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Projected burden of disease for bacillary dysentery due to flood events in Guangxi, China

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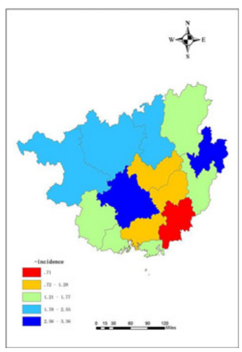
HIGHLIGHTS

- Floods would increase in severity and frequency in the future.
- To quantify the relationship between the morbidity of bacillary dysentery and floods
- To project the burden of bacillary dysentery relate to floods based on various scenarios
- Floods-related health burden of bacillary dysentery may increase in the future due to change in climate.

GRAPHICAL ABSTRACT



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ABSTRACT

Many researchers have been studying the influence of floods on intestinal infection in recent years. This study aimed to project the future disease burden of bacillary dysentery associated with floods in Guangxi, China. Relying on the longitudinal data, a generalized additive mixed model was applied to quantify the relationship between the monthly morbidity of bacillary dysentery and floods with two severity levels from 2004 to 2010, controlling for other meteorological variables. Years Lived with Disability (YLDs) was used as the measure of the burden of bacillary dysentery in the future of Guangxi, China. According to the generalized additive mixed model, the relative risks (RR) of moderate and severe floods on the morbidity of bacillary dysentery were 1.17 (95% CI: 1.03–1.33) and 1.39 (95% CI: 1.14–1.70), respectively. The regression analysis also indicated that the flood duration was negatively associated with the morbidity of bacillary dysentery (with RR: 0.63, 95% CI: 0.44–0.90). Considering the effects of floods only, compared with the YLDs in 2010, increasing flood events may lead to a 4.0% increase in the YLDs for bacillary dysentery by 2020, 2100, 0.0% by 2050, and an 8.0% increase by 2030 in Guangxi, if other factors remain constant. Considering all potential changes include floods, temperature and population size, the YLDs for bacillary dysentery may increase by up to 16.0% by 2020, 20.0% by 2030, 2050, and 0.0% by 2100, compared to that in 2010 under the moderate flood scenario; Under the severe flood scenario, the YLDs for bacillary dysentery may increase by up to 16.0% by 2020, 20.0% by 2030, 2050, and 4.0% by 2100.

1. Introduction

Occupying 50% of various natural hazards around the world, floods are regarded as a common and serious type of natural hazard

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(Alderman et al., 2012; Wakuma Abaya et al., 2009; Feng et al., 2007). As some studies predicted, with the increasing higher sea levels and more server and frequent precipitation under future climatic variations, floods would increase in severity and frequency (Cao et al., 2013; Ramin and McMichael, 2009). China is a country susceptible to various natural hazards, where flooding accounts for a major meteorological disaster affecting many areas (Xu et al., 2014). A study suggested that the population exposed to floods shows a significantly increasing trend in all provinces of China (Wang et al., 2015).

The effects of floods are widespread and complicated, including increased deaths and incidence of bacillary dysentery. Resulted from *Shigella* bacteria, bacillary dysentery refers to a kind of bacterial infections in intestines causing serious diarrhea. This infection is spread from person to person via oral-feces route, food or drinking water (Nie et al., 2014). This is still a main health issue all over the world, particularly in a few developing countries (Kosek et al., 2003). As the National Report of Notifiable Diseases from the Ministry of Health of China reveals, bacillary dysentery is among the top three notified infectious diseases (Zhang et al., 2012). Though the Chinese government has carried out a tactic plan for the state supervision of bacillary dysentery, the health burden from the bacillary dysentery still has increased recently (Zhong et al., 2010).

In the past decade, many researchers have studied the association between meteorological factors and bacillary dysentery (Ma et al., 2013; Gao et al., 2014; Zhang et al., 2012). For example, several researchers deem that the floods caused by heavy precipitation are likely to impact the death rate and incidence of bacillary dysentery (Alderman et al., 2012; Du et al., 2010; Ahern et al., 2005). Moreover, another study shows that the incidence of bacillary dysentery tends to affect more people through transmitting and infecting the pathogens after floods (Kondo et al., 2002). However, few studies have been performed to project the future disease burden for bacillary dysentery associated with floods in China. Therefore, the aim of the study was not only to quantify the correlation between the incidence of bacillary dysentery and floods, but also to project the burden of bacillary dysentery relate to floods in Guangxi based on various scenarios.

