Relationship Between Climatic Factors and Regional Drowning Mortality in China

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Research Article

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Abstract

Drowning is the leading cause of death for young people. For a long time, drowning mortality is much higher in southern China than in northern China. Climate of the two parts of China are quite different. The aim of this study is to explore relationship between precipitation, temperature in summer, water system distribution and higher mortality rate of drowning in southern China than in northern China. We collected geographical distribution of drowning mortality, precipitation, temperature, population density, water system and income of China. Statistical tests were performed to find if there are any statistical difference of drowning and its influencing factors between northern and southern China. We conducted a logistic regression to evaluate the association between drowning and climatic factors. Life expectancy lost caused by drowning in northern and southern China were calculated. Abundant water system and plenty precipitation (OR: 1.589, 95%CI: 1.350 ~ 1.871), hotter summer (OR: 1.252, 95%CI: 1.075 ~ 1.459) and longer summer (OR: 1.357, 95%CI: 1.161 ~ 1.585) in southern China leaded to significantly higher drowning compared with northern China, especially for children. Life expectancy lost caused by drowning in southern China in 1990 and 2013 was 0.492 and 0.162 year, respectively, while the data in northern China is 0.245 and 0.101 year, respectively. High temperature in summer and low economic performance in part of Xinjiang are key reasons for its high ranking in drowning mortality, despite the fact that Xinjiang is located in northern China. Climatic factors formed higher mortality of young people in southern China. Our findings suggest decision-makers of different region should take more adaptive and effective measures to reduce drowning risks.

1 Introduction

The geographical distribution of climatic factors can deeply influence health, mortality and longevity of human beings. Among the climatic factors, temperature, air pressure, precipitation and flood, air quality and air contamination, humidity, etc. are crucial factors for health and death. The relationship between ambient temperature and death is well studied, both extreme high temperature and low temperature resulting extra mortality all over the world. 14.33% of non-accidental total mortality was attributable to non-optimum temperatures in China, of which cold and heat temperatures corresponded to attributable fractions of 11.63% and 2.70% (Chen et al., 2018). Humidity is an important factor that can adjust the risk of temperature on mortality (Huang, et al., 2015; Barreca, et al., 2011). Research showed that atmospheric pressure was positively associated with lung cancer mortality rates (Merrill, et al., 2018).

Studies are mainly focusing on direct influence of climate on disease and mortality, especially in temperature related disease (i.e. cardiovascular and respiratory diseases) mostly occurred in elderly. But climate also have some indirect impact on mortality that are not caused by disease. Drowning is leading cause of death in young people, especially in low-income and middle-income countries (World Health Organization, 2014). Current studies on drowning are concentrated in epidemiological characteristic (i.e. age, sex, position) (Wang, et al., 2017; Claesson, et al., 2021; Alkhalaf, et al., 2021), clinical treatment (Roberts, et al., 2021) and social risk factors (poverty, the education of their parents, children with full-time or part-time care, safety education, etc.) (Xu, et al., 2019; Liu, et al., 2019). Different from social factors of

drowning that can be changed by economic performance, natural risk factors can prove a decisive force of drowning between regions with same development stage.

The main objectives of this study are: 1) Explaining why young people in southern China are easier to die compared with those living in northern China. 2) Studying the relationship between regional climatic factors and drowning mortality in China and giving corresponding suggestions. 3) Calculating life expectancy lost caused by drowning in China.

2 Data And Methods

2.1 Data Collection

Mainland China has 31 provinces with the north-south boundary of China being Qingling Mountain and the Huai River, southern and northern China each containing 15 provinces with Tibet not included in either northern or southern China, because average elevation in Tibet is over 4500 m, and its temperature is lower than most northern provinces of China. The provinces of northern China and southern China are illustrated in Fig. 1.

(1) Age-specific drowning mortality rate.

About 63 724 persons died from unintentional drowning in China in 2016, accounting for 21% of global drowning deaths (GBD 2016 Causes of Death Collaborators, 2017). We collected age-specific mortality rate of drowning in China in 1990 and 2013 from national disease monitoring system of China, national maternal and child health monitoring network, China CDC (Centers for Disease Control and Prevention) death cause registration and reporting information system, and related study (Deng, et al., 2017).

(2) Monthly mortality data of young people in China.

As the first cause of death for 1–14 years people, drowning contributed half of 1–14 years all-cause mortality in 1990. Drowning has close links with seasons, we collected monthly mortality data of young people in China from the fourth China population census data conducted in 1990.

(3) Data of precipitation, temperature, per capita income, population density, water system

To explore why drowning mortality rate is much higher in southern China than in northern China, and why Xinjiang has highest drowning mortality rate, relevant factors that may influence drowning were collect. Most of drowning incidents occurred in natural waters (ponds, canals, streams, rivers, reservoirs, lakes, etc.) and agricultural water sources (aquaculture water sources, irrigation water sources) (Wang, et al., 2018; Guo, et al., 2009), while close to waters is a very important risk factor for drowning (especially for rural areas), 71.6% of the dead lived within 100m of a body of water, and fatal drowning mainly occurred in summer, it may be because temperature is higher in summer and children usually swim (Wang, et al., 2020; Wallis, et al., 2015). Other study also found hot temperatures and abundant rainfall increases the probability of drowning, children who were always swimming or playing near the water have a higher risk

of fatal drowning (Liu, et al., 2019). In summary, precipitation, proximity to water system, per capita income, temperature in summer and the duration of summer are selected to study spatial differential of drowning in China.

