Impact of Tree Locations and Arrangements on Outdoor Microclimates and Human Thermal Comfort in an Urban Residential Environment

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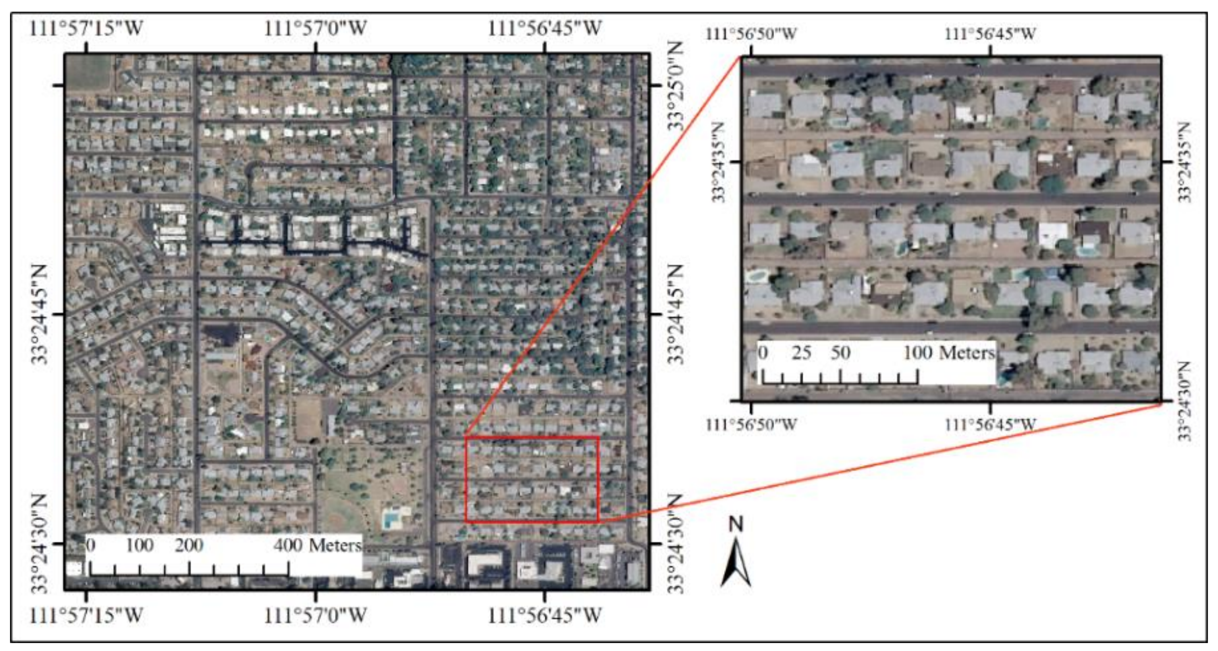
Introduction

Trees serve as a valuable asset in the urban environment. In an arid city like Phoenix, trees are one of the primary urban green infrastructures to ameliorate extreme heat stress. Because of the cost of water and space in the desert residential environment, designing the optimal tree arrangement to maximize overall thermal benefits for residential neighborhoods, is important and necessary. The goal of this research is to compare and evaluate differences in outdoor microclimates and human thermal comfort by simulating different tree layouts (cluster, equal interval, or disperse) in the residential neighborhood.

Research Objectives

- Explore how tree locations and arrangements influence the outdoor microclimates and human thermal comfort by microclimate numerical simulation in the compact residential neighborhood
- Design tree locations and arrangements strategically to benefit both individual houses and residential neighborhood simultaneously