2. Materials and methods

2.1. Study area

Guangxi is in the Pearl River basin of southern China (Fig. 1), from 20°54′ to 26°23′N and 104°29′ to 112°03′E. It is located in the tropical and subtropical monsoon region, suffered from flood disasters frequently. Average annual temperature is 17–23 °C, and average annual precipitation is 1250–1750 mm. In Guangxi, a considerable burden of bacillary dysentery still exists though the morbidity and the mortality of bacillary dysentery have decreased considerably since the 1990s (Nie et al., 2014). Therefore, bacillary dysentery is still a public health problem in the area. In this study, all the prefecture-level cities of Guangxi, which include Baise, Hechi, Liuzhou, Guilin, Chongzuo, Nanning, Laibin, Hezhou, Wuzhou, Guigang, Yulin, Qinzhou, Beihai and Fangchenggang, were selected as our study areas.

2.2. Data collection and management

2.2.1. Disease surveillance data

The study collected monthly disease data of bacillary dysentery between January 2004 and December 2010 from the National Notifiable Disease Surveillance System (NDSS). According to the DNSS, bacillary dysentery refers to the group of some diseases resulted from Shigellae, with the typical clinical manifestations like stomachache, fever, bloody stool and tenesmus. In our study, all bacillary dysentery cases were defined based on the diagnostic criteria and principles of management for dysentery (GB 16002-1995) launched by the Ministry of Health of the People's Republic of China. Only the cases identified by both biochemical identification and microscopy were chosen in this research. Listed as a statutory notifiable category B infectious disease in China, bacillary dysentery cases must be reported to local health organizations if found. Subsequently, the local health organizations need to report to those to a higher degree of organizations immediately within one day (WOHC, 2006). Hence, it is assumed that the disease notification of the research duration is consistent.

2.2.2. Data on floods

The yearbooks of meteorological disasters specifically recorded the incidence, mortality, disaster-stricken areas, and economic loss of flood events between 2004 and 2010 (China Meteorological Administration, 2004–2012). All flood events which were reported by the Yearbooks of Meteorological Disasters from 2004 to 2010 in the study area were included in the study. In consideration of the limitation of the meteorological data and the requirements of the project group, the scenarios of flood events in 2020, 2030, 2050 and 2100 were projected based on the daily precipitation. According to the flood classification defined by the Comprehensive Study Group of Major Natural Disasters of the State Science and Technology Commission in China, a

Fig. 1. Administrative map of Guangxi, China.

Table 1
Future demographic and temperature changes in Guangxi.

Years	Population size	Temperature change (°C)
2010	46,026,600	–
2020	48,150,497	0.59
2030	48,586,301	0.82
2050	46,269,849	1.24
2100	34,474,136	1.68

moderate flood is a natural disaster that cumulative rainfall of >80 mm for three consecutive days or 250 mm for ten consecutive days; cumulative rainfall of >150 mm for three consecutive days or 350 mm for ten consecutive days is defined as a severe flood (Ding et al., 2013). In this study, the flood scenarios included both moderate floods and severe floods. Based on the daily precipitation in 2020, 2030, 2050 and 2100 and the definition of the flood events, scenarios for floods in 2020, 2030, 2050 and 2100 could be developed.

2.2.3. Meteorological data

Monthly meteorological data were collected from the China Meteorological Data Sharing Service System (http://cdc.nmic.cn/home.do). The meteorological variables included monthly cumulative precipitation (MCP), monthly average temperature (MAT), monthly average relative humidity (MARH), and monthly cumulative sunshine duration (MCSD).

The projected meteorological data were obtained from the China Meteorological Data Sharing Service System, which were projected by a coupled climate model MIROC (Model for Interdisciplinary Research on Climate), which was developed cooperatively by CCSR (Center for Climate System Research, University of Tokyo), NIES (National Institute for Environmental Studies), and FRCGC (Frontier Research Center for Global Change) of Japan. And the Representative Concentration Pathway 4.5 (RCP 4.5) was as the emission scenarios. A study showed that MIROC is the best model to capture and simulate the characteristics of Chinese climate (Wang and Yu, 2013).Many climate researchers have adopted Representative Concentration Pathways (RCPs) to project a range of possible futures of atmospheric composition (Meinshausen et al., 2011). RCP 4.5 is a set of climate scenarios for climate change assessments, which has projected the daily precipitation in 2020, 2030, 2050 and 2100 based on the medium level of greenhouse gas concentration and emission in the future (Thomson et al., 2011; Meinshausen et al., 2011). In RCP 4.5, the radiative forcing would increase steadily during the 21st century and stabilize at 4.5 W m^{-2} by the year 2100, which may be more suitable for China's national conditions in the future (Moss et al., 2010; van Vuuren et al., 2011). So the MIROC model and scenarios of RCP 4.5 were chosen as projections of the future climate.

2.2.4. Demographic data

Historical demographic data were obtained from the Center for Public Health Science Data in China (http://www.phsciencedata.cn/). The future demographic data were projected according to the estimation method of WHO. It provided a way to project the population size of China according to the projected population growth rate. In the study, we assumed that the population growth rate in the study area would be consistent with the population growth rate of China reported by the WHO.

