

Urbanisation and human health in China: spatial features and a systemic perspective

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Abstract

Background, aims and scope Current studies have paid little attention to the dynamism in urban spatial expansion and its possible environmental and health effects or to the health effects of rapid urban environmental change at different points along the urbanisation gradient. This study adopts a public health ecology approach to systematically understand the relationship between urbanisation, urban environmental change and human health in China.

Method Remote sensing image analysis, based on night light data at five different time periods in recent decades, was used to determine changes to the overall urban area. Through a review of the evidence on the relationships between environmental health, urbanisation and health, we advance a pathway framework for explaining urban human health ecology. The Spearman rank correlation coefficient was used to measure the correlation between disease prevalence and urbanisation level, adding a further dimension to a systemic understanding of urban health.

Results and conclusions Urban areas have been increasing spatially, but unevenly, in recent decades, with medium and small cities also expanding rapidly in the past decade. Urbanisation and urban expansion result in changes to land use/coverage change, the urban environment and the residents'

lifestyle, which result in human health problems. Regions with the highest urbanisation level were more inclined to have a high prevalence of chronic disease in recent decades. An ecological public health approach provides insights into the multiple types of data which need to be routinely collected if human disease is not to become a barrier to social and economic development.

Keywords Public health · Night light data · Ecological system · Chronic disease

1 Introduction

Since the 1990s, urbanisation has entered a period of accelerated development in China (Chan and Hu 2003), and the urban area has expanded at an unprecedented speed, reflecting an important characteristic of urbanisation (Zhou et al. 2006). The current shift in China's population from rural to urban areas is predicted to continue, with nearly 200 million moving over the next decade (Zhu and Jones 2010). Empirical studies of China show a strong association between economic growth and urban spatial expansion (Lichtenberg and Ding 2009). Recognising urbanisation's central role in further economic growth and social development, China will continue to give high priority to urbanisation in the coming decades (Chen 2007).

Rapid economic development and the consequent improvement in living conditions, nutrition and health care have resulted in declines in infant mortality and deaths from infectious diseases, leading to increases in life expectancy in China, similar to many developing countries (He et al. 2005). China has experienced an epidemiological transition shifting from infectious to chronic diseases in a much shorter time frame than many other countries (Yang et al. 2008). However, the term epidemiological transition is only limited to the cause

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of death rather than disease burden, which was formulated by Abdel Omran in the 1970s (Abdel 1977). Typically, chronic diseases have been considered a public health problem only in developed countries and among the elderly (Yach et al. 2004). However, research suggests that chronic diseases affect a much higher proportion of people during their prime working years in China as compared with developed countries (He et al. 2005). China's epidemiologic transition can be captured through changes in the causes of death in the adult population. For men and women aged 40 years and older, the leading causes have changed quite dramatically since the mid-1950s, when vital statistics for 13 Chinese cities showed the top 3 causes to be diseases of the respiratory system, acute infectious diseases and TB. By 1999–2000, vascular disease and cancer had become the leading causes of death, with the major contributions coming from hypertension, smoking, physical inactivity and underweight. Rates of smoking and physical inactivity were higher among urban residents than rural residents. Underweight was less of an issue in urban areas (He et al. 2005). These findings indicate the rise in 'new' chronic diseases and the important role the place of residence plays in health outcomes and health transitions. Particularly, urban areas in some developing countries are moving through a nutritional transition towards Western-style diets, dominated by more processed and higher-fat-content foods (Popkin 2003; Popkin and Du 2003).

Despite numerous benefits originating from urbanisation, a rapidly urbanising world, including China, faces intensified resource scarcity and environmental degradation (Li et al. 2010). Rapid urbanisation impacts on natural and built infrastructure, environmental health and human well-being (Zhu et al. 2011). In many countries, the urban poor even have higher rates of stunting and mortality than their rural counterparts (Poel et al. 2007). Some studies in China revealed that more overweight people and a high prevalence of hypertension in more unurbanized areas have a relation to low physical activity (Poel et al. 2009). Urbanisation in China, characterized by large-scale rural–urban migration and built-up area expansion, produced many urban villages where many migrants lived under poor health care and living conditions (Liu et al. 2010).

