Chapter

Impact of Climate Change on International Health Security: An Intersection of Complexity, Interdependence, and Urgency

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Abstract

Climate change (CC) can be defined as a long-term shift in global, continental, and/or local climate patterns. Although many equate CC to the rise in global temperatures, the issue is much more complicated and involves a large number of interconnected factors. Among some of the less discussed considerations of CC are its effects on a broad range of public health issues, including the emergence of novel infectious diseases, the encroachment of infectious disease vectors into previously unaffected geographic distributions, and crop failures resulting in threats of malnutrition and mass migration. This chapter will be devoted to key issues related to CC in the context of international health security (IHS).

Keywords: climate change, emerging infectious diseases, global warming, hunger, human migrations, invasive species

1. Introduction

Planet Earth is a highly complex and truly unique celestial body, fine-tuned to sustain life within a very narrow range of tolerances [1, 2]. Within this narrow band of environmental parameters, our civilization emerged over the past several thousand years. As we discovered ways in which to harness the energy stored within our planet, from burning wood, to coal, to petroleum products, we began to increasingly change the environment we live in [3, 4]. The resultant slow but persistent climate change (CC) is beginning to manifest itself across multiple domains of human existence, from rising sea levels, to wind disasters and forest fires, to the emergence of new invasive species [5–8]. This chapter will discuss the impact of CC on various domains of human health and well-being, with specific focus on their relationship to international health security (IHS). Given the vastness of this important topic area, our goal will be to provide an overview of the most pressing issues and most relevant subdomains (**Figure 1**). However, it is simply not feasible to cover this entire subject within a single book chapter, thus limiting the current manuscript to a bullet-point synopsis.

Figure 1.
Word cloud demonstrating the most common and dominant themes within this chapter. The highly complex nature of the issue of climate change and its relationship to human health is clearly evident.

2. Methodology

The current study constitutes a systematic review of the literature regarding the impact of climate change on human health and well-being. Relevant sources were identified using an exhaustive search strategy utilizing Google™ Scholar, PubMed, EBSCO, Bioline International, as well as any relevant cross-referenced articles and websites. Specific search terms included "climate change," "global warming," "invasive species," "emerging infectious diseases," "public health," "food security," "sea level change," "quality of life," and "vector-borne diseases." A total of 17,194,311 search results were subsequently narrowed down to 1,247 interdisciplinary full-text, English language articles directly relevant to our discussion. Further screening demonstrated 479 articles that directly address questions related to the interaction between climate change and human health and wellness. Of those, a final list of 266 definitive sources was derived.

3. Environmental pollution: air and water

The effects of air pollution on public health have become increasingly acute, heterogeneous, complex, and unpredictable [9–12]. In recent years, natural disasters such as wildfires and non-natural disasters such as human-made pollution have caused fundamental changes in air quality, leading to special measures and precautions deemed necessary to protect populations from air pollutants [13, 14]. Various effects of air pollution, both in the indoor and outdoor setting, on health include but are not limited to: asthma, chronic obstructive pulmonary disease (COPD), cardiovascular diseases, and an array of pulmonary malignancies [15–18]. Although naturally evolving changes in climate and temperature have some effect on air quality, direct human contribution to air pollution may play and even greater role [19, 20]. For example, humans are thought to be responsible for approximately 95% of all wildfires in California and in Mediterranean Europe [21, 22]. Wildfires diminish air quality by scorching thousands of acres of land – creating arid, dry, desert like soil, and a deterring vegetative and agricultural growth. Wildfires are only one example of many human activities that contribute to poor air quality [7, 23].

The continued growth of industrial activity, both in the United States and globally, has contributed to a sharp increase in air pollution, especially among the urban areas [24, 25]. This was accompanied by the general decline in measured air quality around the globe [26, 27]. Nowadays, air quality indexes are common in daily weather reporting, in addition to weather alerts for air quality standards [28, 29]. Despite the successful deployment of these largely descriptive and informative measures, much remains to be accomplished. For example, asthma amongst newborns and young children has increased sharply in the recent past [30].

