Ecological Response to Land Use Change Along an Urban – Wildland Gradient

Fourth Annual Symposium
Research Insights in Semiarid Ecosystems

John Briggs (john.briggs@asu.edu) and Nancy Grimm (nbgrimm@asu.edu)

Central Arizona – Phoenix Long-Term Ecological Research CAP LTER

Global Institute of Sustainability

T. Trimble photo

BOX 1. KEY RESEARCH QUESTIONS TO GUIDE DEVELOPMENT OF CONTINENTAL AND REGIONAL OBSERVATIONAL NETWORKS FOR UNDERSTANDING THE INTERACTIONS OF URBANIZATION, POLLUTION, AND CLIMATE CHANGE

- Q1: What are the ecological and socio-ecological consequences of local land-use changes at regional and continental scales?
- Q2: Does urbanization increase or decrease social, physical and biological connectivity at local, regional, and continental scales?
- Q3: How will varying patterns of urbanization interact with climate change across continental gradients in climate and land cover to affect ecosystem processes and services?
- Q4: How are pollutant source and deposition regions (connected through air and water vectors) related to patterns of land use, and how do ecosystem structure, function and services respond to changes in pollutant loadings resulting from changing land use?

Central Arizona-Phoenix Ecosystem

Climate: precipitation ~ 180 mm/y
Salt and Gila river confluence
CAP study area=6,400 km^2
Rapidly growing human population:
1950: 330,000
2007: >4 million
Rapid urban expansion


D.Hope photo

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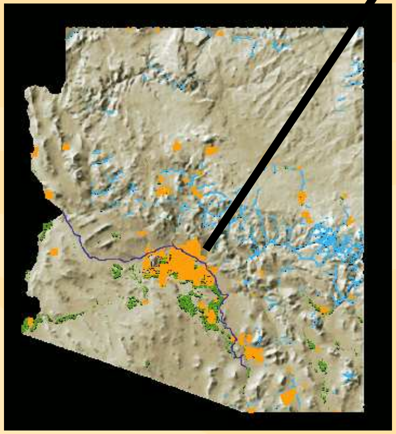
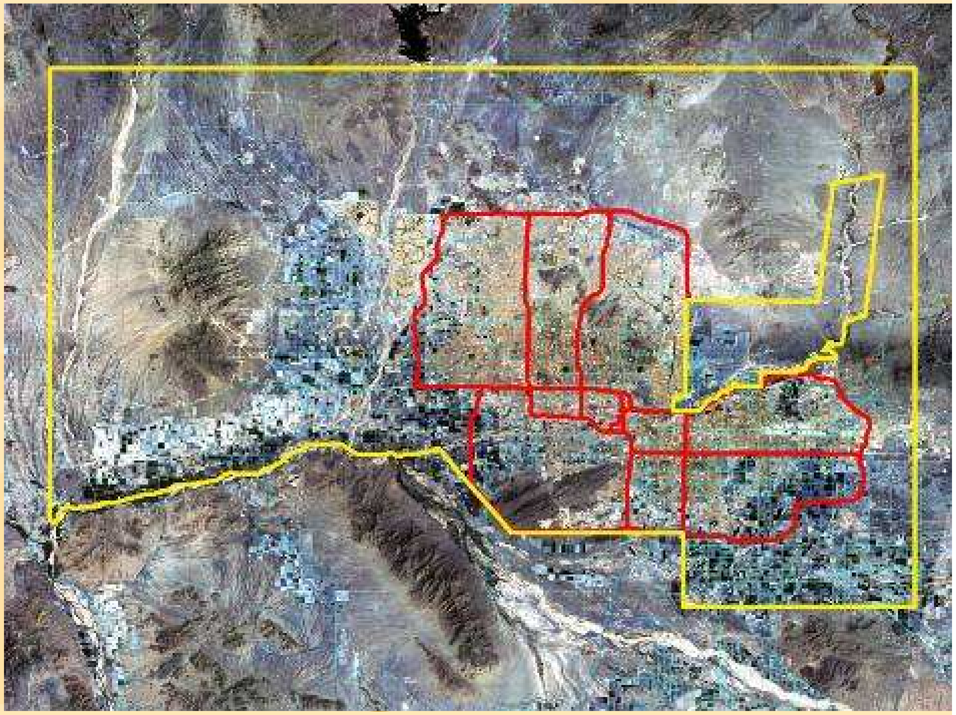
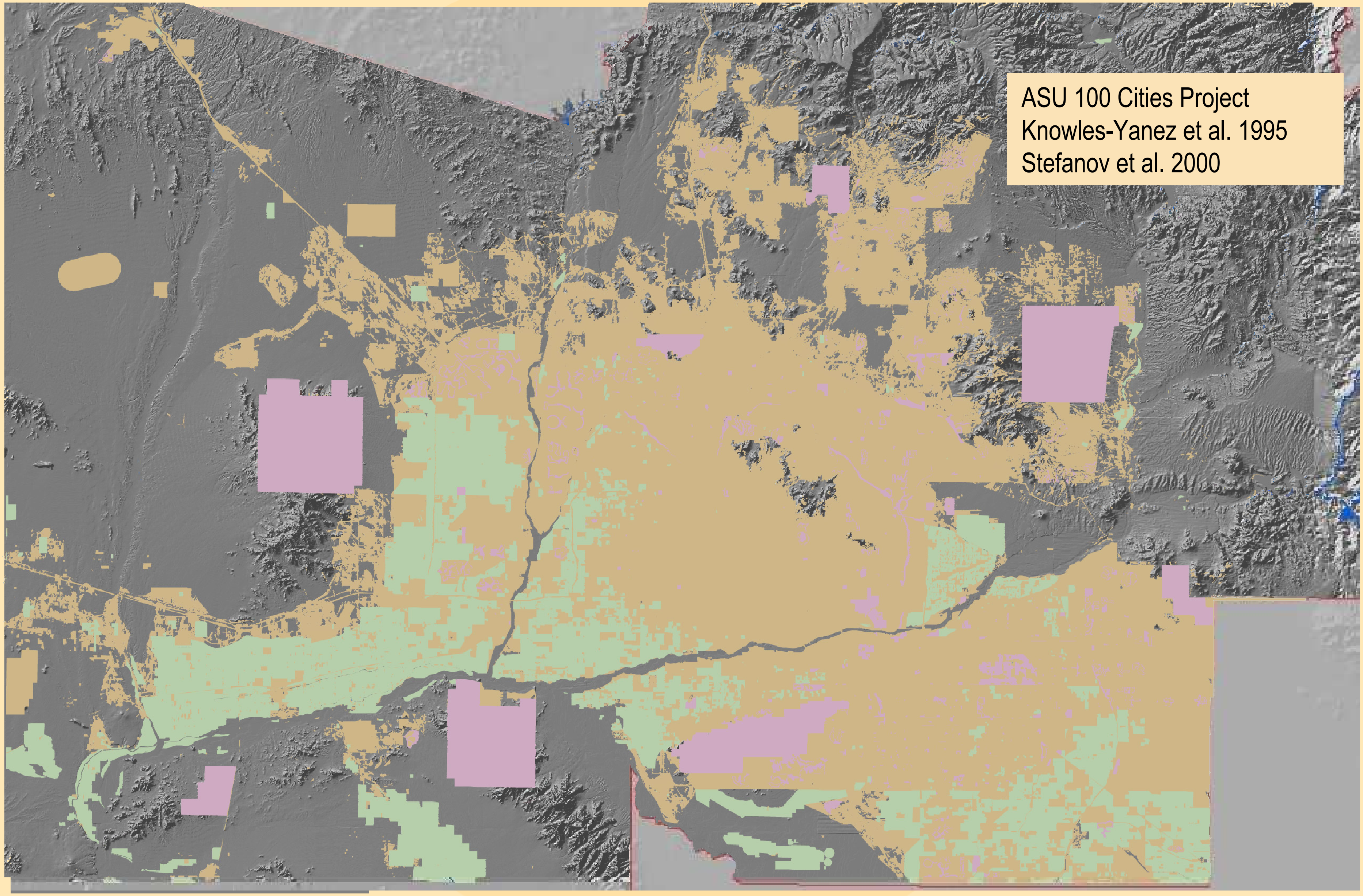
LTER