Numerous studies have examined urbanisation in China and its effects on environmental change and health transition, respectively. However, few studies investigate the interactions between the three processes, and little attention has been paid to the following aspects which are of importance to policy makers and urban planners: (1) dynamic urban spatial expansion and its possible environmental and health effects and (2) the health effects at different points along the urbanisation gradient, not simply a broad urban–rural comparison. What is needed is an ecological public health approach (Rayner 2009) which considers the interactions between the process of urbanisation including its

spatial–temporal characteristics, environmental change and human health. Such an approach adopts ecological thinking applying the biological sciences, with attention to natural processes, history and timescales, as well as the broad sweep of sciences devoted to human and social development. It attempts to sidestep the distinction between natural and human ecology and to consider their interdependence.

2 Data and method

This paper brings together a new analysis of urban spatial–temporal expansion in China, alongside what is known about urbanisation's effects on environmental change. It then reanalyses infectious and chronic disease data in terms of a novel urban–rural gradient, with attention to differences in environmental change.

2.1 DMSP/OLS nighttime imagery

Nighttime imagery from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) provides a new data source for large-scale urban research. DMSP/OLS can work at night and detect lights in urban areas which make the urban background obviously different from the black background of rural areas (Elvidge et al. 1999). Many researchers analysed the linear correlation between nighttime imagery and socioeconomic factors; the socioeconomic factors comprised population density (Sutton 1997), urban sprawl (Imhoff et al. 1997), urban heat island (Gallo et al. 1995) and energy consumption (Amaral et al. 2003). In the paper, we used DMSP stable light images to delineate urban areas in five different years—the years 1992, 1995, 2000, 2005 and 2009—which are determined according to the Five-Year Plan of China since the 1990s.

The choice of appropriate thresholds is a major challenge for researchers applying DMSP imagery to delineate urban areas (Henderson et al. 2003). Henderson adopted the thresholds of 6% and 80% to delineate urban areas in China based on DMSP stable light imagery. Nevertheless, the two thresholds have some deficiencies: urban areas delineated based on the threshold of 6% are larger than the real urban areas, and urban areas delineated based on the threshold of 80% are larger than the real urban areas or less than the real urban areas according to the different urban development levels. In this paper, we adopt the 6% threshold to preprocess the DMSP images and determine the candidates for urban areas in the DMSP images.

The most urban areas can be determined according to the threshold, but there are also some errors in the results. It is thought that urban areas should not be changed into rural areas; the values of the pixels in the DMSP/OLS imagery cannot be turned from larger than zero to zero. Therefore,

when the frequency values of the DMSP/OLS imagery in 1992, 1995, 2000, 2005 and 2009 meet one of Eqs. 1–5, the pixels in the DMSP/OLS imagery are determined as urban pixels (Zhou 2006).

$$(F_{1992} > 0) \text{ and } (F_{1995} > 0) \text{ and } (F_{2000} > 0) \text{ and } (F_{2005} > 0) \text{ and } (F_{2009} > 0) \tag{1}$$

$$(F_{1992} = 0) \text{ and } (F_{1995} > 0) \text{ and } (F_{2000} > 0) \text{ and } (F_{2005} > 0) \text{ and } (F_{2009} > 0) \tag{2}$$

$$(F_{1992} = 0) \text{ and } (F_{1995} = 0) \text{ and } (F_{2000} > 0) \text{ and } (F_{2005} > 0) \text{ and } (F_{2009} > 0) \tag{3}$$

$$(F_{1992} = 0) \text{ and } (F_{1995} = 0) \text{ and } (F_{2000} = 0) \text{ and } (F_{2005} > 0) \text{ and } (F_{2009} > 0) \tag{4}$$

$$(F_{1992} = 0) \text{ and } (F_{1995} = 0) \text{ and } (F_{2000} = 0) \text{ and } (F_{2005} = 0) \text{ and } (F_{2009} > 0) \tag{5}$$

where F_{1992} , F_{1995} , F_{2000} , F_{2005} and F_{2009} are the frequency values of the DMSP/OLS imagery in 1992, 1995, 2000, 2005 and 2009, respectively.

2.2 Data on human health

The human health data used in this study include two data sets reporting on mortality and chronic disease, respectively. Mortality data are based on the cause of death investigation conducted by the Ministry of Health, and the chronic diseases data are based on the National Health Services Survey. All of these data are available online at the web site of the Ministry of the Health of the People’s Republic of China and the web site of the National Population and Family Planning Commission of China.

2.2.1 Mortality caused by infectious diseases

The mortality data set reports on the causes of death in both urban and rural regions, covering most main cities and rural regions of most provinces in China. The diseases are classified according to the ICD-9 in 1990, 1995 and 2000; ICD-10 is used after 2000. For this study, we use mortality caused by infections and the rate of the death caused by infections in relation to the total death rate. These data were collected in 1990, 1995, 2000, 2005 and 2009. Because the 2010 data are not available yet, we report the 2009 data.

