Urban tree water demand

Comparison of modeling results to measured sap flow and soil moisture data

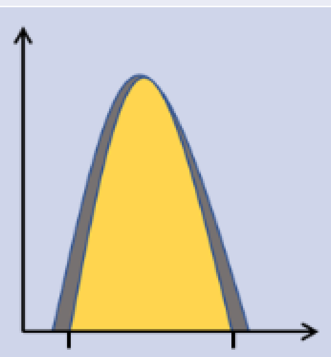
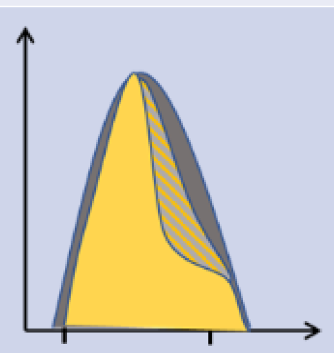
by Laura Tams, Eva Paton and Björn Kluge, Technische Universität Berlin, Institute of Ecology, Department of Ecohydrology

INTRODUCTION

Current shifts in rainfall and temperature regimes towards dryer and hotter periods in central Europe have caused substantial water stress for urban trees. To be able to adapt water supply to urban trees under a changing climate, a quantification of evapotranspiration and water availability becomes necessary and is at the same time, very challenging in the heavily modified urban environments. Both processes are influenced by soil sealing and complex shading patterns of the surrounding street canyon.
For five urban street trees in the city center of Berlin, evapotranspiration (ETA) and water availability were monitored in the vegetation period of 2022. The monitoring results were then used to test the hydrological urban tree model with an integrated shading model which specifically takes into account the shading and sealing variability of the surrounding built environment.

HYPOTHESIS

1. Shading reduces evapotranspiration significantly.
2. Water stress reduces evapotranspiration significantly.
3. Shading reduces water stress periods significantly.

	HZ1	HZ2	HZ3
SAMPLING SITEs			
Tree age (year)	10	10	36
Crown area (m²)	6	8	24
Stem circumference (cm)	41	34	61
Soil type	FLL substrat	FLL substrat	Sandy soil
Treepit size	4 m²	4 m²	0 m²
Soil sealing	Grave	Gravel	Asphalt, pavers
Shading scenario	 7 Uhr – 19 Uhr	 6 Uhr – 16/17 Uhr	 Ab 12 Uhr
Sap flow	1x SAP UP	2x SAP UP	1x SAP UP
Soil moisture	PR2	PR2	none
Irrigation	On demand	On demand	none

- Sap flow and soil moisture measurements of three tillia cordata street trees were selected for this analysis (HZ1-HZ3). The different tree characteristics and site conditions that can be implemented into the URbanTRee model are listed above.
- The impact of shading on evapotranspiration is most pronounce on clear sky days (Fig. 3).
- The impact of limiting soil water conditions was investigated during four irrigation periods for HZ1 (Fig. 4) and HZ2 (Fig. 5).

METHODS

The URbanTRee model (Fig. 2) includes extensions and adaptions for individual street trees in typical urban settings and calculates hourly potential and actual water losses by evapotranspiration. A combined bucket model calculates soil moisture storage and routines for interception, infiltration, runoff and percolation losses are included. Further the shading model reduces direct and diffuse radiation depending on the shading scenario (Fig.1).

