Leaf-turning tree species and their local climatic impacts on the the city

Timo Wundsam[1], Sascha M. Henninger[1],

[1] *University of Kaiserslautern, Pfaffenbergstrasse 95, 67663 Kaiserslautern,Germany,*
Timo.Wundsam@ru.uni-kl.de; Sascha.Henninger@ru.uni-kl.de

1. Introduction

Currently, the urban heat island effect as well as the missing cooling effect within urban areas is a decisive topic in urban planning discussions, because they affect also human beings and their surroundings [Matzarakis 2008]. Therefore, these effects will be counteracted by targeted use of certain tree species. Based on the huge number of investigations, the following properties of trees can be assumed, which will be useful to reply on urban heat island effects:

- flattening of climate extremes,
- decrease of local effects of urban heat islands,
- improvement of air and water quality,
- lowering of surface temperature,
- enhancement of life quality,
- creation of possibilities for recovering and recreation [Brack 2002].

Therefore it is a main concern for urban planners to intervene these matters to achieve a better urban climate within the cities [Reiss-Schmidt 1987]. One possibility to obtain a cooling effect will be by planting trees and to extend the greening. In order to attain a high subsequent goal by planting trees, species are required, which need to be extremely resistant towards urban heat stress and even resistant to environmental influences for defending themselves. One more significant attribute, that this kind of tree species should be able to support, is a special cooling effect to their nearby vicinity, which can accomplish an impact on the urban hyperthermia as well as to the population. The following research project investigates certain tree species, being able to turn their leaves, especially the ones with dark green leaves on the top and a silver-light side on the bottom. The leaves of these trees are expected to turn their silver-white side up towards the sun at a certain temperature. This rotation should implicate a cooling effect directly under the trees and in their surroundings, which is the aim of this investigation. Furthermore, trees of different ages need to be considered to be able to compare the different species among themselves.

2. Methodology

2.1 Reasearch objects

Objectives of the research are primarily silver-linden trees (*Tilia tomentosa*) of different ages. Therefore, the age of the trees must be categorized. The categorization refers to the size of the tree top as well as to the circumference of the tree´s trunk. The older the trees are, the bigger the tree tops grow and they even sprawl (s. fig. 1). For this reason, three categories of age for silver-lindens were defined:

- 0 - 10 years
- 10 - 25 year and
- 25 years and older.

Fig. 1: Trees of different ages (0 – 10 years; 10 – 25 years, 25 years and older)

This categorization does not represent a final process, it is rather a preselection for further measurements. At least, this kind of categorization is required to comprehend, if trees of different age groups all act the same way. Actually, it is assumed that the crown of trees in younger periods acts more active, than older ones do. So, a comparison of the trees can be performed.

Additionally to silver-linden trees, other species with similar properties will be examined to see, if they are also able to effect the surroundings positively by turning their leaves. But for being able to proceed a comparison between leaf turning species and standard trees, these will also be examined.

2.2 Measurement setup

The context of the project requires a thermal imager for in-situ measurements. For this reason it will be possible to detect stress points of leaves, where they are located and which temperature needs to be achieved until they will react on air and surface temperature and turn their silver side up. While using a thermal imager, the movement and development can be ascertained in detail. For detecting several heat stress points along the complete tree top, the measurement proceeds from several positions, which are used in every transition process. Here, each transition is repeated in five minute steps, which represents a useful description of the temperature process within a day.

Furthermore, meteorological stations are used for measuring the air temperature, the relative humidity, wind speed, long- and short-wave radiation. Currently, two stations are used to capture the situation. One is placed underneath the treetop, close to the trunk while the other one is nearby the tree for measuring the impact on the surrounding area of these species (s. fig. 2). Additionally, several pictures of the tree top will be taken from different positions, to comprehend how the leaves and the crown develop and react while turning the silver side of the leaves up towards the sun in heat periods.

