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Climate Regulation Provided by Urban Greening
Examples from a High Latitude City

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ABSTRACT

Cities exert a strong influence on urban climate, and consequently on human health and wellbeing. This increases the importance of considering climate issues in urban planning, particularly in the context of global climate change. One of the key adaptation strategies in climate-sensitive planning is urban greenery. The purpose of this thesis is to increase understanding of how urban greenery influences the air temperature and outdoor thermal comfort in a high latitude city. The thesis consists of three main parts. In the first part the aim is to describe the urban greenery at various scales in terms of the amount of foliage. In the second part different aspects of the cooling effect of urban vegetation and the resulting intra-urban thermal variations are discussed. Finally, the last part deals with the modelling of mean radiant temperature (T_{mrt}), an important parameter governing human thermal comfort, in vegetated urban areas.

The thesis is based on extensive meteorological and plant physiological measurements conducted in Gothenburg, Sweden. Study sites ranged from single street trees to parks and woodlands. Moreover, a LiDAR dataset and high resolution digital surface models (DSMs) of ground, buildings and vegetation were used to analyse spatial characteristics of the study sites, including effective leaf area index (L_e) describing tree foliage, and sky view factor (SVF), a measure of obstruction of sky commonly used in urban climate studies.

The results show substantial variations in L_e between different types of urban greenery, with the highest L_e observed in an urban woodland and the lowest in residential green yards. These variations were accurately modelled using LiDAR data. However, when averaged over large areas only partly covered by trees, variations in L_e were found to result mostly from tree fraction rather than structural characteristics of tree canopies.

Single urban trees of five common species were shown to provide a strong shading effect throughout the year, with a potentially positive effect on thermal comfort in summer and negative in winter in high latitude cities. Parameterisation of transmissivity of solar radiation through tree crowns significantly improved the modelling of T_{mrt} in SOLWEIG, a model simulating radiation fluxes in complex urban environments.

While tree transpiration in temperate climates is often assumed negligible in darkness, night-time transpiration was observed in all of seven common tree species, and data analyses indicated its contribution to the evening cooling on clear, calm nights of the warm season.

The cooling effect of trees due to both shading and transpiration was found to be influenced by tree growing conditions and access to sunlight. Trees growing on wide grass lawns had denser crowns and higher stomatal conductance than those surrounded by impervious surfaces. When provided with good growing conditions, sun-exposed trees can strongly influence microclimate by providing additional shade and by intensive transpiration.

Parks exhibited a cooler microclimate than built-up sites throughout the day and year, and in different weather conditions, with the strongest cooling effect on clear, calm days of the warm season. While the evening cooling in a high latitude city is best correlated with SVF, spatial characteristics describing buildings and vegetation proved useful in the analysis of intra-urban thermal variations. When high resolution DSMs are not available, near-infrared hemispherical photography can be used to calculate SVFs accounting for the obstruction of sky by buildings and trees separately.

The findings presented in this thesis can be used in climate-sensitive planning, in urban climate modelling as well as in valuation of ecosystem services provided by urban greenery.

Keywords: Gothenburg, Sweden, high latitude city, urban greenery, urban trees, leaf area index, tree transpiration, sky view factor, mean radiant temperature, hemispherical photography, climate-sensitive planning.