The impact of vertical greening on local microclimate: preliminary results of field monitoring in Ghent, Belgium

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Abstract
Urban environments, especially city centres, are subjected to higher temperatures and higher pollution levels relative to their less dense surroundings due to the urban heat island effect. The key factor to mitigate those drastic consequences for human and natural environments is implementing green initiatives. Despite the abundance of built heritage in city centres, they are often excluded from the mitigation strategies of cities due to several reasons such as concerns about their impact on materials and structural integrity. The uncertain impact of vertical greening on the built heritage can be investigated in different ways, such as monitoring case studies, laboratory studies, analysing literature and additional simulations, which are complementary in order to understand the real impact. This paper scopes the preliminary results of a case study in Ghent where vertical greening is able to reduce the amount of incoming solar irradiation and the amplitude of the temperature and relative humidity fluctuations on a wall.

Author keywords
Vertical greening; Built heritage; Monitoring case studies; Microclimate; Urban heat island

Introduction
Historic buildings determine the landscape and identity of cities, which makes them an essential part of the urban environment. Due to its cultural and economic values, it is necessary to preserve and maintain our built heritage. Current global challenges such as climate change and the urban heat island effect, where city centres experience higher temperatures and higher pollution levels relative to their less dense surroundings, complicate heritage preservation (Huerto-Cardenas et al., 2021; Oke, 1982). Due to their location in city centres where the urban heat island effect is strongest, and their associated cultural and economic value, built heritage must be included in the urban mitigation strategies to enable sustainable conservation. While urban environments are implementing green initiatives such as green walls, green roofs or street trees, the built heritage is excluded from the mitigation due to the limitation of a dense urban fabric (especially in city centres), the conservation rules and the uncertainty about the structural integrity and the consequences of this implementation on the historic building materials.

Research context
This research scopes the impact of vertical greening on the local microclimate and the corresponding impact on the common forms of degradation of historic building materials caused

by salts, frost, bio-activity and air pollution. Vertical greening in this research represents plants, rooted in the ground, and climbing up the façade by either attaching themselves to the surface or trellising (Dover, 2015). Vertical greening is seen as one of the green initiatives with great potential in dense historic environments due to their limited footprint while still being able to cover a large area of greening (Norton et al., 2015; Ottelé, 2011).

By monitoring case studies, analysing literature, performing experiments and additional simulations, we aim to understand the impact of an implementation of vertical greening on built heritage. In order to understand the complex impact of vertical greening on the local microclimate which determines the risk of weathering of historic building materials, we try to combine the different approaches. The monitoring of the case studies will determine the impact of vertical greening in the urban environment of Antwerp, which is subjected to an urban heat island effect and thus the focus in this research.

This paper will discuss the case study's setting, findings, and the environmental parameters that the monitoring focuses on. The results of the bare wall and the wall with vertical greening in front are compared with each other to illustrate the impact of vertical greening on the local microclimate.

Preliminary data

This paper scope the test case study in Destelbergen, Ghent (Belgium). Destelbergen is a submunicipality of Ghent and rather a rural environment. This case study was undertaken to establish the mounting requirements for measurement instruments and their monitoring capabilities and settings.

Monitoring environmental parameters

The main focus of monitoring this case study is on how the implementation of vertical greening can affect the local microclimate. Therefore, the environmental parameters are measured in front of both walls – the wall with and without vertical greening – and compared with each other. In literature, the most frequently discussed environmental parameters affected by vertical greening are air temperature, surface temperature and relative humidity. These parameters are also significantly impacted by the urban heat island effect. Air temperature and relative humidity are responsible for the comfort of people in the city, while the surface temperature is seen as the energy balance centre of urban surface and as the most important factor affecting the urban climate (Yang et al., 2016). Additional, solar irradiation is strongly connected with the temperature and relative humidity values which makes this parameter as important as the others.

This case study explores the impact of vertical greening on the air temperature, surface temperature, relative humidity and solar irradiation nearby or on the wall. Each parameter has its significant impact on the four aforementioned degradation of historic building materials. For example, freeze-thaw weathering needs low temperatures and high moisture levels to occur. A change in those environmental parameters due to the implementation of vertical greening can have, beneficial or adverse, impacts on the degradation of historic building materials (Baer et al., 2009; Camuffo, 2014; Godts et al., 2021; Moncmanová, 2007; Siegesmund & Snethlage, 2014).

Case study features

The case study wall is located in a test centrum PCS (Proefcentrum voor Sierteelt) in Destelbergen (Ghent). PCS is an independent knowledge centre for floriculture and greenery in Flanders, Belgium (PCS, n.d.). This wall exists of different types of mature ivy and is facing a north orientation. Our case study was only a part of this wall and was performed on the part with *Hedera*

Helix ‘Glacier’. The measurement devices were installed in the vertical greening and at the bare wall on the same height and recorded environmental conditions from 21 September 2022 until 23 December 2022.

