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Direct and indirect health impacts of climate change on the vulnerable elderly population in East China

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ABSTRACT

The latest scientific advances on the impacts of climate change on the health of the elderly in East China were reviewed consulting peer-reviewed publications from 2000-2017. The direct impacts of climate change result from rising temperatures, heatwaves, and increases in the frequency of complex extreme weather events such as windstorms, floods, and droughts. The health and social consequences of these events are far-reaching, ranging from reduced labour productivity and heat-related deaths, through to direct physical injury during extreme weather events, the spread of infectious diseases, and mental health effects following widespread flooding or prolonged drought**.** Research has indicated that climate change will have the greatest impact on vulnerable groups of people, including the elderly population. However, there is a dearth of empirical evidence, a lack of focus on vulnerable segments of the population (especially elderly), limited understanding of how health status will change in the future, and lack of acknowledgement of how different regions in China vary in terms of the consequences of climate change. The main risk in East China that climate change may exacerbate is flooding (sea level rise, coastal and riverine, flood risk). However in some regions of East China such as in the provinces of Anhui, Jiangsu, Hebei and Shandong the biggest climate change risk is considered to be drought. Main health risks linked to climate change are evident as cardiovascular and respiratory diseases (heat stroke, exhaustion, and asthma), often caused by interactions between heatwave episodes and concurrent poor air quality.

Key words: Climate change, East China, elderly, health impacts, flooding, heatwaves.

I. Introduction

Many prevalent human diseases respond to climatic conditions (Liang and Gong 2017). Links between weather and climate exist for cardiovascular diseases (Kim et al. 2015), respiratory illnesses (Hopkinson et al. 2017) and infectious diseases, including water-, food- and vector-borne, are well established (Patz et al. 2005). Climate change is one of the greatest challenges currently facing humanity and it is considered to be the biggest global threat to public health this century (Costello et al. 2009). *The Lancet* Commission on Climate Change and Human Health note that the impacts of climate change, through rising temperatures, heatwaves, and increases in the frequency of complex extreme weather events such as windstorms, floods, and droughts are already being felt and through these events climate change impacts will have substantial costs to human health (Costello et al. 2009; Portier et al. 2013). Climate change will affect human health via multiple pathways of direct and indirect impacts (Frumkin et al. 2008; Massad et al. 2011). The effects of climate change on human health will include health problems linked to heat stress, flooding, and increased frequency and intensity of storms (Easterling et al. 2000). For example, cardiovascular and respiratory diseases, may be induced by heatwaves and air quality interactions (Kan et al. 2012). Climate change also indirectly threatens human health through adverse changes in temperature (Peel et al. 2013), vector borne infectious diseases (Epstein 2001) and via food and water quality and security (Myers et al. 2017). Forced migration and shortage of resources can also be predicted as indirect impacts of climate change on human health (Watts et al. 2015).

The climate in China and East China have already experienced significant changes in recent years (Qin et al. 2015). This review focuses on the impacts of climate change on health in the elderly in East China, which is home to 408 million people, and is one of the key economic areas in China. Demographically, population projections predict that by 2050 one third of the Chinese population will be elderly (aged older than 65) (Yao-Dong et al. 2013). The elderly are a population group that has been identified as being particularly vulnerable and susceptible to the wide range of environmental and societal impacts of climate (Zeng et al. 2010). Thus, the future health profile and needs of this population needs to be a key consideration for Chinese policymakers. Several studies have been carried out in China related to the health concerns of climate change and some have quantified the direct impacts of climate change in the health on elderly population (McMichael et al. 2006; Wu et al. 2016; Zhou et al. 2017). Most studies focuses on health impacts of extreme heat and highlights the health risks to the elderly population (cardiovascular, respiratory, stroke, ischemic heart disease) (Chen et al. 2017; Zhang et al. 2017). Given the large size of the affected population, the climate and environmental diversity across regions and the diverse socio-economic status across East China, it is considered timely to review and summarize the latest scientific advances in understanding the likely future health impacts of climate change. Here, a broad range of studies on the potential risks of climate change impacts in China are reviewed, and the current state of knowledge on the health impacts of climate change in the elderly Chinese population is presented and methods and limitations of previous research are examined.

