Earth News: Adapt, Mitigate or Die

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Abstract

In 1967, Martin Luther King, Jr. said "We are now faced with the fact, my friends, that tomorrow is today. We are confronted with the fierce urgency of now" (Blair 2009). Although stated more than 40 years ago, his words are fitting for climate change today. Scientific data indicates that increased greenhouse gas concentrations are prompting precipitation patterns to shift, droughts to worsen, heat waves to intensify, and monsoons to fail. Conversely, we are seeing increased precipitation intensity, destructive storms, and ocean acidification. Between 1990 and 2001, world flooding affected 1.5 billion people and their food security. For example since 1990, China's Yangtze River floods and related crop failure have claimed more than a million lives. As food shortages increase, civil conflict and potential for disease increase. Many earlier civilizations collapsed due to food insecurity and civil conflict.

Unabated climate change adversely affects world food supplies, health and civilization. The fierce urgency of now is here. Citizens of the world need bold visionary goals to mitigate climate change by using low-carbon technology, energy efficiency, renewable energy, carbon capture and storage. This paper reviews the links among climate change, crop failure and effects on health, followed with suggestions for adapting to the effects of climate change and mitigating greenhouse gas emissions.

Introduction

If the Earth could communicate to its residents, a warning scripted on the clouds might read: *Adapt, Mitigate or Die*. With increasing evidence for the human contribution to increased carbon dioxide emissions and climate change, foresight and action are critical to evade an uninhabitable environment for future generations. The first part of this paper presents evidence supporting human-influenced climate change and its effects on crops and human health. Strategies by which the world's populace can adapt to a warmer environment or mitigate (lessen) the negative impact of climate change are found in the second part. Emphasis is placed on mitigation since effective mitigation strategies could decrease the need for adapting to higher global temperatures.

1.0 Brief overview of climate change research

The complex, interactive array of the atmosphere, land surface, snow, ice, oceans, lakes and all living things forms the Earth's climate system. What is known today about this system comes from the work of literally thousands of scientists over the span of three centuries. As early as the 1800s, British scientist John Tyndall (NASA 2009) suggested that the atmosphere gasses, specifically carbon dioxide (CO_2), affected the earth's temperature. Later in the 19th century, Svante Arrhenius from Stockholm published the first calculation of global warming attributed to human emissions of carbon dioxide (Arrhenius 1896, 237-76). Four decades later, Guy Stewart Callendar presented evidence to the London-based Royal Meteorological Society that burning fossil fuels caused global warming (Callendar 1938, 223-240). First to confirm the accumulation of CO_2, Charles David Keeling measured CO_2 emissions atop the volcanic peak on Mauna Loa in Hawaii for almost 50 years (Scripps n.d). Data from Mauna Loa have often been called the "Keeling Curve," a symbol of the impact of human activity on planet Earth. For readers wanting a more in-depth history of climate change research, *The Discovery of Global Warming* (2003) by Spencer R. Weart is recommended.

Since these initial discoveries, researchers from the physical, biological, and social sciences have exponentially increased knowledge about climate change and its effects on the Earth. As evidence accumulated, it became evident that climate change findings needed to be placed into the hands of decision-makers and government leaders. In 1988, global organizations of the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) created the Intergovernmental Panel on Climate Change (IPCC) (Weart 2003). This Panel was mandated to provide an objective source of information about climate change. Since its origination, IPCC has prepared scientifically based reports about climate change and its impact on the planet and its inhabitants, in addition to strategies for adapting to a warmer environment and mitigating the increase in global temperatures. For the non-scientist reader, a user-friendly edition of the IPCC Fourth Assessment Report is available in *Dire Predictions – Understanding Global Warming* (Mann and Kump 2008). Efforts of climate scientists from around the world and IPCC have not gone unnoticed. In 2007, IPCC and Al Gore, Jr. were awarded the Nobel Peace Prize "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures needed to counteract such change" (IPCC n.d.). At the March 10-12th International Scientific Congress meeting (ISC 2009) on climate change in Copenhagen, Denmark, the key message was that the worse-case IPCC scenario climatic trends are being realized sooner than expected. Global average surface temperature, sea-level rise, ocean and ice sheet changes, ocean acidification and extreme climatic events have moved beyond the patterns of natural variability and are at risk for abrupt or irreversible climatic shifts. The conclusions of this meeting will be published in a final report June 2009.

1.1 Effect of human activity on carbon dioxide emissions

With "very high confidence", the IPCC Fourth Assessment Report (IPCC Working Group I 2007) states that "global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750." Levels of carbon dioxide have increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005, with fossil fuels identified as the primary source contributing to the increased concentration of carbon dioxide. Fossil carbon dioxide emissions are defined as those from the production, distribution and consumption of fossil fuels and as by-products from cement production. During the last decade, the annual carbon dioxide concentration growth rate was greater than any decade since the beginning of atmospheric measurements in 1960. *Radiative forcing*, a new term used in the Fourth Assessment Report, provides an index of the importance of a factor as a potential climate change mechanism. From 1995 to 2005, radiative forcing for carbon dioxide increased by 20%. This is the largest change for any decade in the last 200 years.

