Ecological Indicators 72 (2017) 921–933

Contents lists available at ScienceDirect

Ecological Indicators

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

Original articles

Relationship between green space-related morphology and noise pollution

Efstathios Margaritis, Jian Kang*

School of Architecture, University of Sheffield, Sheffield, United Kingdom

ARTICLE INFO

Article history:
Received 20 May 2016
Received in revised form
12 September 2016
Accepted 19 September 2016

Keywords:
Noise pollution
Green spaces
Urban morphology
GIS
Cluster analysis

ABSTRACT

Green spaces have been proved to have a positive effect on traffic noise pollution in the local scale; however their effects have not been explored on the urban level. This paper investigates the effects of green space-related parameters from a land cover viewpoint on traffic noise pollution in order to understand to what extent greener cities can also be quieter. A triple level analysis was conducted in the agglomeration, urban and kernel level including various case study cities across Europe. The green space parameters were calculated based on land cover data available in a European scale, while traffic noise data were extracted from online noise maps and configured in noise indices. In the first level 25 agglomerations were investigated, six of which were further analyzed in the urban and kernel levels. It was found that the effect of green spaces on traffic noise pollution varies according to the scale of analysis. In the agglomeration level, there was no significant difference in the cluster of the higher green space index and the percentage of people exposed in the lowest (55–59 dB(A)) or the highest noise band of more than 70 dB(A). In the urban level it was found that lower noise levels can possibly be achieved in cities with a higher extent of porosity and green space coverage. Finally, in the kernel level a Geographically Weighted Regression (GWR) analysis was conducted for the identification of correlations between noise and green. Strong correlations were identified between 60% and 79%, while a further cluster analysis combined with land cover data revealed that lower noise levels were detected in the cluster with higher green space coverage. At last, all cities were ranked according to the calculated noise index.

1. Introduction

The problem of exposure to traffic noise is rapidly increasing and is closely related with the rapid urbanization process taking place around the world. Nowadays, 54 per cent of the world's population lives in urban areas, a proportion that is expected to rise to 66 per cent by the year 2050 (United Nations, 2012). As a consequence of this process noise annoyance problems are caused, leading one out of five Europeans to be regularly exposed to sound levels during the night that can infer serious damage to health (WHO, 2009). This is the reason why the European Community adopted measures for noise reduction through the Environmental Noise Directive (2002/49/EC), hereinafter called the "END".

Other benchmarking reports on a European scale classified cities according to various urban forms (Schwarz, 2010) or sustainability indices (The Economist, 2009). In particular, the last report refers to transport variables, which cannot provide a direct assessment of the noise pollution in these cities. From the viewpoint of soundscape, studies on a European context are rare and there is the need to establish a common protocol for soundscape exposure assessment (Lercher and Schulte-fortkamp, 2015). Lastly, in the European Green Capital Award (European Comission, 2014), the quality of the acoustic environment was taken into consideration using the exposure of people above or below certain noise bands whenever these results were available.

On the other hand, green spaces comprise one of the inherent elements of urban form, apart from outdoor spaces, road and building infrastructure (Valente-Pereira, 2014). All these factors can affect traffic noise distribution in various levels. Previous studies have examined their effect either on the building level (Oliveira and Silva, 2010; Salomons and Berghauser Pont, 2012; Silva et al., 2014) or in large neighbourhoods (Hao et al., 2015a; Tang and Wang, 2007). At the city level, traffic noise has been measured either through the use of landscape metrics (Oliveira and Silva, 2010; Mõisja et al., 2016; Weber et al., 2014) or with the help of indicators related to road and building characteristics (Aguilera et al., 2015;

* Corresponding author at: School of Architecture, University of Sheffield, Western Bank, Arts Tower – S10 2TN Sheffield (UK).
E-mail addresses: ar1em@sheffield.ac.uk (E. Margaritis), j.kang@sheffield.ac.uk (J. Kang).

http://dx.doi.org/10.1016/j.ecolind.2016.09.032
1470-160X/

Table 1
General characteristics of the 25 agglomerations sorted in a descending form for the population density field.

