EMS Annual Meeting 2023

Cooling potential of green spaces in the Vienna metropolitan area during extended periods of drought

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Introduction

To curb urban heat, major efforts are being made to plant more vegetation and remove sealed surfaces. However, many green roofs and green facades are not irrigated, which in turn causes drought stress for plants during extended summer heat periods without precipitation. As a result, evapotranspiration from vegetated areas is reduced and the desired cooling effect is not achieved. Additionally, the agricultural lands near cities cannot develop its full cooling effect even during the day.

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Objective

In the framework of the ACRP project Imp_DroP (Impact of longer Drought Periods on Climate in Greater Vienna: appropriate Mitigation measures), the cooling potential of green areas in and around Vienna is determined via evapotranspiration potentials and related future irrigation demand.

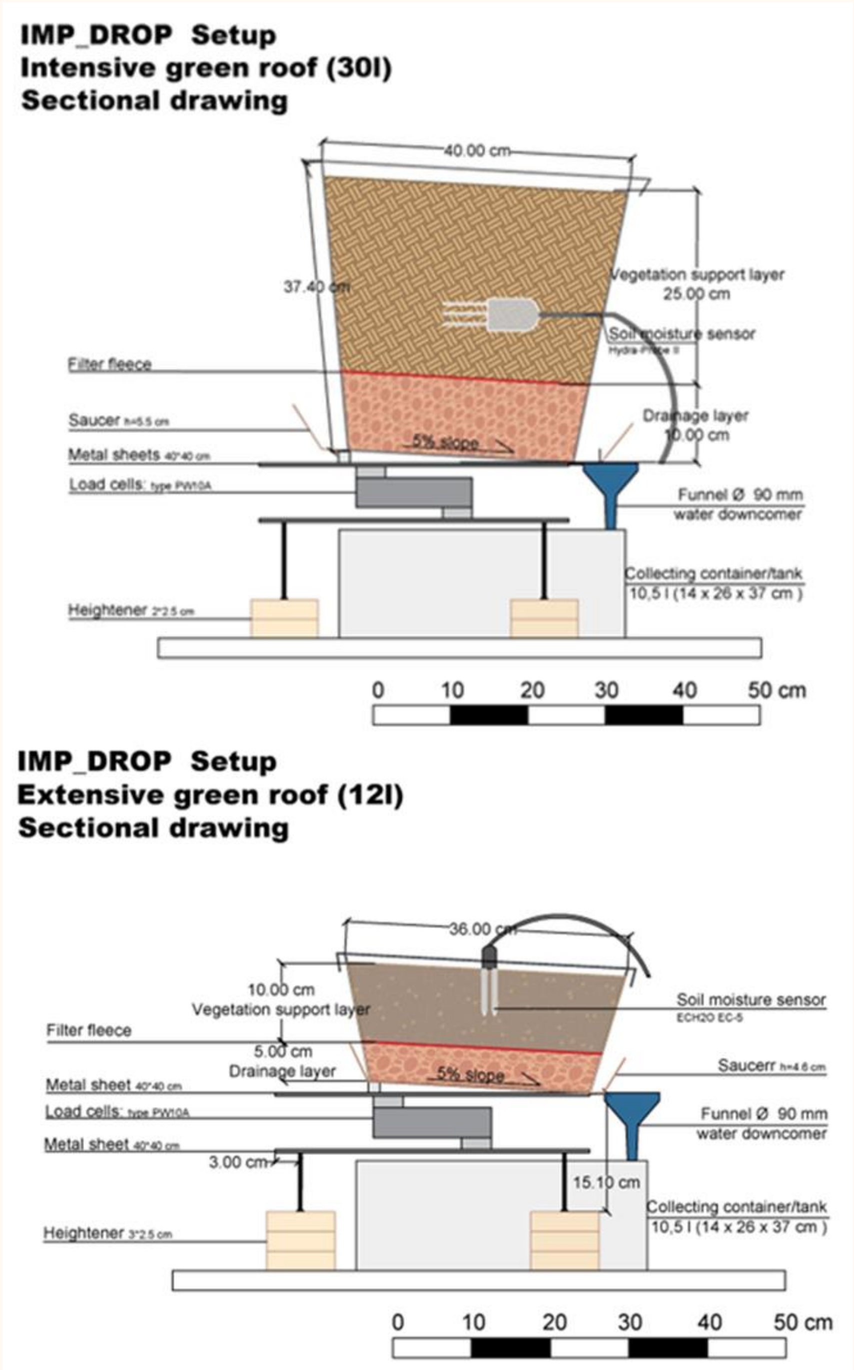

Figure 1: Sectional drawing of the experimental setup of the lysimeter for the investigation of an intensive (top) and extensive (below) green roof

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Methodology

(a) In-situ measurements (2022/23):
