I. General information

Project title: In-depth measurements of thermal effects linked to trees and green surfaces in street canyons
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II. Summary of the proposed research project/program

Project description

The urban comfort lab (UCLab) is an ongoing research project to investigate the impact of urban and architectural design on climate resilience, air pollution, and noise attenuation. The project aims to develop new design strategies for areas prone to environmental and thermal-climatic challenges. Trees and vegetation are seen as a key solution for all three topics, as trees and vegetation can reduce heat stress, improve local air quality and absorb/scatter sound in streets. In the UCLab, the influence of trees and vegetation of ground and wall surfaces is tested in a semi-controlled outdoor environment in Hoofddorp. A network of sensors continuously monitors the local temperature, sound levels and air quality levels in three full scale mock-up streets, making it possible to study seasonal trends and interaction effects. Urban trees and vegetation have been studied extensively using numerical simulation and real measurements. However, many computational models have oversimplified the cooling and purifying mechanisms, while the existing measurement studies are location-specific, challenging the validity and extrapolation of research findings to other (and different) urban contexts. Further validation of simulation models is essential, based on measurements in controlled or semi-controlled laboratory experiments.

Currently, the UCLab owns three courtyards constructed by shipping containers with similar building configurations (height to width ratio, materials, orientation). The three courtyards provide a unique setting to benchmark the environmental performance with and without tree in cooling performance and noise attenuation in real semi-enclosed built environments. The same applies for vertical and horizontal vegetation which will be placed in two of the tree courtyards. The meteorological and acoustic investigations of ‘vegetation’-free scenarios have been carried out since early 2022.

Starting in 2023, UCLab will collaborate with some of the TU Delft flagship projects such as I-tree 2.0 NL, which features the tree arboretum in front of the architecture department. Using the same monitoring techniques, the in-situ measurements of the same tree species in the UCLab courtyards can be compared and benchmarked with the I-trees located in various urban green spaces in Rotterdam. The comparative data can be used to draw broader conclusions about the cooling efficiency of tree and green wall/lawn configurations and to validate the computational models. The combined assessment of trees’ thermal-climatic and acoustic functions will enable a multilevel analysis of different bioclimatic designs in courtyards and urban environments. The ambitions of the project align with the ambitions of TU Delft’s Climate Action Programme in respect to developing and testing climate adaptation strategies.

Objectives

- To investigate the microclimatic effects of trees, living walls and green ground surfaces in a semi-controlled outdoor (courtyard) environment, e.g. by controlling water-content and evaporation in soil and substrates
- To identify the cooling properties of trees and living walls in depth, by mapping heat transmission and air flow between layers, by placing sensors between different parts inside the systems
- To test and improve the accuracy and reliability of parametric microclimate models to inform early-stage designs of sustainable buildings and neighbourhoods

Methodology

- At canopy level, we propose monitoring the growth and foliation of trees, lawns and living walls, as well as the seasonal-diurnal thermal variability in three courtyards. (Davis and Kestrel weather stations, Kip & Zonen CNR4 radiometers, Ricoh T4 spherical cameras)
- At leaf level, we utilise miniature temperature and humidity sensors to observe the biocycles and thermal cycles of canopy and soil environments (iButton DS1922/3, xx)

- At facade level, we incorporate thermal imaging to measure the heat exchanges between the vegetated ground, roof and wall surfaces (FLIR A70/700 thermal cameras)
- Inside the facades we intend to place iButtons (DS1921K-temp) to measure moisture content and heat exchange between the layers inside the systems.

Hypotheses
It is expected that trees will induce a cooling effect, and that horizontal and vertical greenery will reduce the surrounding wall temperature during heat waves. However, it is expected that the moisture content and air temperature will play a key role in the cooling mechanisms, together with the position of trees inside streets (e.g. linked to shading/day light). Also, we expect that the driving mechanisms to achieve cooling/extraction of fine particulate matter and noise reduction are juxtaposed, linked to the moisture content of the soil and substrates.

Collaboration and organisation
The project is an extension to the ongoing UCLab project, which aims to study the impact of urban and architectural design on (aircraft) noise abatement, heat-stress mitigation, and local air quality. UCLab is funded by a consortium of two Dutch ministries (IenW, BZK) and the city of Haarlemmermeer. This means that the project is closely followed by these organisations, and innovations will be further rolled out in practice. Trees and green surfaces are partially sponsored by companies involved in the project. We are currently seeking additional sources of funding to cover expenses for acquiring and transporting trees, and for maintenance of the trees (e.g. travel expenses from/to the site). To expand the scope of the project, this grant application is written to cover additional costs for equipment, as set out under 'methodology'. The total project budget is 562k for research, which covers the costs of two postdoc researchers, a junior researcher, and noise and weather stations (amongst other expenses), which should be regarded as co-funding for this grant application. For this project we closely collaborate with researchers from CiTG (Marc Ottole, green walls), and ABE (landscape architecture (Renee van der Velde) and urbanism (Daniela Mailullari), trees/microclimate), and Wageningen U&R (Julie Fry, air quality).

Timeline and proposed planning
- Until March 2023, all trees and sempering green will be positioned in the courtyard
- Until June 2023, 3 months monitoring data will be collected for tree growth
- Until September 2023, human adaptation data will be collected during heat waves
- Until December 2023, observe the defoliation of trees, living walls, and lawned gardens
- January 2024, project is formally finished, and the UCLab will be disassembled

Follow-up & spinout projects
The project could lead to several follow-up projects / grant proposals. First, the project could be seen as a demonstrator project that can be scaled up to several test sides in the wider Amsterdam region, all focusing on the role of greenery in retrofitting strategies for areas grappling with a multiple of environmental challenges (e.g. heat stress, air pollution, noise). We are currently investigating this option with a consortium of public partners (e.g. min. IenW/BZK/province of Noord-Holland). Second, measurements could lead to grant proposals for additional research in the field of green facades and urban microclimate (computational) studies, e.g. focussing on the optimization of the thermal properties of green facades by developing and validating optimization models, or the optimization of (green) facades on achieving both noise absorption, cooling and thermal insulation. This could e.g. result in RVO or NWO proposals.

III. Budget (concise)

Description of costs	Costs
Equipment (sensors and hardware)	17.900,00 EURO
Facilities (transport/return of trees, support for mounting equipment)	4.700,00 EURO
Maintenance (watering plants, irrigation, travel expenses to location)	4.000,00 EURO
Others (returning hired equipment / insurance for equipment)	1.100,00 EURO
Total	27.700,00 EURO

Budget (in detail)

Equipment	6 CNR4 net radiometers (Kipp & Zonen);	5,298 €
	2 FLIR A70 thermal cameras (1-month rent);	2,500 €
	1 FLIR A700 thermal camera (3-month rent);	5,400 €
	1 waterproofed spherical cameras (Ricoh T4);	349 €
	50 iButton DS1921K-temp (Digikey);	1,703 €
	10 iButton DS1923-temp+humidity (Digikey);	1,421 €
	3 iButton analog devices (Digikey);	423 €
	1 ethernet package, 3 cables for the instruments;	500 €
	1 laptop for logging the data	105 €
	Mounting and dismounting 3 thermal cameras	200 €
Facilities	Transport/return 30 trees;	4,500 €
	Mounting and dismounting 3 thermal cameras	200 €
Maintenance	Tree nursery (weekly care, water, nutrients)	1,500 €
	50 round trips to Hoopddorp (trains, bikes)	500 €
	Water tanks and weekly water replenishing of tanks	2,000 €
Others	Return the hired equipment;	100 €
	Insurance for the hired equipment;	1,000 €
Total		27,699 €