Shift of paradigm in urban irrigation: Finding the optimal scheme for building energy efficiency

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Problem Statement

In the United States, around 40% of the total final energy consumption in the cities is in the building sector. To lesson greenhouse gas emissions and to slow down depletion of non-renewable energy resources, recent years have seen a number of studies and initiatives to cut back the building energy consumption. Building energy consumption in cities is closely related to environmental temperatures, on which irrigation has cooling effects by increasing the supply of surface moisture for evapotranspiration. While the objective for agricultural irrigation is focused on the yield of produces, irrigation of urban vegetation apparently needs **a new paradigm**.

It is therefore imperative to understand the **relationship between water and energy consumption** in the urban environment to develop an **optimal urban irrigation scheme**. In this study we applied a state-of-the-art urban canopy model to identify the environmental impact of urban irrigation in the Phoenix metropolitan area. A variety of uncontrolled and controlled irrigation schemes is investigated, including (1) daily constant scheme, (2) soil-moisture-controlled scheme, and (3) soil-temperature-controlled scheme.

Research Questions

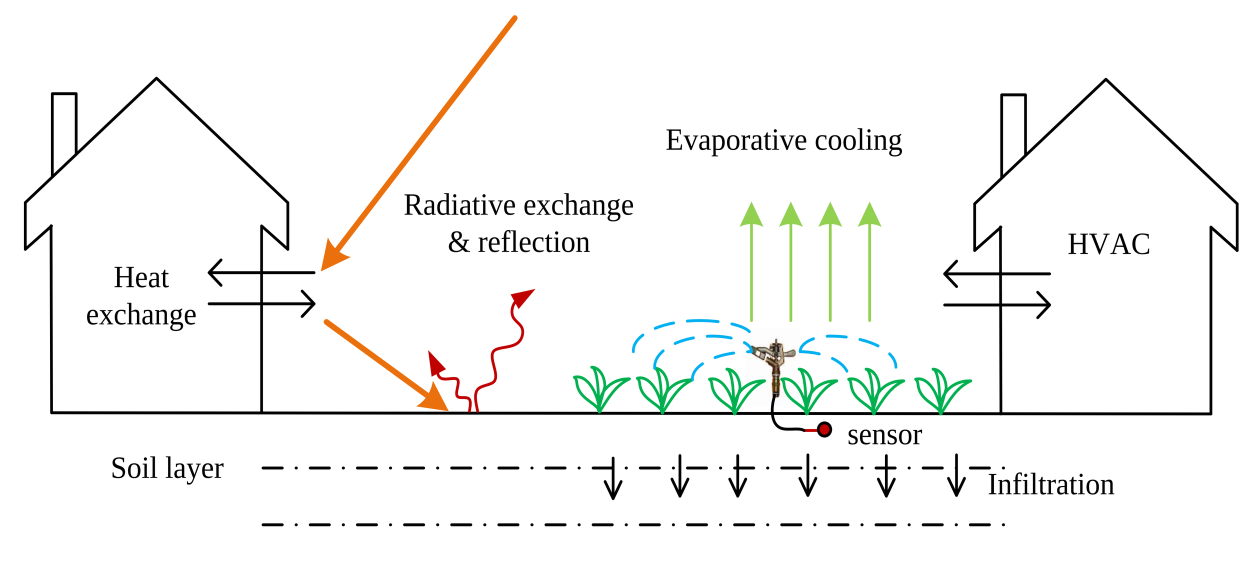
1. What is the effect of various urban irrigation schemes on building energy efficiency for Phoenix?

