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Review

Climate change and dengue fever transmission in China: Evidences and challenges

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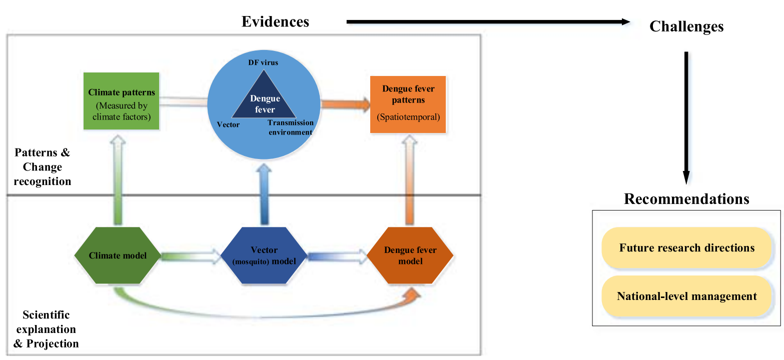
HIGHLIGHTS

- Climate change may bring increased risk of DF to China, especially to its south and southeast coast regions.
- Projection of DF under climate change is related to the development of weather-based DF model, vector and climate models.
- Lack of national-level DF model in China and uncertainties in vector model and climate model are challenges.
- Promoting interdisciplinary collaboration and further developing public health education are recommended for China.

GRAPHICAL ABSTRACT



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ABSTRACT

Dengue Fever (DF) has become one of the most serious infectious diseases in China. Dengue virus and its vector (*Aedes* mosquito) are known to be sensitive to climate condition. Climate impacts DF through affecting three essential bioecological aspects: DF virus, vector (mosquito) and DF transmission environment. Weather-based DF model, mosquito model and climate model are the three pillars to help the prediction of DF distribution. Through a systematic review of literature between 1980 and 2017, this paper summarizes empirical evidences in China on the impact of climate change on DF; it further reviews the related DF incidence models and their findings on how changes in weather factors may impact DF occurrences in China. Compared with some well-known research projects in the western countries, there is a lack of knowledge in China regarding how the spatiotemporal distribution of DF will respond to climate change. However, being able to predict DF distribution is key to China's efforts to prevent and control DF transmission. We conclude this paper by recommending four focused areas for China: promoting more advanced research on the relationship between extreme weather events and DF, developing regional-specific models for the high risk regions of DF in south China, encouraging interdisciplinary collaboration between climate studies and health services, and enhancing public health education and management at national, regional and local levels.

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Contents

1. Introduction

After malaria, Dengue Fever (DF) is the second-most serious infectious disease worldwide in terms of mortality and morbidity (Wu et al., 2010). DF is an acute infectious disease caused by four serotypes of dengue virus (DENV-1 to DENV-4), mainly transmitted to humans by *Aedes aegypti* and *Aedes albopictus*. DF is prevalent in tropical and subtropical regions, infecting about 390 million people annually. It is considered as an endemic or epidemic disease in nearly 119 countries, many of which are in Asia (Bhatt et al., 2013; Guzman et al., 2010).

The earliest recorded DF case in China was in the Yangze River Basin in the late 19th century (Luo, 2003). In the early 1940s, sporadic cases of DF were reported in China's southeast coastal regions (Mao and Zhang, 2007). The first outbreak of DF occurred in Foshan City, Guangdong Province in 1978. From 1978 to 1991, DF cases were mainly concentrated in Guangdong Province and Hainan Province. After 1990, DF spread gradually from the southeast coastal regions (e.g. Guangdong Province) northwards, reaching provinces such as Yunnan, Zhejiang, and Fujian (Xiong and Chen, 2014). Until 2008, a total of 677,446 DF cases with 626 deaths have been reported (Qin and Shi, 2014). In 2014, the unprecedented outbreak of DF in Guangzhou City accounted for more than 30,000 cases (Sang et al., 2015). DF is currently included on the list of serious infectious diseases in China (Wu et al., 2010). With rapid urbanization and continuous growth of international tourism in China, the transmissions of infectious disease are faster than ever. Without effective measures, DF may turn into an endemic disease in China's south and southeast coastal regions where the climate is suitable for virus survival and transmission.

