Title

Climate Change: The Public Health Aspect of Extreme Weather Events in Europe

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Abstract

Climate change is the biggest global health threat of the 21st century. With the anthropogenic activities increasing the greenhouse emissions since the industrial evolution, the climate change impacts are now more than ever evident. Among them, extreme weather events seem to increase in frequency and intensity which is a threat for human health, ecosystems, society, and economy. More specifically, Europe is experiencing extreme weather events that affect the continent as a whole. For example, the 2003 heat event has caused the life of 40,000 people. Since we are aware of the dramatic effects of such events, adaptation and mitigation strategies should be implemented on a regional, national, and continental level especially due to the fact that future projection predict that the worse climate change impacts have yet been observed.

Contents

Introduction

Climate change is the biggest global health threat of the 21st century [1]. Climate change refers to any significant change in the measures of temperature, precipitation, or snowfall patterns, among other effects, lasting for an extended period of time. Consequently, climate change affects the Earth's weather, oceans, snow, ice and ecosystem, with the society experiencing the holistic impact. The causes of climate changes until recently have been of natural origins such as the sun's energy changes and ocean currents' shifts. However, since the industrial revolution, anthropogenic activities came into play, with carbon dioxide (CO_2) and other greenhouse gases (GHGs) emissions contributing the most to climate change. Such activities include fossil fuels combustion for heat and energy, clearing forests, fertilizing crops, storing waste in landfills, and raising livestock among others. Along the line, changing the Earth's surface and coverage through agriculture and construction has an impact on the Earth's surface reflectivity that subsequently impacts the local temperature of an area. Finally, aerosols emissions such as black soot and SO_2 that are associated with absorption and reflection of solar radiation, respectively, can also result changes on climate [2].

Climate change has impacts on different components of life such as the environment and natural resources that influence society and more specifically human health either directly or indirectly. The impacts of climate change in the environment can be found in the air, water, weather, oceans, and ecosystem [3]. In particular, the impacts of climate changes have already been and are expected to be observed in the future with the scale of impacts in both regional and global level. The list of these impacts includes: global warming, rising of sea levels, patterns changes in rainfall, timing and amount of stream flow, and increases in the frequency and

intensity of extreme weather events (heat waves, droughts, floods, tropical cyclones, tornadoes, etc.) [2].

The purpose of this paper is to assess the public health impact of extreme weather events in response to climate change, focusing on the European region. This is a review of published articles providing a brief description of the current and future projections of extreme weather events in the area and a summary of the resulted public health impacts.

Extreme Weather Events and Public Health Impacts

According to the Intergovernmental Panel on Climate Change (IPCC), an extreme weather event is defined as an event that is rare (rarer than the 10^{th} or 90^{th} percentile) within its statistical historical reference distribution at a particular place [4]. In other words, extreme weather events can be seen as unusual, severe or unseasonal weather events not observed in the past. The duration of these events ranges from less than a day to 6-10 days [5]. Although these events are rare by definition and may have natural causes, evidence from observations gathered since 1950 illustrate that extreme weather events are in agreement with climate change scenarios as a result of anthropogenic activities associated with GHGs emissions [6]. It is worth mentioning that the evidence supporting this association varies by event. The strongest association is to be found in heat waves followed by coastal flooding. There are also strong evidence regarding extreme participation events and severe droughts. On the other hand, regarding tornadoes and hurricanes the association is not clear since there is limited evidence to support it [4].

Extreme weather events can have a variety of impacts such as environmental, social, economic, and public health that can be influenced both directly and indirectly. The direct health effects concern the widespread of infectious diseases (person-to-person, vector-borne, water-borne, etc.), heat-related mortality and morbidity, and disaster-posed injuries and deaths. The indirect health effects include: alterations in the range and activity of vector-borne infectious diseases, alterations in the environment of water-borne diseases and pathogens, malnutrition through impacts in agricultural and food security, and lack of fresh water [7]. However, it is important to mention that these effects illustrate great variability by region as a result of the frequency, severity, and duration of the extreme event as well as health-related factors such as the general characteristic of the communities that the region is consisted of such as age, gender, health-status, and socio-economic status. Along the line, the readiness and effectiveness of a community's public health and safety systems to address or prepare for the risk are also important. Finally, variation is also expected according to sub-population biological susceptibility, extend and duration of events, and ability to adapt to these events [2, 3].

