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Life expectancy impacts due to heating energy utilization in China: Distribution, relations, and policy implications



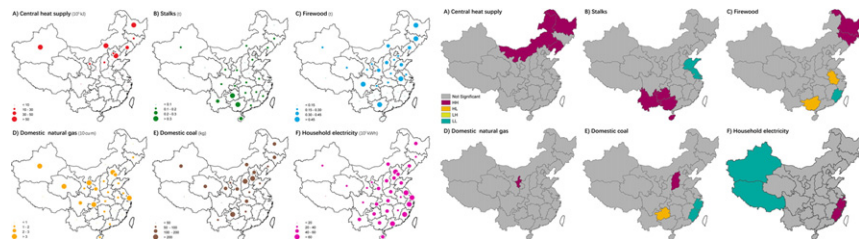
Shaobin Wang*, Kunli Luo

Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China

HIGHLIGHTS

- Spatial distribution of life expectancy at birth and heating energy use in China was explored.
- Spatial relations between LEB and heating energy use were conducted.
- Central heating, residential boilers and natural gas lack any significant correlations with LEB.
- Domestic coal shows a negative effect on LEB, rather than central heating.
- To control domestic coal consumption and other low quality solid fuel is imperative.

GRAPHICAL ABSTRACT



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ABSTRACT

The relation between life expectancy and energy utilization is of particular concern. Different viewpoints concerned the health impacts of heating policy in China. However, it is still obscure that what kind of heating energy or what pattern of heating methods is the most related with the difference of life expectancies in China. The aim of this paper is to comprehensively investigate the spatial relations between life expectancy at birth (LEB) and different heating energy utilization in China by using spatial autocorrelation models including global spatial autocorrelation, local spatial autocorrelation and hot spot analysis. The results showed that: (1) Most of heating energy exhibit a distinct north-south difference, such as central heating supply, stalks and domestic coal. Whereas spatial distribution of domestic natural gas and electricity exhibited west-east differences. (2) Consumption of central heating, stalks and domestic coal show obvious spatial dependence. Whereas firewood, natural gas and electricity did not show significant spatial autocorrelation. It exhibited an extinct south-north difference of heat supply, stalks and domestic coal which were identified to show significant positive spatial autocorrelation. (3) Central heating, residential boilers and natural gas did not show any significant correlations with LEB. While, the utilization of domestic coal and biomass showed significant negative correlations with LEB, and household electricity shows positive correlations. The utilization of domestic coal in China showed a negative effect on LEB, rather than central heating. To improve the solid fuel stoves and control consumption of domestic coal consumption and other low quality solid fuel is imperative to improve the public health level in China in the future.

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1. Introduction

Energy use is central to human development and it provides many health benefits, but each kind of energy may entail different health impacts (World Health Organization, 2006; Smith et al., 2013). In most

* Corresponding author.

E-mail address: wangshaobin@igsnr.ac.cn (S. Wang).

places, heating energy is essential to humankind which can generate heat (i.e. warmth) for their buildings. In actual scenario, there are several kinds of energy used for heating, and there are growing concerns over air pollution from combustion of solid energy such as domestic coal and biomass fuel and the associated health problems (Li et al., 2011a, 2011b; Luo et al., 2011; HosgoodIII et al., 2013; Liu et al., 2013; Rao et al., 2013; Duan et al., 2014; Shen et al., 2014).

Meanwhile, researches on the influence due to environmental factor on life expectancy have risen in recent decades (Crimmins and Saito, 2001; Pope et al., 2009; Chen et al., 2013; Correia et al., 2013; Wang et al., 2015a), despite a large number of researches on the influencing factors of life expectancy (Wilkinson, 1992; Crimmins and Saito, 2001; Guo et al., 2008; Meara et al., 2008; Allen et al., 2016). Among them, the relation between life expectancy and energy utilization is of particular concern (Goldemberg et al., 2000; Wilkinson et al., 2007; Chen et al., 2013). Therefore, heating energy assessment especially for solid fuels such as coal and biomass and their health impacts are of importance for public health and energy policy.

With the rapid economic growth and urbanization in China, heating energy has become an important part of energy consumption. Various types of energy, including traditional solid fuels (such as coal and biomass fuel) and cleaner energy (such as natural gas and electricity), are widely consumed for household heating in China (Duan et al., 2014). Moreover, two different heating methods are used by the Chinese residents which included central heating system and individual heating with domestic coal/biomass stoves (Edwards et al., 2004; Chen et al., 2006; Pachauri and Jiang, 2008). However, the pros and cons of central heating policy in China is still controversial, and it is obscure that what kind of heating energy or what pattern of heating methods is the most related with the difference of life expectancies in China as well.