Neville Island, PA is an inland island near Pittsburgh, PA where three major rivers meet, with at the apex of the city's heaviest population density [31]. The island houses more than 50 corporate industrial sites, coal processing facilities, and oil company foundries. The pollutants from these companies are ingested and breathed by the nearby population of the Allegheny County. During awareness campaigns in 2003, Neville Island was said to pollute river water with as many as 13 toxic chemicals hazardous to human health, reportedly released each night after the closing of the factories. Notably, the island is located just upstream to the County's major water treatment plant. Consequently, a broad range of pollutants (both airborne and non-airborne) find their way directly into the city water systems. Statistically, the County is among the highest in the nation for still births, childhood asthma, COPD, and pulmonary malignancy [31–33].

Historically, governmental regulations pertaining to air pollution tended to represent a more reactive (versus proactive) approach [34–36]. This is not universal, however. For example, the State of California has instituted aggressive standards for vehicle emission regulations. As a result, over a 20-year period there was a 65% decrease in reactive organic gases, and a 54% decrease in oxides of nitrogen [37]. Of importance, these positive changes occurred despite a 22% growth in population and a 38% increase in overall motor vehicle usage throughout the state [23]. There was an associated sharp and well-defined decrease in air pollution related breathing disorders among children. This included favorable changes in terms of asthma and bronchitis, with significant (21%-39%) reductions. With strict and appropriately enforced regulatory standards, a significant decline in adverse consequences of air pollution can clearly be achieved [23].

Still, environmental regulations are still poorly defined and/or neglected in many areas globally. Under such circumstances, countries like China experience a significant number of adverse health effects of air pollution, to the point of the issue becoming one of the most serious national public health threats [38]. Coal-burning power generation is among the leading culprits of air pollution in China [39]. The magnitude of coal-related pollution in China can be appreciated from recent data showing that in 2010, there were more than 10 million tons of fine particles (e.g., diameter under 2.5 μm) released in the Beijing-Tianjin-Hebei region alone [40]. The impact of such massive air pollution on human health and health security (locally, regionally, nationally, and internationally) is truly difficult to grasp. Even more importantly, it has been estimated that the pollution from the approximately 200 coal-fired power plants in the capital region of Beijing-Tianjin-Hebei may be associated with nearly 10,000 premature deaths and approximately 70,000 outpatient visits or hospitalizations during a single calendar year [40–42]. Despite the need for urgent reform at the global level, governments have been slow to act, including the recent unilateral (and hopefully temporary) withdrawal of the United States from the Paris Climate Pact [43].

4. Climate change: increase in allergens

One effect of global warming is an increase in allergens. Allergens can be associated with various respiratory diseases such as Asthma or allergic reactions such as hay fever. An increase in hay fever can be attributable to global temperature increases due to synergistic effects of atmospheric warming on the pollination season of plants [44]. The observed rise in the number of airborne allergens is directly proportional to the increase in pollen content of the air [45]. From human health perspective, it can be expected that allergic reactions, as well as their severity, may worsen over time. This may be further exacerbated by the declining air quality, both indoors and outdoors [46, 47].

The decrease in air quality is compounded by other factors such as smoking, diesel fuel utilization, and the generation of nitrogen dioxide [48–50]. Temperature fluctuations also lead to mold formation and propagation [51]. This can further decrease air quality and can cause intense allergic response in some people [52, 53]. Some other common allergies include ragweed allergy causing hay fever and poison ivy causing contact dermatitis. **Table 1** lists a set of common allergens. When an allergen enters the body, its presence leads to an immune response featuring the sensitization of mast cells [54, 55]. When the allergen enters the body repeatedly, it attaches to the specific antibodies on mast cells resulting in mast cell degranulation, which leads to the release of histamine and other inflammatory mediators [56, 57]. Associated symptoms may include commonly encountered reactions such as watery eyes, itching, sneezing, and nasal/sinus congestion. Pertinent to CC and global warming, it has been noted that patterns and distribution of common allergens typically present in different parts of the globe are changing [58]. The awareness and the ability to identify these patterns, coupled with modern mobile technology advances and point-of-care testing, will allow health-care providers to adequately prepare for the evolution and changing incidence of allergic reactions, especially in the context of preventive health measures and effective clinical management approaches [59–61].

