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# Influence of rainfall on the noise shielding by a green roof

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ABSTRACT

The potential of a green roof to reduce diffracting sound waves towards a shielded side of a building has been assessed before by both in-situ and laboratory experiments, and by numerical simulations. However, like any porous material, the acoustic performance of the green roof's substrate could suffer from the presence of water. A 46-day lasting controlled sound propagation experiment was set up near the edge of a 6-m tall building equipped with an extensive green roof, having a substrate thickness of 7 cm. At selected moments, test signals were emitted, allowing to monitor the attenuation between a reference microphone and a microphone at low height positioned on the green roof (at 15.3 m from the roof's edge). Meteorological parameters and the green roof's substrate moisture content were continuously measured. Sound diffracting over a green roof showed to be sensitive to the substrate moisture content in a specific sound frequency range, more precisely between 250 Hz and 1250 Hz. The difference in noise attenuation between a rather dry state (0.1 $m^3/m^3$) of the substrate and the maximum observed volumetric water content (close to saturation, 0.33 $m^3/m^3$) could range up to 10 dB. However, calculations show that the impact of the water content in an extensive green roof substrate for the specific case of road traffic noise abatement is expected to be limited.

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## 1. Introduction

The environmental, ecological and economic benefits of green roofs are manifold. The reader is referred to a number of review articles for an overview [1–5]. During the last decade, the noise reduction was recognized as an additional benefit. Scientific research points e.g. at the increased acoustic roof insulation provided by a green roof [6,7]. Of most practical interest is the ability of green roofs to reduce sound waves diffracting over buildings or parts of buildings [8–11]. A green roof, in contrast to common rigid building envelopes, could therefore help making a facade really silent, on condition that the dominant sound path between source and (shielded) facade interacts with the green roof. This is important in the view of the so-called quiet side effect that has shown to reduce noise annoyance and noise-induced sleep disturbance [12–15].

Two numerical studies with full-wave techniques [8,9] initially showed that green roofs significantly reduce the intensity of diffracting sound waves when opposed to rigid roofs. In addition, green roofs were found to have the highest potential for road traffic noise abatement among other building envelope greening measures in a typical urban setting [16]. The in-situ experiments reported in Ref. [10] allowed measuring the real noise insertion loss of extensive green roofs, since measurements were performed before and after their placement. Measurements under controlled laboratory conditions [11] confirmed the efficiency of green roofs in reducing diffracting sound waves over low-profiled structures.

Adding water to any porous material deteriorates its absorbing properties. This effect has been studied in case of common soils. In general, the acoustic impedance increases (or the absorption coefficient decreases) with increasing moisture content [17–20]. This decreased absorption in soils is caused by the reduced effective layer thickness of the porous medium when the mean water level increases. The soil therefore acts as a hard-backed layer. This is especially true when gravitational forces dominate capillary forces after a rainfall event. In addition, infiltration of water might lead to a decrease in porosity by swelling of soil particles that absorb water. Also clogging of pores might prohibit sound entering the soil [18], the latter being essential to benefit from absorption of sound. Even adding small amounts of water was shown to potentially lead to strong changes in the acoustic surface admittance of sand [19] or specific flow resistance of various types of soils [17]. In the limit, when all air voids are filled with water, the soil surface must approach that of a perfect reflector for sound waves [18]. In addition, complex layering effects, especially at higher frequencies, have

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been observed [18]. Similar to natural soils, green roof substrates are negatively effected by the presence of water: Impedance tube measurements showed a decrease in absorption coefficient (at normal incidence) with increasing moisture content [21].

However, sufficient water retention in green roofs is important, and is often the main motive for placing a green roof on a building: Runoff peaks to the sewers are reduced, smoothened out and delayed. A green roof therefore helps in reducing flooding risks [2,22–26]. The green roof layer build-up is often adapted based on the local needs. In some cases, an additional water retention fabric (e.g. a mineral wool mat) is added in between the bottom of the substrate layer and the top of the water drainage layer. This means that water retention might conflict with the acoustical absorption provided by a green roof. In addition, thermal insulation will be negatively affected by the presence of water in the substrate as well [3].

