REVIEW

Climatic risks of Beijing–Tianjin–Hebei urban agglomeration and their changes

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ABSTRACT

Aiming at building an international urban agglomeration, Beijing–Tianjin–Hebei urban agglomeration takes an active part in international cooperation and competition in a greater depth, and plays a crucial role in supporting and guiding the national economic and social prosperity. In the passing years, Beijing–Tianjin–Hebei urban agglomeration has been severely subjected to extreme weather–climate events, which has aroused tremendous response and enormous concern among all social strata. This thesis sums up the impact of building the Beijing–Tianjin–Hebei urban agglomeration on extreme events such as rainstorm, high temperature and heavy haze, and the meteorological disaster risks faced by Beijing–Tianjin–Hebei urban agglomeration in the context of climate change, and comes up with corresponding countermeasures and suggestions for planning and building Beijing–Tianjin–Hebei urban agglomeration and Xiong'an New Area in the context of climate change.

1. Introduction

IPCC AR4 points out: in the context of global warming, many changes of extreme weather and climate events have been observed since the middle of the 20th century, including the decrease of low temperature extreme events, the increase of extreme high temperature events, the increase of extreme high sea level events and the increase of heavy rainfall events in some regions; it is expected that high temperature and rainstorm events in some regions of the world will increase in the 21st century. Urban areas are highly risky areas of climate change, which are characterized by dense population, concentrated buildings, traffic congestion, agglomerated assets, high exposure and vulnerability (Kazmierczak et al. 2011; Wang et al. 2014). Cities are influenced by the superimposed effects of global changes and urbanization effect in the course of fast growth, which imposes huge pressure on sustainable development. A growing body of research seems to indicate that cities are influenced by global...
climate change and local climate change triggered by urbanization itself, which makes high temperature and heat wave (Ye et al. 2013; Chen et al. 2017), intense precipitation (Song et al. 2014; Liang and Ding 2017) and severely polluted weather (Ding and Liu 2014) more frequent and serious. Apart from that, cities accommodate about 55% of the world’s population in dense space and gather most of human assets and economic activities, and thus they are extremely vulnerable to the negative impact of climate change. Meanwhile, cities are also the center of fossil energy, and emissions of carbon dioxide and pollutants take a large proportion. In the future, cities throughout the world will further expand and the urban population will further increase, which suggests that the risky situation of climate change faced by cities in the future may be more severe (Zhai et al. 2019). Currently, climate change and sustainable development of cities in the future will be one of the major research subjects facing mankind, and it is of vital strategic significance to actively discuss the impact of climate change on urban agglomerations.

Beijing–Tianjin–Hebei urban agglomeration constitutes an indispensable part of core economic zone in China, which intended to build an international urban agglomeration takes an active part in international cooperation and competition in a greater depth and plays a crucial role in supporting and guiding the national economic and social prosperity (Lv et al. 2016). The coordinated development of Beijing, Tianjin and Hebei is intended to form an international urban agglomeration led by the capital and construct a demonstration zone for ecological rehabilitation and environmental enhancement. Beijing is the focus of Beijing–Tianjin–Hebei urban agglomeration and the key to forming an international urban agglomeration. It is a significant initiative to boost the integrative growth of Beijing–Tianjin–Hebei by setting up Xiong’an New Area (Zhang 2017). Xiong’an New Area closely concerns with the success or failure of the construction of Beijing–Tianjin–Hebei international urban agglomeration, shouldering the significant mission of “perceiving with a global vision, maintaining international standards, keeping Chinese characteristics and making high-point positioning, and building a Chinese sample of international urban agglomeration", which is a significant support for China’s strategy of reinvigorating the country. In recent years, Beijing Tianjin Hebei Urban agglomeration has been seriously affected by extreme weather and climate events, which has aroused strong repercussions and great concern in the whole society. This paper summarizes the urbanization effect of the construction of Beijing Tianjin Hebei Urban Agglomeration the contribution of urban development on the extreme changes such as rainstorm, high temperature and severe haze, as well as the meteorological disaster risks faced by Beijing Tianjin Hebei Urban Agglomeration under the background of climate change, and puts forward countermeasures and suggestions for the planning and construction of Beijing Tianjin Hebei Urban agglomeration and Xiong’an new area under the background of climate change.

