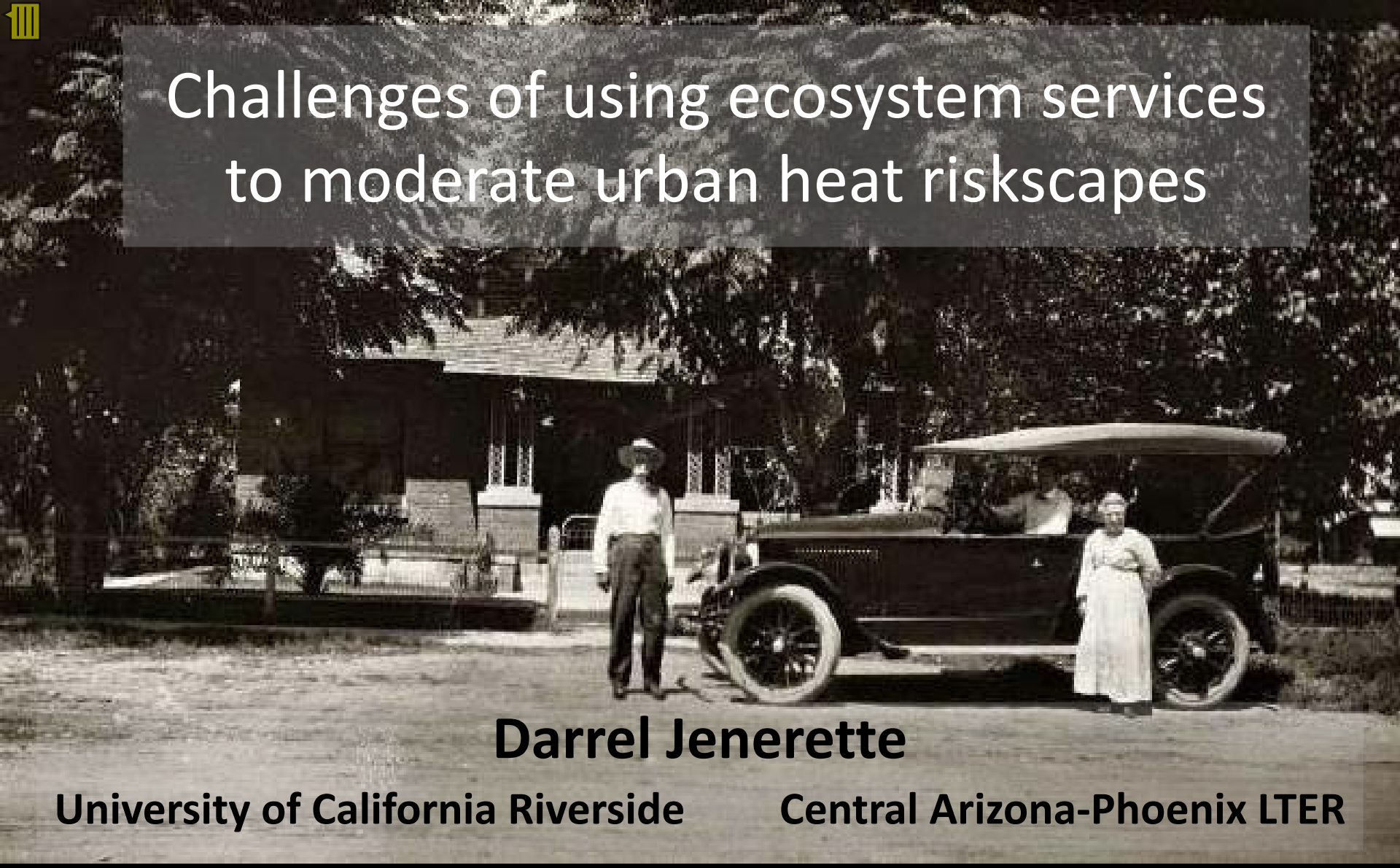
Challenges of using ecosystem services to moderate urban heat riskscapes



Darrel Jenerette

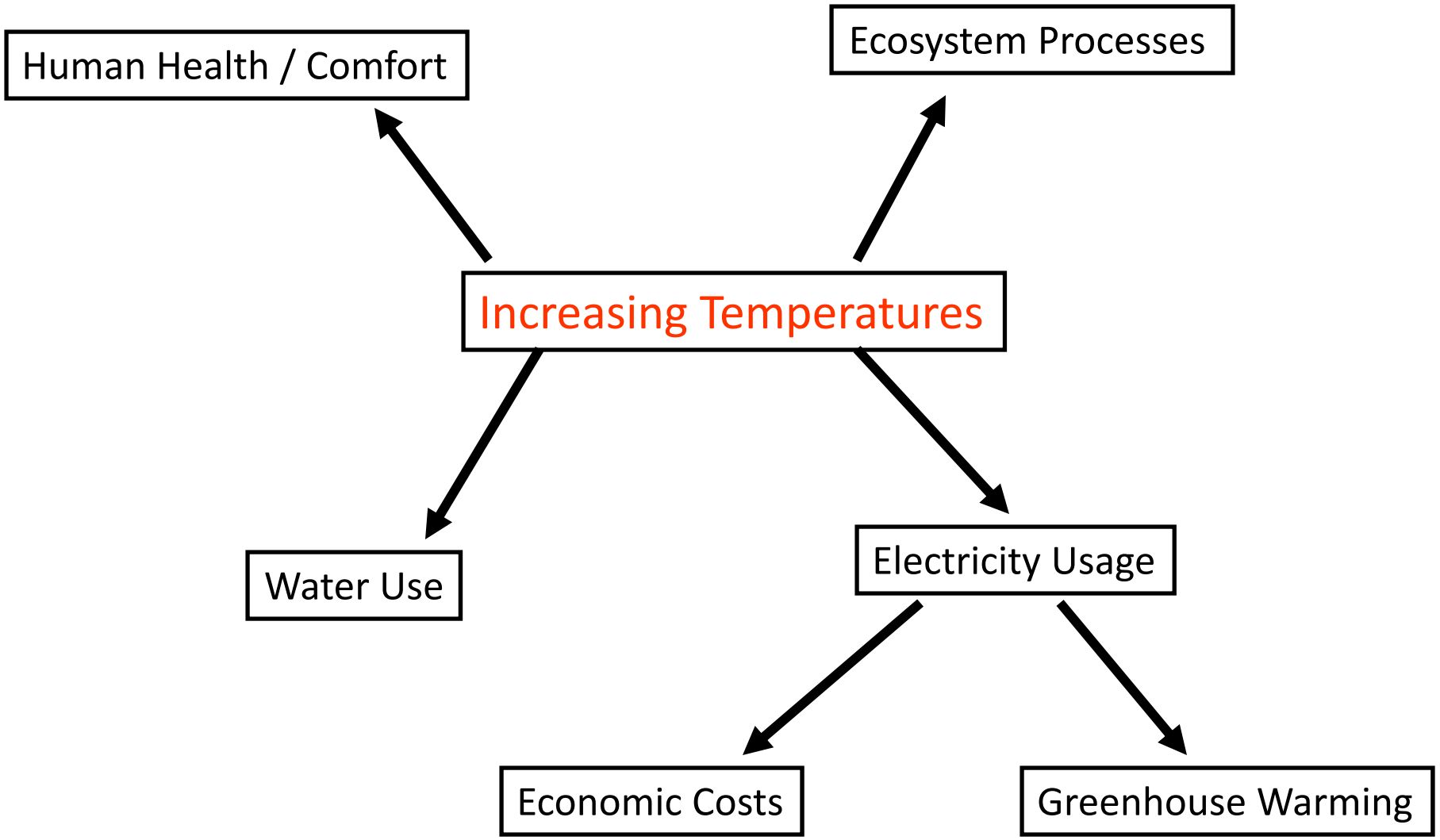
University of California Riverside **Central Arizona-Phoenix LTER**

Image: 1920 Chamber of Commerce Report

Funding: National Science Foundation

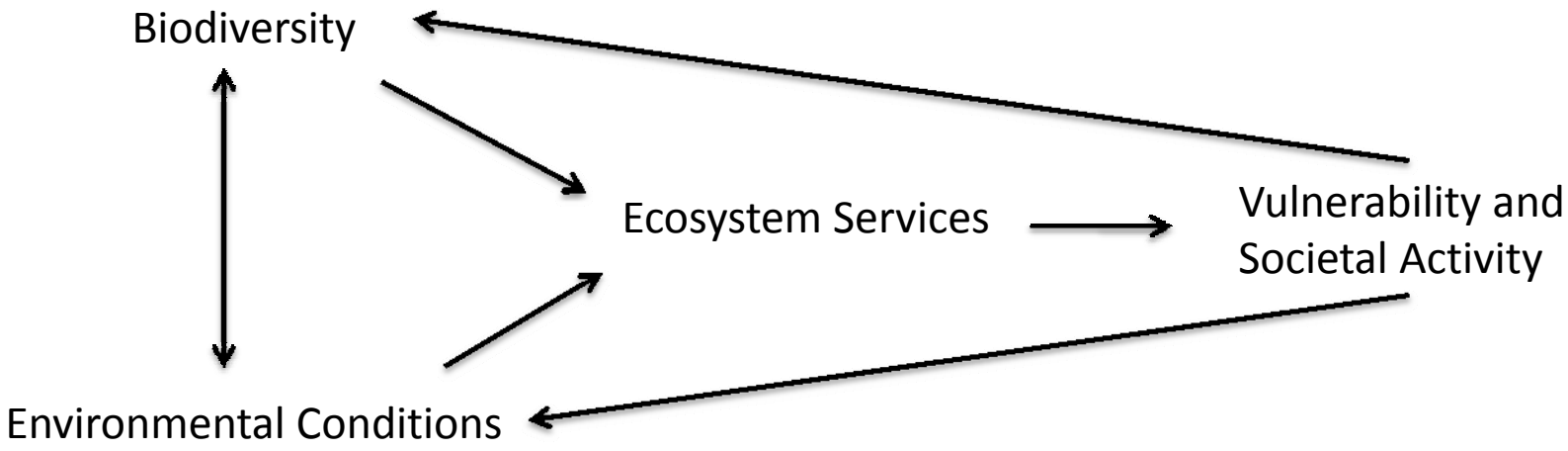
Collaborators: Sharon Harlan, Will Stefanov, Chris Martin, Susanne Grossman-Clarke, Tim Lant, Tony Brazel, Darren Ruddell, Juan Declet-Barreto, Bob Bolin

