The influence of vegetation and shape-related features in making parks more noise resistant

Efstathios MARGARITIS[1]; Karlo FILIPAN[2]; Jian KANG[3]; Dick Botteldooren[4]

[1,3] University of Sheffield, UK

[2,4] Ghent University, Belgium

ABSTRACT

The aim of this paper is to assess the effect of vegetation-related parameters and shape-related features on noise levels in park areas. For the current research, eight case study parks of various sizes were identified in Antwerp and noise levels were measured inside and around them. The measurements were conducted during multiple days using portable custom-made sound recording devices. The analysis was performed by correlating the input with the output parameters. Input data include green space and shape metrics, while output parameters consist of various noise indices (L_{10}, L_{50}, L_{90}, L_{Aeq}, L_{Ceq}-L_{Aeq}) averaged for the entire parks. In a more focused scale the same analysis was attempted referring to measurement points inside the parks. Correlations in this case were identified only between green space features and L_{90}. The entire analysis denotes that green space features can be an important factor in noise reduction within the parks, independently of the effects from the surrounding environment.

Keywords: Dynamic noise mapping, Green areas, Noise control planning I-INCE Classification of Subjects Number: 68.7

1. INTRODUCTION

The traditional noise mapping framework as described in the Environmental Noise Directive (END) (2002/49/EC) can provide useful information for traffic noise in a strategic level. In this context, the need to identify and preserve quiet areas in the urban environment led to the formulation of further criteria, which include both sound pressure levels, and the users' experience (1). However, in a micro-scale approach traditional static noise mapping techniques cannot depict time variable fluctuations. In this case dynamic noise mapping can be more appropriate as a way of representing noise levels (2), especially in places such as parks, which are likely to be designated as "quiet areas" in the urban context.

Previous studies have tried to assess noise level variability in parks in terms of soundscape quality based on the human experience (3) (4)However, few studies have tried to correlate noise levels with quantitative attributes related to parks' characteristics, such as the tree cover and the area size (5), or based on audio-visual stimuli (6).

As a result the aim of this paper is to investigate the noise level distribution in different parks of Antwerp and reach to a conclusion as regards whether: a) there is a correlation among green space parameters, park features and noise levels when considering the parks as whole entities and b) whether there is a correlation between green space parameters and noise levels as far as the measurement points in each park are concerned.

2. METHODS

2.1 Case study sites

The data presented in this study was collected in eight urban parks in Antwerp, Belgium. Antwerp is the largest city in Flanders and the second largest city in Belgium. A big part of the city's economy is a major

[1] e.margaritis@sheffield.ac.uk
[2] karlo.filipan@intec.ugent.be
[3] j.kang@sheffield.ac.uk
[4] dick.botteldooren@intec.ugent.be

European harbor which has its incoming and outgoing traffic routes along the city. Additionally, Antwerp's ring road is integrated in the European traffic corridors. Therefore, traffic creates substantial noise problems for the surrounding living areas.

The data used in this study was collected in cooperation with Antwerp city council environmental authority. Investigated parks as presented in Figure 1 were chosen to be sufficiently spread over the whole city area and with a large number of people that has access to the parks. Additionally, the parks present significant variations in the green space coverage as presented in Figure 2a and the area size as shown in Figure 2b. The smallest one (Bischoppenhof) has an area of 3 ha, while the largest one (Rivierenhof) measures 129 ha. Most of the parks are also located relatively close to the ring road, except for Sorghvliedt, which is located in the suburbs and Stadspark, which is near the core city centre.