Two minilysimeters for extensive and intensive green roofs (Fig 1) are set up at four measurement sites on green roofs in Vienna (Fig 2). Additionally, weather parameters and soil moisture is measured.

Figure 2a-c: Final setup of the experimental units covered up with white foil at the non-irrigated setups at the site (a) AKH Vienna and Kandlgasse with intensive (b) and extensive (c) green roofs

(b) Modelling:
The in-situ measured parameters are used for the calibration/validation of the daily actual evapotranspiration using the FAO-approach (Allen et al., 1998) and the related model AquaCrop (Steduto et al., 2009). For the surrounding agricultural areas of Vienna, soil-crop water balance is simulated using the GIS-based ARIS model at 1 km grid scale.

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Preliminary results

The for the year 2022 calibrated FAO model shows good agreement with slight overestimation at high evaporation rates in the simulation at all sites (see AKH roof site Fig 3a + Fig 4 and Kandlgasse roof site Fig 3b as examples). The identified critical factor for calibration is the crop factor (Kc) due to its temporal variability at green roofs under rainfed conditions. Data from the second year (ongoing measurements 2023) will be used for validation.

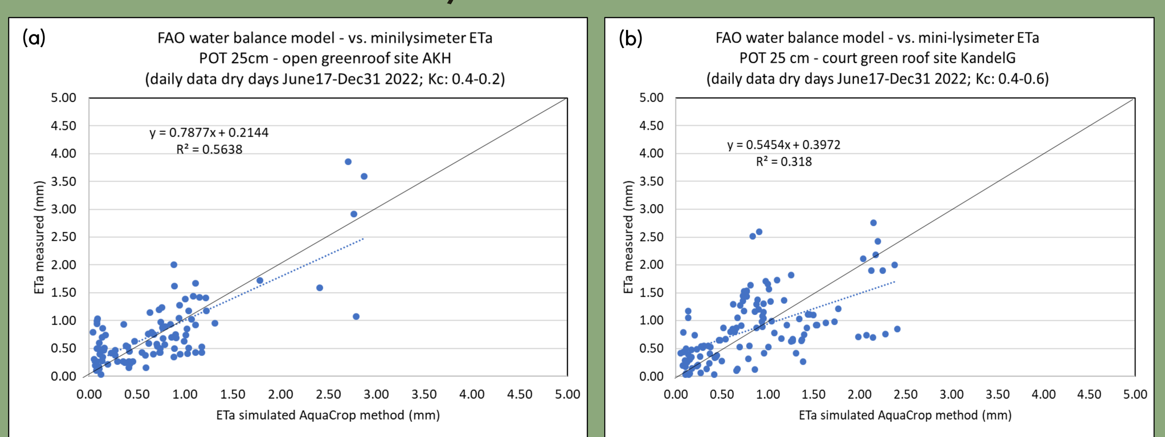

Figure 3a-b: Comparison of daily actual evapotranspiration measured by minilysimeter vs. simulated by the FAO method (calibrated)