For the above mentioned reasons, six kind of data were collected, the spatial data of annual precipitation, annual temperature in July, annual number of days that mean temperature is above 25 centigrade were obtained from the China Meteorological Data Network (http://data.cma.cn). Daily temperature data of 839 temperature monitoring stations across the country from 2000 to 2019 were collected. The data of per capita income was obtained from the China and provincial Statistical Yearbook (http://www.stats.gov.cn/tjsj/ndsj/), the 1km×1km population density grid map and the map of river and lake systems were collected from Resource and environment science and data center (http://www.resdc.cn) owned by Chinese Academy of Sciences, a total of 110 596 rivers and 134 650 lakes and reservoirs were collected.

2.2 Methods

(1) Normal-test and T-test

The statistical tests were performed to find if there are any statistically difference of life expectancy, drowning and climatic factors between northern and southern China.

(2) Calculation of proximity to water system

Residents live near water system are tend to swim in summer, especially in hot temperature, the indicator of proximity to water system are determined by three parameters, water system density (including rivers, lakes, reservoirs, etc.), population density, the distance between residential area and water system. Kernel density was used to calculate density of lakes and reservoirs, and line density was used to calculate density of rivers, the proximity to water system can be calculated in Eq. 1.

$$PW_i = P_i \times K_i \times L_i \qquad (1)$$

Eq. 1. PW_i, proximity to water system in grid i; P_i, population density in grid i (1 km ×1 km); K_i, kernel density of lakes and reservoirs in grid i (1 km ×1 km); L_i, line density of rivers in grid i (1 km ×1 km).

(3) Logistic Regression

Logistic Regression was applied to quantify the association between temperature in summa, per capita income, precipitation, proximity to water system and drowning rate, the Logistic Regression was as follows:

$$P(y = 1 \mid x) = \frac{e^{\alpha+\beta x}}{1+e^{\alpha+\beta x}} \qquad (2)$$

Where α is constant term, β is coefficient of x.

(4) Calculation of life expectancy reduce caused by drowning between northern and southern China

Life expectancy refers to life remaining at birth, which is an estimate of the average expected life-span under certain conditions according to the current mortality rates, life expectancy is calculated by age-specific mortality rate, mortality rate at young age and old age are both have crucial influence on life expectancy. The life expectancy lost caused by drowning between northern and southern China were calculated.

3 Results

3.1 Spatial distribution of drowning and climatic factors.

Figure 2 shows the spatial character of drowning in China. Mortality rate of drowning is higher in southern China with much precipitation and higher density of river and lake system, especially in inland less developed region, suggesting that precipitation, water system and economic performance are crucial factors of drowning, the 2nd-10th in ranking of drowning mortality among 31 provinces are located in the south. In addition, mortality rate of drowning in Xinjiang Uygur Autonomous Region (located in northwestern Chia) is ranked first place in China, despite rare precipitation in Xinjiang.

Figure 3 shows the monthly proportion of death in China with different ages, young people in China were easier to die in summer, especially in July, the month with highest temperature in China, followed by June an August. As the first cause of mortality of Chinese young people, drowning is compactly associated with temperature.

Figure 4 shows mean half-month temperature from May to October in different zones, summer in the south subtropical zone (southern China) is longer than six months every year, the temperature is suit for swimming and water related playing during May to October. Summer in south Xinjiang and north-middle subtropical zone (Yangzi river basin) is as long as four or five month, although it is shorter than the south subtropical zone, the temperature in July and August usually even hotter compared with south subtropical zone.

Figure 5 shows the distribution of provincial annual precipitation, temperature in July, population density, river system, lake and reservoir system, per capita income in China. Precipitation decreases from southeastern China to northwestern China, spatial character of temperature in July is not entirely consistent with precipitation, highest temperature in July is not located in southern China, but in the south-central China (Hunan province, Jiangxi province, Fujian province and Zhejiang province), which is covered by the subtropical high and has several days of mean temperature more than 35°C almost every year in July. Another center of hot summer is southern Xinjiang Uygur Autonomous Region because of its special terrain and underlying surface, which is located in northwestern inland China. Density of water system is higher in southern China than in northern China. Precipitation is the main source of rivers and

lakes, plenty of precipitation shapes developed water system in southern China, especially in the Yangzi river basin. There is no significantly north-south difference of per capita income in China, the coastal region, both the north and the south, have a higher per capita income than the central and western China.

3.2 The statistical difference in drowning and climatic factors between northern and southern China

In order to find if there is any statistically significant difference between the two parts of China, normal-test and T-test were performed and the results of drowning mortality rate, precipitation, temperature in July, income between northern and southern China are shown in Table 1.