Carbon dioxide emissions from fossil fuel combustion can now be viewed in interactive maps funded by the National Aeronautics Science Association and the U.S. Department of Energy (NASA 2007). The project, named *Vulcan* for the Roman god of fire, provides an inventory of carbon dioxide emissions from the burning of 48 different types of fossil fuel. Maps show estimates of hourly carbon dioxide outputs from factories, power plants, vehicle traffic and residential and commercial areas. Another NASA funded project is underway to create similar inventories of carbon dioxide emissions for Canada and Mexico.

1.2 **Effects of climate change on temperature, ice masses, and oceans**

A direct observation of recent climate change has been the warming of the climate system. During the 20th century, the global average surface temperatures increased about 0.6 $^{\circ}$ C. For eleven of the years (1995 to 2006), these temperatures ranked among the 12 warmest records. In addition, a linear warming trend over the past 50 years is nearly twice that of the last 100 years. Supporting these surface observations are analyses of balloon-borne and satellite measurements of lower- and mid-tropospheric temperatures, which show similar warming rates to those of land surface temperatures. In conjunction, the average temperature of the global ocean has increased to the depths of at least 3000 m. The ocean plays an important role in climate change, since it absorbs more than 80% of the heat added to the climate system.

With ocean warming, seawater expands and contributes to a rise in sea levels. The global sea level increased about 15 to 20 cm during the 20th century. Contributing to this rise has been the melting of large snow and ice masses. On average, glaciers and ice caps in the Northern Hemisphere and Patagonia have consistently lost mass. Evidence now exists that this melting "very likely" contributed to the observed rise in sea levels (IPCC Working Group I 2007). Noted contributors were the Greenland and Antarctic continental ice sheets. Using satellite data for Greenland, researchers Velicogna and Wahr (2006) detected that the rate of ice loss increased 250 percent during the periods April 2002 to April 2004 and May 2004 to April 2006. This was almost entirely due to accelerated rates of ice loss in southern Greenland. In 2008, Tedesco and colleagues recorded extreme melting in the northern fringes of the Greenland's ice sheet. The summer melting period was longer than average, with many locations experiencing a record number of melt days and the average temperature between June and August 2008 as much as 3 $^{\circ}$ C above average. New record temperatures were noted at many ground-based weather stations (Tedesco, et al. 2008, 391). At the recent meeting of the American Association for the Advancement of Science, Richard Alley (2009) warned that if the Greenland ice sheets completely melt, it would contribute a rise in sea level across the globe of about 7 meters (23 feet).

In the Arctic, temperatures are currently rising at twice the global rate (Lynas 2008, 47). Since the 1970s, unprecedented change has been observed in the Arctic as climate warming has increased glacial and sea ice melting. Since initial satellite measurements in 1978, Arctic sea ice has declined, with the largest decrease typically observed during the month of September.

Including 2008, the rate of decline in September sea ice has been about 12 percent per decade, with the rate accelerating since 2002. Loss of sea ice has been suggested to affect atmospheric circulation and precipitation patterns extending into middle latitudes (Magnusdottir, et al. 2004, 857-876). For example, more rapid Arctic melting in 2007 has been related to an unusual pattern of atmospheric circulation, featuring a high surface pressure over the Beaufort Sea north of Alaska and low pressure over eastern Siberia. Persistent warm winds from the south over the Chukchi and East Siberian Seas promoted greater melting (Serreze and Stroeve 2008, 142-43). Consensus in current global climate models indicates that the Arctic Ocean will be seasonally ice-free anywhere from 2040 to beyond the year 2100. More sobering simulations, which predict summer ice-free conditions in the Arctic within a decade, come from the Climate Community System Model 3 used by the U.S. National Center for Atmospheric Research (NCAR 2006).

Changes in glacier area and volume are being used as indicators for global warming and climate change. Due to its popularity (*The Snows of Kilimanjaro* by Hemingway) and focus of many news reports, Mount Kilimanjaro in Tanzania Africa has become an icon of climate change. In 1912, the average measure of the mountain's snow was estimated at 12 km^2, but has decreased to an estimate of 1.5 km^2 in 2007 (Mann and Kump 2008, 58). Thompson and fellow researchers (2002, 589-93) suggest that the remaining ice fields will likely disappear between 2015 and 2020 if current climatological conditions persist. As a primary source of fresh water, the demise of Kilimanjaro snow mass presents a real threat to inhabitants of the region. For all of Africa, close to 50 percent of its glaciers has disappeared (Cullen et al., 2006, 33). Changes such as these foreshadow severe fresh water shortages in the near future. For those who pay for water, prices have risen or are predicted to rise. The cost of water has increased about 400 – 500 percent since 1990 in the Indo-Gangetic Basin of India (UNEP 2009).