Consequences of Rising Urban Temperature

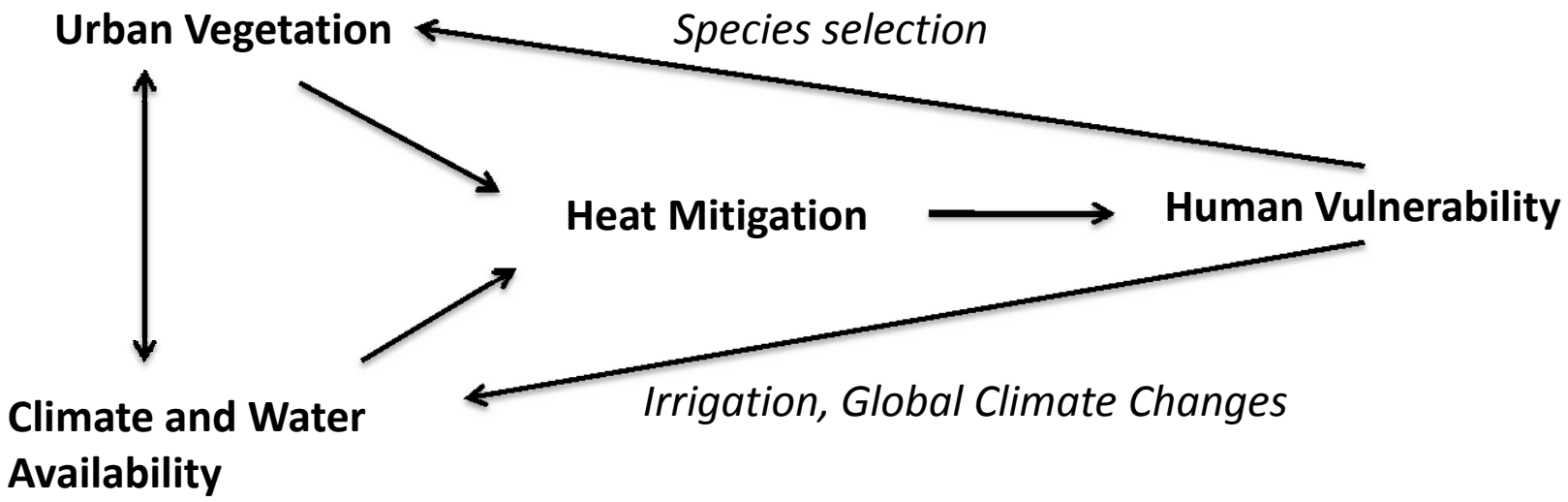


Sustainability

"Meeting the needs of the present generation without compromising the ability of future generations to meet their needs." *Brundtland Report 1987*



Ecosystem Services and Urban Sensitivity to Climate Extreme



Ecological Questions:

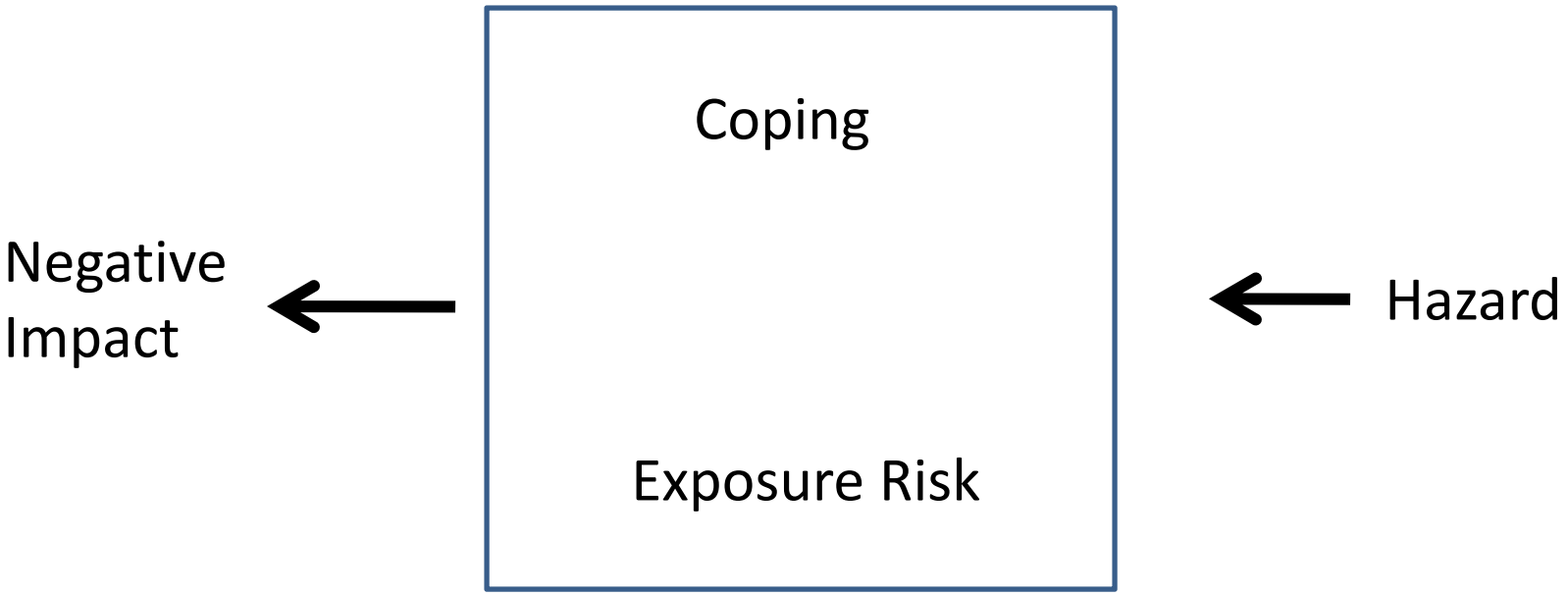
How do global and regional warming interact?

What is the potential for vegetation to mitigate excessive heat?

What are the costs associated with using vegetation for heat mitigation?

How do species differ in their efficiency for heat mitigation?

Vulnerability



Urban Heat Vulnerabilities

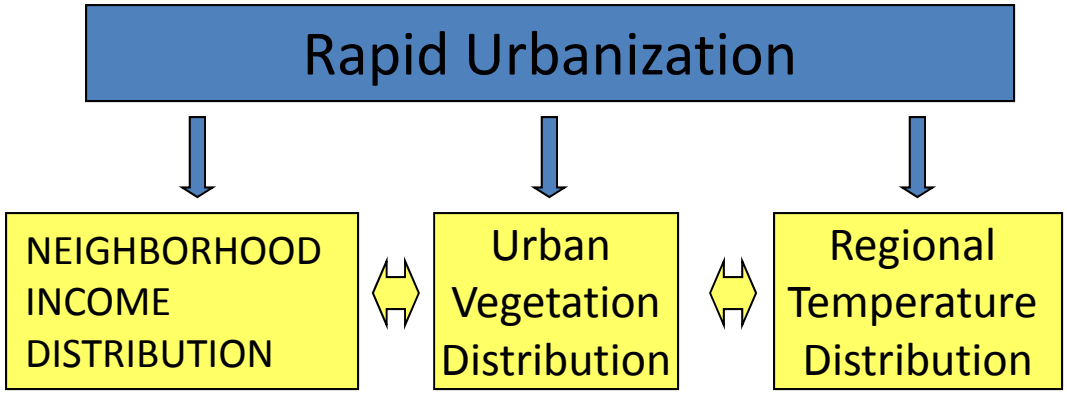
Coping

Humans have varying heat coping capacities

- Insulation
- Electrical cooling
- Health resources
- Social networks

Exposure Risk

Hypothesis: The distribution of urban vegetation is an important intermediary between patterns of human settlement and local temperature: **riskscapes**