Table 1
Drowning, precipitation, temperature, and income between northern and southern China

	Drowning 1990	**Drowning 1990, 1–4**	**Drowning 1990, 5–14**	**Drowning 2013**	**Drowning 2013, 1–4**	**Drowning 2013, 5–14**
T-value	-3.453	-2.825	-2.359	-3.552	-1.456	-2.352
P-value	0.002**	0.009**	0.026*	0.001***	0.157	0.026*
	Precipitation	Temperature In July	Income 03–18	Temperature > 25℃	proximity to water	
T-value	-10.317	-4.091	-0.574	-4.845	-2.396	
P-value	0.000***	0.000***	0.570	0.000***	0.024*	
* Significant at p < 0.05 level, ** significant at p < 0.01 level, *** significant at p < 0.001 level.						

Table 1 shows that per capita income keeps balance between northern China and southern China. Drowning mortality, precipitation, temperature, proximity to water are statistically lower in northern than in southern China.

3.3 Relationship between precipitation, proximity to water system, temperature in summer, per capita income and drowning

To quantitatively study the relationship between climatic and comprehensive factors and drowning, precipitation, proximity to water system, temperature in summer, per capita income were chosen as the

independent variable, drowning mortality rate in 2013 were chosen as dependent variable. A logistic analysis of factors and drowning mortality rate calculated odds ratio (OR) and its 95%CI, as illustrated in Table 2.

Table 2
Relationship between precipitation, economy, temperature, proximity to water system and drowning mortality rate

	precipitation	**proximity to water system**	**temperature in July**	**temperature > 25°C**	**per capita income**	**per capita GDP**
P-value	0.000***	0.170	0.004**	0.000***	0.000***	0.000***
OR	1.589	1.111	1.252	1.357	0.467	0.471
95% CI	1.350 ~ 1.871	0.956 ~ 1.291	1.075 ~ 1.459	1.161 ~ 1.585	0.388 ~ 563	0.391 ~ 0.567
* Significant at p < 0.05 level, ** significant at p < 0.01 level, *** significant at p < 0.001 level.						

3.4 Calculation of life expectancy reduce caused by drowning

Life expectancy lost caused by mortality of drowning is 0.245 ± 0.067 year in northern China and 0.492 ± 0.089 year in southern China in 1990, the data dropped to 0.101 ± 0.027 in northern China and 0.162 ± 0.018 year in southern China in 2013. The provincial map is illustrated in Fig. 6. There is an apparent boundary of life expectancy lost caused by drowning between southern and northern China, the middle streme and upstream of Yangzi river basin with developed water system, hot summer, plenty precipitation and low income suffered most by drowning.

4 Discussion

This is the first published study, to our knowledge, to investigate regional difference in climate on drowning mortality in China. Drowning is the first major cause of young people (< 14 year) in China, according to China Health Statistics Yearbook in recent ten years (2008–2017), about one quarter of 1–14 years child died of drowning.

Precipitation, duration and temperature in summer, river and lake density, regional development level are crucial factors of drowning, as one of the biggest country in the world, land of China covers a range of 4000 kilometers from the north to the south and climate varies a lot, annual precipitation varies from less than 200 millimeter in northwestern China to more than 2000 millimeter in southeastern China, with a fluctuation of as much as 1800 millimeter. Southern China has abundant water bodies, while northern China has serious problem of water shortage. This study found precipitation is the primary leading factor

of north-south difference in drowning mortality (OR: 1.589, 95%CI: 1.350 ~ 1.871), precipitation and water system are direct reason for drowning, precipitation in China are concentrated in summer, especially in the Yangtze River basin in June and July, it is called “rainy season”. In addition, southern China usually suffered by typhoon (a very violent tropical storm) in summer and autumn that is generate in tropical Pacific Ocean, rainy season and typhoon brings short term heavy rainfall that always lead to flood. The soared water level and violent water flow increase proportion of drowning of local residents.

Temperature in summer (OR: 1.252, 95%CI: 1.075 ~ 1.459) is easy to be ignored, average temperature in July varies from 19 centigrade in northeastern China to 31 centigrade in the south. Swimming is one of main causes of drowning, people prefer to swim to against hot temperature in summer, especially for children, they always play in the water body together, water temperature in southern China is suitable for swimming and playing, while low atmospheric temperature resulting lower water temperature and less drowning mortality rate. Water temperature in northern China is cold for swimming and playing. Temperature in summer can be used for explaining why Xinjiang Uygur Autonomous Region is the single northern province that has high ranking in drowning mortality, different from other northern provinces, average temperature in July in southeastern Xinjiang can be 33 centigrade because of the unique terrain, the temperature is even higher than hottest province in southern China (Fig. 5), higher temperature increases the probability of water loving.

