EXPLORING THE RELATIONSHUPS BETWEEN THE LAND USE TYPES DERIVED FREM SATELLITE IMAGERY AND AIR POLLUTION

Jian-wen Dong , Re-Yang Lee , Yi-ting Cai

Han-xiu Zhang , Yu-fang Yen , Guan-jie Chen , Chia-Hui Hsu

e-mail: kitty105136@gmail.com

Department of Land Management, Feng-Chia University

No. 100, Wenhwa Rd., Seatwen, Taichung, 40724 Taiwan (R.O.C.)

KEY WORDS：Formosat II, land use regression, PM2.5

ABSTRACT：

In recent years, due to the vigorous development of industry and commerce, air pollution is becoming increasingly serious. Especially, PM 2.5 pollution problems caused by the anthropogenic combustion process have caused wide attentions by the community. This study aimed to explore the relationships between the land use types and PM 2.5 pollutants. The study area located in Taichung city of central Taiwan.

Land use types interpreted from the three years of Formosat II images(2012, 2014, and 2016) and air pollutants data of the corresponding years from 5 monitoring sites were used to develop land use regression (LUR) models. Land use types that affect the quality of air include：greenland, water, building, and barren land. SPSS regression analysis was performed to calculate the regression coefficient between land use classification and pollutant concentration index. The result indicates that the correlation coefficient of the green land is -46.3%, standing for negative moderately correlation. The R2, however, is only 26.1% for the regression equation. It means that the estimation of PM2.5 concentration cannot only use these four land use types.

1.INTRODUCTION

In recent years, many epidemiological studies have shown that both short-term and long-term exposure to air pollutants can cause adverse effects on human health, particularly with respiratory and cardiopulmonary effects (Liang, 2010). Urban air pollutants include CO, NO2, O3, SO2, and suspended particles with particle size less than 10μm (PM10) or 2.5μm (PM 2.5). Several researches have demonstrated the relationship between the air pollution and human health (Brunekreef and Holgate, 2002; Brook et al., 2010). It has also been pointed out that the land use types have a considerable relationship with air pollution (Jacobson and Mark, 2009). Weng and Yang (2006) investigated the relationship of local air pollution patterns with urban land use and thermal landscape using a GIS approach. Xu et al. (2006) studied the quantitative relationships between land use (build-up, water, and vegetation) and air quality (SO2, NO2, PM10) in central Wuhan and found the air quality was significantly affected by land use types.

The land use regression (LUR) model has been used in several land use changes related researches (Turner and Willian, 1990; Vesterby and Heimlich, 1991; Aaviksoo, 1993; Turner and Meyer, 1994; Skinner, 1995; US National Research Council, 1997; Paquette and Domon , 1997; Landis and Zhang, 1998; Wu, 1998; Verburg et al., 1999; Barassoulis, 2000; Hudson and Birnie, 2000; Beelen et al., 2013; Wu et al., 2014; Alexeeff et al., 2015). Hoek et al. (2008) used LUR model to assess the variability of air pollution in the city by using predictive variables obtained from geographic information systems. Sun et al. (2016) indicated that water, woodland, grassland, arable land, urban and unused land have impacted on the concentration of air pollutants. Therefore, the purpose of this study is to explore the relationships between the land use types and PM2.5 pollutants. Since the satellite imagery has the characteristics of multi-period, wide range, rapid acquisition of data, and lower cost than that of artificial ground survey, different from previous researches, this study established the LUR model by utilizing the remote sensing technique to obtain the land use types.

Taichung city, the most suitable residential city in Taiwan, was selected as the study area. Land use types interpreted from the three years of Formosat II satellite images (2012, 2014, and 2016) and the concentration of fine suspended particulates (PM2.5) data of the corresponding years from 5 monitoring stations were used to develop land use regression (LUR) models. Air pollutants data was provided by the Environmental Protection Administration of Taiwan. Four types of land use were used to build the LUR model including green land, water, building and barren land. Regression analysis was carried out to obtain the relationships between the land use types and PM2.5 pollutants. The impacts of the land use types on the pollutant concentration were evaluated.

2. MATERIALS AND METHODS

2.1. Study Area

Taichung City is located in central Taiwan (about 120.40o E and 24.09o N)(Figure 1). The total area is about 2,215 square kilometers. The population is the second largest in Taiwan and was assessed as Taiwan's most livable city by the United States Cable Network (CNN) in 2016. The selected five major air quality monitoring stations for the study were Seatwen, Shalu, Jhongming, Dali, Fongyuan (Figure 1).