City	Area (km^2)	Pop. Density (people/km^2)	Total Green (km^2)	Total Green (m^2/person)
Brussels	160	6,249	38	38
Valencia	130	6,249	94	115
Copenhagen	302	3,546	104	97
Helsinki	200	2,805	69	123
Sofia	492	2,760	116	85
Frankfurt	250	2,660	107	160
Tallinn	159	2,527	100	250
Lille	426	2,348	196	196
Prague	496	2,340	282	243
Hannover	238	2,333	96	174
Antwerp	205	2,062	35	83
Gratz	128	1,960	56	223
Linz	111	1,911	48	225
Varna	169	1,892	95	297
Montpellier	155	1,855	70	242
Amsterdam	152	1,752	46	173
Rotterdam	150	1,752	38	146
Alicante	200	1,674	136	406
Dresden	329	1,387	187	410
Grenoble	327	1,315	405	942
Ruse	127	1,240	80	508
Innsbruck	110	1,133	84	672
Burgas	219	1,050	204	884
Vitoria–Gazteiz	276	857	230	972
Bruges	139	842	71	602

Hao et al., 2015b). Finally, on regional level, an attempt to approach noise issues by emphasizing on the identification and designation of “quiet areas” according to land use criteria was performed by Votsi et al. (2012).

The relationship between traffic noise and green spaces has been investigated in multiple scales. The majority of these studies focuses on the small-scale, where the absorption or scattering effects of branches and leaves are investigated (Attenborough, 2002; Aylor, 1972; Hosanna, 2014; Huddart, 1990; Van Renterghem et al., 2014). This kind of researches are extended from a single tree (Yang et al., 2011) to different plant types (Horoshenkov et al., 2013) or various tree belts (Van Renterghem et al., 2012). Interesting quantitative approaches on the park scale have also been developed by Pheasant et al. (2010) with the Tranquillity Rating Prediction (TRAP) tool and by Brambilla and Gallo (2016) with the QUIETE index. At the city scale, previous works have selectively emphasized the quantitative assessment of parks concerning traffic noise reduction (Cohen et al., 2014; González-Oreja et al., 2010). Other studies - investigating also the users' perception of the acoustic quality in the parks-have been performed by Brambilla et al. (2013), Brambilla and Maffei (2006), Weber (2014).

However, there is little evidence on the effect of green spaces as a land use parameter on traffic noise. The most frequent use is through land use regression (LUR) models (Goudreau et al., 2014; Ragettli et al., 2016), or in a local scale through the TRAP tool by Pheasant et al. (2010) which can be very useful in the absence of noise maps, but still of limited range and dependent on on-site noise measurements.

Widely used indicators for green spaces usually refer to green space coverage (Fuller and Gaston, 2009; Zhao et al., 2013) or green space per inhabitant (ISO 37120; WHO, 2010). Others include also the proximity to green areas (Herzele and Van Wiedemann, 2003; Hillsdon et al., 2006; Kabisch et al., 2016; Morar et al., 2014; Natural England, 2010; Ståhle, 2010) or more complex indices referring to the balance between green and built up areas (De la Barrera et al., 2016). Finally, there are shape-oriented indices, which can also measure the distribution of green spaces (Margaritis and Kang, 2016; McGarical and Marks, 1994; Verani et al., 2015).

Consequently, the aim of this research is to provide, through the analysis of noise mapping and land cover data, an evidence of whether greener cities can also be quieter. This research question was investigated on three geographical levels (agglomeration, urban, kernel) using a top-down perspective in order to investigate also the effect of the scale on the results. The correspondent targets were: 1) the effect of forest, urban green and agricultural areas on noise distribution in the agglomeration level, 2) the effect of green space indicators on noise indices in the urban level and 3) the effect of green space indicators on noise indices in the kernel level of the investigated cities.

2. Methods

The methodology used investigates the relationship between green space and noise indicators in three different levels starting from a general to a more focused scale. For comparison purposes, the six cities namely: Antwerp, Helsinki, Brussels, Prague, Amsterdam and Rotterdam mentioned in levels two and three also exist in level one. The first part refers to the agglomeration level as defined in the END, while the second one refers to the urban level, which is equal to or smaller than the administrative borders of the cities. Finally, the third level refers to small kernel areas of 500×500 m each, covering the six cities. It should also be made clear that the level of accuracy in these noise maps is acceptable for this kind of strategic analysis, in spite of the differences in the production softwares or input data, since all the results have to comply with the END requirements.

2.1. Agglomeration level

2.1.1. Case studies selection

Out of the available 216 agglomerations in the European Environment Information and Observation Network database (EIONET, 2015), 25 were selected (12%) covering 11 out of 20 European countries. This was the maximum available sample size, since the selection process was based on the availability of both noise mapping and land cover data for the same agglomerations. The aim was to mostly cover medium-sized cities between 100,000 and 500,000 inhabitants, with bigger ones to serve as a means of comparison. The population density of the sample as shown in Fig. 1 has a broad range between 842 and 6,249 people/km^2, while the