Central Arizona - Phoenix Historic Land Use



1912 1934 1955 1975 1995 2000 2006

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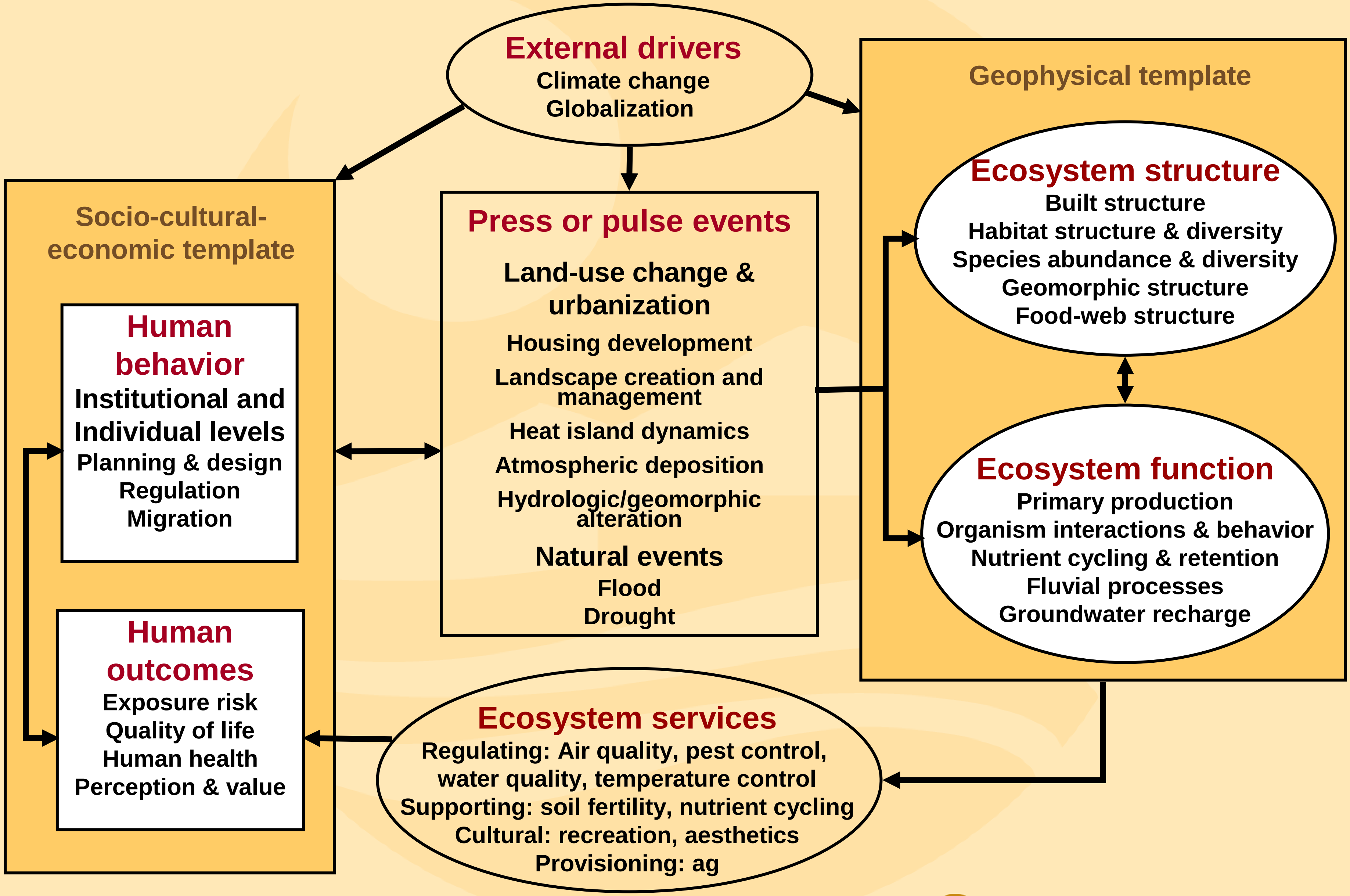
Overall Conceptual Theme – Socio-Ecological Interaction

How do the patterns and processes of urbanization alter ecological conditions of the city and its surrounding environment, and how do ecological consequences of development feed back to the social system to generate future changes?

N. Grimm photo

Conceptual Framework for CAP2 – July 2007



After Collins et al. 2007 ISSE

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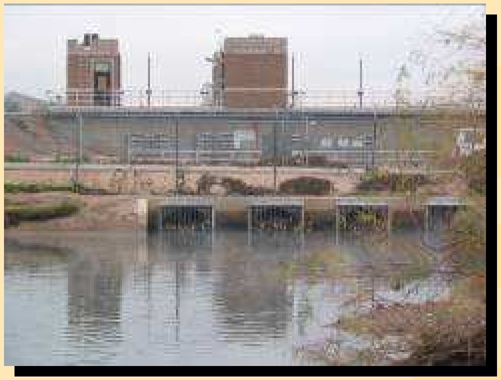
Integrative Project Areas

- Land-use /land-cover change
- Climate-ecosystem interactions
- Water policy, use, and supply
- Fluxes of materials and socioecosystem response
- Human control of biodiversity

Research Approaches

- Analysis and synthesis of existing data
- Long-term monitoring
- Experiments
- Comparative ecology
- Models



