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50 Grades of Shade - Assessment of Engineered and Natural Shade in Hot Dry Communities

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Under hot, dry, clear-sky conditions with low wind speed, daytime outdoor thermal comfort and heat stress is mainly driven by Mean Radiant Temperature (MRT) and the availability of shade resulting from different urban features such as trees and buildings. However, MRT and urban shading patterns vary significantly in heterogeneous environments. They can be manipulated through varying urban design strategies, especially when providing green infrastructure, which are of strong interest to urban planners as intervention schemes for heat mitigation purposes.

Cities are increasingly recognizing the importance of shade to improve walkability and reduce vulnerability to extreme heat, especially in the face of rapid urbanization, future climatic uncertainty, and increased risks of heat waves leading to public health concerns. A growing number of municipalities have developed and implemented “Tree and Shade” Masterplans as a framework to invest in urban forestry, minimize heat risks, and improve quality of life. However, in dry desert environments, drought conditions and resulting water use concerns pose a potential conflict with the implementation of comprehensive tree and shade plans. Therefore, it is important to understand if and when artificial shade structures can provide similar benefits to be utilized as a viable alternative to trees.

This study investigates the impact of various shade types on human thermal comfort in the hot dry urban landscape of Tempe, Arizona, USA. Hourly microclimate transects were conducted from 8:00 a.m. to 9:00 p.m. to sample 50 shade types on Arizona State University’s main campus during three consecutive summer days of 2018. A mobile human-biometeorological station (MaRTy) was used to record air temperature, relative humidity (1.5-m), 2D wind speed and direction (1.7-m), six-directional radiation flux densities (1.1-m), and GPS location. In addition, surface temperature of the ground and shade type were measured with an IR gun. Sampling locations featured various shade types, which we classified as either urban form, engineered shade structure, or tree and further analyzed in the context of the surrounding surface type composition using 6-directional fisheye photos and a deep learning image segmentation method.

Observations were averaged for each hour and individual stop. The averages were time-detrended to allow inter-stop comparison for each hour. At daytime, the difference dMRT between MRT at each stop and the average MRT of all exposed stops was calculated to determine the effect of individual shade structures on MRT and rank the shade types by efficacy. After sunset, the heat retention of different surfaces under similar shade structures was analyzed. Preliminary results show inter alia that urban form and engineered shade structures can be more effective in reducing daytime MRT than trees. Such findings provide important insight for urban planners and inform policy supporting microclimate-responsive urban design and active shade management.