Cooling Cities with Less Water: Assessing Heat Mitigation Potential of Common Urban Tree Species in an Arid Urban Environment

Paige Rearick,[1] prearick@asu.edu; Dr. Bjoern Hagen[2]; Dr. Ariane Middel[3]; Peter Price[4]

[1]School of Life Sciences, [2]School of Sustainability, [3]School of Arts Media and Engineering, [4]The Design School, Herberger Institute for Design and the Arts

Urban Climate Research Center
Arizona State University

Introduction

Problems:

- Cities are increasingly experiencing the **Urban Heat Island (UHI) effect**.[1]
- **Drought** in the Southwest is intensifying stress on regional water supplies.

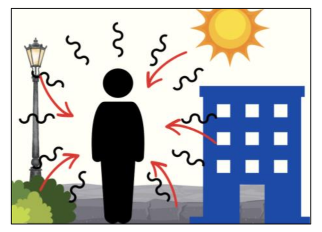
Solution:

- Urban greening (trees) **mitigate** UHI by providing shade and cooling effects.[2]

Gaps:

- Balancing **shade** & cooling benefits with **water conservation**.
- *Does higher water requirement = measurably greater shade & cooling benefits?*

Study Goals:
Evaluate the relative contributions of various tree characteristics to reductions in mean radiant temperature (**MRT***) among commonly planted xeric and mesic tree species in a desert urban environment.



MRT** = Avg temp (in °C) of all the surfaces around a person that emit ***radiation

Methods

Study Area:

- Arizona State University, Tempe campus ***(Fig. 1)***

➢ *87 trees sampled*
➢ *9 species*

Data Collection:

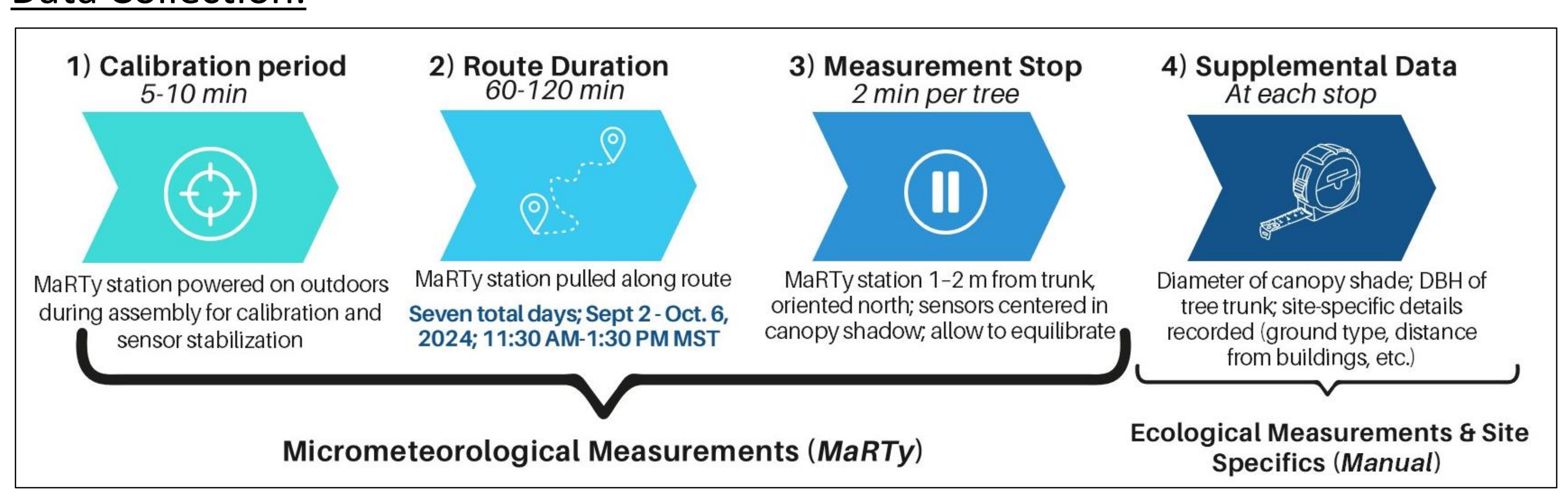


Figure 2. *Graphical Visual of Data Collection Process and Procedures*

- **Water requirement (WR)**** rankings assigned to each species (low, mod, high).
  - *Low = Xeric species;* *Mod or High = Mesic species*

