty

Did CO₂-induced global warming during the second half of the twentieth century cause rising levels of poverty in developing countries? If the IPCC's catastrophic claims (IPCC, 2007-II, 835) were true, one would expect to see some evidence of this in economic statistics. But the data, in fact, show just the opposite trend.

The proportion of the developing world's population living in extreme poverty (defined as less than \$1.25 per day in 2005 dollars) was halved from 52 percent in 1981 to 25 percent in 2005 (World Bank, 2010b). The number of people living in extreme poverty declined from 1.9 billion to 1.374 billion even as world population grew from 3.7 billion to 5.5 billion. See Figure 10.1.4.

The most spectacular improvements in personal income were in East Asia and the Pacific, where the headcount of those in poverty dropped from 1.071 billion to 316 million. More people escaped poverty at a faster rate in these countries than at any other time in human history. It is no accident that the fastest reductions in poverty occurred in areas that experienced the greatest increases in both economic development and greenhouse gas emissions.

10.1.4. Extreme Weather Events

The IPCC claims death, disease, and property damage from extreme weather events will increase if manmade greenhouse gases were not restricted. While property damage indeed has increased over time, this seems to be due to an increase in both population and wealth, which increases the property at risk (Bouwer, 2010; Neumayer and Barthel, 2011), losses of life due to extreme weather events have fallen.

Data for 1900 to 2008 indicate that since the 1920s, cumulative annual deaths from all extreme weather events – droughts, floods, extreme temperatures (both extreme heat and extreme cold), wet mass movement (slides, waves, and surges), wildfires, and storms (hurricanes, cyclones, tornados, typhoons, etc.) – declined globally by 93 percent on average while the annual death rate dropped by 98 percent (Goklany, 2009b). See Figure 10.1.5.



Figure 10.1.4. Poverty rates in the developing world, 1981-2005. Source: PovCalNet, World Bank (2010b).



Figure 10.1.5. Global deaths per year and death rates due to extreme weather events, 1900-2008. Extreme events include the following: droughts, floods, extreme temperatures (both extreme heat and extreme cold), wet mass movement (slides, waves, and surges), wildfires, and storms (hurricanes, cyclones, tornados, typhoons, etc.). Data for the last period are averaged over nine years. Source: Goklany (2009b), using data from EM-DAT (2009).

Between 1900 and 2008, droughts were responsible for most (58 percent) of the global fatalities due to extreme weather events. Global deaths and death rates from droughts peaked in the 1920s and have since fallen by 99.97 percent and 99.99 percent, respectively (Goklany, 2009b). The death toll that inevitably used to follow in the wake of drought has been reduced almost to the vanishing point.

In 2000–2009, according to the EM-DAT, the International Disaster Database, an average of only 116 people died annually due to drought (EM-DAT, 2010), compared to 472,000 deaths annually in 1920–29. To place these numbers in context, currently more than 58 million people die each year due to all causes worldwide (WHO, 2008).

With respect to floods, the second most deadly form of extreme weather event, deaths and death rates crested in the 1930s. By 2000–2008 they were down by 98.7 percent and 99.6 percent, respectively (Goklany, 2009b).

Extreme weather events today contribute only 0.06 percent of the global (and U.S.) mortality burdens in an average year. They have declined even

as all-cause mortality has increased (Goklany, 2009b). This indicates that the world, including the developing world, is coping better with risks of death from extreme weather events than it is with other, larger health risks. It also suggests that it might pay greater dividends to society if more resources were expended on the latter than on reducing man-made greenhouse gas emissions.

10.1.5. Water Shortages

The possibility of water shortages leading to droughts and hunger are recurring themes in the climate change literature (e.g., Freeman and Guzman, 2009; IPCC, 2007-II). Droughts, which are a manifestation of severe water shortages, have plagued humanity from time immemorial, and deaths from droughts are probably the best indicator of the socioeconomic impact of such water shortages. As noted above, deaths and death rates from droughts have declined by 99.97 percent and 99.99 percent since the 1920s. This decline occurred despite a more-than-tripling of the global population. There is also a concern that the combination of population growth and global warming might reduce access to safe water. Yet between 1990 and 2008, although global population increased 27 percent, the percentage of global population with access to safe water increased from 76.8 percent to 86.8 percent. An additional 1.8 billion people gained access to safer water over this period (World Bank, 2010a; WRI, 2010). At the same time, 1.3 billion more people gained access to improved sanitation..

Even Sub-Saharan Africa, historically a slowdevelopment region, has seen improvements. Despite a 60 percent increase in population, the proportion with access to improved water sources increased from 48.9 percent in 1990 to 59.7 percent in 2008, as 240 million more people in that region gained such access (World Bank, 2010a; WRI, 2010).

Clearly, long-term trends for hunger, disease, and deaths from droughts, floods, and other extreme weather events are not consistent with the IPCC's narrative regarding the impacts of global warming. Perhaps global warming is not happening after all, or if it is, its effect are relatively small and/or overwhelmed by improvements in human adaptive capacity or other factors. Or perhaps the global warming narrative is simply based on false expectations, that warming's real impacts are more positive than negative. Whichever explanation (or combination of explanations) is correct, the salient fact is that real-world data do not support claims that global warming is reducing human well-being.

References

Bouwer, L.M. 2010. Have disaster losses increased due to anthropogenic climate change? *Bulletin of the American Meteorological Society* doi: 10.1175/2010BAMS3092.1.

EM-DAT. 2009. The OFDA/CRED International Disaster Database. Brussels, Belgium: Université Catholique de Louvain. Available at http://www.em-dat.net. Data downloaded 24 August 2009.

EM-DAT. 2010. The OFDA/CRED International Disaster Database. Brussels, Belgium: Université Catholique de Louvain. Available at http://www.em-dat.net. Data downloaded 22 May 2010.

Food and Agricultural Organization (FAO). 2009a. *State of Food Insecurity 2009*. Rome, Italy: FAO.

Food and Agricultural Organization (FAO). 2009b. *The State of Food Insecurity in the World: Economic crisis:*

impacts and lessons learned. Available at http://www.fao.org/economic/es-policybriefs/ multimedia0/presentation-the-state-of-food-insecurity/en/.

Food and Agricultural Organization (FAO). 2010a. *FAOSTAT*. Available at http://faostat.fao.org/default.aspx, visited 9 May 2010.

Food and Agricultural Organization (FAO). 2010b. *State of Food Insecurity 2010*. Rome, Italy: FAO.

Freeman, J. and Guzman, A. 2009. Climate change & U.S. interests. *Columbia Law Review* **100**: 101–171.

Gething, P.W., Smith, D.L., Patil, A.P., Tatem, A.J., Snow, R.W., and Hay, S.I. 2010. Climate change and the global malaria recession. *Nature* **465**: 342–345.

Goklany, I.M. 1998. Saving habitat and conserving biodiversity on a crowded planet. *BioScience* **48**: 941–953.

Goklany, I.M. 2007. *The Improving State of the World*. Washington, DC: Cato Institute.

Goklany, I.M. 2009a. Have increases in population, affluence and technology worsened human and environmental well-being? *Electronic Journal of Sustainable Development* 1(3). Available at http://www.ejsd.org/docs/HAVE_INCREASES_IN_POPU LATION_AFFLUENCE_AND_TECHNOLOGY_WORS ENED_HUMAN_AND_ENVIRONMENTAL_WELL-BEING.pdf.

Goklany, I.M. 2009b. Deaths and death rates from extreme weather events: 1900–2008. *Journal of American Physicians and Surgeons* 14: 102–09.

IPCC (Intergovernmental Panel on Climate Change). 2001. *Climate Change 2001. Impacts, adaptation, and vulnerability.* New York, NY: Cambridge University Press.

IPCC. 2007-II. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Edited by M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson. Cambridge, UK: Cambridge University Press.

Neumayer, E., and Barthel, F. 2011. Normalizing economic loss from natural disasters: A global analysis. Global Environmental Change 21: 13-24.

World Health Organization (WHO). 2008. *Global Burden* of Disease and Risk Factors: 2004 Update. Geneva, Switzerland: WHO.

World Health Organization (WHO). 2010. World Malaria Report 2010. Geneva, Switzerland: WHO.

World Bank. 2010a. *World Development Indicators*, available at http://ddp-ext.worldbank.org/ext/DDPQQ/member.do?method=getMembers&userid=1&queryId=135

World Bank. 2010b. *PovCalNet*. Available at http://iresearch.worldbank.org/PovcalNet/povDuplic.html, visited 28 May 2010.

World Resources Institute (WRI). 2010. *EarthTrends*. Available at http://earthtrends.wri.org/.

10.2. Projected Impacts and Damages from Global Warming

The basic premise for policy proposals aimed at mitigating climate change is that without them the net impacts of climate change would be severely negative and future populations would be worse off than humans are today. The magnitude of these impacts and their associated damages depends on society's adaptability (adaptive capacity), which is determined by, among other things, the wealth and human resources society can access in order to obtain, install, operate, and maintain technologies necessary to cope with or take advantage of climate change impacts (IPCC 2001; IPCC 2007-II, p. 138; Goklany 2007a). Thus, estimates of the impacts of global warming must necessarily consider the adaptive capacity of the societies that experience it.