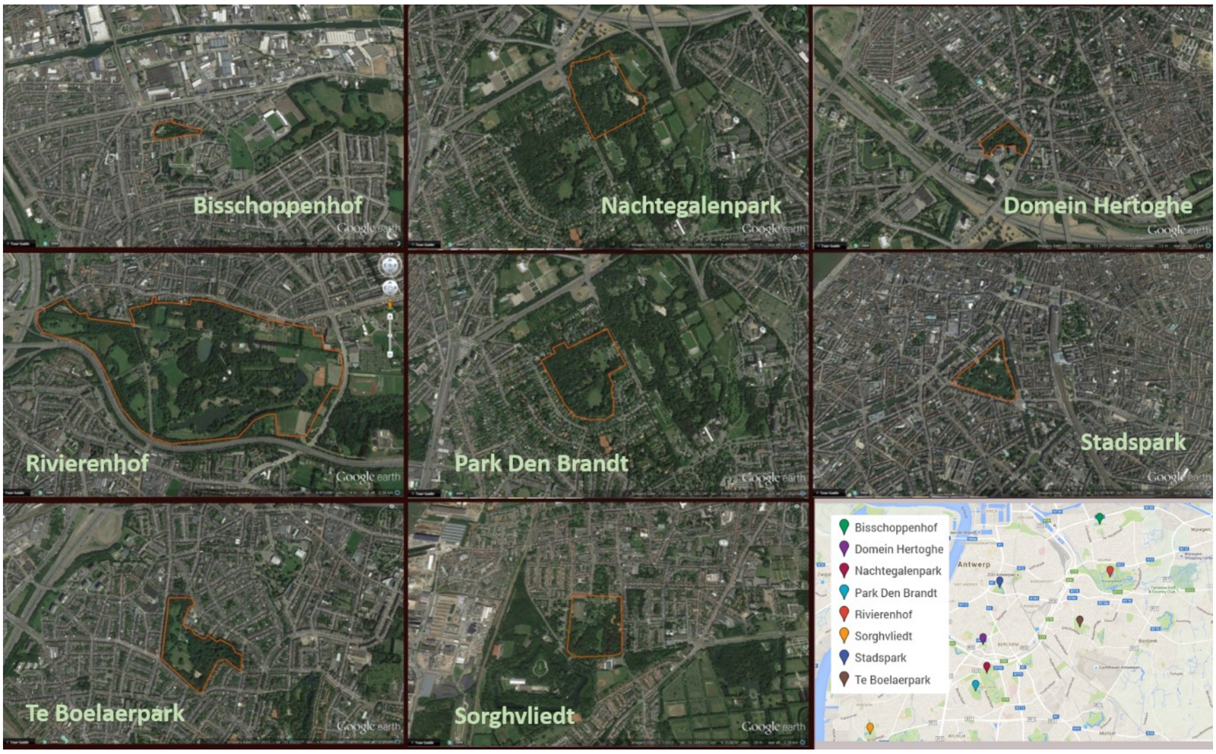

Figure 1 - Locations of the eight parks depicted in the same scale within Antwerp

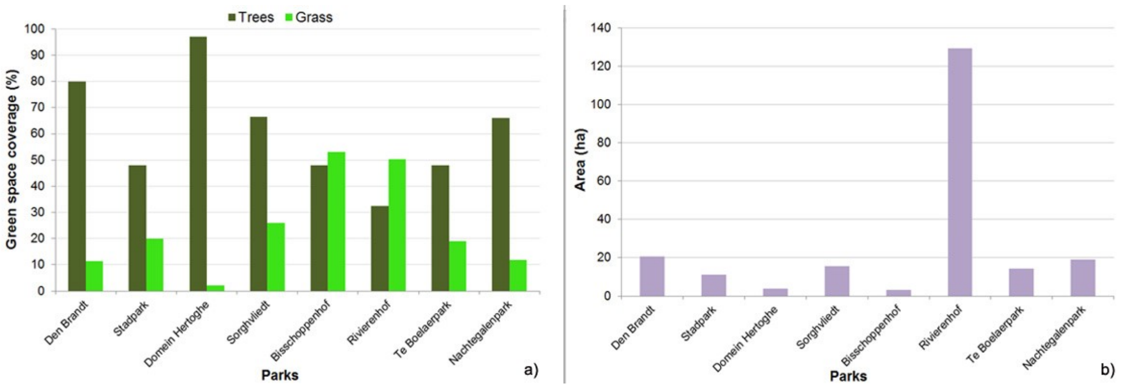

Figure 2 – Comparison of: (a) the tree coverage and (b) area size for the eight parks

2.2 Measurements

Measurements were performed using mobile recording devices carried in backpacks. Researchers carrying the equipment were specifically instructed to mind their walking manner so as not to disturb the recorded sonic environment. The walks were made on the existing paths in the park, while no directions were given in order to have the coverage more arbitrary. Additionally, the researchers were asked to make stationary recordings by placing the backpack on the benches for 10 minutes every half an hour. Finally, in order to measure the sound environment outside the park, the researchers walked around the park and its surroundings as it can be seen in Figure 3.

