Environment International 86 (2016) 14–23

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Review article

Impact of climate change on human infectious diseases: Empirical evidence and human adaptation

Xiaoxu Wu [a], Yongmei Lu [b,*], Sen Zhou [c], Lifan Chen [a], Bing Xu [a,c,d,*]

[a] State Key Laboratory of Remote Sensing Science, College of Global Change and Earth System Science, Beijing Normal University, Beijing 100875, China
[b] Department of Geography, Texas State University, San Marcos, TX 78666-4684, USA
[c] Center for Earth System Sciences, Tsinghua University Beijing, 100084, China
[d] Department of Geography, University of Utah, Salt Lake City, UT 84112, USA

ARTICLE INFO

Article history:
Received 22 March 2015
Received in revised form 28 August 2015
Accepted 2 September 2015
Available online xxxx

Keywords:
Climate change
Human infectious diseases
Health impact
Transmission
Pathogen
Adaptation

ABSTRACT

Climate change refers to long-term shifts in weather conditions and patterns of extreme weather events. It may lead to changes in health threat to human beings, multiplying existing health problems. This review examines the scientific evidences on the impact of climate change on human infectious diseases. It identifies research progress and gaps on how human society may respond to, adapt to, and prepare for the related changes. Based on a survey of related publications between 1990 and 2015, the terms used for literature selection reflect three aspects — the components of infectious diseases, climate variables, and selected infectious diseases. Humans' vulnerability to the potential health impacts by climate change is evident in literature. As an active agent, human beings may control the related health effects that may be effectively controlled through adopting proactive measures, including better understanding of the climate change patterns and of the compound disease-specific health effects, and effective allocation of technologies and resources to promote healthy lifestyles and public awareness. The following adaptation measures are recommended: 1) to go beyond empirical observations of the association between climate change and infectious diseases and develop more scientific explanations, 2) to improve the prediction of spatial–temporal process of climate change and the associated shifts in infectious diseases at various spatial and temporal scales, and 3) to establish locally effective early warning systems for the health effects of predicated climate change.

Contents

1. Introduction

Climate change refers to long-term statistical shifts of the weather, including changes in the average weather condition or in the distribution of weather conditions around the average (i.e. extreme weather events). Despite many discussions on the causes for climate change, there is a general recognition of an on-going global climate

* Corresponding authors at: College of Global Change and Earth System Science, Beijing Normal University, Xinjiekouwai 19, Beijing 100875, China.
E-mail addresses: yl10@txstate.edu (Y. Lu), bingxu@tsinghua.edu.cn (B. Xu).

http://dx.doi.org/10.1016/j.envint.2015.09.007

change and the non-minor role of human activities during this process (IPCC, 2007). According to the European Environment Agency (EEA, 2008), the global average surface temperature has increased by 0.74 °C in the 20th century, the global sea level has been rising 1.8 mm per year since 1961, and the Arctic sea ice has been shrinking by 2.7% per decade. Moreover, mountain glaciers are contracting, ocean water becomes more acidic, and extreme weather events occur more often. The Intergovernmental Panel on Climate Change (IPCC) predicted an average temperature rise of 1.5–5.8 °C across the globe during the 21st century, accompanied by increased extreme and anomalous weather events including heat-waves, floods and droughts (IPCC, 2001). Responding to global changes by pursuing a sustainable development is a major challenge to human society (Weng et al., 2013; Yang et al., 2013). Climate change can affect human health (Costello et al., 2009; Epstein, 1999; Kovats et al., 2000; Willox et al., 2015), especially when infectious diseases are concerned (Altizer et al., 2013; Bouzid et al., 2014; Epstein, 2001a). Three components are essential for most infectious diseases: an agent (or pathogen), a host (or vector) and transmission environment (Epstein, 2001a). Some pathogens are carried by vectors or require intermediate hosts to complete their lifecycle. Appropriate climate and weather conditions are necessary for the survival, reproduction, distribution and transmission of disease pathogens, vectors, and hosts. Therefore, changes in climate or weather conditions may impact infectious diseases through affecting the pathogens, vectors, hosts and their living environment (Epstein, 2001a; Wu et al., 2014). Studies have found that long-term climate warming tends to favor the geographic expansion of several infectious diseases (Epstein et al., 1998; Ostfeld and Brunner, 2015; Rodó et al., 2013), and that extreme weather events may help create the opportunities for more clustered disease outbreaks or outbreaks at non-traditional places and time (Epstein, 2000). Overall, climate conditions constrain the geographic and seasonal distributions of infectious diseases, and weather affects the timing and intensity of disease outbreaks (Kuhn et al., 2005; Wu et al., 2014).

