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Influence of stand characteristics on the acoustic forest floor effect

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ABSTRACT

Forest floors contribute significantly to the noise abatement one might get from tree belts along surface transport infrastructure. However, little is known on what type of forest floor is most effective in maximizing the ground attenuation, and to what extent this is influenced by tree species. In addition, the spatial variability of the forest floor effect is of interest as well. In the current study, a two-microphone measurement setup was used to derive, by reverse engineering, the soil properties of concern for the interaction between the forest floor and sound waves. The Zwikker and Kosten phenomenological and slit-pore impedance model were considered and evaluated for their ability to reproduce the measured short-range spectral level differences (assuming rigid-backing). For both models, parameters were successfully derived for mono culture plots of ash, cherry, lime, maple, beech and oak.

1. INTRODUCTION

Forest floors contribute to the noise abatement one might get from tree belts or strips of forests along surface transport infrastructure. Compared to sound propagation over other types of (natural) grounds, a very pronounced and broad destructive interference dip is commonly observed between the direct sound path and the ground reflected path [1]. In addition, this effect occurs in the low frequency range for a typical source-receiver geometry, so at sound frequencies where atmospheric absorption by air is very limited, and where noise abatement infrastructure relying on diffraction

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(like e.g. a traditional noise wall) has a limited efficiency only. In contrast to the noise reducing effects of above ground biomass, the forest floor effect is often seen as a robust effect [2].

Although “default” acoustical parameters for forest floors can be found in more advanced outdoor sound propagation engineering methods (see e.g. Harmonoise [3]), the use of a fixed value for any type of forest could be questioned. Similarly to “grassland” [4], forest floor parameters might vary strongly.

Extensive and systematic measurements of acoustical forest floor properties are lacking. Given that forest floors have a complex build-up, consisting of a mineral layer, a humified layer and a litter layer with less decomposed material, their relative contributions to the ground effect are unknown. In addition, tree species and stand characteristics might influence the forest floor properties. The spatio-temporal variability of the forest floor effect is of interest as well, where soil moisture content could potentially play a significant role [5].

In this paper, results from a measurement campaign in the “Mortagne” forest (Kortrijk, Belgium) are presented. There, monoculture plots of different tree species were planted on former agricultural land, all in 1971. In the current measurement campaign, for each species stand considered, two different locations were selected. Each measurement was repeated by rotating the experimental setup (see further) over 90 degrees to get information regarding short-range variability.

2. MEASUREMENT METHODOLOGY

2.1. Short range spectral level difference measurements

Two type-1 microphones were positioned at different heights on top of each other, at short range from a portable battery-driven loudspeaker. The source-receiver geometry was largely inspired by the NORDTEST methodology [6], meaning that the source and one of the microphones were at 0.5 m above the ground. The lowest microphone was placed at a height of 0.2 m. The distance between source and receiver in our setup was 1.75 m. Such a distance ensures that the loudspeaker could be considered as a point source for the range of frequencies considered, yet allowing a good signal-to-noise ratio at the microphones. Measurements were performed at the spectral detail of 1/3 octave bands. A dedicated frame was constructed (see Fig. 1) ensuring relative distances and heights to be exactly reproduced at each measurement location.

Figure 1: Experimental set-up showing the two microphones for the level difference measurements.

2.2. Deducing the acoustical soil parameters

The acoustical ground parameters were deduced by reverse engineering using the spectral level difference data. A two-ray analytical sound propagation model in a homogeneous and non-moving atmosphere was assumed [1]. The accuracy of this point source model and the instrumentation was confirmed by a preliminary measurement in a semi-anechoic room, where the floor properties (more precisely : fully rigid) were known.

Instead of directly deriving the surface impedance of the forest floor, the parameters of ground impedance models will be seeked for. This information is then directly applicable to outdoor sound propagation models. Depending on the physical soundness of the models used, either “effective” or physical parameters will be obtained.

Forest floors might behave in a complex way since they are essentially multi-layered. Little is known on what ground impedance model is most suited for this type of outdoor ground. Therefore, a few candidate models were selected that showed reasonably accurate fits on short-range spectral level difference data of natural grounds (mostly grasslands) [4]. The Zwikker and Kosten phenomenological model (ZK) [7] and the so-called slit-pore model (SP) (see e.g. [4]) were considered in a so-called “rigid backing” configuration. A two-parameter version of the ZK model was used, assuming a fixed relationship between the “structure factor” k_S (which is parameter similar to the tortuosity) and the porosity φ, namely $k_s = \varphi^{-0.5}$ [4]. In addition, a two-layered ground impedance model [8], where the bottom layer was terminated by a rigid plane, was considered as well.

