Comparing Cooling Effects of Trees and Lawns in Phoenix: Implications to Building Energy Consumption

Xiaoxi Zhao, Zhihua Wang, Jiyun Song and Jiachuan Yang; School of Sustainable Engineering and the Built Environment

Central Arizona-Phoenix Long-Term Ecological Research
CAP LTER

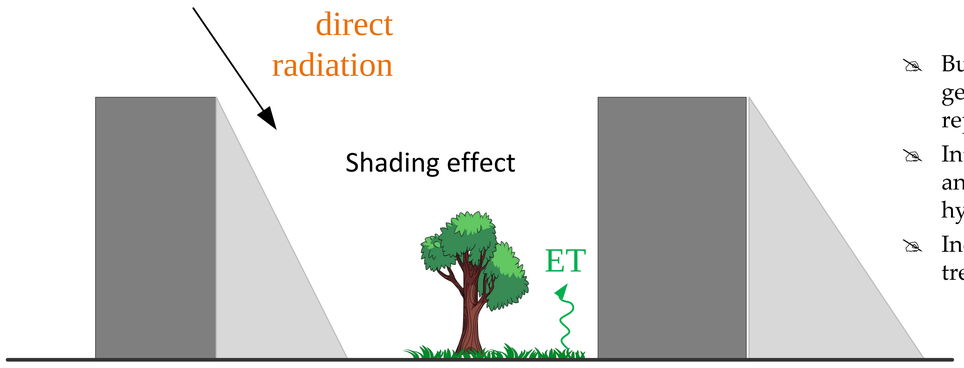
Arizona State University

1. Introduction

In the United States, building energy consumption costs nearly half (47.6%) of the energy produced every year. The large building energy consumption gives rise to environmental problems such as the urban heat island (UHI) effect, air quality degradation, and health problems. Urban vegetation, such as lawns and shade trees, is proved to be an effective means in alleviating the UHI effect, and can potentially reduce building energy consumption in cities.

By adopting an advanced urban canopy model (UCM) developed by Wang et al. (2013), the complex urban configuration is realistically represented. In particular, evaporation and transport of water are adequately resolved. In addition, recent advances enable the shading effect of trees to be effectively incorporated in radiative heat exchange in street canyons, based on Monte Carlo algorithm. Here we investigate the two main cooling mechanisms, viz. the evapotranspiration (ET) by urban lawns, and the shading effect by trees, using Phoenix metropolitan as our study area. Meanwhile, building energy conservation and the following saving expenses are considered. This study also involves an assessment of human thermal comfort presented as "suspend work percentage", which is a part of temperature humidity index (THI).

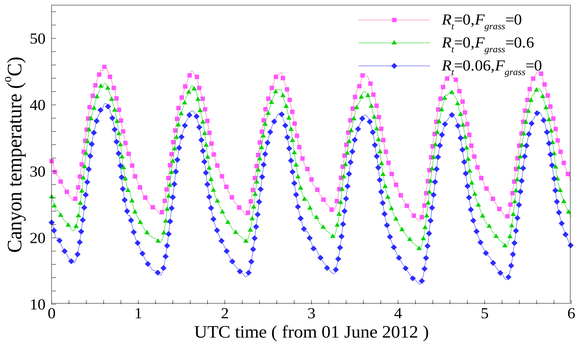
2. Urban Canopy Model

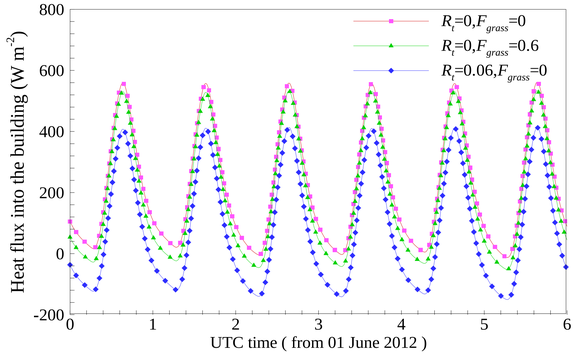


- Buildings and street canyon geometries are realistically represented
- Integrate urban vegetation and the associated hydrological processes
- Incorporate the presence of trees and their shading effect