Measurement devices were custom made, Linux based sensor network nodes (7) created to incorporate both sound and location recording. Therefore, the collected data comprised sound recordings, 1/3-octave band levels saved eight times per second, as well as the GPS positions recorded per second. Finally, to ease the data processing and presentation, spectral levels and GPS values were transferred to the spatial database.

Figure 3 – Measurement points distribution inside and outside the park

2.3 Indicators

The indicators representing the sonic environment were calculated from the stored measurements data. They were extracted on the same selected time steps by taking the 1/3-octave band values of one minute duration. Additionally, the overlapping window was used every 10 seconds, thus creating the 5/6 overlap in data selection. Finally, GPS data was included and related to the acoustic indicators by interpolating the dataset to the same 10 second period time lapse.

The indicators used for the analysis as presented in Table 1 consist of widely adopted (8) A-weighted values: L_{10}, L_{50}, L_{90}, L_{Aeq} and L_{Ceq}-L_{Aeq}. The percentile indicators were calculated to get the dynamic characteristics of the 1-minute sonic environment: 50-percentile illustrating the average, 90-percentile the background and 10-percentile the high values. On the other hand, A-weighted equivalent levels were used because of their overall relation to the human hearing characteristics. Additionally, the difference between C-weighted and A-weighted equivalent levels gives an indicator that in general depicts the low frequency content of the measured sound.

The second category refers to shape indicators widely used in landscape ecology for pattern analysis (9). In this case, the ones used refer to the dimensions and the configuration of the parks' borders as polygon features. The ones used are: the mean patch fractal dimension (MPFD), the mean shape index (MSI), the total edge (TE) and the class area (CA). Overall, depending on their values it is feasible to retrieve information about the shape of a polygon, its complexity in terms of edges and whether it is closer to a rectangular or a circular form.

Finally the last category refers to green space indicators relevant to the tree and grass coverage, since these elements can affect noise level distribution due to the different properties in absorption, diffusion or scattering. As regards the calculation process, five ontological categories were recognized in total - as described in Figure 4 - and classified based on the maximum likelihood classification method provided by ArcGIS. The produced raster file was converted to a vector format and intersected with the measurement points.

Table 1 – Noise, shape and green space indicators tested for correlations

Variable	Comments
	Noise indicators
L_{10} (min, max , mean)	10-percentile
L_{90} (min, max , mean)	90-percentile
L_{50} (min, max , mean)	50-percentile
L_{Aeq} (min, max , mean)	
L_{Ceq}-L_{Aeq} (min, max , mean)	
	Shape indicators
	MPFD → 1 for shapes with very simple perimeters such as circles or squares
MPFD	MPFD → 2 for shapes with highly convoluted, plane-filling perimeters.
MSI	MSI → 1 when all patches in the landscape are circular (vector) or square (raster).
TE	TE→ simple shapes ↓TE, more complex shapes ↑ TE.
CA	Area size
	Green space indicators
Tree coverage	Trees (%)
Grass coverage	Grass (%)

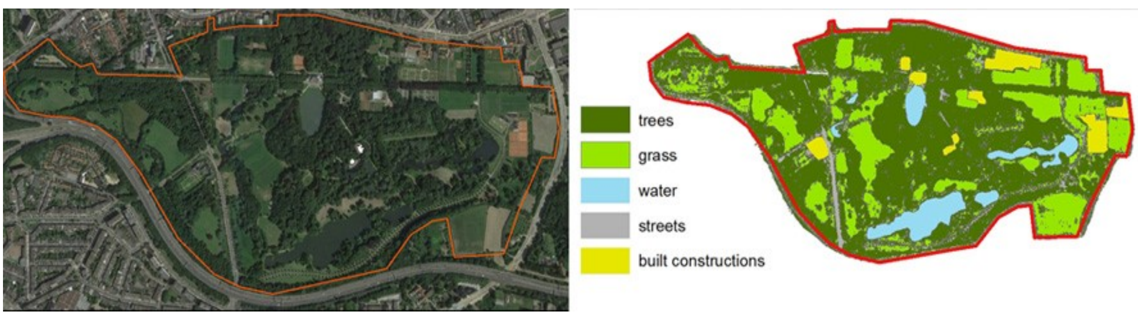

Figure 4 – Identification of contextual characteristics in Rivierenhof park via a supervised classification

In this way all relevant points were allocated either to the "tree coverage" or the "grass coverage" class. Road paths inside the parks were not recognizable in the classification process, apart from Rivierenhof, so they were not further considered. Water features were also not taken into consideration as they were present only in three cases. On average 2,056 points intersected with trees and 513 with grass per park.