2.3. Study design and statistical analysis

2.3.1. Estimating the risk of flood events

First of all, the study utilizes a descriptive analysis to illustrate the distribution of morbidity of bacillary dysentery from 2004 to 2010. Subsequently, Spearman's correlation was applied to evaluate the relationship between floods, meteorological factors, and the morbidity of bacillary dysentery with different lagged effects. The lagged value with the maximum correlation coefficient of each variable was included in the following regression analysis. Based on the latent period of bacillary dysentery as well as the living habits of the pathogen, a time lag between 0 and 2 months was taken into account (Kudaka et al., 2005).

Secondly, to examine the association between floods and the morbidity of bacillary dysentery, a Poisson regression with a generalized additive mixed model (GAMM) was established. The result of the residual test indicated no overdispersion, and therefore, Poisson regression was used to quantify the association between various degrees of floods and monthly morbidity of bacillary dysentery. As an extensively applied method, the generalized additive model (GAM) is an efficient approach for implementing linear or non-linear regression analysis in time–series research with a Poisson regression (Wood, 2004). The GAMM allow the parametric and nonparametric functions to be analyzed together. It has been widely applied in the studies of the association between meteorological variables and health outcomes (Zhang et al., 2014). A few studies revealed that meteorological factors, such as average relative humidity, average temperature, cumulative precipitation, and cumulative sunshine duration, were associated with diarrhoeal diseases (Gao et al., 2014; Chou et al., 2010; An et al., 2012). Hence, the GAMM model was used to assess the relationship between the morbidity of bacillary dysentery and flood variables with regulation for the several-lag effects of MAT, MCP, MARH and MCSD. Considering the high correlation between floods and flood duration, this study examined floods and flood duration using two separate models to avoid collinearity. The regression models were described as follows.

Model 1:

$$\begin{aligned}\mathrm{Ln}(\mathrm{Y_t}) = {} & \mathrm{Ln}(\text{population}) + \beta_0 + \beta_1(\text{floods}) + s_1(t) + s_2(\text{precipitation}) \\ & + s_3(\text{temperature}) + s_4(\text{humidity}) + s_5\,(\text{sunshine duration}) \\ & + s_6(\,\sin 2\pi t/12)\end{aligned}$$

Model 2:

$$\begin{aligned}\mathrm{Ln}(\mathrm{Y_t}) = {} & \mathrm{Ln}(\text{population}) + \beta_0 + \beta_1(\text{duration}) + s_1(t) \\ & + s_2(\text{precipitation}) + s_3(\text{temperature}) + s_4(\text{humidity}) \\ & + s_5\,(\text{sunshine duration}) + s_6(\,\sin 2\pi t/12)\end{aligned}$$

where Y_t signifies the monthly quantity of bacillary dysentery cases in time t, which stands for a certain month. Ln (population) was used as an offset to make the model appropriate for rate data. "Floods" was coded as a categorical variable, with 0, 1, and 2 referring to the various levels of floods, i.e. non-flood, moderate floods, and severe floods. s_2 (precipitation), s_3 (temperature), s_4 (humidity) and s_5 (sunshine

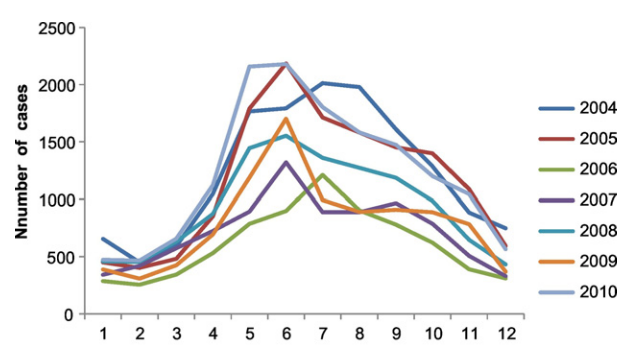

Fig. 2. Monthly distribution of bacillary dysentery in Guangxi, 2004–2010.

duration), were smooth functions of MCP, MAT, MARH and MCSD, respectively, which were designed to control the effect of confounding meteorological factors. To avoid the effect of long-term tendency, the smooth spline of specific month was projected as s1(t). Moreover, due to the seasonality of the disease (bacillary dysentery occurs more in summer and autumn), a sinusoidal term $\sin(2\pi t / 12)$ was incorporated in the models to control seasonal variations.

2.3.2. Projections of extra cases of bacillary dysentery

To estimate future YLDs for the study disease, the expected number of excess cases of bacillary dysentery attributable to different scenarios was needed. The temperature and population size, which may affect the number of excess cases, were also taken into account. Projected demographic and temperature changes in the study area are summarized in Table 1.

