Climate Change and Human Health Consequences

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Introduction

There has been much debate about whether or not global warming is actually happening and the severity of climate warming. Extensive scientific research is definitive concerning the Earth's climate history for the past one thousand years. The research utilized ice cores, arctic sediment cores, coral cores, and tree ring analyses. This paper will acknowledge that global climate change is in fact occurring and that variability exists in climate models about the magnitude of future climate change. It will focus on the human health consequences of climate change as a means for developing practical and efficient strategies to cope with this challenge. Rising sea levels, increasing extreme weather events, expanding vector-born diseases, shifting agricultural zones, and decreasing water availability are just some of the climate change impacts to human health and well-being. The intensity and geographic range of these circumstances is still uncertain, but a 'safer rather than sorry' approach is the only certain way to soften the impacts of global climate change. If nothing is done to mitigate the anthropogenic global warming, the costs to humans can and will be profound. Will we have enough time to adapt? If we are to effectively mitigate and adapt to these impacts, it is imperative to understand the potential effects to human health.

Extreme Weather Events

Human health impacts related to climate change can be direct (fatalities during heat waves, cold spells, or natural disasters) or indirect (increased vector-borne diseases, decreased food security, or increased climate migrants). Although natural disasters are more obvious, dramatic events, indirect forces on human health pose a larger threat to more people over a larger area. One forecasted change is the increase in frequency and intensity of extreme weather events (McMichael et al. 2006). Characteristics of these events include severe high or low temperatures, violent rains and downpours, acute and extensive droughts, and powerful storms. Humans, who have adapted to their local or

regional climatic variations, are biologically, socially, and culturally acclimated to environmental patterns. Now that extreme weather events are on the rise, human adaptations are not enough to protect their population from the random intensity of extreme weather. Stressed populations are more vulnerable to disease and mortality. In order to abate these impacts, it is critical to understand how and who is at risk.

Heatwaves

As temperatures increase beyond the zone of tolerance, mortality rates increase. The variation of human fatalities to temperature extremes depends on the latitude and climate of the population's particular region (McMichael et al. 2006). Residents in warmer environments tend to be more sensitive to cooler weather, while inhabitants in cooler climates are more sensitive to hotter weather. In areas with lower-income or inadequate living conditions, shelter against the elements is simply a joke. These populations, who are exposed to the cold, have no protection from the elements and mortality increases. Epidemiological studies of extreme temperatures have concluded that mortality is correlated with heat waves among the elderly (McMichael et al. 2006). Seniors, especially elderly women, are vulnerable because they are not as physiologically able to regulate their body temperatures as they once were. Other segments of the population that are susceptible to thermal stress include "mentally ill people, children, and others in thermally stressful occupations or with pre-existing illness" (McMichael et al. 2006: 861). The devastating European heat wave of August 2003 struck with such intensity that approximately 30,000 people died. Why were there so many deaths and could the fatalities have been prevented? Many people, who are suffering from cardiovascular disease including people, who have had a heart attack or stroke as well as individuals suffering from chronic respiratory disease, are more vulnerable to heat wave mortality. Also, city-dwellers are a higher risk group due to the urban heat island effect. Urban areas are sub-climates of a particular region in that they are usually warmer than the prevailing climate. With many locomotives, blacktops, skyscrapers, and pollution, heat is produced

and prevented from escaping. Urban regions act like a magnifying glass, intensifying the hottest days and brewing a deadly situation for weaker individuals.

Studies have concluded that, over the past decades the numbers of people affected by extreme weather events have significantly increased. These studies evaluated the impacts of extreme weather events on various societies over time. In Alaska, Canada, central and eastern Europe, Siberia, and central Australia, the extent or length of heat waves was observed to increase in the past fifty years (McMichael et al. 2006). Individual occurrences of extreme weather cannot be directly linked with climate change; however, these studies provide comprehensive data through time that fit the model of increasing global temperatures. Recent studies have shown that heatwaves such as the intense European summer of 2003 followed climate change models that included anthropogenic warming variables (McMichael et al. 2006).

Climate change is projected to increase the variability and frequency of intense precipitation. Whether the frequency and magnitude of river flooding is related to climate change remains inconclusive. Nonetheless, there has been a worldwide increase in the frequency of major floods occurring in river basins greater than 200,000 km² (McMichael et al. 2006). Although correlations between climate change and the rise and spread of floods are not exact they are probable and should be considered as a potential threat to human health. According to McMichael et al. 2006: 862, "Floods are low-probability, high-impact events that overwhelm physical infrastructure, human resilience, and social organization." Of the 2,257 natural disasters— including extreme temperature events, droughts, famines, floods, fires, hurricanes, and windstorms—recorded from 1992 to 2001, floods were the most common disaster at forty-three percent of the total. These floods caused around 100,000 fatalities and affected over a billion people.