5. Vector borne diseases and climate change

Another important aspect of the ongoing CC, and a source of indirect evidence for global warming, is the gradual evolution in disease vector distribution [8, 62]. An 'infectious vector' can be defined as any agent which carries and transmits an infectious pathogen into another living organism [63]. Many vector-borne diseases are characterized by a significant component of seasonality, and changing geographic distributions of vectors may significantly alter such seasonality [64, 65]. For example, higher rates of tick-borne diseases are seen during the spring to fall seasons in

Type of Allergen	Common Reaction to Allergen
Pollen	Seasonal allergies
Spores	Seasonal allergies, fungal infections
Dust mites	Asthma
Animal dander	Allergies
Drugs and insect venoms	Anaphylactic reaction

Table 1.
List of allergens and common reactions to those allergens.

eastern North America [66, 67]. With gradual temperature changes throughout the globe, we are more likely to see a change in the patterns of incidence of tick-borne illnesses [66, 67]. Moreover, novel tick-borne diseases have been on the rise, such as those carried by the Asian long-horned tick which has been found in the western hemisphere only in the past decade [66, 68]. Increased globalization and changes in environment due to global warming have been thought to increase the amount of tick-borne infections.

Some of the most common disease vectors are ticks and mosquitos. A summary of areas of prevalence and seasonality of tick- and mosquito-borne diseases are listed in **Tables 2** and **3**. When they reach sufficient magnitude, changes in environmental conditions are likely to disrupt the life cycle of various disease vectors and potentially alter the transmission of the diseases in question, including their geographic and seasonal distribution [66, 113].

Tick-Borne Illness	Areas of Prevalence	Predominant Months
Anaplasmosis [69]	USA: NY, MN, CT, RI, MD	May-October
Babesiosis [70]	USA: NY, NJ, MN, CT, MA, RI, WI	June-August
Colorado Tick Fever [71]	USA: WY, MT, UT, OR, CO, ID	May-July
Crimean-Congo [72, 73]	52 countries throughout Africa, Asia, Eastern Europe, and the Middle East	Spring-Summer
Ehrlichiosis [69]	USA: MO, OK, TN, AR, MD	May-September
Heartland Virus [74, 75]	USA: KS, OK, AR, MO, TN, KY, IN, GA, SC	May-September
Omsk Hemorrhagic Fever [76]	Western Siberia	May-June, August-September
Powassan Disease [77]	USA: MA, MN, NY, WI, NH, NJ, ME, ND, PA, TN, VT, VA, CT Canada: NB, QC, ON, NS, PE, AB, BC Russia: Primorsky Krai	May-November
Kyasanur Forest Disease [78]	India: Karnataka state and surrounding areas in the Western Ghats	January-May
Rocky Mountain Spotted Fever [79, 80]	USA: Contiguous states, >60% cases from NC, OK, AR, TN, and MO Canada, Mexico, Brazil, Columbia, Costa Rica, and Panama	April-September
Other Spotted Fevers [81–84]:		
African Tick-bite fever [81]	Sub-Saharan Africa and West Indies	November-April
Mediterranean spotted fever [82]	Africa, India, southern Europe, Middle East, Mediterranean	July-September
North Asian tick-borne rickettsiosis [83]	Armenia, central Asia, Siberia, Mongolia, China	April-May
Queensland tick Typhus [84]	Australia	June-November
Tularemia [85, 86]	North America, central Asia, Russia, the Nordic countries, the Balkans, and Japan USA: All states except HI, 50% of cases from AR, OK, and MO	April-October

Table 2.
Tick-Borne illnesses categorized by geographic distribution and yearly time range, focusing on the correlates of the highest prevalence of disease. United States and Canada jurisdictions are denoted using accepted two letter postal abbreviations.