The case of Europe

Europe is one of the world's seven continents. Covering about 10 million km^2, Europe covers 2% of the Earth's surface. It is consistent of approximately 50 countries with a total population of 733 million (11% of the world's population). It is watered by the Arctic Ocean to the north, the Atlantic Ocean to the west, the Mediterranean Sea to the south, and the Black Sea and connected waterways to the southeast [8].

Europe has been suffering from extreme weather events over the years [6]. Although common patterns appear to be emerging, there is great variability within the continent in both type and characteristics of these events such as severity, duration, and frequency [5]. According to the European Severe Weather Database (ESWD), 42078 severe weather events have been reported in Europe since 2000. Overall, increase in minimum temperature has been observed in the continent as a whole. In particular, the European atmospheric temperature has increased by almost 1°C over the last century with the warmest years in the regional history reported the last 15 years. In addition, precipitation studies illustrate increases in total precipitation in the majority of the European territory [6]. The extreme weather events in Europe and their impacts are illustrated by region in Figure 1.

Heat Waves

Heat waves have yet been universally defined. However, these extreme weather events are associated with high temperatures known to produce notable impacts on human mortality, regional economy, and ecosystems [9]. Hence, there are three important features of heat waves: temperature threshold (95^{th} percentile of local probability historical density function), spatial extension, and temporal extension (at least 4 consecutive days). The physical mechanism of heat wave formation is persistent anticyclonic pattern over high temperature area. In addition, monsoon and anomalous sea surface temperature reduce precipitation and cloud formation [10]. In Europe, there is a north-south gradient regarding heat waves, with more severe events in the Mediterranean region and less severe in the northern Europe, with approximately 4°C difference. However, it is expected that areas that are currently unaffected will come into play such as France, Germany, and the Balkans [9].

The impacts of heat waves mainly concern human health and more specifically heat-related morbidity and mortality. Morbidity includes heat exhaustion, heat cramps, heat stroke, dehydration, hyperthermia, neurological conditions, renal disease, and mental illness [11, 3]. Heat-related mortality is associated with respiratory and cardiovascular diseases, with 1-4% mortality increase for each degree of temperature raise [12]. Although health impacts may affect the entire population, there are sub-populations that are more susceptible including the elderly, children, pregnant women, people with pre-existing chronic diseases, and people that live alone or that are isolated [12, 11, 3]. In addition, populations in regions where heat waves are not a usual phenomenon are more vulnerable in terms of lack of behavioral adaptation and inappropriate housing [11]. Important to realize, other factors also affect the relationship between heat waves and health impact. For example, air pollution, demographic structure, cultural patterns, housing equipment, socioeconomic status, public health services, and readiness to adapt and mitigate to such events can determine the severity and extent of the impact [12]. Finally, it is worth mentioning that heat waves also affect vegetation by reducing productivity, increase air pollution, increase the risk of wildfires, affect agricultural activities and stress water availability, restrict electricity due to increased demand, and most importantly increase significantly economic burden on communities [10].

The 2003 Heat Wave Event

Two distinct heat wave events year recorded in 2003, the 1st in June and the 2nd during the first half of August with the latter referred to as European Heat Wave 2003 (EHW03). During these events, there were significant regional variations with the Mediterranean, southern Adriatic,

and much of the northwestern part of the European continent experiencing higher temperatures [13].

Focusing on the EHW03, France, Germany, Switzerland, Portugal, and the UK experienced record-breaking maximum temperatures while approximately 40,000 extra deaths were attributed to this event. France experienced the greatest increase in mortality (60% compared to mean values in the 1999–2002 for the same period). The most affected were the elderly and women, with impacts in the entire population. Although, excess mortality varied by region and was associated with the duration of the heat wave, there was somewhat of a homogeneity in patterns across Europe. In addition to the health impact of this event, ecological, societal, economic, and environmental impacts were also observed. The environmental and ecological impacts concerned forest fires, increased air and water pollution, loss of livestock, wilted crops, and loss of forest cover and wildlife. Moreover, significant crops and Alpine Glaciers losses, threats to water and energy supply systems were observed. It is estimate that the total economic impact of this event is in the order of 13 billion Euros. Finally, due to the impacts in agriculture and livestock, trade and consequently economy were at risk during this event, with subsequent effects in society [13].

