Effects of planting sites on growth and services of inner-urban small-leaved lime (*Tilia cordata* Mill.)

Astrid **Moser**[a], Mohammad A. **Rahman**[b], Hans **Pretzsch**[a], Stephan **Pauleit**[b], Thomas **Rötzer**[a]

[a]Chair for Forest Growth and Yield Science and [b]Chair for Strategic Landscape Planning and Management
School of Life Sciences Weihenstephan, Technische Universität München, 85354 Freising, Germany

finanziert durch Bayerisches Staatsministerium für Umwelt und Verbraucherschutz

Introduction

Trees in urban environment mostly grow in highly paved, compacted sites with reduced soil moisture, higher soil temperatures and greater vapor pressure deficits. Moreover, limited rooting space with higher above- and belowground pollution loads, urban sites provide the most harsh conditions for urban trees to grow. The effects of these prerequisites on tree growth have been investigated in several studies over the last decades. However, there is still a knowledge gap regarding the impact of highly paved, compacted environments on urban tree growth during drought years, since water availability is an important proxy for tree growth. This study analyzed the growth patterns and related underlying mechanisms of growth under drought stress of the common urban tree species small-leaved lime (*Tilia cordata*) at two contrasting sites (highly paved public square vs. more open, greener square).

Research Questions

(1) Do *T. cordata* trees grow differently when planted at two contrasting sites in terms of the degree of impervious surface (highly paved site compared to open, greener site)?

(2) How do the reaction patterns to drought stress differ between contrasting environments?

(3) What are the main driving forces behind the revealed growth reaction patterns of urban trees in relation to the microclimate?

Material & Methods

Our study site, the city of Munich, is characterized by a warm temperate climate with a long-term (1961–1990) annual precipitation mean of 959 mm and a mean annual temperature of 9.4 °C[1], with monthly mean UHI intensity up to 6 °C in the city center[2]. Two sites within the city center were chosen, representing typical urban conditions: Bordeaux Platz is an open, green square with less pavement (**OGS**), while Pariser Platz is a highly compacted, heavily paved square (**CPS**) (Fig. 1).

Our criteria for site selection were:

(1) two sites with contrasting characteristics in terms of micro-meteorology and surface cover
(2) commonly planted and healthy matured street trees of the same species in a sufficient number
(3) situated close to the city center with pronounced urban heat island (UHI) effect

Applied Methods:

- Dendrometer generating high-resolution growth data
- Sap flow data
- Meteorological data
- Dendrochronological data with increment cores

Five *T. cordata* trees at each plot (10 trees in total) were selected and data collection was done from June 23rd to October 21st 2015.