Extreme weather and Infectious Diseases

Communicable diseases are expected to increase where extreme weather events and related flooding occur. Infectious disease transmission is influenced by a variety of elements, "including extrinsic social, economic, climatic, and ecological conditions, and intrinsic human immunity" (McMichael et al. 2006:862). Vector-born diseases or pathogens and their rate of replication are modified and controlled by change in climatic forcings. Climatic conditions that favor the habitat expansion of these pathogens could instigate human epidemics. Standing water and warmer temperatures can provide a breeding ground for harmful microorganisms such as salmonella and cholera that may be ingested by animals and humans (McMichael et al. 2006). At high temperatures, salmonella and cholera multiply precipitously. The wide-spread migration of these vectors can cause severe epidemics among human populations.

Various studies have shown that the changing climate is affecting the proliferation of infectious diseases. Reports indicate that there is a relationship between Sweden's warmer winter temperatures over the past two decades and the rise in tick-borne viral encephalitis. Ticks, which can carry Lyme disease and viral encephalitis, have experienced northward expansion of its habitat into Sweden (McMichael et al. 2006). The expansion of these vectors follows the recent climate projections that ENSO (El Nino-Southern Oscillation) will increase in intensity and frequency. Studies report evidence of a relationship between ENSO and cholera outbreaks in Bangladesh (McMichael et al. 2006). Cholera bacteria reside within marine algae and crustaceans inhabiting the coast or estuaries. Climate and seasurface temperatures dictate the population expansion or reduction of various algae and crustaceans. Climate change trends show an increase in global sea-surface temperatures, which can disrupt healthy marine ecosystems. Higher sea-surface temperatures trigger burgeoning algal blooms—algae in which cholera may be present. Although there remain critics of these data interpretations and each of these studies on its own show inconclusive evidence of relationships between climate change and disease expansion, the collective data is more telling—that expansion of disease is related to recent warming

trends. In order to understand how disease carrying vectors are influenced by climate, an examination of the individual vectors is required.

Vector Borne Diseases

Climate change is also expected to change the home ranges of disease carrying vectors. Climate variables affect "the ecology, development, behavior, and survival of arthropod vectors and hosts and the transmission dynamics of the diseases they transmit" (Gubler et al. 2001: 226). These variables include humidity, precipitation, temperature, wind, and day length. The day-to-day high and low temperatures are known to influence the rate at which diseases are proliferated within the insect. If there is a greater number of pathogens present within the insect, the insect's saliva becomes contaminated and is more likely to transmit the disease (Gubler et al. 2001). At the same time, the lifespan of the insect or vector can be diminished during high temperatures. In this case, the pathogen would not have enough time to infect another host because of the premature mortality of its vector. The complex interactions and feedbacks between vector and climate, pathogen and climate, and vector and pathogen dictate the transmission rate of vector borne diseases.

Tick Vectors

Ticks are another potential disease vector that can affect human health. "Ticks and their mammalian hosts are influenced by land use, land cover, soil type, elevation, and weather conditions" (Gubler et al. 2001: 228). The Rocky Mountain Spotted Fever (RMSF) illness is a severe tick-borne disease in the United States. Climate-change scenarios have modeled the proliferation of this disease and have found that the Southeast's summer temperatures are too high for ticks to withstand. This is one example where climate change can positively affect human health.

Rodent Vectors

Climate change influences on rodent-borne diseases are not as conclusive as influences on other vector-borne diseases. According to Gubler et al. 2001, understanding climate change implications of ENSO can reveal rodent population dynamics and the diseases they transmit including hantavirus and plague. In addition, the increased precipitation will modify the regional and disease ecology. Hantavirus outbreaks are related to climate changes that create conditions where the rodent populations spike up and then suddenly decrease (Gubler et al. 2001). The climate conditions that produce these characteristics are a period of abnormally high precipitation succeeded by a drought. In 1993, there was an outbreak of rodent-borne disease in the Four Corners region of the United States. Before the outbreak occurred, there occurred a period of increased rainfall during the ENSO of 1992-1993. The surplus water increased the subsistence resources for the rodents and consequently increased the carrying capacity. The rodent population increased twenty times, therefore increasing human contact with the disease. Within a couple years the human cases of hantavirus dropped off as well as the number of rodents (Gubler et al. 2001). The outbreak of hantavirus pulmonary syndrome (HPS) in Paraguay from 1995-1996 also mirrored the sequence of events that characterized the Four Corners outbreak. Studies conducted on rodent fleas in the western United States have shown that the fleas' seasonal profusion is affected by fluctuations in temperature, precipitation and relative humidity (Gubler et al. 2001). Fleas, that can carry plague, are also influenced by climatic events that determine rodent populations. Following extraordinary downpours in winter and spring in New Mexico, the frequency of flea-borne plague increased with the expansion of the rodent population.