Cross-Cutting Research

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Land-use and cover change

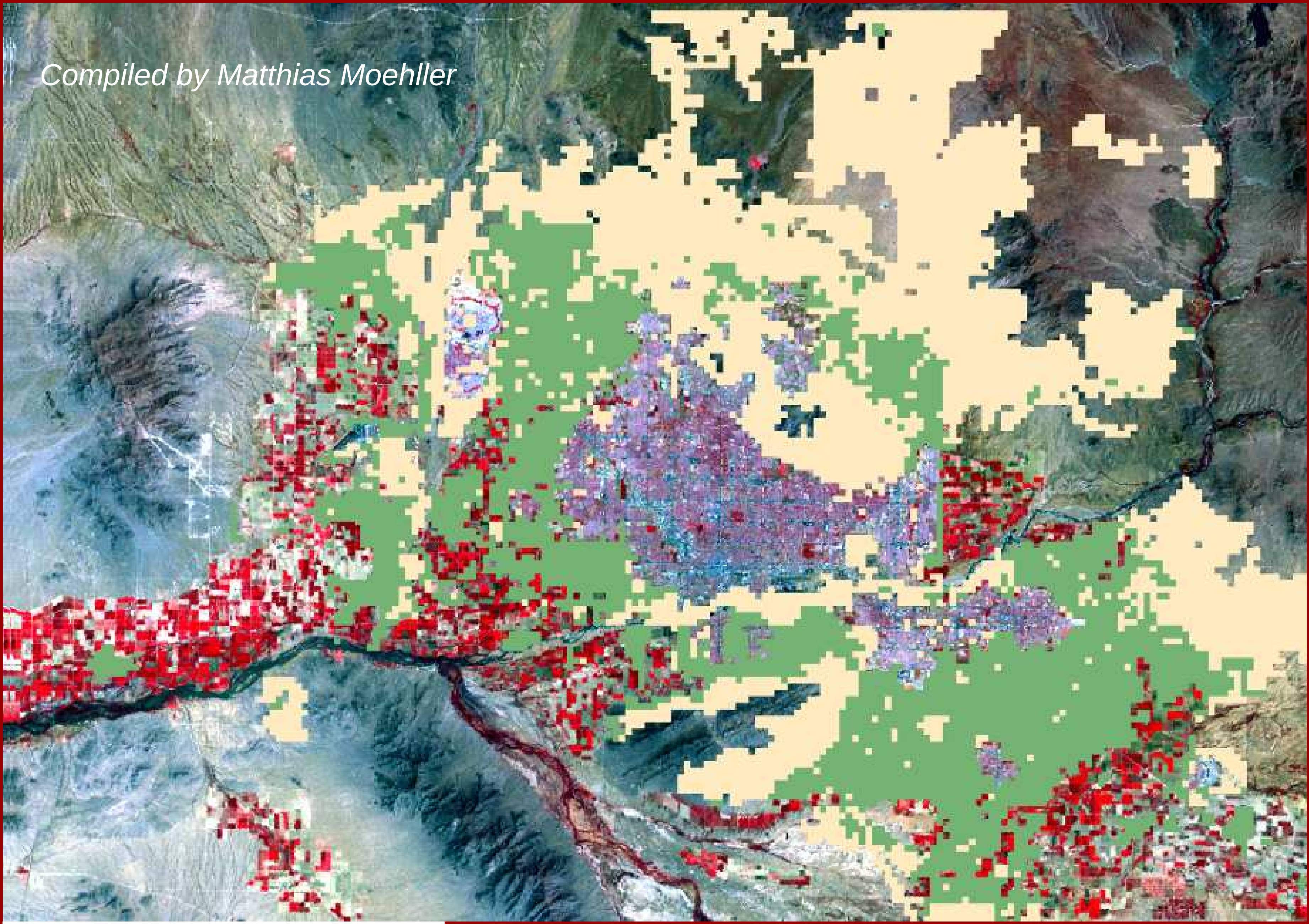
How have land use and land cover changed in the past, and how are they changing today?

- **CAP scientists have documented rapid land transformations using remote sensing and classification**

How do land-use and land-cover changes alter the ecological and social environment in the city, and how do human perceptions of these changes alter future decision making?

- **This question sets the stage for all other IPA research**

B. Shears photo

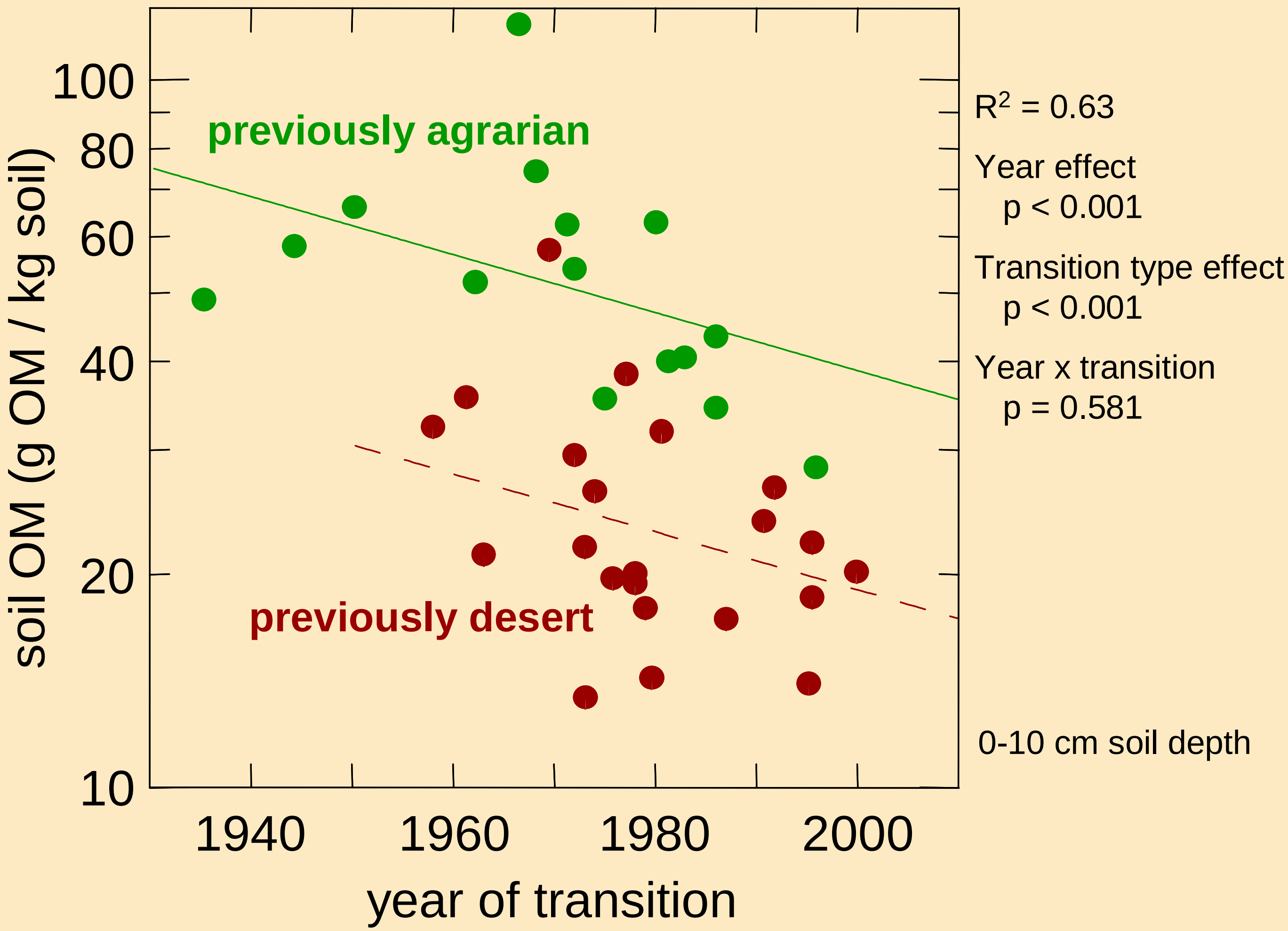


Transition 1973 - 2003

transition from agricultural use to urban use

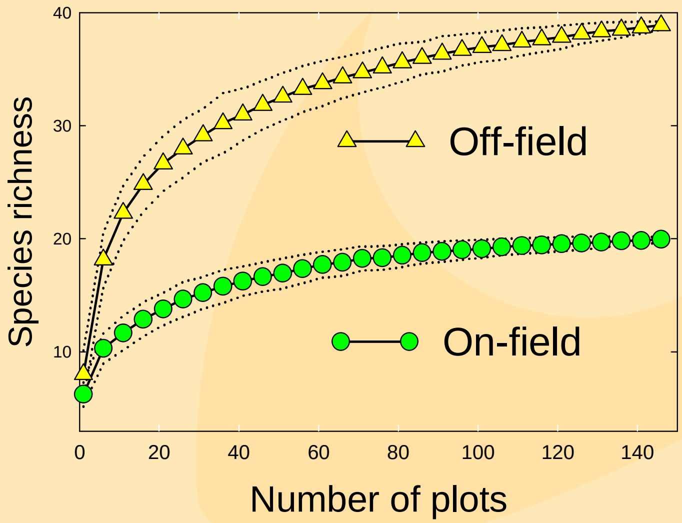
transition from desert lands to urban use

