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Nonlinear prediction model of noise reduction by greenbelts

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ABSTRACT

Based on the noise-reduction mechanism of greenbelts, a noise-reduction model of greenbelts is proposed along with their sound-propagation characteristics. Two *Populus tomentosa* greenbelts suitable for noise experiments were selected. A noise-reduction prediction model was established for *P. tomentosa*. The parameters for this model were the distances between the measuring point and the sound source and the frequencies of the sound source. The model error was 4.1 dB, approximately 9.8% of the average noise attenuation. When the noise frequency was 500 Hz (frequency equivalent to the road traffic noise), the average error was minimized. The experimental method and the model may be extended to noise reduction studies for other greenbelts and used to provide guidelines for road greenbelt construction.

Introduction

Prevention and control of traffic noise primarily employs three approaches (Ding et al., 2004; Li and Tao, 2002): prevention and control of the sound source, cutting the route of transmission and protection at the point of sound reception. For cutting the transmission route, the principal methods are building sound barriers and planting greenbelts. However, sound barriers are expensive and most of them have monotonous appearances. A greenbelt can reduce noise while providing landscaping. So in the case of general noise reduction target, reducing noise by greenbelts is an effective and practical method (Ozer et al., 2008; Islam et al., 2012). The noise reduction effect of greenbelts is mainly related to noise source frequencies and the structural characteristics of greenbelts. For these reasons, the development of a greenbelt noise-reduction model that may be used to guide greenbelt construction for traffic-noise prevention and control is of great significance. Existing noise-reduction prediction models may be divided into univariate and multivariate models (Xie, 2003; JTGB03-2006 China, 2006; Du et al., 2007; Yuan et al., 2009; Yuan, 2009; Zhang, 2009; Zhang et al., 2009; Guo et al., 2009). However, according to research methods, due to background conditions and the complexity of noise attenuation by the greenbelt, greenbelts of different structures have different effects on acoustic waves. The sound transmission losses under the canopy are associated with ground impedance (Arnold and Michelle, 2009; Arnold, 2010). With the aim of establishing a more precise and practical greenbelt noise-reduction model, separate models should be developed for greenbelts composed of different plants. In this study, the common greenbelt species *Populus tomentosa* was selected as the research subject. Noise attenuation of various noise frequencies at several measuring points was measured and a noise-reduction prediction model was developed for *P. tomentosa* greenbelts. Measured data were used for validation with the aim of providing a method and basis for later designing of noise-reduction greenbelts and a guide for the construction of road greenbelts.

Materials and methods

Selection of sound source and sample area

Given the relationship between the noise reduction effect of greenbelts and the noise frequency (Margaret et al., 1988; Tarrero Femandez and Gonzalez, 2002; Yuan, 2008), seven different frequencies of pure noise were selected as experimental sound sources: 125, 250, 500, 1000, 2000, 4000 and 8000 Hz. Pure noise as octave-band centre frequency noise, was generated by the Adobe Audition software (Adobe Audition 1.5, Adobe Audition(C)1992·2004 Adobe System, Incorporated), which is often used in the acoustic field. The selected noise frequencies included the main frequencies of traffic noise (Guo et al., 2009). The experimental sound source was a point sound source transmitted through loudspeakers as pure noise of different frequencies. The

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Table 1
The characteristics of the sample plots.

Sample number	Area of per plan (m^2/per plan)	Average tree height (m)	Average height under branch (m)	Average breast diameter (cm)	Length (m)	Width (m)	Green belt location
1	24.5	13.7	4.5	19.0	513	40	Dong Xiaokou forestry park
2	16.1	15.0	3.9	19.9	180	80	Bajia country park