Mosquito Vectors

Climate change and the projected effects may create situations that are more favorable for mosquito expansion. Regions that were once devoid of these insects could experience increases in the number of mosquitoes. Floods create suitable habitats for mosquito reproduction and place more human populations in direct contact with these disease carrying organisms. In the aftermath of

hurricanes or floods within the United States, viruses have been found in mosquito- and other mammalian-vectors; however, encephalitis epidemics were incongruous with these disasters (Gubler et al. 2001). In the tropics, climatic influences on the transmission of malaria are intricate and fluctuate with region and the ecology of the vector. Higher temperatures are associated with an increase in the chance of transmission as well as acceleration in biting and laying eggs. The survival rate of mosquitoes has been observed to decrease when the temperature is high but the humidity is low; however, some species are acclimated to these conditions. The female *An. Gambiae* tolerates Sudan's intense droughts and extreme temperatures by taking shelter in dwelling huts and other shaded areas (Reiter 2001).

Downpours can leave behind pools of stagnant water where mosquitoes can breed, but torrential rains can cleanse the standing water of the mosquitoes. A similar caveat involves the fact that drought can evaporate standing water and eliminate their breeding environment but can also stifle flowing water. Therefore, dryer regions that experience a long lasting drought may see a reduction in malaria cases, while wetter environments that encounter a drought may see an increase in malaria cases (Reiter 2001).

Although climate has a significant impact on malaria transmission, the condition can be exacerbated by human activities whether they are land use practices, socioeconomic influences, or political forces. Demographics and levels of economic development also play a role in a country's susceptibility to malaria transmission. Because most of the world's population lives in developing regions (which are malarial zones), the cases of malaria are still high in these areas and have huge implications on human health.

Water Availability and Quality

Climate change will have major effects on global water distribution, availability, and quality.

These effects will have major implications on our surface water and groundwater. Higher surface water temperatures will increase the susceptibility and abundance of algal blooms, which can damage human

and animal health. Not only do algal blooms infect the water, but they also reduce the scent and flavor of drinkable water (Levin et al. 2002). The dangers posed to humans are more ambiguous than simply drinking degraded water. Certain algal blooms produce biotoxins that infiltrate the flesh of shellfish and can act as neurotoxins when consumed by humans. Children are more vulnerable to dying when exposed to the toxins produced by cyanobacteria (blue-green algae). Other algal blooms, such as red tide, can generate air-born toxins that irritate the respiratory system and can induce asthmatic symptoms. Some algal blooms are known to be cytotoxic (causing cell damage) and can induce dermatitis in some individuals (Levin et al. 2002). Another potential effect of a warmer environment is an increased percentage of microbes and nutrients in drinking water supplies. Different algae that feed on this excess load will create a biofilm that can overwhelm drinkable water (Levin et al. 2002). Some algae can potentially carry some pathogens and reduce the water quality making it unfit for human consumption.

Increased regional warming will decrease the volume of water available for human consumption and food production. Human health could be at risk from water shortages that affect the agricultural sector. Continued high demand with diminishing water availability puts a huge stress on the hydrologic cycle. A significant determining factor of water availability is the amount of snowpack accumulated over the winter. This cycle is very important for recharging the water budget of particular regions. In regions, such as California, the collection of snow during the winter is released as liquid water during times of low precipitation in spring and summer. Warmer temperatures will decrease the volume of the snowpack and induce it to melt earlier in the season. This would mean that by the time water was crucial for growing crops, there would be an immense deficit in the water budget (Levin et al. 2002). The possible resulting food shortages could have a major economic impact on the United States that may affect human health. These shortages may prompt the United States to import a greater portion of food from questionable sources, such as countries that do not have as rigorous food safety regulations.

Lesser developed countries are even more impacted by food shortages since prolonged famine in these regions can cause malnutrition and starvation.