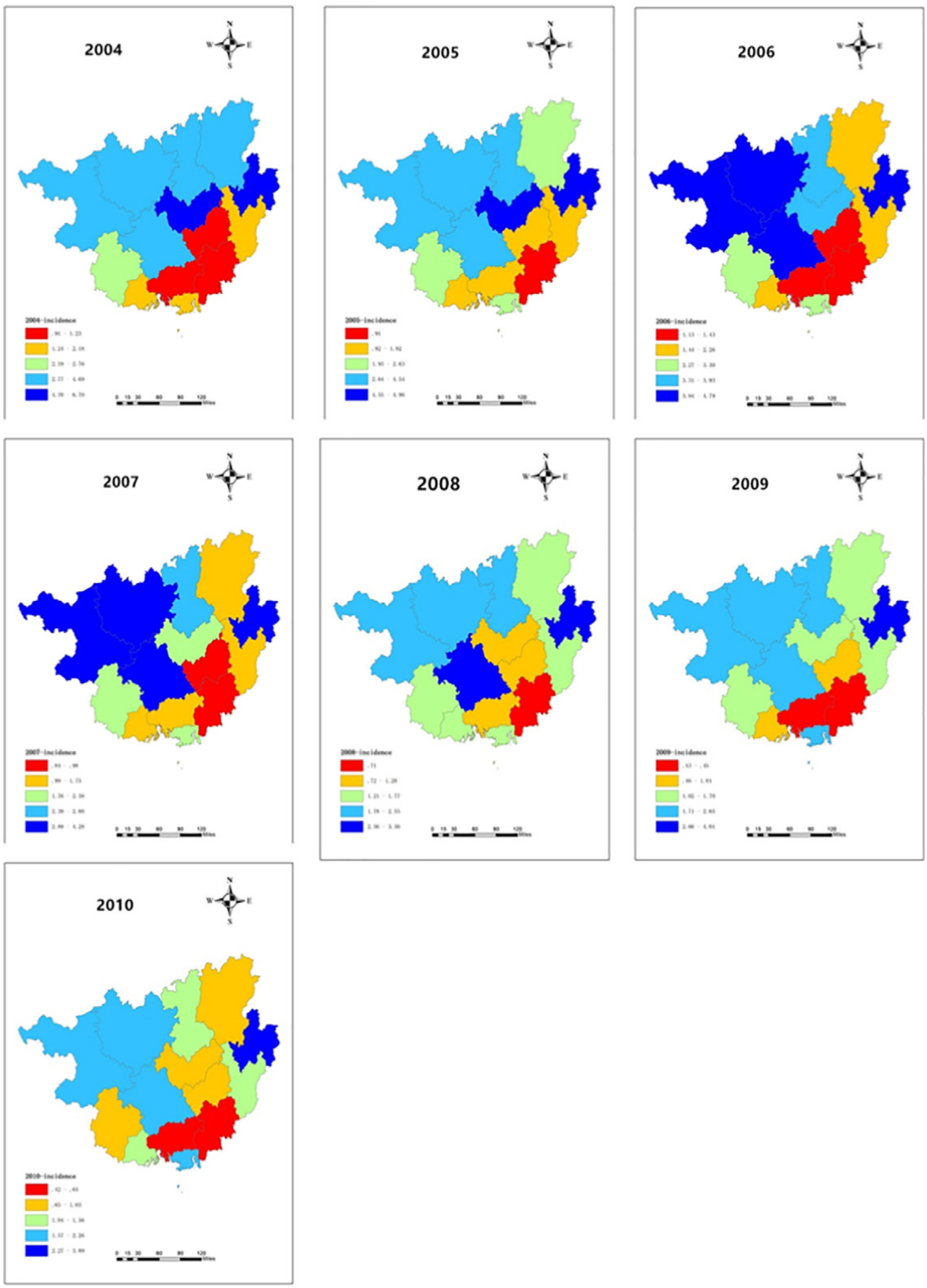

Fig. 3. The spatial distribution of the incidence of bacillary dysentery in Guangxi (2004–2010).

Table 2
Correlations between the morbidity of bacillary dysentery and explanatory variables among monthly data in Guangxi from 2004 to 2010.

Variables	Lag (months)	r	P value
Floods*	0	0.56	<0.01
	1	0.40	0.05
	2	0.38	<0.01
MCP (mm)*	0	0.49	<0.01
	1	0.41	<0.01
	2	0.42	<0.01
MAT (°C)*	0	0.48	<0.01
	1	0.43	0.03
	2	0.36	<0.01
MARH (%)*	0	0.31	0.02
	1	0.26	0.23
	2	0.24	0.17
MAWV (m/s)	0	−0.26	0.11
	1	−0.35	0.21
	2	−0.22	0.24
MCSD (h)*	0	0.29	<0.01
	1	0.40	<0.01
	2	0.22	0.37

* $P < 0.05$.