3. RESULTS

3.1 Noise level distribution in the parks

The noise level distribution was assessed through the analysis of L_{10} and L_{90}. The final graphs on Figures 5a, 5b were built based on the frequency range of noise levels between 42-76 dB(A) for L_{10} and 39-66 dB(A) for L_{90}. In most of the cases the distribution of noise levels follows a bell-shaped pattern except for Den Brandt, which is skewed to the left. The corresponding results for L_{90}, (Figure 5b) reveal that noise level distribution among the parks presents more variations compared to the L_{10}, where half of the curves follow a similar pattern. Characteristic examples that can be considered marginal cases, both in L_{10} and L_{90} are the parks Den Brandt in the lower dB(A) scale and Rivierenhof in the upper scale. Den Brandt appears to be the quietest and the third largest in size, surrounded only by local roads. On the other hand, Rivierenhof has the highest noise levels between 60-75 dB(A), located adjacent to a very busy highway, the effect of which is depicted also on the L_{90} levels, as background noise.

The examination of L_{10} and L_{90} in the vertical axis reveals that two distinctive groups can be recognized. The first one has the highest frequency values between 52 and 63 dB(A) including three out of the four largest parks (Te Boelaerpark, Nachtegalenpark, Rivierenhof , Den Brandt). The second group involves the rest (Domein Hertoghe, Stadspark, Bischoppenhof, Sorghvliedt) with significantly lower frequency values in the entire dB(A) scale.

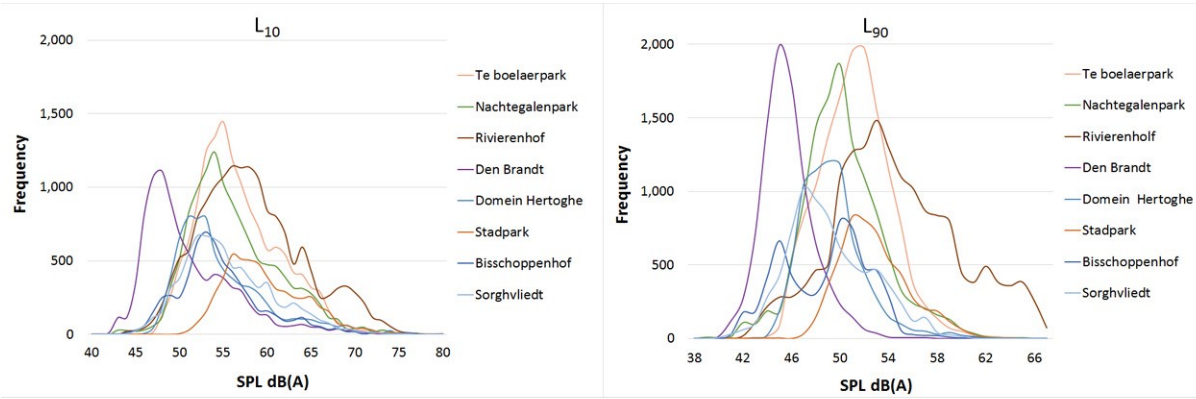

Figure 5 – Frequency distribution of (a) L_{10} and (b) L_{90} in the eight parks

3.2 Large scale

3.2.1 The effect of green space indicators on noise levels

At this level the parks are investigated as single entities. Possible correlations between noise levels and park features were investigated through the Pearson product-moment correlation coefficient. A negative correlation was identified between tree coverage and the average L_{10} (r=-0.68, n=8, p<.01), as well as between tree coverage and the average L_{90} (r=-0.74, n=8, p<.01). Results are depicted in Figure 6 through the coefficient of determination. Practically, these results reveal that the presence of land use with trees can have a higher impact in noise mitigation than the presence of land use with grass within parks. These results also confirm the outcomes of previous studies (10) and show that the effect of vegetation is evident, independently to other factors that can affect noise levels within the parks context. Additional parameters, such as shape indicators were not found to be correlated with noise levels.