II. Approach

Peer-reviewed publications that reported the impact of future climate scenarios on risks to health are reviewed. Web of Science, Environment Complete (EBSCO), Google Scholar and Science Direct databases were used for the research. The review is based on a structured literature search, but did not include a formal meta-analysis, as too few studies reported suitable effect size for meaningful comparison. The search terms were used in combination and included 'climate change', 'health', 'China', and 'elderly', 'East China' were used to filter the resources. This search returned many off-topic articles, as evidenced by their titles and abstracts. Due to the large number of publications we cannot give an exhaustive overview of all studies. Instead, the most important, relevant and novel publications were considered to form the main body of review. Overall, since 2000, 970 full articles were identified including 940 confirmed as peer reviewed. Within these results a further search was performed with the term 'health impacts' and this filter resulted in 361 articles. The final search identified 163 studies and 114 studies were chosen for this review as they were highly relevant (Figure 1).

<<Insert Figure 1 Here>>

III. Recent and Future Climate Change in China

Future predictions indicate that climate change may exacerbate a wide range of extreme weather events in China, including typhoons, floods, and droughts (Kan 2011). For China different emission scenarios estimate that, by the year 2020 averaged annual mean temperature will increase by 1.5–2.1°C, by the year 2050 by 2.3–3.3°C, and by year 2100 by 3.9–6°C (Ding et al. 2007). Across most of China future temperatures are expected to rise another 1.3 to 5 °C by the end of the century, in comparison to the global average predicted rise of 1 to 3.7°C (Ding et al. 2007; Guoju et al. 2005).

Studies have shown recent trends in annual and summer total precipitation, and the large regional precipitation variability in China (Shi et al. 2003; Zhai et al. 2005). In the last decade China has suffered a series of extreme droughts, including the spring-summer drought in northern China in 2000 and 2001, the spring drought in Yunnan in 2005, the spring-summer drought in Sichuan and Chongqing in 2006, the summer drought in southern China in 2007, the summer drought in Chongqing in 2008, and the spring-summer drought in five southwest provinces in 2010 (Barriopedro et al. 2012). Indeed, data on droughts and floods in the Yangtze and Yellow Rivers over the last 2000 years found that while the intensity of flooding in the 20th century was comparable to historical events, previous drought events were less intense (Zheng et al. 2006). Between 1876 and 1878 a drought occurred in China which was considered as an extreme climate event after the cold climate at the end of the Little Ice Age (this is a period between about 1300 and 1870) (De'er and Youye 2010).

Sea level rise in East China is another further concern (Wellner and Bartek 2003). China Meteorological Administration states that a sea level rise of 60 cm by 2050 could make economic growth in Shanghai vulnerable, and also poses risks to health for vulnerable segments of the population (Hu 2017).

IV. Vulnerability to Climate Change

The concept of vulnerability is defined as an important extension of traditional risk analysis, which is focused primarily on natural hazards (Kok and Jäger 2009; Leichenko and O'Brien 2002; Otto et al. 2017; Turner et al. 2003). Table 1 presents various concepts of vulnerability (Füssel 2007).

<<Table 1 Here>>

Vulnerabilities may vary greatly from those associated with human health to built infrastructure (Heltberg et al. 2009). Human vulnerability factors can be divided into five groups: natural vulnerability, human vulnerability, social vulnerability, financial vulnerability and physical vulnerability (Thow and de Blois 2008) (Figure 2). The vulnerability level of human populations vary depending on conditions (McMichael 2003). For example, some population subgroups may have difficulty adapting to climate change because of scarce resources, lack of information, poor public health infrastructure, as well as a lack of effective guidance and help (Corvalan et al. 2005).

<<Insert Figure 2 Here>>

Population groups including the elderly, children, and disabled people are considered particularly vulnerable to climate change (Watts et al. 2015). Age is a well-known risk factor for heat related illness and death and the elderly are under the greatest risk (Basu and Samet 2002).

Increased human health vulnerability to climate change is associated with many factors including rapid population growth, (as in the case of China) poverty and hunger, poor health, low levels of education, and lack of access to information on climate change (Demirkesen and Evrendilek 2017; Füssel and Klein 2006). It has been shown that the elderly (people who are 65 years or older) are particularly vulnerable to the impacts of heat waves (Li et al. 2017b). For example, the 2003 heatwave in Shanghai was reported to have caused a 12 percent increase in total deaths and a 19 percent increase in cardiovascular mortality amongst the elderly (Huang et al. 2010). It has also been reported that high temperature mortality risks were highest for women over 65 years old in Jinan, China (Li et al. 2017a). A recent study established a social vulnerability index at the county level with a composite index to climate change focusing on urbanized cities on the Chinese east coast (54 cities govern 407 county-level divisions containing counties, county-level cities, and city districts) and found that more work on health and social care should be put toward this sensitive elderly group (Ge et al. 2017).