Mosquito-Borne Illness	Areas of Prevalence	Predominant Months
Plasmodium Malariae [87, 88]	Africa and South Asia, Central and South America, the Caribbean, Southeast Asia, the Middle East, and Oceania	September-December
Dengue Virus [89, 90]	Americas, Eastern Mediterranean, South East Asia, and Western Pacific	March-August
Yellow Fever [91, 92]	47 countries throughout Africa (34) and Central and South America (13)	Africa: July-October South America: January-May
West Nile Virus [93–95]	Canada, USA-48 contiguous states, Europe, Africa, Middle East, Asia, India, Australia, Central America, Caribbean, South America	Northern Areas: July-October Southern Areas: Early months of the year
Zika Virus [8, 96, 97]	Africa, South East Asia, Oceania, Pacific Islands, South America, Central America, Caribbean, USA	Sporadic outbreaks Yap State: May 2007-June 2007 Pacific Islands: Late 2013-Early 2014 Americas 2015-2016: January 2016-July 2016
Bancroftian Filariasis [98]	72 countries throughout South East Asia, Sub-Saharan Africa, islands of Pacific, and selected areas in Latin America	Spring-Summer
Jamestown Canyon Virus [99, 100]	Canada: NL, QC, ON, MB, SK, NT USA: CT(1), LA(1), ME(2), MA(7), MI(1), MS(1), MT(1), NH(3), NJ(1), NY(4), NC(1), OH(2), OR(1), RI(1), TN(2), >50% MN(26) and WI(66)	April-September
Rift Valley Fever [101, 102]	Continental Africa, Yemen, Saudi Arabia, Madagascar, Comoros Islands, Mayotte	Outbreaks occur after heavy, prolonged rainfall
Chikungunya Virus [103, 104]	Africa, Asia, Indian Subcontinent	Northern Hemisphere: June–September Southern Hemisphere: October-March
Eastern Equine Encephalitis Virus [105, 106]	USA: AL (1), AR (1), CT (1), FL (13), GA (6), LA (2), ME (2), MD (1), MA (10), MI (7), MO (1), MT (1), NH (3), NJ (1), NY (8), NC (7), PA (1), RI (1), VT (2), VA (1), and WI (2)	April-October
Japanese Encephalitis Virus [107–109]	China, Japan, North Korea, South Korea, Australia, India, Pakistan, Russia, Singapore, Cambodia, Indonesia, Laos, Myanmar, India, Nepal, Malaysia, Philippines, Sri Lanka, Thailand, and Vietnam.	May-October
La Crosse Encephalitis Virus [110–112]	Upper Midwestern, mid-Atlantic, and Southeastern states	April-October

Table 3.
Mosquito-Borne illnesses organized by geographic area and seasonal time range characterized by the highest prevalence of disease. United States and Canada jurisdictions are denoted using accepted two letter postal abbreviations.

Countries around the globe are actively working on prevention measures intended to curb incidence levels of various vector borne diseases [114, 115]. Examples of preventative methods include application of insecticide spray, installing insecticide screens, improving sanitation methods, genetic modification

Infection	Source of contaminant
Escherichia coli 0157:H7	Undercooked beef
Giardiasis	Contaminated water
Cryptosporidiosis	Contaminated water
Campylobacteriosis	Undercooked poultry
Cyclosporiasis	Contaminated water or food
Listeriosis	Unpasteurized dairy products and deli meat
Salmonellosis	Undercooked poultry
Shigellosis	Contaminated water
Campylobacter	Undercooked poultry & other meats, contaminated water.
toxoplasmosis	Undercooked pork, lamb, shellfish, and venison.
Vibrio cholerae	Brackish and marine waters, or undercooked shellfish.

Table 4.
Common food and water borne illnesses and their source of contamination.

of vectors, as well as vector control through prophylactic treatment for travelers. Many countries are also intensifying awareness and education campaigns focusing on vector borne illness to help maintain prevention methods [114–117].

6. Food and water borne diseases

Global CC exerts impact on rainfall, humidity, length of growing season, and other environmental factors that are vital to the development of certain crops [118, 119]. Shifting environmental factors, along with the emergence of biofuels, are pushing food producers to implement various techniques that increase the yield of the crops [120]. One such method involves treating crops with antibiotics. However, unintended consequences of longer growing seasons and higher crop yields have resulted in greater frequency and intensity of food- and water-borne illness (**Table 4**) [121, 122]. Another way of coping with CC in terms of international food security is the introduction of insect-based, microbial/fungal-based, and laboratory-based food substitutes [123–129].