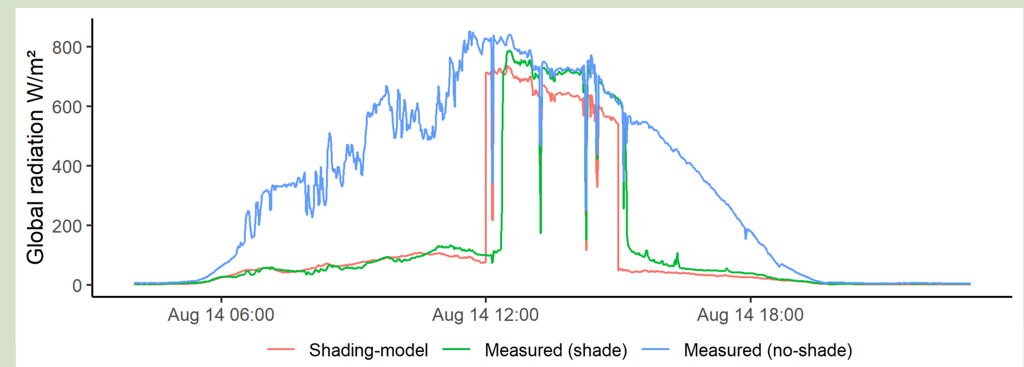


Figure 1: Comparison of modelled (Shading-model) and measured diurnal radiation rates influenced by shading and no-shading.