Per capita income is a crucial factor to decrease drowning, the OR is 0.471 (95CI%:0.391 ~ 0.567) in this study. The result is in accordance with formal studies about urbanization and drowning, drowning mortality rate in rural place and less developed region is much higher than urban and developed region. Urbanization could affect the risk of drowning in many ways (Wang, et al., 2018). Urbanization would reduce people’s access to natural waters because there are many swimming pools in city. Urbanization increases income and drowning rates vary inversely with per capita income (carter, et al., 2011; baca, et al,. 1988). In addition, safety and first aid education in urban is more adequate than rural place, 83.1% of rural residents had no knowledge of first aid skills for drowning (Wang, et al., 2020). Western China with lower per capita income has a higher drowning mortality although some western provinces are not so hot and rainy. There is no statistical difference of per capita income and urbanization rate between northern and southern China (Table 1), therefore, they are not main reason for the north-south difference in drowning.

Distance between residence and water system is also an important factor, the young people are more likely to swim if they live near the water system. But the result of this study doesn’t find statistically significant evidence (OR: 1.111, 95%CI: 0.956 ~ 1.291). This may attributed to the reason that the resolution of our data is too large to find meaningful results, the drowning incidents usually occurred within 100 meters of a body of water (Wang, et al., 2020), but the resolution of our data (i.e. population density) is 1kilometer, the distance is too long for children to find a natural water body.

Children and teenagers are high-risk age groups of drowning because they are curious and motivated with high-frequency wide-range activities and a lack of self-safety awareness (Wang, et al., 2018).

Abundant water resources and higher temperature increases drowning mortality of young people in southern China. With society and economy development of China, mortality rate attributed to drowning will continuously decrease in future, but drowning mortality will still higher in southern China than in northern China in future because of plenty rainfall and higher temperature.

Therefore, we can conclude that the spatial heterogeneity of regional drowning mortality could be attributed to comprehensive effects from multiple climate-economy factors. Consequently, it is indispensable for local government to prevent drowning according to local temperature performance. For example, southern China should take longer defense measurements because the daily mean temperature is above 25 centigrade as long as six month (May to October); the Yangzi river basin and south Xinjiang should pay attention to hottest temperature (usually above 30 centigrade) in July and August. The central government should take more effective measures to mitigate economic inequality in China, which will be helpful to ensure the appropriate measures would be taken in low income regions to better respond to drowning, especially in western China.

There are some limitations of this study. For example, the periods of drowning and risk factors are not entirely consistent with each other, which affects the accuracy of the results.

5 Conclusion

1 Drowning mortality rate is statistically higher in southern China than in northern China, drowning caused 0.247 and 0.061 year of extra life expectancy lost in southern China compared with northern China in 1990 and 2013, respectively.

2 Precipitation and temperature are key factors resulting north-south disparity of drowning, high temperature in summer resulting leading ranking of drowning mortality rate in Xinjiang although it is located in northwestern China.

These findings suggest that the government in China should take more positive and efficient adaptions, especially balance regional economic development, to ensure a few well-directed method and reduce the adverse effects of climate on drowning.

Declarations

Funding

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Conflicts of interest/Competing interests

The authors declare that they have no competing interests.

Availability of data and material (data transparency)

The datasets generated during and/or analysed during the current study are available in the http://data.cma.cn, http://www.stats.gov.cn/tjsj/ndsj/, http://www.resdc.cn, https://www.cnki.net/.

Code availability

Not applicable

Authors' contributions

Yi Huang and Hujing Shi collected the data and drew the maps. Yi Huang and Jin Zhang designed ideas of the paper and were major contributors in writing the manuscript.

Ethics approval (include appropriate approvals or waivers)