2.2.2 Chronic disease data

Chronic disease data were analysed from the National Health Services Survey conducted in 1993, 1998, 2003 and 2008. A multistage stratified cluster random sampling method is used in the surveys. The 1993 survey included 215,163 people from 92 sample counties, and the 1998 survey included 216,101 people from 95 sample counties; 210,000 people from 95 sample counties were included in 2003, and 180,000 people from 94 sample counties were included in 2008. In each of the four surveys, urban residents and rural residents are distinguished according to their long-term living region. Cities are classified into three groups by population size: large cities (more than 100 million people), medium cities (30 million to 100 million people) and small cities (<30 million people). Rural regions are classified into four groups on the basis of a composite of socioeconomic indicators, resulting in: class 1 (rich counties), class 2 (well-off counties), class 3 (food- and clothing-satisfied counties), class 4 (poverty counties).

2.3 Statistic method

2.3.1 Nonparametric correlation

Pearson’s correlation is the most common measure of correlation. Pearson’s correlation reflects the degree of linear relationship between two variables. However, Pearson’s correlation is not suitable for nominal or ordinal variables which were used in our study. For this reason, we used a nonparametric correlation coefficient, the Spearman rank correlation coefficient. The Spearman rank correlation coefficient is defined by

$$r_s = 1 - \frac{6 \sum_{i=1}^N d_i^2}{N^3 - N} \tag{6}$$

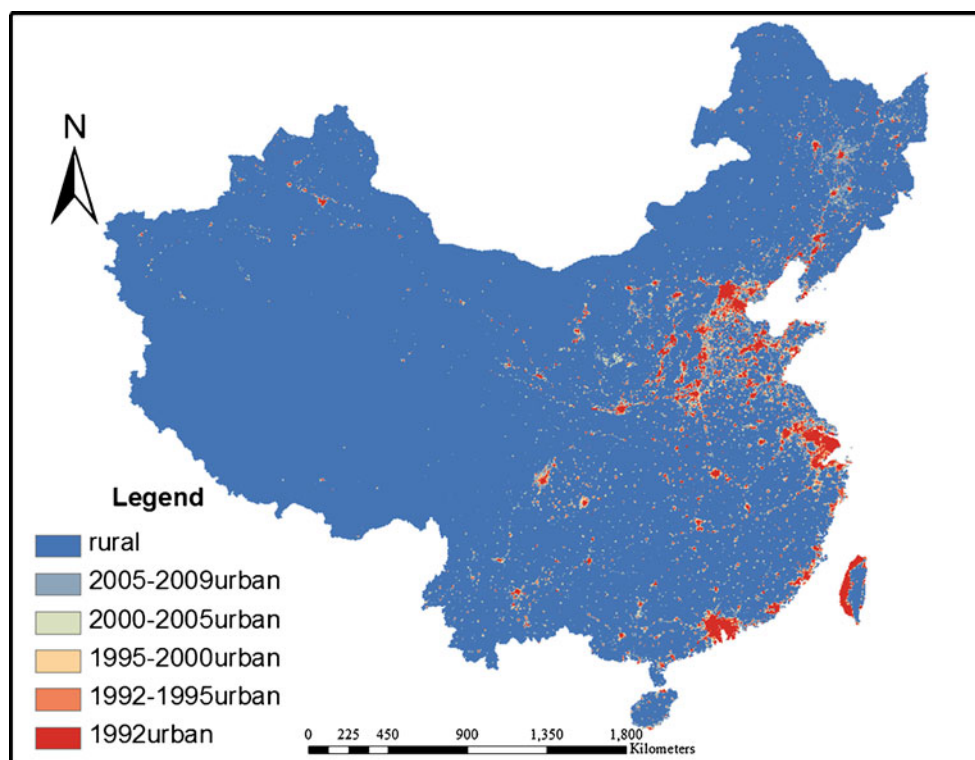
where d is the difference in the statistical rank of the corresponding variables and N is the number of subjects.

3 Results

3.1 Dynamic urban spatial expansion in China in recent decades

Based on DMSP stable light images, the spatial patterning of urbanisation and city expansion, or urban sprawl, in China are evident since the 1990s. Figure 1 shows that the urban area has been increasing and indicates that this growth has been uneven in space. Most of the urban region is distributed in the eastern part of China, especially near the coastal zone. As the heavily populated regions have more

Fig. 1 Urbanisation of China based on DMSP stable light images



intensive economic activities, the proportion of land claimed by human settlements and economic infrastructures in East China has been well above the country average (Chen 2007). Urban areas have expanded mainly around big cities; however, in the recent decade, medium and small cities have also expanded in space.