2. High temperature risk in the development of Beijing–Tianjin–Hebei urban agglomeration

Urban heat island effect takes shape due to the combined action of human factors triggering urbanization and local weather and climate conditions (Lin and Yu 2005),
which is in close connection with the release of urban human heat, the nature and structure of underlying surface, vegetation coverage, population density, weather conditions, etc., and besides, the urban heat island will increase in both intensity and scale day by day along with the continuation of urbanization. According to research, the urban heat island effect of 100,000 people can be as high as 0.32°C, and that of 1 million people can be up to 0.91°C (Karl et al. 1988). The urban heat island in China is particularly remarkable for the reason of the higher population density and less greening in Chinese cities (Zhou et al. 2004). From the meteorological monitoring point of view, the average intensity of heat island in Beijing, Tianjin and Shijiazhuang in recent 40 years is 1.26, 0.9 and 0.75°C respectively (Liu et al. 2016).

The monitoring and evaluation results of satellite remote sensing reveal that the heat islands in Beijing, Tianjin, Tangshan and Shijiazhuang are large in area and strong in intensity (Figure 1), which suggests that the urban heat island effect of super-large, mega-cities and resource-based cities is prominent. Area increase of strong heat island chiefly occurs in megacities, the shortest spatial distance between the strong heat island areas of Beijing and Tianjin has been gradually reduced from 94 km in 1994 to 52 km in 2014, and it is possible to form a "heat island group in Beijing and Tianjin" in the future (Liu et al. 2017). Since 1990s, high temperature and hot weather has been frequently seen in China in summer (Ye et al. 2013). Figure 2 shows that the annual high temperature days in North China from 1961 to 2017 are increasing, with a trend value of 0.41 d/10a, and passing the significance test of 0.05. The annual average high temperature days have obvious inter decadal variation characteristics, which are relatively few from the mid-1970s to the mid-1990s, and the annual average high temperature days have increased significantly since the mid-1990s (Xing et al. 2020). The regional and intensity of the persistent high temperature events have increased or increased significantly (Zhang et al. 2004; Li et al. 2012). In

![Figure 1. Variation of daytime heat island intensity in summer of 1994 (a), 2004 (b) and 2014 (c) in Beijing–Tianjin–Hebei region (from Liu et al. 2017). The legend represents the intensity of heat island. From dark blue to red, the 7-level color code successively indicates stronger cold island, strong cold island, weak cold island, no heat island, weak heat island, strong heat island and stronger heat island.](image-url)
May 2017, there was a continuous high temperature process, and the maximum temperature of multiple stations exceeded the historical extreme value of May. Tianjin has 21 days of high temperature, 15 days more than the year round, and there are three high temperature weather lasting for more than 5 days; Beijing has 22 days of high temperature days, and has been experiencing 6 consecutive days of high temperature weather.