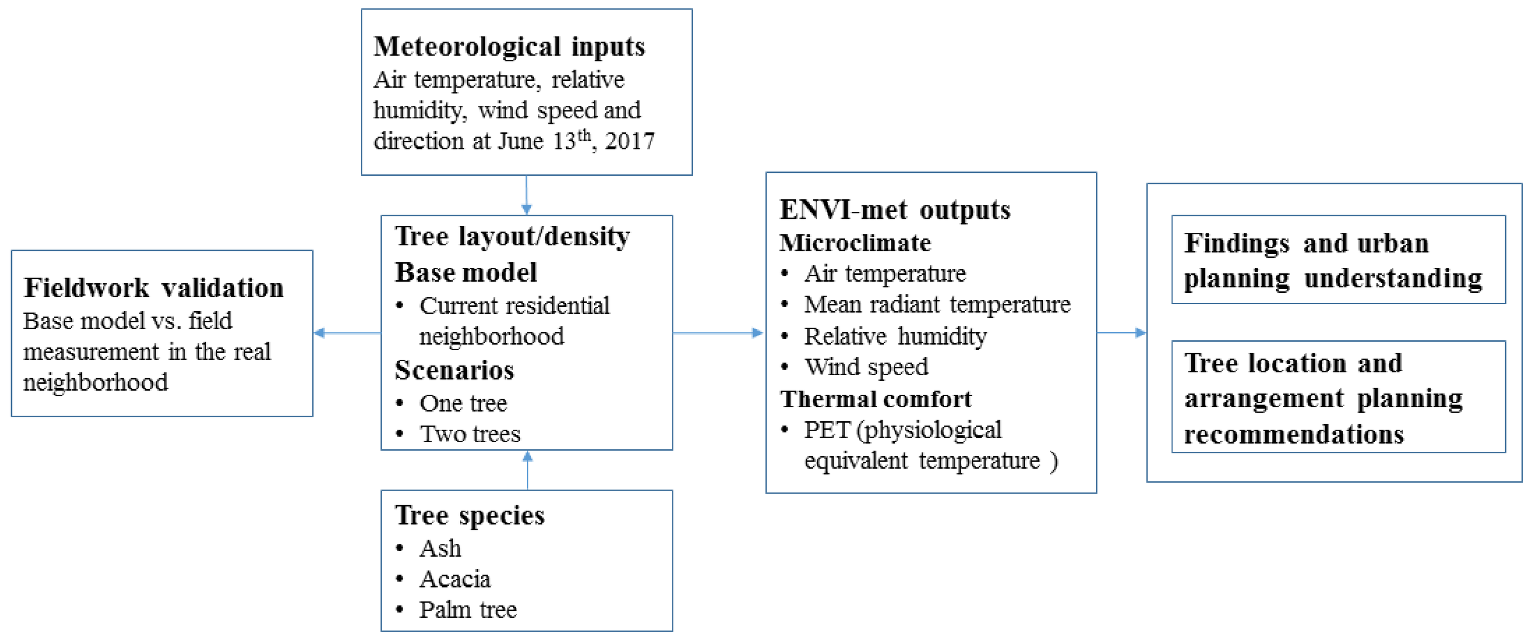
Study Area



(a)

Target neighborhood in Tempe, AZ. (Figure **(a)**)

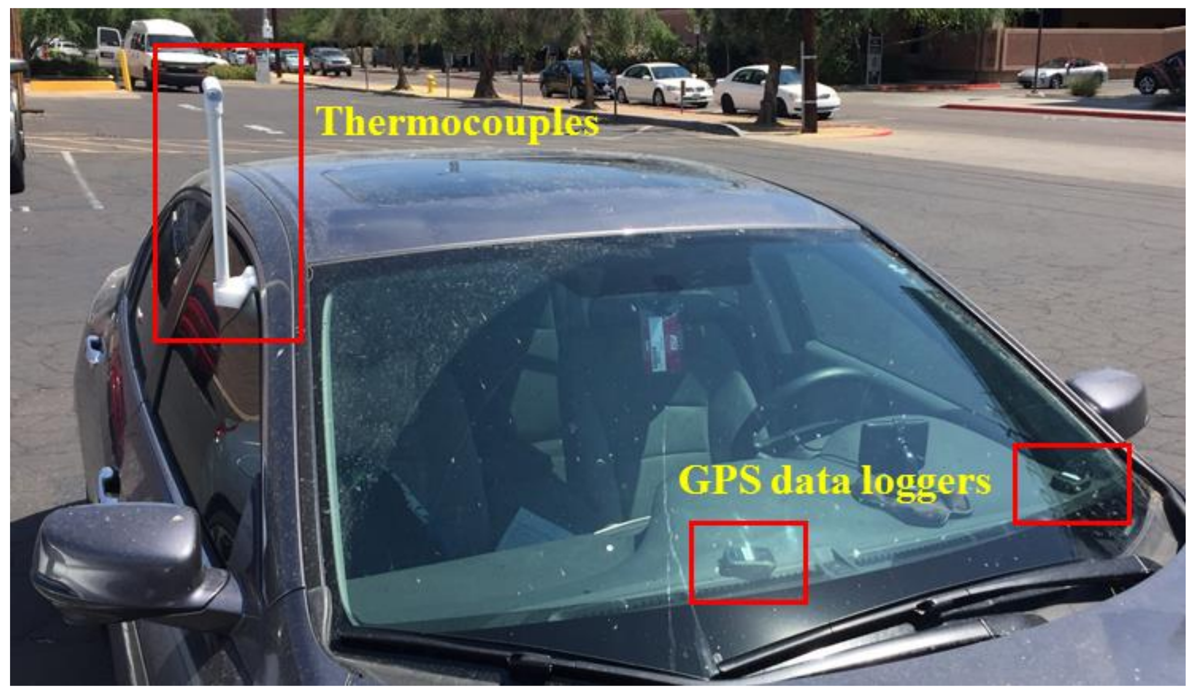
Methodology Framework



(b)

Figure **(b)** demonstrates the methodology framework of this research.