Extreme Precipitation Events and Coastal Flooding

An extreme precipitation event is defined as daily rainfall exceeds a certain percent of its seasonal or annual mean [14]. In most cases the 90^{th}, 95^{th}, and 99^{th} percentiles are used. The physical mechanism of extreme precipitation formation lies in global warming. Since atmosphere is warmer, it has the ability to withhold more water vapors while at the same time water bodies worldwide increase their surface due to increase in sea level resulting more water

evaporation. Consequently, there is higher energy potential in precipitation events, enhancing their intensity and frequency [15]. Equally important are the resulted flooding events that are caused by overflowing of rivers and lakes as well as accumulation of rainwater on saturates ground in an areal flood.

There is great variability in annual precipitation in Europe, yet the north-south gradient stands. In particular, northern Europe has been experiencing 10-40% annual precipitation increases over the last century whereas in southern Europe precipitation has decreased by 20% [6]. However, the overall change in precipitation in Europe is a 2% annual increase [15]. At the same time, a seasonality pattern is also observed in the whole area with a strong increase (20%) during the winter, excluding the south, and a decrease (11%) during the summer, excluding the northeast. Furthermore, there is a clear reduction in the number of wet days in the south while the same is not observed in the north where the number of wet days is increased. However, increase in average precipitation intensity is observed in both north and south Europe. As a result, Europe experiences weather events in which precipitation is less frequent but very intense [15].

Extreme precipitation and flooding events have direct effects on human health including death from drowning, injuries, increased water-borne diseases from pathogens, and increased food-borne disease [14]. Nevertheless, increased exposure to toxic chemicals and heavy metals may result from extreme precipitation events posing a direct threat to human and marine animal life as well as increase soil, crop, and water bodies' contamination [3]. Point often overlooked is the fact that these events may allow the explanation of infectious disease (vector-, food-, and

water-borne) into new geographic region and thereby affect new populations [16]. At the same time, humans are affected due to coastal erosion and flooding events that cause population displacement which is both a societal and economic impact. Moreover, the sewage and water supply systems may also be threatened in such events [3]. Although the entire population may be affected, sub-groups such as the elderly, children, and residents in low-lying areas are more susceptible, with socioeconomic status influencing the impact [14]. Finally, agricultural productivity, livestock, and infrastructure are threatened during these events [3].

The 2000 flooding event in the UK

During autumn 2000, the UK suffered from severe flooding events with this period recorded as the wettest since the 1700s. Extreme precipitation events throughout this period were the result of storm combination that is some cases lasts over 14 weeks starting mid-September [16]. In fact, 24 out of 27 UK Met Office regions reported receiving higher than normal precipitation with an average of 503 mm of rain from September–November [17]. Consequently, a range of increased river flows and groundwater levels causing flooding in different parts of the country. Regional variation in effects was observed with Kent and Sussex experiencing the worst effects during October and Shropshire, Worcestershire and Yorkshire during November. The impacts of this extreme weather event were mainly ecological, social and economic. More specifically, 10,000 homes were flooded in 700 locations forcing temporal population displacement [17]. In addition, transportation and agriculture were also affected. Finally, significant erosion and other geomorphological impacts such as landslides were observed [16]. The total economic burden was estimated at £1 billion [17].

Future Projections

Climate projection involves energy production scenarios in terms of GSGs emission. Taking into account the carbon cycle climate effect such as changes in temperature and precipitation are estimated. Consequently, future projections for Europe regarding the time period 2071-2100 suggest widespread higher median temperatures with increases of 4–8°C compared to the interval 1961–1990. In addition heat waves are expected to increase in frequency and duration across most of Europe, along with prolonged dry periods. Changes are also expected in precipitation amount and spatial distribution, with this projection being more uncertain compare to temperature. Nonetheless, it is expected that winter precipitation will increase while summer precipitation will decrease. However, in some parts of Europe more intense summer precipitation events are expected [5]

Adaptation and Mitigation Measures

In order to cope with the climate change and extreme weather event impacts, communities and governments have turned to mitigation and adaptation measures. Mitigation measures concern actions to reduce GHGs emissions and interfere with the carbon cycle as an attempt to reduce the extent of global climate change. These measures include changes in land use, transport, energy production, and buildings. On the other hand, adaptation refers to actions to reduce the impact of climate change that cannot be prevented through mitigation. Thereby, flood controls, transportation infrastructure, coastal development, urban planning concerning zoning and planning to avoid building in at-risk areas, heat warning systems, better access to medical care, reinforcing the built environment against hazardous weather events, and evacuation planning

are some of the adaptation strategies. Both mitigation and adaptation measures can significantly reduce the impacts of climate change and extreme weather events [3].