Accelerated urbanisation with spatial expansion is important for human health for several reasons. China's rapid urbanisation, characterized by large-scale rural–urban migration and radial expansion of urban built-up areas, produces urban villages where people live in houses with high-density, narrow building distance, and poor ventilation and lighting (Liu et al. 2010). These conditions bring the risk of respiratory disease and injury, as well as facilitating the rapid spread of viruses (WHO-UN Habitat 2010). Furthermore, urban–industrial spread is a major category of human-induced environmental change (McMichael 2009). Rapid urban expansion induces extensive change of land use and coverage. Wetland and arable land reduction are becoming major problems for China (Li et al. 2009). Loss of cultivated land places significant pressure on agricultural production, with some believing that accelerated urbanisation and industrialization will decrease cultivated areas to the point where China can no longer feed its people in the next decades. In addition, urbanisation increases the risk of soil pollution through waste disposal and acid deposition derived from urban air pollution (Chen 2007), further compromising food yields and food quality.

Due to their transport systems, high fossil fuel dependency and consumption patterns, cities, especially wealthy cities, are

a major contributor to climate change. On the other hand, coastal cities are predicted to be major casualties of climate change-induced sea rise, and the eastern seaboard of China could be particularly at risk (WHO-UN Habitat 2010).

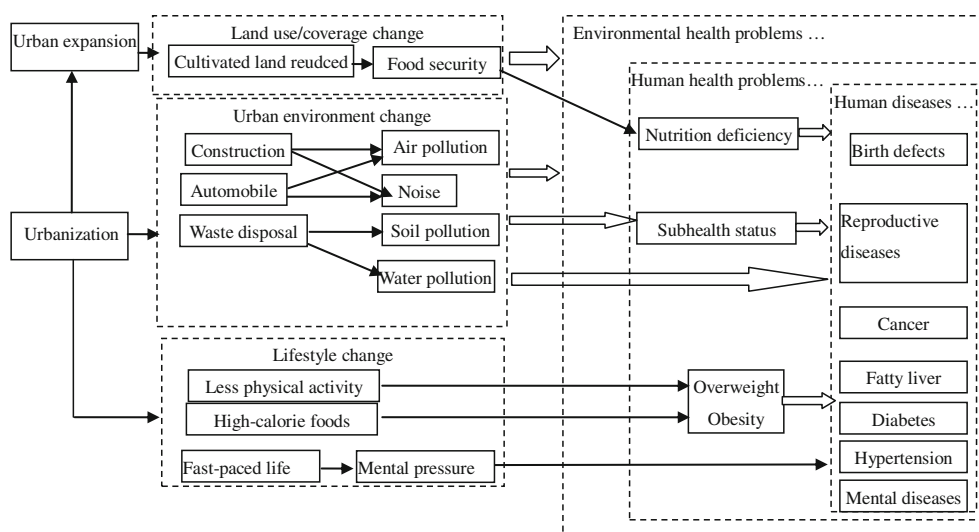
3.2 Urbanisation and human health in China

3.2.1 Framework of the correlation between urbanisation and health

Urbanisation and urban expansion result in urban environmental changes, and residents' lifestyle change, which can lead independently and synergistically to human health problems. Particularly, uncontrolled urbanisation is associated with pollution, social isolation, overcrowding, changes in dietary and physical activity patterns, and inadequate service capacity for providing drinking water, sanitation and waste disposal, which will harm the health of the population (Popkin 2003; Moore et al. 2003). Adopting an ecological public health approach, Fig. 2 summarises the available literature.

The figure illustrates the multiple pathways between systemic changes in the environment as a result of urbanisation and human health. Rapid, and often unplanned, urban growth is the source of environmental hazards which have direct and indirect effects on human health. Urban expansion is one of the major driving factors of land use/coverage change in China (Li et al. 2011), and these changes have extensive effects on local ecological systems by reducing biodiversity,

Fig. 2 Systemic understanding of the relationship between urbanisation, urban environment change, lifestyles and health



air deterioration and contributing to water shortages. Accelerated urbanisation along with explosive economic growth has further worsened the shortage of agricultural land over the last two decades (Chen 2007), with possible consequences for food security and nutritional deficiencies threatening the overall health status of the population. Reduced cultivated land places pressures to intensify agricultural production, which depends on both the progress of agricultural technology and the higher use of fertiliser and pesticides. Such inputs have repercussions for the availability of safe food, and also of the price of food as fertiliser costs increase in line with oil prices.