Of note, salmonella and campylobacter infections tend to be more common when the climate is warmer [130]. Relevant to human consumption, these bacteria have been shown to have higher growth rates at warmer temperatures during food preparation and storage [131], which in turn corroborates one possible relationship between CC and emerging human disease patterns.

The effect of CC on water borne diseases is equally important, yet it appears to be disproportionately neglected [132]. It is well known that precipitation can influence the transport and dissemination of infections, especially as it relates to existing water and sanitation systems [133]. More direct impact of the above can be seen during the increasingly more frequent coastal flooding as it relates to sea-level rise. Due to various factors, including human activity, water contamination exposes local populations to a variety of potential fecal-oral pathogens [134]. Indirect factors affecting the overall risk of water-borne infection propagation include changes in temperature and humidity, leading to alterations in pathogen lifecycle and survival, up to and including the creation of environments where new patterns of geographic disease spread emerge [135]. The effects of CC on water borne diseases, both indirect and direct, can be profound and unpredictable, mandating that dedicated scientific research efforts in this critically important area are increased.

7. Food security

Because agriculture relies heavily on the presence of favorable environmental parameters, any uncertainty related to agricultural conditions places food security into a state of flux and thus creates a potential threat to food sustainability and security for humans [136, 137]. Threats to food security are vast, diverse, and have increased sharply during the past three decades. Issues affecting food security involve agricultural, industrial, and climate-related components (e.g., from natural disasters to heavy pollution) [138, 139]. Protein-based food products from animal derived sources may contain significant antibiotic residue because antibiotics are increasingly utilized to maintain product viability and longevity during transport and distribution [140, 141]. Downstream effects of using antimicrobials in animal feed include various patterns of antibiotic resistance seen in both animals and humans who ingest animal-based food products [121, 142, 143]. Consequently, we are increasingly seeing emerging antibiotic resistance patterns that render many of our available therapeutics ineffective, leading to excess mortality [144–146]. Moreover, antibiotics have also leaked into water and food chains, creating complex and challenging matrices for the detection of their source of origin, which is vital to effective disease control [147, 148]. The importance of this complex phenomenon, in addition to introducing excess risk into the food chain and endangering the overall food security, is the potential for synergistic interactions between CC, emerging novel pathogens, and often unpredictable patterns of antimicrobial resistance [149–151]. As such, the confluence of the above factors is projected to result in significant food shortages, on *per capita* basis, by the year 2050. The attributable mortality may exceed 500,000 deaths around the globe [152]. Increased focus on ensuring food availability will be a crucial component of IHS in the future, and will be inextricably tied with the ongoing CC [7, 14]. Among promising sustainable growth strategies in this important area is the introduction and increasing implementation of the vertical farm concept [153]. Last, but not least, the gradual acidification of the oceans is beginning to affect the overall aquaculture and food chain sustainability, especially across the densely populated coastal areas that heavily rely on fish and other forms of seafood for ongoing food security [154–156]. Associated phenomena include harmful algal blooms which further damage aquatic ecosystems [157].

8. Flooding and flood-related events

Over the past several decades, floods have become a growing problem throughout the world [158, 159]. This has been especially problematic among low-lying areas of the planet, including large river deltas [160–164], and thought to be associated with rising sea levels [165–167]. It has been estimated that roughly 40-50% of environmental disasters are due to floods, and there is also a significant correlation between flooding and wind disasters [165–168]. From IHS perspective, floods may lead to drinking water contamination and associated increases in water borne and diarrheal diseases [169, 170]. It is therefore vital that we understand how to address and prevent deleterious public health consequences associated with flooding, inclusive of additional focus on a plethora of downstream effects of flooding on human populations [171–174].