Conclusion

Climate change and subsequently extreme weather events have significant impacts in human health, the environment, society and the economy. Especially in the case of Europe, the public health impacts of extreme weather events are evident. Heat waves, extreme precipitation and flooding events have already affected many locations in Europe spreading death and causing damages of billion Euros. Given the future climate projections in the area that predict frequent and intense weather events by the end of this century, communities and governments have turned to adaptation and mitigation measures that address and minimize the effects of such events. Readiness and preparation for such events could significantly decrease their impacts.

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Figures

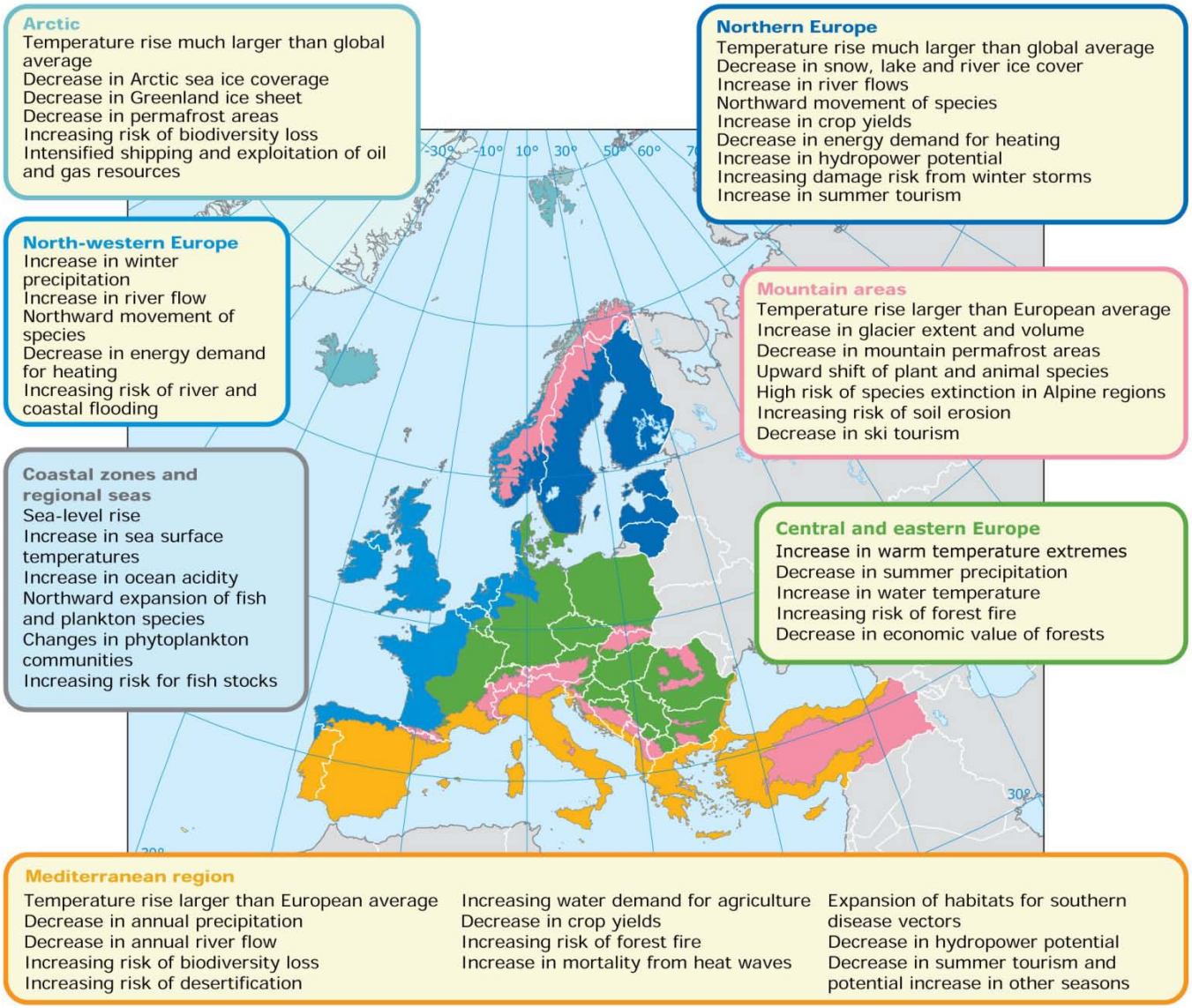

Figure 1. Summary of the extreme weather events and their impacts by region in Europe.