Urban environmental change includes air pollution and noise caused by construction and transportation, and soil pollution and water pollution caused by waste disposal (McMichael 2009; Wickramasinghe et al. 2011). Soil and water pollution can compound the problems already described in the food supply and can cause human diseases directly. Studies indicate that urban noise has adverse effects on human health (King and Davis 2003; Rabinowitz 2005), which may result in behavioural, psychological and physiological processes that pose risks to health (Fyhri and Aasvang 2009). Noise exposure can impair the hearing system, producing temporary or permanent deafness (Marcos et al. 2009). China does not regulate the noise produced by construction activities and motor vehicles, to which urban residents are particularly exposed.

Urbanisation not only changes the urban environment but also encourages change in people’s lifestyle, which is recognised by researchers and the World Health Organization as a key determinant of human health (Dixon et al. 2007; Li et al. 2008; WHO 2008; WHO-UN Habitat 2010). Growing numbers of people become reliant on automobile use; they can afford to buy computers and have high levels of car and computer use, which displace more vigorous physical activity with passive activity. Fast food with high calories is more

readily available and is an increasing source of lunch foods for urban workers. Reduced physical activity and high-calorie foods are the major contributing factors to the rise in overweight and obesity worldwide, and China is no exception (Popkin 2003). Moreover, the fast-paced life in cities brings mental stress to residents (WHO 2008), which, like noise exposure, can result in changed physiologic, psychological and behavioural processes.

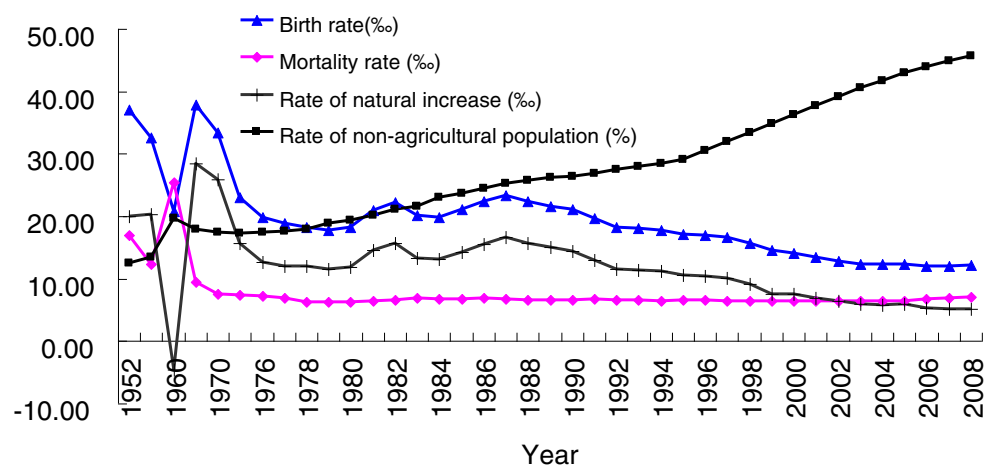
3.2.2 Temporal variability of urbanisation, birth rate and mortality in China

In Fig. 3, the temporal trends in birth rate, mortality rate, natural population increase rate and the non-agricultural population proportion are illustrated. The black line is the proportion of the non-agricultural population relative to the total population, a commonly used indicator for the level of urbanisation. In that particular trend line, two time points should be given attention: since 1975, urbanisation has been increasing continuously in China, and the speed of urbanisation increased after 1995. Around 1987, the birth rate and natural population increase rate began decreasing, and the mortality rate has stabilized at a low level since the 1970s.

A continuously decreasing birth rate and low mortality accompanied with an increasing life expectancy will result in population ageing in China. The percentage of people over 65 years old increased from 4.9% in 1982 to 8.3% in 2008, as shown in Fig. 4.

Although population ageing is a worldwide phenomenon, it will be more serious in China because of the big population size and the implementation of the one-child-per-couple policy since 1979 (Christensen et al. 2009). Rapid population ageing in developing countries poses additional economic, social and public health challenges because this demographic change is progressing much

Fig. 3 Temporal variability of urbanisation, birth rate and mortality in China



faster than in developed countries (Lai 1999), which is particularly true in China (Zhong 2011).