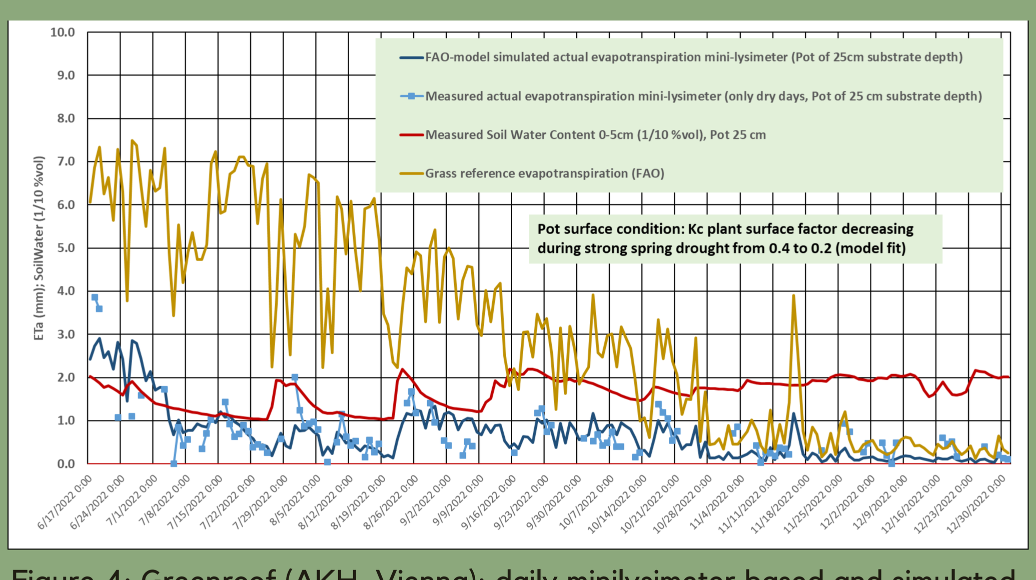

Figure 4: Greenroof (AKH, Vienna): daily minilysimeter based and simulated water balance parameters (June-December 2022, calibrated)

Using ARIS, daily actual evapotranspiration and soil water content is derived at the 1 km grid level using relative soil saturation (RRS) (Fig 5). This has been simulated over two soil layers (topsoil and subsoil) for the main crops (maize, spring barley, winter wheat) and grassland taking into account the specific growing seasons and crop acreages for irrigated and rainfed conditions of the different crops in the region around Vienna.

