Atmospheric Pollution Research xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Atmospheric Pollution Research

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

Effects of Green space landscape patterns on particulate matter in Zhejiang Province, China

Haitian Wu[a], Chang Yang[b], Jian Chen[a,*], Shan Yang[a], Ting Lu[a], Xintao Lin[a]

[a] State Key Laboratory of Subtropical Silviculture, Zhejiang A & F University, Lin'an, Hangzhou, 311300, China
[b] College of Environment and Design, The University of Georgia, Athens, GA 30602, USA

ARTICLE INFO

Keywords:
$PM_{2.5}$
PM_{10}
Green spaces
Edge length
PCA
HCA
Spatiotemporal variation

ABSTRACT

Particulate matter (PM) pollution and its health effects are receiving more attention. Green space can provide critical ecosystem services, and increasing the supply of green space can reduce PM pollution, but effects of green spaces on PM at different scales are not clear. Based on the traffic and meteorological factors from 50 monitoring stations, principal composition cluster analysis (PCA) and hierarchical cluster analysis (HCA) were implemented. Daily PMs (PM_{10} and $PM_{2.5}$) concentrations were measured at 50 monitoring stations in Zhejiang (1 Feb 2015 to 28 Feb 2017) to quantify the spatiotemporal change of PM concentration and its empirical relationship with green spaces and landscape structure. The result shows: (1) At 5-km, or smaller, scale, the correlation between green space and $PM_{2.5}$ is stronger than PM_{10}; (2) at 2-km scale or less, the total edge length has more impact on PMs than green cover area, while at 3–5-km scale, the influence of green cover is more dominated; (3) In the mountain and hilly area in Zhejiang that are dominated by meteorological factors, we can establish the $PM_{2.5}$ forecast model by 3–4-km scale green spaces, while in those basins or low lands, we can build the $PM_{2.5}$ forecast model by using 1–2-km scale green spaces. The results are of great importance for urban green space planning, especially when it comes to the size and shape of the green space. In addition, it can provide guidance to the future application of LUR model in Zhejiang area.

1. Introduction

Air pollution is widely spread in highly-developed industrial areas and densely-populated regions (Mathers et al., 2001), and particulate matter (PM) pollution is one of the major pollutions in urban areas (Chen et al., 2012). PM pollution affects humans health and the public environment directly, especially PM_{10} (particles with an aerodynamic diameter smaller than 10 μm) and $PM_{2.5}$ (particles with an aerodynamic diameter smaller than10 μm). In Europe, $PM_{2.5}$ pollution led to an average reduction of 8.6 months in average life expectancy (Prendes et al., 1999). According to a Chinese government report, the number of people in Beijing, Guangzhou, Shanghai, and Xi'an who died from diseases caused by inhalable particles rose from 7700 to 8500 from 2010 to 2012 (Liu et al., 2017). The PM pollution spread widely in European and North American regions in the 1950s and 1960s, but now it has become more serious in developing countries (e.g., China, India) (Rohde and Muller, 2015). According to 2014 State of Environment Report, only 8 out of China's 74 biggest cities met the new ambient air quality standard. Reducing PMs (PM_{10} and $PM_{2.5}$) concentration has become one of the main tasks of ecological restoration in China. Vehicle emissions are a major source of PM pollution in urban area in China (Wang et al., 2017). According to Wu et al. vehicle emissions are the greatest source of PM on foggy and hazy days, while on clear days, they contribute to more than twenty percents of the different PM categories (particles < 0.2 μm, 2.5–10 μm, and 10–100 μm) (Wang et al., 2017; Wu et al., 2014). On the contrary, the increase of motor vehicles has been very rapid in China, especially in developed regions. For example, the motor vehicles in Zhejiang Province increased from 680,000 to 15,510,000 from 2000 to 2016 (Zhejiang Statistics Bureau, 2000). Meteorological conditions have also been identified as an important source of PM pollution, which has been proved by several studies (Chen et al., 2016a, b; Chen et al., 2017; He et al., 2017). Wind speed, relative humidity, precipitation and temperature have been found to exhibit a relation with PM concentration. Therefore, the meteorological and traffic condition as the main factors affecting the transmission and deposition of PM would be the two control variables in our study.