The IPCC recognizes this principle. Its "standard" impacts assessment methodology incorporates consideration of autonomous adaptation (IPCC 2007-II, p. 136, footnote 2). However, many of the studies that it draws upon fail to recognize that these autonomous adaptations should be based on society's adaptive capacity at the time for which impacts are to be estimated. That is, if impacts are to be estimated for 2100, the adaptive capacity used to develop those estimates also should be projected for 2100. Equally importantly, projections for adaptive capacity must be consistent with the assumptions about economic growth and technological change used to drive the emission scenario that is used to estimate climate change.

As will be shown below, for the most part impact assessments account only partially for changes in adaptive capacity between the baseline year and the projection year. As a result, negative impacts are overestimated and positive impacts are underestimated. Together, these errors inflate the forecasts of net damage from projected climate change.

The following discussion examines the dependence of adaptive capacity on economic and technological development; whether economic

growth assumptions used in the IPCC scenarios should reflect a significantly different adaptive capacity relative to the baseline level; and the extent to which such changes were incorporated in state-ofthe-art global impact assessments used in the IPCC's 2007 report, and the implications for future per-capita incomes and human well-being.

10.2.1. Determining Adaptive Capacity

Among the determinants of adaptive capacity are economic development, availability of and access to technology, and human capital. Many of the indicators of human well-being – education level, health status, availability of food supplies, malnutrition level, access to safe water and sanitation, health expenditures, and research and development expenditures – enhance these determinants and, in turn, are enhanced by them (Goklany, 2007a). In effect, these indicators of human well-being also serve as determinants of adaptive capacity.

For any specific level of economic development, these indicators and determinants improve with time. Time is a surrogate for technology, where technology is defined broadly as including hardware (such as tractors, dams, carbon adsorption systems) and software technologies (e.g., policies and institutions that govern or modulate human actions and behavior, trade, and other forms of exchange; culture, management techniques; computer programs to track or model environmental quality; and emissions trading) (Ausubel, 1991; Goklany, 1995).

Cross-country data show that at any point in time, each of these indicators of well-being generally advances with the level of gross domestic product (GDP) per capita, a measure of economic development or per-capita income. The five figures that follow show the close correlation between percapita GDP and cereal yields (a surrogate for agricultural productivity), available daily food supplies per capita, the prevalence of malnutrition (which is a consequence of hunger and a determinant of health), infant mortality, and life expectancy. The latter two – infant mortality and life expectancy – capture the aggregate effect on human well-being of many of the indicators noted previously, such as education, health status, availability of food supplies, prevention of malnutrition, access to safe water and sanitation, and health research and development

expenditures (Goklany, 2007a, 2007b)¹. That is, they capture the total effect of societies' abilities to cope with death and disease from *all* causes.

Figure 10.2.1 shows cereal yields measured in thousands of kilograms per hectare increased linearly with per-capita GDP in both 1975 and 2003. The upward displacement of the cereal yield curve from 1975 to 2003 indicates that, in general, yield increased at any given level of income with the passage of time. This upward displacement can be attributed to secular technological change which, under the definition employed here, includes increases in fertilizer and pesticide usage, improvements in yields due to greater knowledge, improved management techniques, exchange of ideas, and more reliable weather forecasts.

Higher yields should result in greater food supplies, and Figure 10.2.2 shows available food supplies per capita per day (FS) increases with percapita income. However, the relationship between food supplies and income is log-linear, not linear as it is for yield, probably because wealthier countries can buy food (via trade) on the world market and even a small amount of additional income goes a long way toward meeting food requirements. Increasing income from \$100 to \$1,000 (or from \$1,000 to \$10,000) increases average daily FS by 816 kcal per capita per day, while secular technological change raised food supply by 166 kcal per capita per day from 1975 to 2002, regardless of income level (Goklany 2007b).



Figure 10.2.1. Cereal yields vs. per-capita GDP across countries, 1975–2003. Source: Goklany (2007b).

¹ Figures 10.2.1 through 10.2.5 are taken from Goklany (2007b), which uses the same methodology as in Goklany (2007a), except the former used per-capita GDP adjusted for purchasing power, whereas the latter uses per-capita GDP based on market exchange rates.



Figure 10.2.2. Available food supplies per capita per day (FS) vs. per-capita GDP across countries, 1975–2002. Source: Goklany (2007b).

Higher food supplies should lower malnutrition rates, and Figure 10.2.3 indicates malnutrition as percent of population declines as GDP per capita rises. Because of technological change, even if a country's average income were frozen at a dollar a day (in 2000 international dollars, adjusted for purchasing power), malnutrition would drop from 79.5 percent in 1987 to 58.6 percent of population in 2000. If average income were doubled in 2000, malnutrition would drop further to 35.2 percent (Goklany 2007b). Malnutrition declines more rapidly as per-capita income rises than food supplies increase at the lowest levels of income. This is because although food supplies are critical to reducing malnourishment, other income-sensitive factors, such as public health services and infrastructure to transport food and medicine, reinforce the resulting reductions in malnutrition. Lower malnutrition (better nutrition) also reduces susceptibility to disease, and thus the amount of food needed to maintain healthy weight is lowered; better health helps reduce malnutrition even if food supplies are fixed.



Figure 10.2.3. Prevalence of malnutrition (as percent of population) vs. per-capita GDP across countries, 1987–2000. Source: Goklany (2007b).

Lower malnutrition should also translate into lower mortality rates. As shown in Figure 10.2.4, infant mortality improves with income and technological change (time). If a country doubled its average income from \$1 to \$2 a day, infant mortality would decline from 355 per 1,000 live births to 199 in 1980, and from 207 to 116 in 2000. The combination of the two – a doubling of income and technological change – would, therefore, reduce infant mortality from 355 per 1,000 live births in 1980 to 116 in 2000.

If infant mortality rates decline, life expectancies should increase. Figure 10.2.5 confirms life expectancy improves with economic development and time. Had per-capita income doubled from \$1 a day to \$2 a day, life expectancy would have increased from 40.7 years to 46.2 years in 1977, and from 44.6 to 50.2 years in 2003 (Goklany 2007b).

These figures illustrate that both economic

development and time (a surrogate for technology), meaning secular technological change, independently and together increase society's ability to adapt to and cope with whatever problems it faces. Many other indicators of well-being, such as access to safe water and sanitation and educational levels, also improve with income and technological change (Goklany (2007a; 2007b).

These figures also indicate the compounded effect of economic development and technological change (time) can result in quite dramatic improvements even over the relatively short period over which these figures were developed. Figure 10.2.5, for instance, covered 26 years. By contrast, climate change impacts analyses frequently look 50 to 100 years into the future. Over such long periods, the compounded effect of economic development and technological change could be spectacular.



Figure 10.2.4. Infant mortality vs. per-capita GDP across countries, 1987–2000. Source: Goklany (2007b).



Figure 10.2.5. Life expectancy vs. per-capita GDP across countries, 1977–2003. Source: Goklany (2007b).

Longer-term analyses of climate-sensitive indicators of human well-being show the combination of economic growth and technological change can, over decades, reduce negative impacts on human beings by an order of magnitude - that is, a factor of ten - or more. In some instances, this combination has virtually eliminated such negative impacts. For instance, during the twentieth century, deaths from various climate-sensitive waterborne diseases were all but eliminated in the United States. From 1900 to 1970, U.S. per-capita GDP nearly quadrupled, while deaths from malaria were eliminated and death rates for gastrointestinal disease fell by 99.8 percent (Maddison 2010; Goklany 2009a). From 1900 to 1997 per-capita GDP rose sevenfold while deaths from typhoid and paratyphoid were eliminated, and from 1900 to 1998 the death rate for dysentery fell by 99.6 percent (Goklany 2009a). Similarly, since the 1920s global per-capita GDP has risen fivefold while aggregate global death rates from all extreme weather events were reduced by 98 percent and death rates from droughts have fallen by 99.99 percent.

These trends suggest global warming impact analyses that extend more than two or three decades into the future should account for the *compounded* increases in adaptive capacity from increasing percapita income and secular technological change. Higher adaptive capacity enables a society to adapt, overcome, and even thrive in the presence of climate changes that, in their absence, might be expected to cause hardships. The models used by the IPCC and other voices in the debate over global warming incorporate this economic growth in their emission and climate change scenarios, but fail to take it into account when projecting society's response to whatever climate change those emissions might generate. As a result, these models almost invariably tend to overestimate the net future damages from climate change.

10.2.2. Future Income and Human Well-being in a Warmer World

Virtually all impact assessments undertaken since 2000 have relied on the IPCC (2000) temperature and emissions scenarios, all of which assume substantial economic growth in both developing and industrialized countries (Arnell et al. 2002). Using the insights gained from the previous section, what can we say about the future adaptive capacities and human well-being under these scenarios?

One way to answer the question is to accept the economic assumptions built into the various IPCC scenarios and the resulting estimates of per-capita income for developing and industrialized countries in the absence of any future climate change relative to the base year. Then we can adjust these estimates downward to account for the highest estimates of the losses due to climate change based on the same IPCC scenarios. For the latter, we rely on the highest damage estimates from Stern et al. (2006), a report that anchors the alarmist end of studies of the potential impact of climate change. Figure 10.2.6 shows the results of that highest exercise.

Figure 10.2.6 provides per-capita GDP for 1990, the base year used by the IPCC's emissions scenarios, and estimates of future per-capita GDP in 2100, using four IPCC reference scenarios for areas that comprise today's developing and industrialized countries. It also provides estimates for 2200, as detailed below. As indicated, the net per-capita GDP is calculated by subtracting the equivalent costs per capita of global warming, as reported by Stern et al., from per-capita GDP in the absence of any warming (unadjusted percapita GDP) as forecast by the IPCC.



