Journal of Environmental Management 212 (2018) 405–414

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Examining the impacts of urban form on air pollutant emissions: Evidence from China

Chenjing Fan [a], Li Tian [a, *], Lin Zhou [a], Deyi Hou [b], Yan Song [c], Xiaohui Qiao [b], Jingwei Li [a]

[a] School of Architecture, Tsinghua University, Beijing, 100084, China
[b] School of Environment, Tsinghua University, Beijing, 100084, China
[c] Department of City and Regional Planning, University of North Carolina at Chapel Hill, NC, 27599-3140, USA

ARTICLE INFO

Article history:
Received 23 October 2017
Received in revised form
28 December 2017
Accepted 1 February 2018
Available online 22 February 2018

Keywords:
Urban form
Air pollution
Non-point source emissions
Geographically weighted regression analysis

1. Introduction

Air pollution problems are becoming increasingly serious with the high rate of urbanization seen in China. This is leading to an increase in the number of people exposed to contaminated air, as well as an increase in the number of deaths related to this exposure (Cheng et al., 2013). Because of the severity of this phenomenon, it has gained global attention. The Health Effects Institute (HEI), based on extensive research (175 countries), found that China faces the deadliest air pollution in the world (HEI, 2017). Every time a large-scale air pollution incident occurs, it brings about a public health crisis and a crisis in government trust and largely affects the development of social sustainability (Zhang et al., 2017). In 2016, 75.1% of prefecture-level cities in China did not meet the required standards for urban air quality in accordance with the "China Environment Status Bulletin 2016."

Air quality deterioration may be attributed to a variety of anthropogenic activities and land use changes, especially in urban areas. In addition to point source pollutant emissions from factory and energy facilities, the uncontrolled expansion of urban areas might also result in more Vehicle Kilometers of Travel (VKT), land contamination and dust generation, and vapor emission from non-point sources (Chen et al., 2015; Hou and Li, 2017; Hou et al., 2012; Ma et al., 2016; Song et al., 2018). Non-point source emission was found to account for half the total of NOx and PM2.5 emissions in developed countries (Bereitschaft and Debbage, 2013). Accordingly, from the perspective of urban planning, an increasing number of scholars find that a more compact city—with less sprawl, fragmentation, and complexity shape might reduce air pollution emissions (Stone, 2008). With low-intensity residential dwellings in suburban and exurban areas—as measured by population density—there will be an increase in distance for residents to travel to their jobs in the center of the city (Pourahmad et al., 2007). Urban fragmentation shows the degree of urban landscape continuity by using indices such as the number of patches, largest urban patch index and mean urban patch area. Higher urban fragmentation is expected with more "leapfrog" development, resulting in heightened numbers of VKT and larger non-point source emissions (Stone, 2008; Hou et al., 2014, 2018). Complexity of the urban form measured by the urban compactness ratio and aggregation index provides a jagged urban boundary (Bereitschaft and Debbage, 2013, Zou et al., 2016), where highly convoluted urban landscapes are also expected to increase the VKT (Fig. 1).

Investigating air pollution modeling plays a key role in policy-making (Hao et al., 2007). Some empirical studies (Table 1) are used to test the relationship between urban form and air pollutant emissions in order to explore ways to reduce pollutant emissions. Most of these empirical studies used the OLS linear regression method to analyze which urban form index is related to the air quality or pollution emission, as well as to estimate the coefficient of the form index in the model. Before constructing the regression model, it was necessary to consider the characteristics of the study area and the research objectives. It should be noted that the multi-collinearity between the different indices needs to be considered as well (Lu and Liu, 2016). In order to explore the impact of urban form variables on air pollution in different regions, some papers subdivide the samples into different regions (Clark et al., 2011), urban and rural areas (McCarty and Kaza, 2015), different levels of cities (Bereitschaft and Debbage, 2013), or different population inflows (Yuan et al., 2017). Additionally, Lu and Liu (2016) and McCarty and

* Corresponding author.
E-mail address: litian262@126.com (L. Tian).