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

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Figures

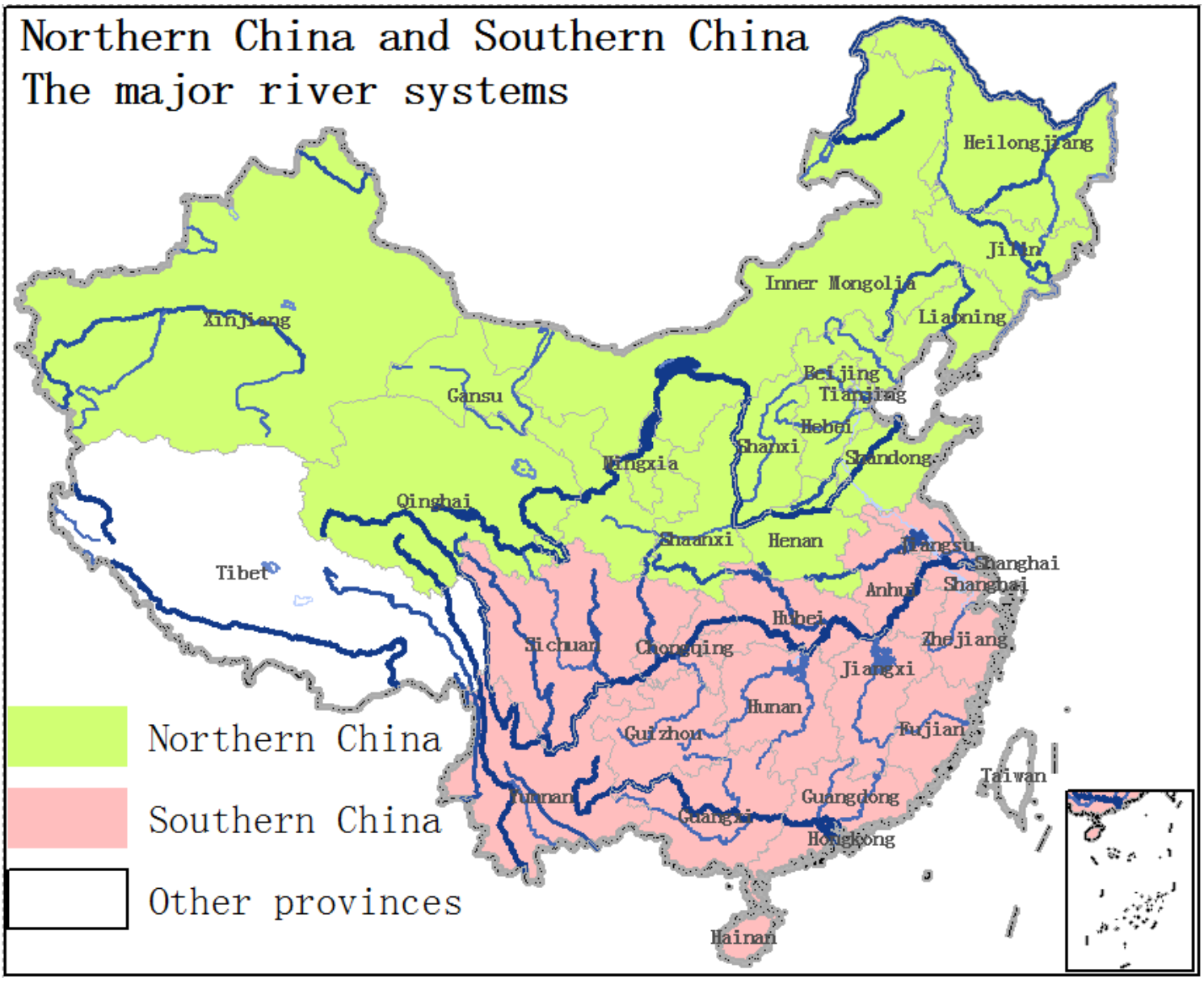

Figure 1

Northern China and Southern China

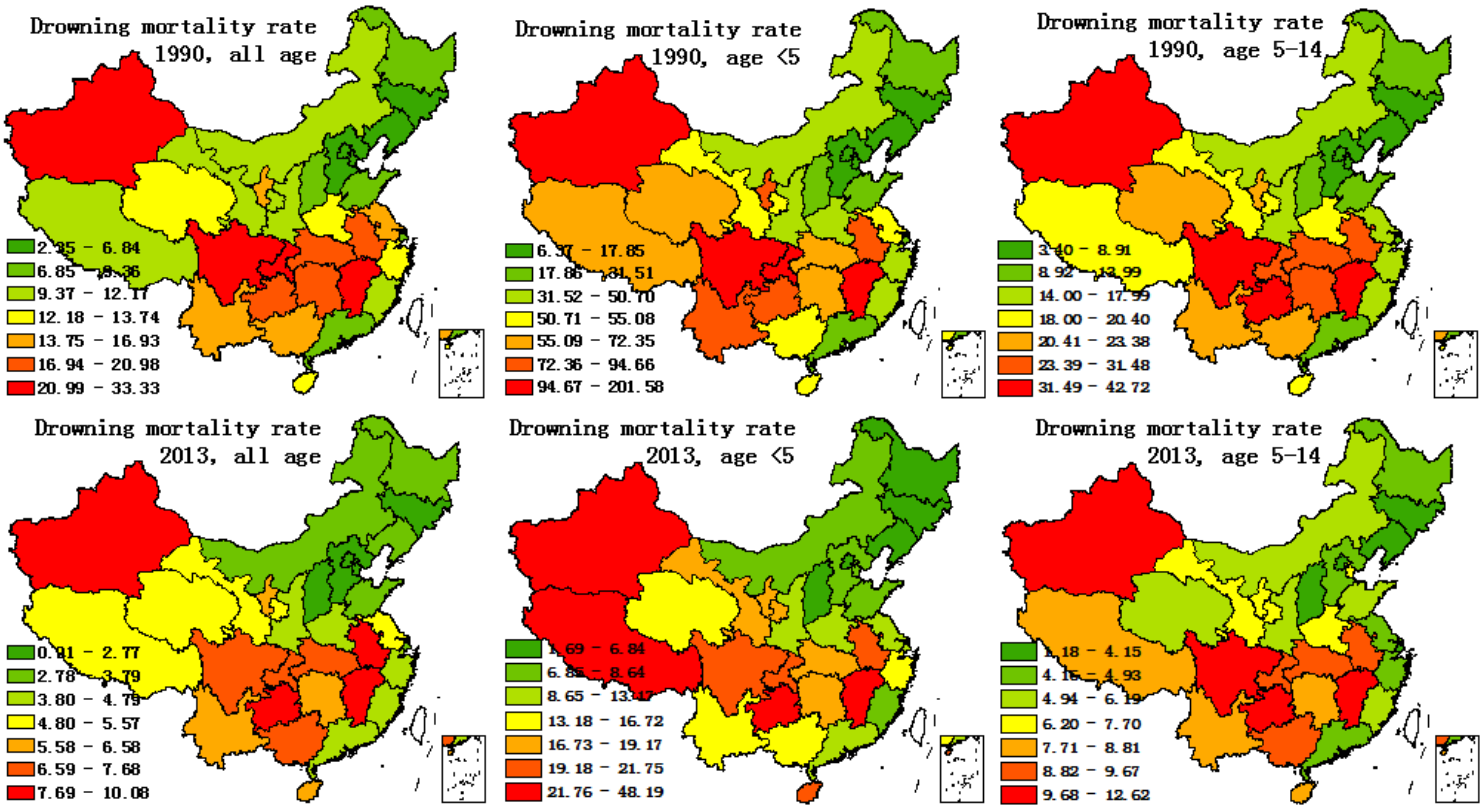