The overall accuracy of the fit, and the soundness of the physical ranges of the parameters deduced, might indicate what type of ground model might be most suited for forest floor acoustical characterization. To quantify this goodness-of-fit, the root-mean-square error (RMSE) between the best predicted and measured spectral level differences were used.

2.3. Non-acoustical data

A main goal of this research is to predict the suitability of forest floors for noise abatement based on non-acoustical data like tree species, stand density, and commonly measured parameters like biomass surface density of the litter layer and its moisture content, and properties of the mineral layer. In the current paper, focus is on tree species and the amount of biomass in the litter layer.

3. RESULTS AND DISCUSSION

Overall, the rigid-backed SP impedance model (average RMSE of 1.22 dB over all measurements) shows a very similar RMSE as the rigid-backed ZK model (RMSE of 1.19 dB). Above some forest floors (like e.g. *Prunus avium* – Sweet cherry), these models perform significantly better, suggesting that there might be different physics involved. A two-layered approach, where the bottom layer was rigid backed, relying in both layers on the ZK model (similarly using the fixed relationship between structure factor and porosity as discussed before) was considered as well. The latter yields a smaller average RMSE of 0.84 dB over the full measurement campaign. Fig. 2 shows an example fit using these three impedance models, for one of the beech plot measurements.

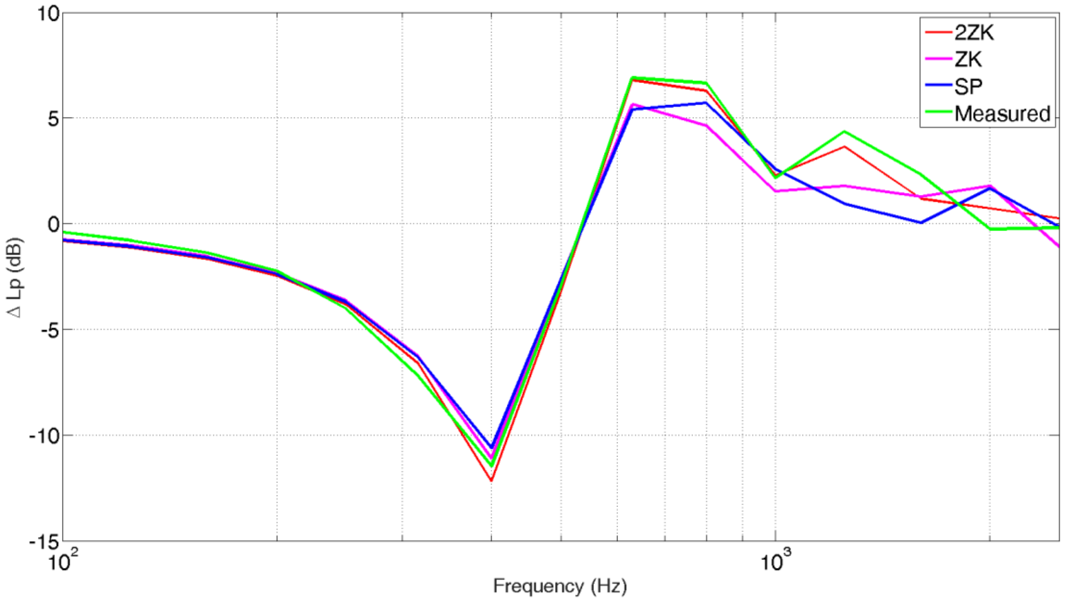

Figure 2: Best fits on the measured spectral level differences (beech stand, Fagus sylvatica) using the Zwikker and Kosten impedance model (ZK), the slit-pore impedance model (SP), and a two-layered Zwikker and Kosten impedance model (2ZK), all being rigid backed. RMSE values for this specific example are 1.16 dB (ZK), 1.32 dB (SP) and 0.55 dB (2ZK), respectively.

The distribution of the parameters of the SP and ZK (mono-layer, rigid backing) are shown in Figs. 3 and 4. The data was first classified based on species (4 measurements per species). Overall, both models provide rather similar predictions of the flow resistivity, porosity and layer thickness.