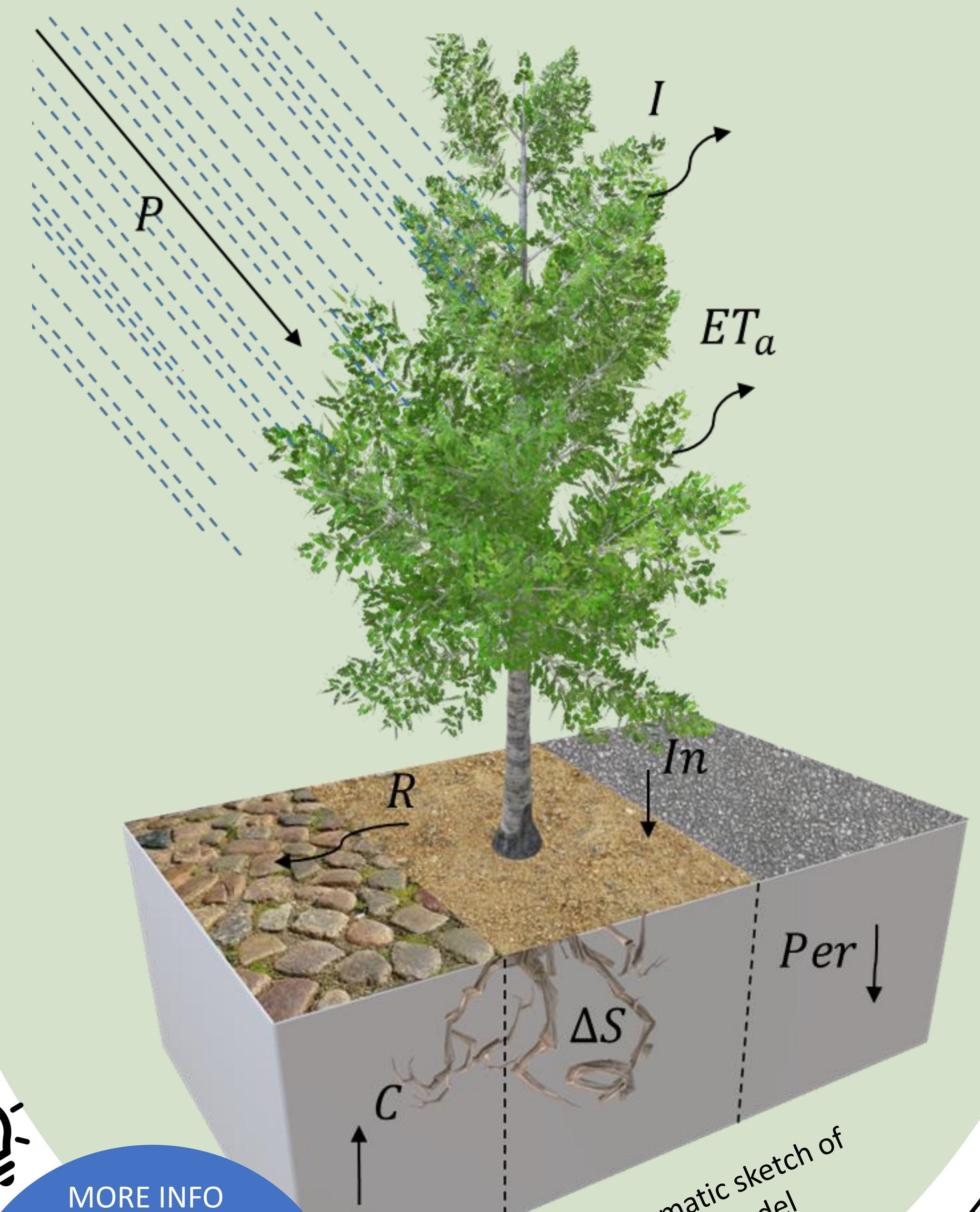


Figure 2: Schematic sketch of URbanTRee model

MORE INFO
Tams et al. (2023, under review): Impact of shading on evapotranspiration and water stress of urban trees

IMPROVEMENTS/CHALLENGES

- Implementation of partial shading necessary
- Over- and underestimation of evapotranspiration depending on soil moisture content
- Impact of additional runoff from surrounding surfaces

RESULTS and DISCUSSION

DIURNAL SHADING PATTERNS

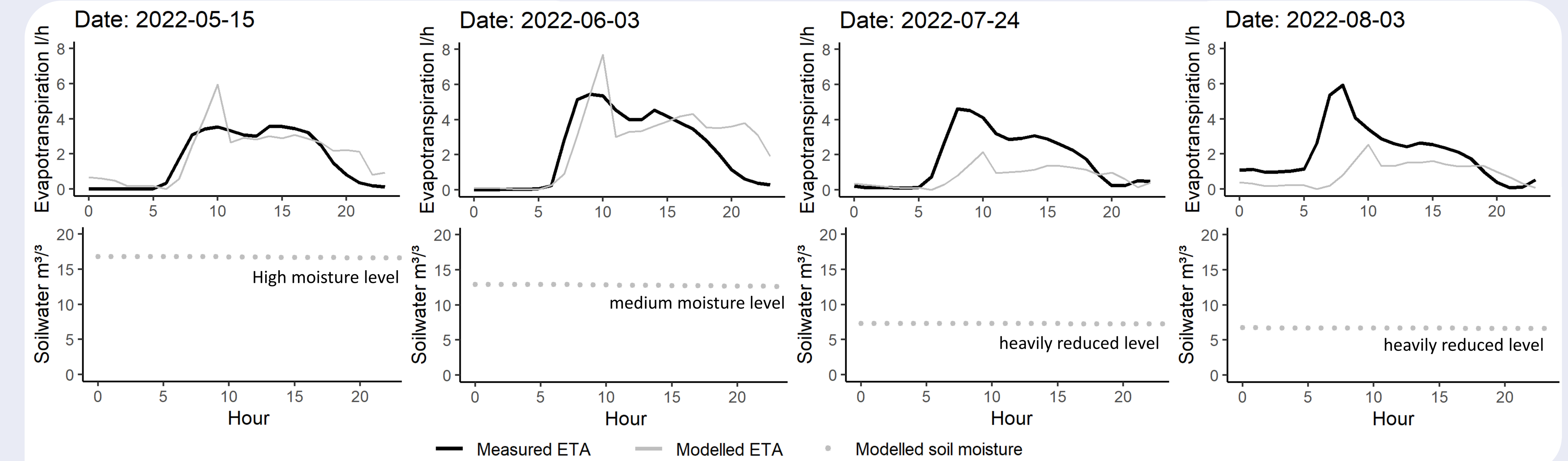


Figure 3: Diurnal patterns of modelled and measured actual evapotranspiration rates (l/h) on clear sky days for HZ3 (influenced by shading after noon).

