Evaluating the cooling potential of green walls and green roofs in Central European cities

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Abstract

Incorporating green infrastructure such as green walls and green roofs as nature-based solutions for the urban environment has the potential to mitigate climate change, enhance climate resilience, increase urban circularity and biodiversity, reduce urban heat island (UHI) and surface urban heat island (SUHI) intensities, reduce energy consumption in buildings, improve air quality, retain rainwater, and enhance human outdoor thermal comfort, health and well-being. In a bilateral project between Serbia and Austria, measurements of the cooling potential of green walls and green roofs are carried out in Novi Sad (Serbia) and Vienna (Austria). The obtained results indicate the cooling potential of these types of nature-based solutions that can provide a more comfortable climate and outdoor thermal comfort conditions in urban areas. Local temperature reductions near green infrastructure (compared to reference locations) were up to 2-3 °C in both cities. However, the cooling intensity depends on the season, time of day, type of green infrastructure, and the availability and type of water used for irrigation of green infrastructure. The obtained results can be used to develop guidelines for green infrastructure design and can be provided to interested stakeholders in their pursuit to create sustainable, resilient, circular, and climate-neutral cities in the future.

Study areas, data and methods

The investigated pot-based green facade is installed in the courtyard of the Muthgasse campus of the University of Natural resources and Life Sciences, Vienna (BOKU) (Austria). The experimental site consists of four individual walls (Wall 1 to Wall 4) illustrated in Fig. 1. Wall 1 represents a dry system with reduced water supply and is irrigated with tap water. Wall 2 and Wall 3 are irrigated daily. Wall 2 uses tap water, while Wall 3 is irrigated with synthetic untreated greywater. Wall 4 is set up as a vertical greywater treatment system. Each wall is constructed using ten planter-boxes (150 cm × 20 cm × 20/12 cm) with a surface area of 0.3 m^2 each. Each planter-box has an impounded bottom layer of 2 cm. The water flow in each wall follows a low-tech design to simplify the irrigation. Water enters on top of the first planter-box and flows horizontally through the box. In this process, the 2 cm impounded area is filled up, and the overflow enters the planter-box below. The plant growing media (PGM) used is composed of expanded clay (4–8 mm), zeolite (1–2.5 mm), perlite (0–6 mm), sand (0.06–2 mm) and crushed expanded clay (0–8mm). The plant selection was i) suitable for Austrian climatic conditions and ii) according to the different conditions of the irrigation. Three species were used as indicator plants and planted in every wall, namely *Sedum telephium* for dry conditions, *Geranium cantabrigiense* for moist conditions and *Iris pseudacorus* for wet conditions. Water flow to the wall is measured using a standard water meter coupled to an impulse logger (EASYLOG 80 IMP, GHM Group, Remscheid, Germany). The accuracy of the measurement is one liter. The excess water of Wall 1, Wall 2 and Wall 3 is measured using a tipping bucket with an accuracy of 0.01 l. For Wall 4, a non-continuous measurement of excess water was performed. Air temperature was measured for each wall, and the Bare Wall using air temperature sensors (ATMOS 14 temperature sensor, METER Group AG, Munich, Germany) was recorded in a ten-minute interval and processed as mean hourly data (Fig. 1). The sensors are mounted 4 cm in front of the vertical greening system (VGS) while the Bare Wall sensor has a distance of 2 cm from the wall. Measured temperature data is therefore used to evaluate the near surface air temperature of each wall. Experiments on greywater treatment were carried out from March 2020 until August 2021, while the presented data for the irrigation scenarios as well as the plant biomass are for the growing period April–September 2021 (2nd growing period). The measured local air temperatures of each Wall (1 to 4) are compared, including the measurement on the unvegetated Bare Wall. The performance in temperature reduction is evaluated for heat days defined as days with a maximum temperature higher than 30 °C. The temperature differences between the Bare Wall and each VGS were tested for significance using one-way analyses of variance (ANOVA) (Pucher et al., 2022).

Within the GReENERGY project, green infrastructure was implemented on a public school in Novi Sad (Serbia) (Fig. 2). An extensive green roof of 480 m^2 and a green wall of 82 m^2 was installed at the school “Milan Petrović” in Novi Sad. The new green roof has a substrate between 7 and 12 cm thick, and the surface mass of peat is about 150 kg/m^2 without plants. Selected plant species are meadow sedum and grass due to the small root system, but also resistance and minimal maintenance requirements because they tolerate drought well. The green wall was placed on the existing wall for the substructure, including the waterproof membrane, and the installation itself was performed on the part of the street facade of the north-eastern orientation. Four Vantage Pro2 automatic weather stations are mounted on building walls. Each station is equipped with Davis Vantage Pro2 sensor set, together with included sensors for measuring air temperature, air humidity, wind speed and direction and solar radiation. One additional, Testo Globe sensor, is equipped on each station (Savić et al., 2021) (Fig. 2).