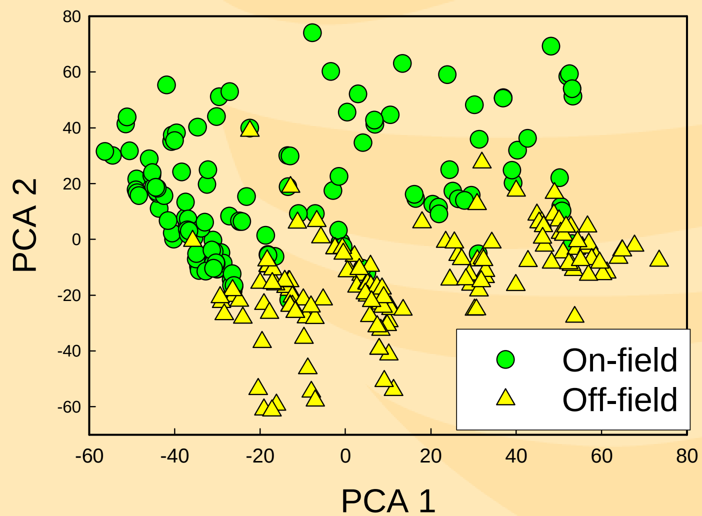
Agrarian landscapes in transition:
Soil organic matter in urban, residential yards



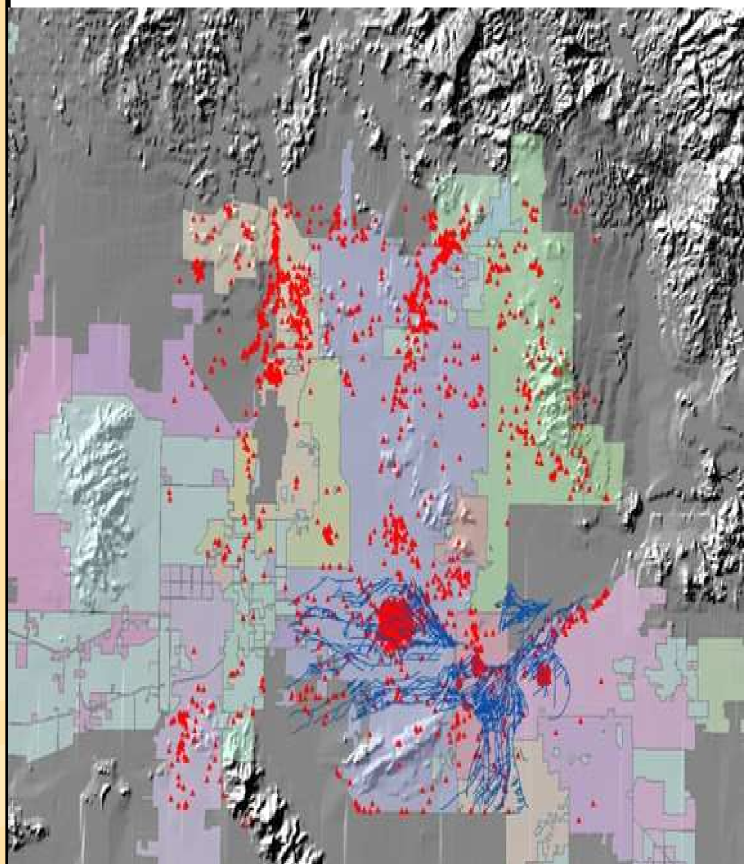
Lewis et al. 2006 Glo Chg Biol

Prehistoric Agrarian





Prehistoric Extent of Settlement in the Phoenix Basin



Map of Phoenix Basin showing location of Hohokam villages ▲ and canal system ∿ with modern city areas..

Pastel areas represent modern cities.

Briggs et al. 2006. Ecology needs archaeologists: Archaeology needs ecologists. Frontiers in Ecology and the Environment 4:180-188

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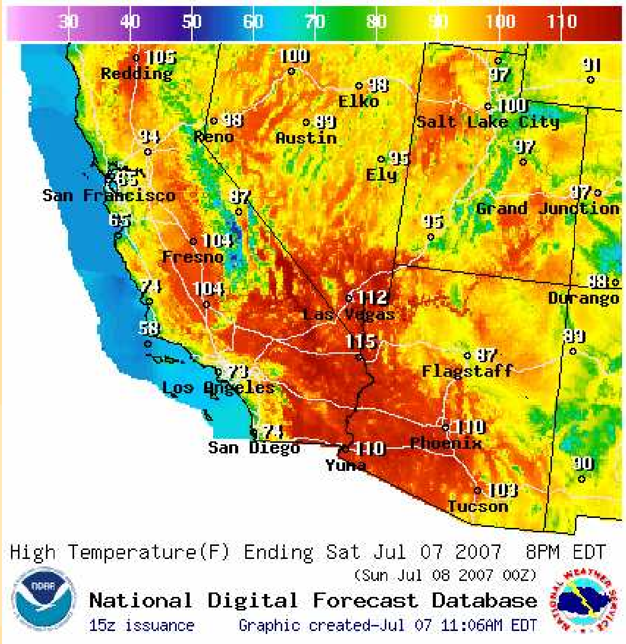
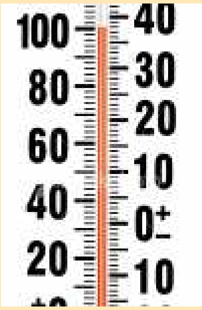
Climate – Ecosystem Interactions

How do regional drivers influence local climate as urbanization proceeds?

What are people's perceptions of their local environment, including climate, and how does that affect their assessment of neighborhood or regional quality of life?



What are the interactions among local management, local climate, net primary production and vegetation processes?



Temperature increase over the past 50 years of urbanization due to UHI exceeds any rise yet attributable to global climate change. This change has both ecological and social effects (Brazel et al 2000, Baker et al. 2002).

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"INFLUENCE OF URBANIZATION ON WEATHER IN THE ARID PHOENIX METROPOLITAN AREA"

NSF ATM-0710631

PI: S. Grossman-Clarke, ASU
Co-PI: C.S.B. Grimmond, King's College London & J.A. Zehnder, Creighton University
Collaboration: F. Chen, National Center for Atmospheric Research
Other key personnel: W. Chow, Graduate Student, ASU

An Urban Canopy Model (UCM) was recently released by the National Center for Atmospheric Research for use with the Weather Research and Forecast Model (WRF), to improve model performance in urban areas for weather, climate and air quality applications. The WRF/UCM represents the geometry of urban land use/cover and includes urban specific processes in the surface-energy balance such as anthropogenic heating, radiation trapping, and heat storage in built surfaces.

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Influence of Urbanization on Meteorological Processes in the Arid Phoenix Metropolitan Area

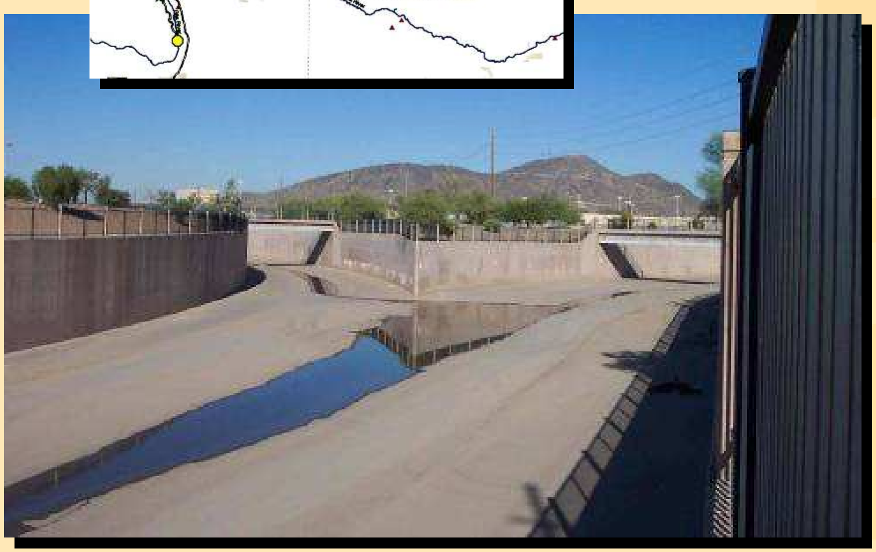
- Influence of land use changes on urban surface meteorological variables and planetary boundary layer characteristics.
- Interaction of thermal circulations driven by complex terrain with potential mesoscale circulations caused by land use changes.
- Influence of urbanization on convective activity during the North American Monsoon.