Using plants as a “natural filter” to deal with PM was widely recognized by the public (Dockery et al., 1993; Popek et al., 2013; Aničić et al., 2011). In the United States, according to Nowak et al. the total amount of $PM_{2.5}$ removed annually by trees varied from 4.7 tons in

Peer review under responsibility of Turkish National Committee for Air Pollution Research and Control.

* Corresponding author.
E-mail address: chenjian@126.com (J. Chen).

https://doi.org/10.1016/j.apr.2018.03.004
Received 2 December 2017; Received in revised form 9 March 2018; Accepted 13 March 2018

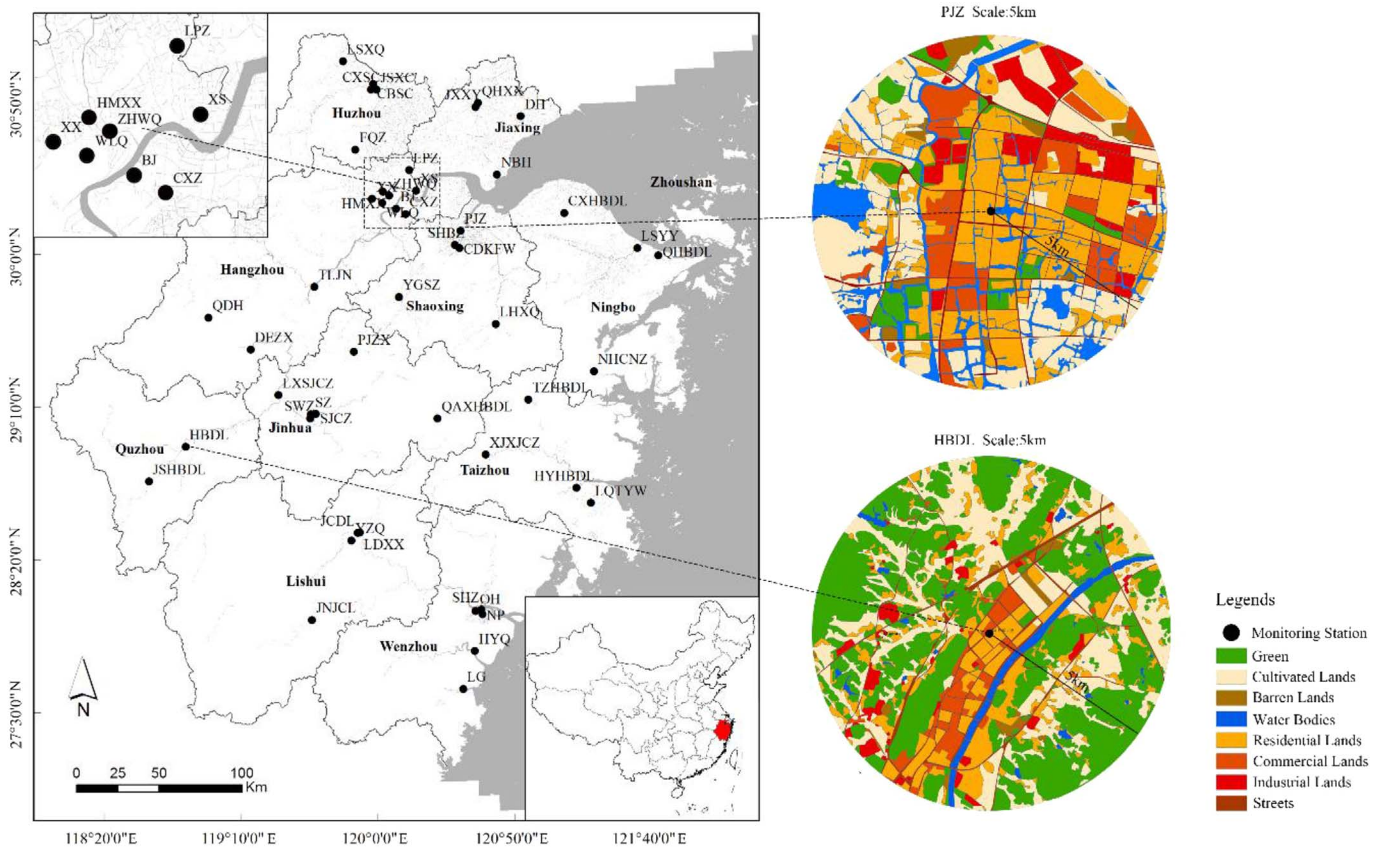

Fig. 1. Fifty monitor stations' distribution and visual interpreted land use maps. Black points represent the monitoring stations. Capital letters stand for the abbreviation of monitoring sites. Land use maps center on two monitoring stations (PJZ and HBDL) with radius of 5 km are shown in the right panel as examples.

Syracuse to 64.5 tons in Atlanta (Nowak et al., 2013). A study in Shanghai shows that the PM_{10} in an urban forest park are 9.1%lower than that of outside (Shan et al., 2011). In England, the concentration of inhalable particles in the West Midlands was reduced by 10% and 10 tons of PM_{10} settled every year as the urban forest coverage increased 12.8%, and the deposition value would be 200 tons per year if the coverage would increase to 54% (Mcdonald et al., 2007). Understanding the relationship between green space and PM is becoming necessary and essential for urban sustainable development. In summary, previous studies mainly focus on the influence of coverage of green space on the PM, while few focus on the edge length. Therefore, in our study, we will focus on both green space cover area and edge length.

PM concentrations vary greatly in time and space because of the dynamic meteorological conditions, heterogeneous land surface properties, uneven distribution of emission sources, landforms, and other human activities (Janhäll, 2015; Pui et al., 2014). Thus, in large-scale PM influence studies, environmental elements should be considered. Recently, more researchers have focused on the relationship of PM and urban landscape patterns due to the development of geographic information systems (GIS) and remote sensing (RS). Among these technologies, predicting the $PM_{2.5}$ and PM_{10} by using the land use regression model (LUR), which analyzes the potential factors based on GIS, are mostly used to explore pollutant sources, including factors, such as road networks, population density, land use, elevation (DEM), etc. (Ross et al., 2007; Henderson et al., 2007; Yang et al., 2018). Landscape pattern analysis has a very large impact based on different landscape scales. To improve the accuracy of prediction model, suitable landscape scales need to be selected according to different characteristics of the landscape patches (Morani et al., 2011). Landscape patches include green space, wetlands, cultivated land, and water bodies that can suppress the PM concentration in urban landscape patterns. Green space has an outstanding performance among these patterns (Liu et al., 2017; Wu et al., 2015). In Beijing, the PM deposition velocity is 0.06–0.39 cm/s in the green space, while on the water surface, it only remains around 0.01–0.04 cm/s (Liu et al., 2016). Although various studies concerning PM are carrying on, the relationship between green space at different scales and PM is still not clear. Previous studies have a very large diversity between landscape scales, from 0 to 1, 0–3, to 1–5 km (Marloes et al., 2012; Han et al., 2016; Weber et al., 2014). These studies are mostly based on former experiences rather than the actual environment. To some extent, they did not consider the influence of landscape patterns, especially green space patterns, on PM. In our study, we will explore the relation between PM and different scales of green space landscape pattern and find out the influence of green space pattern on PM concentration under different conditions.

Zhejiang, as the heartland of Yangtze River Delta (YRD), is in the process of rapid urbanization and the PM generated by urbanization has a negative impact on its environment. A long-term visibility observation has shown a trend of 0.24 km decrease per year during 1981–2005 (Gao et al., 2011). The haze days in Hangzhou increase continually from about 50 in 1980s to 160 after 2001 (Cheng et al., 2013). Zhejiang province has vast green space (the green cover in 2015 is about 59.1%), but the retention capacities of green spaces has not been effectively developed. This paper aims at analyzing the effects of green space on urban air particle pollution, with the aim of exploring the relationship between $PM_{2.5}$, PM_{10} concentration, and different green space scales. Based on a serious of meteorological and traffic factors, the study categorizes different monitor stations into clusters to make them comparable. Three analyses are made after the clustering: 1) the spatial and temporal variation of PMs (PM_{10} and $PM_{2.5}$); 2) the relationship between different scales of green space edge length and green cover, and