3.2.3 Urbanisation and infectious diseases in China

In China, the mortality caused by infectious diseases reduced significantly around the end of the twentieth century, and this was particularly true in rural regions, as shown in Fig. 5. Before 2000, mortality caused by infections was obviously higher in rural than in urban regions. However, the gap has been decreasing, with the difference between the regions being not significant in 2005 and 2009. This trend indicates that with the economic development during the process of urbanisation, some of the causes of sickness were removed, and this was also true in

rural regions. Moreover, after the 2003 SARS epidemic, the Chinese government improved its disease surveillance system. The Ministry of Health built the world's largest Internet-based disease reporting system, called the China Information System for Disease Control and Prevention. The system reports diseases in real time and case-based information is gathered and reported instead of the past aggregate reporting.

3.2.4 Urbanisation and chronic diseases in China

To understand the relationship between urbanisation and the prevalence of chronic diseases, cities and rural regions were grouped into seven groups according to the urbanisation level, namely: big cities, medium cities, small cities, rural

Fig. 4 Temporal variation of percentage of people over 65 years old in China

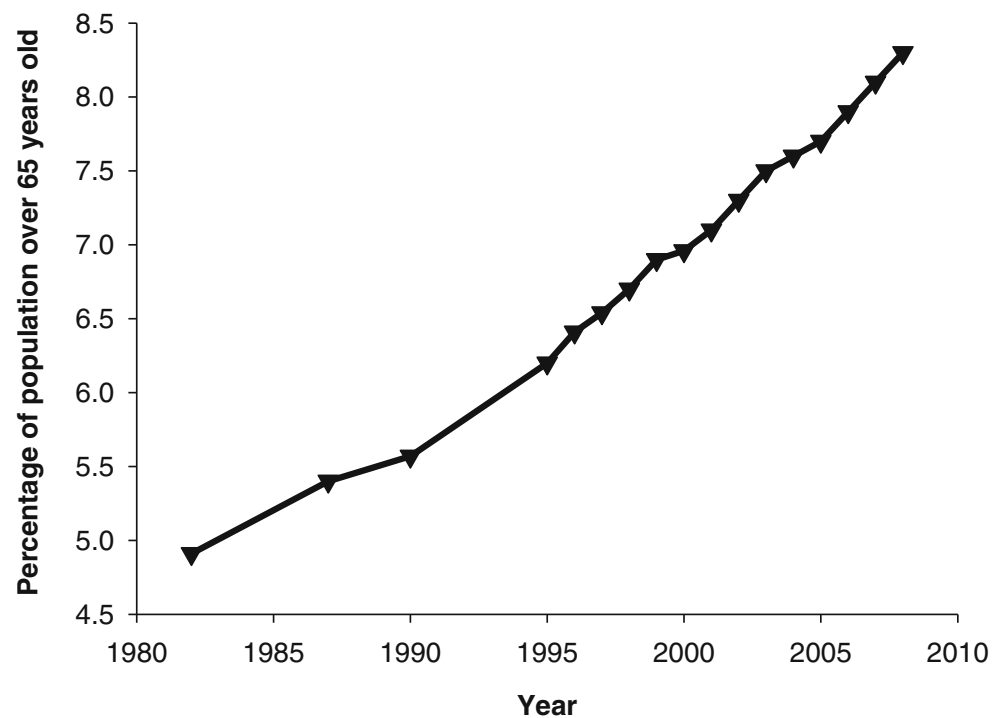
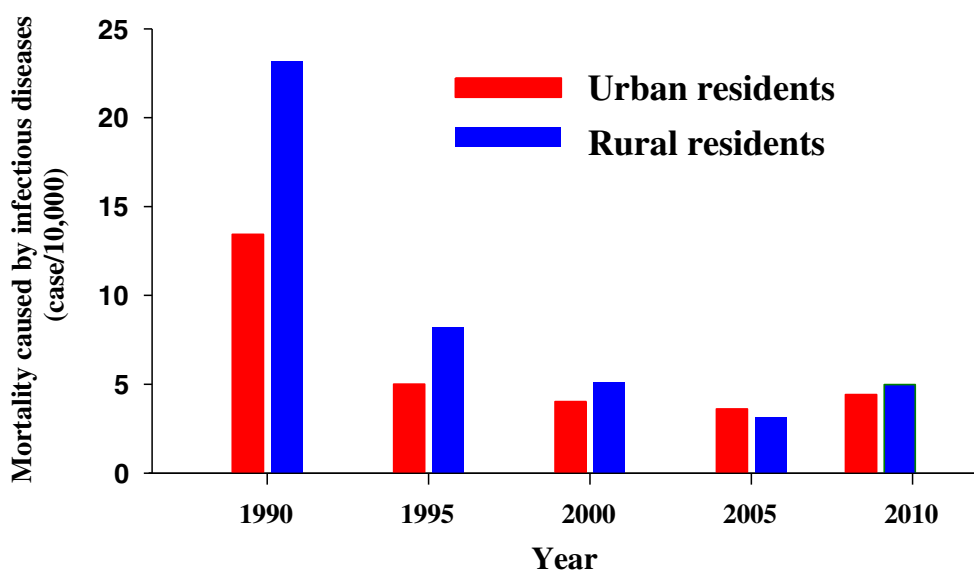