Figure 1. Set-up of monitoring devices on the wall of the case study in Destelbergen with a set-up on the bare wall and a set-up in the vertical greening (Hedera Helix ‘Glacier’).

Methodology

In order to make a good comparison between the environmental conditions surrounding the bare wall and the green wall, the same monitoring devices are installed on both parts of the wall (Figure 1). The air temperature and relative humidity are measured together with a HOBO S-THC-M002 smart sensor which is covered by a solar radiation shield (HOBO RS3-B) to prevent the measurements from being affected by the solar irradiation. This device is installed at a distance of 10 cm away from the wall surface. The surface temperature is measured with a HOBO TMC6-HE temperature sensor, which is mounted against the wall. The amount of solar irradiation is measured with a silicon pyranometer sensor (HOBO S-LIB-M003) covered by an light sensor level (HOBO MLLA) to receive accurate measurement and is mounted as close as possible against the wall.

The sensors for air temperature, relative humidity and solar irradiation are connected to a HOBO USB Micro station data logger, which collects their data at a frequency of 15 minutes. The surface temperature is connected to a 4-Channel Analog Data Logger, HOBO UX120-006M, and provides measurements at a frequency of 15 minutes.

Results and discussion

By analysing the data of the test case study, it is clear that vertical greening has a significant impact on the environmental parameters.

First of all, vertical greening is able to lower the amplitude of fluctuations of the surface temperature significantly over the whole monitoring period. More specifically, vertical greening is able to reduce the maximum surface temperature by up to -1.12°C while the minimum surface temperature increases by +1.88°C. The average surface temperature of a wall with vertical greening is 0.57°C lower relative to the corresponding bare wall.

Secondly, the effect of vertical greening over three months of monitoring is less pronounced in the air temperature, probably due to the positioning of the measurement device at a distance of 10 cm from the wall surface. Vertical greening causes a negligible difference in the average air temperature relative to the corresponding bare wall. Similar to the surface temperature, the fluctuations of the air temperature are smaller due to an implementation of vertical greening. The maximum air temperature is 0.16°C lower in front of a green wall compared to the bare wall and the minimum air temperature is 0.13°C higher.

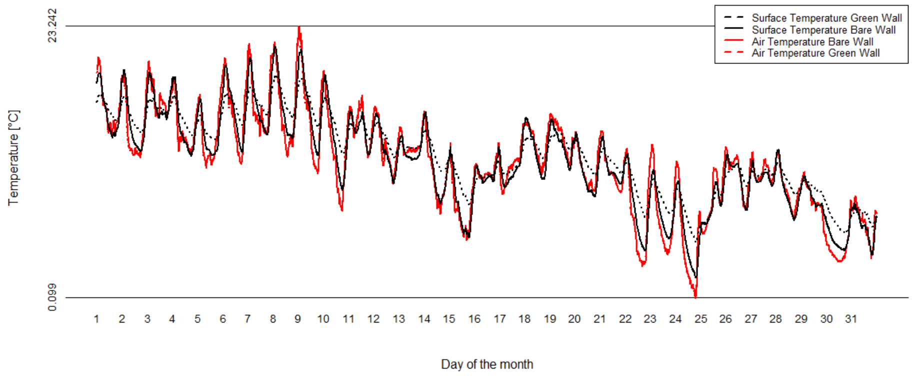

Figure 2. This graph is a subset of the whole measuring period and illustrates the surface (black) and air temperature (red) of the wall behind vertical greening and the corresponding bare wall during the month October 2022.

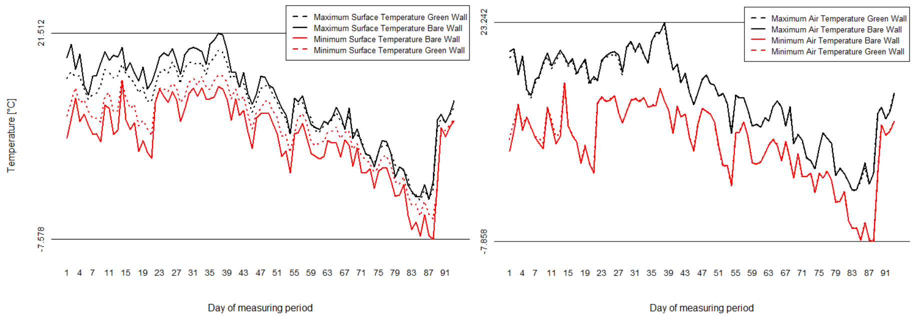

Figure 3. The graphs illustrate the maximum (black) and minimum (red) values of the surface temperature (left) and air temperature (right) of the wall behind the vertical greening compared to the corresponding the bare wall (red) during the whole measuring period.