Climate change not only puts water availability at risk, but it also creates conditions that can affect water quality. Higher temperatures will increase evaporation rates, since warmer air has the ability to carry more water vapor. As a result, more intense droughts will appear in regions with high evaporation. When extreme weather events hit regions suffering from severe drought, their water supplies may be inundated and polluted by runoff carrying sediments, chemicals, and other matter (Levin et al. 2002). Prolonged exposure to contaminated drinking water, even in regulated amounts, can cause chronic health effects. Because drought can leave landscapes barren, there may not be enough vegetation to adequately absorb the precipitation. Less water percolated into the soil will not be able to replenish freshwater aquifers and can result in water shortages that affect human health. On the other hand, areas where precipitation is expected to increase may see an increase in water availability. Climate change is expected to increase the melt of glaciers and thermally expand oceans. In coastal areas, the resulting sea level rise can detrimentally affect the quality of their aquifers. These possibilities should not be taken lightly when taking into consideration that most of the world's population lives within five miles of the coast. The threat to water quality has economic implications as well. In order to manage a safe and healthy public water infrastructure, the United States EPA determined that over the next two decades investments need to increase to a minimum of 151 billion dollars (Levin et al. 2002). They decided to divide up the total investments accordingly: \$38 billion for water treatment, \$83 billion for repairing and replacing components of the water distribution system, and \$28 billion for protecting and maintaining watersheds and storage. Water wars and other fights over water resources can be mitigated by preparing for the imminent effects of global climate change. Many human lives can be protected through careful planning.

Land Inundation and Human Migration

Climate change is projected to increase land-based glacier melts and thermal expansion of the oceans. Many low lying islands are at a formidable risk of disappearing as sea-levels continue to rise. The Republic of Kiribati, located in the western-central Pacific Ocean, is a small island nation with thirtythree reef islands that stretch across 5,000 km of ocean. Studies show that climate change is having serious impacts on this nation that are causing detrimental environmental, social, and economic consequences. Even humanitarian organizations based in Kiribati have reported coastal erosion and salinization that are stressing the already dwindling resources of potable water and agricultural land (Locke 2009). Many of these atolls barely measure over two meters above sea level and barely measure a mile wide. The International Institute for Environment and Development declared Kiribati one of the top ten most susceptible countries in the world to the effects of climate change (Locke 2009). As a whole, Kiribati's population density is 127 people per square kilometer; however inter-island population density is diverse. Kiritimati Island has thirteen people for every square kilometer, while South Tarawa (the urban capital of Kiribati) has 2,558 individuals for every square kilometer. South Tarawa's growth rate rose sharply between 1995 and 2000 as inhabitants from other islands migrated to the city (Locke 2009). The influx of people into a small area has created overwhelming conditions that are harmful both to the environment and the people's health. There has been a growth in the density of squatter settlements throughout South Tarawa. These types of settlements now make up around twenty five percent of the housing on the island. Overpopulated areas are a breeding ground for disease. While the United States' infant mortality rate is seven deaths per 1000 live births, Kiribati's infant mortality rate is sixty-nine deaths per one thousand live births. Kiribati's high infant mortality rate is attributed to its high rates of malnutrition and worm infestations (Locke 2009).

Due to sea level rise, coastal erosion continues to inundate the coasts. Coastal erosion on the outer islands is causing the coastal and inland decline in flora. Kiribati is known to experience at least

two storm surges (king tides) a year, but recently five to eight king tides each year are not uncommon (Locke 2009). Rising sea level is also a threat to coastal fresh water resources. The contamination of Kiribati's fresh water aquifers is a huge hazard since the human carrying capacity of these islands is already quite low. Kiribati's fresh, potable water "is held within a shallow underground, slightly brackish, freshwater lens by the porous coral that forms the island, hydrostatically floating above the more dense salt water" (Locke 2009: 175).

The thermal expansiveness of water is a serious factor contributing to sea level rise as well as the increased melt rate of land-based glaciers worldwide. Kiribati's porous water table is experiencing salt water intrusion, and the inhabitant's fresh resources are continually diminishing. With fewer resources and more people, Kiribati is experiencing more health problems than ever. The government of Kiribati has responded to South Tarawa's overpopulation and human health crises by proposing the 'Integrated Land and Population Development Programme.' This proposition was defined under the National Republic of Kiribati Climate Change Adaptation (CCA) Strategy and approved in August 2005. Under the CCA strategy, the Kiribati government's objective is to stabilize their population at 125,000 by 2025, "through government-sponsored family planning programmes and large-scale inter-island relocation" (Locke 2009: 175).