Urban Vulnerability to Climate Change

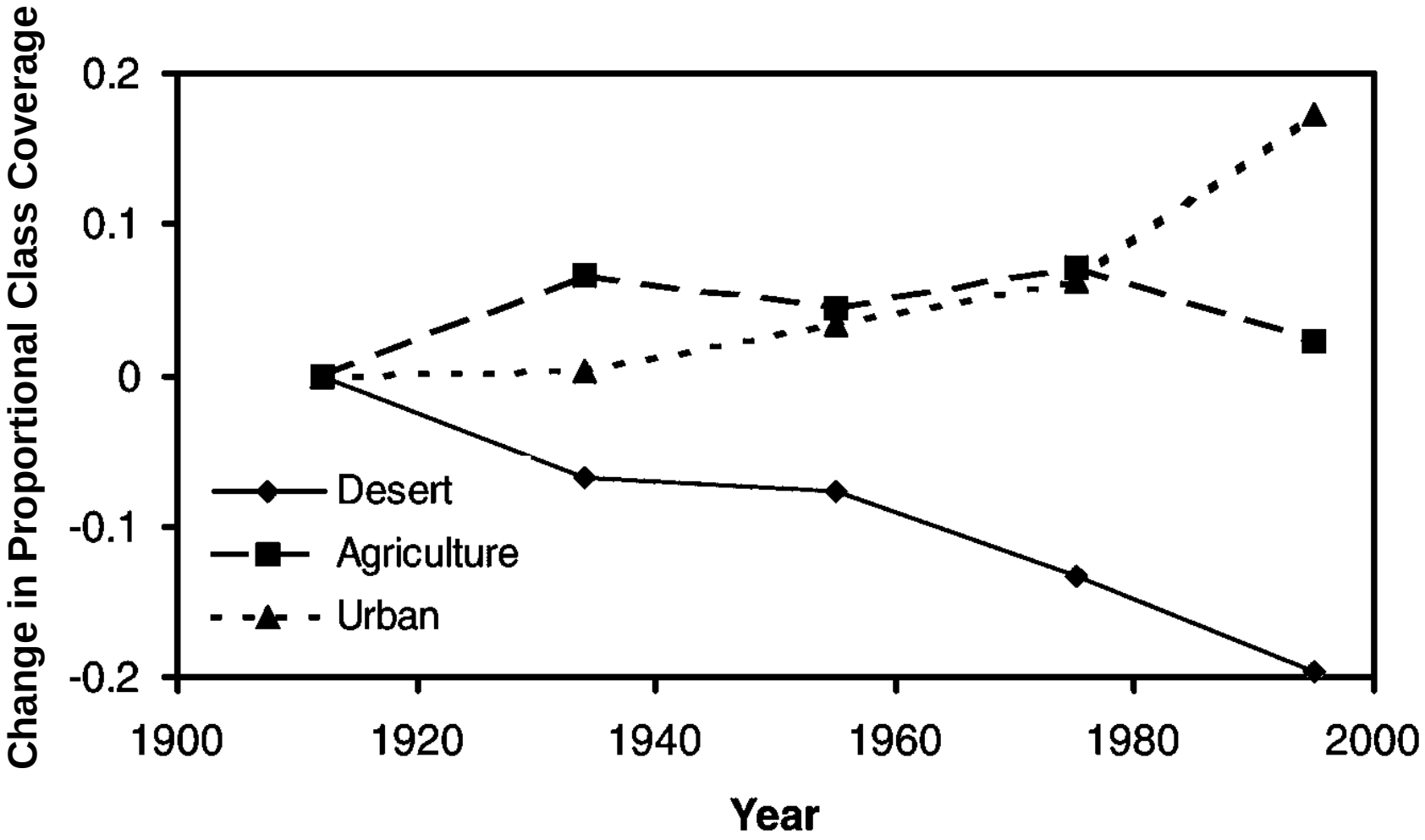
- What impact does the development and intensification of global climate change/urban heat islands have on health disparities?
- Are people in certain types of neighborhoods more vulnerable to the health effects of extreme temperature?
- What is the role of vegetation and other land covers in regulating neighborhood heat vulnerability?
- How can neighborhood built environments be reconfigured to reduce negative health impacts of climate change in arid cities?

Phoenix, AZ: Model and well studied system

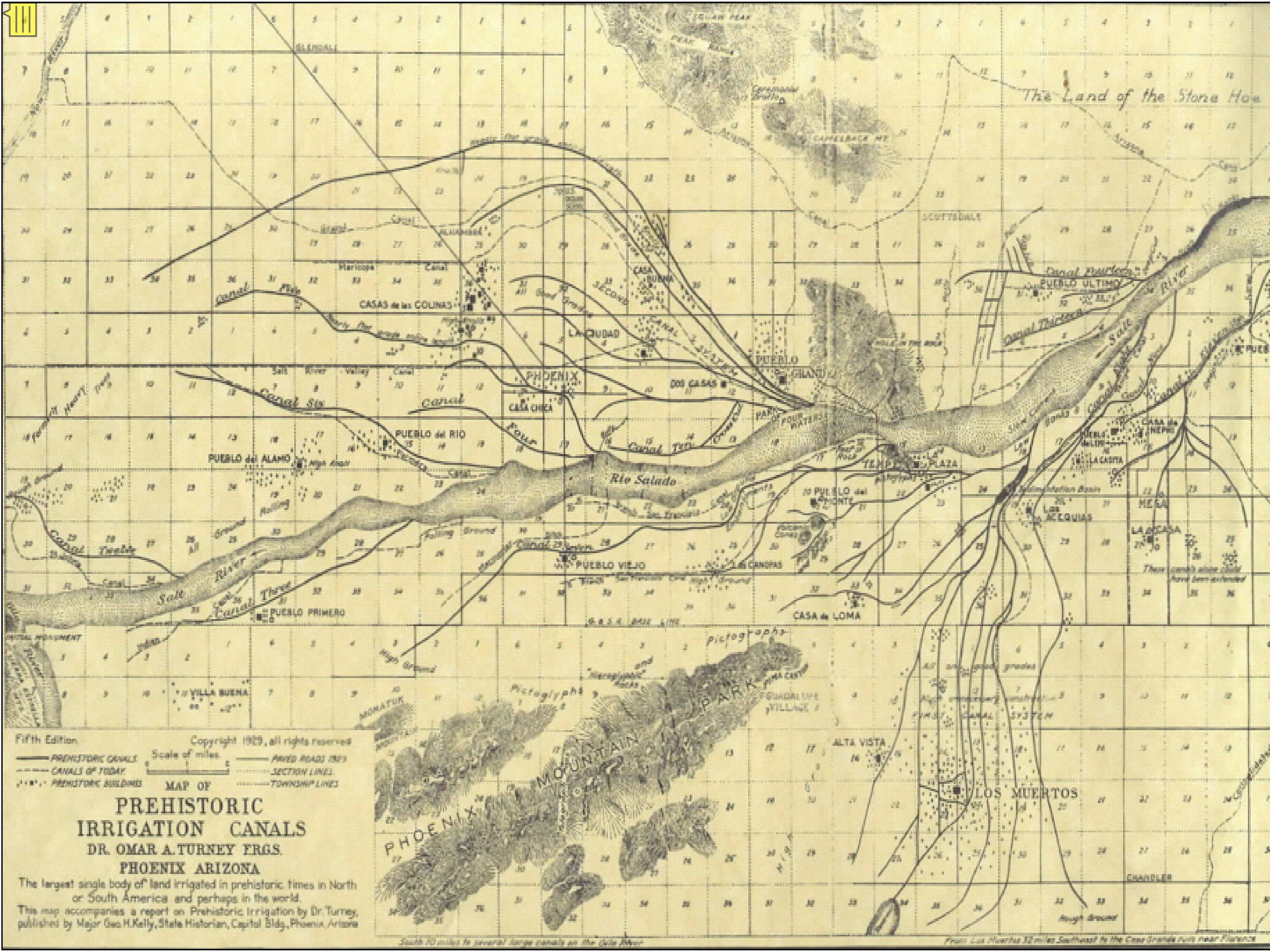
Jack Swilling

Modern Phoenix, AZ

Phoenix Land Cover Trajectory

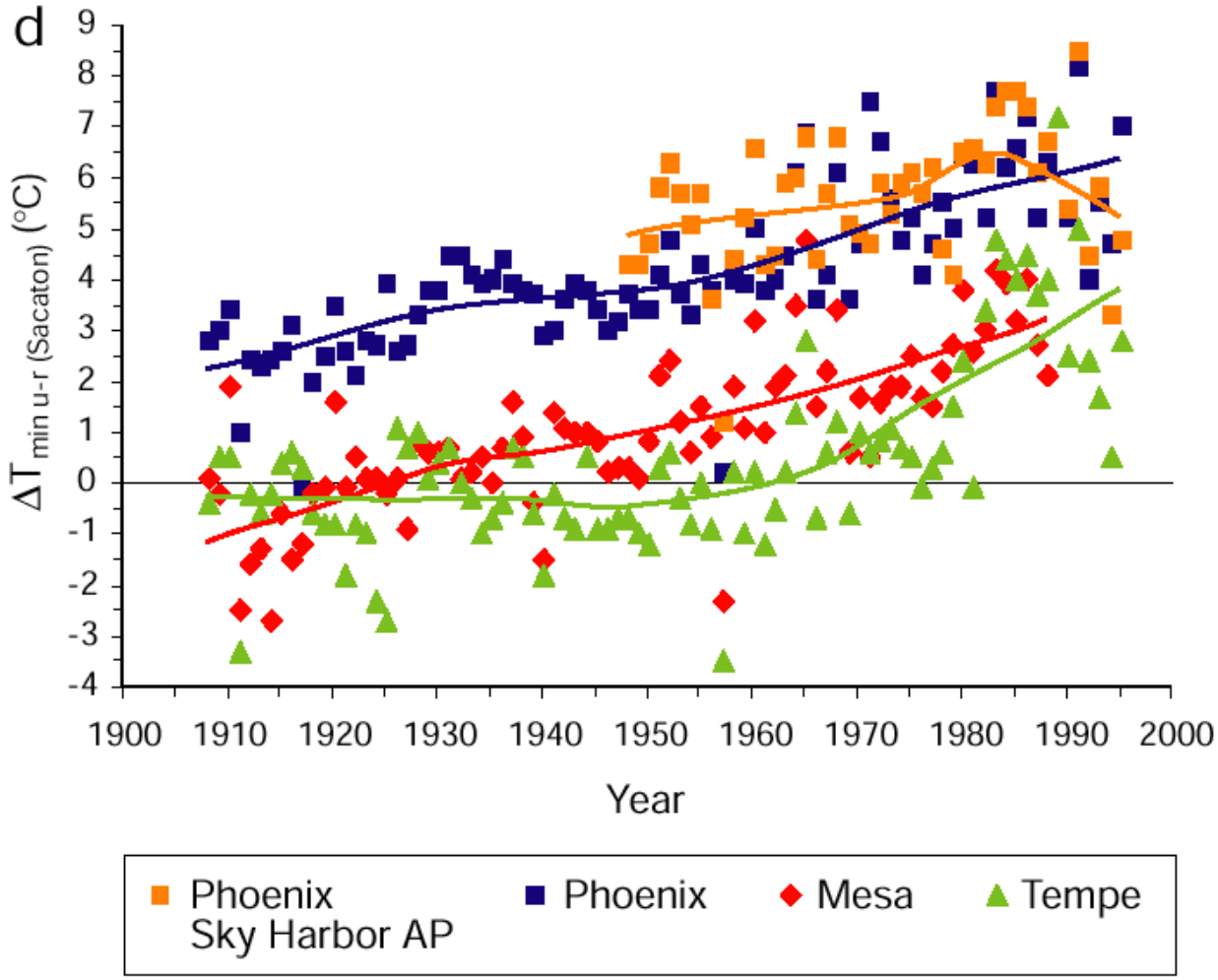


Jenerette GD and J Wu. 2001. Analysis and simulation of land-use change in the central Arizona - Phoenix region, USA. *Landscape Ecology* 16:611-626.