These findings indicate that human health interventions aimed at mitigating the climate change health impacts require an in-depth understanding of vulnerable populations (Berrang-Ford et al. 2011). Improving understanding of vulnerability to climate change health impacts is a clear research gap in China that requires urgent attention from public health researchers.

V. Uncertainty on Climate Impacts and Human health

Uncertainty defined in the context of risk, restricts our ability to measure the risks associated with different events (Hillen et al. 2017). In China much of the climate change uncertainty has focused on crop yields and scarcity in water resources which are two of the biggest indirect impacts of climate change on health (Kang et al. 2017). The uncertainty of the direct impacts of climate change on human health has received very little attention in China. However, some research has examined climate change issues that will indirectly impact on human health, including precipitation, temperature, weather variability and water management. Research has found that the uncertainty in predictions of future precipitation (Piao et al. 2010), future temperature trends (Wang et al. 2012b), weather variability (Piao et al. 2010), and water security of the responses of crops to changes in climate, diseases, pests and atmospheric constituents all of which can have an important impact on human health (Pahl-Wostl 2007). Climate change challenges on existing water resources management practices should be considered amongst the factors that have additional uncertainty in future (Pahl-Wostl 2007). For adaptation to change, integrated water resources management must therefore take climate change impacts under full consideration to enhance the potential of the resources (Guo et al. 2002). On water management uncertainty, there are still many gaps in the climate change assessment methodologies and many uncertainties in the climate health projections (Yong-Jian et al. 2013). Some studies have focused on the potential uncertainty of the effect of climate change, and mathematical methods have been employed for model constructions (Piao et al. 2010). On temperature extremes, uncertainty ranges were completed as 0.084°C/decade and 0.037 °C/decade for the minimum and maximum temperature trends, respectively (Wang et al. 2012b). Due to the lack of reliable observations, there are uncertainties on tropical cyclones in the exploration of results (Zou and Zhao 2010). In a study which focused on rich range of uncertainties related to heat related climate change impacts, population demographics and adaptation, however in this study modeling future adaptation is still considered as a big challenge (Li et al. 2016).

VI. Impacts of Climate Change on Health

The WHO (2016) estimated that, in 2012, 12.6 million deaths (23% of all deaths worldwide) were attributable to modifiable environmental factors, many of which could be influenced by climate change or are related to the driving forces of climate change (Neira and Prüss-Ustün 2016). Links between weather and climate exist for cardiovascular diseases (Kim et al. 2015), respiratory illnesses (Hopkinson et al. 2017) and a number of infectious diseases (Patz et al. 2005). As noted above, many prevalent human diseases respond to climatic conditions (Liang and Gong 2017). Human health in China will also be affected by climate change in numerous ways such as mortality from extreme weather events; changes in quality of air and water; and changes in the ecology of infectious disease vectors (Kan et al. 2012). Indeed, some of the most common infectious diseases including malaria and dengue, are those transmitted by mosquitoes, many of which have exhibited changes to their species range in the last decade (Liang and Gong 2017; Tian et al. 2015; Yu et al. 2015). *The Lancet* Commission (Costello, 2009) identified six factors that connect climate change to adverse health outcomes: changing patterns of disease and mortality, food, water and sanitation, shelter and human settlements, extreme events, and population and migration. The following sections will focus on the impact of increased extreme events linked to climate change will have on human health (Figure 3).

<<Insert Figure 3 Here>>

<<Insert Table 2 Here>>

a. Climate Change Impacts on Health: Storms and Typhoons

Climate change is expected to lead to an increased number of storms and typhoons and East China is one of the regions seriously affected by tropical storms (Lu and Zhao 2013). Previous research in Guangdong, South China, found that the landing of tropical cyclones not only causes substantial direct economic losses but also threatens human health (Kang et al. 2015). Research has found that tropical cyclones increase the risk of transmitted infectious diseases (Zheng et al. 2017). Study in Guangdong city between years