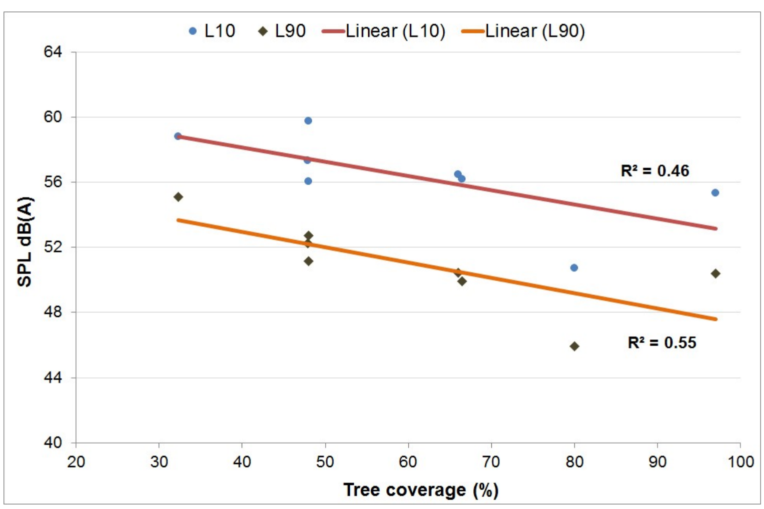

Figure 6 – Correlations between tree coverage and noise levels (L_{10}, L_{90})

3.3 Small scale

3.3.1 The effect of green space indicators on the measurement points

The correlation between green space features and the recorder noise levels for L_{90} – as presented in Figure 7 – shows that in most of the cases the average values for both classes are very close. Apart from Domein Hertoghe, where no grass was detected, the rest of the parks display values between 45.5 dB(A) for the "tree coverage" class in Den Brandt and 56.8 dB(A) for the "grass coverage" class in Rivierenhof. In all the seven cases, noise levels in the "grass coverage" class were slightly higher than in the "tree coverage". The lowest difference between noise levels in the two classes was detected in Den Brandt (0.41) and the highest in Rivierenhof (1.73). For the rest of the parks there were also small differences between 0.49 and 0.79 dB(A). Particularly for Stadspark, noise levels were higher in the "tree coverage" class by 0.49 dB(A), since "grass coverage" was limited to a few measurement points.

The above results seem to be consistent to some extent with the effect of "tree coverage" analyzed in section 3.2, since lower noise levels were detected also in that class for the current scale of analysis. However, noise level variability for L_{90} is low between the two green space categories. Possibly the effect of other parameters related to the presence of human or natural sound sources has a stronger influence than the green space coverage itself. Further insight on the effect of green space parameters can be provided by the examination of more noise indices for the same measurement points.