Urban heat island effect will exert a superimposed effect at extreme high temperature in summer. On the one hand, the intensity of urban heat island during extreme high temperature is greater than that during non-high temperature days, and it is stronger during daytime than at night (Ao et al. 2019), the influence of urban heat island is also amplified, and the intensity of urban heat island tends to increase along with the increase of ambient temperature in summer (Zheng et al. 2014); on the other hand, the urban heat island effect not merely influences the distribution of high temperature in summer, but distinctly enhances the intensity of high temperature. Especially, the more distinct heat island effect at night makes the urban temperature decrease at night, which leads to the continuous high-intensity heat stress of urban residents during the day and night (Basara et al. 2010), which aggravates the impact of high temperature on the health of urban residents. Since the 1980s, the urbanization process in Beijing has accelerated and the intensity of urban heat island effect has increased, which makes the number of high temperature days in urban areas more than that in suburbs and outer suburbs (Cui et al. 2009; Zheng 2011). In North China, the index associated with the minimum temperature is more significantly influenced by urbanization, which contributes more than 50% to the increased number of warm nights (Zhou and Ren 2014). Numerical simulation indicates that urban development and its accompanying changes in land use result in the enhancement and expansion of regional heat stress experiencing extreme high temperature (especially high temperature at night); meanwhile, the wind speed in the urban boundary layer decreases significantly during the day, while at night, the closer to the ground, the more severe the wind speed decreases, which makes the convection of cold air entering the city weaker (Grossman-Clarke et al. 2010; Zhang et al. 2011).
Under climate change, urban heat island effect can intensify the unfavorable impact of the scale and frequency of hazards on urban lifeline system. Primarily, the scale increase of extreme climatic events or the synergistic effect of all types of weather events may quickly result in the full load or even overload of urban lifeline system. For instance, the superposition of climate warming and urban heat island effect increases the possibility of high temperature and heatwave, which will increase the morbidity and mortality of cardiovascular and respiratory diseases, and cause serious health risks to urban residents, especially the elderly population. The vertical distribution of urban heat island renders it difficult to spread air pollutants at a certain height and aggravates pollution as a result. In summer, urban heat island intensifies the severe heat, reduces urban comfort and increases the economic burden of residents. The energy consumed by air conditioning and refrigeration is considerable. Every $1^\circ \text{C}$ increase in urban temperature in summer, the energy demand for cooling will increase by 2–4% (Shi et al. 2011). Second, increasingly frequent extreme climatic events increase the probability of accidents in urban lifeline system as well as the risk of urban disasters. Both in the current and future climate change scenarios, the area and intensity of urbanization have a significant amplification effect on high temperature heat stress. With the rapid economic development, rapid population growth and rapid urban expansion, the increasing number of extreme high temperature events in urban agglomerations will bring greater risks to the safe operation of cities.

3. Risk of rainstorm waterlogging in the development of Beijing–Tianjin–Hebei urban agglomeration

Urbanization has altered the energy balance, structure of boundary layer and atmospheric composition in local places, incurring the change of local circulation state and influencing the spatial–temporal distribution of precipitation in urban areas (Jiang and Chen 2007; Tan and Gu 2015). A large number of studies have revealed that urbanization boasts the effect of increasing precipitation in urban areas as well as their downwind direction, and this anomaly of precipitation distribution is most notable in summer (Changnon et al. 1991; Kug and Ahn 2013), and present a trend of further enhancement along with the process of urbanization. For instance, the average intensity of short-term precipitation in Guangzhou during the fast urbanization period increases by more than 7.4%, and the proportion of extreme hours increases by 2.4% (Chen et al. 2017). The precipitation effect in Shanghai chiefly exists during the period of plum rains and typhoons from June to September (Jin et al. 2017). When the large-scale precipitation system is comparatively weak or the local precipitation system is strong, the urban effect in Beijing becomes distinct, and the local precipitation in the urban area and downwind direction increases (Li et al. 2012). Not only individual cities are like this, and urban agglomeration influences precipitation distribution as well. The urban effect of Yangtze River Delta is chiefly manifested in the summer half-year precipitation intensity and spatial distribution. Under the control of 700 hPa average steering flow, the summer half-year precipitation intensity in urban center and downwind area increases by 5–15% in comparison with that in upwind area, and the maximum value is usually situated 20–70 km downstream of
The precipitation in the Pearl River Delta urban agglomeration is distinctly more than that in its surrounding areas, suggesting that urbanization may increase the precipitation in the region, which is chiefly in the pre-flood season. The areas with increased precipitation are usually situated in the urban agglomeration and its neighboring areas in the downwind direction. The weather–climate effects of the Pearl River Delta urban agglomeration merely exert an impact on convective precipitation, while the distribution of layered precipitation is not distinctly associated with the location of the urban agglomeration (Li et al. 2009).