Fig. 2: Measurement setup around a silver-linden tree

In prospective, a new type of thermal imager will be deployed, that approaches both a high resolution picture (thermal and real-time) and provides the possibility to record thermal images and videos at the same time. With this option, the research will achieve a higher level, because the progress of turning leaves will be better comprehensible and a certain temperature might be figured out of the turning action. In order to reach an obvious result, trees of different sizes and ages need to be estimated. At least, for securing the results of the weather stations and for being able to compare them, an additional USB data logger for temperature and relative humidity is attached close to each tree at the top of the trunk, where the growth of crown leaves starts (s. fig. 2, right side). This data is supposed to confirm the data of the weather stations.

2.3 Test sequence

As a first step for the data ascertainment, both weather stations need to get adjusted, justified and set up correctly underneath or close to the tree, so that they can acquire the mentioned data in five-second-steps for having continuous recordings of the processing values. Later on, these values will be linked with photos and thermal images, to evaluate every single detail concerning about the leaves turning and a possible cooling effect, that is proceeding by the tree.

As already described in chapter 2.2, the thermal imager is be used to detect the development of the crown leaves. In the beginning, it was only possible to detect single thermal images. Every five minutes thermal images were taken from the same position in transaction. According to increase the measurement equipment a thermal imager will be used to record videos of thermal developments in further measuring sequences. While using a tripod to keep the position, all recordings will achieve a better possibility for comparing the data and results among themselves. For this reason it will be expected, that the stress points and the temperature will be detected more precisely than with current measuring procedures in this project.

Additionally, photos of the trees through the daily sun routine are supposed to document the development and the process of the leaves' rotation.

2.4 Evaluation

The current results of the measurements are not yet convincing enough to make a clear statement about the effects of the silver-linden trees. But the first results indicate that there is a certain temperature level, in which the leaves use to turn their silver side up to protect themselves from the heat and other urban stress indicators. At least, for being able to determine the exact temperature range, in which the protection mode of the crown leaves occurs, lots of significant measurements need to be accomplished. Using this knowledge including some further values, e.g. the temperature underneath the trees, more researches and comparisons can be started. Currently, comparisons with trees are missing, that offer comparable premises about the impact on their surroundings.

One example for a similar kind of tree with analogical properties is the silver-poplar (*Popolus alba*), which has a dark green leaf and also a white backside. One of the differences, in comparison to the silver-linden trees, is an extremely flexible leafstalk, so the leaves use to move easily with the wind. Furthermore, other trees with big leaves and a wide crown, e.g. chestnut trees like the *Quercus robur*, also need to be compared to have a wide array of trees, that are able to cool down their surrounding areas. In case that they will be planted in higher stock or in case that they should be planted in suburban areas, they will be used to create cooling effects, which will be combinable with wind effects that stream into urban areas.

As soon as the measurements will be completed, it is intended to perform computer simulations for certain areas, which will be based on the results of the effect about the mentioned trees. These simulations are supposed to support urban planning proceedings. It will be able to show the development of urban areas whether with or without planting the trees within urban heat islands or in suburban areas using the land breeze, which transports cool winds into the city. In this way, it will be possible to simulate in advance how trees could affect their surroundings. For these kind of simulation urban areas need to be figured out which demonstrate an extreme urban heat island potential, so that comparisons can clearly point out the difference between the different status.

2.5 Measurement report

Currently, a structured report is produced individually of each measurement. The structure of the logs includes a photo of the tree as well as a thermal image at the same time with nearly the same angle and adjustment in order to figure out extreme heat areas in the crown and at least to be able to locate these areas more precisely. Therefore, several measuring points are set within the thermal image, to check the temperature of the selected points, which are conspicuous on the image (s. fig. 3).