The expected number of excess cases attributable to the change of population size (ED_p) in each city of Guangxi could be calculated by the formula as follows:

$$ED_p = \left(\frac{N_p}{N_b} - 1\right) \times n_b$$

where N_p is the population size of the projected year; N_b is the population size of the baseline year; n_b is the number of cases of the baseline year.

The expected number of excess cases attributable to floods (ED_f) in each city of Guangxi was calculated by the formula as follows:

$$ED_f = N^*(RR-1)^*L$$

where N is the average annual number of cases of non–flood months in the year for projection, RR is the relative risk of flood events on bacillary dysentery compared to the periods without flood events. RR − 1 is the attributable risk (AR) to floods, and L is the frequency of floods in each city of Guangxi in the future.

The expected increment for bacillary dysentery cases caused by temperature (ED_t) was calculated by the formula as follows:

$$ED_t = N^*RT^*(RR-1)$$

where N is the number of cases in the baseline year, RT is the rising in temperature, RR is the relative risk of temperature on bacillary dysentery, and RR − 1 is the attributable risk (AR) to temperature.

2.3.3. Calculation of the YLDs

Because there was no flood event happened in 2010 in Guangxi, the YLDs for the bacillary dysentery disease in 2010 was chosen as the baseline for the projection. Projections from that baseline were then conducted for 2020, 2030, 2050 and 2100. For the purpose of estimating the future burden of bacillary dysentery under various scenarios in the future, measured in terms of the YLDs, the framework of the Global Burden of Disease (GBD) study was used. There are some assumptions related to the methods, including a set of assumptions on incidence, prevalence, remission and case-fatality rates (Murray and Lopez, 1996; Zhang et al., 2012). In this study, there were three assumptions as flows: firstly, the quantitative relationship between flood events and bacillary dysentery was assumed to remain constant in the future, despite the association may be altered by some potential changes such as socio-economic status or medical level. Secondly, flood evens in the future were used as a proxy for future climate scenarios. In our study, the effects of other meteorological variables on bacillary dysentery have been assumed to be constant. Finally, any future change in the vulnerability of the population to climate change was not taken into account.

The methods used to calculate the YLDs in the study are adopted from the GBD studies (Murray and Lopez, 1996). YLD was calculated from the incidence cases, the average duration of disease and the average disability weight. In the GBD studies, the disease of bacillary dysentery had been subsumed within the category of "diarrhoeal disease". Therefore, the weights used for the entire category of "diarrhoeal disease" were used as a disability weight for bacillary dysentery in our study. This research used the average disability weight (0.09) and the average duration (0.04 years) for diarrhoeal disease used in the WHO defined subregion, "WproB1", a WHO burden of disease reporting region mainly including China with a low child mortality, as described in the GBD 2002 study (Zhang et al., 2012; Mathers et al., 2004).The formula used to calculate the YLDs in this study is presented as follows:

$$YLD = I \times D_W \times L$$

where I is incidence cases; D_W is disability weight; L is average duration of disability (years).

SPSS 16.0 (SPSS Inc., Chicago, IL) and R 3.1.3 (R Foundation for Statistical Computing, Vienna, Austria) were used in the statistical analyses with a significant level of 0.05.

3. Results

3.1. Descriptive and correlation analysis

There were 138 floods recorded in the yearbook between 2004 and 2010 in Guangxi, including 86 moderate floods and 52 severe floods. In total, 78,794 cases of bacillary dysentery were diagnosed in Guangxi over non-flooded and flooded months from 2004 to 2010. The monthly cases of bacillary dysentery had a mild secular trend and a distinct seasonal trend with most cases occurred in summer (Fig. 2). The spatial distribution of the incidence of bacillary dysentery in Guangxi from 2004 to 2010 was shown in Fig. 3.

Table 2 demonstrates the results of spearman's correlation analysis. The results suggested that the monthly morbidity of bacillary dysentery was in a positive correlation with the floods, MCP, MAT, MARH and MCSD with relevant lag times from 0 to 1 month. The lagged impacts of all meteorological variables were incorporated in the next regression analysis.

3.2. Regression analysis

The parameters of the GAMM are presented in Table 3. The observed monthly morbidity of bacillary dysentery fitted well with the figures predicted by the developed regression model, with a goodness of fit of 85% (adjusted R square $r_1^2 = 0.85$) for model 1 and 89% (adjusted R square $r_2^2 = 0.89$) for model 2. Moderate floods, severe floods and temperature were in a close correlation with the incidence of bacillary dysentery (with coefficients: 0.16 for moderate floods, 0.33 for severe floods and 0.08 for temperature). Nevertheless, the flood duration was

Table 3
Parameters coefficients from the GAMM for the bacillary dysentery disease.