Figure 2

Distribution of standardized and age-specific mortality rate of drowning in 1990 and 2013 (1/100 000)

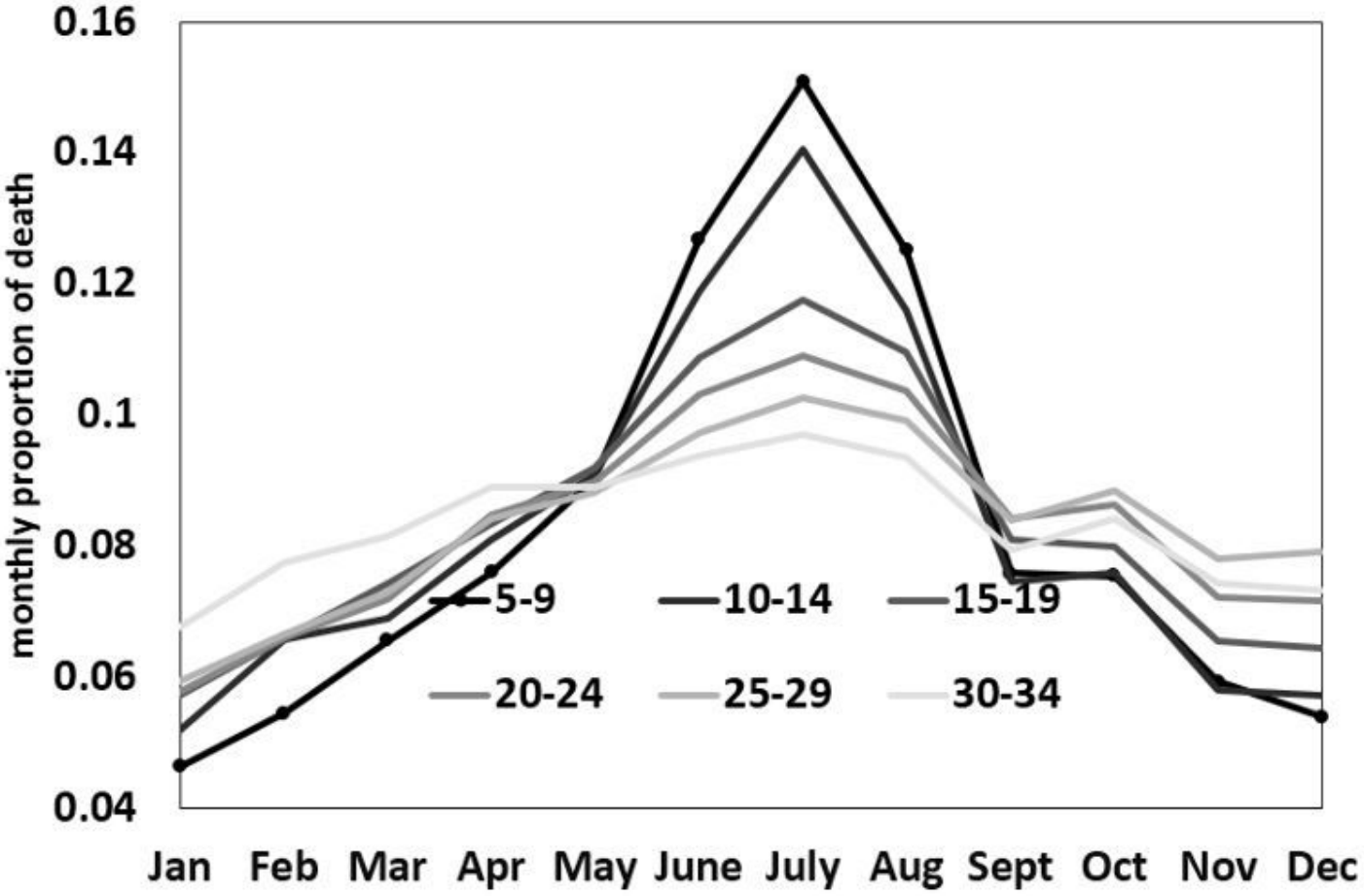

Figure 3

Age-specific monthly proportion of death in China (668 thousand people)