2005-2011 concluding that there is an increase on the infectious diarrhea incidents after tropical cyclones (Kang et al. 2015). An assessment on the public health risks and impacts of a tornado in Funing, East China concluded that elderly (75-84 year group) was at the highest risk death (RR (relative risk) = 82.16; 95% CI (confidence interval) = 19.66, 343.33) and injury (RR = 31.80; 95% CI = 17.26, 58.61), and females were at 53% higher risk of death than males (RR = 1.53; 95% CI = 1.02, 2.29) (Wang et al. 2017).

b. Climate Change Impacts on Health: Heatwaves and Cold Spells

Heat waves are increasing in frequency (Luber and McGeehin 2008; Robinson 2001). Population groups with high vulnerability to heatwaves and cold spells (Davídkovová et al. 2014) include the elderly, children and/or people with chronic diseases who are more susceptible to extreme temperatures, both hot and cold (Tian et al. 2012). Being exposed to extreme heat can cause heat stroke and dehydration, as well as cardiovascular, respiratory, and cerebrovascular disease risks which may cause insomnia, fatigue, clinical exacerbation, or death from heatstroke (Yao-Dong et al. 2013; Zeng et al. 2014). It is estimated that the heat waves will cause severe health impacts on the metropolitan areas in the Pearl River Delta as heat waves become more intense and longer in duration (Yao-Dong et al. 2013). Many studies that have investigated heat wave related mortality (Li et al. 2017b; Luo and Lau 2017; Yin and Wang 2017; Zhou et al. 2017) but less attention has been given to the health effects of cold spells (Staddon et al. 2014) in the context of global climate change (Zhou et al. 2014). It is important to note that climate change may lead to warmer winters but with greater weather variability leading to the counter intuitive effect of more cold spells occurring. A recent study shows that a total of 5 % excess deaths were associated with heat waves in 66 Chinese communities, with the highest excess deaths in North China, followed by East China and South China (Ma et al. 2015). In Beijing research on the elderly found that ignoring adaptation and demographic changes among elderly who are most susceptible to heat leads to differences in estimations on future heat-related mortality (Li et al. 2016).

Increased mortality rates are associated also with cold waves in populations around the world (Ryti et al. 2016). Both extremely cold and hot temperatures increase heart disease mortality in China (Guo et al. 2012). The elderly are more vulnerable to low temperatures than young people which can trigger some chronic diseases (De'Donato et al. 2013). Also, cold spells lead to increases in patients with fractures from the possible injuries of icy ground (Yao-Dong et al. 2013). In Shanghai a study done on the elderly showed that cold spells had a significant impact in elderly people with increasing mortality rates (age greater than 65) (Ma et al. 2013).

c. Climate Change Impacts on Health: Flooding

River Flooding

Flooding events are generally considered among the deadliest natural disasters, and have led to the highest number of mortalities in the 20th century (O'Connor and Costa 2004). Flood disasters have been recognized as the most severe natural hazard in China since the country frequently experiences natural disasters, of which flooding is of great concern to the different levels of Chinese government (Zhang and Liu 2006). For East China disastrous flooding in several river valleys across East China in 1755, serious flooding occurred in the middle and lower reaches of the Yellow River in 1756 and 1757, a rarely seen precipitation pattern of north-flood and south-drought in China for two successive years (Zhang 2012). In 1931 in Central China there were a series of floods that occurred and these floods took the lives of nearly 4 million people (Zong and Chen 2000). In the summer of 1991, an area in the East of China measuring 130,000km^2 was flooded and 3 million houses were damaged or destroyed resulting in health impacts including injuries (for those who sustained open wounds etc.) (Gautam and Van Der Hoek 2003). After, China suffered extensive flooding in three areas during the 1998 summer: along the Yangtze River in South Central China (Ye and Glantz 2005). East China also experienced a series of severe floods during the summer of 1998 and these floods adversely affected the human population, directly and indirectly (Jonkman 2005). Regions most at risk are: central North China, the Huaihe River (provinces: Henan, Anhui, Jiangsu), the middle and lower reaches of the Yangtze River, and the Pearl River Basin (cities around Shanghai, Nantong, Zhenjiang, Nanjing, Tongling, Wuhu, Jingzhou) (Shao-Hong et al. 2012). Drowning, injuries, hypothermia are amongst the immediate direct health impacts of floods (Du et al. 2010). All populations affected by a flood are at direct or indirect risk of health impacts during and after the event, but the literature also mentions the certain groups are at higher risk than others. People with limited physical capacity or limited mobility, who require home care or regular visits to health care facilities, and who have weak social networks, poor flood awareness, few resources and little access to flood warnings are at particularly high risk (Galea et al. 2005). Information on risk factors for flood-related death remains limited, and those drowning in their own homes are largely the elderly as they are less mobile (Jonkman and Kelman 2005).