2. In terms of environmental sustainability, what is the optimal urban irrigation scheme?

Experimental Design

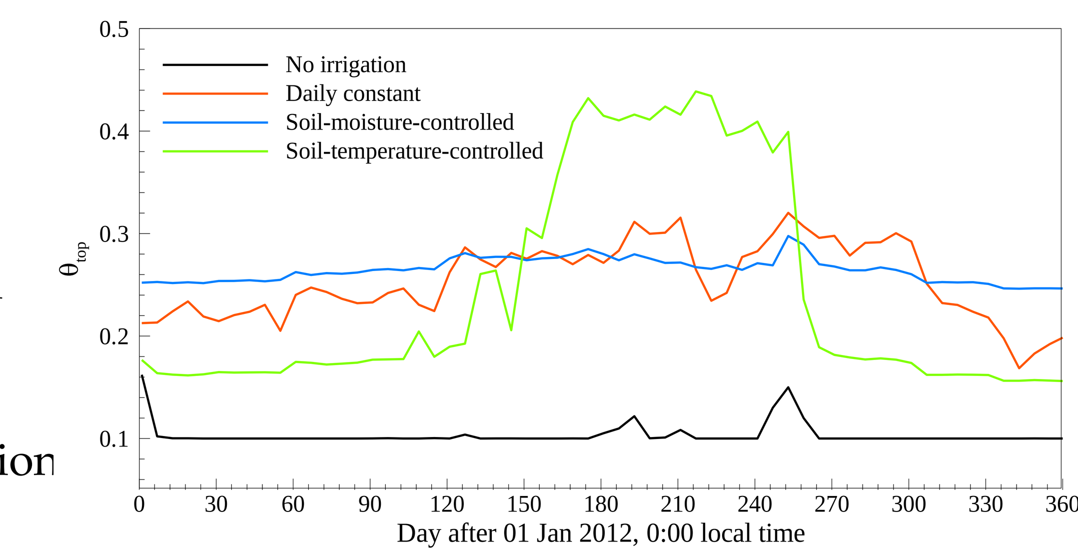
Irrigated urban canopy model:

- Realistic representation of hydrological processes
- Sub-facet heterogeneity (impervious surface, bare soil, vegetation)
- Analytical solutions to heat diffusion equations