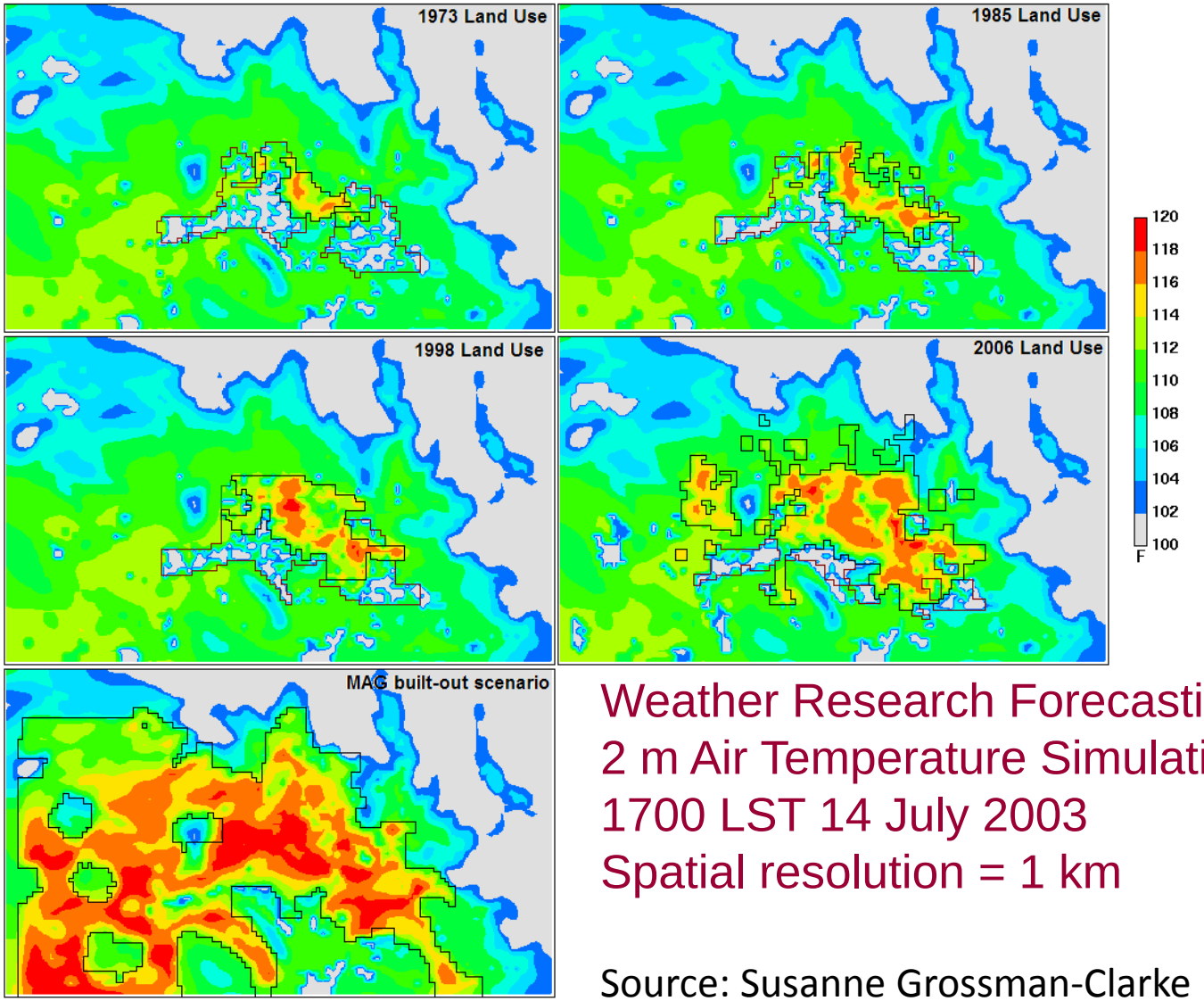
Fifth Edition.
Copyright 1929, all rights reserved
PREHISTORIC CANALS
CANALS OF TODAY
PREHISTORIC BUILDINGS
Scale of miles
PAVED ROADS 1929
SECTION LINES
TOWNSHIP LINES
MAP OF
PREHISTORIC
IRRIGATION CANALS
DR. OMAR A. TURNEY F.R.G.S.
PHOENIX ARIZONA
The largest single body of land irrigated in prehistoric times in North or South America and perhaps in the world.
This map accompanies a report on Prehistoric Irrigation by Dr. Turney, published by Major Geo. H. Kelly, State Historian, Capitol Bldg., Phoenix, Arizona
The Land of the Stone Hoe
GLENDALE
CAMELBACK MT.
SCOTTSDALE
PHOENIX
CASAS de las COLINAS
LA CIUDAD
PUEBLO GRANDE
DOS CASAS
CASA CHICA
PUEBLO del RIO
PUEBLO del ALAMO
PUEBLO VIEJO
PUEBLO PRIMERO
PUEBLO ULTIMO
CASA de LOMA
LOS MUERTOS
ALTA VISTA
VILLA BUENA
LA CASITA
LAS ACEQUIAS
MESA
CHANDLER
Rio Salado
Salt River
Canal Five
Canal Six
Canal Four
Canal Three
Canal Twelve
Canal Fourteen
Canal Thirteen
Salt River Valley Canal
Grand Canal
Maricopa Canal
FIRST CANAL SYSTEM
SECOND CANAL SYSTEM
PHOENIX MOUNTAIN PARK
GUADALUPE VILLAGE
INITIAL MONUMENT
G. & S. R. BASE LINE
Pictographs
Pictoglyphs
These canals since 1929 have been extended
South 10 miles to several large canals on the Gila River
From Los Muertos 32 miles Southeast to the Casa Grande ruin near Florence

How has urbanization affected regional climate?



Brazel, A., Selover, N., Vose, R. and Heisler, G. 2000. The tale of two climates - Baltimore and Phoenix urban LTER sites. - Climate Research 15: 123-135.

Land cover and an Expanding Heat Island



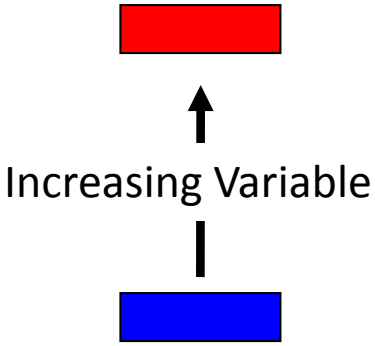
Weather Research Forecasting Model
2 m Air Temperature Simulations
1700 LST 14 July 2003
Spatial resolution = 1 km

Source: Susanne Grossman-Clarke

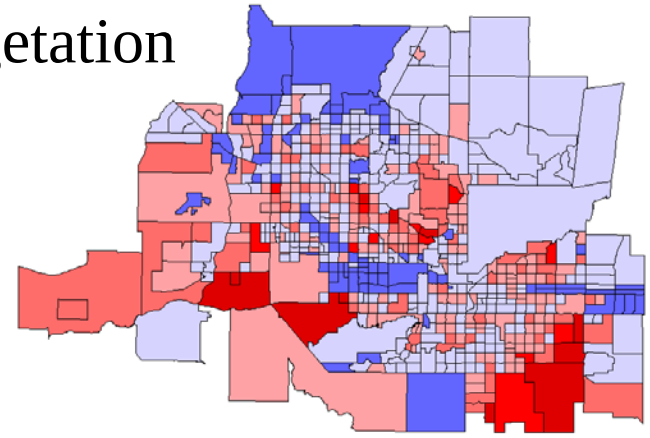
Applications of decadal ground and satellite measurements for UHI research

- Weather station
  - Local meteorology
- Landsat satellite
  - Temperature, NDVI
- Census and health incident data
  - Social segregation and heat related deaths
- Analysis
  - GIS overlays, Monte-Carlo resampling, process modeling

Regional Societal, Vegetation, and Climate Relationships

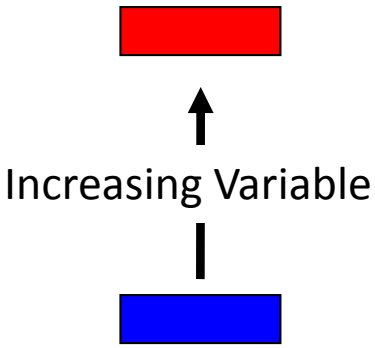


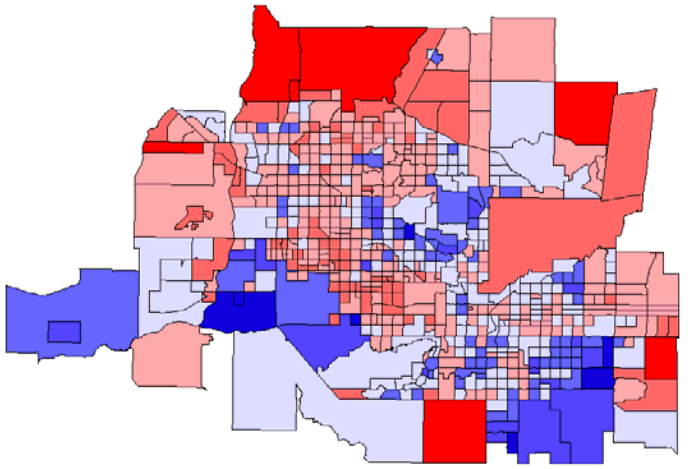
Vegetation



Jenerette, G. D., S. L. Harlan, A. Brazel, N. Jones, L. Larsen, and W. L. Stefanov. 2007. Regional relationships between surface temperature, vegetation, and human settlement in a rapidly urbanizing ecosystem. Landscape Ecology **22:353-365.**