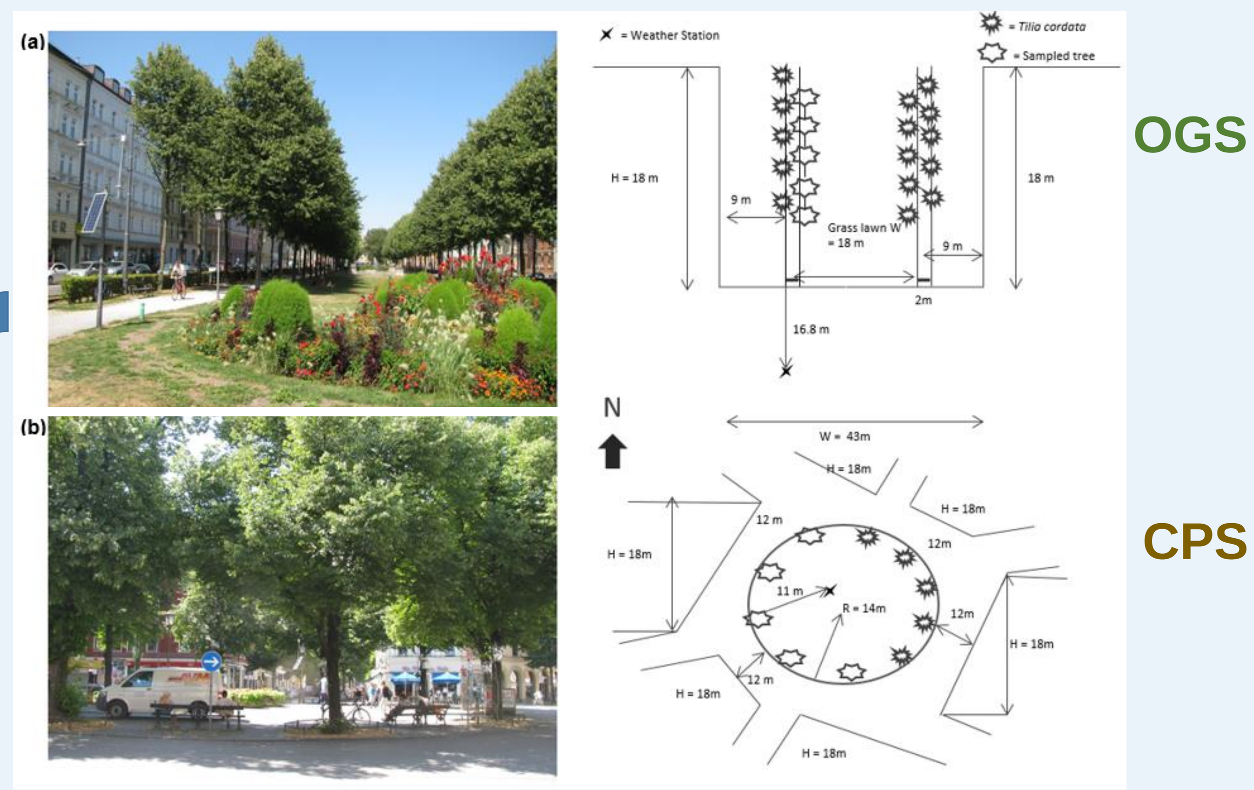

Figure 1: Illustrations of Bordeaux Platz (open green square OGS) (a) and Pariser Platz (compacted paved square CPS) (b) in Munich

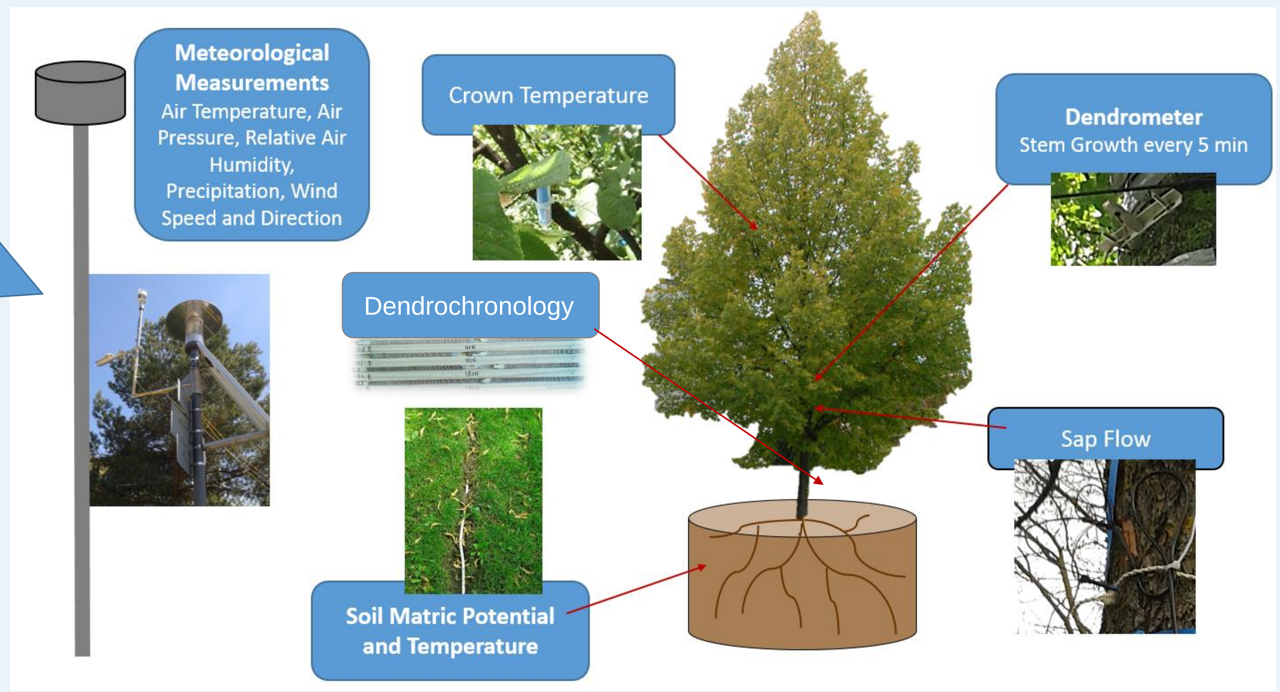

Figure 2: Field measurements with installed sensors on 10 sampled *Tilia cordata* trees at two sites in Munich 2015

Results

Overall: The growth of *T. cordata* at the sites CPS and OGS was significantly different: The trees at OGS grew until mid-August, while the trees at CPS exhibited significantly decreased growth rates. The growth patters were influenced by the meteorological conditions at both sites. Whole tree transpiration, air temperature, soil temperature and vapor pressure deficit (VPD) resulted in reduced growth, only precipitation was positively correlated with growth. Moreover, the tree growth at CPS had the strongest negative relationship with transpiration, which was mainly influenced by the prevalent harsh conditions.