Tuvalu is a small island nation just south of Kiribati. It is the fourth smallest country in the world comprising a chain of nine small islands and providing homes for a population of 9,561. Five of these islands are merely coral atolls, while the rest are separate islands. Tuvalu's average land elevation is about one meter above sea level. In the coming decades, the sea will most likely inundate the islands to a point where people can no longer live there. One of Tuvalu's islands was swallowed up by the ocean during 2007. Tuvalu has also experienced lengthening flood seasons. In 2000, the floods lasted for over five months instead of the normal three to four months (Locke 2009). Increased floods cause water to percolate up through the soil, leaving the islands soppy and soggy. Climate change is projected to

expand the occurrences of flooding in various regions. Unfortunately, the geography of low-lying islands makes them a prime target for these natural disasters.

Climatologists forecast that in the next few decades low-lying islands will become uninhabitable and eventually disappear. Kiribati and Tuvalu are only two examples of this tragedy to human health.

As ocean levels continue to rise, these inhabitants will continually emigrate from their vanishing homes into growing urban areas. As these islanders migrate to their capitals, they will overwhelm the already overpopulated cities. These climate-induced immigrants may not be welcomed by nearby countries or if allowed entry, may face serious economic and cultural obstacles that could still diminish their overall health (Locke 2009).

Impacts of climate change on adapting populations not only affect their physical well-being, but also affect their social and cultural traditions. Around one million people are estimated to live on coral islands, and even more live on low lying islands. To be certain, the health of these people is at risk, but their distinctively diverse cultures are also threatened (Locke 2009). Migration to other countries may have significant detriments to the country losing and the country gaining the migrant. Some people view these relocations as a benefit to the island people. The younger generations of islanders, who lack educational and economic prospects, may find their new lives filled with opportunities. They could potentially experience the freedom to acquire an education, participate in the job market, and receive health care. Industrialized countries should be prepared for the fact that the rate of climate change refugees will increase. Although this new way of life is perceived as an advantage for islanders, the older generations of Pacific islanders may be at a disadvantage. These members of the population "may experience psychological trauma and perhaps suffer from a sense of cultural crisis, and they may have difficulty adapting to modern Western market-based culture" (Locke 2009: 178). Although the Pacific islanders physically will survive, their culture may be another story. With a total culture transformation, Pacific islanders' unique and diverse cultures could potentially disappear. Also, assuming developed

countries allow environmental refugees to become permanent residents, the country's resources may not be enough to support an entire island nation of immigrants. Potentially, island populations could be segregated and allocated to different countries.

Not only have humans affected global climate change, but humans have ultimately affected themselves. Paradoxically, the ones who have not contributed a major impact on global warming are also the ones suffering most from climate change effects. The loss of these diverse social and cultural groups can ultimately be seen as a cultural genocide, where the Pacific Islander way of life becomes extinct.

The events unfolding on Kiribati and Tuvalu are harbingers of a world yet to come. They can be seen as models to plan adaptation strategies and mitigate climate change effects on human health. With climate change affecting weather patterns and subsequently affecting the availability of food, water, and land resources, the number of environmental refugees will continue to expand. According to Locke 2009, no official global assessment of the numbers of displaced people from an 88cm sea level rise has been produced, but the numbers possibly afflicted remain extraordinary. Most of the world's largest cities are near the coast and twelve of the sixteen located on the coast are in developing countries. Developing countries, which do not have the proper economic means to adapt to climate change, may experience a fatal crisis. Lack of health resources in densely populated areas will be a major obstacle to these populations. Migration may be the only remaining strategy to survive the effects of climate change. As shown by the cases in Kiribati and Tuvalu, climate change has decreased the availability of vital resources such as food and water and has created a domino effect where these stressed populations migrate to inner islands, increase the population density, and start another process of diminished resources and health decline. Since most of the world's population lives on the coast, adaptation strategies and mitigation measures must be implemented soon if human health is to be managed.

Air Quality and Respiratory Health

Climate change affects human health in many ways. Air quality is projected to decrease as warmer temperatures and sunlight mix with air-born pollutants to intensify the potency of smog. The intensity of smog in certain regions may vary depending on the projected warming for that area. Smog is an urban phenomenon, and therefore more people's respiratory health will be impacted.