In addition to immediate loss of life and property, there is a noticeable increase in diarrheal diseases, and studies suggest that there may also be an increased risk of all-cause mortality during the year following a flooding event [175, 176].

This troubling trend can be further exacerbated when flooding occurs in the presence of human overcrowding [176]. Of importance in this particular context, when planning and preparing for natural disasters it is important to understand the ecosystem of communicable diseases within the region and understand the vectors that may come into play. Effective management of flooding and subsequent post-event recovery requires proper sanitation, clean water supply at shelters/temporary housing for displaced individuals, as well as adequate control of disease vectors (e.g., rodents, mosquitoes) [177, 178]. Consequently, preventing contamination of standing water with mosquitoes should be priority during a flooding event [179, 180]. Governments planning for natural calamities, including floods and wind disasters, should ensure that appropriate supplies of clean water and food are readily available to large number of individuals. At the same time, it is also important to educate individuals on the importance of proper food and water preparation, through boiling, during any natural disaster that may potentially affect water supply [181–184].

9. Wildfires

Rising global temperature affects public health in urban and rural communities across the world [185]. In recent years urban heat waves have become more severe, which has corresponded with an increase in heat-attributable deaths during times of extreme summer temperatures [186]. In rural communities, phenomena such as dust storms and crop failures, along with invasive insect infestations and invasions, have increasingly appeared [187–193]. To make things worse, CC also creates an environment more prone to wildfires, which are affecting rural communities with increased frequency, and are progressively more common near more densely populated areas [7, 14, 194]. Human consequences of all of the above factors, especially when acting synergistically, will be both profound and difficult to calculate [7, 14]. As average global temperatures continue to rise it is imperative to quantify the burden that the health systems will face due to more severe heatwaves and wildfires [195].

Heatwaves are often defined as 2 or more consecutive days with temperatures above the 95th percentile for the summer [196, 197]. Relative risk of mortality increases during heatwaves in urban centers, particularly among elderly patients and patients with pre-existing cardiorespiratory conditions [198, 199]. This was demonstrated during an August 2003 heatwave in Europe, when heatwave-attributable mortality reached 14,800, the risk of out-of-hospital cardiac arrests increased by 14%, and hospitalizations significantly increased among asthma patients [200, 201]. Patients with pre-existing cardiorespiratory conditions were most at-risk for heat-related mortality [200, 201]. It is important to consider cardiovascular and respiratory conditions because they are among the most common pre-existing conditions within a progressively aging general population [202–205]. The specific physiologic processes causing increased mortality in patients with existing cardiovascular conditions during heatwaves are still poorly understood. However, it can be postulated that longer and more severe heatwaves place more strain on the cardiovascular system to maintain physiologic body temperatures via thermoregulation. Additionally, high temperatures are associated with elevated heart rate, increased blood viscosity from dehydration, and higher blood cholesterol levels. These factors together with sub-optimal electrolyte balance and reduced cerebral perfusion place higher demands on the cardiovascular system, which could exacerbate symptoms in vulnerable patients [206, 207].

Respiratory conditions on the other hand could be worsened because of lengthening frost-free periods and increasing levels of dusts and other pollutants in the urban atmosphere [208, 209]. This can be further exacerbated by the simultaneous presence of wildfires (e.g., California or Colorado, Summer 2020) [7, 14, 210, 211]. Evidence suggests that as carbon dioxide levels increase, ragweed (which is ubiquitous in urban communities) flowers earlier and produces 30-90% more pollen [212, 213]. By association, allergic sensitivity may lead to exacerbations of respiratory illness like asthma, but the phenomenon may have other synergistic components that are also directly or indirectly tied to CC [214].

Traditionally, rural communities have offered a relative escape from the smog and heat trapping environment of the city [215]. However, rising global temperatures are diminishing the air quality of rural communities by creating a dry landscape that is prone to wildfires and dust storms [216–218]. More specifically, particulate matter smaller than 2.5 um (PM2.5), carbon monoxide, nitrogen oxide, ozone precursors, and other harmful substances are released from wildfires, with various other components present within the cloud of a typical dust storm [154, 219, 220]. Of note, PM2.5 exposure during wildfires has been associated with increases in emergency department and hospital visits related to respiratory illnesses [221], with asthma exacerbations and wheezing in patients 65 and older having the greatest morbidity impact [222]. Evidence of cardiovascular and non-cardiopulmonary morbidity from particulate matter exposure is less consistent, with clear need for further research to better characterize any potential underlying associations [7].