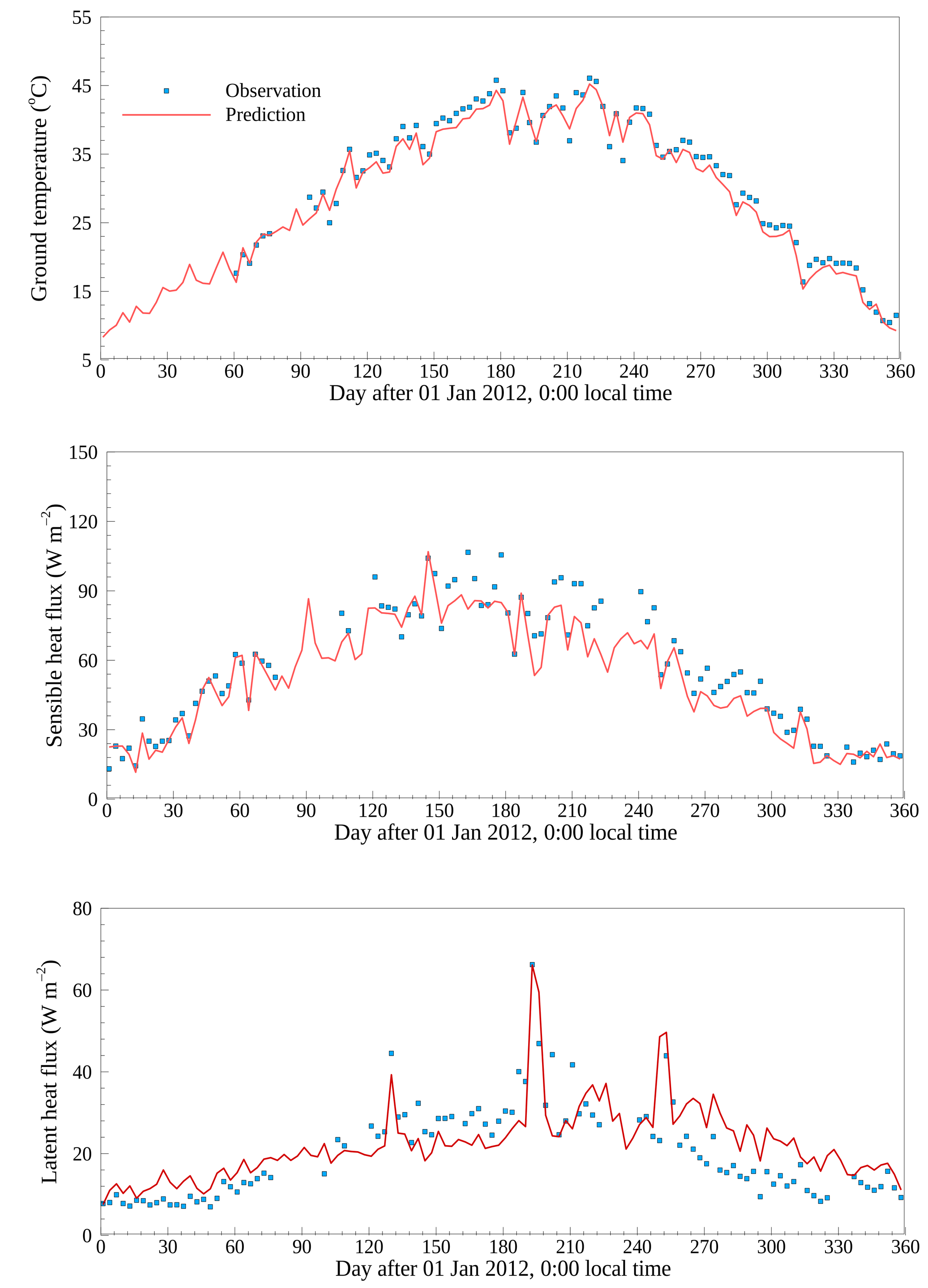


Investigated urban irrigation schemes:

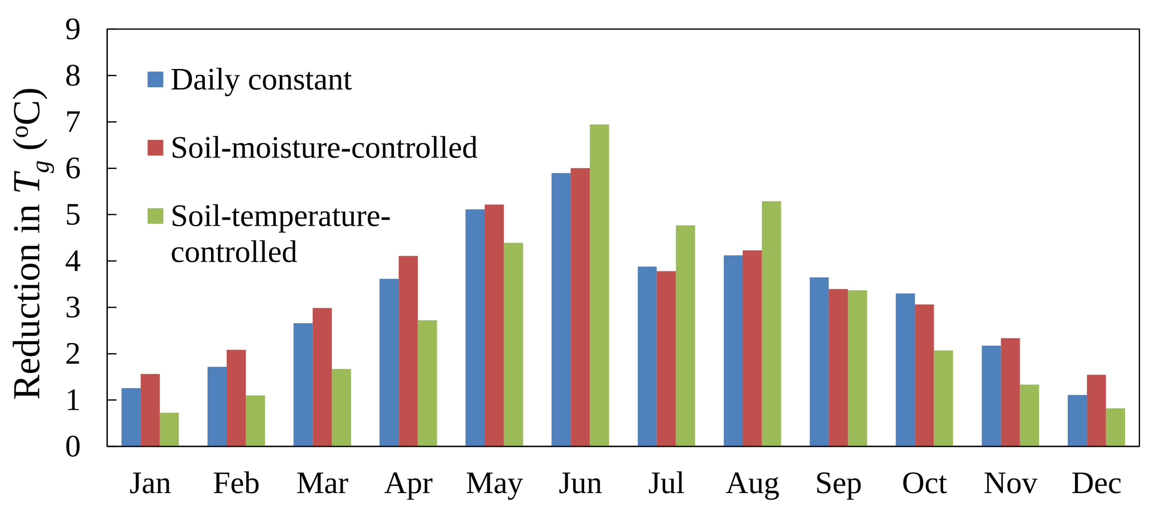
- No irrigation
- Daily constant irrigation (8 pm local time every day)
- Soil-moisture-controlled irrigation (Whenever θ_{top} drops below 0.24)
- Soil-temperature-controlled irrigation (Whenever T_{top} exceeds 38 °C)