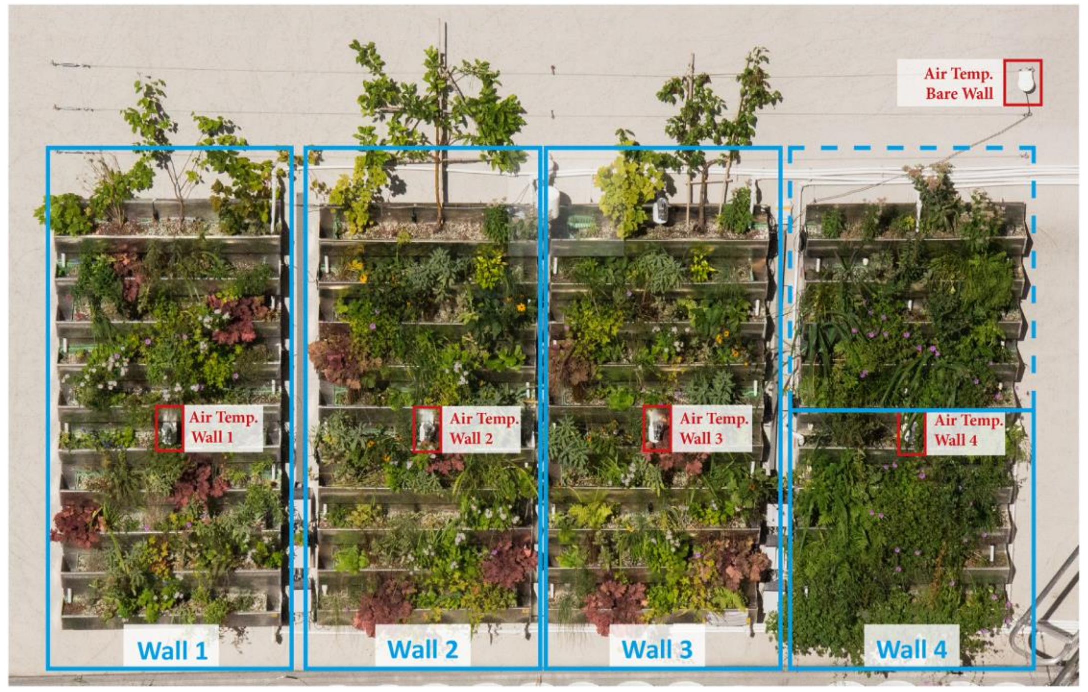

Fig. 1. Experimental green wall site including the positions of the air temperature probes in Vienna (Pucher et al., 2022)

Fig. 2. Green roof and installed weather stations in Novi Sad, Serbia (Savić et al., 2023)

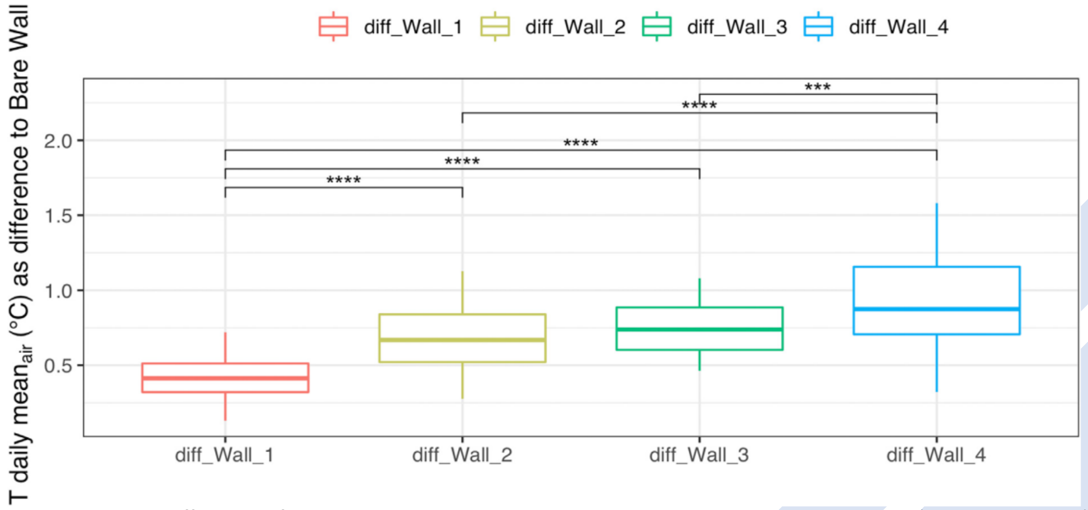

Fig. 3. Calculated differences of air temperature between the Bare Wall and Wall 1, Wall 2, Wall 3, Wall 4 (Pucher et al., 2022)

Results

GREEN WALL IN VIENNA, AUSTRIA

The effect of the irrigation practice on the local air temperature is evaluated for so-called hot days (n=61), which are defined as days with a maximum temperature over 30 °C. The highest temperature difference was measured between Wall 4 and the Bare Wall with 3.4 °C based on hourly data. Fig. 3. compares the calculated differences of air temperature between the Bare Wall and each of the greened walls. The results show no significant difference between Wall 2 and Wall 3. Between all other Walls, a significant difference is detected. The mean daily and the maximum differences of air temperature between the Bare Wall and each VGS wall are 0.43 °C and 0.72 °C (Wall 1), 0.70 °C and 1.13 °C (Wall 2), 0.76 °C and 1.08 °C (Wall 3), and 0.94 °C and 1.58 °C (Wall 1). In the study, the mean daily air temperature difference between the Bare Wall and the VGS was as high as 1.5 °C for Wall 4, which received the highest daily irrigation (90 l). The highest value based on hourly data reached 3.4 °C (Pucher et al., 2022).

GREEN ROOF IN NOVI SAD, SERBIA

For detailed analysis we selected two heatwave periods that occurred in June and July 2022. Analysis of Ta (air temperature) present very similar values from all four stations/locations (particularly during the first heatwave period) (Fig. 2). However, some differences are noticeable between locations 301/302 and 303/304 in maximum values (about 2 °C of difference). Very similar values among locations are visible for RH (relative humidity), i.e., the differences are not higher than 2-3%. Some obvious differences are visible in Tg (globe temperature) values among stations, particularly between site 303 and sites 302/304. The Tg values in the site 303 are 4-5 °C lower (in average and max) than on other stations, and the highest differences are occurred during the intensive heatwave in July. Obviously, that extensive green roof with low vegetation (sedum mix) has some impact on microclimate conditions, particularly in reducing thermal discomfort and minimally lowering the humidity based on more intensive water absorption (Savić et al., 2023).

References

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