Viewing from the Beijing–Tianjin–Hebei region, there is a distinct decrease in the precipitation and precipitation frequency in major urban areas of Beijing, Tianjin and Tangshan, while the precipitation and precipitation intensity in the downwind direction of urban agglomerations have distinctly increased and enhanced, among which the precipitation above 50 mm has changed to the most significant degree. In summer, a rainy island center structure with its main body situated in the downwind edge of the city takes shape. Surface characteristics of the city have reduced the percentage of precipitation above 50 mm in Beijing, Tianjin and Tangshan by 6–20%, while the percentage in the downwind areas increases by 8% (Zhang et al. 2015). Numerical simulation experiments also demonstrate that urban expansion enhances local precipitation in urban areas or their downwind areas. In the course of large-scale expansion in Beijing, summer rainfall centers move to urban areas, and precipitation in urban areas increases while rainfall in other areas decreases (Hou 2012; Zheng et al. 2014). Different stages of urbanization impose different impacts on precipitation. In the early stage of urbanization, as the heat island effect plays a dominant role in precipitation, the urbanization of the Beijing–Tianjin–Hebei region chiefly shows the precipitation enhancement benefits. However, when the urban agglomeration expands to a certain extent, the urbanization of the underlying surface will cause the water supply to decrease and enhance the inhibition of precipitation (Wang et al. 2015).

Urban expansion increases the impervious area of the region in a rapid manner, changes the cyclic process of urban water, and increases extreme precipitation events, runoff coefficient and runoff volume, and enlarges the risk of torrential rain and flood (Cheng et al. 2010; Hallegatte et al. 2013). In the passing years, a lot of cities on a global scale have been attacked by extreme rainstorm process, giving rise to huge casualties and property losses. In respect of these extreme torrential rain and flood disasters, which suddenly occurred in cities or urban agglomerations, the increase of extreme weather–climate events is the main inducement of frequent rainstorm disasters, and besides, there are also human factors such as the change of urbanization to rainstorm process, which changes the danger of "disaster-causing factors" (Hu 2016). The hydrological characteristics of urban surface formed by urban land use and land cover change also make urban areas more sensitive to rainstorm and waterlogging disasters (Hu and Zhang 2014). Apart from that, the backward construction of urban infrastructure leads to the lack of flood discharge capacity of urban pipe network, which is also a significant factor for frequent rainstorm and waterlogging disasters in urban areas. By studying the spatial–temporal variation characteristics of the risk of rainstorms in Beijing area, it is suggested that though the annual

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precipitation in this area is decreasing year by year, the risk of rainstorms has increased year by year since the rapid urbanization in 1984 (Hu 2015). Urbanization may trigger urban characteristics such as urban heat island effect, urban canopy and urban aerosol through population expansion, change of land use type, etc., which affect the water–heat–gas cycle and form radiation forcing, thus indirectly affecting the increase of the probability of extreme precipitation (Zhu et al. 2018).

The vigorous development of the city has damaged the original pattern of nature and geography (especially the water system network), the urban expressways and viaducts have altered the micro-topography, the infrastructure construction in the old city is severely insufficient, and the fortification criteria for floods in urban areas is relatively low (Ren et al. 2012). Viewing from the impact of torrential rains and waterlogging in megacities such as Beijing, Shanghai, New York and London, extreme rainfall produces a direct impact on urban traffic, causing many traffic accidents and even casualties (Hu et al. 2018). For instance, on July 21, 2012, an extraordinary rainfall event occurred in Beijing, and serious water accumulation interrupted the road, causing 77 deaths and economic losses of tens of billions of yuan (Zhang et al. 2013); on the afternoon of September 13, 2013, a once-in-a-century rainstorm hit Shanghai, causing serious water accumulation in more than 80 roads in the urban area, rendering numerous traffic lines to be paralyzed, and severely affecting citizens’ travel (Hu et al. 2018).