Model	Variables	Coefficients	P value	RR (95% CI)
Model 1*	Moderate floods	0.16	<0.01	1.17 (1.03, 1.33)
	Severe floods	0.33	<0.01	1.39 (1.14, 1.70)
	MAT	0.08	<0.01	1.08 (1.03, 1.14)
	Reference (no flood)	–	–	–
Model 2*	Duration	−0.46	<0.01	0.63 (0.44, 0.90)

CI = confidence interval; GAMM = mixed generalized additive model; RR = relative risk.
* Adjusted R^2 was 0.85 for model 1 and 0.89 for model 2.

Table 4
The scenarios of flood events in 2020, 2030, 2050 and 2100 in Guangxi.

Cities	2020		2030		2050		2100	
	Moderate	Severe	Moderate	Severe	Moderate	Severe	Moderate	Severe
Baise	0	2	1	0	1	1	2	1
Hechi	1	3	1	2	0	1	0	3
Liuzhou	2	1	0	2	0	0	3	0
Guilin	1	1	3	1	0	1	4	2
Chongzuo	2	0	1	0	0	1	2	1
Nanning	1	0	1	0	0	0	1	0
Laibin	2	2	1	1	0	0	1	2
Hezhou	0	1	2	3	2	0	1	2
Wuzhou	0	1	2	2	2	1	2	2
Guigang	1	0	2	0	0	0	1	1
Yulin	1	0	1	3	1	2	1	3
Qinzhou	1	0	2	0	1	2	0	2
Beihai	0	1	1	0	1	0	1	3
Fangcheng	2	0	1	1	2	0	2	2
Total	14	12	19	15	10	9	21	24

in a negative correlation with the incidence of bacillary dysentery (with coefficient: −0.46). After controlling for the other meteorological variables, monthly incidences of bacillary dysentery were in a positive correlation with the moderate floods (RR: 1.17, 95% CI: 1.03–1.33) and the severe floods (RR: 1.39, 95% CI: 1.14–1.70). The GAMM also suggested that a 1 °C increase in temperature was related to an extra 8% (RR = 1.08, 95% CI = 1.03–1.14) incidence of bacillary dysentery. A negative correlation existed between the floods duration and the incidence of bacillary dysentery (RR: 0.63, 95% CI: 0.44–0.90).

3.3. Scenario-based projections

The scenarios of flood events in 2020, 2030, 2050 and 2100 based on projected daily precipitation of each city of Guangxi were showed in Table 4. The results suggested that the exposure scenarios of flood events would be 26 (14 moderate and 12 severe) in 2020, 34 in 2030 (19 moderate and 15 severe), 19 in 2050 (10 moderate and 9 severe) and 45 in 2100 (21 moderate and 24 severe) in Guangxi.

Tables 5–8 list the projected extra cases of bacillary dysentery in 2020, 2030, 2050 and 2100 under different scenarios of flood events, temperature and population change in Guangxi. It can be observed that considering the influence of floods only, the cases of bacillary dysentery may increase by up to 5.1% (350) by 2020, 6.8% (471) by 2030, 3.1% (212) by 2050, and 11.3% (783) by 2100 (in 2010, 6929 cases were observed in the study area) if other factors remain constant. Considering all potential changes include floods, temperature and population size, the projected cases of bacillary dysentery may increase by up to 14.8% (1023) by 2020, 20.2% (1402) by 2030, 19.4% (1346) by 2050, and 1.8% (127) by 2100, compared to that in 2010 under the moderate flood scenario; Under the severe flood scenario, the projected cases of bacillary dysentery may increase by up to 16.0% (1111) by 2020, 20.6% (1429) by 2030, 19.4% (1346) by 2050, and 3.0% (208) by 2100.

3.4. Projected YLDs for bacillary dysentery

Table 9 lists the calculated YLDs for bacillary dysentery in 2010, and projected YLDs in 2020, 2030, 2050 and 2100 under scenarios of flood events, temperature and population change in Guangxi. It can be observed that under the flood scenarios alone, the YLDs may increase by up to 4.0% (26) by 2020, 2100, 0.0% (25) by 2050, and 8.0% (27) by 2030 if other factors remain constant. With Considering of all scenarios, which include floods, temperature and population size, the YLDs for bacillary dysentery may increase by up to 16.0% (29) by 2020, 20.0% (30) by 2030, 2050, and 0.0% (25) by 2100, compared to that in 2010 under the moderate flood scenario; Under the severe flood scenario, the YLDs for bacillary dysentery may increase by up to 16.0% (29) by 2020, 20.0% (30) by 2030, 2050, and 4.0% (26) by 2100.

4. Discussion

Much work on flooding risk assessment research has been done (Ding et al., 2013; Ni et al., 2014; Liu et al., 2015). However, most of these researches are based on historical floods, little on future flood risks. This analysis represents the first assessment to quantify the risks of flood events on bacillary dysentery infection as well as projected the YLDs of bacillary dysentery infection in 2020, 2030, 2050 and 2100 in Guangxi, China.