Figure 10.2.6. Net per-capita GDP, 1990–2200, after accounting for losses due to global warming for four major IPCC emission and climate scenarios. See text for definitions. Source: Goklany (2009c).

For 2100 and 2200, the scenarios are arranged from the warmest (A1FI) on the left to the coolest (B1) on the right. The average global temperature increases from 1990 to 2085 for the scenarios are as follows: 4°C for A1FI, 3.3°C for A2, 2.4°C for B2, and 2.1°C for B1.

Unlike most other studies, Stern et al. account for losses due not only to market impacts of global warming but also to nonmarket (i.e., environmental and public health) impacts, plus the risk of catastrophe (see, e.g., Freeman and Guzman 2009, 127). Thus, the net per-capita income shown in Figure 10.2.6 is a good surrogate for human well-being.

For context, in 2006, per-capita GDP for industrialized countries was \$19,300; for the United States, \$30,100; and for developing countries, \$1,500.

Also, the figure uses the Stern Review's 95th percentile (upper bound) estimate of the losses in GDP due to global warming. Per the Stern Review, these costs amount to 7.5 percent of global GDP in 2100 and 35.2 percent in 2200. These losses are adjusted downward for the cooler scenarios per Goklany (2007c, 2009c). Many economists believe even the central estimates of the Stern Report overstate losses due to global warming. Tol (2008), for example, observes, "[The Stern Review's] impact estimates are pessimistic even when compared to other studies in the gray literature and other estimates that use low discount rates" (p. 9).

For 2200, the unadjusted per-capita GDP is assumed to be double that in 2100, which is equivalent to a compounded annual growth rate of 0.7 percent, which is less than the Stern Review assumption of 1.3 percent. Thus, we substantially understate the unadjusted per-capita GDP and, therefore, also the net per-capita GDP, in 2200.

The answer to our question, as shown in Figure 10.2.6, is that future societies – whether developing or

industrialized – will be much wealthier in 2100 and 2200 despite any global warming and despite the various assumptions designed to overstate losses from global warming and understate the unadjusted percapita GDP in the absence of any warming. And their well-being will be correspondingly higher. In fact, under the IPCC's warmest scenario, which would increase globally averaged temperature by 4° C from 1990 to 2085, net per-capita GDP in developing countries in 2100 will be *double* the 2006 level of the United States, and *triple* that level in 2200. Thus, even developing countries' future ability to cope with climate change and, more importantly, their levels of well-being would be much better than that of the United States today.

Additional implications of the above exercise are:

- For populations living in countries currently classified as "developing," net per-capita GDP (after subtracting the cost of global warming) will be at least 11–65 times higher in 2100 than it was in the base year. It will be even higher (at least 18–95 times) in 2200.
- Industrialized countries will have net percapita GDP three to seven times higher in 2100 than in 1990. In 2200 it will be five to ten times higher.
- Net per-capita GDP in today's developing countries will be higher in 2200 than it was in industrialized countries in the base year (1990) under all scenarios, despite global warming. That is, regardless of any global warming, populations living in today's developing countries will be better off in the future than people currently inhabiting those nations. This is also true for 2100 for all but the "poorest" (A2) scenario.
- Under the warmest scenario (A1FI), the one that prompts many of the apocalyptic warnings about global warming, net percapita GDP of inhabitants of developing countries in 2100 (\$61,500) will be double that of the United States in 2006 (\$30,100), and almost triple in 2200 (\$86,200 versus \$30,100). [All dollar estimates are in 1990 US dollars.]

In other words, everywhere - even in developing countries – people will be wealthy by today's standards, and their adaptive capacity and well-being should be correspondingly higher. Therefore, even if one assumes that there would be no secular technological change - no new or improved technologies, nor would the price of technology drop between the 1990s – and 2100 – developing countries' adaptive capacity would on average far exceed that of the United States today. Therefore, although claims that developing countries will be unable to cope with climate change (UNEP 1993) might have been true for the world of 1990 (the base year), they simply would not hold for the world of 2100 under the assumptions built into the IPCC scenarios and the Stern Review's own (exaggerated) analysis.

The problems of poverty warming that supposedly would exacerbate (such as low agricultural productivity, hunger, malnutrition, malaria, and other vector-borne diseases) would be reduced if not eliminated by 2100, even if one ignores (contrary to the lessons of history captured in Figures 10.2.1 through 10.2.5) any secular technological change that ought to occur in the interim. Tol and Dowlatabadi (2001), for example, show malaria has been functionally eliminated in a society whose annual per-capita income reaches \$3,100. Therefore, even under the poorest scenario (A2), the average developing country should be free of malaria well before 2100, even assuming no technological change in the interim.

Similarly, if the lower bound of the average net per-capita GDP in 2100 for developing countries is \$10,000–\$62,000, then their farmers would be able to afford technologies that are unaffordable today (such as precision agriculture) as well as new technologies that should come on line by then (such as droughtresistant seeds formulated for specific locations).

It may be argued that the high levels of economic development depicted in Figure 10.2.6 are unlikely. But these are the estimates built into the IPCC emission scenarios. If they are overestimates, then so are the estimates of emissions, temperature increases, and impacts and damages of global warming projected by the IPCC.

10.2.3. Systematic Overestimation of Negative Impacts Cited by the IPCC

It is possible to obtain an idea of whether and to what extent the impact assessments used in the IPCC's latest assessment report account for changes in adaptive capacity over time. Consider the so-called Fast Track Assessments (FTAs) of the global impacts of climate change. These British governmentsponsored FTAs, which were state-of-the-art at the time of the writing of the IPCC's Fourth Assessment Report (AR4WG2), have an impeccable provenance from the point of view of proponents of greenhouse gas controls. Many of the FTA authors were major contributors to the IPCC's Third and Fourth Assessments (IPCC, 2001; 2007). For instance, the lead author of the FTA's hunger assessments (Parry et al., 1999; 2004), Professor Martin Parry, was co-chair of IPCC Working Group 2 during its latest (2007) assessment. Similarly, the authors of the FTA's water resources and coastal flooding studies also were lead authors of corresponding chapters in the same IPCC Fourth Assessment Report.

An evaluation of the FTA methodologies shows the following shortcomings:

- The water resources study (Arnell 2004) completely ignores adaptation even though many adaptations to water-related problems – such as building dams, reservoirs, and canals – are alreadyexisting technologies and, in fact, are among mankind's oldest adaptations (Goklany 2007c, pp. 1034–35).
- The study of agricultural productivity and hunger (Parry et al. 2004) allows for increases in crop yield with economic growth due to greater usage of fertilizer and irrigation in richer countries, decreases in hunger due to economic growth, some secular (time-dependent) increase in agricultural productivity, and some farm level adaptations to deal with climate change. But these adaptations are based on 1990s technologies instead of technologies that would be available at the time for which impacts are estimated (i.e., 2025, 2055, and 2085 in the FTA). Nor do Parry et al. account for any technologies developed specifically to cope with the negative impacts of global

warming or take advantage of any positive outcomes (Parry et al., 2004, 57; Goklany 2007c, pp. 1032–33). The potential for future technologies to cope with climate change is large, especially bioengineered crops and precision agriculture (Goklany, 2007b; 2007c).

- The Nicholls (2004) study on coastal flooding from sea level rise makes an effort to incorporate improvements in adaptive capacity resulting from increasing wealth, but it includes several questionable assumptions. First, it assumes societies will implement measures to reduce the risk of coastal flooding in response to 1990 surge conditions, but not to subsequent sea level rise (p. 74). This defies logic. One should expect that any measures implemented would consider the latest available data and information on the surge situation at the time the measures are initiated. That is, if the measure is initiated in, say, 2050. the measure's design would at least consider sea level and sea level trends as of 2050, rather than the 1990 level. By that time, we should know the rate of sea level rise with much greater confidence. Second, Nicholls assumes a constant lag time between initiating protection and sea level rise. But one should expect that if sea level continues to rise, the time lag between upgrading protection standards and higher per-capita GDP will be reduced over time, and might even turn negative. That is, the further we go into the future, if sea level rise accelerates (as indicated by some models), then it is more likely adaptations would be anticipatory rather than reactive, particularly as societies become more affluent (as the IPCC scenarios assume they will) (see Figure 20.2.6). Third, Nicholls does not allow for any deceleration in the preferential migration of the population to coastal areas, as is likely if coastal storms and flooding become more frequent and costly (Goklany 2007b, pp. 1036-37).
- The analysis for malaria undertaken by van Lieshout et al. (2004) incorporates

adaptive capacity as it existed in 1990 (the base year) but does not adjust it to account for any subsequent advances in economic and technological development. There is simply no justification for such an assumption. If the IPCC's assumptions about future economic development are even half right, it is, as already noted, likely that malaria will have been eliminated by 2100.

Consideration of both economic development and technological change would make a large difference in the estimated impact of global warming on humanity. If impacts were to be estimated for five or so years into the future, ignoring changes in adaptive capacity between now and then probably would not be fatal, because neither economic development nor technological change likely would advance substantially during such a brief period. However, the time horizon of climate change impact assessments is often 35 to 100 years or more beyond the base year. The Fast Track Assessments, for example, use a base year of 1990 to estimate impacts for 2025, 2055, and 2085. The Stern Review's time horizon extends to 2100-2200 and beyond. Over such periods one ought to expect substantial advances in adaptive capacity due to increases in economic development, technological change, and human capital.