WRF with the UCM-KK

Urban Canopy Model UCM-KK (Kusaka and Kimura, 2004)

Evaluation of the UCM-KK

- Use independent surface energy balance measurements for several cities.
- Implement model refinements into WRF.



Water policy, use, and supply

- What are the ecological and economic consequences and potential vulnerabilities of shifting natural hydrology to managed/engineered systems?
  - **Large modifications to the hydrosystem**
  - **Water-conservation education efforts as yet ineffective (Gustafson, Larson and Hirt, unpublished data)**
  - **This IPA very connected to DCDC and fluxes research**

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Fluxes of materials and socioecosystem response

How do urban element cycles differ qualitatively and quantitatively from those of non human-dominated ecosystems?

- ► **Altered atmospheric chemistry, climate, and hydrology, added nutrients, and changes in land use affect the cycling of materials within and transfer between air, soil, water, and groundwater (Kaye et al. 2006)**

What are the sociospatial distributions of anthropogenic toxins and other pollutants in the CAP ecosystem, and what hazards to organisms (plants, animals, humans) result from these distributions?

- ► **Toxic materials disproportionately affect poor and minority populations (Bolin et al. 2002, Grineski et al. 2007)**

Human control of biodiversity

How do human activities, behaviors, and values change biodiversity and its components—population abundance, species distribution and richness, and community and trophic structure?

- **Biodiversity declines (exc. plants)**
- **Our designed ecosystems are not functionally equivalent to natural ones (Faeth et al. 2005, Cook et al. 2006, Hope et al. 2003)**

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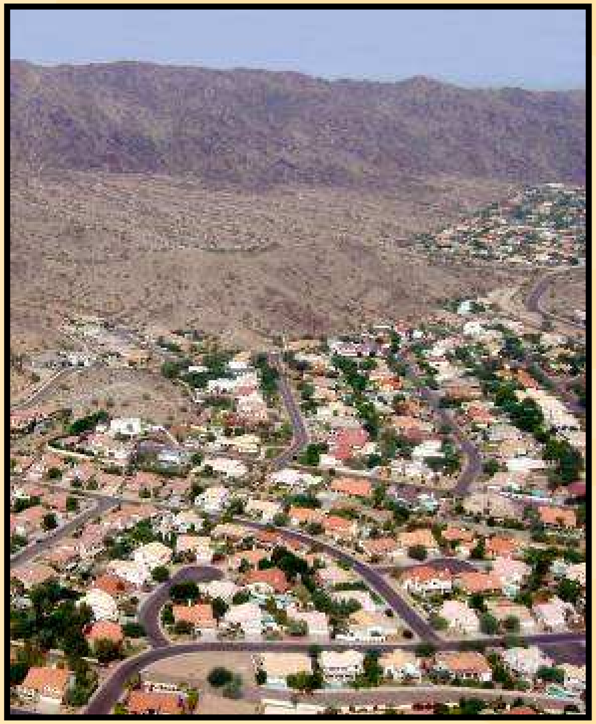
Cross-cutting research activities

- 200-Point Survey ("Survey 200") - monitoring
- Phoenix Area Social Survey ("PASS") - monitoring
- 'Suburbosphere' at North Desert Village ("NDV") - long-term experiment
- Ecosystem services



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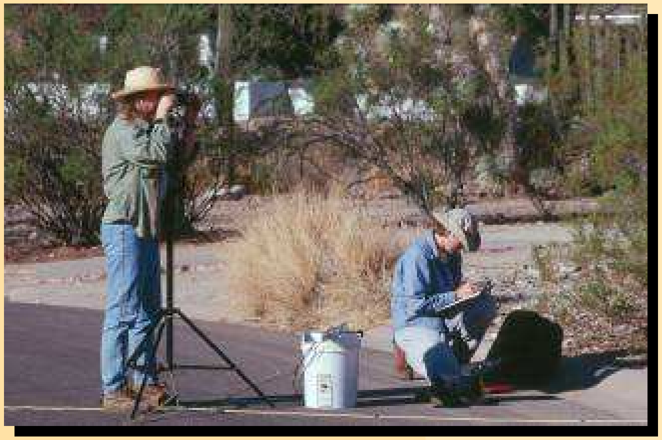
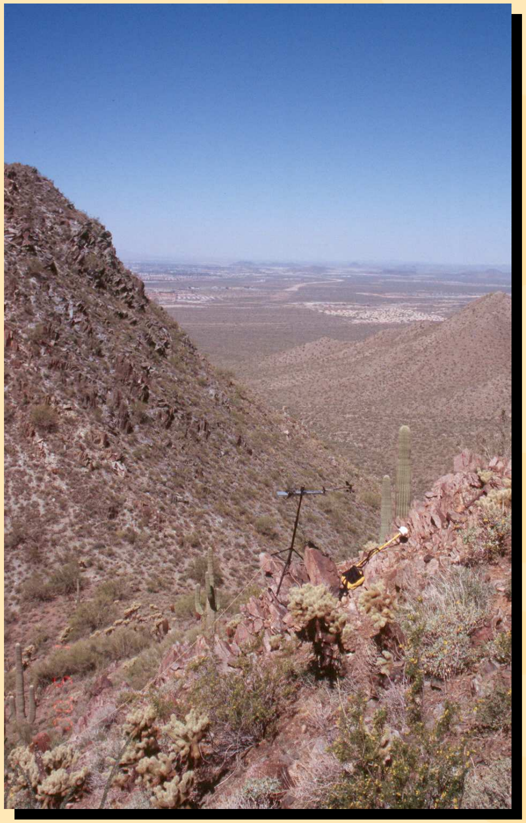
Survey 200: Research goals and key questions





- **What are the main ecological characteristics of CAP?**
  - Obtain snapshot of key slow-cycle variables
- **Are they best explained by physical, ecological, or geographical variables, or by land use (current & past) and socioeconomic variables?**
  - Tie-in with other survey data (e.g., 2000 Census)

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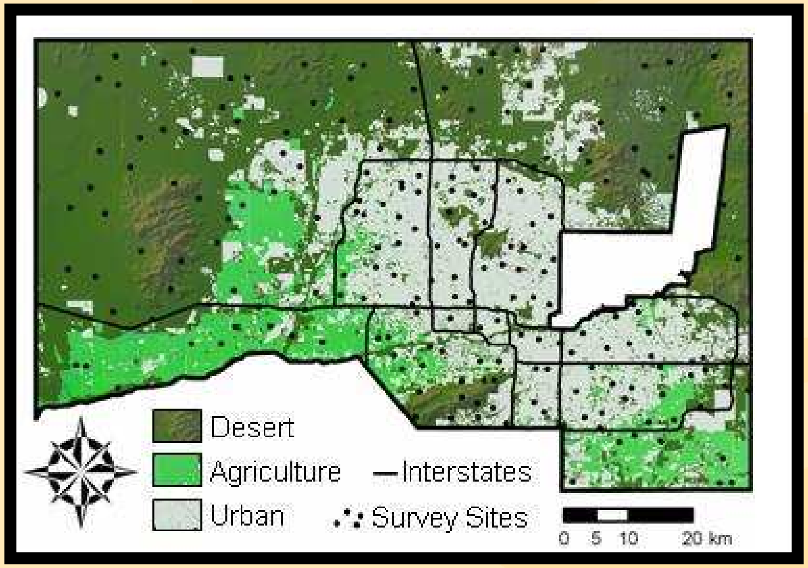
Design