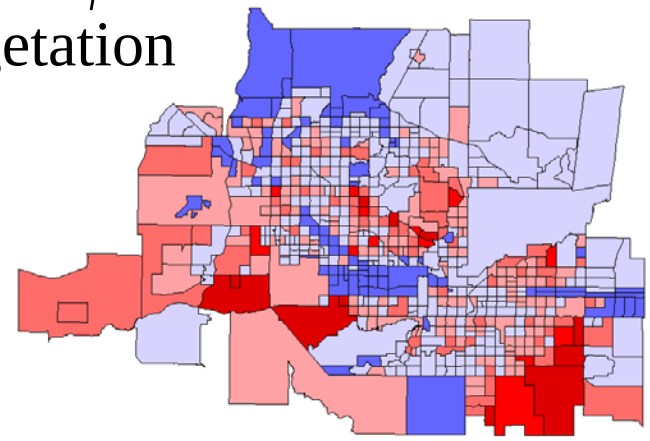
Regional Societal, Vegetation, and Climate Relationships





Temperature

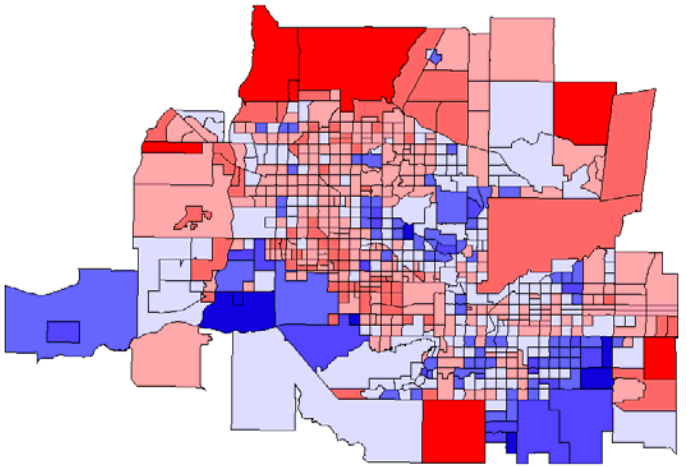
Vegetation

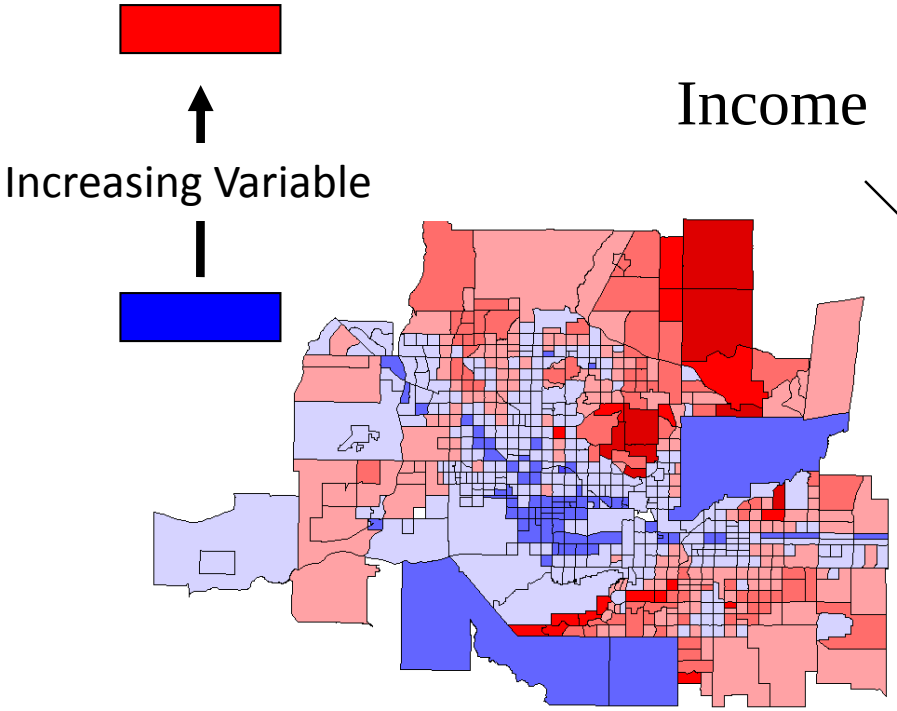


Jenerette, G. D., S. L. Harlan, A. Brazel, N. Jones, L. Larsen, and W. L. Stefanov. 2007. Regional relationships between surface temperature, vegetation, and human settlement in a rapidly urbanizing ecosystem. Landscape Ecology **22:353-365.**

Regional Societal, Vegetation, and Climate Relationships

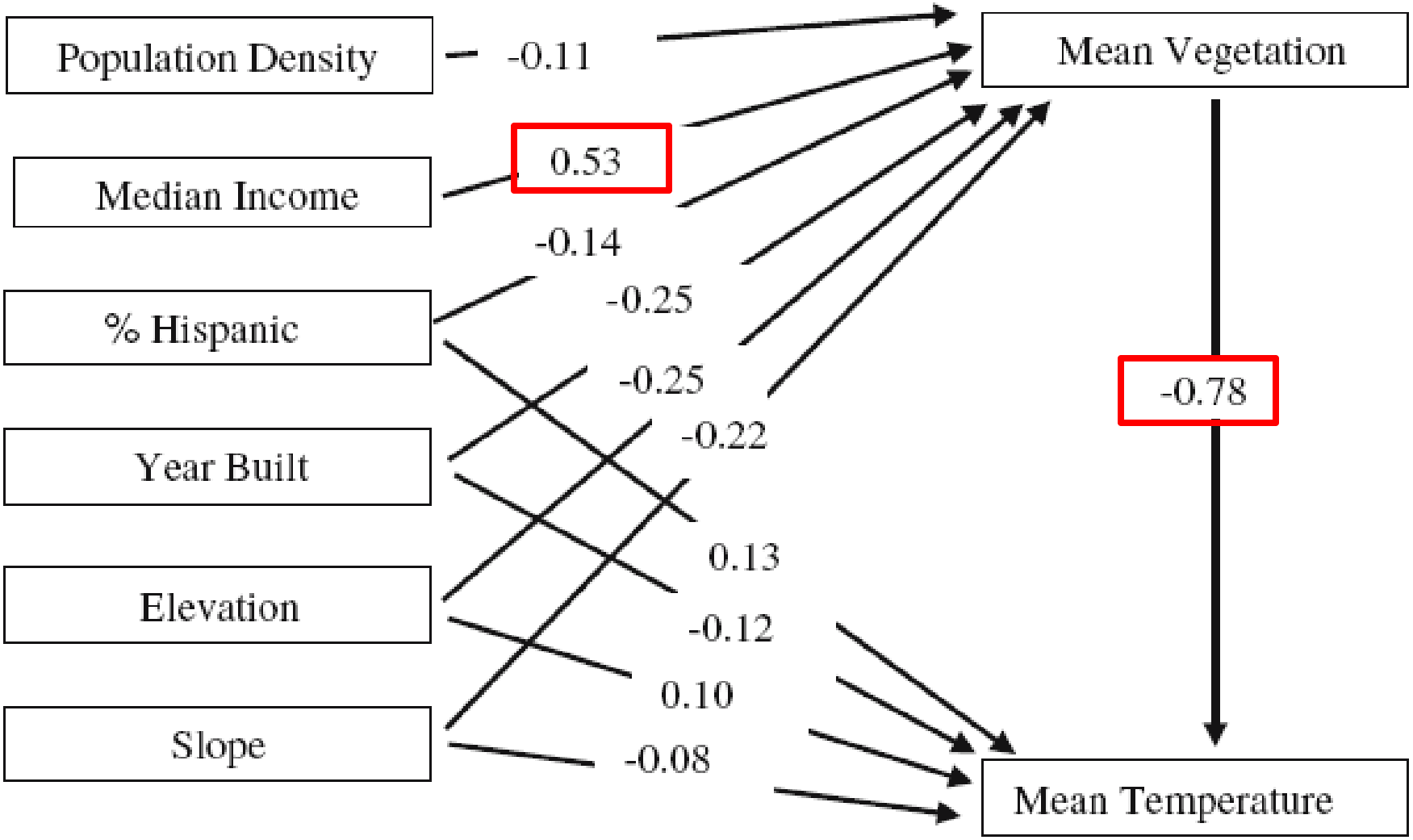
Warming and vegetation are associated with socio-economic status



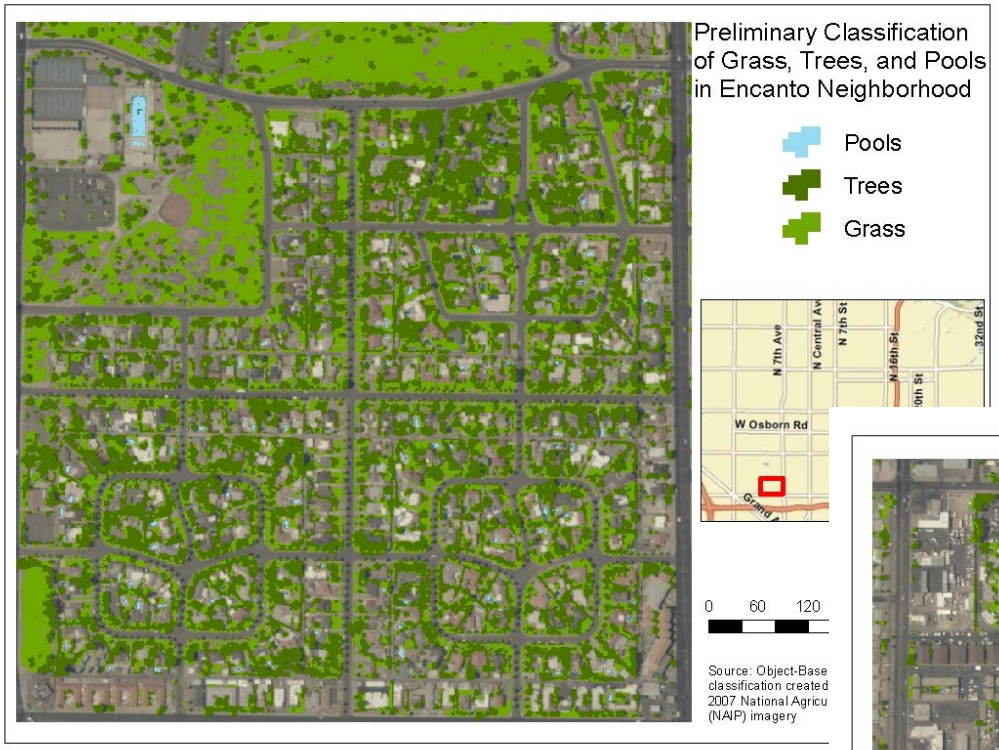


Jenerette, G. D., S. L. Harlan, A. Brazel, N. Jones, L. Larsen, and W. L. Stefanov. 2007. Regional relationships between surface temperature, vegetation, and human settlement in a rapidly urbanizing ecosystem. Landscape Ecology **22:353-365.**