Table 5
Increment for bacillary dysentery cases caused by population: 2020, 2030, 2050 and 2100.

Cities	2020	2030	2050	2100
Baise	24	29	3	−131
Hechi	23	28	3	−127
Liuzhou	26	32	3	−142
Guilin	33	40	4	−179
Chongzuo	14	17	2	−75
Nanning	46	56	5	−252
Laibin	15	18	2	−79
Hezhou	14	16	2	−74
Wuzhou	20	24	2	−109
Guigang	29	34	3	−155
Yulin	38	46	4	−207
Qinzhou	21	26	2	−116
Beihai	11	13	1	−57
Fangcheng	6	7	1	−33
Total	320	385	37	−1737

Table 6
Increment for bacillary dysentery cases caused by temperature: 2020, 2030, 2050 and 2100.

Cities	2020	2030	2050	2100
Baise	9–43	13–60	19–91	26–123
Hechi	9–42	12–58	19–88	26–119
Liuzhou	10–47	14–65	21–99	29–134
Guilin	13–59	18–82	27–124	36–168
Chongzuo	5–25	7–34	11–52	15–71
Nanning	18–83	25–115	37–174	51–236
Laibin	6–26	8–36	12–55	16–74
Hezhou	5–24	7–34	11–51	15–69
Wuzhou	8–36	11–50	16–76	22–103
Guigang	11–51	15–71	23–108	31–146
Yulin	15–68	20–95	31–143	42–194
Qinzhou	8–38	11–53	17–80	23–109
Beihai	4–19	6–26	9–40	12–54
Fangcheng	2–11	3–15	5–23	7–31
Total	123–572	171–795	258–1203	349–1630

Table 7
Increment for bacillary dysentery cases caused by floods: 2020, 2030, 2050 and 2100.

Cities	2020		2030		2050		2100	
	Moderate	Severe	Moderate	Severe	Moderate	Severe	Moderate	Severe
Baise	0	27–41	12–16	0	12–16	14–20	25–32	14–20
Hechi	16–21	55–82	16–21	36–54	0	18–27	0	55–82
Liuzhou	19–24	10–15	0	21–31	0	0	28–36	0
Guilin	9–12	10–15	28–36	10–15	0	10–15	37–48	21–31
Chongzuo	6–8	0	3–4	0	0	3–5	6–8	0
Nanning	24–31	0	24–31	0	0	0	24–31	0
Laibin	8–11	9–14	4–5	5–7	0	0	4–5	9–14
Hezhou	0	18–27	33–43	55–82	33–43	0	16–21	37–54
Wuzhou	0	10–15	19–24	21–31	19–24	10–15	19–24	21–31
Guigang	7–9	0	14–19	0	0	0	7–9	8–12
Yulin	5–7	0	5–7	17–26	5–7	11–17	5–7	17–26
Qinzhou	2–3	0	4–5	0	2–3	5–7	0	5–7
Beihai	0	7–10	6–8	0	6–8	0	6–8	21–31
Fangcheng	4–5	0	2–3	2–3	4–5	0	4–5	5–7
Total	100–131	146–219	170–222	167–249	81–106	71–106	181–234	213–315

The study indicates that the period of floods could trigger more morbidity of bacillary dysentery than the period of non-floods in the research region, which is consistent with the reports in both developed and developing countries. For instance, a study conducted in Germany suggested that contacting the floodwater was a major reason for diarrhea (with $OR = 5.8$, 95% $CI = 1.3–25.1$) (Schnitzler et al., 2007). Another study carried out in China showed that the RRs of floods on bacillary dysentery were 11.47 (with 95% CI: 8.67–15.33), 2.75 (with 95% CI: 1.36–4.85) and 1.35 (with 95% CI: 1.23–3.90) respectively in Kaifeng, Zhengzhou, and Xinxiang of Henan province (Ni et al., 2014).Similar conclusions were produced by these studies in spite of they conducted in different regions which may differences in weather conditions, public facilities, health services, and so on. It revealed that floods could be an independent risk factor for the morbidity of bacillary dysentery after the adjustment of confounding factors.

The result of Table 4 identifies that there will be an increase in frequency of flood events in the future in Guangxi. The study also suggests that there will be a considerable increase in the morbidity burden of bacillary dysentery in the study area due to the increase in frequency of flood events. And with consideration of all scenarios (floods, temperature and demographic data), a considerable increase in the morbidity burden of bacillary dysentery was observed in 2020, 2030, 2050 and 2100. The burden growth is relative little in 2100 is greatly determined by the fall sharply of future population size, which the number fall to 34,474,136 in 2100 from 46,026,600 in 2010. So a considerable health burden of bacillary dysentery associated with increasing flood events is inevitable if no effective policies are considered in the future.