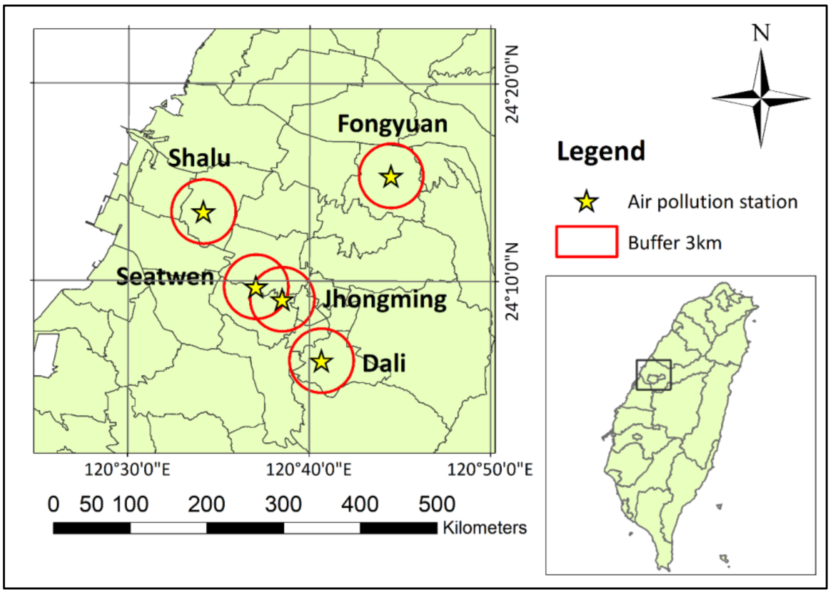

Figure 1. Five major air quality monitoring stations of Taichung City

2.2. Calculations of Land Use Areas

Since the land use variables were assumed that the maximum buffer distance of 3000m (Su et al., 2009), the land use types which circular buffer with radius of 3000m around each monitoring station was interpreted using satellite images. Considering higher air pollution concentration in the winter period, several winter time Formosat II images were used for the analysis, including 1/10 and 2/5, 2012, 2/1 and 2/23, 2014 as well as 1/9 and 1/26, 2016. Figure 2 is the mosaicked pan sharpened image for 1/9 and 1/26, 2016.

A supervised classification approach using the maximum likelihood classifier was used to classify the four land cover types. The areas of each land use for each station were then calculated as the independent variables to build the LUR models.

Figure 2. The mosaicked pan sharpened image for 1/9 and 1/26, 2016.

2.3. Air Pollution Measurement Data

The fine particle concentration data of the monitoring station was provided by the EPA Taiwan. In order to be able to exclude outliers of the diurnal variation of fine suspended particles data, we used the median for the selected month. We first sorted the daily average concentration data according the level of order and took the intermediate values as the median for each selected month (Table 1). The medians were then used as the dependent variables to build LUR models.

Table 1. The medians of fine sediment concentration (μg / m3) data for each selected month.

Stations \ Time	January 2012	February 2014	January 2016
Shalu	28.67	28.09	17.32
Seatwen	26.63	28.42	18.22
Jhongming	28.51	29.69	19.08
Dali	29.38	28.54	19.40
Fongyuan	21.88	20.97	18.14

2.4 Land Use Regression Model

Regression analysis focuses on the relationship between a dependent variable and one or more independent variables. It helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied.

In this study, the LUR equation was expressed as Y = a1X1 +a2X2+…+ b. "Y" was the estimated value of air pollution, "aj" was the coefficient of the independent variable, "Xj" was the areas of land use, and "b" was the constant.

3. RESULTS AND DISCUSSION

The classifications of the land use types for three years are shown in Figure 3. Table 2 is Pearson correlation coefficients between land use and PM2.5 concentration for all three years. The result indicates that the correlation coefficient of the green land is -46.3%, standing for negative moderately correlation. It means the more green land areas, the less PM2.5 concentrations. Followed by water, building and barren land, the coefficients are positive correlation. Representatives of four land use types affect the change of PM2.5 concentrations. The R2, however, is only 26.1% for the regression equation. It means that the estimation of PM 2.5 concentration cannot only use these four land use types. More land use types are necessary to attain better explanation.

