Atmospheric Environment 129 (2016) 9–17

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Public health in China: An environmental and socio-economic perspective

Wenjing Song [a, c], Yonghua Li [a, b, *], Zhe Hao [a, d], Hairong Li [a, **], Wuyi Wang [a]

[a] Key Laboratory of Land Surface Pattern and Simulation, Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[b] Beijing Key Laboratory of Environmental Damage Assessment and Remediation, Beijing, China
[c] University of Chinese Academy of Sciences, Beijing 100049, China
[d] Key Laboratory of Engineering Oceanography, Second Institute of Oceanography, SOA, Hangzhou 310012, China

HIGHLIGHTS

- Association between health outcomes and environment and socio-economy was analysis.
- Using GWR and SR models to detect the association.
- High SO_2, PM_{10}, CC & EC have negative impact on public health outcomes.
- Public health outcomes show clear regional differences in China.

ARTICLE INFO

Article history:
Received 24 June 2015
Received in revised form
20 November 2015
Accepted 7 December 2015
Available online 18 December 2015

Keywords:
Public health
Centenarian ratio
Longevity index
Environmental and socio-economic indicators
Stepwise regression
Geographically weighted regression

ABSTRACT

Despite the large literature on public health, few studies have examined the associations between public health outcomes and environmental and socio-economic factors. This study bridges this gap by demonstrating the relationships between public health and 10 selected environmental and socio-economic factors from the spatial perspective. In particular, three public health outcomes in China are investigated, namely the number of centenarians per 100,000 people (termed the centenarian ratio), the proportion of nonagenarians of the 65 years and older population (termed the longevity index), and life expectancy at birth. We base our analysis on stepwise regression and geographically weighted regression models, with study areas of 31 provinces in China. Our results show that SO_2 (sulfur dioxide) concentration decreases the centenarian ratio; PM_{10} (particles with diameters of 10 μm or less) concentration and coal consumption (CC) per capita decrease the longevity index, and GDP (Gross Domestic Product) per capita prolongs life expectancy at birth, while energy consumption (EC) per capita decreases life expectancy at birth. Further, our findings demonstrate that public health outcomes show clear regional differences in China.

1. Introduction

The proportion of long-lived individuals in a population is often used as a criterion for estimating public health (Azin et al., 2001; Huang et al., 2009), specifically the number of nonagenarians and centenarians (Franceschi and Bonafe, 2003). The elderly are much more vulnerable and sensitive because of the existing diseases, depressed immune systems, and accumulation of toxic agents in their bodies (Balfour and Kaplan, 2002; Fischer et al., 2003). Therefore the healthy condition of centenarians can be influenced by many factors such as biological, psychosocial, environmental factors and so on (Candore et al., 2006). Studies have shown that production of centenarians appears to have an important latent effect with socioeconomic factors (Kim, 2013; Kim and Kim, 2014). IFurther the influence of air pollutants such as SO_2, PM_{10}, and NO_2 presenting much more obvious on those aged 65 and older(Fischer et al., 2003).

Life expectancy also serves as an indicator of public health

* Corresponding author. Key Laboratory of Land Surface Pattern and Simulation, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China.
** Corresponding author.
E-mail addresses: yhli@igsnrr.ac.cn (Y. Li), lihr@igsnrr.ac.cn (H. Li).

http://dx.doi.org/10.1016/j.atmosenv.2015.12.021

Abbreviations

CR centenarian ratio, number of centenarians per 100,000 people
LI longevity index, the proportion of nonagenarians of the 65 years and older population
LEB life expectancy at birth
NO_2 nitrogen dioxide
PM_{10} particles with diameters of 10 μm or less
SO_2 sulfur dioxide
NO EI nitrogen oxide emission intensity
SO_2 EI sulfur dioxide emission intensity
SD EI smoke and dust emission intensity
GDP per capita Gross Domestic Product per capita
CV per capita civilian vehicles per capita
EC per capita energy consumption per capita
CC per capita coal consumption per capita

because of its capacity to summarize mortality in a single measure (Auger et al., 2014).a This measure, which was proposed in the 1960s and developed in the 1970s (Manton, 1982; Sanders, 1964), can thus be used to assess morbidity in a population (Bone, 1992; Sullivan, 1971). It has been proposed that life expectancy is influenced by multiple factors, with environmental and socio-economic factors considered to be two of the most important (Christensen and Vaupel, 1996; Cournil and Kirkwood, 2001; Gonos, 2000; Hosseinpoor et al., 2012; Huang et al., 2009; Kawata, 2009; Sun et al., 2014; Wang et al., 2015b). People in more developed areas tend to have higher average life expectancy (United Nations Development Programme (Ghana), 2011) and Wang et al. (2015a) have demonstrated that life expectancy is affected by both contemporaneous and historical GDP per capita significantly. Moreover, surveys conducted in Northern China have indicated that a large increase of total suspended particulates air pollution can cause the decrease of life expectancy (Chen et al., 2013).

