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Potential effects of climate change on global security

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Abstract The science is clear that climate change is one of the most important issues facing humanity. The changing climate is already affecting humanity and our economies in many ways. These effects will increase as the climate continues to change, and the effects are expected to increase dramatically over the coming decades. Climate-related hazards exacerbate other stressors, often with negative outcomes for livelihoods, especially for people living in poverty. Climate change can amplify existing stresses and vulnerabilities among populations and existing threats to security and can indirectly increase risks of violence and violent conflict. This paper is aimed at examining the changes occurring to the Earth's climate, what additional changes in climate are likely to occur over the coming decades, and how climate change could affect global security.

Keywords Climate · Climate change · Global security

1 Introduction

The novel the Park Service by Ryan Winfield is the story of a post-apocalyptic world set 900 years into the future after much of human civilization was destroyed by nuclear war. Roughly, the premise is that overpopulation and the changes in the Earth's climate and the resulting issues with drought, floods, and famine in various parts of the world led to governments being overtaken by their people. These young governments then initiated nuclear war toward increasing their own power. Greed was a powerful force leading to nuclear destruction.

While we certainly are not implying that we are on a pathway to world destruction, climate change could nonetheless create many additional stresses on the availability of energy, water, and food on our planet. The resulting ramifications are many.

The science is clear that climate change, often referred to as global warming in the media, is one of the most important issues facing humanity. This has been verified in the peer-reviewed science literature over and over again by analyses of observations both for the current and past climates on our planet and by extension of those studies through numerical models of the physics, chemistry, and biology affecting the climate system to examine potential future changes. Assessments by the science community have further validated those findings, including those by the Intergovernmental Panel on Climate Change (IPCC 2013), the US National Climate Assessment (Melillo et al. 2014) and by the US National Academy of Sciences, the UK Royal Society, and similar science organizations throughout the world (UKRS-NAS 2014). While often debated in the media and on blogs, there is essentially no debate in the peer-reviewed scientific literature about the large changes occurring in the Earth's climate and the fact that these changes are occurring as a response to human activities, mainly burning of fossil fuels. Natural factors have always affected our climate in the past and continue to do so today; but now, the dominant influence is human activities. The science shows that climate change is happening, happening rapidly, and happening primarily because of human activities.

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The changing climate is already affecting humanity and our economies in many ways. These effects will increase as the climate continues to change, and the effects are expected to increase dramatically over the coming decades (IPCC 2014; Melillo et al. 2014). Climate-related hazards exacerbate other stressors, often with negative outcomes for livelihoods, especially for people living in poverty (IPCC 2014).

Could climate change affect global security? The answer is clearly yes. Effects of climate change will undoubtedly put many millions of people around the world in harm's way. Climate change can amplify existing stresses and vulnerabilities among populations and existing threats to security and can indirectly increase risks of violence and violent conflict.

This paper is aimed at examining the changes occurring to the Earth's climate, what additional changes in climate are likely to occur over the coming decades, and how global security could be affected as a result.

2 Our changing climate

Climate is defined as long-term averages and variations in weather measured over multiple decades. The Earth's climate system includes the land surface, atmosphere, oceans, and ice. Scientists and engineers from around the world have compiled the evidence that the climate is changing, changing much more rapidly than tends to occur naturally (by at least a factor of ten (Marcott et al. 2013), and that it is changing because of human activities; these conclusions are based on observations from satellites, weather balloons, thermometers at surface stations, ice cores, and many other types of observing systems that monitor the Earth's weather and climate. A wide variety of independent observations give a consistent picture of a warming world, but there are many indicators of this change, not just atmospheric surface temperature. For example, temperatures at the surface, in the troposphere (the active weather layer extending up to about 5–10 miles above the ground), and in the oceans have all increased over the last century. Consistent with our scientific understanding, the largest increases in temperature are occurring closer to the poles, especially in the Arctic (this is primarily related to ice-albedo feedback that as snow and ice decreases, the exposed surface will absorb more solar radiation rather than reflect it back to space). Snow and ice cover have decreased in most areas of the world. Atmospheric water vapor (H_2O) is increasing in the lower atmosphere, because a warmer atmosphere can hold more water. Sea levels are also increasing. All of these conclusions are based on observations.

As seen in Fig. 1, global annual average temperature (as measured over both land and oceans) has increased by more than 0.8 °C (1.5 °F) since 1880 (through 2012). While there is a clear long-term global warming trend, some years do not show a temperature increase relative to the previous year, and some years show greater changes than others. These year-to-year fluctuations in temperature are related to natural processes, such as the effects of