The assumption that few or no improved or new technologies would become available between 1990 and 2100 (or 2200) is clearly unfounded. From 1990 to 2005, for example, the portion of the developing world's population living in absolute poverty declined from 42 percent to 25 percent (World Bank 2009, 47). In Sub-Saharan Africa, the proportion of Internet users increased from 0 to 74 million from 1990 to 2009, and the proportion of cellular phone users went from 0 per 100 to 37 per 100 (World Bank 2011).

Some of the newer impact assessments have begun to account for changes in adaptive capacity. For example, Yohe et al. (2006), in an exercise exploring the vulnerability to climate change under various climate change scenarios, allowed adaptive capacity to increase between the present and 2050 and 2100. However, the researchers arbitrarily limited any increase in adaptive capacity to "either the current global mean or to a value that is 25 percent higher than the current value – whichever is higher" (Yohe et al., 2006, p. 4). There is no rationale for such an assumption: Such a limitation would have missed, for example, most of the increase in U.S. adaptive capacity during the twentieth century that virtually eliminated death and disease from climate-sensitive water-borne vector diseases.

More recently, Tol et al. (2007) analyzed the sensitivity of deaths from malaria, diarrhea, schistosomiasis, and dengue to warming, economic development, and other determinants of adaptive capacity through the year 2100. Their results indicate, unsurprisingly, that consideration of economic development alone could reduce mortality substantially. For malaria, for instance, deaths would be eliminated before 2100 in several of the more affluent Sub Saharan countries (Tol et al., 2007, p. 702). This is a much more realistic assessment of the impact of global warming on malaria in a wealthier (if not more technologically advanced) world than the corresponding FTA study. It is also more consistent with long-term trends in the extent of malaria, which indicate that the extent of P. falciparum malaria - the most deadly kind - declined from 58 percent of the world's land surface around 1900 to 30 percent by 2007 (Gething et al. 2010). Finally, it should be noted that it is precisely the failure to account for the combination of economic and technological development that caused high-profile Malthus's prognostications such as original conjecture about running out of cropland, The Limits to Growth, and Paul Ehrlich's over-population warning, The Population Bomb, to turn out to be so wrong. (Goklany 2007b; 2009a). And there is no reason to believe that the IPCC impact projections will not be just as wrong, unless economic and technological development is stymied.

References

Arnell, N.W. 2004. Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environmental Change* **14** (1): 31–52.

Arnell, N.W., Cannell, M.G.R., Hulme, M., Kovats, R.S., Mitchell, J.F.B., Nicholls, R.J., Parry, M.L., Livermore, M.T.J., and White, A. 2002. The consequences of CO₂ stabilization for the impacts of climate change. *Climatic Change* **53**: 413–446.

Ausubel, J.H. 1991. Does climate still matter? *Nature* **350**: 649–652.

Freeman, J. and Guzman, A. 2009. Climate change and U.S. interests. *Columbia Law Review* **100**: 101–171 (Version 3.1, dated 09/13/2009).

Gething, P.W., Smith, D.L., Patil, A.P., Tatem, A.J., Snow, R.W., and Hay, S.I. 2010. Climate change and the global malaria recession. *Nature* **465**: 342–345.

Goklany, I.M. 1995. Strategies to enhance adaptability: technological change, economic growth and free trade. *Climatic Change* **30**: 427–449.

Goklany, I.M. 2007a. Integrated strategies to reduce vulnerability and advance adaptation, mitigation, and sustainable development. *Mitigation and Adaption Strategies for Global Change* DOI 10.1007/s11027-007-9098-1.

Goklany, I.M. 2007b. *The Improving State of the World*. Washington, DC: Cato Institute.

Goklany, I.M. 2007c. Is a richer-but-warmer world better than poorer-but-cooler worlds? *Energy & Environment* **18** (7 and 8): 1023–1048.

Goklany, I.M. 2009a. Have increases in population, affluence and technology worsened human and environmental well-being? *Electronic Journal of Sustainable Development* 1(3). Available at http://www.ejsd.org/docs/HAVE_INCREASES_IN_POPU LATION_AFFLUENCE_AND_TECHNOLOGY_WORS ENED_HUMAN_AND_ENVIRONMENTAL_WELL-BEING.pdf.

Goklany, I.M. 2009b. Deaths and death rates from extreme weather events: 1900–2008, *Journal of American Physicians and Surgeons* 14 (4): 102–09.

Goklany, I.M. 2009c. Discounting the future. *Regulation* **32** (Spring): 36–40.

Goklany, I.M. 2009d. Is climate change the "defining challenge of our age"? *Energy & Environment* **20**(3): 279–302.

Intergovernmental Panel on Climate Change (IPCC). 2000. Special Report on Emissions Scenarios. New York, NY: Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). 2001. *Climate change 2001. Impacts, adaptation, and vulnerability.* New York, NY: Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate change 2007. Impacts, adaptation, and vulnerability.* New York, NY: Cambridge University Press.

Maddison, A. 2010. *Statistics on World Population, GDP and Per Capita GDP, 1-2008 AD*. Available at http://www.ggdc.net/maddison/Historical_Statistics/horizo ntal-file_02-2010.xls. Visited 15 August 2010.

Morris, J., editor. 2000. *Rethinking Risk and the Precautionary Principle*. Oxford, UK: Butterworth-Heinemann.

Nicholls, R.J. 2004. Coastal flooding and wetland loss in the 21st century: changes under the SRES climate and socio-economic scenarios. *Global Environmental Change* **14** (1): 69–86.

Parry, M., Rosenzweig, C., Iglesias, A., Fischer, G., and Livermore, M. 1999. Climate change and world food security: a new assessment. *Global Environmental Change* **9**: S51–S67.

Parry, M.L., editor. 2004. Special issue: an assessment of the global effects of climate change under SRES emissions and socio-economic scenarios. *Global Environmental Change* **14**: 1–99.

Parry, M.L., Rosenzweig, C., Iglesias, I., Livermore, M., and Fischer, G. 2004. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environmental Change* **14** (1): 53–67.

Ridley, M. 2010. *The Rational Optimist: How Prosperity Evolves*. London, UK: Fourth Estate.

Stern, N. et al. 2006. *The Economics of Climate Change*. London, UK: Her Majesty's Treasury.

Tol, R.S.J. and Dowlatabadi, H. 2001. Vector borne diseases, development & climate change. *Integrated Assessment* **2**: 173–181.

Tol, R.S.J., Ebi, K.L., and Yohe, G.W. 2007. Infectious disease, development, and climate change: a scenario analysis. *Environment and Development Economics* **12**: 687–706.

Tol, R,S.J. 2008. The social cost of carbon: trends, outliers and catastrophes. *Economics: The Open-Access, Open-Assessment E-Journal* **2**: 2008–25. Available at http://www.economicsejournal.org/economics/journalarticles/2008-25.

United Nations Environment Programme (UNEP). 1993. *Climate change and North-South relations*. Climate change fact sheet 109. UNEP, May 1. Available at http://unfccc.int/resource/ccsites/senegal/fact/fs109.htm. Visited 12 May 2003.

Van Lieshout, M., Kovats, R.S., Livermore, M.T.J., and Marten, P. 2004. Climate change and malaria: analysis of the SRES climate and socio-economic scenarios. *Global Environmental Change* **14** (1): 87–99.

World Bank 2009. *Global Economic Prospects 2009*. Available at

http://siteresources.worldbank.org/INTGEP2009/Resources /10363_WebPDF-w47.pdf. Visited 19 August 2010.

World Bank. 2011. World Bank Data Search, available http://databank.worldbank.org/ddp/home.do?Step=3&id=4. Visited 13 June 2011.

World Health Organization (WHO). 2009. *Global Health Risks: Mortality and Burden of Disease Attributable to Selected Major Risks*. Geneva, Switzerland: WHO. Available at

http://www.who.int/healthinfo/global_burden_disease/glob al_health_risks/en/index.html.

Yohe, G., Malone, E., Brenkert, A., Schlesinger, M., Meij, H. Xing, X., and Lee, D. 2006. A Synthetic Assessment of the Global Distribution of Vulnerability to Climate Change from the IPCC Perspective that Reflects Exposure and Adaptive Capacity. Palisades, NY: CIESIN (Center for International Earth Science Information Network), Columbia University. Available at http://sedac.ciesin.columbia.edu/mva/ccv/.

10.3. Biofuels

Biofuels are fuels made from organic matter. They include liquid fuels such as ethanol, biodiesel, and methanol; gaseous fuels such as methane and carbon monoxide; and solid fuels such as biochar and the more traditional charcoal. Biofuels may have some environmental advantages over gasoline and diesel fuels, but they are more expensive to produce and cannot supply more than a small part of the world's total transportation energy needs. And because they compete with food crops and nature for land, water, and nutrients, expanding the use of biofuels could negatively affect human health and natural ecosystems.

The 2009 NIPCC report (Idso and Singer, 2009) addressed the likely adverse consequences of expanding the use of biofuels as reported by several scientists in the peer-reviewed literature. Here we document additional studies that raise similar concerns but were published after those discussed in the 2009 report.