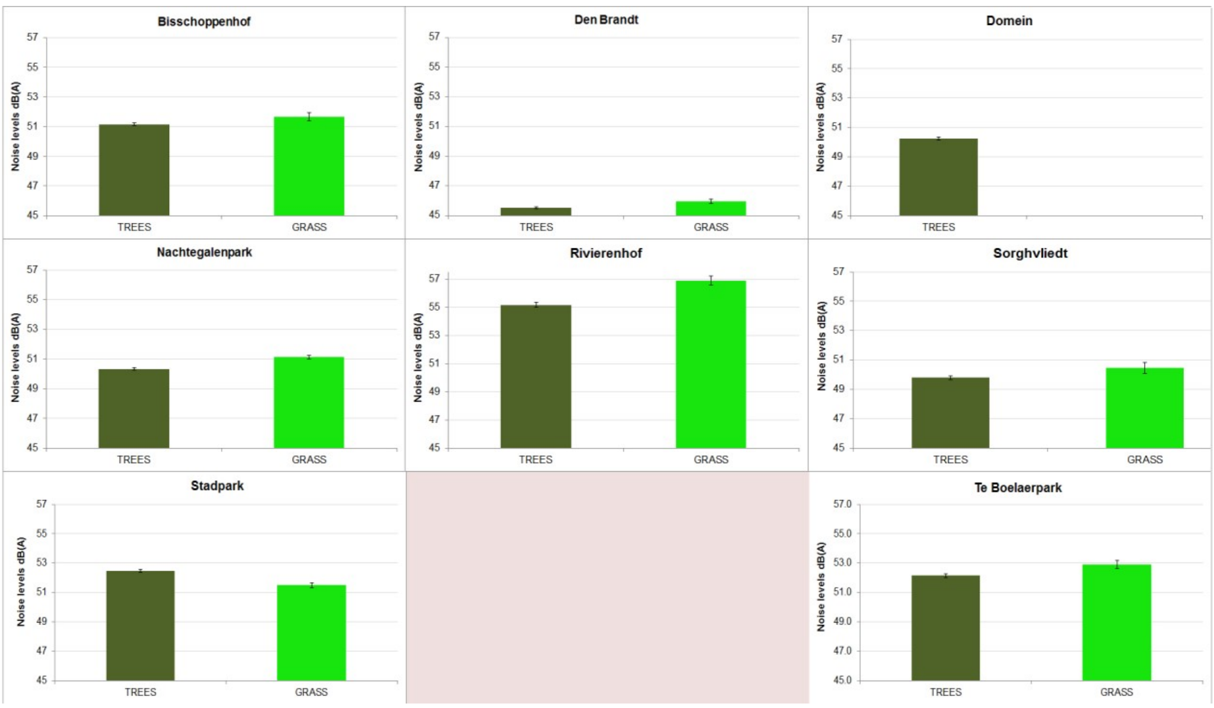

Figure 7 – Average values of L_{90} and relative confidence intervals depicted for each green space category in all parks

4. CONCLUSIONS

The aim of this research was to investigate the effect of green space parameters and park features on noise levels in two different scales. The first scale is broader and refers to the analysis of all parks as entities, while the second scale is focused on point-based fluctuations of noise levels related to the measurements in each park.

In the first scale negative correlations were found between the tree coverage and the average levels of L_{10} and L_{90}, suggesting that an increase in the amount of trees within the parks can provide further noise level attenuation. Park features related to the total area or the number of edges were not proved correlated with noise levels. In the second scale, it was proved that - apart from one case - noise levels within the "tree coverage" class are lower by 0.41 up to 1.73 dB(A) compared to the correspondent levels in the "grass coverage" class. The highest difference in noise levels between the two classes was detected in Rivierenhof and the lowest in Stadspark. The effect of the ring road was evident as expected in the case of Rivierenhof, since it presented the highest L_{90} among all parks. An extended analysis on these results will focus on the identification of clusters between high and low noise levels, as well as correlations between the noise levels measured inside and outside the parks.

ACKNOWLEDGEMENTS

This research received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme FP7/2007-2013 under REA grant agreement n° 290110, SONORUS "Urban Sound Planner". The authors are also grateful to the student Tirthankar Chakraborty for his valuable help in the analysis of the data under the Postgraduate Advantage Scheme of the University of Sheffield.

REFERENCES

1. European Environment Agency. Good practice guide on quiet areas; 2014.
2. Wei W, Van Renterghem T, De Coensel B, Botteldooren D. Dynamic noise mapping: A map-based interpolation between noise measurements with high temporal resolution. Appl Acoust 2016;101:127-140.
3. Nilsson ME, Berglund B. Soundscape quality in suburban green areas and city parks. Acta Acust united with Acust. 2006;92:903-11.
4. Filipan K, Boes M, Oldoni D, De Coensel B, Botteldooren D. Soundscape quality indicators for city parks, the Antwerp case study. Proc Forum Acusticum 14; 7-12 September 2014; Krakow, Poland 2014.
5. González-Oreja JA, Bonache-Regidor C, De La Fuente-Díaz-Ordaz AA. Far from the noisy world ? Modelling the relationships between park size , tree cover and noise levels in urban green spaces of the city of Puebla , Mexico. Interciencia. 2010;35:486-92.
6. Pheasant RJ, Horoshenkov K V., Watts GR. Tranquillity rating prediction tool (TRAPT). Acoust Bull. 2010;35(6):18-24.
7. De Coensel B, Sun K, Wei W, Van Renterghem T, Sineau M, Ribeiro C, et al. Dynamic noise mapping based on fixed and mobile sound measurements. Proc Euronoise 15; 31 May-3 June 2015; Maastricht 2015. p. 2339-44.
8. Aletta F, Kang J, Axelsson Ö. Soundscape descriptors and a conceptual framework for developing predictive soundscape models. Landsc Urban Plan. 2016;149:65-74.
9. McGarical K, Marks BJ. FRAGSTATS: Spatial pattern analysis program for categorical maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available from: http://www.umass.edu/landeco/pubs/mcgarigal.marks.1995.pdf
10. Van Renterghem T, Botteldooren D, Verheyen K. Road traffic noise shielding by vegetation belts of limited depth. J Sound Vib. 2012; 331(10):2404-2425.