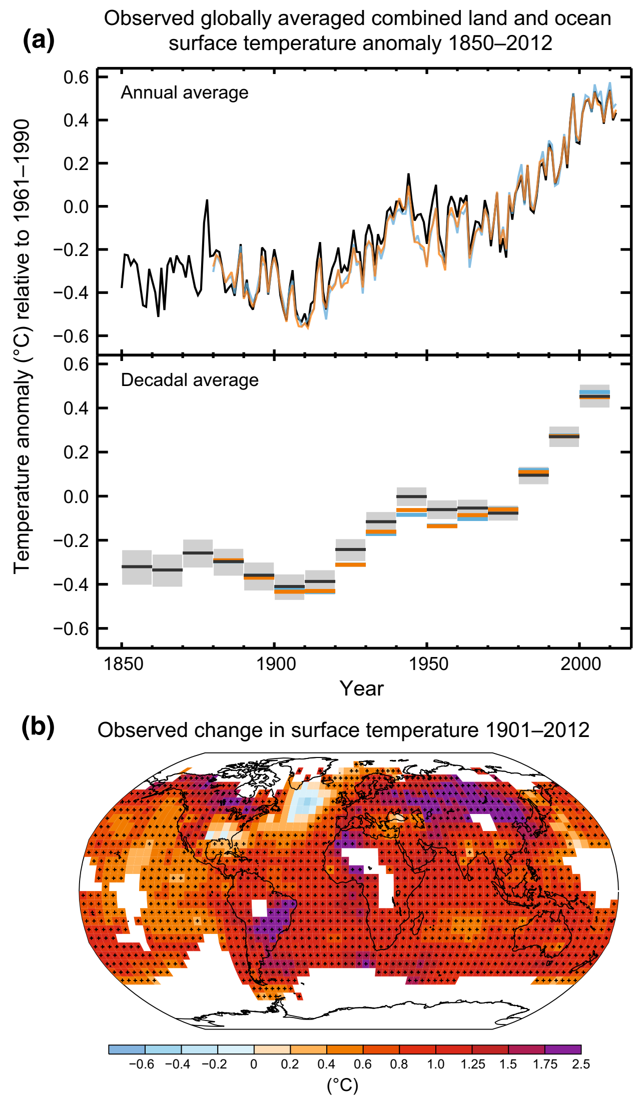

Fig. 1 **a** Observed global mean combined land and ocean surface temperature anomalies, from 1850 to 2012 from three data sets (See IPCC, 2013: Hadley Centre, *black*; NOAA MSLOST, *orange*; NASA GISS, *blue*). *Top panel* annual mean values, *bottom panel* decadal mean values including the estimate of uncertainty for one dataset (from the Hadley Centre). Anomalies are relative to the mean of 1961–1990. **b** Map of the observed surface temperature changes from 1901 to 2012 derived from temperature trends determined by linear regression from one dataset (*orange line* in **a**). Trends have been calculated where data availability permits a robust estimate (i.e., only for *grid boxes* with greater than 70 % complete records and more than 20 % data availability in the first and last 10 % of the time period). Other areas are *white*. *Grid boxes* where the trend is significant at the 10 % level are indicated by a + sign. Figure based on IPCC (2013; Summary for policymakers Figure 1) (Color figure online)

volcanic eruptions or the effects of ocean-induced variations like El Ninos. Globally, natural variations can be as large as human-induced climate change over timescales of up to a few decades. However, changes in climate at the global scale observed over the past 50 years are far larger than can be accounted for by natural variability (IPCC 2013). At the local to regional scale, changes in climate can be influenced by natural variability for multiple decades (Deser et al. 2012).

Over the last five decades, natural drivers of climate such as solar forcing and volcanoes would actually have led to a slight cooling and cannot explain the observed warming over this period. The majority of the warming can only be explained by the effects of human influences (IPCC 2013; Gillett et al. 2012; Santer et al. 2013; Stott et al. 2010), especially the emissions from burning of fossil fuels (coal, oil, and natural gas), and from changes in land use, such as deforestation. As a result of human activities, atmospheric concentrations of various gases and particles are changing, including those for carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), and particles such as black carbon (soot), which has a warming influence, and sulfates, which have an overall cooling influence. The most important changes are occurring in the concentration of CO_2; its atmospheric concentration recently reached 400 ppm (400 molecules per 1 million molecules of air, but this small amount is important because of the heat-trapping ability of CO_2). 400 ppm of CO_2 has not been seen on Earth for over 1 million years, well before the appearance of humans. The increase in CO_2 over the last several hundred years is almost entirely due to burning of fossil fuels and land use change (IPCC 2013). The conclusion that human influences are the primary driver of recent climate change is based on multiple lines of independent evidence (see recent scientific assessments, e.g., IPCC 2013; Melillo et al. 2014). Figure from IPCC (2013).

Globally averaged surface air temperature has slowed its rate of increase since the late 1990s. This is not in conflict with our basic understanding of global warming and its primary cause. The decade of 2000–2009 was still the warmest decade on record. In addition, global surface air temperature does not always increase steadily and can be influenced by natural variability on the scale of a few decades (for further discussion, see IPCC 2013; Melillo et al. 2014; the explanation for the slowdown in global surface temperature is further discussed in a special issue of Nature from March 2014). Other climate change indicators, like the decrease in Arctic sea ice and sea level rise, have not seen the same slowdown.

Precipitation is perhaps the most societally relevant aspect of the hydrological cycle and has been observed over global land areas for over a century, although there does not appear to have been significant changes in globally averaged precipitation since 1900. However, there are strong geographic trends including a likely increase in precipitation in Northern Hemisphere mid-latitude regions taken as a whole. In general, the findings are that wet areas are getting wetter and dry areas are getting drier, consistent with an overall intensification of the hydrological cycle in response to global warming (IPCC 2013; Melillo et al. 2014).

It is well known that warmer air can contain more water vapor than cooler air. Global analyses show that the amount of water vapor in the atmosphere has in fact increased over both land and oceans (Melillo et al. 2014). Climate change also alters dynamical characteristics of the atmosphere that in turn affect weather patterns and storms. At mid-latitudes, there is an upward trend in extreme precipitation in the vicinity of fronts associated with mid-latitude storms. Locally, natural variations can also be important. In contrast, the subtropics are generally tending to have less overall rainfall and more droughts. Nonetheless, many areas show an increasing tendency for larger rainfall events when it does rain (Janssen et al. 2014; Melillo et al. 2014; IPCC 2013).

As important as the above discussion is to the overall changes occurring in climate, much more important to concerns about global security are the changes occurring in trends and intensity of severe weather events. Much of the world is being affected by changing trends in extreme events, including increases in the number of extremely hot days, less extreme cold days, more precipitation events coming as unusually large precipitation, and more floods in some regions and more drought in others (IPCC 2012, 2013; Melillo et al. 2014). High impact, large-scale extreme events are complex phenomena involving various factors that come together to create a "perfect storm." Such extreme weather obviously does occur naturally. However, the influence of human activities on global climate is altering the frequency and/or severity of many of these events. Observed trends in extreme weather events, such as more hot days and more precipitation coming as extreme events, are expected to continue and to intensify over this century. However, trends remain uncertain in some types of severe weather, including the intensity and frequency of tornadoes, hail, and damaging thunderstorm winds, but such events are under scrutiny to determine whether there is a climate change influence.

There is emerging evidence that most of the increasing heat wave severity over our planet is likely related to the changes in climate, with a detectable human influence for major recent heat waves in the USA (Rupp et al. 2012; Duffy and Tebaldi 2012; Meehl et al. 2009), Europe (Stott et al. 2010; Trenberth 2011), and Russia (Christidis et al. 2011). As an example, the summer 2011 heat wave and drought in Oklahoma and Texas, which cost Texas an estimated $8 billion in agricultural losses, was primarily driven by precipitation deficits, but the human contribution to climate change approximately doubled the probability that the heat was record-breaking (Hoerling et al. 2013). So while an event such as this Texas heat wave and drought could be triggered by a naturally occurring event, the chances for record-breaking temperature extremes have increased and will continue to increase as the global climate warms. Generally, the changes in climate are increasing the likelihood for these types of severe events.

In the tropics, the most important types of storms are tropical cyclones, referred to as hurricanes when they occur in the Atlantic Ocean. Over the 40 years of satellite monitoring, there has been a shift toward stronger hurricanes in the Atlantic, with fewer category 1 and 2 hurricanes and more category 4 and 5 hurricanes. There has been no significant trend in the global number of tropical cyclones (IPCC 2012, 2013) nor has any trend been identified in the number of US landfalling hurricanes (Melillo et al. 2014).