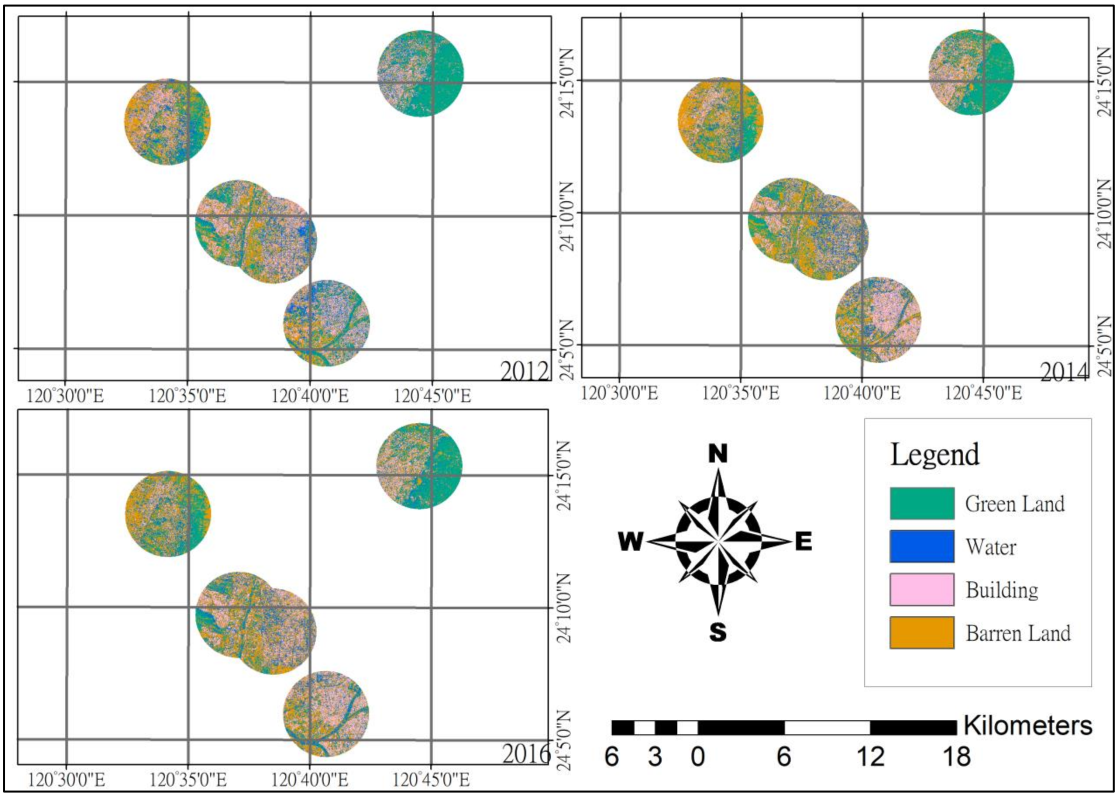

Figure 3. The classifications of the land use types for three years.

Table 2. Pearson correlation coefficients between land use and PM 2.5 concentration for all three years

	Pearson Correlation Coefficients	**P-value**
Greenland	-.463	0.041*
Water	.327	0.117
Building	.298	0.141
Barren Land	.078	0.391

*p-value<0.05

4. CONCLUSIONS AND SUGGESTIONS

The purpose of this study was to evaluate the correlations between the land use types and PM 2.5 concentrations. For most of the former researches, the satellite imagery is seldom used to derive the data of land use. Since the satellite imagery has the characteristics of multi-period, wide range, rapid acquisition of data, and lower cost than that of artificial ground survey, this study attempted to use satellite images to obtain the land use types. Considering the data availability and budget, this study used Formosa-2 satellite images for 2012, 2014, and 2016. Since modern people pays more attention to health problems, we hope the results of this study can be used as a reference for future urban and rural planning to make good plans for health.

The research result indicated the the R2 is only 26.1% for the regression equation. It means that the estimation of PM2.5 concentration cannot only use these four land use types. Possible causes are their residuals not with independent, homogeneous, and normal properties. More land use types are necessary to attain better explanation. The samples for each land use type may be too few. For statistical analysis, the number of optimum samples is usual greater than 30. Comparing the similar research conducted by Chung (2017), however, air pollution data from 70 monitoring stations and 1999-2011 was used in the analysis and the results are significant.

The spatial resolution (8m) of Formosat II imagery may be also too coarse for such kind of study. More detail land use information cannot be interpreted. Therefore, the classification categories of land used in this study are limited to only green land, water, building and barren land. In the future, higher spatial resolution images, such as aerial photography or WorldView III, can be used to derive more detail land use types, such as traffic roads and factory lands where are usual the sources of pollution. The correlation between land use types and air pollutants could be better.

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