The outbreak and transmission of DF are related to a number of risk factors, including dengue virus' presence and vitality (Zhang et al., 2005), mosquitoes' vectorial behavior and capacity (Helmersson et al., 2016), climate or weather conditions (Lu et al., 2009; Wang et al., 2014), human immunity (Endy et al., 2011), and human activity (Tian et al., 2016). However, studies found that the impacts of climate factors on DF are more significant than other factor (Earnest et al., 2012; Hales, 2012; Hales et al., 1996).

With global warming, DF occurrence seasons in China may become longer and climatic conditions are likely to become suitable for DF virus in more regions. DF has been prevalent in China mostly during June to October, with spring and winter as seasons of sporadic occurrence (Wu et al., 2010). Ample sunshine and precipitation in summer provide abundant breeding places for mosquitoes and therefore creating favorable conditions for DF occurrence. A recent research suggested that global warming aggravate the prevalence of DF, as it brings warmer and wetter spring and winter seasons favorable for dengue virus and mosquitoes (Yi et al., 2014). Between 2005 and 2013, DF occurs in most provinces in China (Yue et al., 2015) (Fig. 1). In 2014, a total of 23 out of 34 provinces have reported DF cases (Beijing Youth Daily, 2014). Moreover, the time interval between DF outbreaks has shortened gradually since 2005. All these may suggest that DF is developing from an imported epidemic disease into an endemic disease, especially in the tropical and subtropical regions of China.

Literature reported researches conducted in different countries (e.g. Malaysia and Brazil) that examined the relationship between DF and climate factors (Hii et al., 2016; Limkittikul et al., 2014; Morin et al., 2013; Pang and Leo, 2015; Viana and Ignotti, 2013). As for the studies of China, the magnitude of the relationship has not been adequately addressed. Furthermore, the overall impact of climate change on DF transmission and distribution that involves simultaneous changes in multiple weather factors is less known or investigated. There is a need for national level modeling and prediction of DF distribution in China across space and through time. Through a survey of scientific studies published since 1980 that examined the relationship between climate change and DF in China, this paper addresses the potential impacts of climate change on DF in China, reviews the related modeling and projection of DF based on climate change, and discusses how China can achieve better DF disease control and management under climate change.

2. Research design

The focus of this research is to survey literature for scientific evidences on the impact of climate change on DF distribution in China, and to examine the status of and needs for modeling and prediction of DF in China considering climate change. Climate change includes changes in climate factors and extreme weather events, both of which can affect the distribution of DF. Climate change affects DF transmission through impacting its three essential bioecological aspects: the virus, the vector, and transmission environment (Wu et al., 2016). Therefore, understanding the dynamics of DF under climate change calls for proper modeling and prediction of climate change, that of vectorial (mosquito) abundance and capacity, and that of DF occurrence under certain weather conditions, namely climate model, vector (mosquito) model, and weather-based DF model. We constructed a framework (Fig. 2) named “Tri-model Supported Prediction of Dengue Fever Distribution and Patterns” in order to illustrate the connections between the various elements. Prediction of dengue virus (DENV) transmission and its spatiotemporal patterns must be based on appropriate weather-based DF model, mosquito model and climate model. Weather-based DF model describes the relationship between DF incidence and climate factors. Weather-based DF model serves as the foundation for predicting the spatiotemporal patterns of DF distribution. Mosquito model quantifies the dynamics of mosquito distribution and population, which is closely related to weather conditions. Climate model uses quantitative methods to simulate the interactions of the important drivers of climate (GOESSP, 2011). Climate model not only generates predictions of climate patterns and dynamics of weather conditions but also provides inputs for mosquito model, which will produce outlooks of mosquito abundance and vectorial capacity across space and through time. Projection of DF refers to predicting DF distribution or spatiotemporal patterns based on weather-based DF model when climate factors and their magnitude as well as the related change in mosquito activity are considered. Hence,