When climate change raises temperatures at the surface, it accelerates the rate of photochemical reactions. The more chemical reactions taking place, the more smog is formed. Also, when temperatures are high, trees are known to release considerable amounts of volatile organic compounds (VOCs), which contribute to ozone concentrations and secondary organic aerosols. Some studies have been carried out to determine the effects of a warmer climate on the frequency and intensity of smog formation. In one study, scientists looked at the summers from 1980 to 1988 in order to analyze the effects of temperature on tropospheric ozone concentrations in California and the southeastern and northeastern United States. They concluded that as temperature increased, so did the rate of ozone formation. If the climate continues to warm, there is a significant probability of surpassing the 84 parts per billion (ppb) set as the EPA ozone standard. In the Northeast, at 84 °F, the probability of passing the EPA ozone standard was 5 percent, at 91°F it was 18 percent, at 98°F it was 42 percent, and at 104°F it was 66 percent (Mickley 2007). Although temperatures over 100°F were not as common in past decades, climate change may make higher temperatures more common in the coming decades. Scorching temperatures, especially in urban areas, may intensify smog and cause respiratory health issues. Heatwaves can be viewed as a double threat since it can cause thermal stress as well as respiratory stress. Other factors have the ability to intensify smog.

Stagnation is another determinant in the concentration of pollutants. According to Mickley 2006: 38, "stagnation episodes typically occur during the summer, when the heat and humidity can

become unbearable, but they can occur at other times of the year as well." The frequency and duration of these episodes may increase average temperatures. Stationary air has the ability to contain the dirty air and act as a breeding ground where chemicals can combine while even more pollutants concentrate. Because of the temperature difference between the tropics and temperate latitudes, differential heating is a component in driving atmospheric circulation. As temperate and polar regions warm faster than the tropics from climate change, the differential heating between these areas will decrease. Likewise, warmer air is better able to transport water vapor from equatorial regions to polar regions. Cold fronts have the ability to distribute warm air from tropical regions to temperate regions, but studies indicate that cold fronts may decrease in frequency over the mid-latitude regions (Mickley 2006). In a study that researched the effects of fewer cold fronts, it estimated that these events could "double the average length of pollution episodes in the Midwest from two to four days" (Mickley 2006: 39). The theory is that a reduction in the number of cold fronts would generate less circulation and redistribution of thermal energy, which would increase the frequency and duration of stagnation episodes in various regions. Therefore, human health is at greater risk from polluted, stationary air masses.

Because of the elaborate interactions between pollutants and climate, it is important to recognize the potential effects of regional climate variability on smog levels. The prognosis of air pollution can only reasonably be projected up to five to ten years in the future (Mickley 2006). In areas where precipitation is predicted to increase, this may counteract smog formation. In addition, enhanced cloud formation could inhibit sunlight's ability to interact with chemicals to produce smog. Another counteractive effect to smog production is the fact that a warming planet will expand and increase the height of the atmosphere and therefore be able to dilute more pollution (Mickley 2006). Climate change may also affect the frequency of land-sea breezes and monsoon intensity (Mickley 2006). These breezes are created by the differential heating of the land versus the ocean. The land heats up faster

than the ocean, which has a high specific heat, and coastal areas usually receive a sea breeze in the afternoon when the difference in temperatures is the highest. High continental temperatures over India could instigate intense monsoons in which precipitation and wind cleanse the region of harmful pollutants (Mickley 2006). South and Southeast Asia's summer monsoons are projected to have greater volumes of precipitation, but paradoxically, as pollutants are swept away, floods and potential vector-born diseases may increase (Mickley 2006). Coastal cities, such as Los Angeles, could benefit greatly from more sea breezes, especially during the summer months when smog levels are at its highest; however, regions to the east may end up with LA's harmful pollutants. Therefore, some populations may receive health benefits from these climate patterns, while other populations who were not initially at a health risk may become affected. To say that more land-sea breezes and monsoons are beneficial is a misnomer—human health is still at risk whether it affects 'this or that' region. These examples are potential climate change benefits on human respiratory health, but these possibilities do not negate the potential harm and damage to human health.

Researchers are assessing climate change's influence on air quality using cutting-edge modeling. Studies are projecting tropospheric ozone concentrations to increase in the midwestern and northeastern United States during the summer months. According to some research, these regions' peak ozone concentrations may rise another 5 ppb by the year 2050 (Mickley 2006). This would lower the air quality index to unhealthy levels, and vulnerable individuals such as those with asthma may have an increased risk for an attack. Other studies estimated that these regions' tropospheric ozone concentrations could increase to 10 ppb. On a positive note, the research showed surface ozone could potentially decrease if a soft energy path—one without the use of fossil fuels—was adapted as a mitigation strategy. In the southeastern United States there is more variability and debate on the future concentration of tropospheric ozone. Certain models project that by 2050 this region will attain higher levels of ozone; however, other models anticipate that concentrations will remain stable (Mickley 2006).