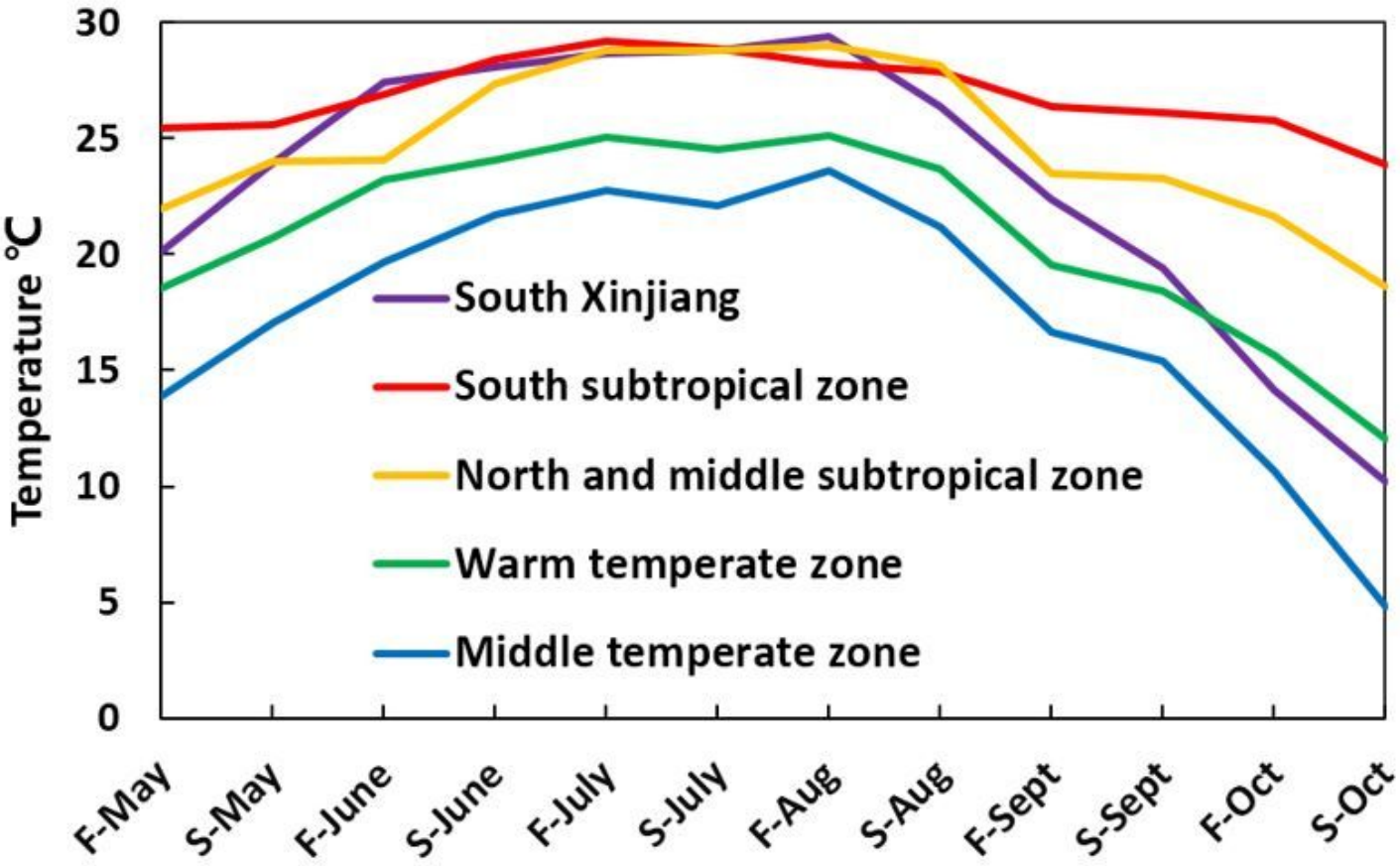

Figure 4

Mean temperature of different zone every half month (2000-2019), F: first half, S: second half