We begin with the study of Delucchi (2010), who is associated with the Institute of Transportation Studies at the University of California, Davis (USA). Delucchi writes, "governments worldwide are promoting the development of biofuels, such as ethanol from corn, biodiesel from soybeans, and ethanol from wood or grass, in order to reduce dependency on oil imported from politically unstable regions of the world, spur agricultural development, and reduce the climate impact of fossil fuel combustion." In light of the magnitude of this endeavor, Delucchi reviews what has been learned by many other students of the subject, after which he discusses "the impacts of biofuels on climate change, water use, and land use."

Delucchi's analysis leads him to state, "it is likely that biofuels produced from crops using conventional agricultural practices will *not* mitigate the impacts of climate change." They will instead "exacerbate stresses on water supplies, water quality, and land use, compared with petroleum fuels." He quotes Phalan (2009) as stating, "if risks and uncertainties are inadequately assessed and managed, even the best biofuels have the potential to damage the poor, the climate and biodiversity."

"To avoid these problems," in Delucchi's words, "biofuel feedstocks will have to be grown on land that has no alternative commercial use and no potential alternative ecological benefits, in areas with ample rainfall or groundwater, and with little or no inputs of fertilizers, chemicals, and fossil fuels." He adds, "it is not clear that it can be done economically and sustainably at large scales."

In a paper focusing on economics, Bryan et al. (2010) "assessed the potential benefits, costs, and trade-offs associated with biofuels agriculture to inform bioenergy policy." Specifically, they "assessed different climate change and carbon subsidy scenarios in an 11.9 million hectare region in southern Australia," where they "modeled the spatial distribution of agricultural production, full life-cycle net greenhouse gas (GHG) emissions and net energy, and economic profitability for both food agriculture (wheat, legumes, sheep rotation) and biofuels agriculture (wheat. canola rotation for ethanol/biodiesel production)."

Results indicated "biofuels agriculture was more profitable over an extensive area of the most productive arable land," producing "large quantities of biofuels" that "substantially increased economic profit." The end result, however, was "only a modest net GHG abatement" that had "a negligible effect on net energy production." In addition, they indicate the economic profit was largely due to "farm subsidies for GHG mitigation" and that whatever benefits were accrued came "at the cost of substantially reduced food and fiber production."

Examining the issue from a different angle, Erisman et al. (2010) state, "there is much discussion on the availability of different biomass sources for bioenergy application and on the reduction of greenhouse gas emissions compared to [emissions from] conventional fossil fuels," but "there is much less discussion on the other effects of biomass, such as the acceleration of the nitrogen cycle through increased fertilizer use resulting in losses to the environment and additional emissions of oxidized nitrogen." Erisman et al. thus provide "an overview of the state of knowledge on nitrogen and biofuels," particularly as pertaining to several sustainability issues.

According to the five researchers, "the contribution of N₂O emissions from fertilizer production and application make the greenhouse gas balance for certain biofuels small positive or even negative for some crops compared to fossil fuels" because "N₂O is a 300 times more effective greenhouse gas than CO₂" and N₂O emissions in the course of biofuel production "might be a factor 2-3[times] higher than estimated up until now from many field trials." In addition, they mention several other nitrogen-related environmental impacts of biofuel production, including modification of land for the growing of biofuels, wastes associated with biomass processing, and the "pollution entailed in constructing and maintaining equipment, transportation and storage facilities," as well as "the higher levels of eutrophication, acidification and ozone depletion" associated with biofuels due to the nitrogenous compounds released to the atmosphere during their agricultural production.

In a contemporaneous article published in Ecological Applications, Bouwman et al. (2010) assessed the global consequences of implementing first- and second-generation bioenergy production in the coming five decades. They focused on the nitrogen cycle and used "a climate mitigation scenario from the Organization for Economic Cooperation and Development's (OECD's) Environmental Outlook, in which a carbon tax is introduced to stimulate production of biofuels from energy crops." They calculated "the area of energy crops will increase from 8 Mha in the year 2000 to 270 Mha (14% of total cropland), producing 5.6 Pg dry matter per year (12% of energy use) in 2050." They also found "this production requires an additional annual 19 Tg of N fertilizer in 2050 (15% of total), and this causes a global emission of 0.7 Tg of N₂O-N (8% of agricultural emissions), 0.2 Tg NO-N (6%), and 2.2 Tg of NH₃--N (5%)." In addition, they observed, "2.6 Tg of NO₃--N will leach from fields under energy crops."

What might be some of the unfavorable impacts of these consequences of carbon-tax-supported biofuel production? For starters, the three employees of the Netherlands Environmental Assessment Agency note the greenhouse gas emissions that are supposed to be reduced by using biofuels instead of fossil fuels "are offset by 20% in 2030 and 15% in 2050 if N₂O emission from the cultivation of energy crops is accounted for." And even this blowback is but a fraction -30-60 percent for maize and sugar cane, according to Bouwman et al. - "of total emissions from the cultivation, processing, and transportation of biofuels." In addition, they write, "on a regional scale, increased N leaching, groundwater pollution, eutrophication of aquatic and terrestrial ecosystems, N₂O and NH₃ emissions from energy crop production, and NO_x emissions from combustion of biofuels may cause relevant loss of human and ecosystem health." With respect to the availability of land for the growing of biofuels, Bouwman et al. write, "the OECD-GC scenario shows a rapid expansion of agricultural land, mainly in Africa and the former Soviet Union," and "this expansion will lead to a further loss of biodiversity." The authors conclude by saying "bioenergy is economically feasible," but only "because of the climate change policies" that are "implemented through carbon taxes."

In an article published in the Journal of Plant Nutrition and Soil Science, Rattan Lal (Lal, 2010) of the Carbon Management and Sequestration Center of Ohio State University (USA) introduces the subject of his concern by writing, "the world is faced with the trilemma of climate change, food insecurity, and energy demand." He states, (1) "there still are more than one billion food-insecure people in the world (FAO, 2009a,b)," (2) "the world food supply will have to be doubled between 2005 and 2050 (Borlaug, 2009) because of the increase in population and change in dietary preferences," and (3) "the world energy demand is also increasing rapidly and is projected to increase by 84% by 2050 compared with 2005." What makes the problem even worse, he observes, is that in an attempt to meet the anticipated increase in the global demand for energy, "the emphasis on biofuels is strongly impacting the availability of grains for food and soil resources for grain production."

In response to this latter problem, Lal notes, crop residues are being "widely considered as a source of lignocellulosic biomass." However, he states that removal of crop residues for this purpose "is not an option (Lal, 2007) because of the negative impacts of removal on soil quality, and increase in soil erosion (Lal, 1995)" and the loss of the residue's "positive impacts" on "numerous ecosystem services." Therefore, observing yet another shift in tactics, Lal reports that degraded soils are being considered as possible sites for establishing energy plantations. However, Lal (2010) notes, the extremely low capacity for biomass production from these soils means the amount of biofuel produced on globally abandoned agricultural land cannot even meet 10 percent of the energy needs of North America, Europe, and Asia, citing the work of Campbell et al. (2009) in this regard. Yet even these considerations are only half the problem.

In addition to the need for a considerable amount of land, the "successful establishment of energy plantations also needs plant nutrients" and an "adequate supply of water," Lal notes. An adequate supply of water is on the order of 1,000 to 3,500 liters per liter of biofuel produced, which is, as Lal puts it, "an important factor." And he notes this strategy also will "increase competition for limited land and water resources thereby increasing food crop and livestock prices (Wise et al., 2009)."

In closing, Lal writes society should not take its precious resource base for granted, stating, "if soils are not restored, crops will fail even if rains do not; hunger will perpetuate even with emphasis on biotechnology and genetically modified crops; civil strife and political instability will plague the developing world even with sermons on human rights and democratic ideals; and humanity will suffer even with great scientific strides."

Additional concerns over the use of biofuels have been expressed by other authors. In a paper published in the *Journal of Agricultural and Environmental Ethics*, Gomiero et al. (2010) examine the wisdom of appropriating much of the planet's land and water resources to support large-scale production of biofuels as replacements for fossil fuels. They come to several damning conclusions about the enterprise.

They report there is not enough readily available land to produce much fuel from biomass without causing a severe impact on global food production, while adding, "even allocating the entire USA cropland and grassland to biofuels production, the energy supply will account for only a few percentage points of the USA energy consumption," which suggests "there is no hope for biomass covering an important share of USA energy demand." Noting "the same is true for the European Union," the researchers go on to observe that "biofuel production cannot, in any significant degree, improve the energy security of developed countries," for to do so "would require so vast an allocation of land that it would be impossible for a multitude of reasons."

Another problem Gomiero et al. observe is that biofuel production, including cellulosic ethanol from crop residues and grasslands, "does not appear to be energetically very efficient." In fact, they note, fierce debates have arisen over whether the energy output/input ratio of various biofuel production enterprises is 0.2 of a unit above or below 1.0, which seems rather small in light of another item they report, that "our industrial society is fueled by fossil fuels that have an output/input ratio 15-20 times higher." Indeed, they write that recent assessments demonstrate extensive biofuels production may actually tend to "exacerbate greenhouse gas emissions and in turn global warming." They also state biofuels "may greatly accelerate" the destruction of natural ecosystems their biodiversity and by "the appropriation of far too large a fraction of net primary production," thus resulting in a threat to their "health, soil fertility, and those key services needed by human society."