10. Wind disasters

The number and severity of wind disasters appears to be increasing over the past two decades [168, 223, 224]. This connection between CC and increasing number and intensity of major hurricanes and other similar weather events is not fully understood [225], but more recent evidence does support a more causative effect [226, 227]. The current 2020 hurricane season in the United States is among the worst on historical record [228]. Its logistical impact is further compounded by the co-presence of the Novel Coronavirus pandemic [228]. Similar to flood disasters (which may also occur simultaneously), wind disasters and their aftermath may also have significant impact on life within the affected regions [229]. The impact of wind disasters on humans goes far beyond direct physical damage and bodily injuries [230]. Forced human migrations and post-traumatic stress add a massive component of complexity to the overall post-disaster recovery process [231–233]. Moreover, there seems to be an association between post-traumatic stress following wind disasters and the emergence of cardiovascular and other comorbid disease manifestations (or exacerbations) [231, 234]. Such longer-term manifestation appear to be more pronounced among members of underrepresented minorities, further highlighting issues of social and health-care inequity [231, 235, 236].

11. Climate change: effects on mental health and societal crises

Public health is influenced by a diverse collection of factors, many discussed in earlier sections of this chapter. One of the most under-appreciated factors is the effect of CC on mental health, both directly and indirectly, at both personal and societal levels [237, 238]. One of many subtle manifestations of societal distress is the proposed link between global warming, crop failures, and armed conflict [239, 240].

As a result, we begin to see greater incidence of mass migrations and refugee crises [241, 242]. An associated surge in mental disorders and stress related diseases is inextricably tied to such occurrences [243, 244]. Given the intersectionality of stress related disorders and their effect on the mental health of populations, it is not surprising that many are being pushed to their coping limits when faced with food insecurity, environmental pollution, increasing frequency of natural disasters, crops failures, and economic and political instability [245]. Moreover, long-term effects of such new global status quo are equally difficult to predict [246].

Large scale human migrations due to natural disasters, conflict, famine, or political and economic instability, have been associated with mental health and stress related illnesses across the globe [247–249]. All population segments are affected, from rich to poor, from urban to rural, from young to old, without exception [250–252]. Exposures to potentially traumatic events, regardless of the exact nature of the event, are known to cause an increased risk for mental disorders including post-traumatic stress disorder (PTSD) [253–255]. Associated down-stream consequences may include increased incidence of depression and increased suicide rates [256].

Significant proportion of the world's population does not have sufficient access to mental health support, including both high income regions (HIRs) and low-and-middle-income regions (LMIRs) [257–260]. Individuals from regions affected by CC (and secondary phenomena related to CC) may find themselves experiencing a myriad of stressors affecting mental health and resulting in various stress related diseases (including substance abuse) [245]. At the personal level, a number of different approaches can be used to effectively manage behavioral health symptoms, including cognitive behavioral therapies, medical-based treatments, as well as short- and long-term coping management therapies, with generally positive outcomes [261, 262]. At the societal level, public health education regarding mental health and wellness is of great importance [263–265]. Of course, governments and societies must continue to curb and address situations that contribute to ongoing stress and mental health related disorders. This focus in particular is critical to stabilizing populations affected most by CC and related crises [266].

12. Conclusion

Global climate change creates a multifactorial, highly complex matrix of direct and indirect effects that have the potential to threaten international health security. The many domains that synergistically affect human health in the context of CC include environmental pollution, the emergence of invasive species and novel pathogens, food security, wildfires, and a broad range of destructive weather events. Of course, the complete list is much more extensive, and beyond the scope of the current chapter. In summary, the global community must come together to more effectively and more systematically address issues associated with the ongoing CC and its many direct and indirect effects. To pretend that CC "does not exist" will be, simply said, too costly.

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