Ocean acidification describes a relative decrease in seawater pH. Through air-sea gas exchange, oceans absorb carbon dioxide and form carbonic acid. The net effect of these chemical changes is an increase in the acidity of seawater and a decrease in the availability of carbonate ions. By absorbing the carbon dioxide from the air, oceans have taken up 30 to 50 percent of post-industrial anthropogenic carbon dioxide emissions (Sabine et al. 2004, 367-71; IPCC 2007). Although oceans acting as carbon sponges may help mitigate effects of anthropogenic emissions of carbon dioxide, the absorption of excess atmospheric carbon dioxide negatively affects marine organisms, which use carbonate to form shells and skeletons. Lower pH interferes with the physiological process of using calcium carbonate to construct cell coverings or skeletons. Coral reef damage is the most documented impact associated with ocean acidification and global warming (Fabry et al., 2007).

Corals, known for their beauty and biological diversity, survive within very narrow limits of temperature, and grow in a symbiotic relationship with photosynthetic algae – zooxanthellae (Crabbe 2009). If stressed, coral will expel the algae and lose its color, a phenomenon called *coral bleaching* (Dove and Hoegh-Guldberg 2006, 1-18). Elevated sea surface temperature and ocean acidification both cause damage to coral reefs. For example, the Great Barrier Reef along the northeast coast of Australia has experienced eight coral bleaching events since 1979. The most significant occurred in the summer of 1998 and 2002. In 1998, approximately 42 percent of reefs bleached to some extent and 18 percent strongly bleached. 2002 was the worst bleaching event with about 54 percent of reefs affected to some extent and 18percent strongly bleached (Berkelmans et al. 2004, 74-83). Using computer modeling, the authors suggested that a 1 °C increase would increase the bleaching occurrence of reefs 50 to 82 percent, while a 2 °C increase would increase the occurrence to 97 percent and an increase to 10 percent with a 3 °C increase. In a more recent assessment of the extinction risk for zooxanthellate reef-building coral species, Carpenter, et al. (2008, 560-563) found that of 704 species, 32.8 percent face an elevated risk of extinction without urgent conservation measures and mitigation of climate warming.

Current evidence about changes in global temperatures, ice masses, and oceans suggests that climate change is adversely affecting global water resources. Crops will fail to survive without timely applications of water during the growing cycle. Global crop failure could decrease worldwide agricultural productivity, weaken regional and global economies, impact animal and human health, and ultimately health of civilization.

1.3 **Effect of climate change on crops and agricultural productivity**

The primary connection between climate and health is adequate food production for all animal species. Authors of the United Nations Environmental Programme's (UNEP) recent report (2009) warn that up to 25% of the world's food production may be lost by 2050 due to environmental breakdown, assuming no action is taken to avert climate change.

Bill Cline, senior fellow at the Center for Global Development (2007), used two agricultural impact models and six IPCC general circulation models to predict an overall decline in total global agricultural productivity between 3 and 16 percent by 2080. Food production is expected to decline more in developing countries than industrialized countries. Developing countries can expect an overall decline, in contrast to industrialized countries that may experience a decline or increase. The increase will depend on whether or crop yields are increased from higher concentrations of carbon dioxide in the atmosphere (known as carbon fertilization).

Table 1 highlights the predicted percent declines with and without carbon fertilization for the listed countries.

Country	With carbon fertilization	Without carbon fertilization
India	29	38
Algeria	26	36
Iran	18	29
Mexico	26	35
South Africa	23	33

Table 1. Percent declines in agricultural productivity by 2080, (Cline, 2007)

These estimates do not take into account any increased losses due to insect pests, more frequent extreme weather events (droughts and floods) and increased scarcity of water for irrigation. If these estimates are foretelling, the long term effects on world agriculture will be substantially negative. Developing countries will suffer first and the most. By 2050, UNEP (2009) projects that the world will have 2.7 billion more people, which will require a 50% increase in food production to sustain demand. If declining global agriculture productivity and population growth projections come true, the *Malthusian catastrophe* may indeed be tested. In 1798, Thomas Malthus, a political economist, suggested that "the power of population is indefinitely greater than the power in the earth to produce subsistence for man" (Guttenberg Project 2001). Published in his *Essay on the Principle of Population*, Malthus postulated that "Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio." If one factors climate change into the Malthusian postulate, exponential growth may overcome linear growth; hence, life may become extremely challenging for future populations, i.e. a *Malthusian nightmare*.

1.31 **Decline in agricultural productivity due to extreme weather events**

Weather, temperature, precipitation, carbon dioxide concentration and availability of water resources directly affect the health of plants. Crop yields and failure are intimately related to the growing season weather. When the growing season experiences drought or floods, crop failure is imminent.