Fig. 5 Mortality caused by e infectious diseases in urban and rural regions, 1990–2009



class 1, rural class 2, rural class 3 and rural class 4 (Chen 2002). The relationship between the urbanisation level and the prevalence of chronic diseases in China is illustrated in Fig. 6.

Overall, the prevalence of chronic diseases in urban regions was significantly higher than that in rural regions. In the urban region, the prevalence of chronic diseases was highest in big cities and lowest in small cities. Changes were observed in the rural region also.

Spearman’s rank correlation coefficient was calculated to describe the relationship between the urbanisation level and the prevalence of chronic diseases during the recent two decades, shown in Table 1. In 1993, the correlation between the prevalence of chronic diseases and urbanisation level was not significant. However, the correlation was significant in 1998, 2003 and 2008, with a confidence probability of 99%. This indicates that regions with a high urbanisation level are inclined to have experienced a high prevalence of

chronic disease in recent decades, and this was particularly true in the most recent decade.

Of all the chronic diseases, cancer is the leading cause in urban China, representing 25% of all deaths. Cancer mortality is higher in urban than in rural areas (Zhao et al. 2010). Smoking and infectious agents are the major known risk factors for cancer. A polluted urban environment, especially air pollution, proved to be a cause of many diseases including cancer (Zhao et al. 2006). More recently, unsafe food caused by food additive abuse has become a troubling risk factor for disease in China (The Lancet 2009).

Hypertension is the most common risk factor for cardiovascular and cerebrovascular diseases worldwide. The prevalence of hypertension has been increasing in China in recent decades, whereas the rates of awareness, treatment and control remain unacceptably low. Hypertension is the leading preventable risk factor for death among Chinese adults 40 years of age and older. Cigarette smoking is also a major preventable risk

Fig. 6 Urbanisation level and the prevalence of chronic diseases in China

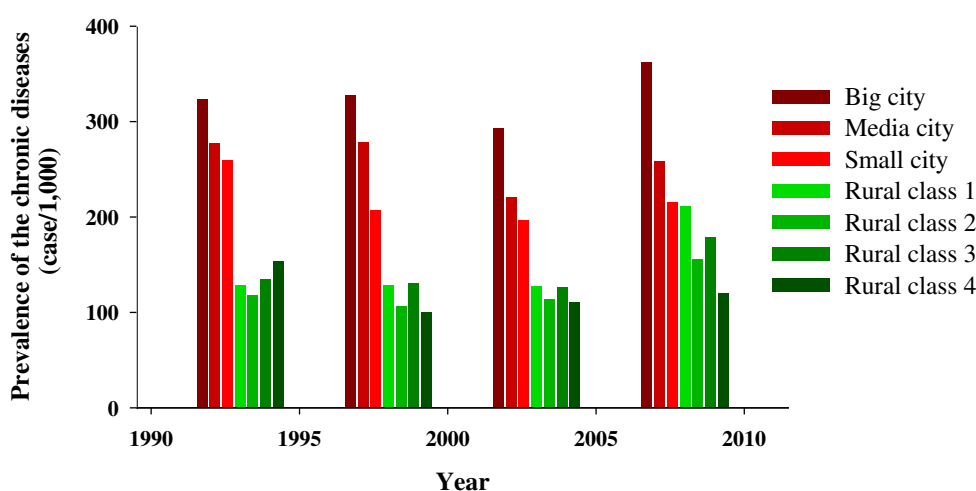


Table 1 Relationship between urbanisation level and prevalence of chronic diseases

Prevalence of chronic diseases	Urbanisation level (big cities > media cities > small cities > rural class 1 > rural class 2 > rural class 3 > rural class 4)	
	Spearman rank correlation coefficient ($N=7$)	P value
1993	0.679	0.094
1998	0.893	0.007
2003	0.964	0.000
2008	0.964	0.000

factor for death in China (He et al. 2005). Overweight and obesity are becoming serious problems among Chinese adults, which Yang and WHO Centre for Health Development (2008) attribute to reduced physical activity.