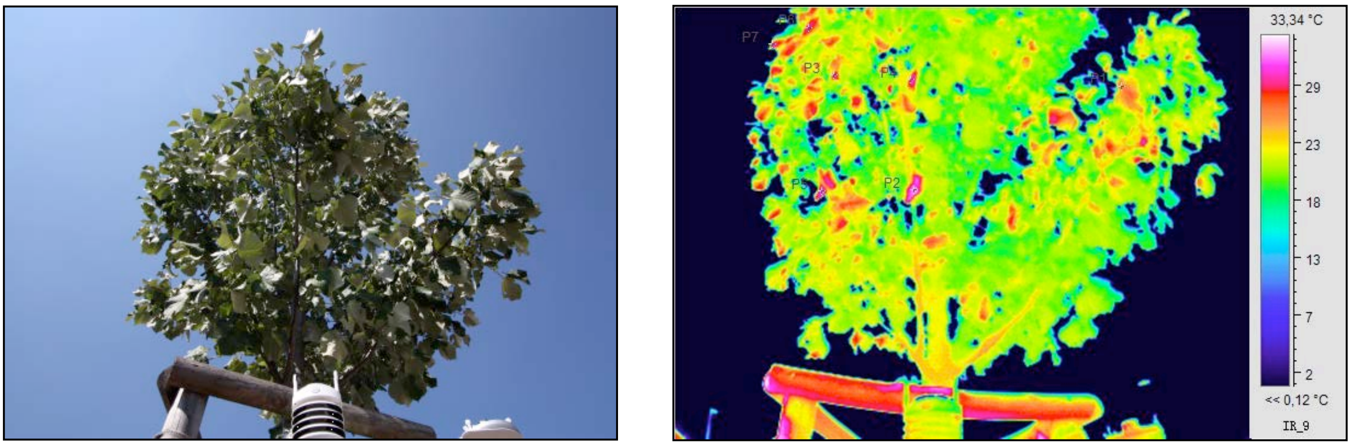

Fig. 3: Excerpt from a measurement report

For being able to compare all thermal images, the colour scheme and also its range are set up similar. Therewith a development of the tree top can be clearly visualized.

Additionally to the results of the thermal imager, the report also includes the results of the weather stations, both as graphs as well as tables containing all the measuring results. The data shows the results of the wind direction, wind speed, air temperature, relative humidity, barometric pressure, quantity of rainfall, and global radiation (s. fig. 4).

Fig. 4: Recorded data and graphs of a measurement of a weather station

At least, the data of the USB logger, which measures the temperature as well as the relative humidity, are included to compare with the ones of the weather stations ensuring the results at the height of about one meter and close to the trunk.

3. Conclusion and recommendation

Generally, the transpiration and shading of trees affect a reduce of the local air temperature [Matzarakis 2008]. But the research of leaf turning tree species offers new ways for the discipline of applied urban climatology and urban planning. Based on the knowledge, that the results of this project seem to promise a high impact on local climatology while planting these kind of tree species can be expected. According to the fact, that the research is not finished yet, many open questions need to be elaborated to secure a scientific result of the first measurements. As a consequence of the research it would be useful to use this knowledge in different levels of urban planning, such as landscape planning arrangements or urban development concepts. For being able to measure the specific impact of leaf turning trees like silver-lindens, at least concepts with these tree species need to be implemented inside cities with heat islands to prove if the trees can affect their surroundings. This can be done by planting tress in heat stressed spots or alternatively by planting trees in outskirts of cities to achieve a cooling effect while using land breezes to transport cooler temperature into the cities. In this case, it needs to be ensured that appropriate wind movements carry on the cooling effect to the urban area.

Finally it becomes necessary, to sensitize the responsible positions for urban planning in city administrations, so they can use the perceptions of the research and implement them into their plannings. However, it must also be paid attention to the resilience of the trees, concerning about other surrounding stress factors, e.g. less humidity, dust, dirt and other impacts.

References

Brack, C. L. 2002: Pollution, mitigation and carbon sequestration by an urban forest. *Environmental pollution*, **116**, 195-200

Ellenberg, H. 2010: Vegetation Mitteleuropas mit den Alpen, **6. Auflage**, Eugen Ulmer KG, Stuttgart.

Matzarakis, A. 2008: Klimawandel und Städte – Stadtklimatischer Einfluss von Bäumen. *Osnabrücker Baumpflegetage – Aktiv für Bäume*, **III**, 1-23

Reiss-Schmidt 1987: Klima und Lufthygiene in der Regional-, Stadtentwicklungs- und Rahmenplanung. In: Klima und Lufthygiene als Planungsfaktoren, 41-71