There are four advantages of our study. Firstly, the study has, for the first time, projected the burden of bacillary dysentery under different scenarios in Guangxi, China. Secondly, we have projected the health burden under the scenarios of flood events, but we have also considered the demographic and temperature changes, which may also affect the cases of bacillary dysentery in the future. Thirdly, the study projects the burden of bacillary dysentery, measured in terms of Years Lost due to Disability (YLD), which is a component of the summary measure of the burden of disease (Disability Adjusted Life Year, DALY). DALYs are calculated by the sum of years of life lost due to premature mortality (YLL) and the equivalent healthy years of life lost due to disability (YLD) (Zhang et al., 2012).YLDs have been projected by this study as the indicator of the health burden of disease because the rate of death from bacillary dysentery was very low in China. Finally, while methods for measuring health effects attributable to climate change are still at an early stage of development and many uncertainties remain, it is important to provide a framework for assessing health burden associate with climate change. This study tries to generate a broad picture of possible trends in the morbidity burden of the target disease associated with future flood events. The study has provided a framework for further study on the health burden attributable to climate change in China and other developing countries.

Similar to other burden of disease studies, limitations are inherent in the methods and scenarios. Firstly, there are other variables, such as the variability of the pathogen, socioeconomic status, changes in behavior and lifestyle, and environmental hygiene, influencing the transmission of bacillary dysentery, which could not be analyzed in this study.

Table 8
Increment for bacillary dysentery cases caused by population, temperature and floods (minimum and maximum increments): 2020, 2030, 2050 and 2100.

Cities	2020		2030		2050		2100	
	Moderate	Severe	Moderate	Severe	Moderate	Severe	Moderate	Severe
Baise	33–67	60–108	54–105	42–89	34–110	36–114	−80–24	−91–12
Hechi	48–86	87–147	56–107	76–140	22–91	40–118	−101 to −8	−46–74
Liuzhou	55–97	46–88	46–97	67–128	24–102	24–102	−85–28	−113 to −8
Guilin	55–104	56–107	86–158	68–137	31–128	41–143	−106–37	−122 to −8
Chongzuo	25–47	19–39	27–55	24–51	13–54	16–59	−54–4	−60 to −4
Nanning	88–160	64–129	105–202	81–171	42–179	42–179	−177–15	−201 to −16
Laibin	29–52	30–55	30–59	31–61	14–57	14–57	−59–0	−54–9
Hezhou	19–38	37–65	56–93	78–132	46–96	13–53	−43–16	−22–49
Wuzhou	28–56	38–71	54–98	56–105	37–102	28–93	−68–18	−66–25
Guigang	47–89	40–80	63–124	49–105	26–111	26–111	−117–0	−116–3
Yulin	58–113	53–106	71–148	83–167	40–154	46–164	−160 to −6	−148–13
Qinzhou	31–62	29–59	41–84	37–79	21–85	24–89	−93 to −7	−88–0
Beihai	15–30	22–40	25–47	19–39	16–49	10–41	−39–5	−24–28
Fangcheng	12–22	8–17	12–25	12–25	10–29	6–24	−22–3	−21–5
Total	543–1023	589–1111	726–1402	723–1429	376–1346	366–1346	−1207–127	−1175–208

Table 9
The YLDs for bacillary dysentery in Guangxi: 2010, 2020, 2030, 2050 and 2100.

Years	Scenarios	YLDs	
		Moderate	Severe
2010		25	
2020	F	25–25	25–26
	F + P + T	27–29	27–29
2030	F	26–27	26–26
	F + P + T	28–30	28–30
2050	F	25–25	25–25
	F + P + T	26–30	26–30
2100	F	26–26	26–26
	F + P + T	20–25	21–26

F: floods; P: population; T: temperature.

Secondly, the limitation is in the projections of future scenarios. In terms of uncertainty in the scenarios, particularly climate change scenarios, projections are limited by largely unpredictable factors both within the climate system itself, and in the interaction between climate and human behaviors, including population growth and economic development. Thirdly, this study was based on the assumption that all the population exposed equally to the floods. Furthermore, no control group was selected for comparison. Fourthly, underreporting bias is inevitable. The reported cases included in this study are those who presented serious symptoms and were diagnosed in hospitals. Cases with mild clinical symptoms and treated by themselves usually did not seek health serves, which may lead to an underestimate of the risk of floods. So the burden of the disease may be much higher than our estimates in this study, if under-reporting is corrected. Finally, we could only obtain the monthly data from the NDSS. More frequent data, e.g. daily or weekly incidences, of the study area would be more accurate than monthly data in our estimation.

5. Conclusion

The study is the first projection on bacillary dysentery in Guangxi province associated with future flood events. It indicates that floods-related health burden of bacillary dysentery in Guangxi may increase in the future due to exposure to flood events, if no effective intervention measures are taken. It has significant policy implications for adaptation and mitigation of future risks of climate change.

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