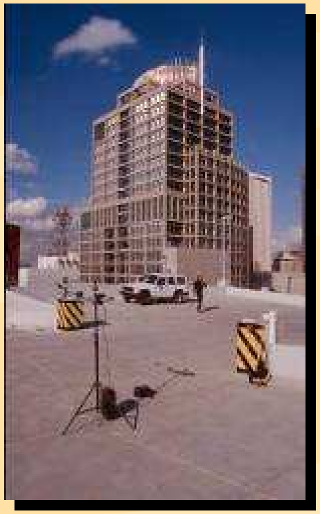
- Tesselation-stratified plot distribution
- 5 km x 5 km grids; more in urbanized area
- Plot location: random within grids, GPS located, aided by air photos/remote sensing
- Plot size: 900 m2 (30 m x 30 m)
- Sample frequency: spring every 5 y

Variables

- photos from plot center
- vegetation species composition and cover
- weather
- soil physical, chemical, and biological properties
- bird point counts and human activity surveys
- arthropods
- built structure



CAP Survey 200



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Survey 200: some recent results

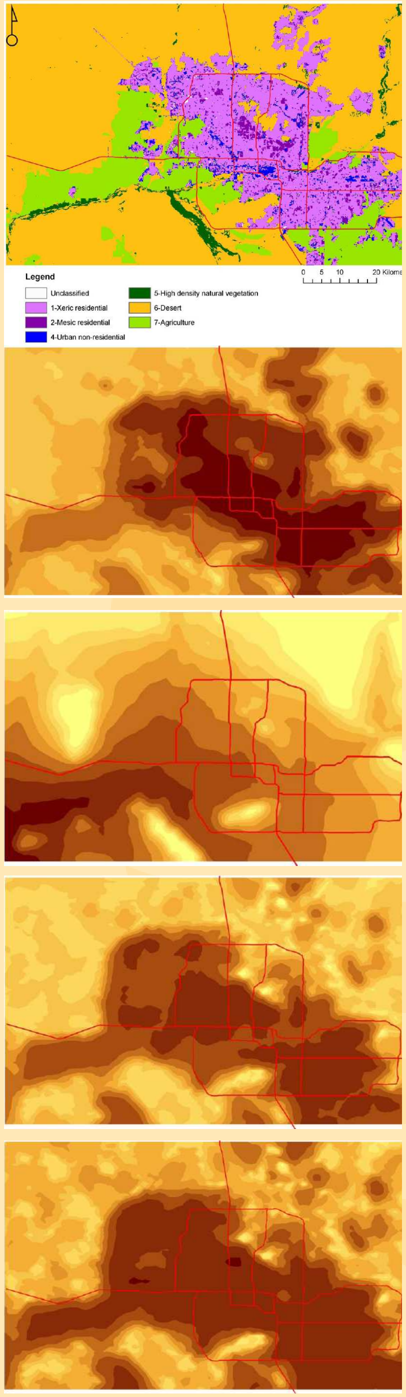
Land use

oC

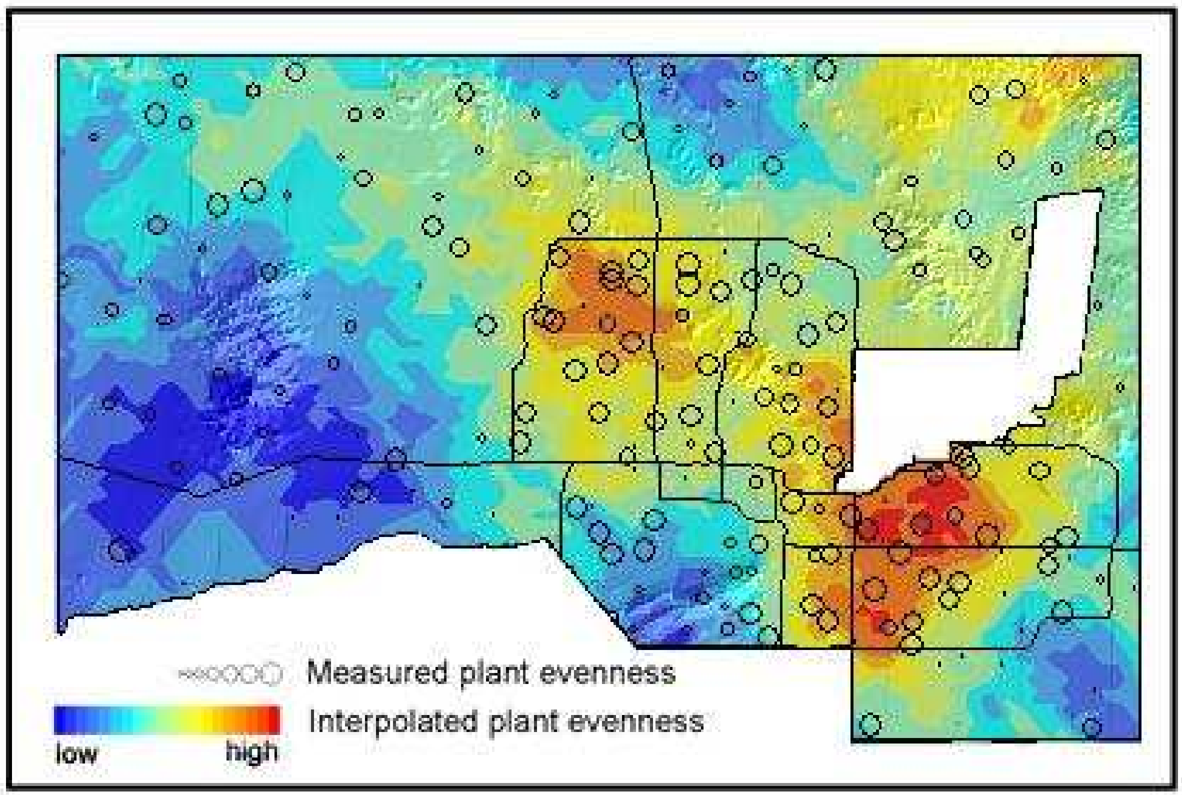
iC

TN

TP



Kaye et al. in press Ecol. Appl.