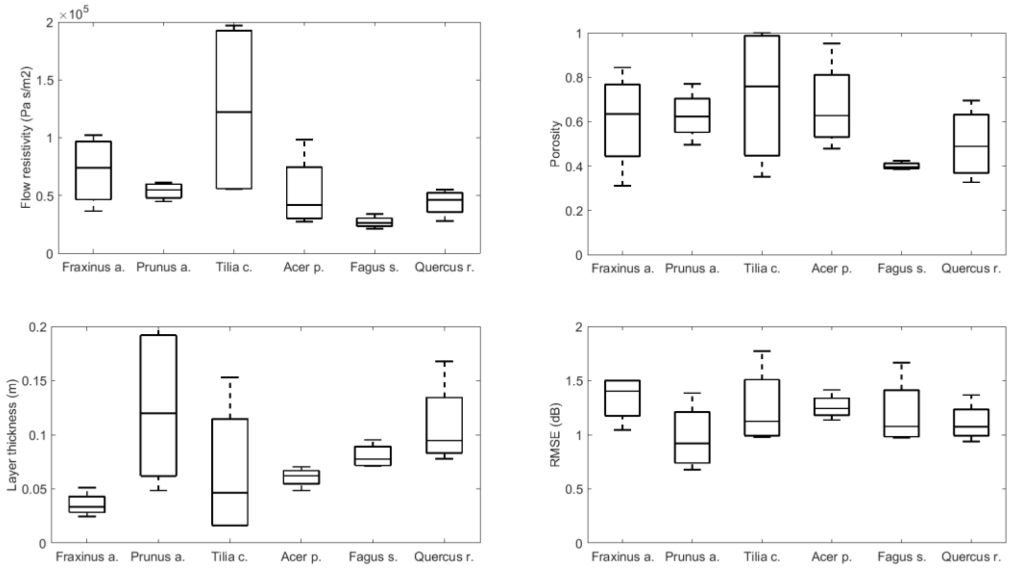

Figure 3: Deduced ground parameters using the rigid-backed Zwikker and Kosten impedance model (ZK), clustered per species. The bottom right subplot shows the distribution of the RMSE per species.

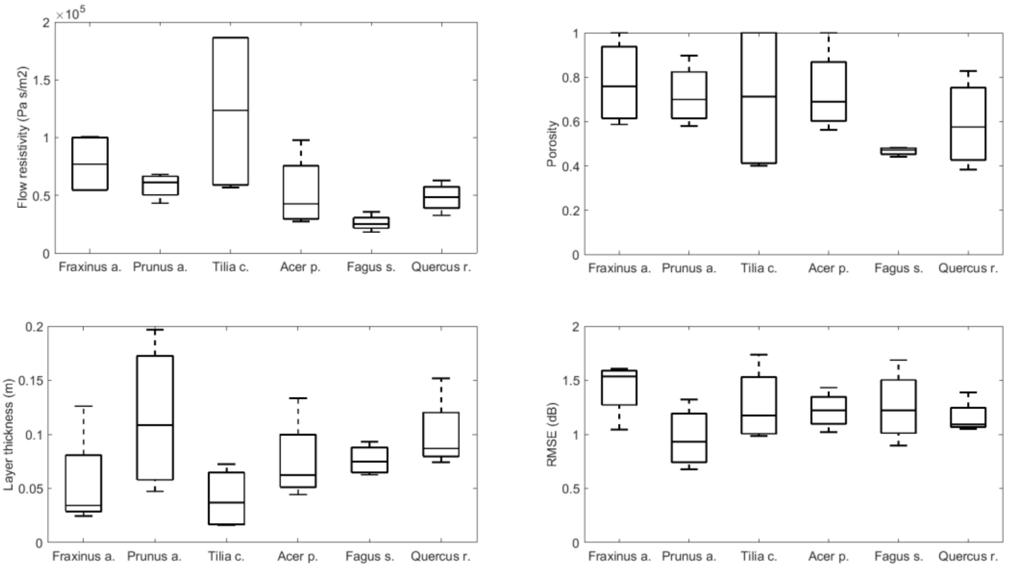

Figure 4: Deduced ground parameters using the rigid-backed slit-pore impedance model (SP), clustered per species. The bottom right subplot shows the distribution of the RMSE per species.