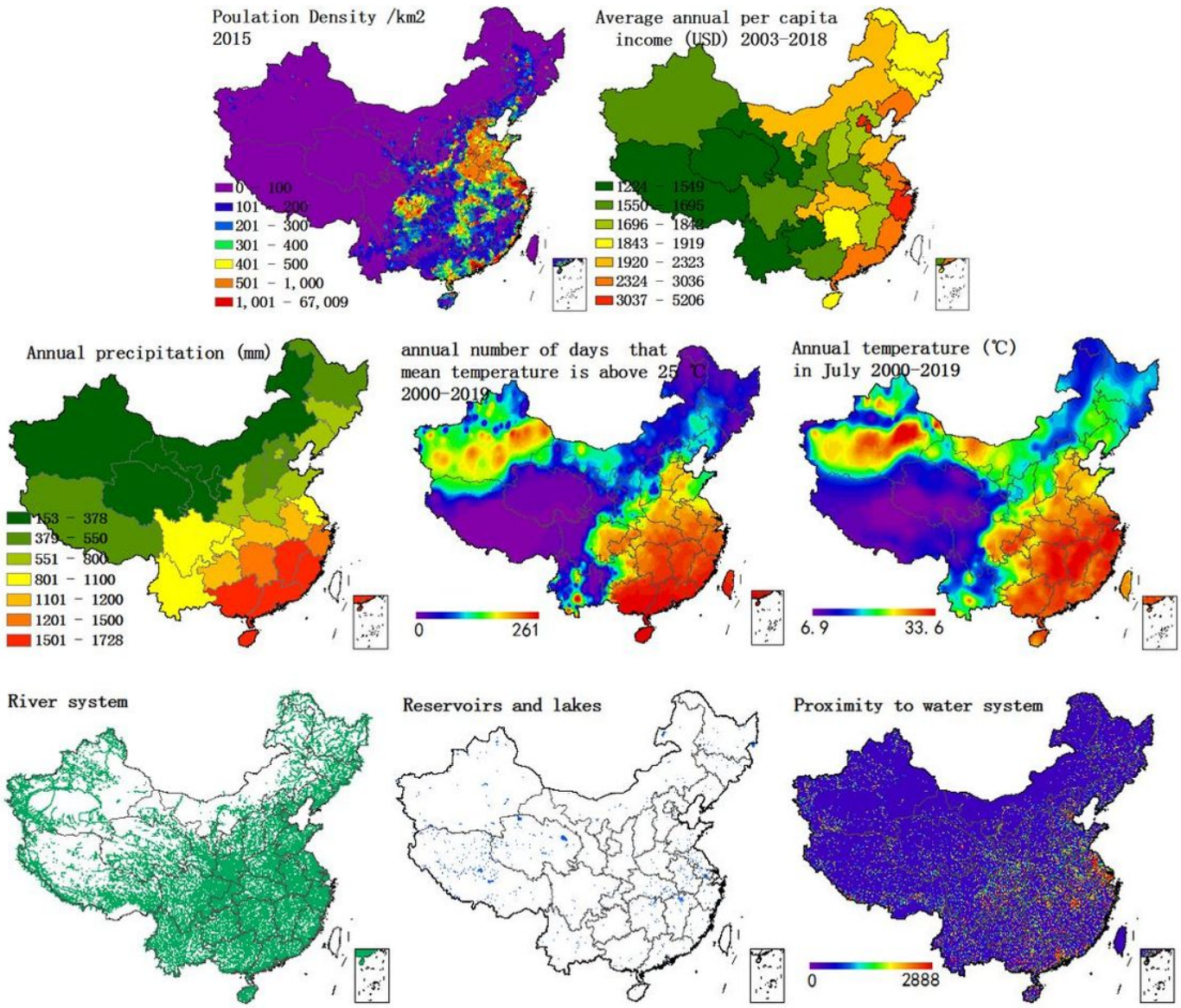

Figure 5

Distribution of provincial annual precipitation, temperature in July, population density, water system and per capita income in China

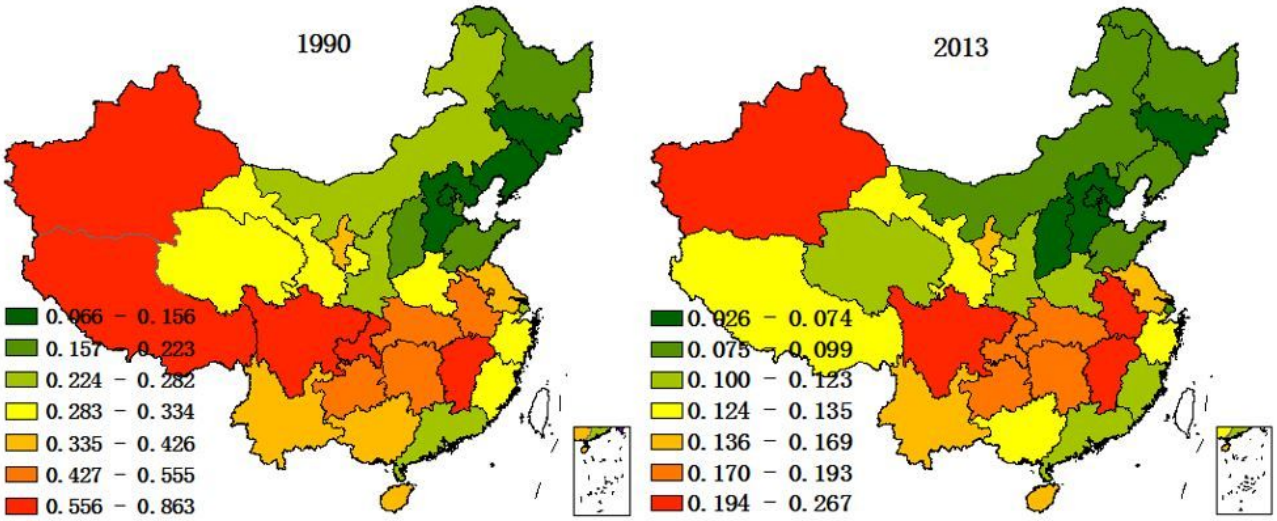

Figure 6

life expectancy lost caused by drowning (year)