Fieldwork Validation



(c)

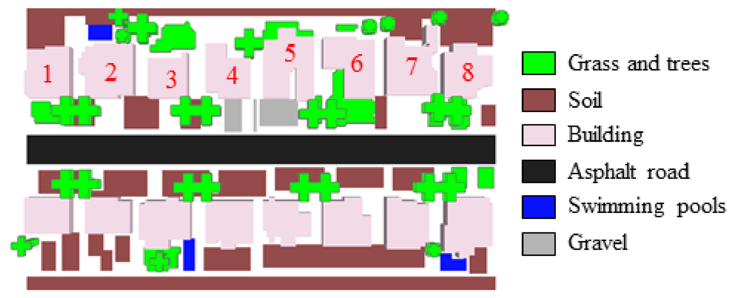
We drove along the transects in a vehicle equipped with GPS data loggers and external shielded air temperature thermocouples (Figure **(c)**). Data were collected in the early morning (7:00) and late afternoon (16:00) on 13 June 2017. We completed each systematic temperature collection transect in 5 minutes with a driving speed of 3 m/s in the target neighborhood. The target neighborhood was measured twice in each transect and two measurement traverses were conducted immediately follow each other. The RMSEs between simulation and validation results were 1.1 °C in the morning and 2.1 °C in the afternoon.

Microclimate Numerical Simulation

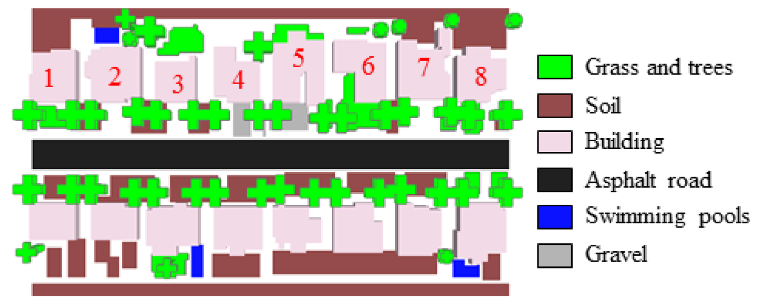
(d)

(e)

Figure **(d)** is the base model in the ENVI-met simulation. The base model simulation results represented the real landscaping and were compared with the fieldwork measurements.



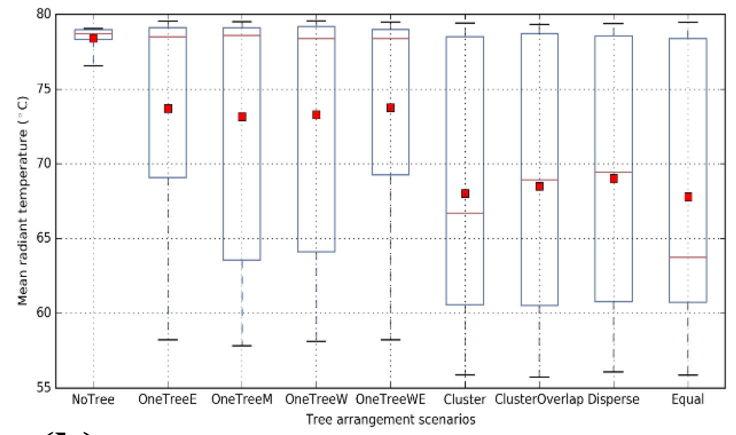
(f)



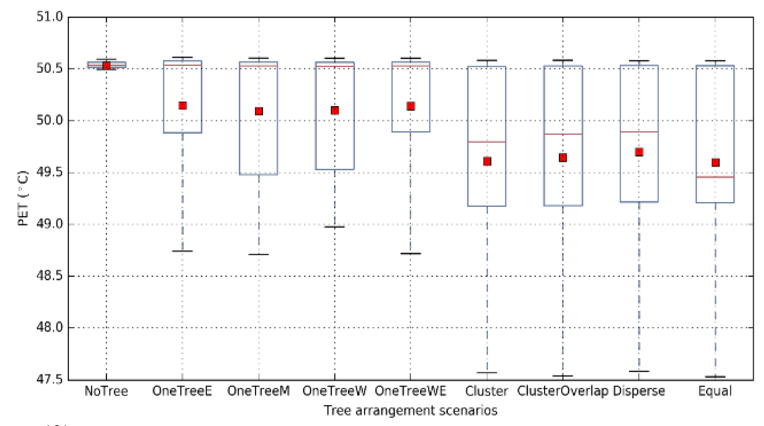
(g)

Figure **(e)**, **(f)**, and **(g)** shows selected tree location and arrangement scenarios Figure **(e)** represented no tree scenario. Figure **(f)** showed one tree arrangement and Figure **(g)** showed two trees disperse arrangement.

Results



(h)



(i)

Figure **(h)** and **(i)** show the mean radiant temperature (MRT) and physiological equivalent temperature (PET) comparison under different tree locations and arrangements. Equal interval and cluster two trees arrangements induced the most benefits for the outdoor microclimates and human thermal comfort.

Conclusions

This research utilizes microclimate numerical simulation to explore how to arrange trees wisely to benefit both individual households and residential neighborhoods. The flexibility of numerical models makes it possible to create, simulate, and compare the outdoor microclimates and human thermal comfort under different tree locations and arrangements. We recommend that urban residents should plant shade trees without canopy overlap. If possible, trees should not block wind tunnels or impede air movement.

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