The impact on the oceans is the other major concern for global security. After at least 2,000 years of little change, the world's sea level rose by roughly 0.2 m (8 in.) over the last century, and satellite data provide evidence that the rate of rise over the past 20 years has roughly doubled. Around the world, many millions of people and many assets related to energy, transportation, commerce, and ecosystems are located in areas at risk of coastal flooding because of sea level rise and storm surge. Sea level is rising because ocean water expands as it heats up and because water is added to the oceans from melting glaciers and ice sheets. Sea level is projected to rise an additional 0.3–1.2 m (1–4 feet) in this century (Melillo et al. 2014; similar findings in IPCC 2013). Scientists are unable to narrow this range at present because the processes affecting the loss of ice mass from the large ice sheets are still the subject of intense study. Large questions remain about how much melting of the ice on Greenland and Antarctica will occur this century. Because of the warmer global temperatures, sea level rise will continue beyond this century. Many millions of people live within areas than can be affected by the effects of storm surge within a rising sea level. The Low Elevation Coastal Zone (less than 10 m elevation) constitutes 2 % of the world's land area but contains 10 % of the world's population based on year 2000 estimates (McGranahan et al. 2007).

As CO_2 concentrations build up in the atmosphere, some of this CO_2 is dissolving into the oceans where it reacts with seawater to form carbonic acid, lowering ocean pH levels ("acidification") and threatening a number of marine ecosystems (Doney et al. 2009). The oceans currently absorb about a quarter of the CO_2 humans produce every year (Le Quéré et al. 2009). Over the last 250 years, the oceans have absorbed 560 billion tons of CO_2, increasing the acidity of surface waters by 30 % (Melillo et al. 2014). The current observed rate of change is roughly 50 times faster than known historical change (Hönisch et al. 2012; Orr et al. 2005; Orr 2011). Regional factors such as coastal upwelling (Feely et al. 2008), changes in discharge rates from rivers and glaciers (Mathis et al. 2011), sea ice loss (Yamamoto-Kawai et al. 2009), and urbanization (Feely et al. 2010) have created "ocean acidification hotspots" where changes are occurring at even faster rates.

The acidification of the oceans has already caused a suppression of carbonate ion concentrations that are critical for marine calcifying animals such as corals, zooplankton, and shellfish. Many of these animals form the foundation of the marine food web. Today, more than a billion people worldwide rely on food from the ocean as their primary source of protein. Ocean acidification puts this important resource at risk. This contribution to concerns about food security could become an ever important aspect of global security throughout this century.

3 Projections of climate change

On the global scale, climate model simulations show consistent projections of future conditions under a range of emissions scenarios (that depend on assumptions of population change, economic development, our continued use of fossil fuels, changes in other human activities, and other factors). For temperature, all models show warming by late this century that is much larger than historical variations nearly everywhere (see Fig. 2). For precipitation, models are in complete agreement in showing decreases in precipitation in the subtropics and increases in precipitation at higher latitudes. As mentioned earlier, extreme weather events associated with extremes in temperature and precipitation are likely to continue and to intensify.

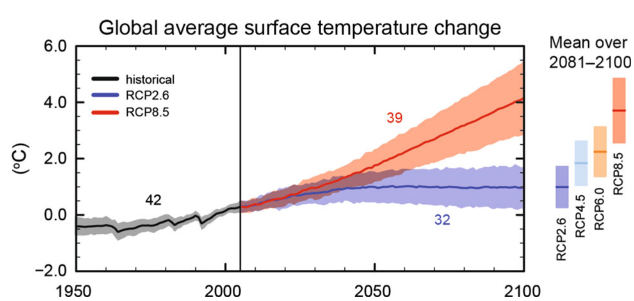

Fig. 2 Multi-model simulated time series from 1950 to 2100 for the change in global annual mean surface temperature relative to 1986–2005. The mean and associated uncertainties averaged over 2081–2100 are given for all of the RCP scenarios as *colored vertical bars*. The numbers of models used to calculate the multi-model mean is indicated (Figure 7a from IPCC AR5 Summary for policymakers)

Choices made now and in the next few decades about emissions from fossil fuel use and land use change will determine the amount of additional future warming over this century and beyond. Global emissions of CO_2 and other heat-trapping gases continue to rise. How much climate will change over this century and beyond depends primarily on (1) human activities and resulting emissions, and (2) how sensitive the climate is to those changes (that is, the response of global temperature to a change in radiative forcing caused by human emissions). Uncertainties in how the economy will evolve, what types of energy will be used, or what our cities, buildings, or cars will look like in the future are all important and limit the ability to project future changes in climate. Scientists can, however, develop scenarios—plausible projections of what might happen, under a given set of assumptions. These scenarios describe possible futures in terms of population, energy sources, technology, heat-trapping gas emissions, atmospheric levels of carbon dioxide, and/or global temperature change.

A certain amount of climate change is already inevitable due to the build up of CO_2 in the atmosphere from human activities. The Earth's climate system, particularly the ocean, tends to lag behind changes in atmospheric composition by decades, and even centuries due to the large heat capacity of the oceans and other factors. Another 0.2–0.3 °C (about 0.5 °F) increase is expected over the next few decades (Matthews and Zickfeld 2012) although natural variability could still play an important role over this time period (Hawkins and Sutton 2011). The higher the human-related emissions of CO_2 and other heat-trapping gases over the coming decades, the higher the resulting changes expected by mid-century and beyond. By the second half of the century, however, scenario uncertainty (that is, uncertainty about what will be the level of emissions from human activities) becomes increasingly dominant in determining the magnitude and patterns of future change, particularly for temperature-related aspects (Hawkins and Sutton 2009, 2011).

As seen in Fig. 2 for a range of scenarios varying from assuming strong continued dependence on fossil fuels in energy and transportation systems over the twenty-first century (scenario RCP8.5) to assuming major mitigation actions (RCP2.6), global surface temperature change for the end of the twenty-first century is *likely* to exceed an increase of 1.5 °C (2.7 °F) relative to 1850–1900 for all projections except for those assuming major mitigation of RCP scenarios except the lowest RCP2.6 scenario (see Fig. 2). An increase of roughly 1.5 °C has been represented as an approximate threshold for dangerous human interferences with the climate system (see IPCC 2013, 2014 for further discussion), but this threshold is not exact and the changes in climate are geographically diverse and impacts are sector dependent, so there really is no defined threshold by when dangerous interferences is actually reached.

The warming and other changes in the climate system will continue beyond 2100 under all RCP scenarios, except for a leveling of temperature under RCP2.6. In addition, it is fully expected that the warming will continue to exhibit interannual-to-decadal variability and will not be regionally uniform.