Drought is an abnormally dry period when there is not enough water to meet the needs of people in that area. To assess drought severity, researchers use the Palmer Drought Severity Index (PDSI), a combination of monthly precipitation totals and temperature averages. The PDSI calculated from the middle of the 20^{th} century illustrates a drying trend since the mid-1950s in several Northern Hemisphere areas: Southern Eurasia, Northern Africa, Canada, and Alaska. The opposite trend was seen in eastern North and South America (Solomon et al., 2007). From 1900 to 2005, the Sahel, southern Africa, the Mediterranean and southern Asia have experienced long-term declines in precipitation; however, significantly wetter trends have been observed in northern Europe and northern and central Asia.

Recent devastating fires in Australia draw attention to the serious ramifications of long-term drought. The Bureau of Meteorology in Australia (2009) report the combination of record heat and widespread drought during the past five to ten years over large parts of southern and eastern Australia is without historical precedent. From June 2007 to February 2009, areas of serious (lowest 10% of historic totals) to severe rainfall deficiencies (lowest 5% of historic totals) spread across mainly southeast Australia, with a few areas in central Australia. This covers most of the agricultural areas of South Australia, central and western Victoria, and northern and eastern Tasmania.

In agricultural based regions, states, and countries, drought and crop failure can be devastating to local economies and communities. In California's Central Valley, unemployment rates are 3 to 4 times the national average (McKinley 2009). The state estimates the 2008 drought losses at more than $300 million and predicts greater losses in 2009 due to loss of jobs. Lack of water supplies has led many farmers to fallow fields and return to low maintenance and less labor intensive crops. Richard Howitt, department chair of Agricultural and Resource Economics at the University of California-Davis, estimates that 60,000 to 80,000 jobs could be lost and as much as $2.2 billion in crop and other losses could be caused by water restrictions and drought. California is USA's biggest producer of vegetables, e.g. tomatoes, artichokes, onions, lettuce and many other crops. Shorter supplies can ultimately result in higher food prices and less consumption of nutrient dense foods, eventually having a negative impact on human health.

Higher surface temperatures and extremes of the hydrologic cycle increase precipitation intensity, particularly in middle and high latitudes. During strong storm surges, the rise in sea level makes coastal areas around the world more vulnerable to flooding. For example, two hurricanes of similar strength hit the Chesapeake Bay USA, the first in 1933 followed by another in 2003. The second storm, Hurricane Isabel, was far more damaging because of a 20 cm rise in sea level (Auer 2008). Any rise in sea water will place densely populated, low lying areas at the greatest risk from future flooding. Celine Herweijer at Organization for Economic Co-Operation and Development (2008) report ten cities currently at highest risk for flooding in terms of assets exposed to coastal floods: Miami, Guangzhou, greater New York City, Calcutta, Shanghai, Mumbai, Tianjin, Tokyo, Hong Kong, and Bangkok.

In addition to a rise in sea level, an increase in precipitation intensity, i.e. severe rain, causes flooding. Some countries, such as Bangladesh and India, have experienced severe flooding. During the monsoons of 1988, 1998, and 2004, 25 to 50 percent of Bangladesh was submerged, resulting in the destruction of infrastructure, water contamination and diarrheal epidemics (Rashid 2000, 240-253). The most recent flood occurred in 2007. According to government statistics, 298 people died, 10,211,780 people were adversely affected and 58,866 houses were damaged. In 2006, monsoon floods caused widespread damage in India. In Gujarat, about 6 million people were affected and in the Surat District, the floods were considered the most devastating in 200 years (UNICEF 2006). During a typical dry harvesting time in Uganda, rain fell for more than 40 days to submerge roads, swamping farmlands, and drastically reducing food availability. Catholic Relief Services (2007) assessed the area to find almost total crop failure due to standing water in the fields. In the U.S., land designated by crop failure has ranged between 5 million and 22 million acres since 1945. In 1988, 1993, 1996, 1998, 2000, and 2001, crop failure was 10 million acres per year due to severe drought, extensive flooding, or wet weather. Since extreme droughts in 1956, the year 2002 posted a record high of 17 million acres of crop failure (ERS-USDA 2002).

In 2008, the U.S. Climate Change Science Program (USCCSP) released a report illustrating that climate change will or is already affecting U.S. water resources, agriculture, land resources, and biodiversity. Specifically, increasing temperatures will increase the risk of crop failures; higher temperatures will negatively affect livestock; forest fires, inset outbreaks and tree mortality will increase in the interior West, Southwest and Alaska; weeds will grow more rapidly under elevated atmospheric carbon dioxide and migrate northward; reduced mountain snowpack and earlier spring snowmelt runoff are expected in the Western U.S.; and the growing season has already increased by 10 to 14 days over the last 19 years.

Climate change has a profound effect on agricultural productivity. Productivity and access to food are decreased as temperatures and frequency of extreme weather events, such as droughts and floods, increase. As a result, people have less access to food forcing them to buy food or go without. Starvation, even if short-term, can lead to malnutrition and poor health; hence, climate change, agricultural productivity and health form an inter-dependent model for survival.