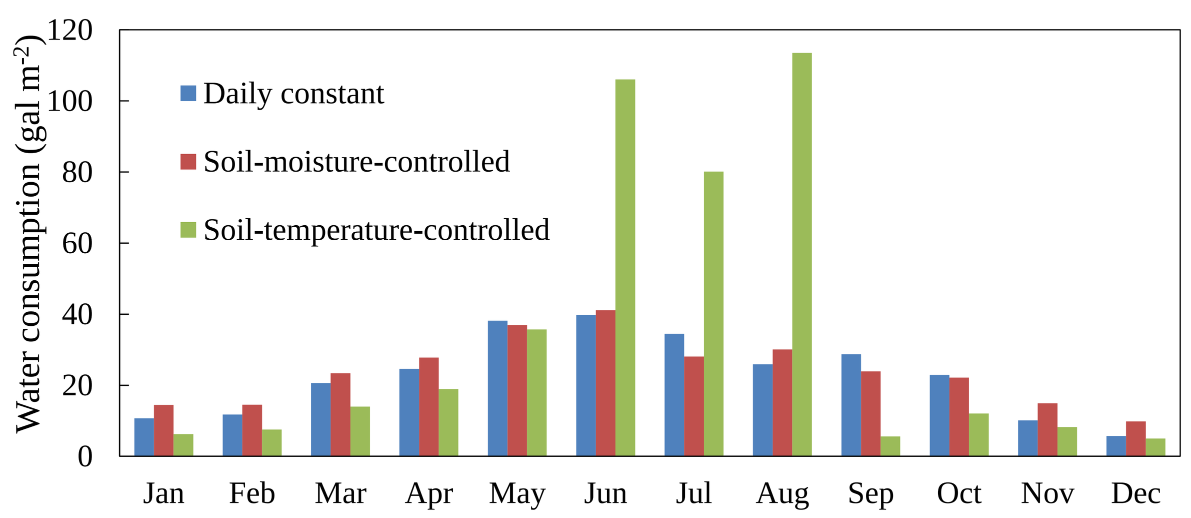


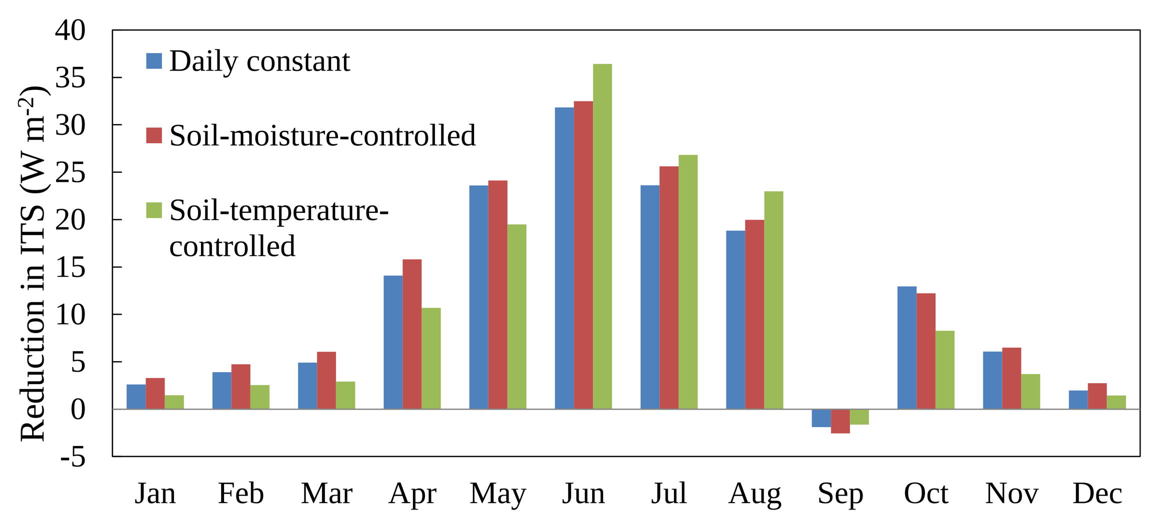
Model Evaluation