Projections of future changes in precipitation show small increases in the global average but substantial shifts in where and how precipitation falls. Generally, areas closest to the poles are projected to receive more precipitation, while the dry subtropics (the region just outside the tropics, between 23° and 35° on either side of the equator) will generally expand toward the poles and receives less rain. Increases in tropical precipitation are projected during rainy seasons (such as monsoons), especially over the tropical Pacific. Certain regions, including the western US (especially the southwest (Melillo et al. 2014) and the Mediterranean (IPCC 2013), are presently dry and are expected to become drier. The widespread trend of increasing heavy downpours is expected to continue, with precipitation becoming more intense (Boberg et al. 2009; Gutowski et al. 2007; Sillmann et al. 2013). The patterns of the projected changes of precipitation do not contain the spatial details that characterize observed precipitation, especially in mountainous terrain, because of model uncertainties and their current spatial resolution (IPCC 2013).

The best estimates for the range of sea level rise projections for this century remain quite large; this may be due in part to what emissions scenario we follow, but more importantly on just how much melting occurs from the ice on large land masses, especially from Greenland and Antarctica. Recent projections show that for even the lowest emissions scenarios, thermal expansion of ocean waters (Yin 2012) and the melting of small mountain glaciers (Marzeion et al. 2012) will result in 11 inches of sea level rise by 2100, even without any contribution from the ice sheets in Greenland and Antarctica. This suggests that about 0.3 m (1 foot) of global sea level rise by 2100 is probably a realistic low end. Recent analyses suggest that 1.2 m (four feet) may be a reasonable upper limit (Rahmstorf et al. 2012; IPCC 2013; Melillo et al. 2014). Although scientists cannot yet assign likelihood to any particular scenario, in general, higher emissions scenarios would be expected to lead to higher amounts of sea level rise. Sea level rise will continue well beyond 2100 because the oceans take a very long time to respond to warmer conditions at the Earth's surface.

Projections indicate that in a higher emissions scenario (that assume continuing use of fossil fuels), ocean pH could be reduced from the current level of 8.1 to as low as 7.8 by the end of the century (Orr et al. 2005). Such large rapid changes in ocean pH have probably not been experienced on the planet for the past 100 million years, and it is unclear whether and how quickly ocean life could adapt to such rapid acidification (Hönisch et al. 2012). The potential impact on the human source of food from the oceans is also unclear.

4 Climate and world security

As we have discussed, climate change is altering the world around us, and these changes will become increasingly evident with each passing decade. Many people are already being affected by the changes that are occurring, and more will be affected as these changes continue to unfold. To limit risks and maximize opportunities associated with the changes, people need to understand how climate change is going to affect them and what they can do to adapt, as well as what we can to reduce future climate change by reducing global emissions. Climate change will affect ecosystems and human systems—such as agricultural, transportation, water resources, and health-related infrastructure—in ways we are only beginning to understand. Moreover, climate change can interact with other stressors, such as population increase, land use change, and economic and political changes, in ways that we may not be able to anticipate, compounding the risks.

Humans share a close bond with the environment around us, and a small change can result in major impacts. Although some impacts will likely be beneficial within limited sectors and regions, economic analyses indicate that the costs of inaction will be many times greater than the costs of action to reduce emissions (Stern et al. 2006; Dietz et al. 2007; Ackerman and Stanton 2008). In general, the larger and faster the changes in climate occur, the more difficult it will be for human and natural systems to adapt. The climate system has been relatively stable during most of the time that human civilizations have existed, but the current pace of change is accelerating. Essentially, today's built infrastructure has been developed based on the assumption that future climate will be like that of the past. This assumption is likely no longer valid.

Changing trends in severe weather events and corresponding shortages in life-sustaining essentials like food and water may lead to social stress and concerns about local and national security. While the effects of climate change alone do not necessarily lead to conflict, they may act as accelerants of instability and/or conflict in various parts of the world.

In several recent studies (e.g., US Department of Defense 2011, 2014a, b), it has become clear that the military sees climate change as a major additional threat to global security. In the Quadrennial Defense Review 2014, the US Department of Defense (DOD 2014a) analyzes some of the associated issues: "Climate change poses another significant challenge for the United States and the world at large. As greenhouse gas emissions increase, sea levels are rising, average global temperatures are increasing, and severe weather patterns are accelerating. These changes, coupled with other global dynamics, including growing, urbanizing, more affluent populations, and substantial economic growth in India, China, Brazil, and other nations, will devastate homes, land, and infrastructure. Climate change may exacerbate water scarcity and lead to sharp increases in food costs. The pressures caused by climate change will influence resource competition while placing additional burdens on economies, societies, and governance institutions around the world. These effects are threat multipliers that will aggravate stressors abroad such as poverty, environmental degradation, political instability, and social tensions—conditions that can enable terrorist activity and other forms of violence." A more recent report (DOD 2014b) examines approaches for the adaptation to the changing climate toward preparing for potential instabilities in other nations.

Climate change is likely to have the greatest impact on security through its indirect effects on conflict and vulnerability. Many developing countries are unable to provide basic services and improvements, much less cope with repeated, sudden onset shocks and accumulating, slow onset stresses. These effects span the spectrum from the basic necessities of livelihood to social conflict, including protests, strikes, riots, inter-communal violence, and conflict between nations. Climate change is more likely to be an exacerbating factor for failure to meet basic human needs and for social conflict, rather than the root cause. Climate change is already intensifying environmental and resource problems that communities are facing (DOD 2011).

In their analysis of climate change as a security risk, Schubert et al. (2008) suggest that the four most important issues that could lead to major national security concerns and increasing global tensions are as follows: (1) natural disasters; (2) lack of freshwater resources; (3) decline in food production; and (4) increased migration of people. In the discussion below, we will examine those four issues and their relationship to climate change.

4.1 Natural disasters

As global climate changes as a result of human activities, there is strong evidence that this increase is being accompanied by changes in the frequency, intensity, and/or duration of certain types of extreme weather events. At the global scale, increasing trends in heat waves, heat