1.4 **Effect of climate change on health**

Overall, climate change is projected to increase threats to human health, particularly in lower income populations. This can be a direct threat, such as mortality from extreme heat events or indirectly through mental stress, decreased food availability, and increased disease vectors. Direct threats will be considered first.

1.41 **Direct effects on health**

With climate change, heat waves could be more frequent, intense, and longer. In the U.S., the most prominent causes of weather-related human loss are extreme heat events (EHE) in the form of heat waves (CDC 2004). Heat waves can kill more people in a shorter time than almost any other climate event. In recent decades, Europe has experienced an unprecedented rate of climate warming (WHO-Europe 2003). In most of Europe, the increase in the mean daily maximum temperatures during the summer was greater than 0.3 deg C per decade in the period 1976-1999 and sustained hot periods are more frequent. Recently, heat waves affected large areas of western Europe, Scandinavia, and western Russia during the months of July and August 2003. In Paris, the intensity, duration and minimum and maximum daily temperatures were the highest measured since 1873. Provisional data from the French government estimated an excess mortality of 11,000 people in the first two weeks of August. As global temperatures and extreme heat events increase, enhanced public health intervention will be needed to prevent human loss from future heat waves.

1.42 **Indirect effects on health**

Crop failure not only creates economic loss, but in some cases, human loss (IANS 2008). In India’s West Bengal, Ashish Mondal and his wife suffered widespread flood damage to their land and house. After surveying their rotting crops, the couple committed suicide. Drought can also cause mental distress to individuals and communities experiencing climatic threats to their livelihood. From focus group data, Sartore, et al. (2008, 950) report that rural communities experience significant mental health problems during prolonged drought. Farmers, farm and non-farm businesspeople, and health workers expressed significant distress from the emotional impact of environmental degradation, from loss of hope for their community's future, financial and workload problems, and from feelings of being misunderstood by the wider Australian community.

Crop failure can have long-term effects on the health of young children. Akresh and Verwimp (2006) assessed the effect of crop failure and civil conflicts on health of Rwandan children born between 1987 and 1991. Girls under the age of 5 were shorter than expected, with the greatest impact on children in poor households; however, no adverse effect was found in young boys. When crop failure or civil conflicts cause mental, economic and physical stress on families, evidence from this study implies a need for early interventions for young children, particularly girls.

Threat to human health can also come from water-borne diseases. During the past 50 years, patterns of emerging arbovirus disease have significantly changed; for example, chikungunya fever in northern Italy, West Nile virus in North America, Rift Valley fever epidemics in the Arabian Peninsula and Bluetongue virus in northern Europe (Gould and Higgs 2009, 109-121). A case study of Volgograd Russia sheds light on the relationship of West Nile virus and climate change. In 1999, more than 500 cases of West Nile infection were reported in the Volgograd Province. Another outbreak of 64 cases was recorded in 2007. Analysis of historical climate data from 1900 to present revealed that those years (1999 and 2007) were the hottest. These epidemic seasons were characterized by mild winters, hotter summers and a high prevalence of species *Culex pipiens* and *Culex modestus*. Findings gave some clues to the predisposing factors for West Nile virus, as well as connecting climate warming to the emergence of West Nile virus in this region.

Malaria, a climate-sensitive tropical disease annually affecting 350-500 million people, remains one of the most important global diseases. Each year, over one million people die from the disease, most of them young children in Africa south of the Sahara (CDC 2009). Malaria has recently emerged in the East African highlands with its expansion exacerbated by rapid population growth and deforestation that can favor mosquito breeding (Patz and Olson 2006). Although several climate experts attribute the increase in malaria to climate change, warmer temperatures, and precipitation changes, others suggest that rising malaria rates are caused by increased drug resistance in malaria parasites and infrequent use of pesticides (SDNetwork 2002).

Threats to Asia's water, food security, and public health have been documented, not only related to global warming, but also to *Atmospheric Brown Clouds (ABCs.)* ABCs are regional scale plumes of air pollution made of soot, sulphates, nitrates, fly ash, and other aerosol components (UNEP 2008).These clouds result from indoor bio-fuel combustion, plus biomass and fossil fuel burning outdoors, typically found in densely inhabited regions and those regions downwind of populated continents. Five areas identified as hotspots include: East Asia, Indo-Gangetic Plain in South Asia, Southeast Asia, Southern Africa, and the Amazon Basin. These clouds cause increased solar heating and surface dimming (reduced solar radiation). ABC-induced dimming is also considered the major cause for decreased rainfall in India and changes in the summer monsoon of Eastern China. Epidemiological studies document the most serious ABC-induced health effects, which include acute and chronic health effects: premature deaths, increased cardio-pulmonary hospital admissions, asthma, chronic obstructive pulmonary disease, and lung cancer.