4. Air pollution risk in the development of Beijing–Tianjin–Hebei urban agglomeration

Triggered by the development of urban industry and the expansion of city size, all sorts of air pollutants emitted from human activities are suspended in the air, especially in cities and regions where fine particulate matter (PM2.5) is the primary pollutant. Liu et al. (2018) analyzed the temporal and spatial differentiation characteristics of PM2.5 in 202 districts and counties of Beijing–Tianjin–Hebei urban agglomeration, and found that in the passing years, the PM2.5 concentration in Beijing–Tianjin–Hebei urban agglomeration has taken on an overall upward trend, and the average concentration of PM2.5 in urban built-up areas is 10–20 µg/m³ higher than that in surrounding suburbs and rural areas. The regional and agglomeration characteristics of air pollution at the scale of urban agglomeration are distinct, and the positive interactive influence range of air pollution between two cities can be as high as 200 km on average. The diffusion and transmission of air pollution between regions make the local PM2.5 significantly influenced by neighboring regions, and every 1% increase of PM2.5 in neighboring regions will result in at least 0.5% increase of local PM2.5. Wind speed, wind direction, air temperature, population density, topography and secondary industry are the main internal and external factors causing air pollution in Beijing–Tianjin–Hebei urban agglomeration (Liu et al. 2018). It is found that the turbulent scale characteristics of urban boundary layer buildings in the spatial structure of urban atmospheric dynamics and thermodynamic characteristics have an important influence on the multiscale characteristics of urban air pollution. The cities with high growth rate of PM2.5 are mainly distributed in
Beijing–Sichuan and Shanghai–Guangxi, among which Beijing–Sichuan is the most serious. It shows that the increase of urban land scale will significantly increase the pollution discharge burden, and then seriously affect the city and its surrounding areas (Han 2018). There exist significant differences in the contribution rate of different pollution sources to the characteristics of air pollution components in Beijing and its surrounding areas in winter and summer, and the composition structure of aerosol particles in winter is chiefly influenced by SO$_2$ and NOx; in summer, the particle composition is chiefly influenced by CO and NOx (Xu et al. 2005). From 1973 to 2013, the change of PM$_{2.5}$ concentration in Beijing was significantly correlated with the urbanization intensity indicators such as the total energy utilization and the number of automobiles. Meanwhile, it was found that the trend of this significant relationship altered significantly in 2004, which may be the turning point of the change of air pollution from industrial type to living type in Beijing (Figure 3).

Beijing–Tianjin–Hebei Urban Agglomeration is "the most acute contradiction area between resources, environment and development" and "the most serious area of air pollution" (National Development and Reform Commission, 2015). In 2016, the concentration of PM$_{2.5}$ in Beijing Tianjin Hebei Urban agglomeration was 71 µg M$^{-3}$, higher than the national average of 51.1% (Wang et al. 2014). The accumulation of particulate matter, especially fine particulate matter PM$_{2.5}$, is an important factor causing haze (Peng et al. 2019). Figure 4 shows the annual average haze days change of Beijing Tianjin Hebei Urban Agglomeration from 1961 to 2016 (Dou et al. 2019). The annual haze days show a weak increasing trend from 1960s to 1980s, and the
increasing trend increases from 1990s to 2000s. The annual average haze days increase in 2014 and reach the maximum value in 2014, which is 48 days. Anthropogenic emission is the main cause of pollution in Beijing Tianjin Hebei area (Miao et al. 2015). From 2014 to 2016, the concentration of PM2.5 in most cities of Beijing, Tianjin and Hebei decreased (Ni et al. 2018).