Variable knowledge such as the local temperature increases, the amount of VOCs that may be emitted by vegetation, and the flow of maritime air into the region creates different estimates in air quality assessments. Europe has been the focus of recent studies on summertime surface ozone, and it is expected to see a rise in tropospheric ozone between 2030 and 2050 (Mickley 2006).

High quantities of tropospheric ozone have been related to cardiac and respiratory diseases. Ozone is known as a lung irritant that can reduce lung performance. High levels can trigger asthma attacks in individuals with respiratory disease. During the August 2003 heat wave, the U.K. experienced around 600 fatalities and thousands of lung disease sufferers due to the high levels of ground level ozone (Mickley 2006). All across Europe people experienced numerous ozone-related respiratory and cardiac distresses as a response to this heatwave. Various studies showed linkages between high levels of particulates and the proliferation of ozone-related illness. A study revealed that as people were exposed longer to particulates, they were at a higher risk of developing atherosclerosis (Mickley 2006). A separate study, over an 18 year period, used a few thousand individuals from the United States to determine their exposure to particulates based on their zip codes. After analyzing the collection of data, researchers found that each 10 gram per square meter of rise in PM2.5 levels was associated with 10-20 percent increases in mortality risk, comparable to or even larger than the risks associated with smoking" (Mickley 2006: 41). They also found that these high levels were associated with ear infections in toddlers. Because of the Clean Air Act, the United States managed to reduce emissions and smog concentrations towards the end of the twentieth century. Anthropogenic VOC emissions decreased 15 percent from 1980 to 1995, and although the average miles driven per year increased by 60 percent, the amount of NO_x emissions remained stable during this same period (Mickley 2006). Since 1999, the Midwest of the United States has experienced a 40 percent reduction in nitrogen oxide emissions from coal-fired power plants. At the same time, research is unclear as to the trends of nitrogen oxide emissions from vehicles and whether they are remaining constant or are increasing. Whatever the case,

climate change is having a significant effect on the intensity and duration of high tropospheric ozone episodes. Heatwaves have the ability to exacerbate already smoggy conditions in which urban population are breathing in a soupy mess of lung irritants. Individuals who are currently afflicted with respiratory or cardiac illness are at a considerable health risk. Steps must be taken to respond to this human health threat.

Food Systems

One of the challenges facing humans is the threat of climate change on global food security.

First there is speculation that equatorial regions of the world will suffer negatively from the warming, while higher latitudes will increase their agricultural yields. Higher latitudes' increased yields especially in the northern hemisphere are partly associated with national wealth and technological advancements, but are also due to more favorable growing conditions. Warming in these areas is seen as an advantage since the longer growing season can be economically profitable. In developing nations, malnutrition and starvation are expected to increase. These areas will be the hardest hit by climate change. In some areas, land has already been pushed to the brink of no return owing to decades of drought and desertification.

According to Gregory et al. 2005: 2141, "food systems are defined as a set of dynamic interactions between and within the biogeophysical and human environments which result in the production, processing, distribution, preparation and consumption of food". The components of food systems include food availability, access, and utilization. Food availability involves the production and distribution of the food, food access involves the affordability, preference, or allocation of food, and food utilization means the nutritional and social value and food safety. When we discuss food security, we mean the food systems functioning so that, "all people, at all times, have physical and economic

access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (Gregory et al. 2005: 2141).

To study the effects of climate change on agriculture, researches have used the five global circulation models (GCMs) to create an agro-climatic assessment. The assessment demonstrates that by 2080 thermoclines will shift toward higher latitudes and considerably reduce boreal and arctic ecosystems by 60 percent or 2.1 billion hectares (Fischer et al. 2005). As northern ecosystems decrease in size, tropical areas will increase in expanse. Of the five GCMs, four of the models consistently produced results that showed the expansion of arid regions in developing countries. Nearly a billion people worldwide live in arid regions, and in Africa 180 million people live in arid regions. Climate studies have produced agro-ecological zone (AEZ) estimates for Africa. Africa's arid and dry or semi-arid regions, which are characterized by less than a 120 day growing period, are currently around 1.1 billion hectares (Fischer et al. 2005). With the impending climate change, AEZ estimates were modeled under climate change scenarios. It found that by the year 2080, Africa's arid and dry or semi-arid regions would expand by roughly 5-8% or 60-90 million hectares.