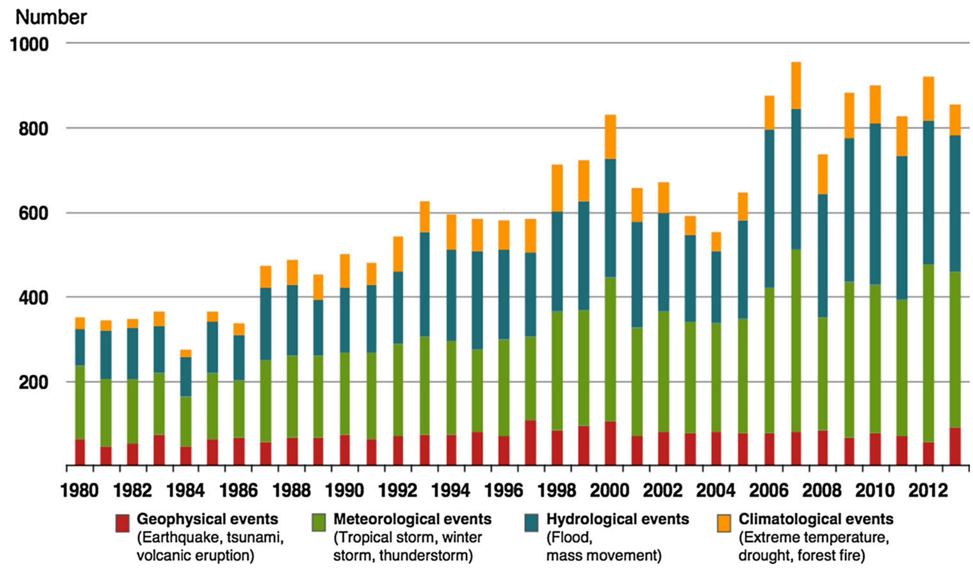

Fig. 3 Number of natural catastrophe loss events worldwide 1980–2013. *Source*: Munich Re Geo risks research

extremes, and heavy precipitation events have been attributed at least in part to human-induced climate change (Min et al. 2011; IPCC 2012; Trenberth and Fasullo 2012; Zwiers et al. 2013).

Weather extremes account for 80 % of the more than $100B in global economic damages incurred by natural hazards annually (Rauch 2011; Meyer et al. 2013), with tens of thousands of deaths each year and more than 1 billion affected over the last decade from flooding alone. As seen in analyses by Munich Re, Fig. 3 shows that the trends for catastrophic events worldwide are increasing. Figure 4 shows natural catastrophic loss events for the year 2013 based on the analyses by Munich Re.

Since 1980, the USA has sustained 144 weather/climate disasters where overall damages/costs reached or exceeded $1 billion that together have cost over $1 trillion (including Consumer Price Index adjustment to 2013; http://www.ncdc.noaa.gov/billions/). Severe weather events in the USA would typically occur only a few times each year, but that rate has increased, especially over the last decade (Smith and Katz 2013). Even when hurricanes (and the effects of large coastal economic growth) are excluded, the number of billion dollar events over the last >30 years has increased. Observed trends include increases in heat waves (Kunkel et al. 2013) and increasing trends in flood risk in the Midwest and northeast coupled with decreasing trends in southwest that correlate with observed trends in mean and extreme precipitation.

The location and timing of severe weather events play a big role in the amount of devastation that results. In particular, poverty stricken regions tend to suffer the most from these events. Along with less economic stability, these regions suffer from high population growth, lack for natural resources, and political instability (Scheffran 2008). However, recent research by Hsiang and Jina (2014) points toward long-run economic implications of tropical cyclones on countries, both rich and poor. Analyzing the effects of 6,700 tropical cyclones between 1950 and 2008, the authors suggest that "a 90th percentile event reduces per capita incomes by 7.4 % two decades later, effectively undoing 3.7 years of average development."[1] Again, the fact that national income was not much of a determinant in how much a country will be impacted by such climatic events is a stark indicator for all countries in the so-called North and South blocks.

A particular concern for global security is clustered events. Clustered events occur close in time with each other. However, they may not be within the same region. These types of events not only affect the regions hit by these disasters but also the countries giving aid. Effects of natural disasters can be felt throughout the world. Humanitarian and economic resources can be stretched thin within the countries trying to help. This not only puts the lives of the devastated people, but it can cause security concerns within the giving country (CNA 2007, 2014).

Along with the unfortunate loss of many lives and economic value, it is critical to also look at how these disasters weaken the social fabric in affected regions that could trigger civil unrest and mass migration to both cities within the country and outside. Such disasters can often aggravate other preexisting stresses and inequities causing disproportionate harm to marginalized communities with societies including women, children, the elderly and infirm (White 2012).

[1] One major factor which determined how much a country was going to be impacted by such activity was its previous experience in dealing with such catastrophes. This clearly emphasizes the role climate adaptation could play going forward.

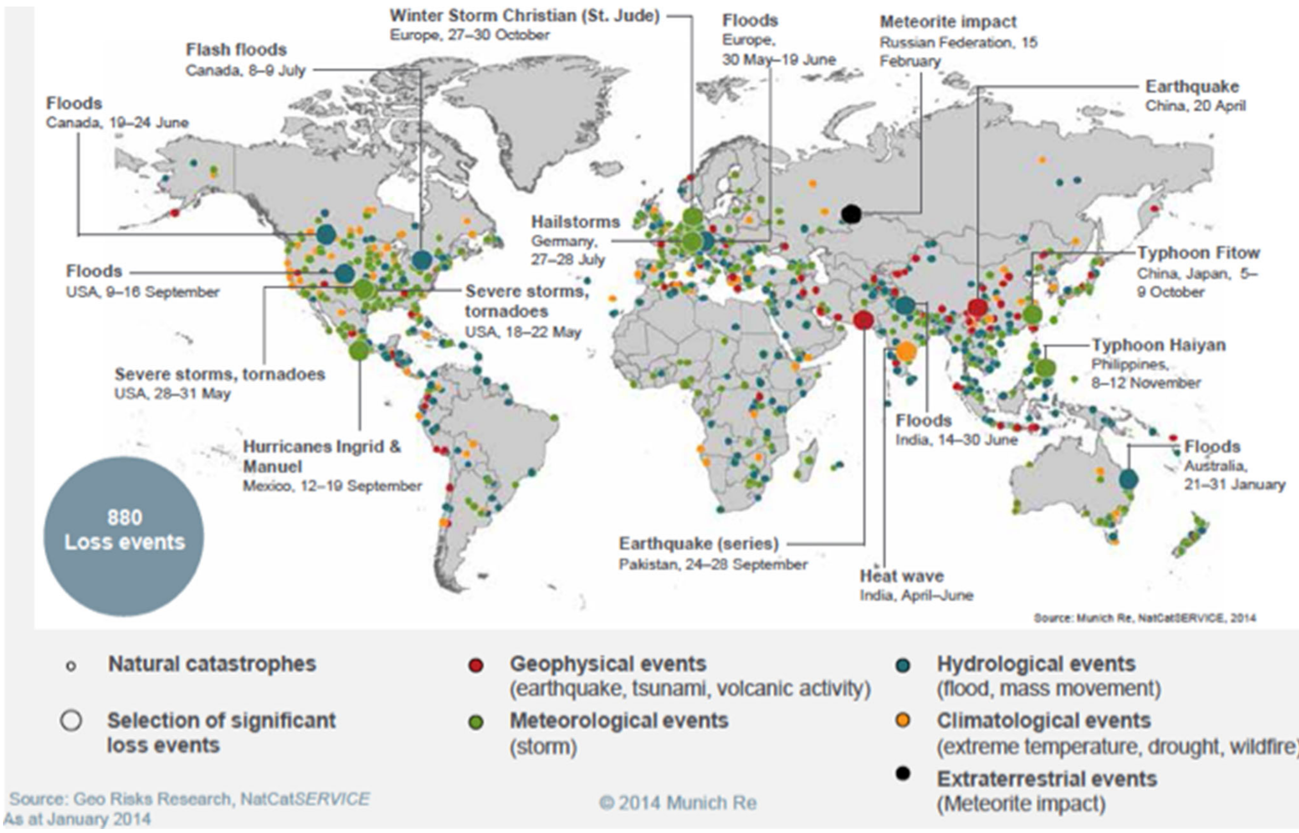

Fig. 4 Map of 2013 natural catastrophic loss events. *Source*: Munich Re NatCatSERVICE