Coastal Flooding

Under future climate change, altered patterns of precipitation and sea level rise are expected to increase in frequency and intensity of floods in many coastal regions (Ahern et al. 2005). China's coastal region is physically vulnerable to sea-level rise and associated coastal flooding because of its low topography (Wang et al. 2011). The East Sea, South Sea and East China regions with high population density have the greatest exposure to coastal flooding risk from sea level rise (Fang et al. 2017; Zhang et al. 2002). Xiamen is proposing an integrated assessment approach to sea-level rise and storm tide-induced flood risks on a coastal urban system (Lilai et al. 2016). Half of Shanghai is projected to be at risk of flooding by the year 2100, and 46% of the seawalls and levees would be breached, and sea level rise projections show 86.6 mm, 185.6 mm, and 433.1 mm rise by 2030, 2050, and 2100, respectively (Wang et al. 2012a).

d. Climate Change Impacts on Health: Drought

Drought is a major natural hazard determined by water availability being significantly below normal conditions for a region (Sheffield et al. 2012). For the period of 1900-2012, China was amongst the countries with the greatest number of people affected by drought (Stanke et al. 2013). During the three most recent decades Northwest, North, and Northeast of China have seen an increase in droughts frequency (Yu et al. 2014). Drought impacts on health are generally indirect and include: malnutrition and mortality due to decreased crop yields, water-related diseases due to increasing concentrations of pollutants and algae, airborne and dust-related diseases, vector borne diseases; mental health effects (Stanke et al. 2013). Although information on droughts' health impacts is available globally, specifically in East China, related elderly population, the information in the literature is very limited.

e. Climate Change Impacts on Health: Air Quality Interactions

There is a considerable literature on the relationship between air quality and numerous health problems, including respiratory infections, cardiovascular diseases, and lung cancer (Arceo et al. 2016; Currie and Neidell 2005; Currie et al. 2009). Air quality is strongly dependent on weather and is therefore sensitive to climate (Jacob and Winner 2009). Changes in the climate will impact air quality, for example by increasing formation of ozone during heatwaves (Stedman 2004). Most air pollutants significantly increase the risk of coronary heart disease mortality especially particular matter (PM_{10}, $PM_{2.5}$) (Zhao et al. 2017). Due to climate change, patterns of air pollution are changing in urban areas, and this brings a huge threat to respiratory health (D'Amato et al. 2013). Other air contaminants of relevance to human health, including smoke from wildfires and airborne pollens and molds, may be influenced by climate change (Kinney 2008).

Studies related PM_{10} induced health losses are evident, covering most of the large and medium-sized cities in China (Zhang et al. 2008). $PM_{2.5}$ is known for its harm to the human respiratory system, and is positively related to daily mortality of people especially of older adults (RR =1.5%, 95% CI: 1.1–1.9%) (RR: Relative risk, CI: Confidence interval) (Schwartz 2000). According to the Chinese disease surveillance report, mortality due to respiratory diseases, cardiovascular diseases and neoplasm is higher in the over 60 age group (Zhou et al. 2016). In Beijing some severe haze events were studied, studies about the quantification of PM_{10} health effects can help in policy making if they are revealed (Gao et al. 2015; Yin et al. 2015). Dust storms have also been positively associated with excess mortality in China (Wang et al. 2004). Respiratory and cardiovascular hospitalization are associated with the dust events after adjusting the effect of sulphur dioxide and/ornitrogen dioxide (Pan and Liu 2011). Although literature provides information on the interaction between air quality and climate change impacts, more research is needed in this area. Research should focus on air quality interactions with climate change and what the consequences will be for population health.

Conclusions

The impact of climate change on human health is beginning to receive more attention, however except for heatwave impacts; specific information on how climate change will impact the health of the ageing Chinese population is sparse. This review highlights the broad range of health risks linked to climate change and identifies where more research effort is needed. In particular, more quantitative and epidemiological studies are required to better understand the likely impact of climate change on the health of the growing elderly populations affected. This research gap requires further investment if we are to have an evidence-based adaptation strategy to climate change. Furthermore, research is urgently required on the indirect pathways by which climate change will impact the health of elderly Chinese and other segments of the population. China, with its ageing population, rapid development and likely climate change impacts, has a great challenge in safeguarding the health of its population in the face of demographic and environmental changes of a magnitude rarely seen. Hence, this research gap on quantitative and epidemiological studies must be addressed if we are to have an evidence-based adaptation strategy to climate change.