PM2.5 not merely influences the energy balance of the near-earth surface by changing the atmospheric visibility, but imposes a potential impact on the health of people exposed to it (Cao et al. 2012). Cities and urban agglomerations are areas with comparatively serious air pollution in China. On the one hand, intense human activities in cities and urban agglomerations emit a large number of air pollutants, for example, the increase of total energy use, the increase of the number of cars and the emission of a large number of air pollutants in winter caused by the development of regional economy have become the source of regional pollution, while on the other hand, a large number of rural residents are attracted by all types of resource advantages of cities and constantly migrate into cities, resulting in a large number of urban residents exposed to air pollution (Bie et al. 2018). That is to say, after urbanization, economic agglomeration and population agglomeration lead to the amplification of pollution emissions. In recent years, the urban population has expanded rapidly (it is estimated that the urban population will reach about 50% of the global population in the early 21st century). Urbanization has become an important background problem of local environmental pollution caused by the development of regional economy. Facing the severe situation of urban environmental deterioration, especially the increasingly serious air pollution caused by urbanization (Xu et al. 2005), WMO has carried out the urban meteorological and environmental research program (Gurme), and actively studies the countermeasures (The Global Atmosphere Watch (GAW) Strategic Plan, 2001). It is indicated in relevant studies that in line with the air quality standards of PM2.5 promulgated by the World Health Organization, in 2010, 69% of susceptible people in China were exposed to the heavy pollution of PM2.5 (>35 μg/m³) (Han et al. 2015). During 2000–2015, PM2.5 pollution became increasingly serious with each passing day, which influenced the urban areas with huge population and high population density in the east. Population migration resulting from urbanization has
rendered an increasing number of people polluted by PM2.5. Enough scientific research results prove that atmospheric fine particles can adsorb a large number of carcinogens and genotoxic mutagenic substances, which impose negative and non-negligible impacts to human health, including increasing mortality, aggravating chronic diseases, worsening respiratory and cardiac diseases (Kan and Shi 2019). The research of Xie et al. (2009) suggested that for every 10 μg/m³ increase of PM10 and PM2.5 concentration, the mortality rate of respiratory diseases will increase by 0.65% and 1.43% respectively. According to the statistics of Beijing Municipal Health Bureau, every time there is severe haze, the number of patients who come to the respiratory department of major hospitals in the city will increase by 20% to 50%.

5. Discussion

A significant measure for the coordinated development of the Beijing–Tianjin–Hebei region is to set up Xiong’an New Area, which is not merely favorable to enhancing the overall economic ties of Beijing–Tianjin–Hebei urban agglomeration, but beneficial to boosting the construction of the Beijing–Tianjin–Shijiazhuang triangle in Beijing–Tianjin–Hebei urban agglomeration and building the core area of Beijing–Tianjin–Hebei urban agglomeration (Fang and Pei 2018). Climate change and the development of urban agglomerations are two major factors that make human society vulnerable to disasters (Dong et al. 2010). Due to the global climate change, the frequency and severity of rainstorms, floods, high temperatures, heavy haze and other disasters resulting from climate change have increased significantly, and the threats to society, economy, health and safety have become increasingly aggravated. Based on the scenarios of moderate emission (RCP4.5) and high emission (RCP8.5), it is predicted by means of multi-model ensemble that the high temperature and heavy precipitation events in China will continue to increase in the 21st century. It is estimated that by the end of the 21st century, the risk of high temperature and flood disasters will increase in China, and urbanization and wealth accumulation will give rise to superposition and amplification effects on the risk of climate disasters (Qin et al. 2015).

Premised on the above analysis, it is suggested that the relevant state departments fully recognize the urgency of building Xiong’an New Area and Beijing–Tianjin–Hebei urban agglomeration so as to respond to the impact of climate change, and take active actions in the following aspects:

1. Beijing–Tianjin–Hebei urban agglomeration is situated in Haihe River basin, which is the edge of the range of influence by summer monsoon, and one of the fragile climate areas in China. The precipitation is not merely concentrated in the year with intense rainstorms, but varies significantly between years, with frequent droughts and floods. The vigorous process of urbanization of Beijing–Tianjin–Hebei urban agglomeration in the passing years has radically altered the original landscape and ecosystem of natural surface, and set up a human-centered urban agglomeration. The rapid expansion of the area of impermeable layer in urban agglomeration causes the increase of intensity and frequency
of convective activities, which is easy to breed rainstorm weather, and besides, the ground convergence is accelerated, and sea pervades in the city, which leads to the aggravation of waterlogging disasters in the city. Thus, in urban flood control and disaster reduction, it is necessary to attach importance to the impact of climate change and urban construction on flood control risk, constantly revise and perfect the comprehensive disaster prevention and mitigation system, reinforce the construction of disaster monitoring, forecasting and early warning system and the capacity building of natural disaster emergency response, and strengthen the planning and construction of urban infrastructure, build sponge cities, improve ecological service capacity, and consolidate the capacity building of metropolises to cope with catastrophe under the guidance of low-impact development ideas. Under the background of climate change, the annual precipitation of Xiong’an new area will increase by 8% (based on 1986–2005, the same below), and the daily maximum precipitation (RX1day) will increase by 16%. The frequency and intensity of heavy rainfall events will increase. The planning and construction of Xiong’an new area will face greater waterlogging risk than the construction of Beijing Tianjin Hebei Urban Agglomeration. Therefore, Xiong’an new district should build an urban waterlogging emergency management system which is in line with the modern urban management concept and operates efficiently. Under the background of the coordinated development of Beijing, Tianjin and Hebei, we should rely on Hebei Province to strengthen the coordination and linkage ability with Beijing and Tianjin region, form a situation of mutual support and emergency coordination, and set up a model of coordinated emergency response of urban agglomerations.

2. Different urban layouts exert distinct impacts on regional climate, and smaller differences in urban distribution can result in relatively large-scale climate differences. Different development scenarios of Beijing–Tianjin–Hebei urban agglomeration affect regional climate in different ways. The centralized development scenario boasts the strongest climate effect, followed by balanced development and beaded development, and the hierarchical development model exerts the weakest climate effect relatively. Thus, it is recommended to build a “green ecological barrier” between Beijing and Tianjin to separate the connection between cities and eliminate the possibility of linking up urban heat islands into a single stretch. The key measures to alleviate the heat island effect include intensifying urban greening and improving the thermal properties of urban underlying surface. One of the more effective methods to increase the green area or the overall green quantity is to do roof greening, especially in the case of urban land shortage and high building density. The government of Chicago in the United States started the roof greening project to lower the city temperature, and Japan’s compulsory roof greening of new buildings or refurbishing old buildings is worth learning (Peng et al. 2005): enable ecological and rational energy planning, urban development mode, transportation planning, green space system planning, and adjust urban industrial structure; use new building materials to boost the reflectivity of solar light; use outdoor building materials that can reduce temperature, save energy and relieve heat island intensify; promote permeable ground paving
materials. It is estimated that the comprehensive adoption of these measures can reduce the energy consumption investment by about 10 billion US dollars every year in the United States (Rosenfeld et al. 1996). People attach more importance to the harm of global warming and heat island effect to urban environment, which should be paid enough attention to in modern urban planning and design. In the middle of the 21st century, the annual average temperature increases in Beijing Tianjin Hebei region and Xiong’an new area are about 1.6 °C. The frequency and intensity of future high temperature heat wave events will increase.

3. Air pollution is the result of the combined action of external natural factors and internal human factors. The high emission intensity of local pollutants in Beijing–Tianjin–Hebei region is the fundamental internal cause of high haze weather, while natural conditions such as wind speed, wind direction, temperature, vegetation and mountain barrier are the external factors of haze gathering and diffusion in Beijing–Tianjin–Hebei region. In the booming development of Beijing–Tianjin–Hebei urban agglomeration, it is necessary to find targeted adaptive strategies, such as optimization of industrial and residential location, design of urban air ducts, and rational layout of green belts; for human factors, effective control strategies can be worked out, including adjusting the energy and industrial structure, optimizing the road network and upgrading new vehicle standards, relieving overloaded population and polluting industries, and strengthening supervision over pollution discharge (Liu et al. 2018). Meanwhile, air pollution is characterized by distinct cross-regional transmission, and the contribution of cross-urban agglomeration transmission from outside the region to PM2.5 concentration in Beijing, Tianjin and Hebei has been up to 20%~35% (Wang et al. 2014). Thus, when working out air pollution prevention and control measures, it is essential to put a high premium on the interactive influence within the urban agglomeration and between the urban agglomeration and its surrounding areas, reinforce joint prevention and control and cooperative governance between regions, build an inter-regional ecological compensation mechanism, innovate pollution discharge supervision and accountability models, and attach importance to environmental protection planning and environmental legislation in planning the urban agglomeration (Fang 2014; Wang et al. 2017).