Other areas in the world experience similar anthropogenic challenges. In the coastal regions of Yemen, Oman, United Arab Emirates, Qatar, and Bahrain, researchers Husain and Chaudhary (2008, 204-212) assessed changes of temperature, precipitation and humidity in relationship to direct and indirect potential effects on human health. Their preliminary assessment predicts increased mortality rates due to cardiovascular and respiratory illnesses, thermal stress, and increased frequency of infectious vector-borne diseases in the region between the years 2070 and 2099.

Overall, climate change challenges people, current and future generations, animal and human societies, and our natural world. In his acceptance speech for the Sustainable Development Leadership Award February 5th, 2009, United Nations Secretary-General Ban Kimoon (U.N. 2009) said "…poverty cannot be overcome if we neglect the environment or deplete our natural capacity. Science has shown that we are depleting the plant's natural assets at an unsustainable rate. Deserts are spreading. Water scarcity is increasing. Tropical forests are shrinking. Our once prolific fisheries are in danger of collapse. The list is long and growing. Looming above all these threats, and indeed exacerbating them, is climate change. ….2009 will be the year of climate change!" The second part of this paper discusses comprehensive and specific recommendations for adapting to or mitigating the effects of climate change.

2.0 Choices for the future

Numerous global organizations have come forth with messages and recommendations that can be used to understand, adapt to and mitigate the effects of climate change. The most recent messages come from the International Scientific Congress on Climate Change that convened March 10-12, 2009 in Copenhagen, Denmark. Almost 1,600 scientific papers from researchers representing more than 70 countries were used to develop key messages that will be published later this year (University of Copenhagen 2009). Preliminary key messages from the Congress follow:

1) **Climatic trends**: Key parameters of the climate systems are moving beyond the patterns of natural variability and an increased risk of abrupt or irreversible climatic shifts exists.
2) **Social disruption**: Societies are highly vulnerable to even modest levels of climate change, with poor nations particularly at risk.

3) **Long term strategy**: Delay in initiating effective mitigation actions significantly increases long-term social and economic costs of adaptation and mitigation.
4) **Equity dimensions**: Effective, well-funded adaptation safety nets are required for people least capable of coping with climate change impacts.
5) **Inaction is inexcusable**: Concerted efforts are needed to alter energy economy, including sustainable energy job growth, reductions in health and economic costs of climate change, and restoration of ecosystems and revitalization of ecosystem services.
6) **Meeting the challenge**: To meet the challenge, reduce inertia in social and economic systems; build on a growing public desire for governments to act on climate change; remove implicit and explicit subsidies; reduce the influence of vested interests that increase emissions and reduce resilience; and transition to norms and practices that foster sustainability.

To avert future crises, UNEP offers seven major recommendations to improve world food security:

1) regulate food prices and provide safety nets for the impoverished;
2) promote environmentally sustainable higher-generation biofuels that do not compete for cropland and water resources;
3) reallocate cereals used in animal feed to human consumption by developing alternative feeds based on new technology, water and discards;
4) support small-scale famers by a global fund for micro-finance in developing diversified and resilient eco-agriculture and intercropping systems;
5) increase trade and market access by improving infrastructure, reducing trade barriers, enhancing government subsidies and safety nets, as well as reducing armed conflict and corruption;
6) limit global warming; and
7) raise awareness of the pressures of increasing population growth and consumption patterns on ecosystems.

These messages and others from governmental and professional organizations comprise suggestions from specific actions for an individual to broad multi-governmental policy changes. Recommendations fall into two categories: adaptation or mitigation. Adaptation refers to altering behaviors that better respond to present or future climate change. Mitigation relates to strategies that lessen effects of climate change. Logically, if mitigation strategies work, there will be less need for adaptive strategies. Mitigation options will be discussed first.

2.1 Mitigation options

Mitigation includes strategies to reduce carbon dioxide emissions, improve energy efficiency, invest in carbon free technology, and promote carbon capture and storage. A number of authors have written books suggesting comprehensive strategies to solve the global challenge of climate change. Brief descriptions of two books follow.

Lester Brown (2008) from Earth Policy Institute offers a comprehensive plan, called *Plan B 3.0 – Mobilizing to Save Civilization* for consideration by a broad audience. The first step in this plan involves eradicating poverty and stabilizing population growth, followed by earth restoration, specifically restoring forests, rebuilding soils, regenerating fisheries, and protecting biodiversity. Central to the plan are strategies to improve food security and re-design cities. In the latter part of Plan B 3.0, raising energy efficiency in appliances, buildings, and transport systems complement strategies to invest in wind, solar, thermal, plant-based, and hydro sources of energy. Being well documented, the book provides stimulating ideas to individuals, policy makers, agencies, and governments.

The book *A Contract with the Earth*, written by Newt Gingrich and Terry L. Maple (2007), may assist in changing political perspectives on climate change. Newt Gingrich was the Speaker of the U.S. House of Representatives from 1995 to 1999 and the chief architect of the Republican *Contract with America*. Gingrich and Maple challenge Americans "to accept the responsibility of global environmental leadership and to overcome our nation's troubled history of vacillation and withdrawal" from climate change. The contract provides commitment to: a) scientific objectivity for public policy, b) education and inspiration of entrepreneurial environmentalists, c) encouragement of green enterprise, d) investment in new technology, and d) a long-term commitment to the environment.

