The Impact of Housing Characteristics and Surface Heat Islands on Water Use in Single Family Residences: The Case of the Phoenix Metropolitan Area

The objective of this study is to determine whether single-family residential water use in Phoenix is impacted by heat island effects, which result in higher than "normal" nighttime temperatures. The study examines how the density and design features of residential units and surrounding neighborhoods affect nighttime surface temperatures leading, in turn, to increased water use. Ordinary least square regression analysis has previously shown that elevated nighttime surface temperatures contribute uniquely and independently to water demand. However, such analysis often suffers from multicollinearities where some independent variables are themselves correlated. In addition, it is well know that water demand is not only determined by the surface temperatures but also modulate the temperature through indirect effects (pools, vegetation, etc.). To account for the indirect effects and control for multicollinearity, the statistical techniques of path analysis will be adopted. Path analysis can provide the strength of relationships between the variables along a hypothesized path. The results of this analysis will provide information necessary to complete the "population water demand" and "land use water demand" portions of the model being developed by researchers in the Decision Center for a Desert City at Arizona State University to study long-term sustainability of water services. It will also augment the model by including additional linkages between land use characteristics and heat. In addition, land use would be quantified by various design related issues (density, pervious surfaces, vegetation, etc.) that would help in planning better residential subdivisions.

The Impact of Housing Characteristics and Surface Heat Islands on Water Use in Single Family Residences: The Case of the Phoenix Metropolitan Area

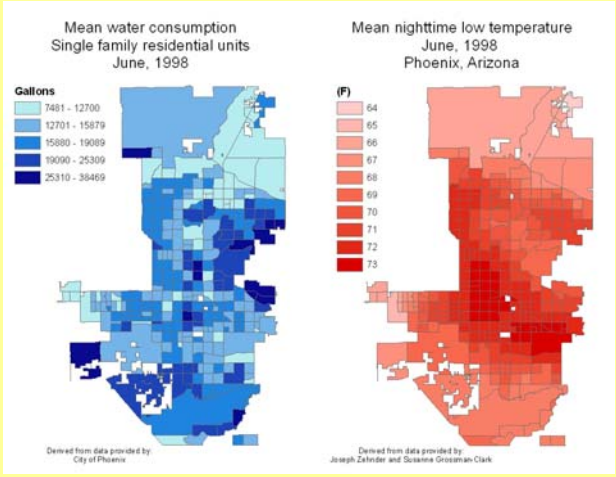
Subhrajit Guhathakurta[1], Jamie Patterson[2], and Patricia Gober[2]
[1]School of Planning and Global Institute of Sustainability, [2]School of Geographical Sciences and DCDC
Decision Center for a Desert City, Arizona State University

Residential water consumption

The vitality of the rapidly growing metropolis of Phoenix, Arizona depends on the availability and accessibility of water. Residential consumption includes personal use (drinking, bathing), indoor use (appliances), and outdoor use (vegetation, pools). This study examines the direct and indirect factors influencing consumption by looking at feedbacks between surface temperatures, housing characteristics, and water use.

Urban heat island in Phoenix

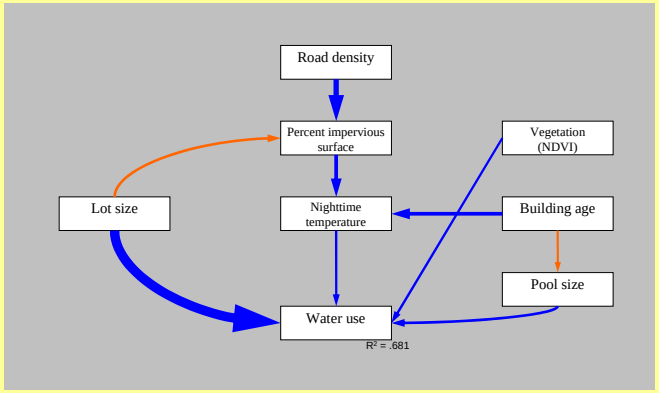
Urban heat island (UHI), the phenomenon of warmer temperatures in the urban core than in surrounding rural areas, has been linked to summer nighttime temperatures differences of almost 10° Fahrenheit between urban and rural areas. Higher summer temperatures could hinder tourism, diminish quality of life, and exacerbate water resource issues.



Study area and variables

This study is limited to the City of Phoenix for single family residential units for June, 1998. All data are aggregated per year 2000 census tracts. Variables were derived from a variety of data sources: City of Phoenix (water use), Landsat NDVI (vegetation), Maricopa County (Lot size, building age, pool size, impervious surfaces, and road density), and temperature (Grossman-Clarke et al. 2005).

Path analysis



This approach provides the strength of relationships between variables along a hypothesized path. Standardized coefficient (beta) values are used to determine the relative influence of independent variables on the dependent variable. Arrows show the direction and relative strength of influence. Blue arrows indicate a positive influence. Orange arrows indicate a negative influence.

Results

Results from path analysis indicate lot size, temperature, vegetation cover, and pool size are direct influences on water use. Lot size plays a dual role, directly increasing consumption, but indirectly decreasing consumption by reducing the percent of impervious surfaces, thus reducing temperature and water consumption. Building age also plays a dual indirect role. Older houses tend to increase water use through higher temperatures. They also have a smaller mean pool size, leading to lower water use. Water use is also indirectly increased by a higher density of roads through impervious surfaces and temperature.

Implications

If in fact urban heat islands are exacerbated by higher density, small-lot residential development leading to higher energy and water use, the principles of good planning may need to be rethought. Planning would be more contextualized and place-based – with significant variations in design principles that are more closely tied to climatic and other environmental conditions of the place.

Further Research

Correlations from path analysis could be included in a simulation model to generate “what if” scenarios of future water demand. The next stage of this research would involve the development of such simulation scenarios based on a range of growth parameters.

Acknowledgment

This material is based upon work supported by the National Science Foundation under Grant No. SES-0345945 Decision Center for a Desert City (DCDC). Any opinions, findings and conclusions or recommendation expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation (NSF).