A warming and unstable climate is playing an ever-increasing role in driving the global emergence, resurgence and redistribution of infectious diseases (McMichael et al., 1996). Many of the most common infectious diseases, and particularly those transmitted by insects, are highly sensitive to climate variation (Kuhn et al., 2005; Tian et al., 2015a). New and resurgent vector-borne communicable diseases, including dengue, malaria, hantavirus and cholera, are evident widely (Tian et al., 2015b; Watson et al., 1997; Yu et al., 2015). Other infectious diseases, such as salmonellosis (Chretien et al., 2014), cholera and giardiasis, may show increased outbreaks due to elevated temperature and flooding. Accordingly, long-term collaborations are called upon to develop Early Warning Systems (EWS) for infectious diseases by considering climate change (e.g. Watson et al., 1997). The successful prediction of a rising malaria risk in Botswana, which initiated timely anticipatory mitigations, was a successful effort of such (Thomson et al., 2006).

This research presents a systematic literature review on the scientific evidences for the impact of climate change on human infectious diseases. The study examines the observed and predicted impacts of changes in major climate variables and extreme weather events on the pathogen, host, and transmission of human infectious diseases. Through discussing the research progress and gaps on the possible strategies for human society to respond to, adapt to, and prepare for the impact of climate change, the research sheds light for future studies. The rest of this article is organized into five sections. Section 2 introduces the research framework that guides the literature selection and review. Section 3 focuses on the scientific evidences on the impacts of climate variable changes on human infectious diseases. Section 4 reviews the literature on extreme weather events' impacts on human infectious diseases, pointing to the needs for better understanding of the changes in climate variables and the combined weather effects during an extreme weather event. Section 5 discusses the social and institutional factors that may interfere or mediate the impacts of climate change on human infectious diseases. The last section summarizes the current status of the related studies and discusses their limitations as well as future directions on reducing vulnerability through adaptation and preparation.

2. Methods

As previously mentioned, the impact of global climate change on human infectious diseases can be examined through its impacts on the three disease components: pathogen, host, and transmission environment. Humans are an important and active factor during this process; they may mitigate the impact of climate change through adaptation practices such as those recommended by Kovats et al. (2000). Fig. 1 illustrates the relationships between climate change, human infectious diseases, and human society, forming the framework that guided the literature search for this review.

Three sets of terms were used to define the searching keywords for the literature survey of this study; the returned records must include at least one entry from each of the three sets. The first set describes the components of diseases: pathogen, host or vector, and disease transmission. The second set describes the climate and weather, including climate variables (such as temperature, precipitation, and humidity), or large-scale extreme weather events (such as El Nino), or meteorological hazards (such as drought, flood, and heatwaves). The third set describes the selected infectious diseases, including vector-borne diseases (e.g. malaria), water-borne diseases (e.g. cholera), air-borne diseases (e.g. influenza), or food-borne diseases (e.g. Campylobacter). Inputs from subject experts were further obtained to revise the search strategy and to locate additional citations.

A comprehensive literature search was conducted using Web of Science/Knowledge, Google Scholar (http://scholar.google.com), Elsevier ScienceDirect (http://www.sciencedirect.com/), Springer Online Journals (http://link.springer.com/) and CNKI (http://www.cnki.net/). The focus was on the peer-reviewed articles and government reports between 1990 and 2015. In addition, a few earlier milestone seminal articles before 1990 were included. Other major and closely relevant synthesis reports were also reviewed, including those by the IPCC, World Organization for Animal Health (OIE), World Health Organization (WHO), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), Pan American Health Organization (PAHO) and Interagency Working Group on Climate Change and Health (IWGCCH).

Initially, a total of around 400 publications were identified. A further review of the abstracts, titles, and keywords led to an elimination of about 270 citations due to their lack of direct relevance. Finally, a set of 131 articles and reports were included for this review research. These publications share a focus on the impact of climate change on pathogen, host and transmission of human infectious diseases, and the related human behavior as a mediator.

3. Climate change and human infectious diseases

Climate changes include alternations in one or more climate variables including temperature, precipitation, wind, and sunshine. These changes may impact the survival, reproduction, or distribution of disease pathogens and hosts, as well as the availability and means of their transmission environment. The health effects of such impacts tend to reveal as shifts in the geographic and seasonal patterns of human infectious diseases, and as changes in their outbreak frequency and severity.

Abundant literature addresses the factorial and potential impacts of climate change on many types of infectious diseases, including vector-borne, water-borne, air-borne, and food-borne diseases. This section of the paper provides a systematic literature survey on the influences of changes in climate variables on the three aspects of disease — pathogen, host, and transmission.