Challenges of using ecosystem services to moderate urban heat riskscapes

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Image: 1920 Chamber of Commerce Report

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Consequences of Rising Urban Temperature

- Increasing Temperatures
  - Human Health / Comfort
  - Ecosystem Processes
    - Water Use
  - Electricity Usage
    - Economic Costs
    - Greenhouse Warming
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

Negative Impact

Coping

Exposure Risk

Hazard
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

![Graph showing change in proportional class coverage over years (1900-2000). The graph indicates a decrease in desert coverage and an increase in agriculture and urban areas.]

MAP OF
PREHISTORIC
IRRIGATION CANALS
DR. OMAAR A. TURNER FRGS.
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. Turner,
How has urbanization affected regional climate?

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

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*Warming and vegetation are associated with socio-economic status*

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Regional Societal, Vegetation, and Climate Relationships
Vegetation Varies in Urban Landscapes

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

Source: Juan Declet-Barreto
Seasonal Dependence of Vegetation Heat Mitigation

Correlation Coefficient: NDVI x Surface Temperature

Day of Year

- 2000
- 1990
Meteorology and Surface Temperatures

- Bare Soil Temperature (°C)
- Temperature Reduction / NDVI (°C)
- Air Temperature (°C)
- Bare VPD (kPA)
Vegetation Surface Temperature Effect

Estimated Surface Temperature (°C)

Day of Year

Bare Surface
Fully Vegetated
Using Irrigation for Cooling

Basic Equation (Watts/m²)

\[ R_n = H + \lambda E + S \]

- Radiation
- Sensible Heat
- Heat of vaporization
- Evaporation rate
- Storage

\[ E = \frac{(R_n - H)}{\lambda} \]

- 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

Evapotranspiration (mm/day)
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

![Graph showing the relationship between Median Income (1000$), NDVI, and Correlation Coefficient over years 1960 to 2010. The graph illustrates the development of heat risks over time.]
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