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LIST OF FIGURES AND TABLES

Figure 1:Prisma flow chart for literature review

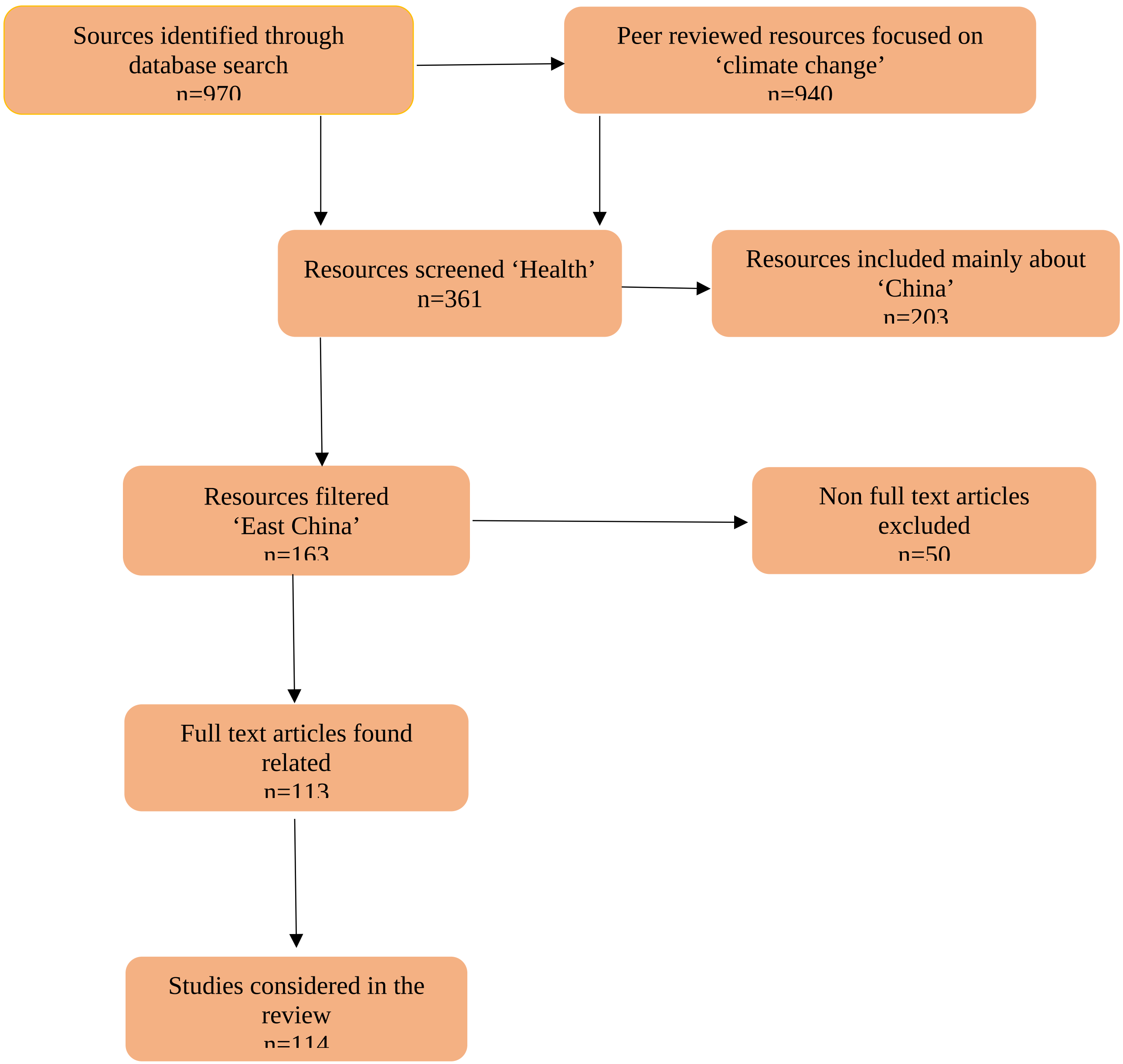

Table 1: Various concepts of vulnerability (Based on Füssel 2007)

System

(The system or region and/or population group and/or sector of concern.)