Walker et al. in review

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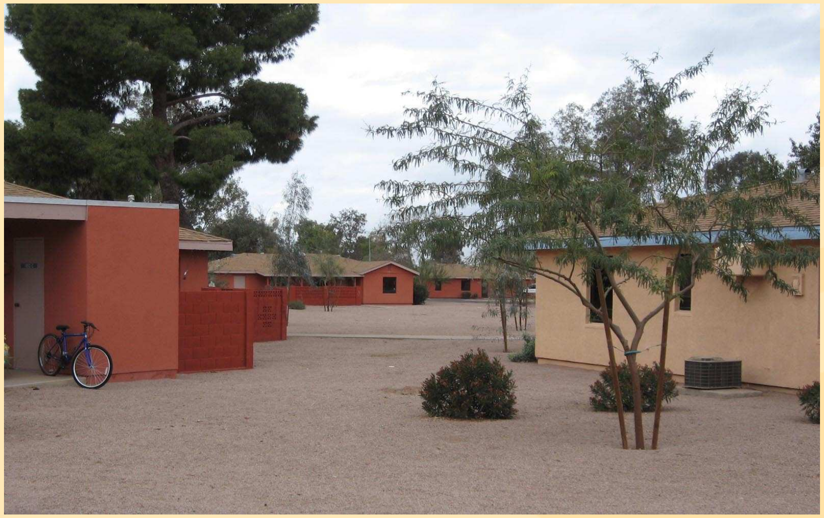
NDV Landscape Design Treatments

Present appearance

Mesic

Oasis



Xeric

Native

Cook et al. 2004

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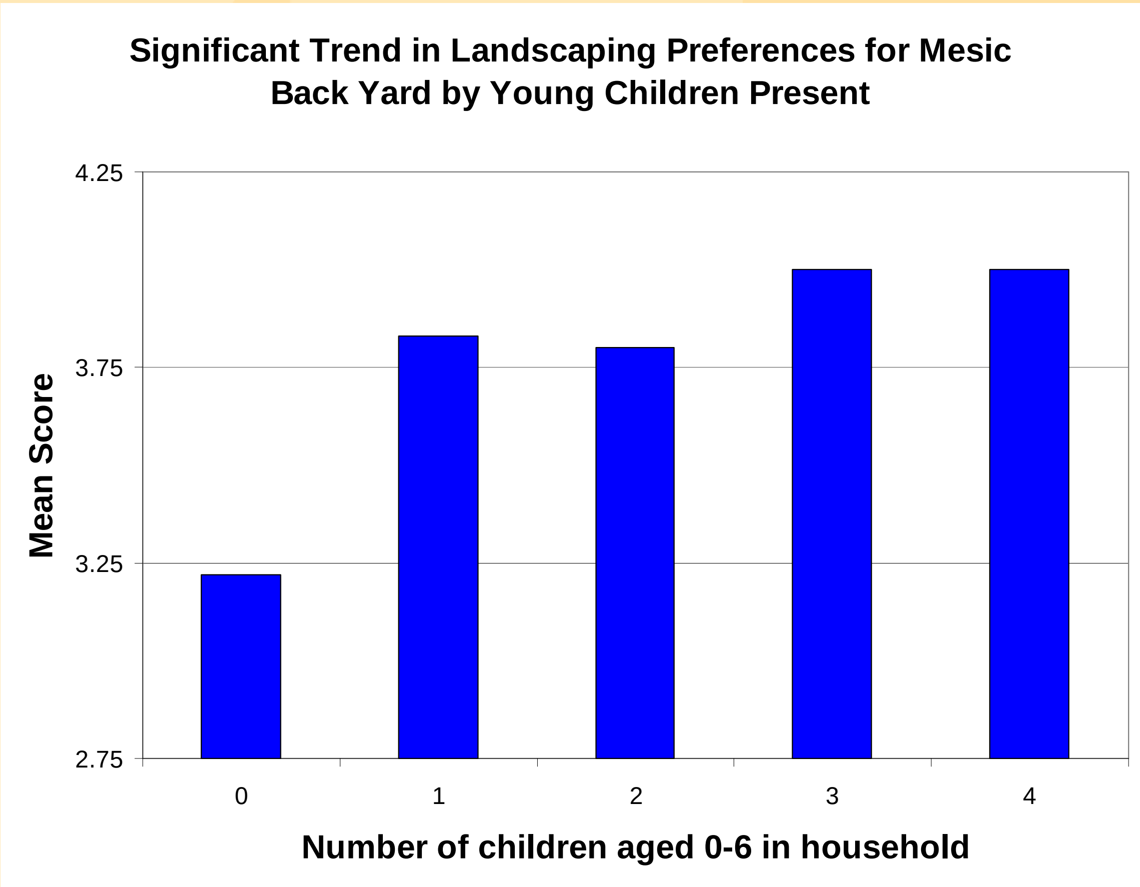
Predictors of Landscape Preferences

- **Households with young children rate mesic landscapes higher**



Yabiku, Casagrande, and Farley-Metzger. Forthcoming. "Preferences for Landscape Choice in a Southwestern Desert City." *Environment and Behavior*.

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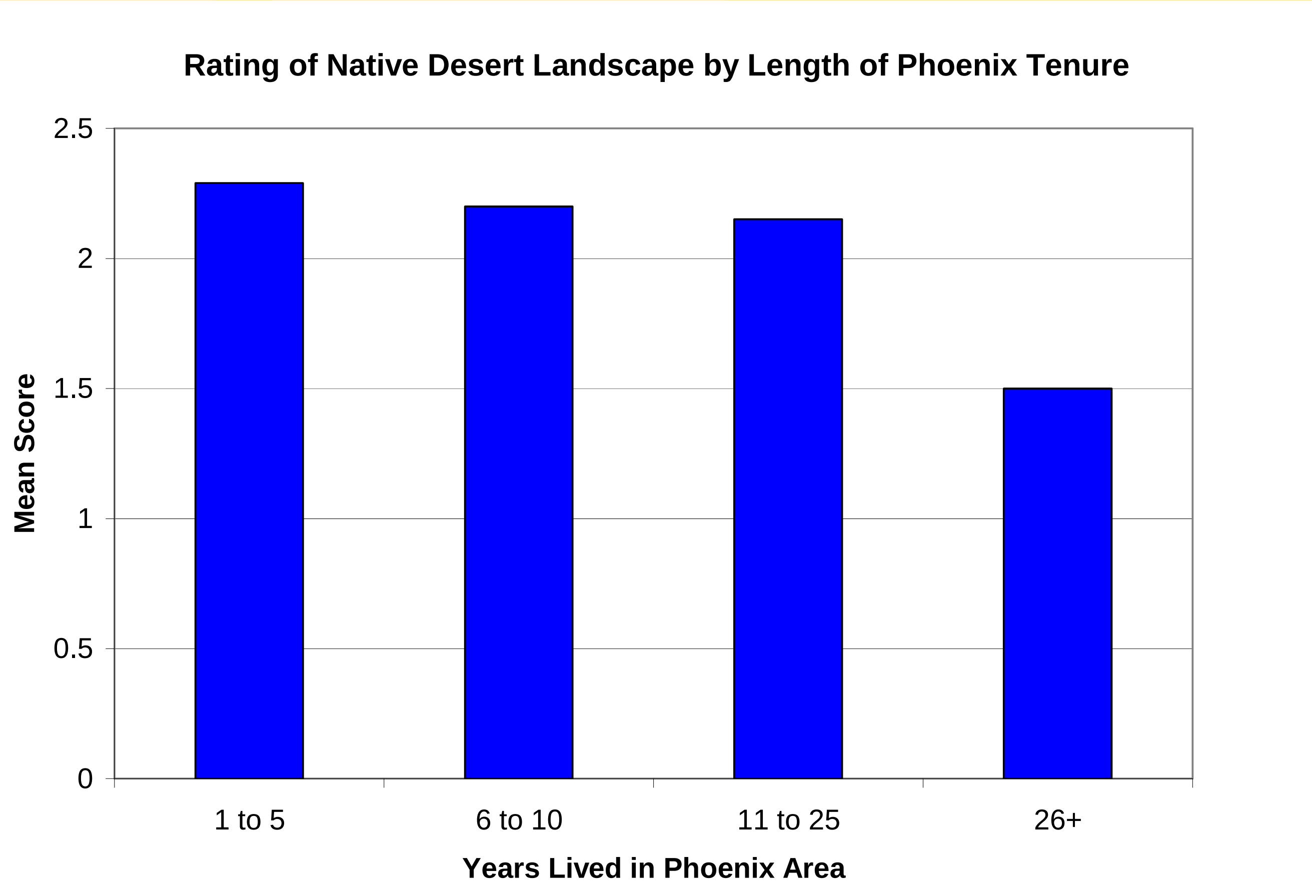
Predictors of Landscape Preferences