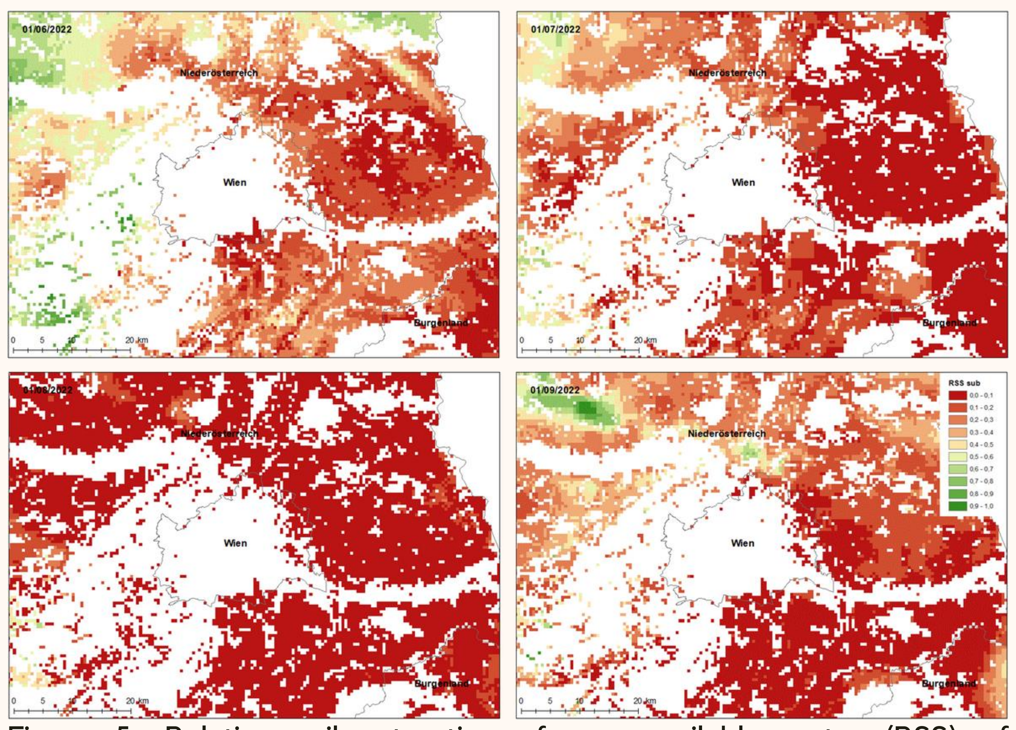

Figure 5: Relative soil saturation of crop-available water (RSS) of surrounding agricultural land of Vienna on 01/06, 01/07, 01/08 and 01/09/2022

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Next steps

All collected data (measured data and calibrated crop water balance simulations) are used in the final step for initialization, execution and validation in the coupled WRF-TEB model to simulate the urban microclimate for current and future summer drought episodes. The selection criterion for drought episodes is defined as a biennial event with a cumulative negative NPET (precipitation - potential evapotranspiration) of no more than 5 mm of precipitation (Fig 6). The time frame is set to the year 2050, with best and worst case scenarios being run and compared. For the climate scenarios, in addition to the drought episodes, a status quo scenario without irrigation, a scenario with maximum irrigation, and a scenario with adapted crop irrigation are considered.

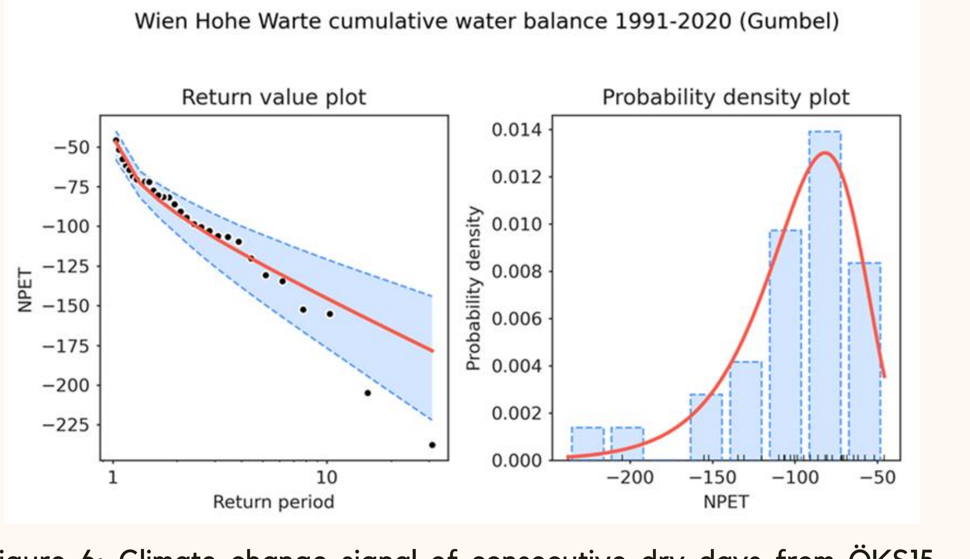

Figure 6: Climate change signal of consecutive dry days from ÖKS15 models for near-time (2030), mid-century (2050) and end od century (2080) projections

Acknowledgement:
This study was supported by the Imp_DroP project of the Austrian Climate Research Programme (ACRP - 13th Call)

References:

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Steduto P, Hsiao TC, Raes D, Fereres E (2009) AquaCrop - The FAO Crop Model to Simulate Yield Response to Water: I. Concepts and Underlying Principles. Agron J 101(3):426-437. https://doi.org/10.2134/agronj2008.0139s