- Human Environment System
- Geographical Region
- Economic Sector
- Natural System

Attribute of Concerns (The valued attribute (or variables of concern) of the vulnerable system that are threatened by its exposure to the hazard.)

- Human Health and Life
- Existence and Natural Identity
- Biodiversity and Ecosystem Services
- Income and Livelihood

Hazards

(The external stressor (or set of stressors) of concern.)

- External- Floods
- Internal- Unsustainable Farming Practices

Temporal Reference

(The time period of interest.)

- Current
- Future

Figure 2: Vulnerability factors (Based on Thow and De Blois, 2008).

NATURAL VULNERABILITY

-Water availability

In case of drought water scarcity or hardships in finding clean water because of extreme events.

-Agricultural Sustainability and Land Degradation

Example:Wetlands, such as the Caroni Swamp, are sensitive to increasing salinity from sea water.

HUMAN VULNERABILITY

-Poverty&Hunger

Lack of food, mulnutrition

Loss of properties

-Health

Direct impacts on health (heatstroke, injuries)

-Vulnerable Populations

Example: Some population groups are more vulnerable than others e.g: kids, sick people, old people.

SOCIAL VULNERABILITY

-Conflict

-Displacement

Example:When flooding occurs some citizens, such as children, elderly and differently-able, may be unable to protect themselves or evacuate if necessary.

-Governance

Maintaining control in the public during extreme events.

FINANCIAL VULNERABILITY

-GDP Density

Example: Poorer families may live in squatter settlements because they cannot afford to live in safer (more expensive) areas.

PHYSICAL VULNERABILITY

-Capacity to access/respond humanitarian emergencies.

Example:Wooden homes are less likely to collapse in an earthquake, but are more vulnerable to fire.