Regional Societal, Vegetation, and Climate Relationships

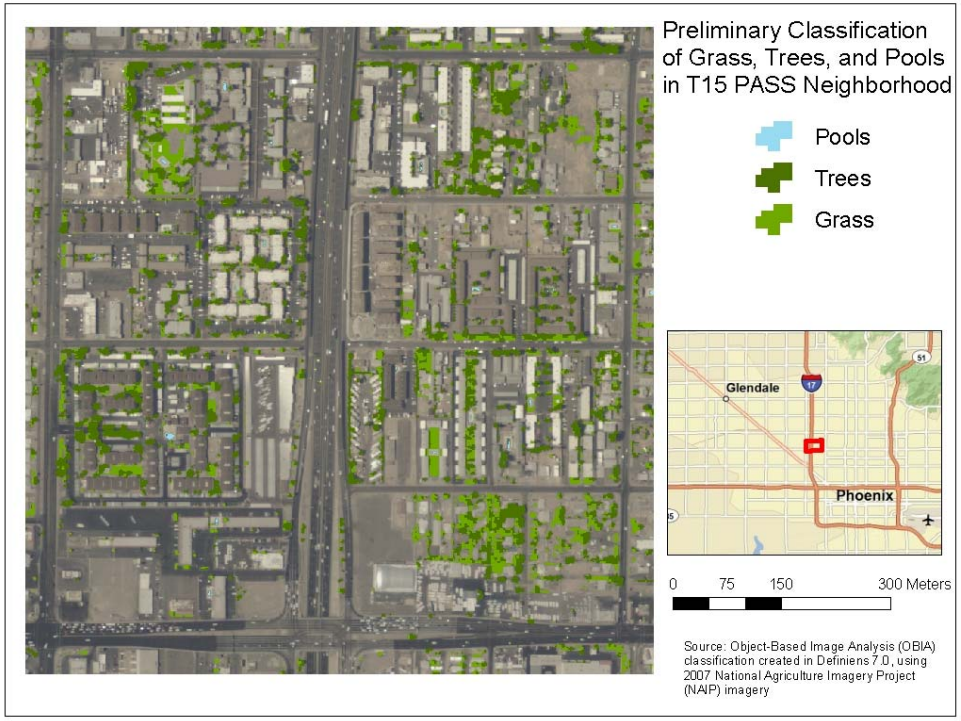


Vegetation Varies in Urban Landscapes



Historic Anglo Phoenix

Black Canyon Freeway

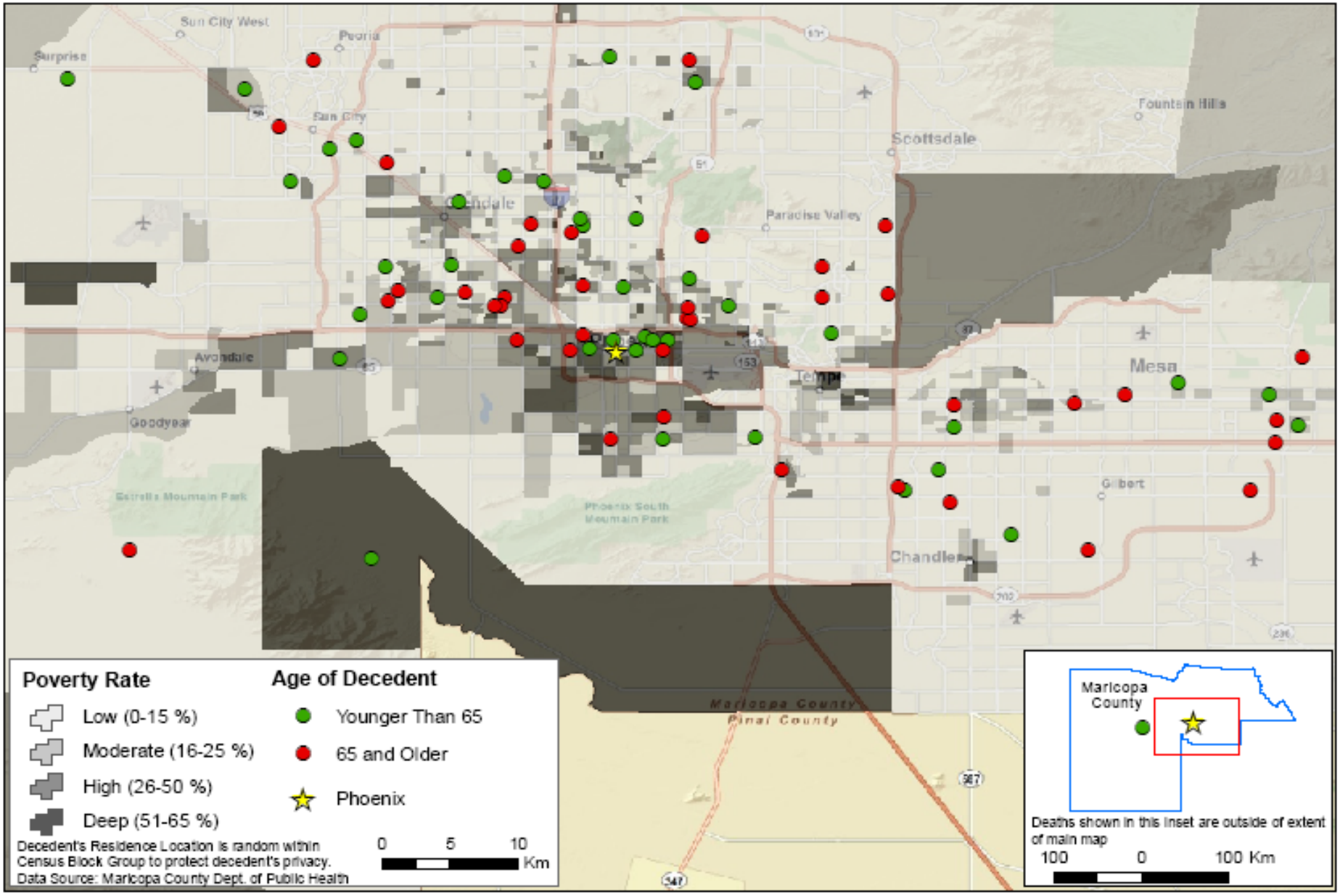


Object Based Image Classification – National Agriculture Imagery Project, 1 m pixel (March 2007)

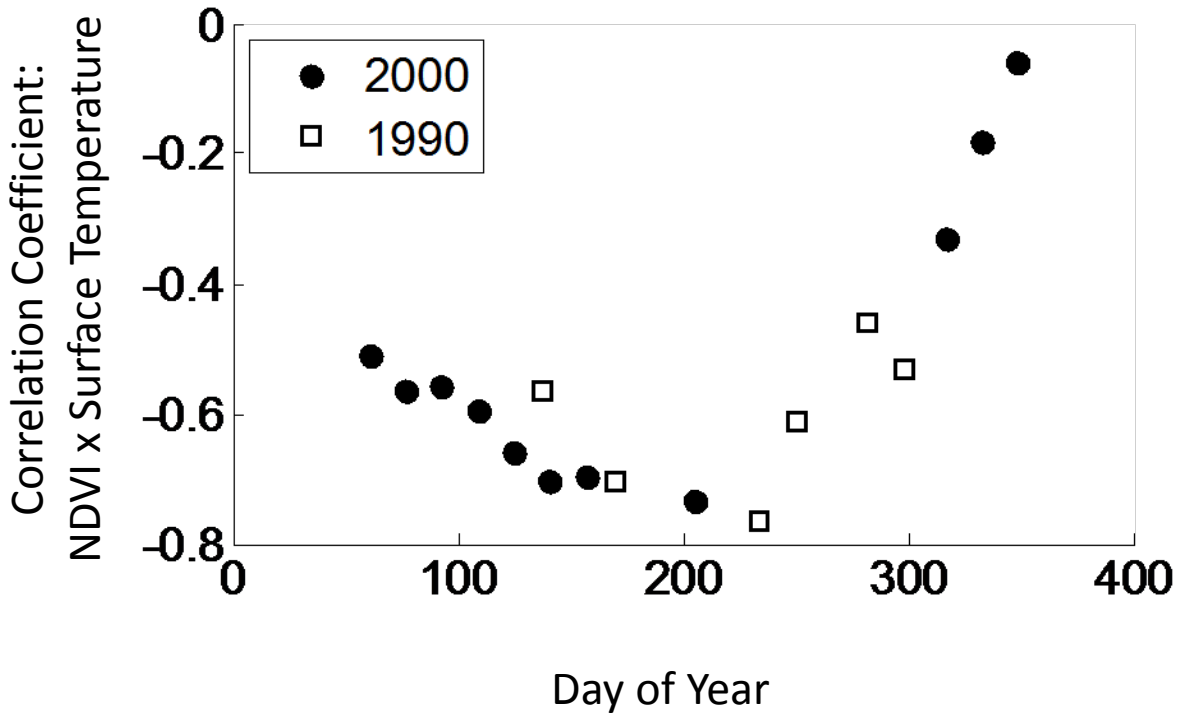
Source: Juan Declet-Barreto

2006-2007 Heat-Related Deaths and Percent Individuals Living in Poverty by Census Block Group of Decedent's Place of Residence in Maricopa County, Arizona