****WR** = Relative amount of irrigation needed to maintain healthy canopy structure (not evapotranspiration rates or minimum survival levels). *Determined through research.*

Data Analysis:

- **MRT Reduction = control (sun exposed) MRT avg - tree shade MRT avg**

–

= MRT Δ

Example: **60°C – 40°C = 20°C MRT Reduction**

Results

Table 1: *Average MRT Reduction (MRT Δ) per Tree Species*

Tree Species (Scientific Name)	WR Level	MRT Δ (°C)
Fraxinus velutina	High	18.3
Ulmus parvifolia	Mod	20.12
Pistacia X 'Red Push'	Mod	17.46
Dalbergia sissoo	Mod	22.77
Quercus virginiana	Mod	21.27
Neltuma Spp.	Low	17.96
Mariosousa willardiana	Low	19.86
Parkinsonia florida/praecox	Low	20.28
Total Avg Reduction		**19.50**

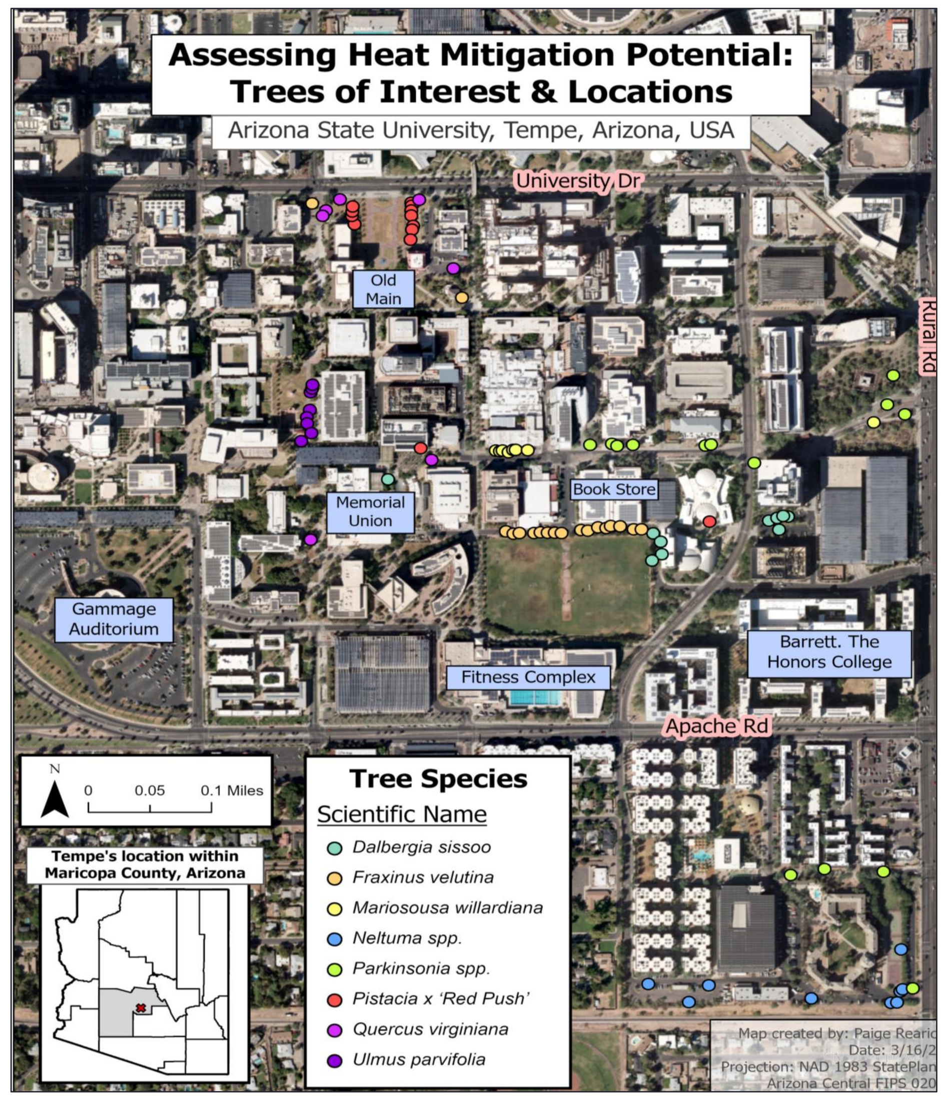


Figure 1. *Map of Tree Species Collected, ASU Tempe Campus*

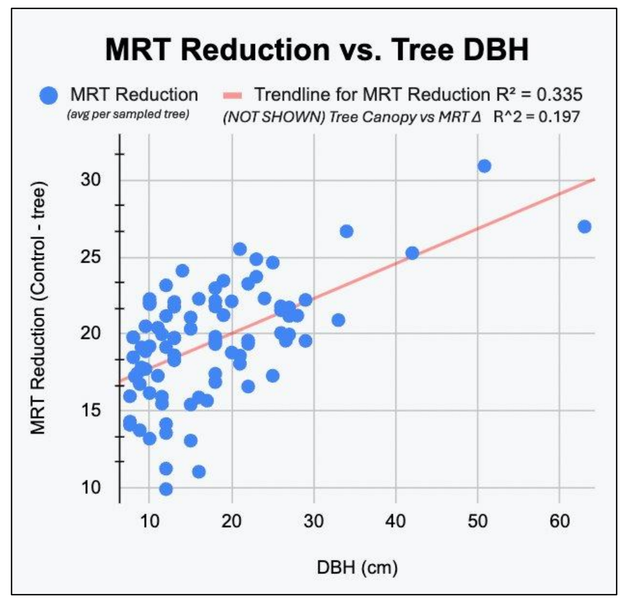


Figure 4: *MRT Δ vs Tree DBH Scatterplot*

***DBH**= Diameter at Breast Height (4.5 ft)

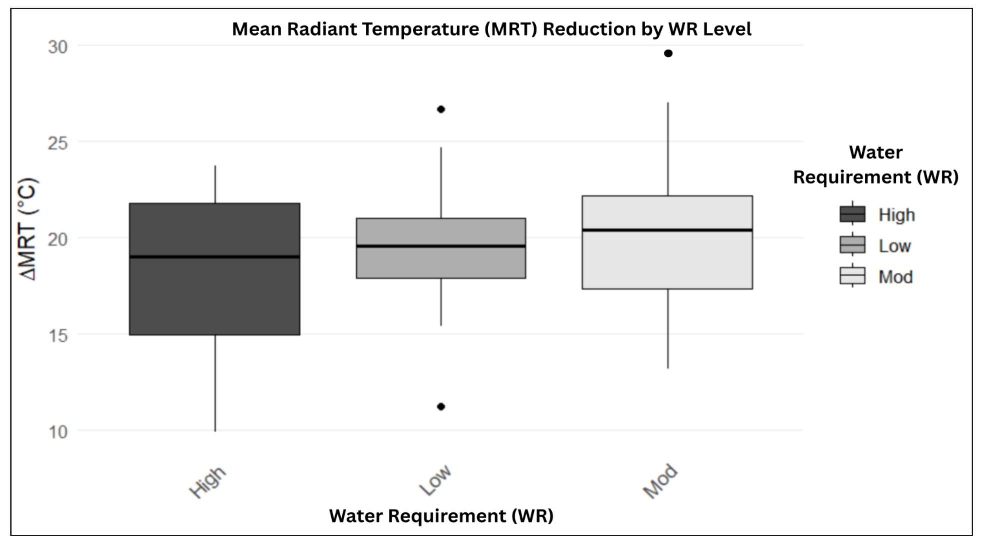


Figure 3. *MRT Δ by Water Requirement Level (low, mod, high)*

ANOVA Statistical Tests

Table 2: *Anova Results Summary – Analysis of Factors Affecting MRT Δ*

Factor	p-value	Effect Size (η²)	Significant (y/n)	Conclusion
Water Use	**0.2340**	0.0340	✗ No	Water requirement does not significantly impact MRT Δ; other factors play a stronger role.
DBH	**0.0000**	**0.2163**	✓ Yes ($p < 0.05$)	Larger trees significantly reduce MRT Δ, confirming DBH as a key predictor of radiative heat mitigation effectiveness.
