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Assessment of direct and indirect impacts of vegetation on building comfort: A comparative study of lawns, green walls and green roofs

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Abstract

Following development and validation of the *Solene-microclimat* tool, the model was used to compare the impacts of various "greening strategies" on buildings' summer energy consumption and indoor comfort. The studied strategies were greening walls, roofs, and ground (lawns). *Solene-microclimat* enables to simulate simultaneously a building's thermal behavior and the microclimate at the district scale, with the retroaction of buildings on climate. Distinguishing between direct (due to the modification of building' characteristics) and indirect impacts (due to the modification of boundary conditions) of these surfaces is also possible. Thus, the strategies were successively implemented on the studied building, the surroundings, and both of them. The simulations were carried out using *Solene-microclimat* considering insulated vs. non-insulated buildings. Findings confirm that the direct and indirect effects of theses surfaces are almost negligible on insulted buildings. For non-insulated ones, green walls have a direct effect on indoor comfort throughout the entire building, whereas the effect of green roofs is primarily confined to the upper floor. Moreover, the indirect effect of a green wall is greater, mainly due to the drop in infrared emissions resulting from a lower surface temperature. It has also been proven that the indirect effects of green walls and surrounding lawns can help reduce the loads acting on a non-insulated building. Direct and indirect effect can't be directly added. This is particularly interesting for heritage buildings or highly glazed ones the refurbishment of which is often difficult.

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Keywords: indoor comfort; urban microclimate; vegetation; simulation; SOLENE-microclimat

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1. Introduction

Reducing summer heat stresses in an urban context may be partially and indirectly achieved by modifying the local climate through the introduction of adaptive techniques. Techniques aimed at expanding the green spaces in cities have been the focus of many studies over the past decade.

The effect of trees, has been broadly studied and shown to be the most efficient source for cooling cities and improving thermal comfort at the local scale[1].

The roofs constituting a high percentage of the exposed urbanized area, green roofs have also received widespread attention for their direct impact on energy consumption, as well as for their impact on urban climate. Santamouris recently presented a state-of-the-art and compared their effects with those of cool roofs[1]. It has been demonstrated that whenever vegetative, or green, roofs are installed in high- or even medium-rise buildings, their mitigation potential becomes almost negligible[2-4]. Nonetheless, depending on climate conditions and building characteristics, results show a variable thermal efficiency[5].

Walls also occupy a high fraction of the total urban surface, with total wall areas potentially greater than the space offered by roofs. Green walls have been shown to reduce a building's cooling load and overall energy consumption while improving indoor comfort[6-11]. Temperatures on city streets are also cooler when green walls are installed on building facades[12-13]; their global impact on a city's climate and outdoor comfort however has not been widely investigated.

Due to their limited impact on climate, lawns have naturally received scant attention despite the fact that these surfaces, which are maintained at low temperatures compared to paved surfaces, do indeed exert a thermal impact on their environment[14].

Urban vegetation has direct impacts namely those due to the building envelop modifications (shading and decrease of convective heat fluxes by lowering near-wall air velocity). When present, a substrate layer also increases the envelop thermal resistance. Indirect impacts are due to the buildings’ environment modifications as air and surface temperatures that influence respectively convective heat fluxes and ventilation and infiltration loads[15], long-wave radiation transfer. Their study requires using both a microclimate model and building energy simulation that is why they are more rarely studied. Djedjig[16] did it at the street scale using TRNSYS and a street canyon model and de Munck[4] at the city scale in TEB.

In this paper, through a case study conducted in Nantes (northwestern France), the direct and indirect effects will be compared from three greening configurations, namely: lawns, green roofs, and green walls. The detailed simulations performed herein will enable analyzing how these configurations modify a city's thermal environment and then alter indoor building comfort.

2. Methodology

2.1. The SOLENE-microclimat model

The *SOLENE-microclimat* model was first developed for purposes of urban insolation assessments. Sub-modules have since been added, now making it possible to incorporate: long-wave radiation exchanges using the radiosity method; conduction heat transfer and thermal storage in walls and soil; airflow and convective exchanges through the coupling with a CFD code; evapotranspiration from natural surfaces (plants and water ponds or humidification systems); the energy balance (energy demand or indoor temperature) for a building, using a multizone building nodal model, nodes corresponding to each building floor and the ventilation and infiltration loads both latent and sensible being included.

The *SOLENE-microclimat* thermo-radiative model, its validation and coupling with the *Code-Saturne* CFD model are presented in details in Malys et al. (2015)[17] and the modules added to study the direct and indirect impacts of adaptation and mitigation solutions in Musy et al (2015)[18] and Malys et al. (2014)[19]. Now *SOLENE-microclimat* includes models for lawns, green roofs and walls, in which the vegetation layer acts upon the following energy transfers:

- Evapotranspiration: latent heat flux due to transpiration and evaporation of water contained in both the plants and substrate.