Aside from comprehensive ideas, more specific suggestions for mitigation come from numerous agencies dedicated to reducing the effects of climate change. The Center for Global Development suggests investing in solar thermal or concentrating solar power. This is a commercially available technology that uses direct sunlight and mirrors to boil water and drive conventional steam turbines. By 2020, solar thermal power production in North Africa and the Middle East could provide enough power to Europe to meet the needs of 35 million people. Ummel and Wheeler (2008) estimate that program implementation would require international clean technology subsidies of about $20 billion over ten years. By the end of the program, expected profitability of unsubsidized projects would be competitive with that of coal and gas power. Solar thermal power plants that are not hybridized with fossil fuel do not generate any direct emissions of carbon dioxide or greenhouse gases. If a carbon dioxide emissions reduction mandate is enacted in several countries, solar thermal power could become an important component of that strategy. As the solar sector expands, attention to the potential environmental and health costs is warranted. With a 20 to 25 year life span, the most widely used solar photovoltaic panels have potential to create a large accumulation of electronic waste (e-waste). In addition, many of the newer photovoltaic technologies are more efficient and less costly, but contain extremely toxic materials with unknown health and environmental risks (SVTC 2009).

Other carbon free technologies currently receiving attention are nuclear and wind power. Nuclear power is a fairly mature technology representing about 20% of the electricity generated in the USA and over 16% of the electricity generated in the world (EPRI 2008). High construction costs, due to safety and security requirements, tend to limit its use. Nuclear plants also generate high- and low-level nuclear water that requires safe storage and disposal. Although wind is unevenly distributed around the world, offshore wind farms are increasing in number since wind is more uniform at sea than on land. Improvements in wind turbine technology and knowledge for this carbon-free power source are promising.

Challenge often yields innovation and creativity. Dann Rossegaarde, one of the designers of a dance floor that transforms mechanical energy of a dancer's movement into electricity, is getting attention from investors. At the Watt dance club in Rotterdam, Netherlands, one dancer generates an estimated 10 watts and the floor has a capacity for 150 dancers. The Sustainable Dance Club company has received business inquiries from around the world. "Watt claims to the first sustainable disco and is aiming to reduce its other energy consumption by 30 percent and water consumption by 50 percent, as well as cutting its garbage production in half" (Drazer 2008).

In the U.S., citizens annually generate more than 230 million tons of solid waste, which is eventually deposited in landfills. Gas from these landfills contains mostly methane and carbon dioxide. The U.S. Environmental Protection Agency (2009) encourages the use of landfill gas as a renewable, green energy source around the country. In January 2009, the agency recognized several innovative community projects that met renewable energy goals and benefitted local and global communities. For example, the Green Energy Center in Grove City, Ohio converted landfill gas to electricity and is expected to produce enough compressed natural gas for vehicles to annually replace nearly 250,000 gallons of gasoline. Another project in Rutland, Vermont produced about 25 megawatts per hour of clean energy at five landfills and the community plans to expand the project in 2009.

Energy efficiency is another method identified as part of the arsenal to slow climate change. In the U.S., electricity consumption has grown at an average annual rate of 1.7% from 1996 through 2006. The U.S. Energy Information Administration projects electricity consumption in the U.S. will increase by 26% from 2008 to 2030. However, energy efficiency programs have the potential to realistically reduce this growth rate by 22 percent. These programs would include efficiency upgrades for electronics, appliances, lighting, heating, cooling, refrigeration and ventilation in residential areas, commercial and industrial sectors (EPRI 2009).

Removing or reducing the amount of carbon in the global economy will not be easy or inexpensive. Electricity is responsible for about one third of global carbon dioxide emissions and any success to "decarbonize" the world is connected to greater availability of these low-carbon or carbon-free technologies to produce electricity and increased efficiency of processes using electricity.

In the future, a carbon-free world would be ideal to mitigate effects of current carbon dioxide emissions. Fortunately, efforts to design a carbon-free, waste and car-free city are being realized in the small, large oil-producing country of United Arab Emirates. A model of Masdar City in Abu Dhabi was unveiled on January 21, 2008 at the World Future Energy Summit. In partnership with the Massachusetts Institute of Technology, plans include developing the Masdar Institute of Science and Technology as the center of the city, along with building research facilities, offering commercial space for clean-tech companies and inviting international tenants who will invest, develop, and commercialize advanced energy technology. In the city, solar and wind power will provide electricity and drinking water will be provided through a solar powered desalination plant. Masdar City will house about 50,000 people with walkways and personal transportation systems instead of roads and parking garages. The hope is to accelerate the development and adoption of technologies in renewable energy, energy efficiency, carbon management, waste management and water usage (ENS 2008).