Hagan and Kaiser (2011) link climate change as well as unsustainable grazing and farming practices in Darfur to state-led genocide of non-Arabs in the that region. They suggest “By the mid-1980s, the intertwined processes of desertification and famine aggravated disputes over land and water and intensified the socially constructed, racially tinged division between Arabs and other Africans. The causes of the conflict in Darfur are clearly a mixture of environmental and political forces. Understanding the interconnection of these forces and how they are played out is central to explaining state-led genocide through elimination of non-Arab groups in this African setting.” It is not unreasonable to expect that tensions will continue to grow in other parts of the world, especially the tropics and subtropics, as a result of climate change.

White (2012) also examines crimes and conflicts that could arise because of severe food shortage resulting from drought or famines. Such situations, the author argues could lead to exploitation of those affected by the few who act as trustees of food or other aid resources—including the state or other influential people within societies (Sanghi et al. 2010). There are also cases of “human trafficking, predatory banditry or extortion of protection money.”

Sanghi et al. (2010) elaborate on several previous cases of conflicts in disaster situations in various different parts of the world and attribute higher probability of internal conflict as a result of droughts and other natural catastrophes. Empirical research in Africa suggests that a 1 % increase in rainfall reduces the chances of civil war by as much as 6 % (Miguel et al. 2004). Similarly, very low rainfall is likely to increase the chances of conflict, suggesting that a 20 % rainfall deficit is likely increases the chances of civil war by 3.6 % (Hendrix and Glaser 2007). However, as Table 1 suggests, the likelihood of conflict as a result of rainfall deficit is much less if the “the rule of law” takes precedence in a society, implying that good governance structures have an important role to play in preventing civil unrests and wars (Keefer 2009). However, the capacity of any government is likely to be tested in cases of extreme prolonged drought that could result from climate change.

Hsiang et al. (2011), based on data collected between 1950 and 2004, also show causal links between climate-related effects—El Niño and armed civil conflict. Research showed that the probability of conflict was almost double at 6 % compared to 3 % in non-El Niño years in the countries affected by this climate phenomenon. Though the exact

Table 1 Civil war, rainfall, and the rule of law

Dependent variable: probability of civil war	Not controlling for rule of law	Controlling for rule of law
Rainfall growth from last period (t − 1) to current period (*t*)	−0.11	−0.05
	(0.04)	(0.34)
Rainfall growth (t − 2) to (t − 1)	−0.08	−0.03
	(0.07)	(0.5)
Rule of law (t − 1)		−0.17
		(0.001)
Rule of law (t − 2)		0.1
		(0.03)
Number of observations, countries	451.32	451.32
R^2	0.08	0.14

Data from Sub-Saharan Africa, 1982–1999 indicates that the probability of civil war is significantly linked to the change in rainfall growth from 1 year to the other. However, controlling for the rule of law (using a proxy), the paper finds that change in rainfall has an insignificant effect on the probability of civil war. The two rule of law proxies have opposite sign because they are an aggregate indicator of the effect of rule of law on the probability of civil war in the current year. An unchanged rule of law from year $t-2$ to $t-1$ will have a net negative effect on the probability of civil war. However, an improved rule of law will have an even larger net negative effect on the probability of civil war in the present year. From Sanghi et al. (2010)

hypotheses behind this link is yet to be ascertained, it could loss of agricultural income in those years or just that exceptionally warm weather triggers aggressive behavior in humans.

4.2 Lack of freshwater resources

Water is the most essential resource on the planet. With 70 % of Earth being covered in water, it seems odd that there are countries that suffer every day to gather enough fresh water to live (of course, most of this water is salt water in the oceans—only 2.5 % of available water is fresh water and 70 % of that is frozen in Greenland and Antarctica). In fact, a third of the world is affected in some way by the lack of water (Schubert et al. 2008). A combination of environmental change and poor water usage has put a strain on our access to fresh water. With water use expected to rise in the coming years along with the increasing global population, water concerns will be compounded.

Frequency and location of precipitation events have had a noticeable change within the past few decades. As noted earlier, it is projected that dry regions will receive less precipitation than average, and wet regions will receive more precipitation than average. This means that dry, desert regions will be in more danger of water scarcity. As shown in Fig. 5, the most notorious regions for conflict, the Middle East and Africa, are also regions with major water issues. Poverty and crime already affect these parts of the world, so any new issue can spark further violence. Water shortages are especially prevalent along the Mediterranean. Some of the countries most affected include those with recent conflicts (e.g., the Israel and Palestine areas, and Egypt and the Nile River basin).

Water overuse appears to be damaging the environment in many major basins. According to UNEP (2008), "high overuse tends to occur in regions heavily dependent on irrigated agriculture, such as the Indo-Gangetic Plain in south Asia, the North China Plain and the High Plains of North America, and in areas undergoing rapid urbanization and industrial development. An estimated 1.4 billion people now live in river basin areas that are 'closed' (in that water use exceeds minimum recharge levels) or near closure." As millions of people in water-stressed areas are discovering, the environment is foreclosing on unsustainable water debts on an extensive scale.

In the USA, 40 % of the freshwater used in the USA comes from groundwater. Since people had started to rely on the Ogallala Aquifer in the Great Plains for irrigation of their fields, 6 % of the aquifer has dropped to an unusable level that can no longer be pumped. If irrigation continues to draw water from the aquifer at the same rate, about 6 % of the aquifer will be used up every 25 years. Recent drought in the Texas panhandle has accelerated the drawdown of the Ogallala in that region. Some parts of the world are much worse. For example, the Mexico City Aquifer has been depleted since the early 1900s. One study showed that from 1986 to 1992, the aquifer lowered anywhere from 6 to 10 m in heavily pumped areas. According to UNEP, farmers near Sana'a in Yemen have deepened their wells by 50 meters over the past 12 years (relative to 2006), while the amount of water they can extract has dropped by two-thirds.