In concluding, Gomiero et al. warn "biofuels cannot be either our energy panacea, nor supply even a minimal share of energy supply for our society without causing major social and environmental problems." Therefore, they suggest we use our "hard earned money," as they put it, to "help farmers, both in developed and developing countries, to adopt energy saving-environmentally friendly agricultural practices, that can really help to cut greenhouse gas emissions, prevent soil erosion, reduce water consumption, relieve the environment from toxic pollutants, preserve wild and domesticated biodiversity and supply many other services." And as the three scientists advise in their concluding sentence, "we should be careful not to let our 'energetic despair' (or vested interest) lead us to worsen the very same environmental and social problems we wish and need to solve."

Introducing their contribution to the subject, Gelfand et al. (2010) write, "recently, the prospect of biofuel production on a large scale has focused attention on energy efficiencies associated with different agricultural systems and production goals," but "few empirical studies comparing whole-system multiyear energy balances are available." In fact, they state that as far as they are aware, "there are no studies that directly compare food vs. fuel production efficiencies in long-term, well-equilibrated cropping systems with detailed descriptions of fossil energy use."

To begin filling this data void, Gelfand et al., as they describe it, "used 17 years of detailed data on agricultural practices and yields to calculate an energy balance for different cropping systems under both food and fuel scenarios." They examined one forage and four grain systems in the U.S. Midwest that included "corn-soybean-wheat rotations managed with (1) conventional tillage, (2) no till, (3) low chemical input, and (4) biologically based (organic) practices, and (5) continuous alfalfa," and "compared energy balances under two scenarios: all harvestable biomass used for food versus all harvestable biomass used for biofuel production."

The three researchers report "energy efficiencies ranged from output:input ratios of 10 to 16 for conventional and no-till food production and from 7 to 11 for conventional and no-till fuel production, respectively." Such a result, Gelfand et al. write, "points to a more energetically efficient use of cropland for food than for fuel production," and the large differences in efficiencies attributable to the different management techniques they evaluated suggest there are "multiple opportunities for improvement."

Exploring a different aspect of the debate, Witt (2010) notes "several studies in the last five years have warned against the potential impact of promoting biofuel crops that are known to be invasive or to have potentially invasive characteristics," citing the studies of Raghu et al. (2006), Barney and DiTomaso (2008), Howard and Ziller (2008), and Buddenhagen et al. (2009). Witt notes "a large number of proposed biofuel crops share the same traits as known invasive plant species," and many of them "are already present in Africa." In light of these observations, Witt assesses the impacts of several species of the invasive Prosopis genus in Kenya and South Africa, where the spiny trees and shrubs have invaded more than four million hectares of crop and pasture land.

Witt writes, "communities in Kenya and elsewhere are becoming increasingly concerned about the displacement of other species important for local livelihoods, especially fodder species for livestock." They are also concerned, he continues, about the

invasive species' encroachment onto "paths. dwellings, water sources, farms and pastureland" and their "negative impacts on animal and human health with injuries due to thorns resulting in some human fatalities," citing Mwangi and Swallow (2005) and Maundu et al. (2009). In addition, he notes the plants' tendency to invade riparian zones, dry river beds, and lowlands, where they "tap into underground water sources," means they "interfere with drainage, blocking watercourses and exacerbating the effects of flooding." Witt states the displacement of native plants by Prosopis species is especially serious, noting "the World Health Organization estimates that up to 80% of the world's rural populations depend on [native] plants for their primary health care."

Witt concludes that nonnative species that are known to be invasive elsewhere and have been deemed to be a high-risk species "should not be introduced and cultivated," because "the costs associated with invasive species, even those that are deemed to be beneficial, in most cases, outweigh the benefits that accrue from their use." He ends with the warning that "no widespread invasive plant species has been controlled through utilization alone in any part of the world."

Lastly, in a paper published in AMBIO: A Journal of the Human Environment, Mulder et al. (2010) assess the connection between water and energy production by conducting a comparative analysis for estimating the energy return on water invested (EROWI) for several renewable and nonrenewable energy technologies using various life cycle analyses. This approach mirrors the energy return on energy investment (EROEI) technique used to determine the desirability of different forms of alternative energy, with the technique's most recent application being adjusted to consider also the global warming potentials of the different forms of non-fossil-fuel energy and the greenhouse gases emitted to the atmosphere in the process of producing and bringing them to the marketplace.

The reason for bringing water into the equation derives from the facts, as noted by Mulder et al., that (1) "water withdrawals are ubiquitous in most energy production technologies," (2) "several assessments suggest that up to two-thirds of the global population could experience water scarcity by 2050 (Vorosmarty et al., 2000; Rijsberman, 2006)," (3) "human demand for water will greatly outstrip any climate-induced quantity gains in freshwater availability (Vorosmarty et al., 2000; Alcamo et al., 2005)," and (4) the increased need for more fresh water "will be driven by the agricultural demand for water which is currently responsible for 90% of global freshwater consumption (Renault and Wallender, 2006)."

The three U.S. researchers state their results suggest "the most water-efficient, fossil-based technologies have an EROWI one to two orders of magnitude greater than the most water-efficient biomass technologies, implying that the development of biomass energy technologies in scale sufficient to be a significant source of energy may produce or exacerbate water shortages around the globe and be limited by the availability of fresh water."

In considering the policy ramifications, these findings will not be welcomed by those who promote biofuel production as a means of combating what they call "the threats posed by 'climate refugees' and 'climate conflict' to international security," as discussed by Hartmann (2010) in the Journal of International Development, where she identifies some of the principals in the spreading of what she calls this "alarmist rhetoric" to various United Nations agencies, NGOs, national governments, security pundits, the popular media, and, specifically, the Norwegian Nobel Committee of 2007, which, as she describes it, "warned that climate-induced migration and resource scarcity could cause violent conflict and war within and between states when it awarded the Nobel Peace Prize to Al Gore, Jr. and the Intergovernmental Panel on Climate Change."

Hartmann goes on to suggest "this beating of the climate conflict drums has to be viewed in the context of larger orchestrations in U.S. national security policy." And in this regard it is clear that the promotion of biofuels to help resolve these concerns will only exacerbate them in one of the worst ways imaginable, providing a "cure" that is worse than the disease.

Hartmann notes, "in the United States, members of Congress eager to pass climate legislation" – which will likely *mandate* the use of more biofuels – "have resorted to the security threat argument as a way to win support on Capitol Hill." She answers this by remarking that "according to the *New York Times* (2009), 'many politicians will do anything for the Pentagon.""

Clearly, there are various motives involved in the debate over possible CO_2 -induced climate change and what to do about it. Yet, it is equally clear that there simply is not enough land or fresh water on the face of the Earth to make the production of biofuels a

viable and significant alternative to the mining and usage of fossil fuels.

References

Alcamo, J., van Vuuren, D., Ringler, C., Cramer, W., Masui, T., Alder, J., and Schulze, K. 2005. Changes in nature's balance sheet: model based estimates of future worldwide ecosystem services. *Ecology and Society* **10**: http://www.ecologyandsociety.org/vol10/iss2/art19/.

Barney, J.N. and DiTomaso, J.M. 2008. Nonnative species and bioenergy: are we cultivating the next invader? *BioScience* **58**: 64–70.

Borlaug, N.E. 2009. Foreword. Food Security 1: 1.

Bouwman, A.F., van Grinsven, J.J.M., and Eickhout, B. 2010. Consequences of the cultivation of energy crops for the global nitrogen cycle. *Ecological Applications* **20**: 101–109.

Bryan, B.A., King, D., and Wang, E. 2010. Biofuels agriculture: landscape-scale trade-offs between fuel, economics, carbon, energy, food, and fiber. *Global Change Biology Bioenergy* **2**: 330–345.

Buddenhagen, C.E., Chimera, C., and Clifford, P. 2009. Assessing biofuel crop invasiveness: a case study. *PLoS One* **4**: 1–6.

Campbell, J.E., Lobell, D.B., and Field, C.B. 2009. Greater transportation energy and GHG offsets from bioelectricity than ethanol. *Science* **324**: 1055–1057.

Delucchi, M.A. 2010. Impacts of biofuels on climate change, water use, and land use. *Annals of the New York Academy of Sciences* **1195**: 28–45.

Erisman, J.W., van Grinsven, H., Leip, A., Mosier, A., and Bleeker, A. 2010. Nitrogen and biofuels: an overview of the current state of knowledge. *Nutrient Cycling in Agroecosystems* **86**: 211–223.

Food and Agriculture Organization (FAO). 2009a. 1.02 billion people hungry. FAO Newsroom, http://www.fao.org/news/story/on/item/20568/icode/.

Food and Agriculture Organization (FAO). 2009b. FAO Statistics Database. Rome, Italy: FAO.

Gelfand, I., Snapp, S.S., and Robertson, G.P. 2010. Energy efficiency of conventional, organic and alternative cropping systems for food and fuel at a site in the U.S. Midwest. *Environmental Science and Technology* **44**: 4006–4011.

Gomiero, T., Paoletti, M.G., and Pimentel, D. 2010. Biofuels: efficiency, ethics, and limits to human appropriation of ecosystem services. *Journal of Agricultural and Environmental Ethics* **23**: 403–434. Hartmann, B. 2010. Rethinking climate refugees and climate conflict: rhetoric, reality and the politics of policy discourse. *Journal of International Development* **22**: 233–246.

Howard, G. and Ziller, S. 2008. Alien alert – plants for biofuel may be invasive. *Bioenergy Business* July/August: 14–16.