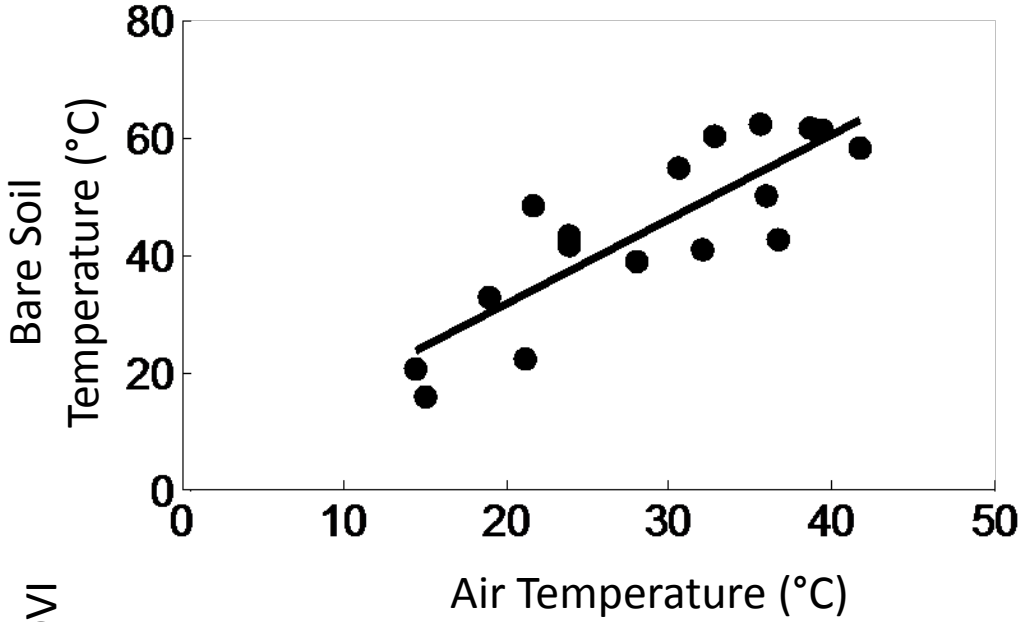
Cartography by Juan Declet-Barreto for the Urban Vulnerability to Climate Change project, Arizona State University. This material is based upon work supported by the National Science Foundation under Grant No. 0816166.

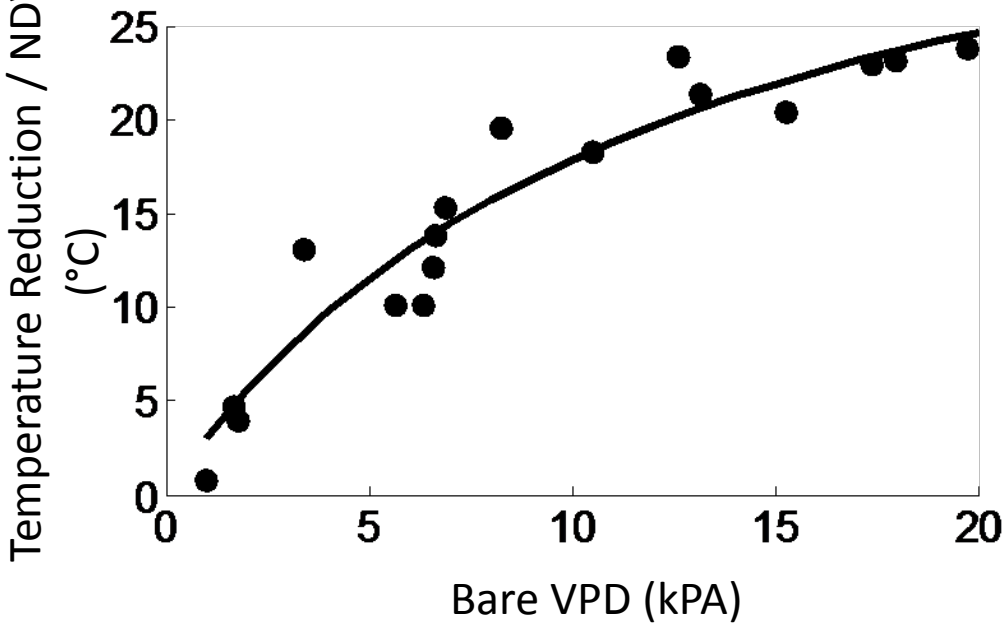


Seasonal Dependence of Vegetation Heat Mitigation

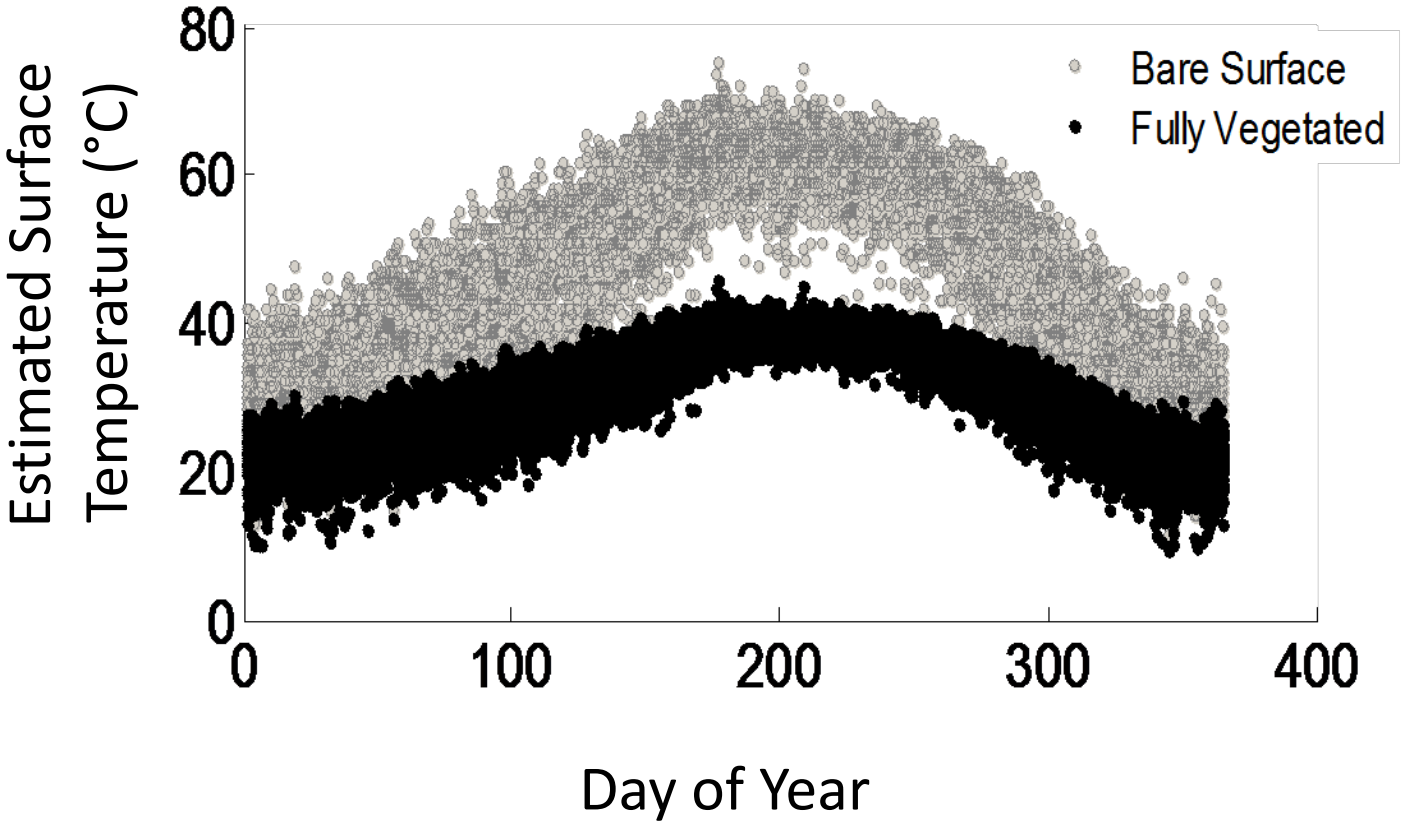


Meteorology and Surface Temperatures





Vegetation Surface Temperature Effect



Using Irrigation for Cooling

Basic Equation (Watts/m2)