China has a vast territory with different levels of social and economic development. The utilizations of different heating energy in different areas in China may exhibit spatial properties, such as spatial dependence or spatial autocorrelation. It also lacks of the spatial characteristics of different environmental health impacts with spatial distribution model of life expectancies in China. Indeed, there lacks of comprehensive research on the environmental-health impacts of different heating energy and heating methods in China.

The high resolution spatial distribution of Chinese life expectancy and its relation to economic conditions and geographic factors have been discussed (Wang et al., 2015a, 2015b), which provided a basis for the health impacts from heating energy use in China. What's more, spatial analysis is a powerful tool to probe the spatial distribution characteristics, and it can detect whether there is a spatial dependency or spatial correlation between different variables (Cliff and Ord, 1981; Griffith, 2013).

This paper firstly investigated the spatial distribution of health indicators (life expectancy at birth, LEB) and heating energy use with different heating methods at provincial level in China. Secondly, we explored the spatial relations between different heating energy utilization and LEB by using spatial autocorrelation models including global spatial autocorrelation, local spatial autocorrelation and hot spot analysis. Last,

comparison study of two main heating methods (central heating and individual heating) and their impacts on LEB was discussed furtherly. Overall, the impact of air pollution due to different heating energy use on life expectancy could be informative to further in-depth analyses of energy policy and public health policy of China.

2. Data and methods

2.1. Data collection and calculation

2.1.1. Heating energy utilization in China

2.1.1.1. Heating energy. In China, the main heating energy includes coal, natural gas, electricity and biomass fuel (e.g. firewood and stalks). Domestic coal and steam coal are the most important heating energy in cities and rural China, which accounted 52.53% in total coal consumption structure in China in 2014 (National Bureau of Statistics of China, 2016). Meanwhile, solid biomass fuel is also an important heating energy in China, especially in the rural areas (Chen et al., 2006). Solid biomass fuels mainly refer to firewood, plant stalks and dung (mainly dry dung of livestock such as cattle, horses, camels, yak). High proportions of plant stalks and firewood to total energy consumption were reported in rural China (Zhou et al., 2008; Wang et al., 2010). China's areas fueled with animal dung are mainly distributed in the livestock-based pastoral areas, such as parts of Tibet, Inner Mongolia and Qinghai Provinces (Liu et al., 2008; Xiao et al., 2015). In addition, natural gas and electricity are also used as heating energy by Chinese residents especially in urban areas (Fig. 2).

2.1.1.2. Heating methods. In this paper, heating method refers to the way that residents choose to generate heat (i.e. warmth) for their buildings. There are two main types of heating methods in China, which include central heating system and individual heating (Cao et al., 2014). In China, central heating systems are widely used in northern cities, while individual heating are used in southern cities and all the Chinese rural areas. Central heating systems include two main types: regional boiler heating and thermoelectricity cogeneration (Fig. 1). Regional boiler heating is the main heating method in northern Chinese cities in winter. Thermoelectricity cogeneration produces heat and power jointly which means that hot water and hot steam generated by centralized heat from power plants is supplied for entire or part of a city through municipal hot water networks (Wang and Yu, 2003).

Individual heating includes household heating systems and domestic coal/biomass stoves. Household heating systems (such as wall-mounted gas boilers and electric radiators) become popular in new residential buildings in Chinese cities (Cao et al., 2014). Wall-mounted gas boilers are most used in cities, and users can manually or automatically adjust the indoor temperature according to their different requirements (Qian et al., 2005). Electric radiators are often used in winter in southern Chinese cities, and coal-based domestic stoves supplemented by burning firewood are widely used in rural China especially in winter.

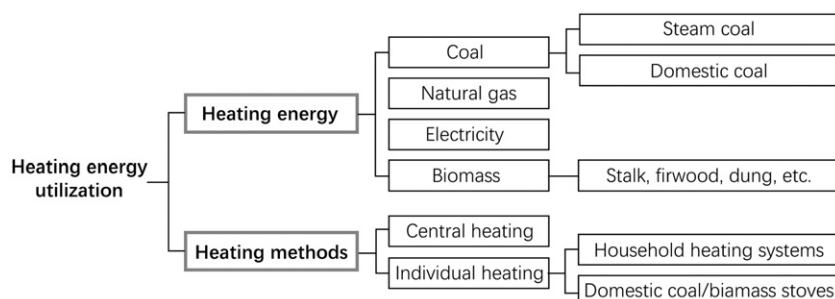


Fig. 1. Schematic diagram of different heating energy utilization in China.

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