Another technology to lessen the amount of carbon dioxide is to capture it before entering the atmosphere and storing in the ground or ocean. This technology is called carbon capture and storage (CSS). The Climate Action Network Europe (2006) believes that governmental and organizational climate policies cannot depend on merely one technology. The organization recommends an informed public debate about carbon capture and storage, a strategy that has potential benefits, but also risks, limitations and uncertainties. A power plant using CCS can reduce the carbon dioxide emissions by 65 to 90 percent, as compared to a non-CCS plant; however, a sudden large-scale escape of carbon dioxide into the atmosphere could have detrimental effects on all living species. Both sides of the issue should be investigated prior to commitment to CSS strategies.

In the U.S., companies use a central exchange to offer a “cap and trade” system for companies that are emitting more carbon dioxide than limits allow. Those companies can purchase offsetting credits from companies emitting less than limits or from others, such as ranches that can “soak up” excess carbon (Ahearn 2009, 52-57). Last year, the Sun Ranch in Montana became the first ranch in the U.S. to participate in the program. Money is paid to the ranch for the amount of grassland that absorbs carbon dioxide from the air. For the Sun Ranch, estimations for carbon sequestration predict that an acre of non-degraded rangeland can sequester 0.12 ton of carbon a year and an acre of improved rangeland can sequester 0.28 ton. Although Sun Ranch is a pilot project, more acres from the north and central U.S. are being enrolled in the program.

The previously discussed options represent only a small compilation of ideas to confront current challenges of climate change. As more individuals and governments get on board to protect the world from climate change, exponential growth in knowledge and discoveries is expected. For additional information about mitigation options, readers are advised to regularly follow the IPCC, UN, and WHO proceedings, in addition to their own country’s environmental programs.

2.2 **Adaptation options**

If mitigation options are not effective in reducing carbon dioxide emissions and climate change continues, all living species will need to adapt to a warmer climate, increased frequency and intensity of extreme heat events, and altered precipitation patterns.

Local public health agencies (Keim 2008, 508-516) are the best positioned to help communities adapt to the effects of climate change. Specifically, the goal would be to reduce excess morbidity or morality to extreme weather events, e.g. heat waves, drought, wildfire, cyclones and heavy precipitation that could cause floods and landslides. The U.S. Environmental Protection Agency has produced the *Excessive Heat Events Guidebook* (2006) to help community officials, emergency managers, meteorologists and others plan for and respond to excessive heat events. The guidebook lists best practices to be used during excessive heat events and options for responding to these events. High-risk groups are identified to help target these populations and reduce health effects from excessive heat. Those populations include older person (age > 65), infants (age<1 year), the homeless, the poor, and people who are socially isolated, with mobility restriction or mental impairments, may be taking certain medications, or those under the influence of drugs or alcohol. Another public health intervention to reduce exposure to extreme heat is to redesign cities to reduce urban heat islands (Semenza et al. 2007, 8-20). For communities to effectively prepare and respond to climate, Ebi and Semenza (2008, 501-507) recommend a stepwise course of action for community-based adaptation that engages stakeholders. It is a proactive problem solving process that can beneficially build social networks across local and national levels.

Countries, states, and cities have formulated adaptation strategies to cope with climate change (Bambaige 2007; California Resources Agency 2009; Greater London Authority 2008; Kerr and McLeod 2001; Sydney Coastal Councils, 2009). In general, farmers are advised to plant crops that are better suited to drier, warmer conditions and use no-till farming practices that do not disrupt the soil and release carbon dioxide into the air. Businesses near the ocean are encouraged to relocate away from coastal areas at risk for sea-level rise and hurricanes. Local governments are advised to initiate new zoning and building codes making buildings less vulnerable to damage from floods, fires, and other extreme events. Public authorities are recommended to provide timely information on likely climate events and educate their citizens about climate change and its potential impact to their health, home, and environment. Through urban greening programs, cities can promote city landscapes that decrease adverse effects from heat islands and identify publically accessible ‘cool’ buildings. Citizens are encouraged to purchase insurance policies for protecting their buildings and personal belongings from adverse climate impacts.

3.0 **Closing comment**

In the address to the DeepWaterway Convention, Theodore Roosevelt said: “The conservation of natural resources is the fundamental problem. Unless we solve that problem it will avail us little to solve all others” (Roosevelt 1907). Like Roosevelt, increasing numbers of global citizens can see that planet Earth is approaching a tipping point, which if climate change continues, will put us on a downward spiral to a failed civilization. To prevent this demise, a multi-faceted approach is needed: climate change education and widespread engagement of children and adults in individual and community projects that promote sustainable living ; promotion and funding of innovative projects for researchers, businesses and governments; financial investment in carbon-free technologies and environments; and greater willingness of the global society to understand and combat climate change. This approach can hopefully mitigate the anthropogenic impact of our past human activity that allowed greenhouse gas accumulation, while the current populace is encouraged to proceed with adaptation strategies to live in this tenuous time.

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