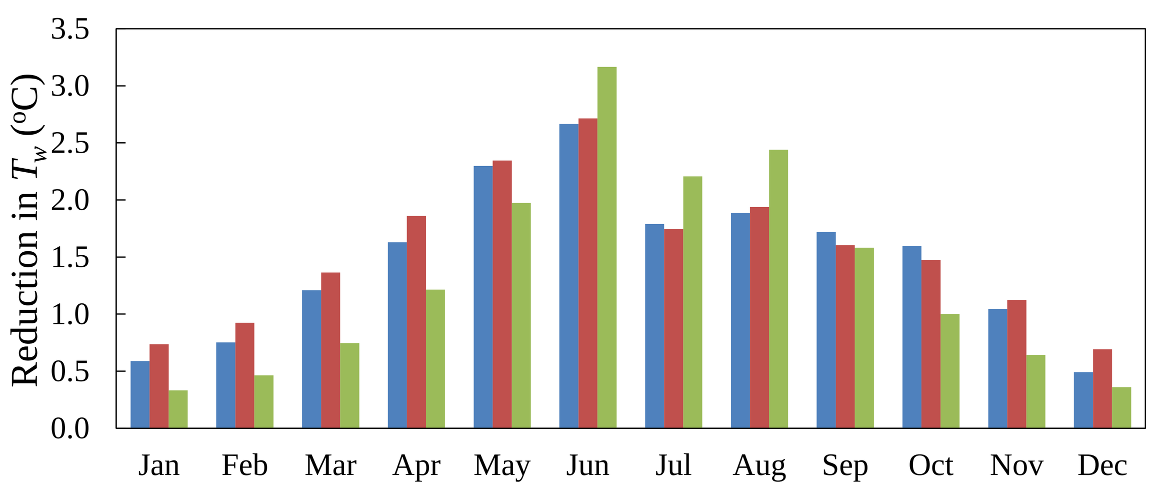


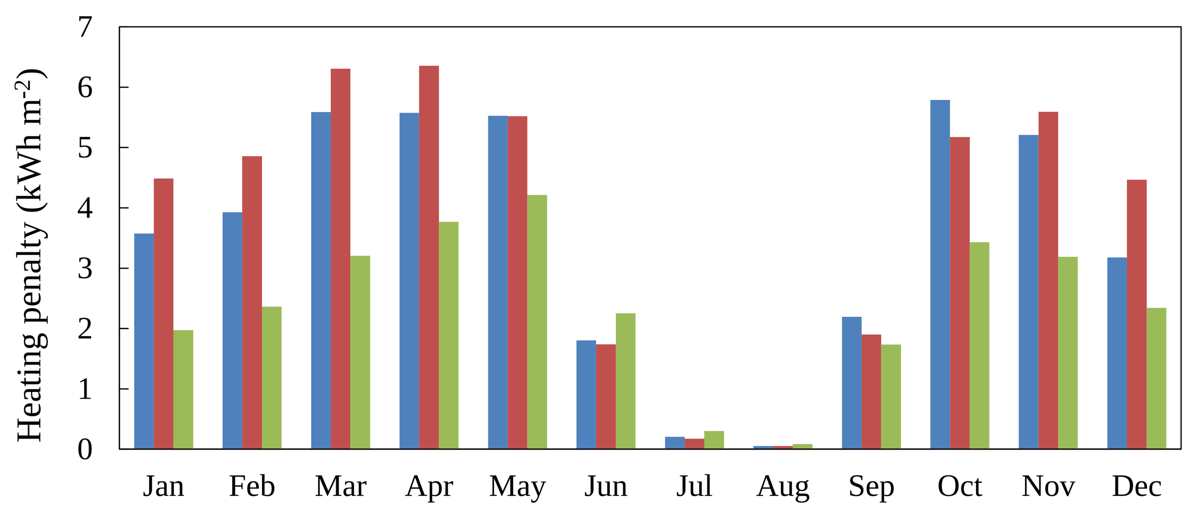
Effect of Various Urban Irrigation Schemes