$$R_n = H + \lambda E + S$$

Radiation

Sensible Heat

Heat of vaporization

Evaporation rate

Storage

$$E = (R_n - H) / \lambda$$

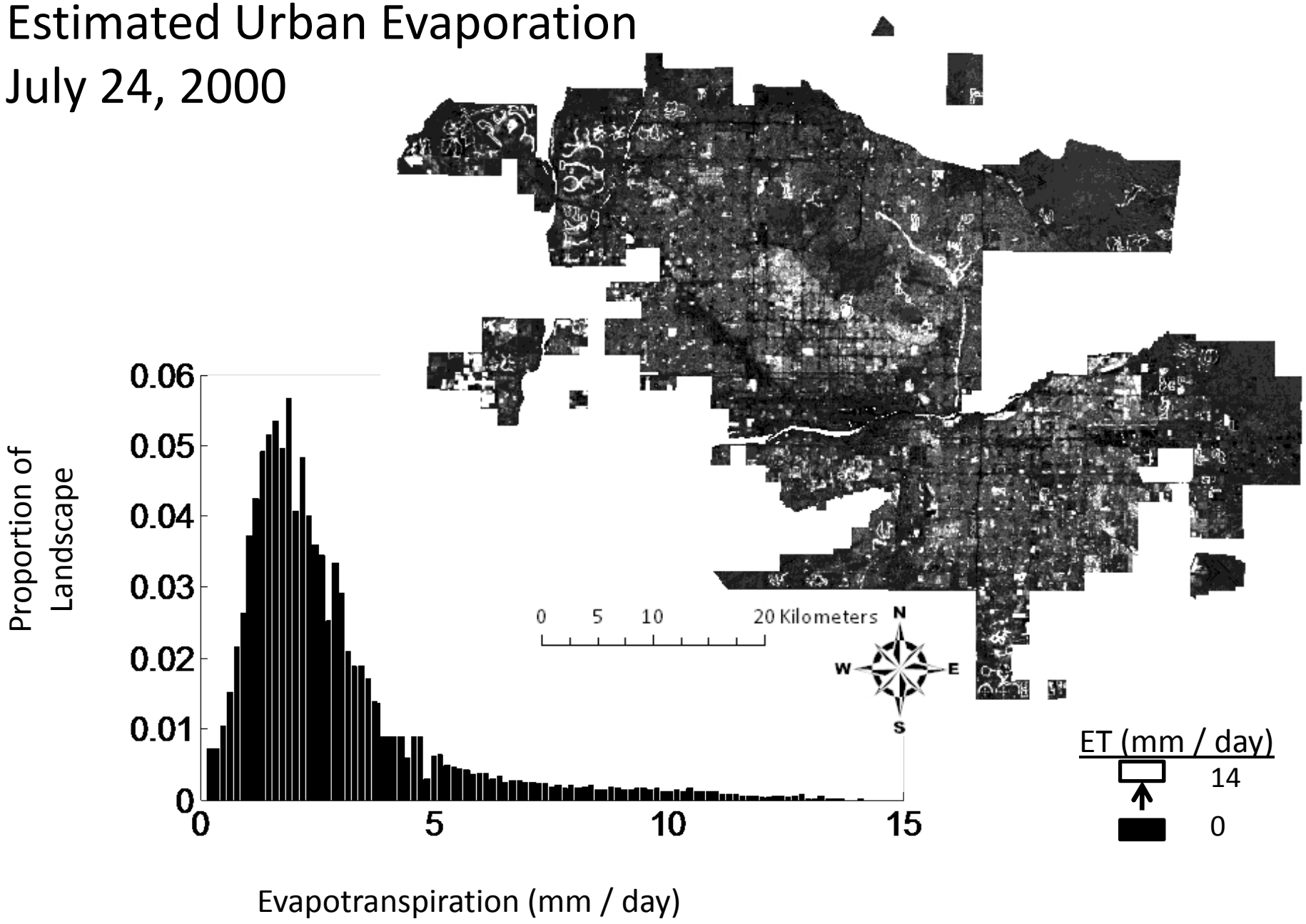
Water used for cooling estimated for each pixel

Estimated from air temperature and bare surface temperature

Estimated from air temperature and surface temperature for each pixel

Physical property of water

Estimated Urban Evaporation
July 24, 2000

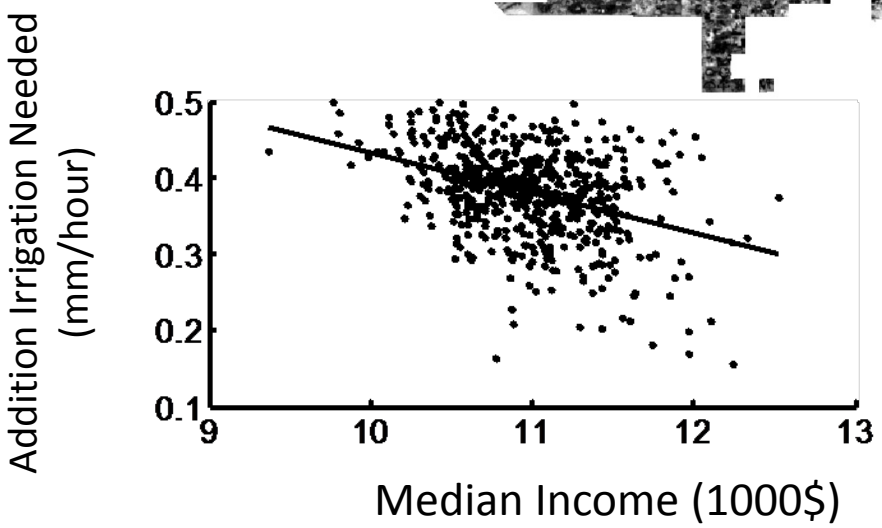


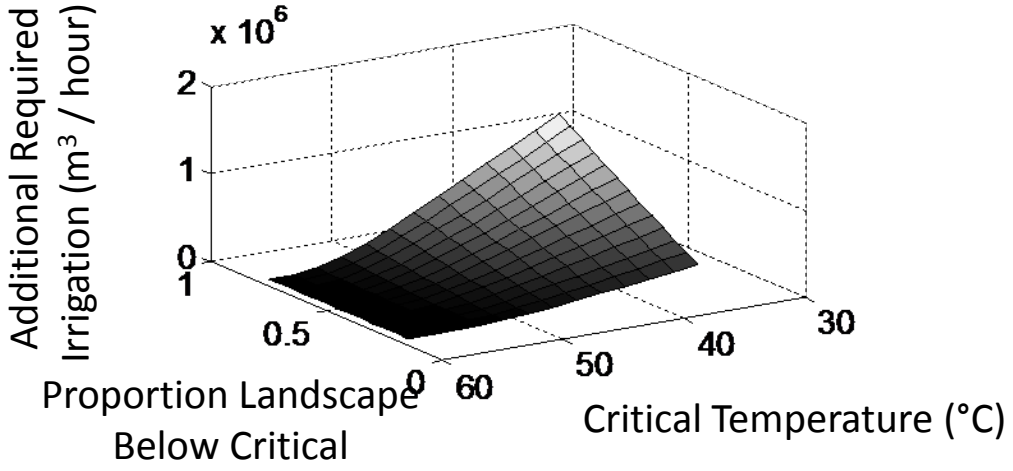
Managing Urban Riskscapes through Irrigated Vegetation

Selecting heat criteria

Designing landscapes for neighborhood cooling

Assessing trade offs of management choices

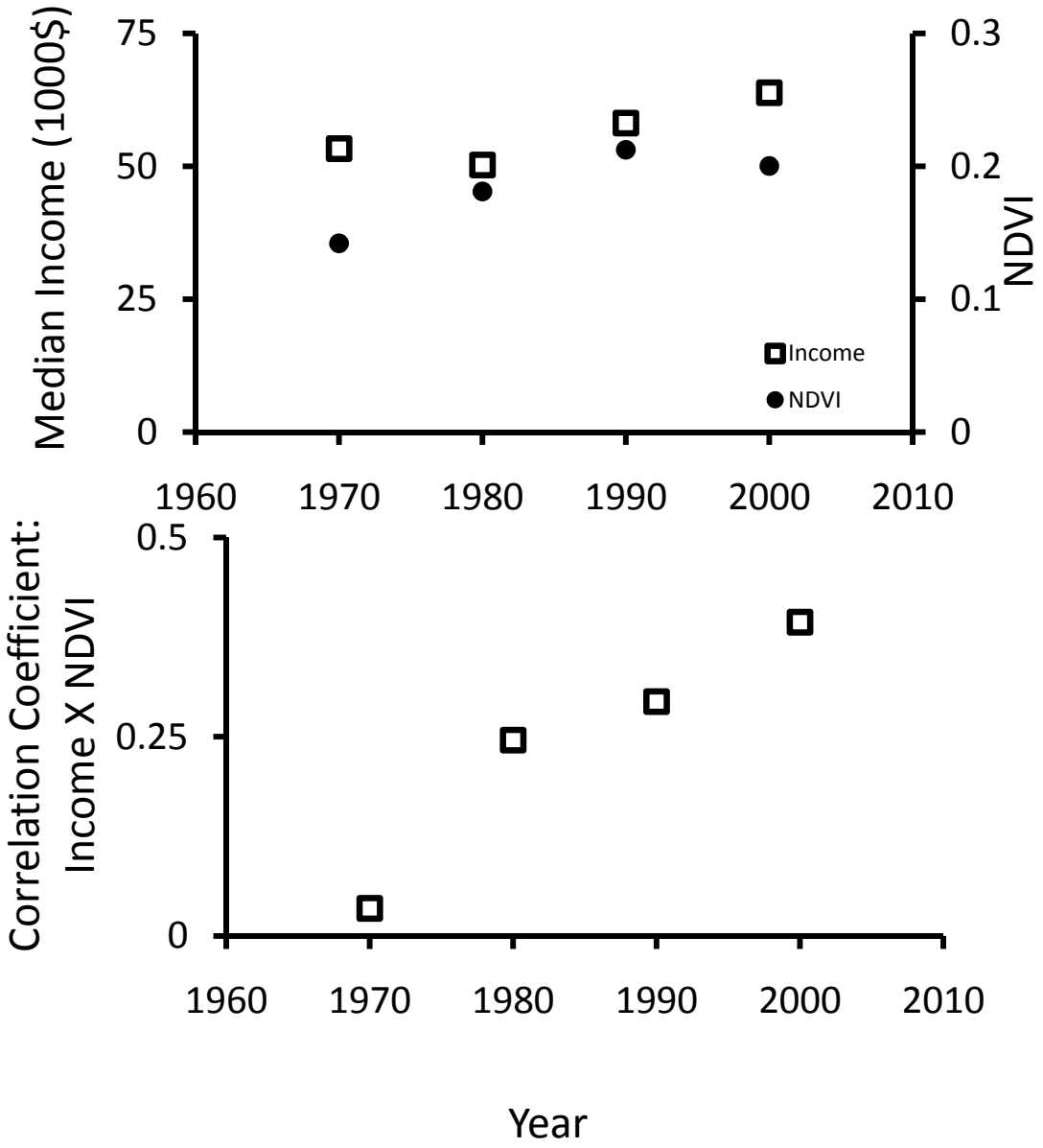




What we have learned

- Vegetation has a large impact on local urban surface temperatures
- Income and ethnicity are strong determinants of vegetation and thus urban heat riskscape
- Surface cooling and water use are a key sustainability trade-off
- **However**, the coupling of risk and income is of recent origin

Long-term Development of Heat Risks



Revised Conceptual Framework

- Socio-ecological systems: humans affect and respond to ecological change
  - Temperature, vegetation, and society are coupled
- Vulnerability to climate change is “distributional” and occurs at multiple scales
  - Neighborhoods vary in risk and coping capacity for heat
  - Vegetated cool refugia are a management opportunity
- Slow and fast variation requires long-term research to understand
  - Local effects of regional high temperature events are determined by decadal landscape changes