Figure 3: Health impacts of climate change

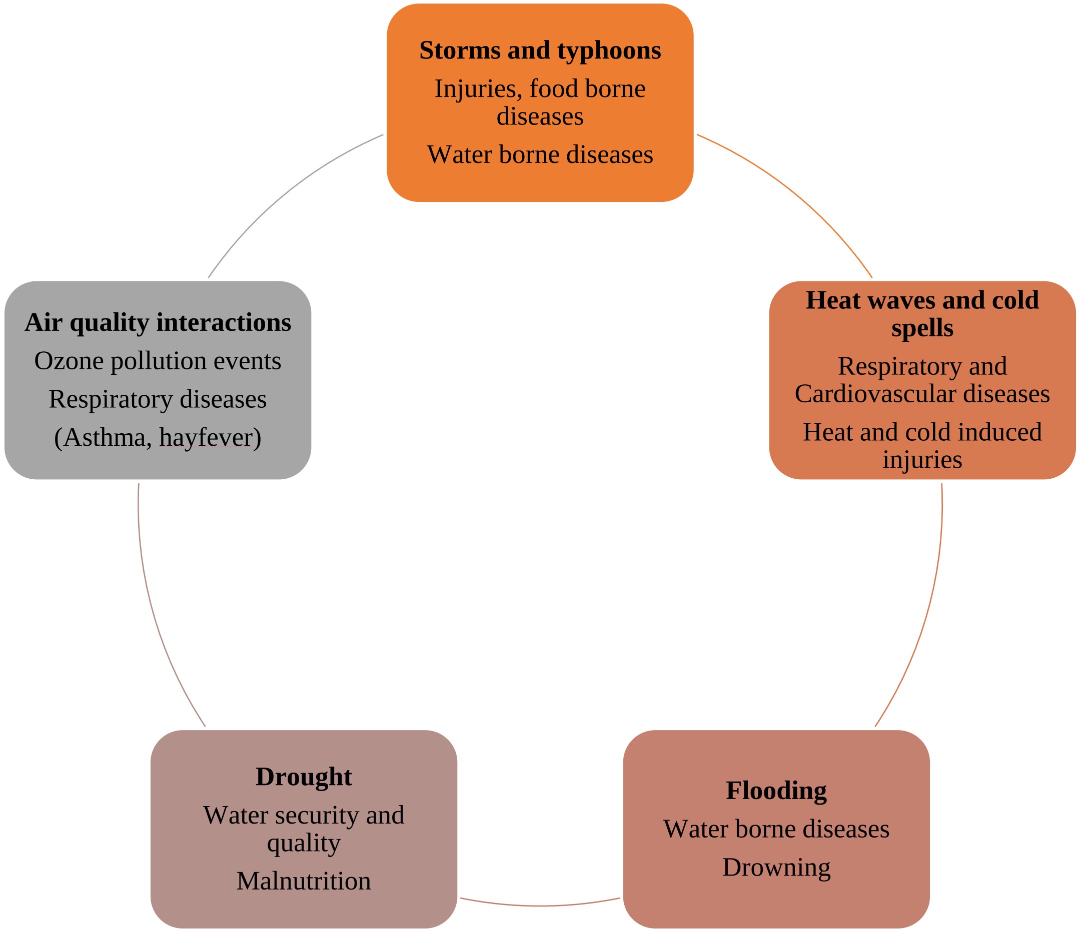

Table 2: Climate change impacts and impacts on health

Climate Change Impacts on Health				
Storms and Typhoons	**Heatwaves and Cold Spells**	**Flooding**	**Drought**	**Air Quality Interactions**
Increased number of storms and typhoons, East China is strictly affected (Lu and Zhao 2013)	Increase in frequency (Luber and McGeehin 2008; Robinson 2001), less attention given to cold spells (Staddon et al. 2014)	Have led to the highest number of mortalities in the 20th century (O'Connor and Costa 2004)	1900-2012, people in China severely affected by drought (Stanke et al. 290 2013)	Respiratory infections, cardiovascular diseases, and lung cancer (Arceo et al. 300 2016; Currie and Neidell 2005; Currie et al. 2009)
Guangdong, potential loss in economy and health(Kang et al. 2015)	Vulnerable population groups susceptible to extreme temperatures, both hot and cold (Davídkovová et al. 2014; Tian et al. 2012; Li et al. 2016; De'Donato et al. 2013; Ma et al. 2013)	Flooding is of great concern to the different levels of Chinese government (Zhang and Liu 2006)	Malnutrition and mortality, water-related diseases, airborne and dust-related diseases, vector borne diseases; mental health effects (Stanke et al. 2013)	Air pollutants-increase the risk of coronary heart disease mortality and respiratory problems (PM10, PM2.5) (Zhao et al. 2017; D'Amato et al. 2013)
Increased risk of transmitted infectious diseases (Zheng et al. 2017; Kang et al. 2015)	Extreme heat can cause heat stroke and dehydration, as well as cardiovascular, respiratory, and cerebrovascular disease risks (Yao-Dong et al. 2013; Zeng et al. 2014).	East China is severely affected by floods throughout the history (Zhang 2012)	Northwest, North, and Northeast of China -increase in droughts frequency (Yu et al. 2014)	PM_{10} induced health losses are evident in China (Zhang et al. 2008)
Public health risks and impacts of a tornado in Funing, East China elderly (75-84 year group) with highest risk of death (Wang et al. 2017)	Metropolitan areas in the Pearl River Delta are at risk of extreme heat (Yao-Dong et al. 2013)	East China-measuring 130,000km2 was flooded resulting in health impacts including injuries (Gautam and Van Der Hoek 2003; Ye and Glantz 2005; Jonkman 2005; Shao-Hong et al. 2012)		$PM_{2.5}$ is positively related to daily mortality of people especially of older adults (Schwartz 2000)
	5 % excess deaths were linked with heat waves in 66 Chinese communities, with the highest excess deaths in North East and South China (Ma et al. 2015)	Drowning, injuries, hypothermia are direct impacts of flood (Du et al. 2010)		In Beijing some severe haze events were studied (Gao et al. 2015; Yin et al. 2015).
	Increased heart disease mortality in China is linked with extreme temperatures (Guo et al. 2012)	People with limited physical capacity or limited mobility are at particularly high risk (Galea et al. 2005; Jonkman and Kelman 2005)		Respiratory and cardiovascular hospitalization are associated with the dust events after adjusting 319 the effect of sulphur dioxide and/or nitrogen dioxide (Pan and Liu 2011; Wang et al. 2004)
	Cold spells lead to increases in patients with fractures due to icy ground(Yao-Dong et al. 2013)	China's coastal region (East China) is physically vulnerable to coastal flooding (Wang et al. 2011; Ahern et al. 2005; Fang et al. 2017; Zhang et al. 2002; Lilai et al. 2016; Wang et al. 2012a)		