Idso, C.D. and Singer, S.F. 2009. *Climate Change Reconsidered: 2009 Report of the Nongovernmental International Panel on Climate Change (NIPCC)*. Chicago, IL: The Heartland Institute.

Lal, R. 1995. Erosion-crop productivity relationships for soils of Africa. *Soil Science Society of America Journal* **59**: 661–667.

Lal, R. 2007. There is no such thing as a free biofuel from crop residues. *CSA News* **52**: 12–13.

Lal, R. 2010. Managing soils for a warming earth in a foodinsecure and energy-starved world. *Journal of Plant Nutrition and Soil Science* **173**: 4–15.

Maundu, P., Kibet, S., Morimoto, Y., Imbumi, M., and Adeka, R. 2009. Impact of *Prosopis juliflora* on Kenya's semi-arid and arid ecosystems and local livelihoods. *Biodiversity* **10**: 33–50.

Mwangi, E. and Swallow, B. 2005. *Invasion of Prosopis juliflora and Local Livelihoods: Case Study from the Lake Baringo Area of Kenya*. ICRAF Working Paper No. 3. Nairobi, Kenya: World Agroforestry Center.

Mulder, K., Hagens, N., and Fisher, B. 2010. Burning water: A comparative analysis of the energy return on water invested. *Ambio* **39**: 30–39.

New York Times. 2009. The climate and national security. Editorial, 17 August. Available at http://www.nytimes.com/2009/08/18/opinion/18tue1.html? _r=1&adxnnl=1&adxnnlx=1254075176-6uv9m0Js29a+HJeDEXZSFg.

Phalan, P. 2009. The social and environmental impacts of biofuels in Asia: an overview. *Applied Energy* **86**: S21–S29.

Raghu, S., Anderson, R.C., Daehler, C.C., Davis, A.S., Wiedenmann, R.N., Simberloff, D., and Mack, R.N. 2006. Adding biofuels to the invasive species fire? *Science* **313**: 1742.

Renault, D. and Wallender, W. 2006. Nutritional water productivity and diets. *Agricultural Water Management* **45**: 275–296.

Rijsberman, F.R. 2006. Water scarcity: fact or fiction. *Agricultural Water Management* **80**: 5–22.

Vorosmarty, C.J., Green, P., Salisbury, J., and Lammers, R.B. 2000. Global water resources: vulnerability from climate change and population growth. *Science* **289**: 284–288.

Wise, M., Calvin, K., Thomson, A., Clarke, L., Bond-Lamberty, B., Sands, R., Smith, S.J., Janetos, A., and Edmonds, J. 2009. Implications of limiting CO₂ concentrations for land use and energy. *Science* **324**: 1183– 1186.

Witt, A.B.R. 2010. Biofuels and invasive species from an African perspective – a review. *Global Change Biology Bioenergy* **2**: 321–329.

10.4. War and Social Unrest

Many political and opinion leaders say it is important to enact legislation to limit carbon dioxide emissions out of concern that global warming is detrimental to society. High among their list of anxieties is the fear that CO₂-induced global warming will lead to social unrest and perhaps even war, given postulated reductions in agricultural output followed by population turmoil due to lack of food.

An emerging body of research suggests those concerns are not only unfounded, but even backwards – that it is global cooling from which society stands the most to lose. Global warming, by contrast, tends to promote social stability, as evidenced in the peerreviewed papers discussed below.

China is a good test case for the relationship between global warming and social stability because it has been a well-populated, primarily agricultural country for millennia, and it has a relatively wellrecorded history over this period. Accordingly, several researchers have conducted analyses of factors influencing social stability in China. Zhang et al. (2005) note historians typically identify political, economic, cultural, and ethnic unrest as the chief causes of war and civil strife there. However, the five Chinese scientists contend climate plays a key role as well, and to examine their thesis they compared proxy climate records with historical data on wars, social unrest, and dynastic transitions in China from the late Tang to Qing Dynasties (mid-ninth century to early twentieth century).

Their research revealed that war frequencies, peak war clusters, nationwide periods of social unrest, and dynastic transitions were all significantly associated with cold, not warm, phases of China's oscillating climate. Specifically, all three distinctive peak war clusters (defined as more than 50 wars in a ten-year period) occurred during cold climate phases, as did all seven periods of nationwide social unrest and nearly 90 percent of all dynastic changes that decimated this largely agrarian society. They conclude climate change was "one of the most important factors in determining the dynastic cycle and alternation of war and peace in ancient China," with warmer climates having been immensely more effective than cooler climates in terms of helping "keep the peace."

In a similar study, Lee and Zhang (2010) examined data on Chinese history, including temperature, wars and rebellions, epidemics, famines, and population for the past millennium. Over the study interval of 911 years, it was found that nomad migrations, rebellions, wars, epidemics, floods, and droughts were all higher during cold periods. All of these factors tended to disrupt population growth or increase mortality. Overall, five of six population contractions, constituting losses of 11.4 to 49.4 percent of peak population, were associated with a cooling climate. The sixth cool period evinced a great reduction in population growth rate during a cool phase, but not a collapse. None of the population contractions was associated with a warming climate.

As background for another study, Zhang et al. (2010) state, "climatic fluctuation may be a significant factor interacting with social structures in affecting the rise and fall of cultures and dynasties," citing Cowie (1998) and Hsu (1998). When the climate worsens beyond what the available technology and economic system can accommodate – that is, beyond the society's adaptive capacity – they state, "people are forced to move or starve."

In this regard, they note, "climate cooling has had a huge impact on the production of crops and herds in pre-industrial Europe and China (Hinsch, 1998; Atwell, 2002; Zhang et al., 2007a), even triggering mass southward migration of northern nomadic societies (Fang and Liu, 1992; Wang, 1996; Hsu, 1998)," and "this ecological and agricultural stress is likely to result in wars and social unrest, often followed by dynastic transitions (Zhang et al., 2005)." In fact, they write, "recent studies have demonstrated that wars and social unrests in the past often were associated with cold climate phases (Zhang et al., 2005, 2007a,b)," and "climate cooling may have increased locust plagues through temperature-driven droughts or floods in ancient China (Stige et al., 2007: Zhang et al., 2009)."

In a study designed to explore the subject further, Zhang et al. (2010) employed "historical data on war frequency, drought frequency and flood frequency" compiled by Chen (1939), and "a multi-proxy temperature reconstruction for the whole of China reported by Yang et al. (2002), air temperature data for the Northern Hemisphere (Mann and Jones, 2003), proxy temperature data for Beijing (Tan et al., 2003), and a historical locust dataset reported by Stige et al. (2007)," plus "historical data of rice price variations reported by Peng (2007)."

In analyzing the linkages among these different factors, the international (Chinese, French, German, and Norwegian) team of researchers concluded "food production during the last two millennia has been more unstable during cooler periods, resulting in more social conflicts." They specifically note "cooling shows direct positive association with the frequency of external aggression war to the Chinese dynasties mostly from the northern pastoral nomadic societies, and indirect positive association with the frequency of internal war within the Chinese dynasties through drought and locust plagues," which have typically been more pronounced during cooler as opposed to warmer times.

Given these findings, Zhang et al. conclude "it is very probable that cool temperature may be the driving force in causing high frequencies of meteorological, agricultural disasters and then manmade disasters (wars) in ancient China," noting "cool temperature could not only reduce agricultural and livestock production directly, but also reduce agricultural production by producing more droughts, floods and locust plagues." They also observe the subsequent "collapses of agricultural and livestock production would cause wars within or among different societies." Consequently, although "it is generally believed that global warming is a threat to human societies in many ways (IPCC, 2007)," Zhang et al. come to a somewhat different conclusion, stating some countries or regions might actually "benefit from increasing temperatures," citing the work of Nemani et al. (2003), Stige et al. (2007), and Zhang et al. (2009), while restating the fact that "during the last two millennia, food production in ancient China was more stable during warm periods owing to fewer agricultural disasters, resulting in fewer social conflicts."

Following in the footsteps of Zhang et al. (2005, 2006), Tol and Wagner (2010) essentially proceeded to do for Europe what Zhang et al. had done earlier for China. In introducing their study the authors state that in "gloomier scenarios of climate change, violent

conflict plays a key part," noting in such visions of the future, "war would break out over declining water resources, and millions of refugees would cause mayhem." The two researchers note "the Nobel Peace Prize of 2007 was partly awarded to the IPCC and Al Gore for their contribution to slowing climate change and thus preventing war." However, they observe "scenarios of climate-change-induced violence can be painted with abandon," citing the example of Schwartz and Randall (2003), because "there is "little research to either support or refute such claims." Consequently, and partly to fill this gaping research void, Tol and Wagner conducted their own analysis of the subject for Europe. And as with their colleagues who studied China, their results indicate that "periods with lower temperatures in the pre-industrial era are accompanied by violent conflicts." However, they determined "this effect is much weaker in the modern world than it was in pre-industrial times," which implies, in their words, "that future global warming is not likely to lead to (civil) war between (within) European countries." Therefore, they conclude, "should anyone ever seriously have believed that, this paper does put that idea to rest."