Some people in water-stressed areas have the economic resources, skills, and opportunities to leave their water problem behind. Many millions, such as small farmers, agricultural laborers, and pastoralists in poor countries, do not (see UNEP 2008).

In areas of insecurity, water can be used as an instrument for conflict. According to the Water Conflict Chronology of the Pacific Institute, there are many different categories of conflict that water can be used as a tool. They believe that authority over water resources is the main concern when it comes to conflict. Water can also be used as a "political" and "military tool." Governments can use water to achieve other goals. With access to water, they can either threaten or negotiate with other states in order to gain power. Finally, water can be targets of violence by terrorist groups or the military. Water resources can be a

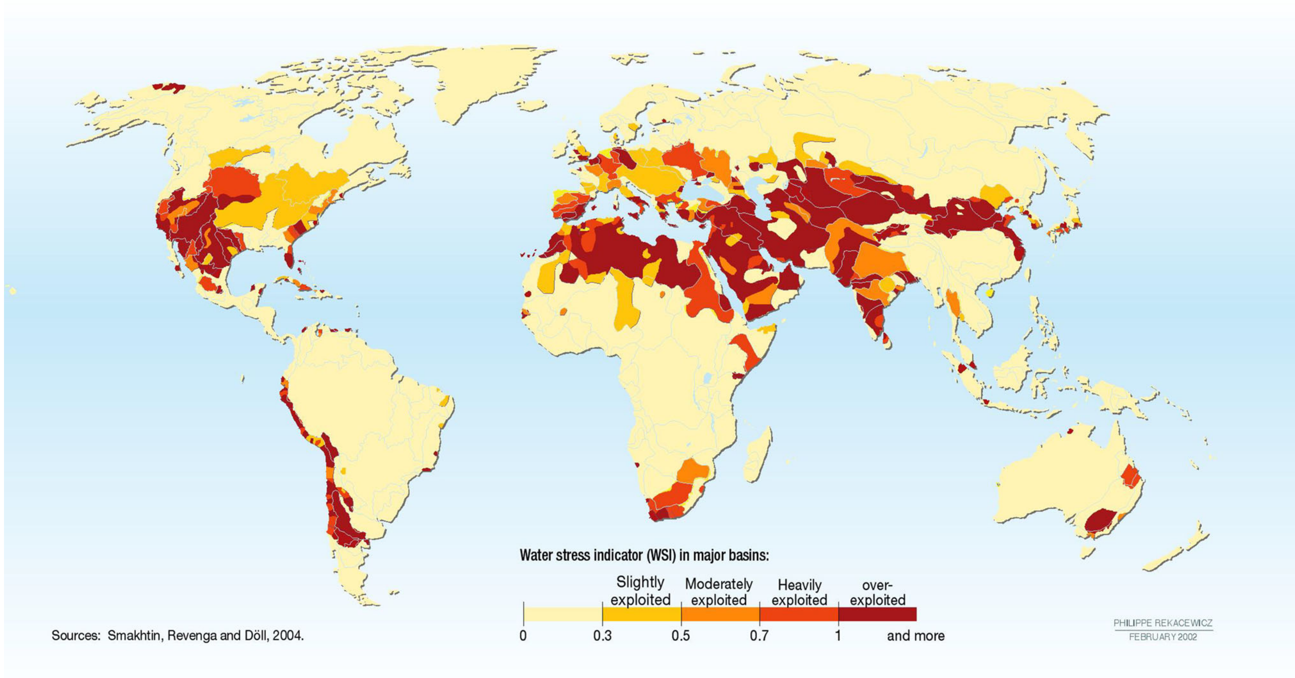

Fig. 5 Water scarcity index. *Source*: UNEP 2008

very important resource in a particular region and acts of terrorism, or military action, affecting that resource can be devastating (National Research Council 2013).

However, the Institute of Water and Watersheds at Oregon State University has found that cooperation is more of the standard when it comes to relationships with water resources (FDI 2011). Over the last 50 years, they suggest that have been no specific instances of water leading directly to war (however, there may be indirect effects, e.g., wars in Sudan and Syria may have resulted in part from the large droughts in those regions). For the most part, water is used a "tool" or "target" instead of a main reason for conflict. Agreements between nations over water have been effective in preventing any type of violence. These agreements seem to hold strong even in times of extreme conflicts. While there is concern of violence over water resources, history shows that cooperation rather than conflict is more likely to occur. With that in mind, the international community must still take the threat of a water shortage seriously. While history may lean toward cooperation, our climate is changing at such a rapid rate that new issues will likely arise.

4.3 Food security

Demand for sustainable and nutritional food production will continue to increase as the world's population grows through mid-century and rapid economic development stimulates the rise of an ever-growing global middle class (Chicago Council on Global Affairs 2014). However, climate change will produce higher temperatures and temperature extremes, changes in rainfall patterns, more floods and droughts in certain regions, and other more frequent natural disasters in others that, if unaddressed, will reduce the growth in global food production by an estimated 2 % per decade for the rest of this century.

The effects of climate change on crop and food production are already being felt in several regions of the world (IPCC 2014). Negative impacts of climate trends have been more common than positive ones, but positive trends are evident in some high latitude regions.

While food production has doubled in the past 50 years, climate change has the ability to change the environmental conditions that could devastate agriculture. Food systems in developing countries, many of which are located in tropical and low-lying coastal areas, will be hardest hit. These countries also lack the resources to adapt effectively to the multiple challenges climate change poses to food production (see, Food Security Index in Fig. 6). Parts of Africa, Asia, and Latin America have a growing population along with a reduction in resources. These regions will be at a bigger risk of climate change-induced famine. Food insecurity will likely be felt the most in Sub-Saharan Africa. It is estimated that by 2080, of all the people that are at risk of going hungry, 75 % will be from this region (IPCC 2007a, b). However, the middle and higher latitudes