Thirdly, the relative humidity is measured with the same measurement device as the air temperature and is therefore also installed on a distance of 10 cm relative to the wall. By comparing the two walls to each other, there is only a small difference noticeable in the relative humidity due to the implementation of vertical greening. Over the whole monitoring period, the relative humidity of the green wall is on average +1.07% higher relative to the corresponding bare wall. Due to the low amount of solar irradiation in the north orientation, it is likely to have a lower amount of evaporation which contributes in rising the relative humidity in front of a green wall.

Lastly, the amount of incoming solar irradiation is affected significantly by an implementation of vertical greening. The average amount of incoming solar irradiation is lowered with 76.88% while the maximum values of the incoming solar irradiation are lowered with 79.70% relative to the bare wall. Those results can have a significant impact on the aforementioned degradation types of historic building materials.

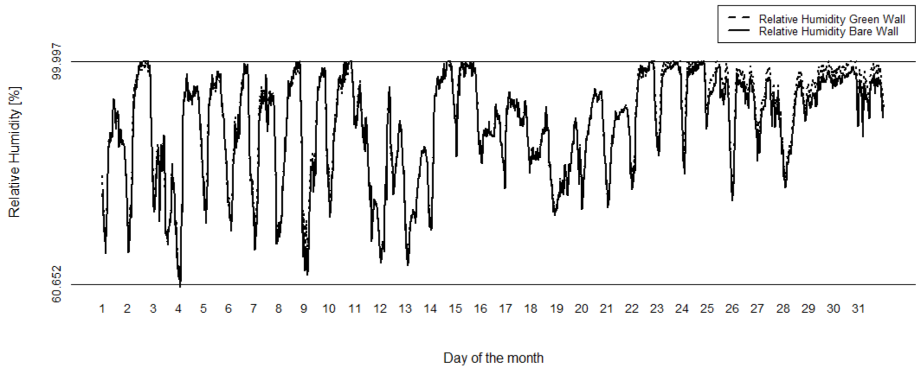

Figure 4. The graph is a subset of the whole measuring period and illustrates the relative humidity of a wall behind the vertical greening and a wall without vertical greening during the month October 2022.

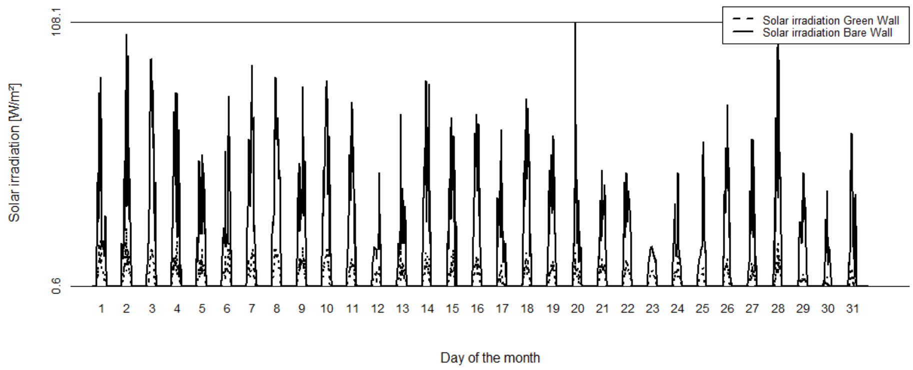

Figure 5. The graph is a subset of the whole measuring period and illustrates the incoming solar irradiation on a wall behind the vertical greening and on a wall without vertical greening during the month October 2022.

The results of this paper represent already a clear impact of vertical greening on the local environment, even though this case study was located in a rather rural environment. In order to have more extensive results, a longer measuring time and a larger amount of walls with different orientations and a location in the city centre should be taking into consideration for the monitoring of future case studies. The more data available, the more interesting connections that can be made between the impact of vertical greening on the local microclimate and different variables such as seasons, orientations and climate types and the more it can be understood how vertical greening can have an impact on the most common degradation types of historic building materials, especially in an dense urban environment.

Conclusion

This case study performed in Ghent illustrates the beneficial impact of vertical greening on the local microclimate. In general, the environmental conditions of the wall will be less extreme and therefore more likely to have a beneficial impact on the degradation of historic building materials. This means that vertical greening is able to reduce the urban heat island effect on a local scale while it only needs a small footprint to cover a large surface area of greening. First, the surface temperature, which is an indicator for the urban climate, is reduced significantly. Further, the impact of vertical greening on the air temperature and relative humidity is smaller but the reduction in air temperature is still beneficial for the comfort of the residents. Last, vertical greening is able to reduce the amount of incoming solar irradiation significantly, which is beneficial for the degradation of historic building materials but also for the comfort and energy efficiency in buildings.

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