To deal with the climate risk brought by climate change and urbanization, we must take the road of green and low-carbon development. According to the Paris Agreement, China’s total emissions will reach the peak in 2030 when the temperature rises from 1.5 to 2 °C. This is the carbon emission budget made by Chinese scientists to take the road of low-carbon development in the future. If we do not take this road, carbon emissions will not meet the standard, and the resulting environmental and climate problems will be irreversible. That is to eliminate fossil energy and backward production capacity, let coal, oil, natural gas and other energy out of the historical stage, and vigorously develop wind energy, solar energy, nuclear energy and other clean energy(http://www.cma.gov.cn/kppd/kppdmsgd/201809/t20180926_478890.html). Under the influence of global warming and urbanization, the disaster causing factors of cities are increasing. Therefore, some effective governance and
adaptive mitigation measures must be taken to reduce the climate risk. In fact, cities also have unique advantages in dealing with climate change. For example, the funds, policies and technologies needed to deal with climate change are very strong in cities. Urban economy is developed, and it is the center of all kinds of technological innovation. The lifestyle and behavior of urban residents are easy to manage, which can provide financial and technical support for coping with climate change.

In order to control the air pollution in Beijing Tianjin Hebei region, we should take the opportunity of coordinated development of Beijing Tianjin Hebei region, focus on the key work of clean energy supply, resolving excess capacity, optimizing transportation structure by means of scientific and technological innovation and internal structural adjustment. We should pay attention to the interaction between urban agglomeration and its surrounding areas, and further strengthen regional joint prevention and control.

6. Conclusion

1. Climate change poses a greater challenge to the traditional disaster risk management of Beijing Tianjin Hebei Urban Agglomeration. The heat island effect of megacities in Beijing Tianjin Hebei region is significant. The high temperature, local rainstorm and severe haze in the city have an increasing trend, which directly affects urban transportation, urban water and electricity consumption, human health and so on. The rainstorm and waterlogging disaster of Beijing Tianjin Hebei Urban Agglomeration is gradually aggravating. Urban expansion makes the local precipitation increase in the urban area or its downwind direction. The summer rainfall center moves to the urban area, which makes the urban precipitation increase, reduces the urban drainage design standard, and increases the risk of urban waterlogging.

2. The warming of climate makes the high temperature and humidity weather increase, and the PM2.5 concentration increases as a whole. The water and electricity load of Beijing Tianjin Hebei Urban Agglomeration increases, which brings serious health risks to the aged.

3. Under the background of climate change, the risk of high-intensity extreme warm events in Beijing Tianjin Hebei region will be further increased, the per capita domestic water and electricity demand of residents in Beijing Tianjin Hebei Urban Agglomeration will be further increased, and the peak daily water and electricity consumption in summer will surge. The risk of high-intensity extreme precipitation events increases, which will increase the risk of rainstorm and waterlogging, and also pose a serious threat to the safe operation of urban traffic.

Quite a number of achievements have been gained in respect of the basic research on the impact of building the Beijing–Tianjin–Hebei urban agglomeration on urban heat island, rainstorm waterlogging and air pollution. Nevertheless, there is a lack of quantitative evaluation on the construction planning and urban functions of the Beijing–Tianjin–Hebei urban agglomeration caused by extreme precipitation, high temperature and heavy haze, as well as relevant research on climate change.
Therefore, it is required to enhance the assessment of impact, vulnerability and risk of climate change in urban agglomerations, draw up future risk zoning of climate change, intensify the study of urban safety and population-carrying capacity in the context of climate change, and exploit the coordinated policies and measures of urban emission reduction, ecological protection, disaster prevention and mitigation.

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Data availability statement (DAS)

Data sharing is not applicable to this article as this paper is a reviewed paper which no new data were created or analyzed in this study. And all the data and results from different literatures which were cited by this paper were checked by our authors.

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