The relationship between the measured biomass of the litter layer and the flow resistivity is presented in Fig. 5. In case of a limited amount of biomass, a wide range of flow resistivities are predicted. However, at higher litter layer biomass per unit surface, the flow resistivity range decreases significantly, indicating that a large amount of biomass on the forest floor might be interesting from the viewpoint of noise reduction. The data provided in Fig. 5 further shows that there can be significant differences in the flow resistivities within a specific species stand, both at short and longer range. The upper and lower flow resistivity resulting in an increase in RMSE of 0.1 dB is provided for each measurement. This is an indication of how well defined the optimum value obtained during the fitting process actually is. For most forest floors, this range is reasonably small.

Note that the flow resistivities are rather high when compared with other published data [3][4]. This can potentially be explained by the fact that the measurements were made during winter, after periods with a lot of rainfall. The average gravimetric moisture content of the litter layer was 2.70 g water per g dry litter (standard deviation of 0.6 g/g). The mineral layer/soil gravimetric moisture content was on average 0.42 g water per g dry soil (standard deviation of 0.06 g/g).

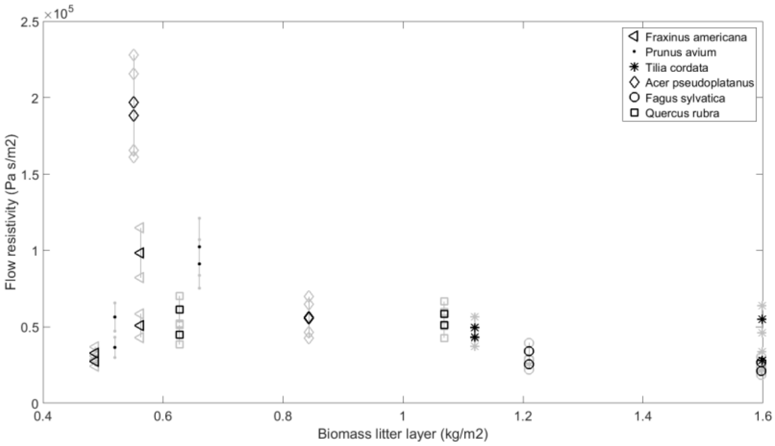

Figure 5: Measured biomass surface density of the litter layer versus flow resistivity by means of reverse engineering with the Zwikker and Kosten impedance model (ZK) in a rigid-backing configuration. The black markers indicate the fitted values leading to minimum RMSE, the gray markers the corresponding flow resistivities leading to an increase of 0.1 dB in RMSE relative to that minimum RMSE value.

4. CONCLUSIONS

A two-microphone technique was explored for its capability of deriving, by reverse engineering, acoustical forest floor parameters. The Zwikker and Kosten and slit-pore impedance model (both rigid-backed) provide reasonably accurate fits on the measured data. The fact that a two-layer model increases the fitting accuracy further indicates that forest floors behave as multi-layered systems. A large amount of biomass in the litter layer seems to reduce the flow resistivity of the forest floor. Some care is needed since current measurements were performed during winter after periods with intense rainfall.

5. REFERENCES

[1] K. Attenborough, K. M. Li, K. Horoshenkov, "Predicting outdoor sound," Taylor and Francis , London and New York, 2007.

[2] T. Van Renterghem, "Guidelines for optimizing road traffic noise shielding by non-deep tree belts," Ecol. Eng. 69, 276-286 (2014).

[3] J. Defrance, E. Salomons, I. Noordhoek, D. Heimann, B. Plovsing, G. Watts, H. Jonasson, X. Zhang, E. Premat, I. Schmich, F. Aballea, M. Baulac, F. de Roo, "Outdoor sound propagation reference model developed in the European Harmonoise project," Acta Acust. united Ac. 93, 213-227 (2007).

[4] K. Attenborough, I. Bashir, S. Taherzadeh, "Outdoor ground impedance models," J. Acoust. Soc. Am. 129, 2806-2819 (2011).

[5] A. Cramond, C. Don, "Effects of moisture content on soil impedance," J. Acoust. Soc. Am. 82, 293-301 (1987).

[6] Nordtest : "NT-ACOU-104: Ground surfaces: Determination of the acoustic impedance," Nordic innovation centre, Espoo, Finland (1999).

[7] C. Zwikker, C. Kosten, "Sound absorbing materials," Elsevier, New York, 1949.

[8] I. Dunn, W. Davern, "Calculation of acoustic impedance of multi-layer absorbers," Appl. Acoust. 19, 321-334 (1986).