Canopy Diameter	0.0031	**0.1284**	✓ Yes ($p < 0.05$)	Canopy size contributes to MRT Δ, but its effect is weaker than DBH, suggesting tree structural maturity as more reliable predictor.
Ground Type	0.0003	0.3344	✓ Yes ($p < 0.05$)	Ground type significantly affects cooling; dead grass and vegetation provide better cooling, while asphalt and concrete retain heat.
Tree Species	0.0089	0.2060	✓ Yes ($p < 0.05$)	Tree species significantly influence MRT Reduction, with some species (e.g., *Dalbergia sissoo*, *Quercus virginiana*) performing better than others.
DBH × Canopy	0.9331	0.3348	✗ No	No significant interaction; DBH and canopy size do not jointly enhance cooling effects.

Key Findings

1) Tree DBH* is the *strongest* predictor of MRT reduction:
*Can be used as a proxy for tree maturity

a. ANOVA results ***(Table 2)*** show DBH is more significant than canopy size, playing a stronger role in MRT reduction.
b. ANOVA results deem any interaction between DBH and canopy size as *not* significant.
c. Scatterplot ***(Fig. 4)*** shows R^2 value for DBH as almost double that of canopy size when plotted against MRT reduction values.
d. Two-way ANOVA: DBH *remained* significant (p = 0.0000), while canopy size was *not* (p = 0.738).

2) Water Requirement is *not* strongly linked to MRT reduction:

a. More drought-tolerant (xeric or low WR) tree species can provide comparable cooling benefits to moderate or high WR species (*more mesic*) ***(Fig. 3)***.
b. ANOVA results ***(Table 2)*** for a tree's WR impact on MRT Δ were *insignificant.*

Final Urban Planning Takeaways

❖ **Prioritize more mature trees** (large DBH), moving beyond just canopy size alone and pushing for solely new plantings.
❖ Select species not just for cooling, but also long-term maintenance and **low water requirements**.

By emphasizing **tree maturity** and **drought tolerance**, cities can become more resilient and enhance cooling while promoting sustainable water use in hot, arid environments.

Future Study

- Test MRT reduction under **varied weather** conditions in other climate regions.
- Explore influence that maintenance factors like **pruning practices** have on tree MRT.
- Link tree shade MRT to **human thermal comfort**—considering humidity, wind, and behavioral/ physiological responses, etc.—potentially using ASU's ANDI.

References

1. Mohajerani, A., Bakaric, J., & Jeffrey-Bailey, T. (2017). The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of Asphalt Concrete. *Journal of Environmental Management*, 197, 522–538. https://doi.org/10.1016/j.jenvman.2017.03.095.
2. Armson, D., Rahman, M. A., & Ennos, A. R. (2013). A comparison of the shading effectiveness of five different street tree species in Manchester, UK. *Arboriculture & Urban Forestry*, 39(4), 157–164. https://doi.org/10.48044/jauf.2013.021.