Since the country's economic opening up, the population's health in China has improved (Zheng et al., 2011) accompanied by significant socio-economic development and increasingly severe environmental problems. However few studies have examined the combined impact of environmental and socio-economic indicators on human public health from the spatial perspective. Therefore, investigating the spatial differences in public health associated with environmental and socio-economic factors is crucial to improving our understanding of public health.

This study estimates the association between public health outcomes and combined environmental and socio-economic indicators from the spatial perspective. We use the number of centenarians per 100,000 people (termed the centenarian ratio, or CR), the proportion of nonagenarians of the 65 years and older population (termed the longevity index, or LI), and life expectancy at birth (LEB) as public health outcomes. SO_2 (sulfur dioxide) emission intensity (SO_2 EI), nitrogen oxide emission intensity (NO EI) and smoke and dust emission intensity (SD EI) are indices measuring the air pollution from the district perspective, while PM_{10} (particles with diameters of 10um or less), SO_2, and NO_2 (nitrogen dioxide) are the most direct way to demonstrate the air quality. GDP (Gross Domestic Product) is used as a proxy of the socioeconomic development of a region (Lim et al., 2015). Numbers of civilian vehicles and power consumption are tremendous increase with the development of social economy and have big effect on atmospheric environment (Huang et al., 2013). So the environmental and socio-economic indicators are represented by GDP per capita, civilian vehicles per capita (CV per capita), energy consumption per capita (EC per capita), coal consumption per capita (CC per capita), SO_2 emission intensity (SO_2 EI), nitrogen oxide emission intensity (NO EI), smoke and dust emission intensity (SD EI), PM_{10}, SO_2, and NO_2.

The major objectives of the study are to (i) demonstrate the distribution of CR, LI, and LEBat the provincial level in China from a spatial perspective; (ii) determine the most influential environmental and socio-economic indicators on CR, LI, and LEB; (iii) to analyze the spatial relationship between these environmental and socio-economic factors and public health; and (iv) compare geographically weighted regression (GWR) with stepwise regression (SR) models.

In the remainder of the paper, we first display the correlations between public health outcomes and environmental and socio-economic indicators; then, we establish SR models in combination with GWRmodels to find the most influential indicators for public health outcomes from the spatial perspective. Next, we present the results before drawing conclusions.

2. Materials and methods

2.1. Study area

We conducted this study at the provincial level in China by taking into account the administrative divisions. Thirty-one major provinces in China were selected as the study area. The study regions are shown in Fig. 1.

2.2. Data

The environmental and socio-economic indicators (GDP per capita, CV per capita, EC per capita, CC per capita, SO_2 EI, NO EI, SD EI, PM_{10}, SO_2 and NO_2) used in this study were collected from the Department of Pollution Emission Control, Ministry of Environmental Protection of the People's Republic of China (China's MEP, 2013). The data of GDP per capita, CV per capita, EC per capita, CC per capita, SO_2 EI, NO EI and SD EI are all statistical data. The concentration of PM_{10}, SO_2 and NO_2 are monitored according to the

Fig. 1. Study areas: 1-Heilongjiang; 2-Jilin; 3-Liaoning; 4- Inner Mongolia; 5-Beijing; 6-Tianjin; 7-Hebei; 8-Shandong; 9-Shanxi; 10-Shanxi; 11-Ningxia; 12-Gansu; 13-Qinghai; 14-Xinjiang; 15- Tibet; 16-Sichuan; 17-Chongqing; 18-Hubei; 19-Henan; 20-Anhui; 21-Jiangsu; 22-Shanghai; 23-Zhejiang; 24-Jiangxi; 25-Fujian; 26-Hunan; 27-Guizhou; 28-Yunnan; 29-Guangxi; 30-Guangdong; 31-Hainan.