AEZ modeling has shown that the current climate contains 8.9 billion hectares that have influential environmental constraints (Fischer et al. 2005). This is two-thirds of land across the globe where it is too cold, dry, steep, wet, or degraded to sustain crops. Climate change will affect the distribution of environmental constraints on crop cultivation. Some regions will experience a positive impact, while other regions may be affected by climate constraints. Agro-ecological zones are expected to alter as a result of climate change. Some areas will experience surpluses or deficits in their water budgets that could affect the abundance of insects or diseases that affect crops. AEZ results showed that by the 2080s Central America and the Caribbean, Oceana and Polynesia, northern Africa, southern Africa, and Western Asia will be acutely restricted in their agricultural production. Southern Africa would be the most restricted from climate change effects with "an additional 11% of a total land area of

265 million hectares to be at risk of being severely constrained for crop agriculture" (Fischer et al. 2005: 2073).

Under climate change AEZ modeling, cultivated land is expected to expand. North America and Russia are projected to receive longer growing seasons than other regions of the world. On the other hand, Africa is expected to suffer from deteriorating growing conditions from climate change. AEZ predictions for the developing world are an expansion of some lands that are acceptable for crop agriculture; however, the growth would be most pronounced in the higher latitudes. North America is estimated to increase its cultivated land by 40 percent from the 360 million hectares currently available (Fischer et al. 2005). Northern Europe's 45 million hectares will increase 16 percent, East Asia's 150 million hectares will increase by 10 percent, and Russia's 245 million hectares will increase by a whopping 64 percent. Over 4 billion people (70 percent of the global population) are from 80 different countries labeled as food-insecure, and around 20 percent of the population from these countries is considered undernourished. Food-insecure populations are expected to increase to 80 percent of the global population (6.8 billion people) during the 2080s (Fischer et al. 2005).

Not only is it important to model the transition of agro-economic zones based on potential crop yield, but it is also critical to base the AEZ model on the "estimation of actual regional production and consumption" (Fischer et al. 2005: 2070). The baseline simulation (BLS) is used as a foundation for examining world food systems. Agriculture is an important part of individual nation's economies, which affect the global economy. Therefore, BLS models are important in evaluating the impact of climate change on national or international prices and on agricultural GDP. The BLS results showed that the price of crops and the agricultural GDP on a global scale changed very little under climate change. Although developed countries were seen to benefit agro-economically from climate change, developing countries were seen to experience decreases in their agricultural GDP (Fischer et al. 2005).

Without considering the effects of high CO₂ concentrations on crops, climate change is anticipated to decrease agricultural yields; however, elevated atmospheric CO₂ concentrations may abate the decrease in yields through the CO₂ fertilization effect. This effect is based on the fact that higher carbon dioxide levels allow plants to reduce their water loss and disease contraction since plants will not have to open their pores as wide to absorb CO₂. By 2050 to 2080, temperate regions may experience agricultural yields increases due to the elevated CO₂ levels. Still, the research on the physiological effect CO₂ concentrations have on plants is inconclusive. According to Long, most studies have been conducted within chambers and therefore overestimate crop increases, which would behave differently in open-air conditions. They further argue that the studies do not include the damaging effects of elevated tropospheric ozone levels and increased water demand of plants. Based on chamber studies that include an O₃ increase, any gains in agricultural yields that the Northern Hemisphere may experience will be offset. The only open-air scale study that implemented these variables showed that the losses in crop yields from high O₃ levels are considerably more than the reported results from chamber studies (Long et al. 2005). Consequently, regions that are predicted to benefit agriculturally from climate change, should heed caution when developing mitigation strategies. Crops may in fact not increase as once projected based on new studies.

Conclusion

Following multiple IPCC projections of climate change impacts on the environment, environmentally related human health consequences have been investigated. Extreme weather events are expected to increase in variability and frequency placing vulnerable individuals such as the elderly or ill at even greater health risk. Vector-born diseases are predicted to spread into higher latitudes and elevations as temperatures warm. Thus, more people will be at risk from contracting malaria or other vector associated diseases. As climate change increases the variability in temperatures and

precipitation across the globe, agricultural zones will shift accordingly. Temperate regions are projected to increase crop yields, while arid regions mostly in developing countries will suffer. Water availability and safety has also impacted human health. Algal blooms are expected to increase and this can affect the drinkable water quality and place humans at risk. Air quality will also be affected by climate change. Tropospheric ozone has been seen to increase in regions with higher temperatures. Those who suffer from cardiac and respiratory diseases are at acute health risks. Sea level rise is rapidly inundating low lying islands. This has caused major resource shortages of food, water, and land and has caused stress on the health of these inhabitants. Human health is directly related to the prevailing environmental conditions. Climate change is a substantial factor that may bolster up or detract from the current status of human health across the globe.

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