Dendrochronology: Due to the younger age, the growth rate of the trees at OGS was 5.0 mm year^{-1} and markedly higher than that of CPS (2.6 mm year^{-1}). The time series of trees at CPS covered the period of 1926 to 2015 while the time series of trees at OGS ranged from 1987 to 2015. In general, the trees at both sites displayed similar growth patterns with low growth episodes e.g., in 2005 and high growth episodes e.g., in 2007.

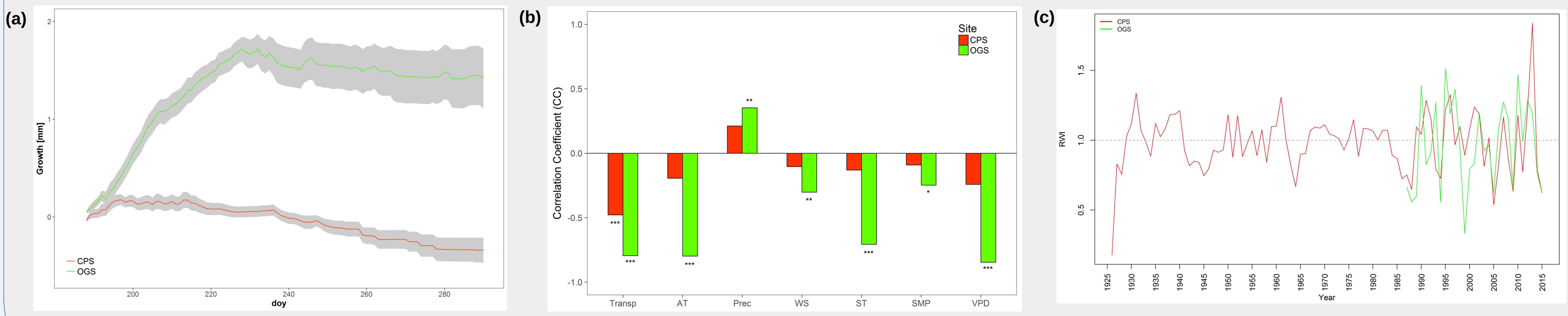

Figure 3: (a) Daily growth of the *T. cordata* trees at OGS (green) and CPS (red) during summer, 2015 (July, 1st to October, 21st, 2015); (b) Correlations between minimum daily growth and transpiration (trans), air temperature (AT), precipitation (Prec), wind speed (WS), soil temperature (ST), soil matric potential (SMP) and vapor pressure deficit (VPD) at OGS (green bars) and CPS (red bars) with asterisks indicating a significant correlation (**at the α < 0.01, ***at an α-level < 0.001); (c) ring width index (RWI) of *T. cordata* at OGS (green) and CPS (red) after double detrending

Discussion

The results illustrated that the growth patterns of *T. cordata* were highly influenced by the surrounding environment: Growth during the drought year 2015 at the highly compacted, paved site CPS was significantly lower than the growth at the more open, greener OGS. This confirmed our hypothesis of reduced growth due to extreme site conditions associated with paving. The observed shrinkage in diameter of the trees at CPS was probably caused by high transpiration rates exceeding the available water. This imbalance can lead to diameter and growth decline as a result of hydraulic conductance loss, reduced photosynthesis, restricted rooting volume and harsh climate. The observed patterns can also be explained with the anisohydric water stress behavior of *T. cordata*, sustaining a high stomatal conductance though at the risk of high water loss. Therefore growth may be reduced as a consequence in the years following drought events.

Conclusions

- Urban tree growth strongly depends on the prevalent site conditions (e. g. soil, size of planting pits, meteorological variables like precipitation and temperature)
- Differences in growth conditions and a severe drought year caused a decrease in the growth of the measured *T. cordata* trees at both sites
- Trees at CPS suffered markedly more to the degree of girth shrinkage, induced by a negative water balance due to insufficient water supply, followed by high water loss rates through transpiration
- Due to the anisohydric water stress response, *T. cordata* can provide high rates of cooling even during drought years, though, although at the expense of growth decline afterwards

Find here the publication „Inter- and intraannual growth patterns of urban small-leaved lime (*Tilia cordata* mill.) at two public squares with contrasting microclimatic conditions" (2016), IJB:

About the Author:
A. Moser is a biologist employed at the chair for forest growth and yield science, TUM, working on growth patterns and ecosystem services of urban trees under current and future climate.

Sources:
[1]DWD, 2016: Deutscher Wetterdienst, www.dwd.de
[2]Pongracz R, Bartholy J, Dezsoe Z, 2010: Application of remotely sensed thermal information to urban climatology of central European cities. Phys Chem Earth 35:95–99

Acknowledgement:
The authors thank the Bavarian State Ministry of the Environment and Consumer Protection (project TUF01UF-64971), the Alexander von Humboldt Fellowship at the TUM, Germany, the department for the municipal green areas of Munich, Chao Xu, Jens Dahlhausen, Teresa Zölch, Alexander Hellwig, Martin Honold, Claudia Chreptun, and Ekaterina Syvcheva and Peter Biber.