4 Conclusion and discussion

Urbanisation dynamics can be mapped at a national scale by using multi-temporal DMSP/OLS nighttime light data. During the recent decades, the urban area in China has increased unevenly in space (Deng and Huang 2004; Sun 2010). Urbanisation and urban expansion result in urban environment change and residents' lifestyle change, which have major consequences for urban human health. Urbanisation also leads to significant alterations of the physical environment far beyond city limits, resulting in habitat loss, climatic changes, and accumulation and spread of wastes in the atmosphere, hydrosphere and pedosphere (Chen 2007; McMichael 2009). Emergently, cooperation among land use, urban planning, environmental protection and health department in China should be made to give a complete solution for a sustainable urbanisation.

One issue that should be paid attention to is rural–urban migration because in the past decades, the major source of China's urban growth is rural–urban migration (Zhang and Song 2003). Living condition is the main concern which has negative effects on the physical and mental health of the migration population. This is especially true for temporary migrants (Hu et al. 2011). Some recent research indicated that rural-to-urban migration can also drive localised declines in biodiversity (Robson and Berkes 2011), which will also affect human health directly or indirectly (Wilson 2008). For these reasons, migrants should be paid special attention for their health status, especially for those living in low-rent urban villages. More importantly, a policy should be made to increase the income of these people and decrease the disparity between migrants and local citizens in health care, education and other public services.

China has experienced an epidemiological transition shifting from infectious to chronic diseases in a much shorter time than many other countries. With more and more people living under an urban environment, many of the known risk factors for chronic diseases have dramatically increased. The pace and spread of behavioural changes, including changing diets, decreased physical activity, high rates of male smoking and other high-risk behaviours, has accelerated to an unprecedented degree (Yang et al. 2008). The proportion of people who are overweight and obese is increasing rapidly in China, especially in the urban areas, whilst undernutrition continues in some areas. Health education is essential for urban citizens, which should give a good direction for health living habits, such as low-salt, low fat-diet and more physical activities through less car use. Urban planner should pay more attention to human health and try to induce an orderly and well-controlled urban construction.

Although infectious diseases are no longer the major causes of mortality in contemporary China, they remain the major causes of morbidity and mortality despite substantial progress in their control. China is a major contributor to the worldwide infectious disease burden because of its population size (Wang et al. 2008). Furthermore, emerging new infectious diseases bring more challenges to the current control efforts even when they have been successful. This is illustrated by the ecological interaction of people with animals in China favouring the emergence of new microbial threats (Wang et al. 2008), such as SARS, highly pathogenic avian influenza and *Streptococcus suis*. Rural–urban migration induced more temporal sex partners for both the migrants and the non-migrants, which increased the risk of HIV infection (Hu et al. 2006). For this reason, a policy should be made to care for not only the migrant themselves but also their family.

The demographic transition poses additional challenges. A rapidly increasing urban population will accompany decreasing birth rate and low mortality in China. The percentage of population over 65 years old has been increasing in recent decades, and the transition to an older population will present the health system with major costs. China has 6 million patients with dementia and, with a rapidly ageing population, was estimated to have 1 million new cases every year (Qiu 2007). Family planning in countries with high birth rates has the potential to reduce poverty and hunger (Cleland et al. 2006). However, China's one-child policy, introduced in 1979 and implemented for over 30 years, has resulted in an increase in older people and a decrease in younger workers, as well as a sex ratio imbalance (Christensen et al. 2009; Grossi 2005). It is both urgent and necessary for China to solve its problems related to ageing, both for public health and for sustainable economic and social development.

A systemic understanding of urbanisation and human health requires a health system which encompasses both environmental health and human health. This is of great importance because disease prevention is less expensive than pharmaceutical and hospital-based care over the long term, and a healthy population is one of the critical pillars of social and economic development. In this paper, we put forward the types of data which need to be collected as part of any early warning, or monitoring and surveillance, health system. Importantly, it includes a role for disaggregated urban–rural data, which, as the WHO points out, is necessary if governments are to counteract health inequities (WHO and UN Habitat 2010). By adopting an ecological public health approach, we show how making human and environmental health central to policy could lead to fairer and more sustainable urban systems.

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