This work aims at building up knowledge on how the acoustic shielding by a green roof is affected by rainfall. Its dynamics are of practical interest if one wants to apply a green roof as a noise reducing measure. A real-life controlled monitoring campaign has been set up. Note that previously reported simulations and measurements, showing the potential of green roofs to abate noise, were mainly performed in case of rather dry substrates, leading to maximally observed effects. Knowledge about the influence of moisture on substrates in laboratory conditions cannot be directly translated to practice, as sound waves shear over the green roof, in contrast to the normal incidence plane-wave approach in e.g. an impedance tube [21].

## 2. Experimental setup

### 2.1. Site description

#### 2.1.1. General

The measurements were conducted near the edge of a rectangular building equipped with a green roof (Kontich, Belgium). A cross-section and plan view of the experimental site is depicted in Fig. 1. A reference microphone M1 (height of the microphone membrane was 1.7 m) and a loudspeaker were positioned next to the building's facade at ground level (see Fig. 2). Microphone M2 was placed on the green roof, near its centre, along the line loudspeaker-M1, involving 15.3 m propagation over the green roof (see Fig. 3). The height of the membrane of microphone M2, relative to the green roof, was at 0.43 m. Such a low height was chosen to avoid shifts in interference pattern due to changes in the absorbing properties of the green roof, leading to non-straightforwardly interpretable results. Furthermore, such a low receiver height is most relevant for the sound pressure levels in situations where a double diffraction (so over two subsequent roof edges) is to be expected.

**Fig. 2.** Picture taken from the edge of the roof showing the reference microphone (M1) and the outdoor loudspeaker.

The reference microphone M1 was used to account for possible variations in the emitted source power level over time. The acoustic parameter of concern is the difference in sound pressure level between microphone 1 and microphone 2, further indicated as "attenuation". The positions of the loudspeaker and the microphones were fixed throughout the experiment; the variation in

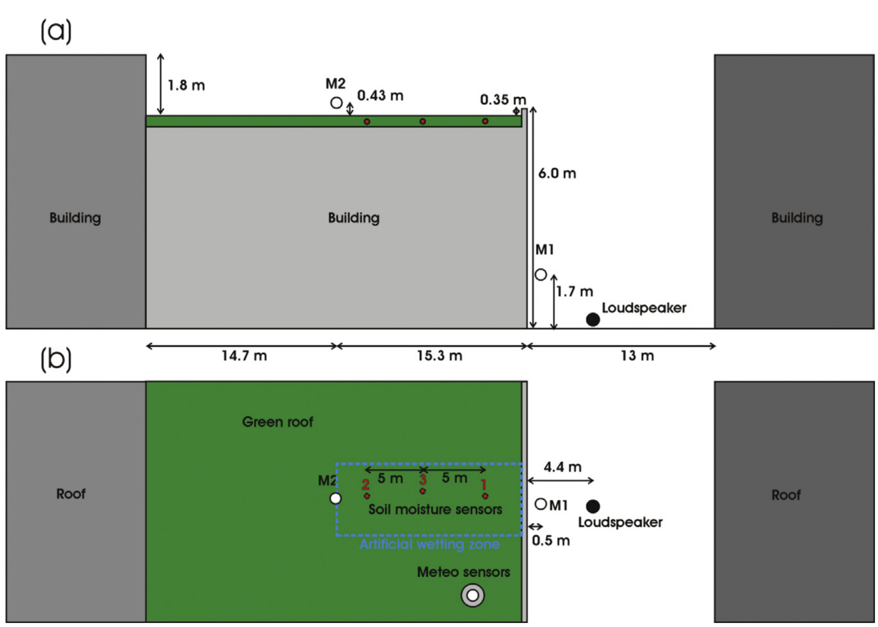


**Fig. 1.** Positioning of the instrumentation at the experimental site : (a) cross section (not true to scale), (b) plan view.

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