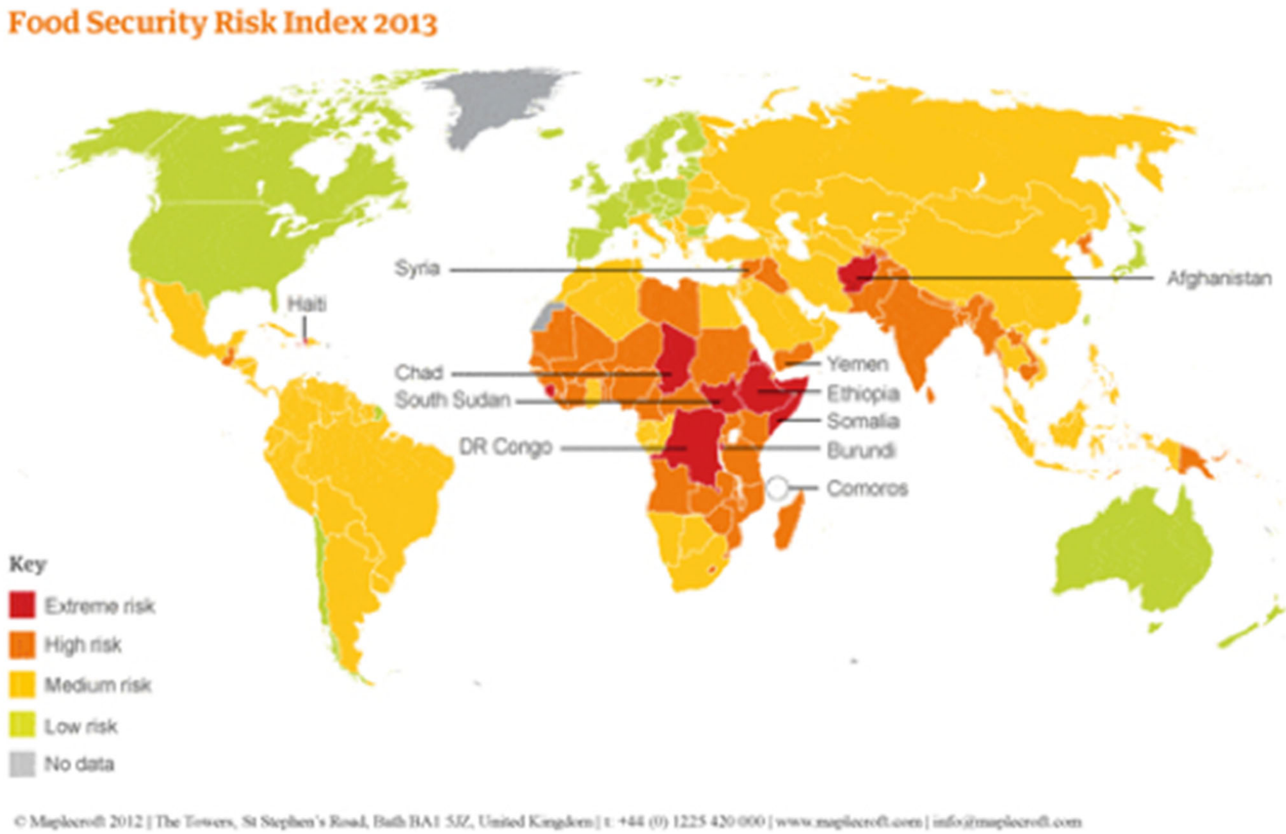

Fig. 6 Food security index for 2013 as developed by Maplecroft (https://maplecroft.com/about/news/Food_Security_Pressrelease.pdf)

may actually see an increase in agricultural production. The overall increase in production in the higher latitudes may offset any shortage in the lower latitudes. Despite that, if the mean global temperature rises by 2–4 °C, there will likely be a worldwide decline in agriculture.

4.4 Migration

Environmentally related migration is the most uncertain of the issues related to global security. However, it could create the most violent and dangerous situations. Uncertainty comes from the many variables in play that could change the outcome of the situation. For example, migration can occur within the country of conflict or it can occur across borders. It can be permanent or temporary. Migration can also be a forced or of free will (NRC 2013). With so many different variables in play, it is hard to get a good grasp of how climate change will actually affect migration and security. According to NRC (2013), the most important type of migration that should be of global concern is disruptive migration. This type of migrations usually occurs with a large movement of people that may cross borders or move internally. They are considered “socially,” “economically,” and “politically” disruptive.

Raleigh et al. (2008) posit that the physical impacts of climate change are just one set of factors that cause migration, and the decision to migrate to another region is manifested through multiple interactions with associated social, political, and economic dimensions that exacerbate an individual’s “vulnerability” in her present location (see Table 2). Coastal flooding as a result of sea level rise, reduced rainfall in agricultural regions, increasing competition over scarce ground water resources, and extreme heat waves will quite likely be among the “push” factors that induce large-scale migration away from such distressed regions to urban areas within countries as well as internationally. In fact, Mueller et al. (2014) use empirical evidence from Pakistan to suggest that unlike flooding induced migration, which receives much attention; heat waves that cause loss in farm and non-farm incomes may be more likely to cause large-scale human migration. Black et al. (2011) argue that migration and human mobility is a form to adapt to the adverse effects of climate change and populations that are unable to do so because of their own economic or social conditions, or restrictive policies that prevent migration will suffer the most. Intranational migration is already quite prevalent in many countries and in Bangladesh coastal floods and riverbank erosion in 2008

Table 2 Effects of timing of climate change on migration

Direct climate changes	Indirect climate changes	Type of movement	Time span
Gradual climate change	Chronic disasters such as drought, degradation	Seasonal labor migration. Temporary circulation	Seasonal
Gradual climate change	Chronic disasters-drought/degradation	Contract labor migration	Yearly
Sudden or gradual climate change	Natural disasters/severe drought/famine/floods	Forced/distress migration	Temporary
Sudden or gradual climate change	Extreme temperatures/sea level rise	Permanent migration	Lifetime

Raleigh et al. (2008) suggest that populations affected by the adverse effects of climate change usually have multiple coping mechanisms and not all of them choose to emigrate permanently because of short-term or gradual manifestations of climate change. Data that could attribute permanent or seasonal migration to climate change is also not conclusive

displaced about a fifth of affected people in these regions to larger cities (Penning-Rowsell 2012). Such dramatic influx of population in larger cities can often increase pressures on local infrastructures and also exacerbate existing tensions between local population and immigrants (Reuveny 2007). Reuveny (2007) maps several previous mass-scale migrations as a result of environmental factors and discovers that in almost all migration cases that led to conflict, “the receiving areas were underdeveloped and depended on the environment for livelihood.”

5 Conclusions

We as humans are dependent and almost inseparable from our physical environment. Dramatic changes in that physical environment as a result of climate change will not go without any comparable changes in our ways of life. Climate change will likely affect global population through multiple direct and indirect linkages that will have huge economic, social, and political implications, which were previously little understood. Climate change will affect world security and stability through various mechanisms including migration, natural disasters, food security, and civil conflict. These tortuous, multi-pronged and demonstrably far-reaching relationships and their socioeconomic impacts are just beginning to be quantified, but it is clear that climate change must be arrested before these damages are impossible to undo.

The extent of future climate change from human activities depends on our choices. Will we reduce our emissions and have a future with less warming and less severe impacts, or will we continue to increase our emissions and have a future with more warming and more severe impacts, including more extreme weather events? The extent of policies for mitigation and adaptation will affect the resulting impacts on humanity and ecosystems. Global security will be greatly affected by those choices.

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