- **Longer residence in Phoenix = lower rating of Native, Xeric**



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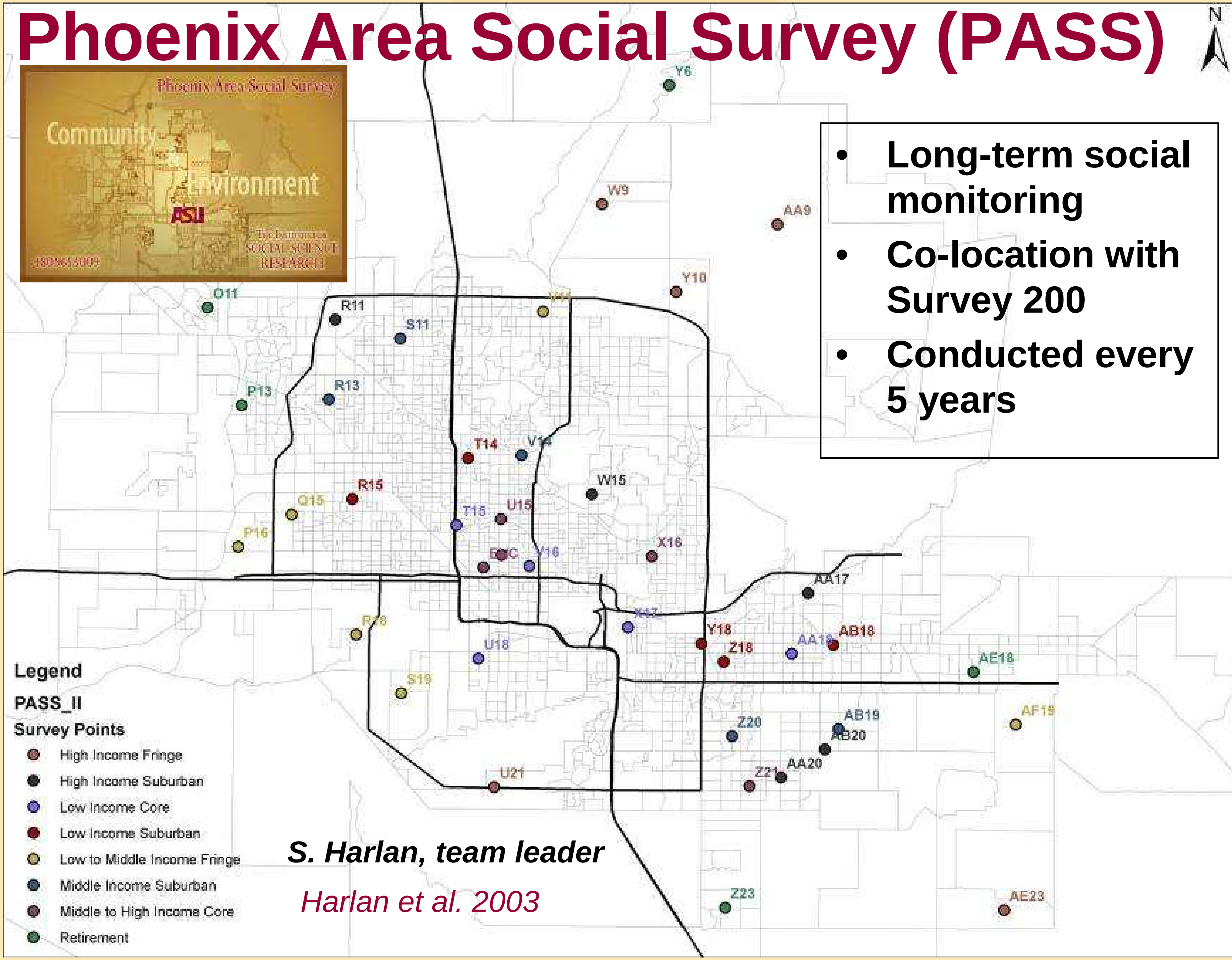
Phoenix Area Social Survey (PASS)



- **Long-term social monitoring**
- **Co-location with Survey 200**
- **Conducted every 5 years**

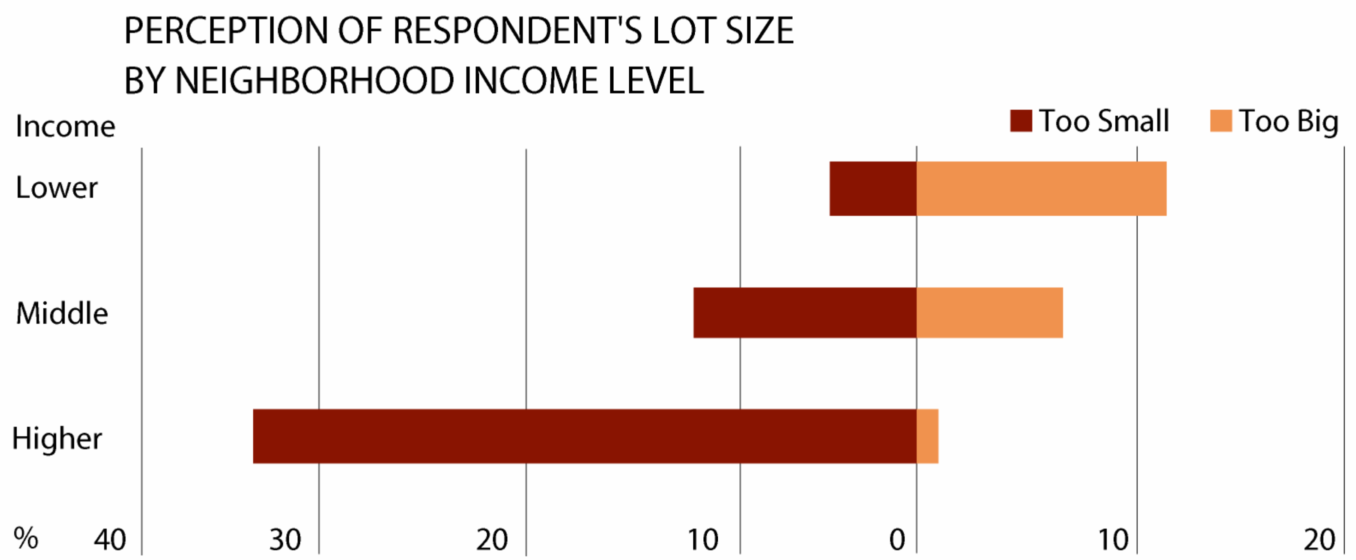
S. Harlan, team leader

Harlan et al. 2003

Phoenix Area Social Survey

SOME QUESTIONS:

- **How are social class inequalities and cultural differences are related to spatial variations in ecosystem characteristics?**
- **How do changes in socio-ecological systems affect the quality of life and vulnerability to environmental hazards for diverse human populations?**



Residents in higher-income fringe neighborhoods are more likely to think their lots are too small.

The reason is that their houses are too big.

ft^2 (median)	Neighborhood Income →		
	Lower	Middle	Higher
Home	912	1,272	2,879
Lot	11,186	8,699	9,797
Ratio (lot:home)	12.2	6.7	3.4
Pop /mi^2	7,980	5,323	1,865

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