WATERSTRESS PERIODS

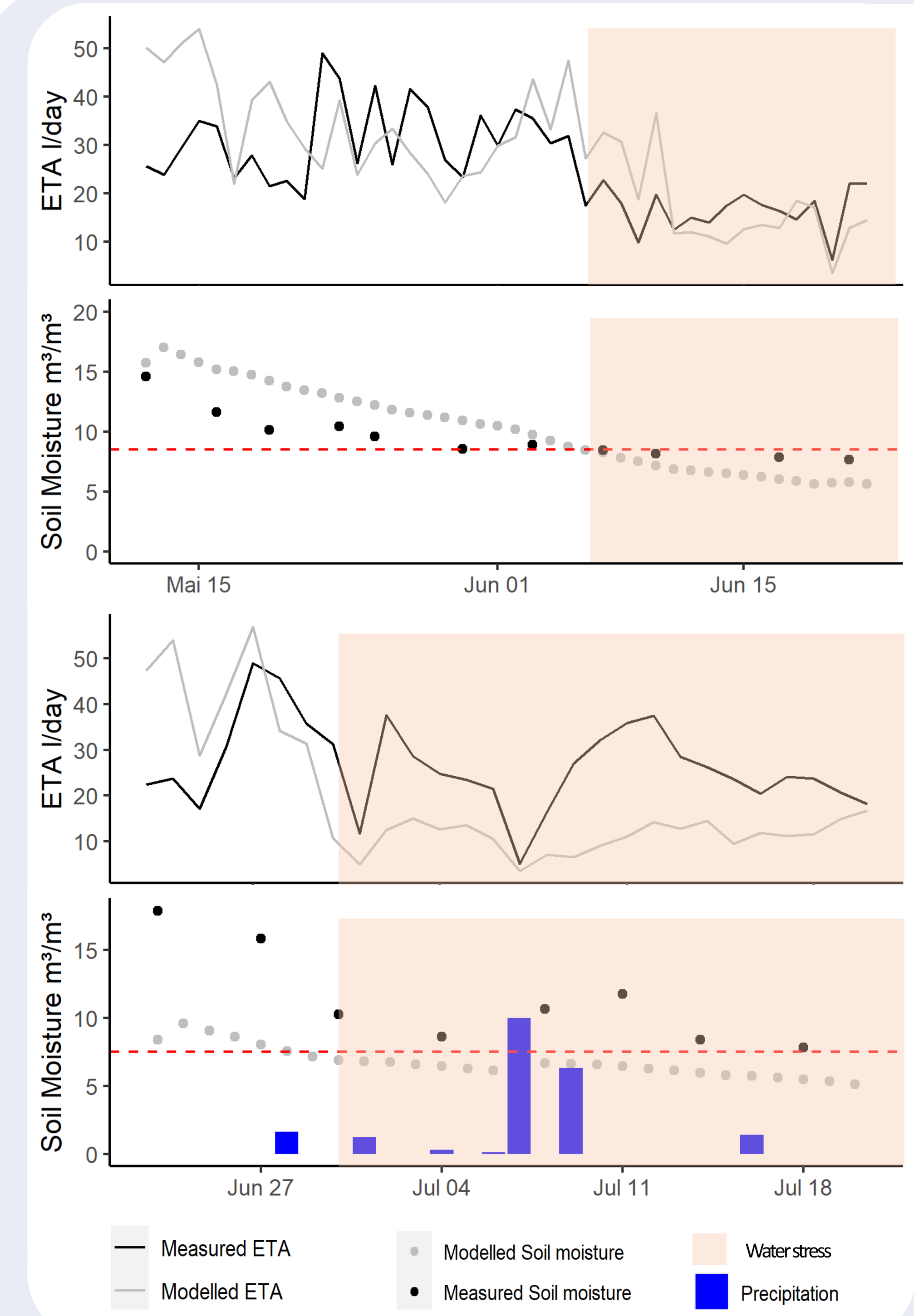


Figure 4: Daily modelled and measured ETA and soil moisture data after two different irrigation events for HZ1.