https://doi.org/10.1016/j.jenvman.2018.02.001

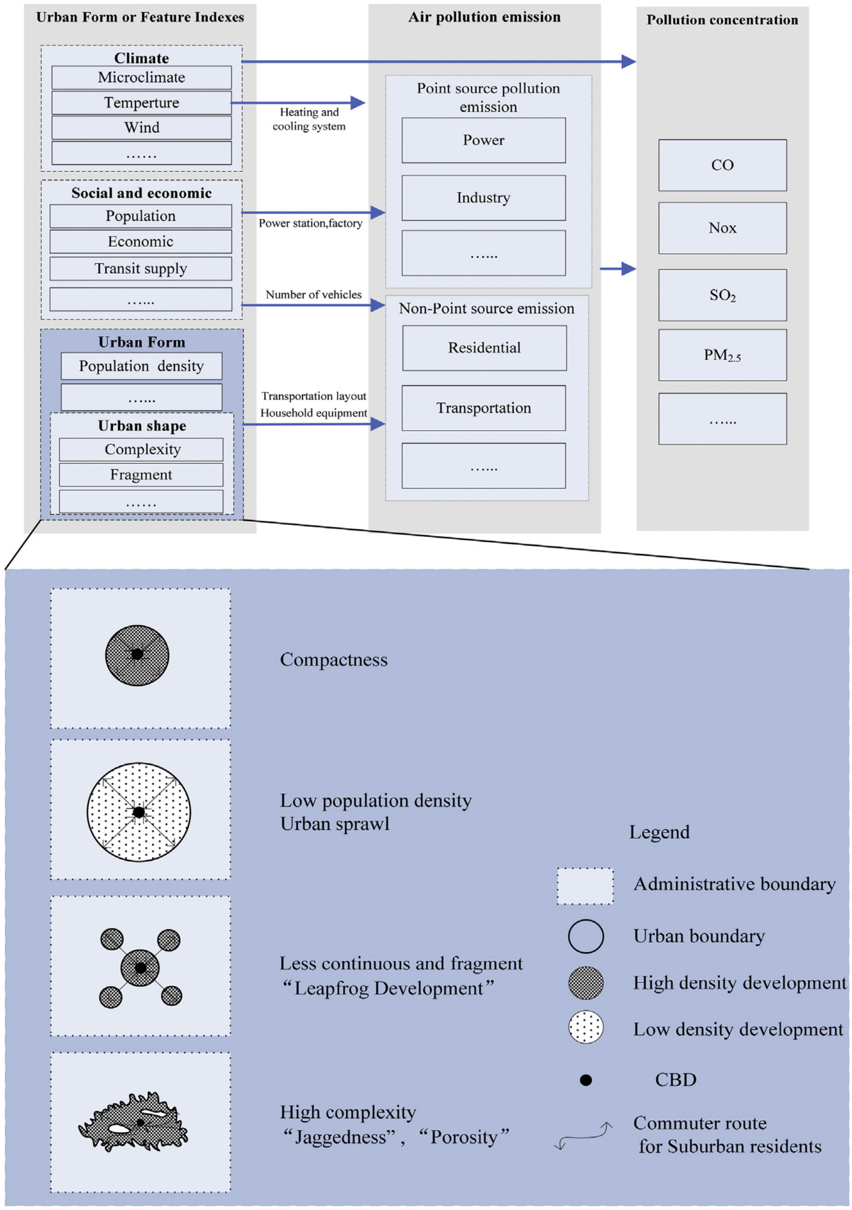

Fig. 1. Framework of relationship between urban form and air pollution.
Source: drawn by the authors.

Kaza (2015) used a spatial statistics method like a geography weighted regression model or spatial lag error model to develop a planning policy according to local conditions. We also see that non-point source emissions data were selected as dependent variables in the study of Bereitschaft and Debbage (2013) in order to exclude emissions from large point source industrial facilities, which are not affected by the urban form (Fig. 1).

During the process of rapid urbanization, the correlation between urban form and air pollution has always attracted global attention, and much of this attention has focused on whether the urban form may have a more profound effect on the environment than air pollution itself. In China, urban transportation (VKT) contributed to 137,000 ambient PM2.5-attributable mortality in 2013 (GBD MAPS Working Group, 2016; HEI, 2017). Much research has argued that development of sustainable urban form for compact cities could result in less VKT and reduce traffic emissions (Yuan et al., 2017; She et al., 2017; Lu and Liu, 2016; Sun et al., 2016). However, the dependent variable in these studies has been mostly from the observed values of pollutant concentration—which are affected by many factors, such as the location of the monitoring site, micro-climate, and point source emissions. None of these studies have been concerned that the ratio of non-point source pollutant emission to all air pollution emission of China is much different from that of developed countries (Li et al., 2015; Bereitschaft and Debbage, 2013). On the other hand, conclusions vary from region to region (Lu and Liu, 2016). In China, research based on prefecture-level cities is rarely reported in literature and the spatial difference characteristics of emissions in different regions has not been fully recognized.

This article takes 344 prefecture-level cities in China as an example and aims to explore the relationship of urban form and non-point source air pollution emissions—including CO, NOx, SO_2, and PM2.5—based on the linear regression model. Next, a geographically weighted regression (GWR) model was used to