In a contemporaneous study, Field and Lape (2010) note it has been repeatedly suggested that in many parts of the world climate change has "encouraged conflict and territorialism," as this response, in their words, "serves as an immediate means of gaining resources and alleviating shortfalls," such as those that occur when the climate change is detrimental to agriculture and the production of food. To investigate this hypothesis, the authors compared "periods of cooling and warming related to hemispheric-level transitions (namely the Medieval Warm Period and the Little Ice Age) in sub-regions of the Pacific with the occurrence of fortifications at the century-level." Their study revealed "the comparison of fortification chronologies with paleoclimatic data that fortification construction indicate was significantly correlated with periods of cooling, which in the tropical Pacific is also associated with drying." In addition, "the correlation was most significant in the Indo-Pacific Warm Pool, the Southwestern Pacific and New Zealand," where "people constructed more fortifications during periods that match the chronology for the Little Ice Age (AD 1450-1850)," as opposed to the Medieval Warm Period (AD 800-1300) when the Indo-Pacific Warm Pool was both warm and saline "with temperatures approximating current conditions (Newton et al., 2006)." Thus, Field and Lape's study provides more evidence that periods of greater warmth have generally led to more peaceful times throughout the world, whereas periods of lesser warmth have typically led to greater warfare.

Considering North America, Cleaveland et al. (2003) developed a history of winter-spring (November-March) precipitation for the period 1386-1993 for the area around Durango, Mexico, based on earlywood width chronologies of Douglas-fir tree rings collected at two sites in the Sierra Madre Occidental. This reconstruction, in their words, "shows droughts of greater magnitude and longer duration than the worst historical drought," and none of them occurred during a period of unusual warmth, as some researchers claim they should; instead, they occurred during the Little Ice Age. They also note, "Florescano et al. (1995) make a connection between drought, food scarcity, social upheaval and political instability, especially in the revolutions of 1810 and 1910," and they note the great megadrought that lasted from 1540 to 1579 "may be related to the Chicimeca war (Stahle et al., 2000), the most protracted and bitterly fought of the many conflicts of natives with the Spanish settlers." If these concurrent events were indeed related, they too suggest that warmer is far better than cooler for maintaining social stability.

An analogous relationship was found to prevail in East Africa by Nicholson and Yin (2001), who analyzed climatic and hydrologic conditions from the late 1700s to close to the present, based on (1) histories of the levels of ten major African lakes and (2) a water balance model they used to infer changes in rainfall associated with the different conditions. concentrating most heavily on Lake Victoria. The results they obtained were indicative of "two starkly contrasting climatic episodes." The first, which began sometime prior to 1800 during the Little Ice Age, was one of "drought and desiccation throughout Africa." This arid episode, which was most intense during the 1820s and '30s, was accompanied by extremely low lake levels. As the two researchers describe it, "Lake Naivash was reduced to a puddle. ... Lake Chad was desiccated. ... Lake Malawi was so low that local inhabitants traversed dry land where a deep lake now resides. ... Lake Rukwa [was] completely desiccated. ... Lake Chilwa, at its southern end, was very low and nearby Lake Chiuta almost dried up."

Nicholson and Yin state that throughout this period "intense droughts were ubiquitous." Some, in fact, were "long and severe enough to force the migration of peoples and create warfare among various tribes." As the Little Ice Age's grip on the world began to loosen in the middle to latter part of the 1800s, however, things began to change for the better. The two researchers report, "semi-arid regions of Mauritania and Mali experienced agricultural prosperity and abundant harvests; floods of the Niger and Senegal Rivers were continually high; and wheat was grown in and exported from the Niger Bend region." Then, as the nineteenth century came to an end and the twentieth began, there was a slight lowering of lake levels, but nothing like what had occurred a century earlier; and in the latter half of the twentieth century, things once again improved, with the levels of some lakes rivaling high-stands characteristic of the years of transition to the Modern Warm Period.

These findings all clearly suggest warmer temperatures favor social stability and peace.

References

Atwell, W.S. 2002. Time, money and the weather: Ming China and the great depression of the mid-fifteenth century. *Journal of Asian Studies* **61**: 83–113.

Chen, G.Y. 1939. *China Successive Natural and Manmade Disasters Table*. Guangzhou, China: Jinan University Book Series.

Cleaveland, M.K., Stahle, D.W., Therrell, M.D., Villanueva-Diaz, J., and Burns, B.T. 2003. Tree-ring reconstructed winter precipitation and tropical teleconnections in Durango, Mexico. *Climatic Change* **59**: 369–388.

Cowie, J. 1998. *Climate and Human Change: Disaster or Opportunity?* New York, NY: Parthenon Publishing Group.

Fang, J. and Liu, G. 1992. Relationship between climatic change and the nomadic southward migrations in eastern Asia during historical times. *Climatic Change* **22**: 151–168.

Field, J.S. and Lape, P.V. 2010. Paleoclimates and the emergence of fortifications in the tropical Pacific islands. *Journal of Anthropological Archaeology* **29**: 113–124.

Florescano, E., Swan, S., Menegus, M., and Galindo, I. 1995. *Breve Historia de la Sequia en Mexico*. Veracruz, Mexico: Universidad Veracruzana.

Hinsch, B. 1998. Climate change and history in China. *Journal of Asian History* **22**: 131–159.

Hsu, K.J. 19998. Sun, climate, hunger and mass migration. *Science in China Series D* – *Earth Sciences* **41**: 449–472.

Intergovernmental Panel on Climat Change (IPCC). 2007. Fourth Assessment Report on Climate Change 2007: Synthesis Report. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

Lee, H.F. and Zhang, D.D. 2010. Changes in climate and secular population cycles in China, 1000 CE to 1911. *Climate Research* **42**: 235–246.

Mann, M.E. and Jones, P.D. 2003. Global surface temperatures over the past two millennia. *Geophysical Research Letters* **30**: 10.1029/2003GL017814.

Nemani, R.R., Keeling, C.D., Hashimoto, H., Jolly, W.M., Piper, S.C., Tucker, C.J., Myneni, R.B., and Running, S.W. 2003. Climate-driven increases in global terrestrial net primary production from 1982 to 1999. *Science* **300**: 1560– 1563.

Newton, A., Thunnell, R., and Stott, L. 2006. Climate and hydrographic variability in the Indo-Pacific warm pool during the last millennium. *Geophysical Research Letters* **33**: 10.1029/2006GL027234.

Nicholson, S.E. and Yin, X. 2001. Rainfall conditions in equatorial East Africa during the nineteenth century as inferred from the record of Lake Victoria. *Climatic Change* **48**: 387–398.

Peng, X.W. 2007. *History of Chinese Currency*. Shanghai, China: Shanghai People's Press.

Schwartz, P. and Randall, D. 2003. An abrupt climate change scenario and its implications for United States national security. San Francisco, CA: Global Business Network. Available at

http://www.edf.org/documents/3566_AbruptClimateChang e.pdf.

Stahle, D.W., Cook, E.R., Cleaveland, M.K., Therrell, M.D., Meko, D.M., Grissino-Mayer, H.D., Watson, E., and Luckman, B.H. 2000. Tree-ring data document 16th century megadrought over North America. *EOS, American Geophysical Union, Transactions* **81**: 121, 125.

Stige, L.C., Chan, K.S., Zhang, Z.B., Frank, D., and Stenseth, N.C. 2007. Thousand-year-long Chinese time series reveals climatic forcing of decadal locust dynamics. *Proceedings of the National Academy of Sciences USA* **104**: 16,188–16,193.

Tan, M., Liu, T., Hou, J., Qin, X., Zhang, H., and Li, T. 2003. Cyclic rapid warming on centennial scale revealed by a 2650-year stalagmite record of warm season temperature. *Geophysical Research Letters* **30**: 10.1029/2003GL017352.

Tol, R.S.J. and Wagner, S. 2010. Climate change and violent conflict in Europe over the last millennium. *Climatic Change* **99**: 65–79.

Wang, H.C. 1996. The relationship between the southern migrations of north nomadic tribes and climate change in China. *Scientia Geographica Sinica* **16**: 274–279.

Yang, B., Braeuning, A., Johnson, K.R., and Shi, Y.F. 2002. General characteristics of temperature variation in China during the last two millennia. *Geophysical Research Letters* **29**: 38–42.

Zhang, D., Jim, C.Y., Lin, C.S., He, Y.Q., and Lee, F. 2005. Climate change, social unrest and dynastic transition in ancient China. *Chinese Science Bulletin* **50**: 137–144.

Zhang, D.D., Brecke, P., Lee, H.F., He, Y.Q., and Zhang, J. 2007a. Global climate change, war, and population decline in recent human history. *Proceedings of the National Academy of Sciences USA* **104**: 19,214–19,219.

Zhang, D.D., Jim, C.Y., Lin, G.C.-S., He, Y.-Q., Wang, J.J., and Lee, H.F. 2006. Climatic change, wars and dynastic cycles in China over the last millennium. *Climatic Change* **76**: 459–477.

Zhang, D.D., Zhang, J., Lee, H.F., and He, Y. 2007b. Climate change and war frequency in eastern China over the last millennium. *Human Ecology* **35**: 403–414.

Zhang, Z., Tian, H., Cazelles, B., Kausrud, K.L., Brauning,

A., Guo, F., and Stenseth, N.C. 2010. Periodic climate cooling enhanced natural disasters and wars in China during AD 10–1900. *Proceedings of the Royal Society B* **277**: 10.1098/rspb.2010.0890.

Zhang, Z.B., Cazelles, B., Tian, H.D., Stige, L.C., Brauning, A., and Stenseth, N.C. 2009. Periodic temperature-associated drought/flood drives locust plagues in China. *Proceedings of the Royal Society B* **276**: 823– 831.