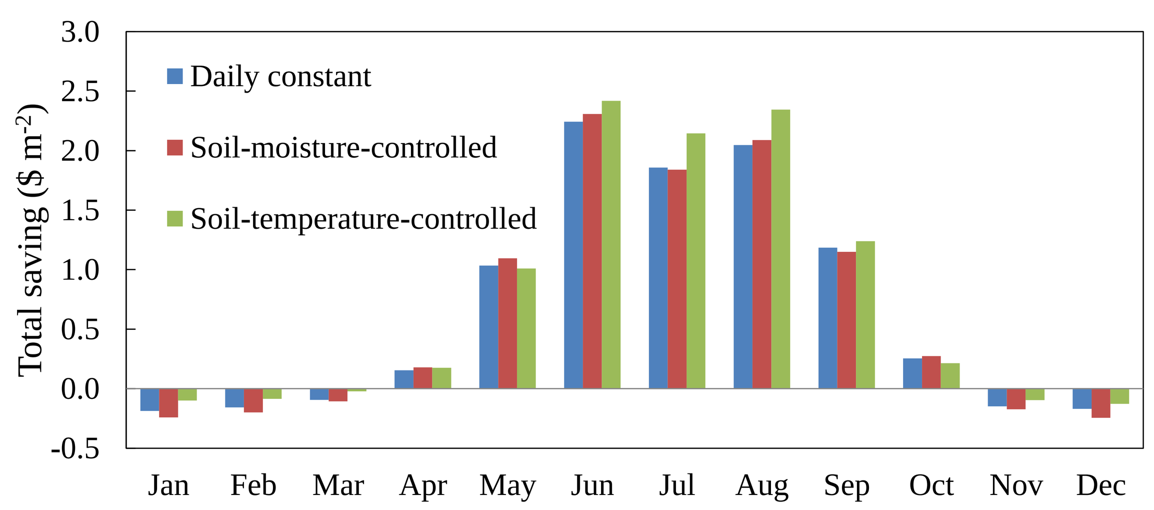


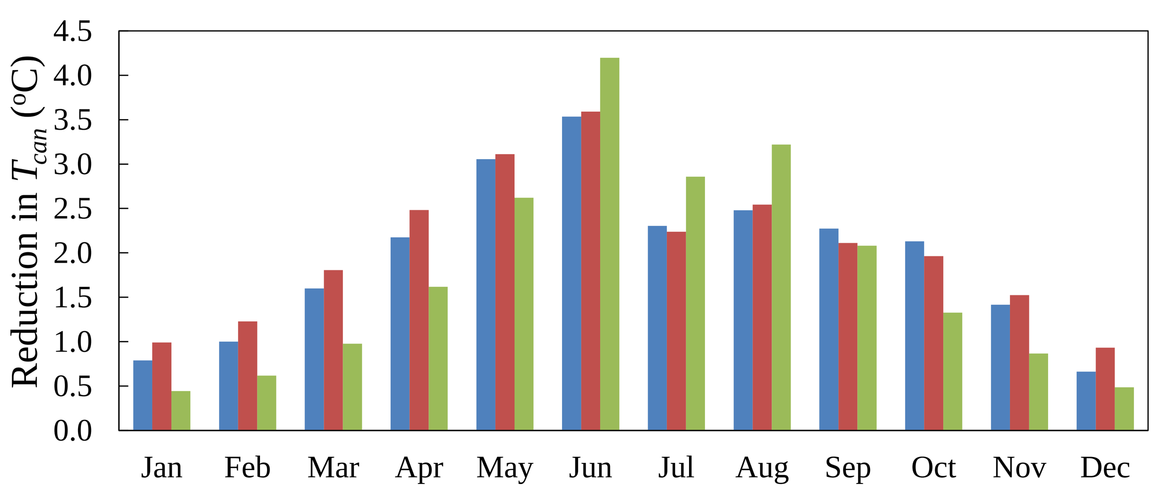


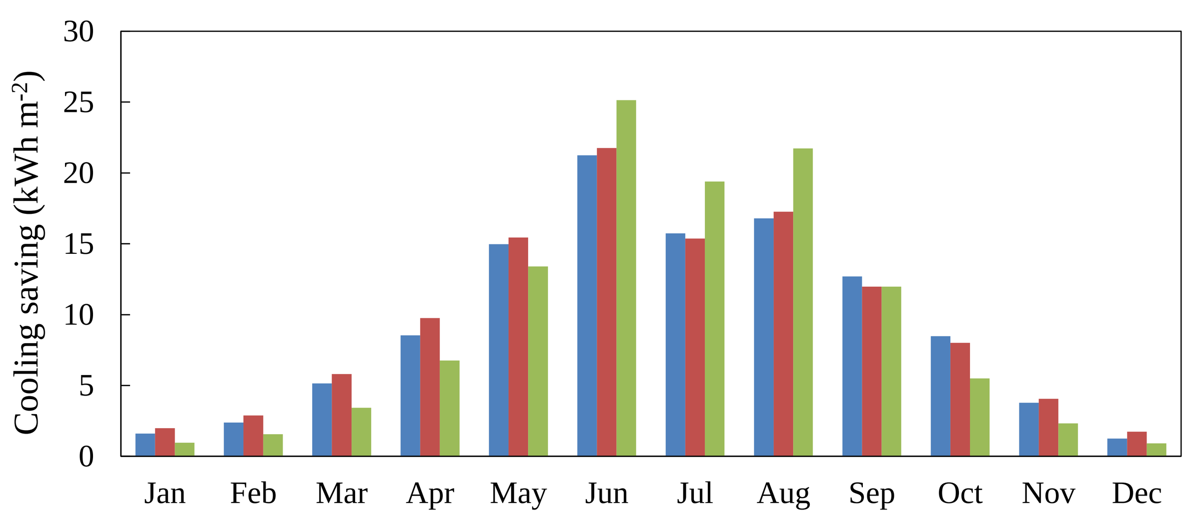






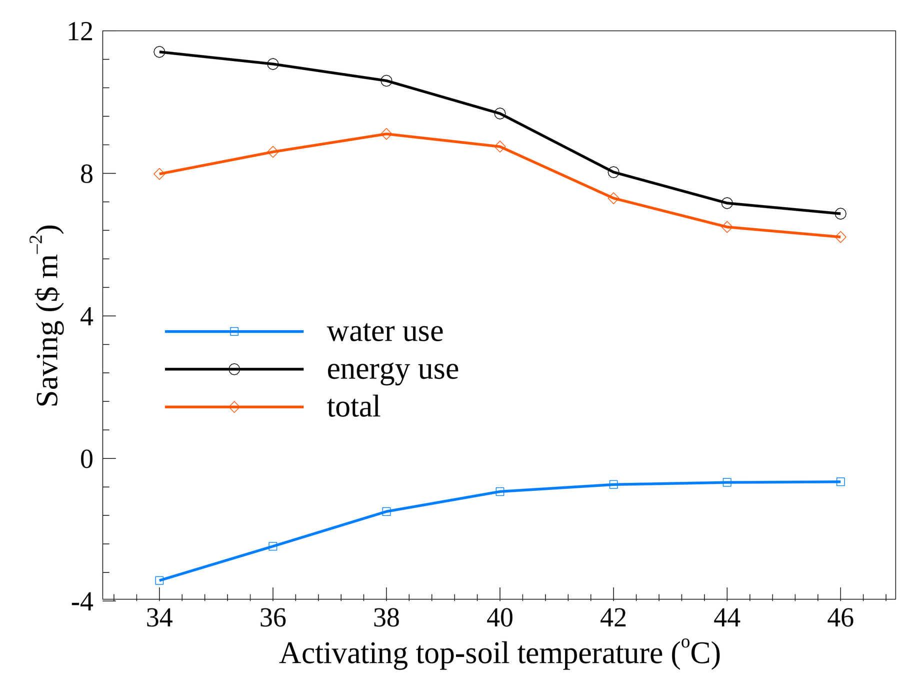






	Irrigation scheme			
	No irrigation	Daily constant	Soil-moisture-controlled	Soil-temperature-controlled
Water usage (gal m^{-2})	0	273.5	287.1	412.9
Energy consumption (kWh m^{-2})	1405.8	1335.7	1336.3	1321.5
Annual total cost ($ m^{-2})	151.29	143.28	143.32	142.18

Optimal Temperature for Irrigation Activation



Conclusion

- Irrigating mesic landscape in urban areas cools the urban environment via enhanced evapotranspiration
- The soil-temperature-controlled irrigation is the most efficient in reducing annual building energy consumption and the combined energy-water cost.
- The total saving of the soil-temperature-controlled scheme requires a fine balance in energy-water use. Site-specific analysis is therefore required to determine the optimal activating soil temperatures

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