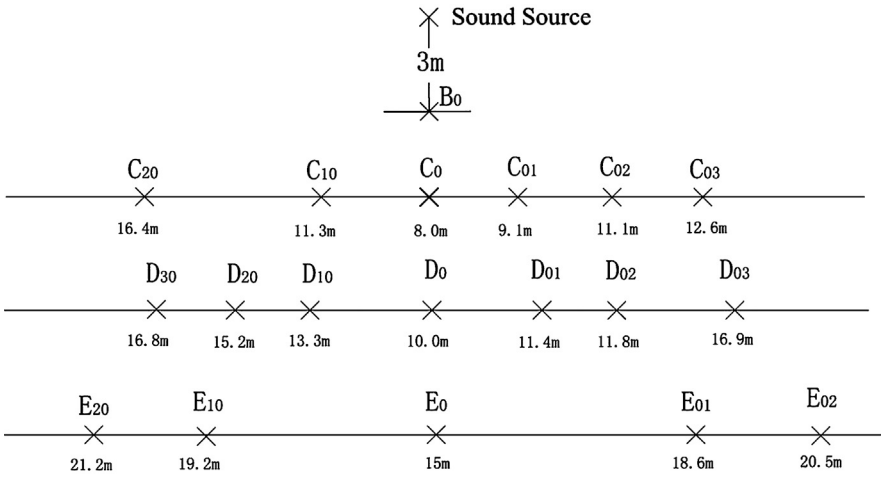

Fig. 1. Measuring points layout plan of *Populus tomentosa* green belt in Bajia country park.

loudspeaker frequency response range was 50 Hz–10 kHz, with a distortion rate lower than 5%.

Following investigation of a large number of greenbelts in Beijing, we chose as test samples two *P. tomentosa* greenbelts with similar planting specifications, moderate scale and low environment noise. The samples are described in Table 1.

Experimental methods

The sound sources were placed in front of the greenbelts, and the measuring points in the greenbelts were at different distances from the sound source (measuring point layouts and cross-sectional views are shown in Figs. 1–3). At every measuring point, the noise attenuation values at different frequencies were measured with a sound level meter (AWA6218B+ noise statistical analyzer, Hangzhou Aihua Instrument Co. Ltd.; range, 35–130 dB; measurement frequency, 31.5–8000 Hz; each successive measurement time, 8 s; sampling interval of analyzer, 0.01 s). The sound pressure level at the measuring point was the equivalent consecutive sound level A of the analyzer statistical output value. At each measuring point, the sound pressure level values at each frequency were measured 10 times consecutively and averaged. Finally, 259 groups of noise attenuation data were measured for the two greenbelts and the relationship between the frequency of the sound source, the distance between the sound source and the measurement point and the noise attenuation by the greenbelt was calculated. This procedure resulted in a noise-reduction prediction model using *P. tomentosa* greenbelts, verified by measured data. All measured values were measured in summer weather with no wind.

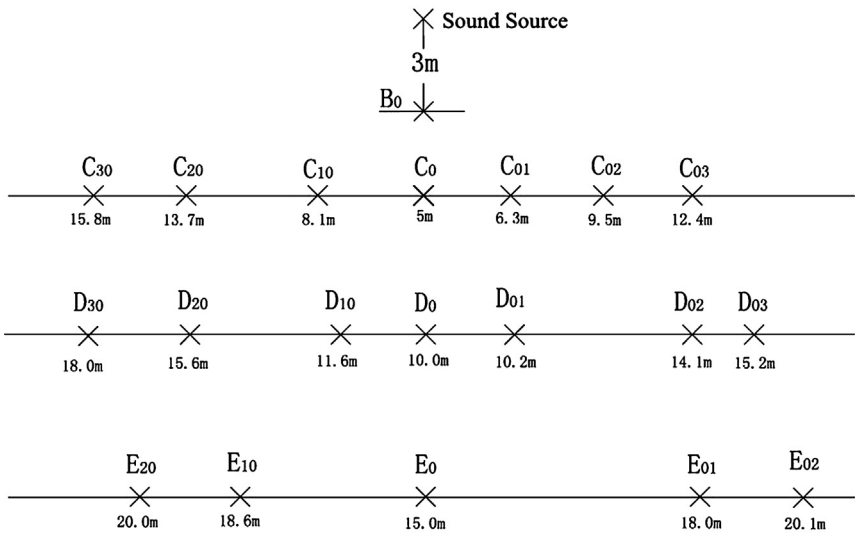

Fig. 2. Measuring points layout plan of *Populus tomentosa* green belt in Dong Xiaokou forestry park.