Phoenix, AZ Heat as a Social Ecological System

A Tool for Analyzing the Urban Heat Island

Paul Chakalian, School of Human Evolution and Social Change, Arizona State University – paul.chakalian@asu.edu

The Urban Heat System

- Heat is a form of energy. Due to the law of conservation of energy, heat cannot be created or destroyed, only moved or transformed..
- Heat in the city can be conceptualized as a social ecological system, diagramed in the system representation to the right.

*Notated parentheticals refer to the system representation throughout this poster.

Heat In The Urban Landscape

The combination of anthropogenic urban heat and high urban heat capacity creates the **urban heat island**– a situation in which an urban area is significantly warmer than its surrounding environment. This is particularly relevant during extreme heat events, when public health is at risk.

- Energy is brought into cities via extraction and generation, modifying the earth's energy equilibrium (C,D).
- Unintentional heat– excess energy not used in the urban system– flows back toward cooler paces, toward equilibrium (D,4).
    - E.g. the heat of a car is unused energy originally inside gasoline (6).
- Landscape features and prevailing atmospheric dynamics dictate how quickly urban waste heat dissipates (D,7).
    - In many cases, the physical features of a city store more heat than undeveloped land, i.e. urban land usually has a higher heat capacity than rural land.
- This type of heat can warm a large or dense city beyond the temperature of its surrounding environment before the heat can equilibrate back into the environment.

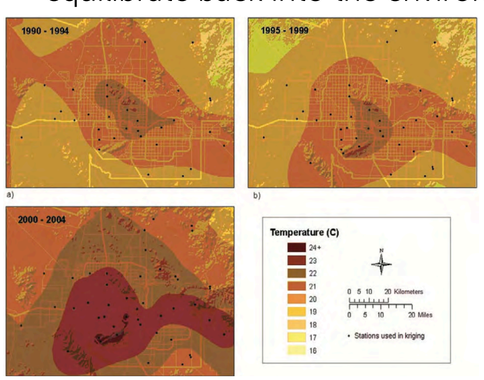

Fig 1. "Mean June minimum air temperature patterns interpolated through ordinary kriging over 5-yr periods in the PMA [Phoenix Metro Area]. Temperature data were taken from 37 stations distributed throughout the PMA (Source: Brazel et al. 2007)."

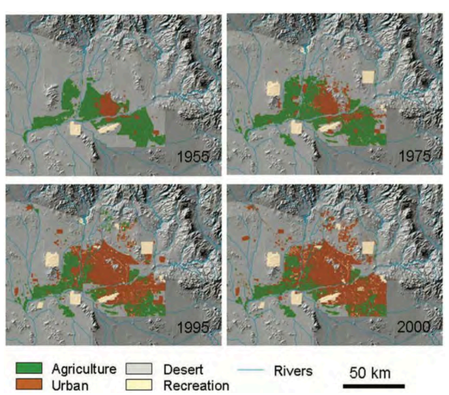

Fig 2. "Land use/land cover (LULC) change in the PMA from 1912 to 2000 [Source: Central Arizona–Phoenix Long-Term Ecological Research (CAP-LTER)]."

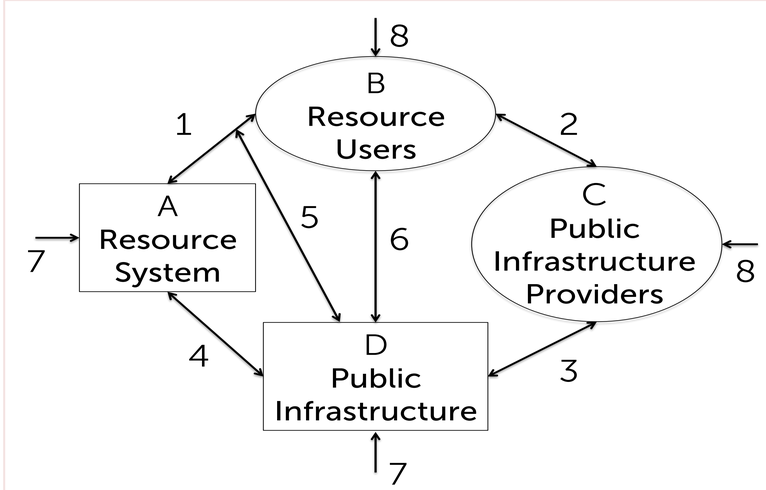

Fig 3. System representation of urban heat

Urban Heat is a Social Ecological System

Cites have finite capacities to dissipate heat (A), and resources users (B) in the city use that capacity when they bring unintended heat into the city via mechanical inefficiencies and land use changes (1,6).

- City residents create more heat when they cool their personal environments using air conditioning and fans, creating a positive urban heat feedback (1,6).

Hard and soft human made public infrastructure (D) provided by the city (C) mediates the relationship between the resource users and the resource via building materials, shade structures, flora, urban design, zoning, coding, and policy (4,5,6).

The entire system is vulnerable to exogenous shocks:

- The public infrastructure providers are vulnerable to socks through political and economic variability.
- Resource users are vulnerable to shocks from variable finances and mobility.
- The resource system is vulnerable to shocks through climactic and weather changes– particularly from global warming.
- The public infrastructure is vulnerable to shocks through disasters and natural entropic processes.

Urban Heat is a Common Pool Resource Problem

The potential for under investment in public infrastructure and over appropriation of the resource creates a common pool resource problem. The institutions in the Phoenix case study create a public goods social dilemma: no individual will pay enough for the non-excludable benefits of public cooling infrastructure (2), resulting in private cooling behaviors (6) at the expense of optimal aggregate cooling.

- Every resource user acting in their own best interest undermines the best interest of the group.
- The availability of the resource can be amplified or attenuated by human-made public and private infrastructure (5).
    - E.g, public green spaces, building codes, and public transportation, or private net-heat-generating air conditioning, automobiles, and freeways.

What are the Governance Challenges?

By using a system representation to help identify where policy interventions would be most effective policy makers are better equipped to handle the urban heat problem.

In the Phoenix, AZ case, several specific governance challenges present themselves:

- Measuring the city's capacity to dissipate heat (C,D).
- Determining an equitable distribution of that resource (2).
- Monitoring and sanctioning that distribution (5,2,3).
- Keeping the resource and its distribution robust to shocks (7,8).

References:
-Figure 1. Adapted from "Urban Heat Island Research in Phoenix, Arizona: Theoretical Contributions and Policy Applications" Winston T. L. Chow, Dean Brennan, and Anthony J. Brazel, 2012. *Bull. Amer. Meteor. Soc.*, 93, 517–530.
Figure 2. Adapted from "Urban Heat Island Research in Phoenix, Arizona: Theoretical Contributions and Policy Applications" Winston T. L. Chow, Dean Brennan, and Anthony J. Brazel, 2012. *Bull. Amer. Meteor. Soc.*, 93, 517–530.
-Figure 3 Adapted from "A framework to analyze the robustness of social- ecological systems from an institutional perspective" by Anderies, J. M., M. A. Janssen, and E. Ostrom. 2004. *Ecology and Society* 9(1): 18 Copyright 2004 by the authors.