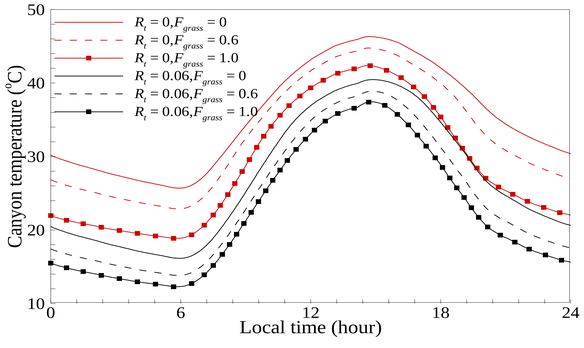
3. Case Study

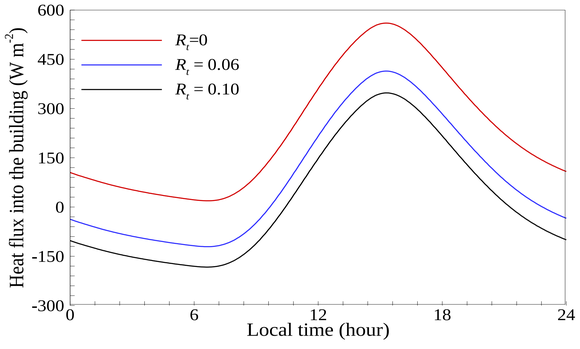
(a) 6-days simulation



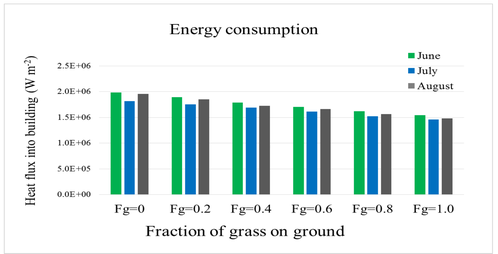


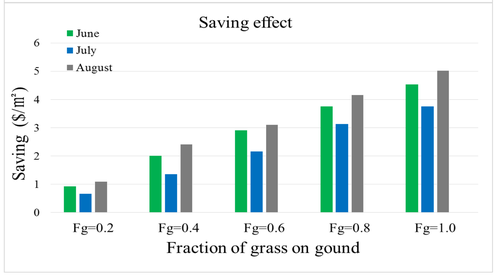
(b) Monthly test



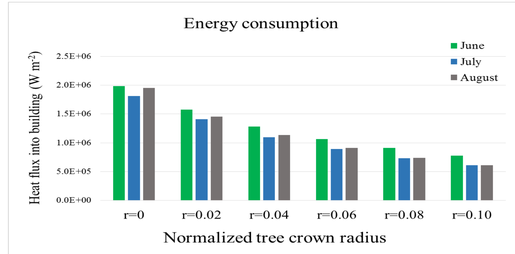


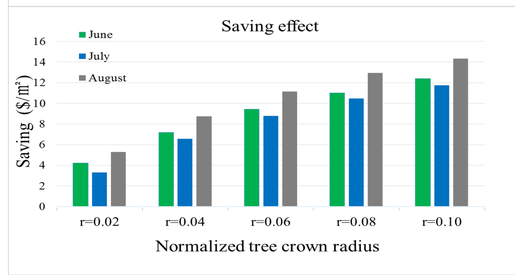
(c) Energy consumption and saving





Lawn cooling effect

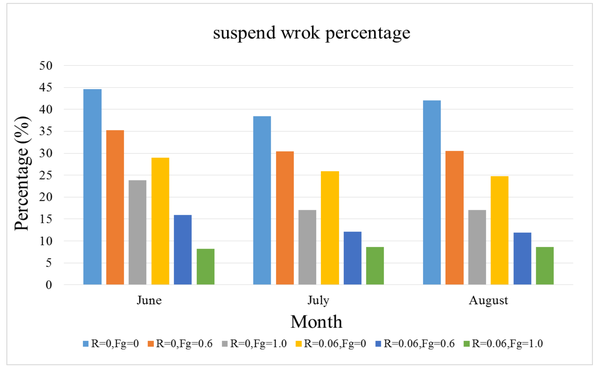


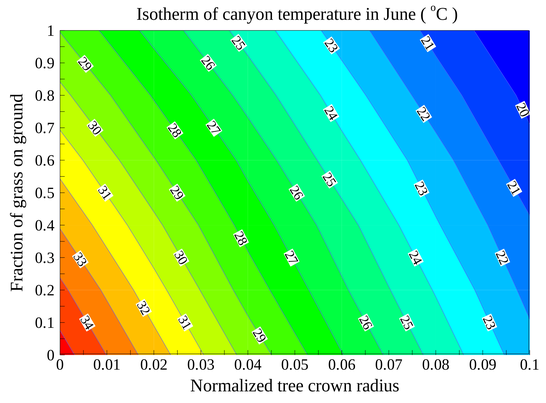


Tree shading effect

4. Summary

- Comparing with green roofs (not shown here), lawns have more profound effect on the nocturnal canyon temperature.
- Vegetation is crucial in urban areas. Apart from the mentioned above consequences, it also decreases human thermal uncomfortable moments, by reducing the "work should be suspended" percentage.
- Results reveal that trees can significantly decrease canyon temperature in summer and promote building energy efficiency due to shading effects. Comparisons also indicate that the shading effect is more prominent than evapotranspiration.





5. Future Work

- How do shade trees influence radiation redistribution at different locations and with different crown shapes?
- Will saving expenses still be cost-efficient by accounting the irrigation water cost and maintenances fees (life cycle cost)?

Acknowledgement

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References:

[1] Wang ZH, Bou-Zeid E and James A. Smith (2013) A coupled energy transport and hydrological model for urban canopied evaluated using a wireless sensor network, *Quarterly Royal Meteorological Society*, 139: 1643-1657.

[2] Wang ZH (2014) Monte Carlo simulations of radiative heat exchange in a street canyon with trees. *Solar Energy*, 110 (2014): 704-713.