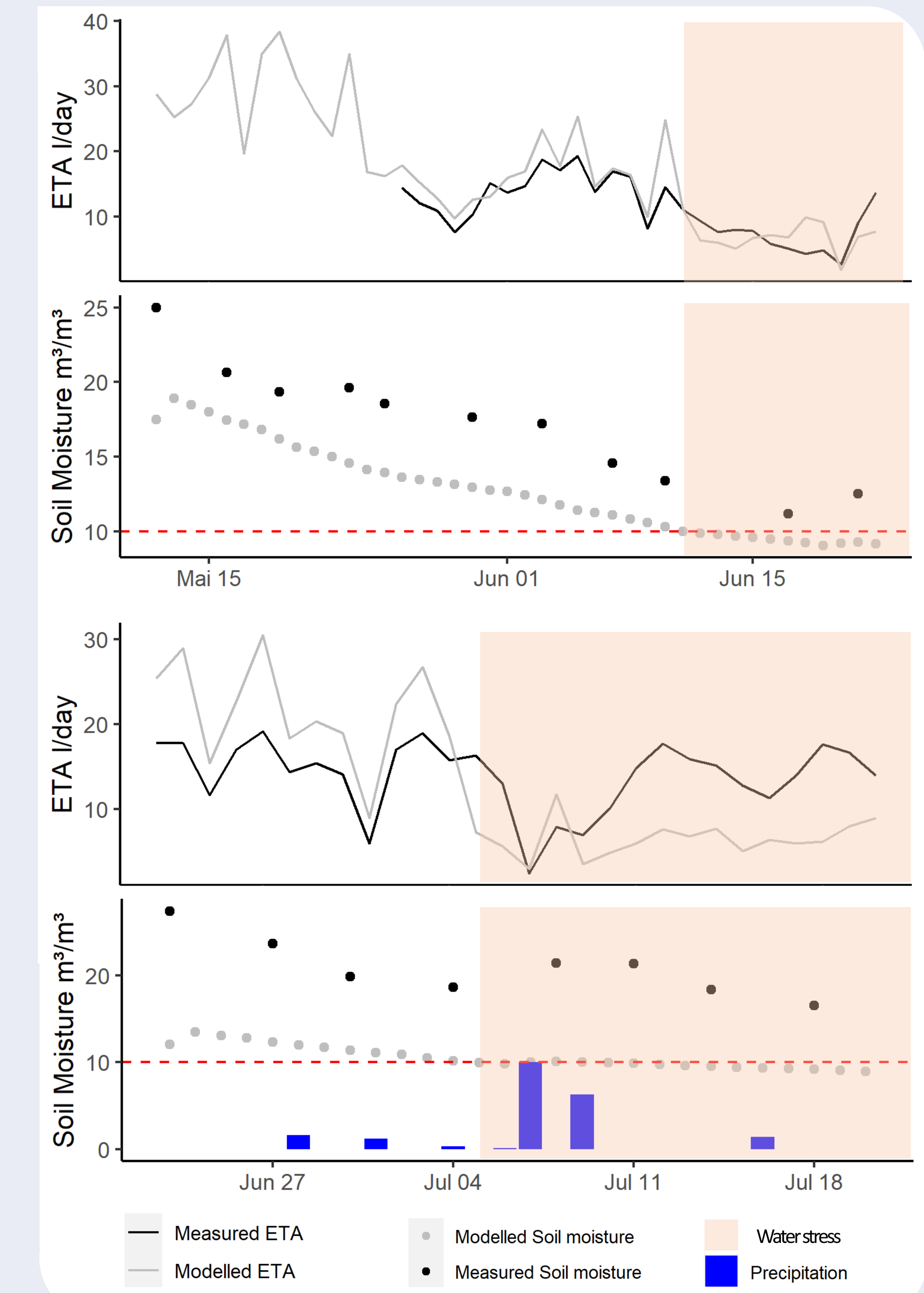


Figure 5: Daily modelled and measured ETA and soil moisture data after two different irrigation events for HZ2.

SUMMARY

1. Shading reduced evapotranspiration by up to 50% on clear sky days.
2. First quantitative evidence showing a reduction of daily evapotranspiration rates by 80% under water stress conditions.
3. Water stress periods occurred up to one week earlier for the tree with higher evapotranspiration rates (for example due full to exposure to sunlight).

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