COST FP1204 GREEN INFRASTRUCTURE

Nature based solutions for sustainable and resilient cities

ORVIETO, ITALY 4-7 April 2017

A SETS Perspective on Green Infrastructure and its Services

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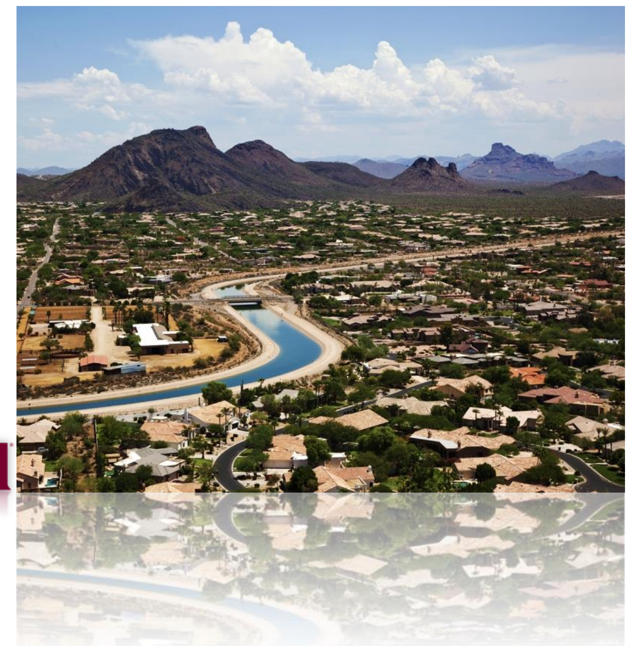
Professor, Arizona State University

Co-Director, Urban Resilience to Extremes Sustainability Research Network

6 April 2017



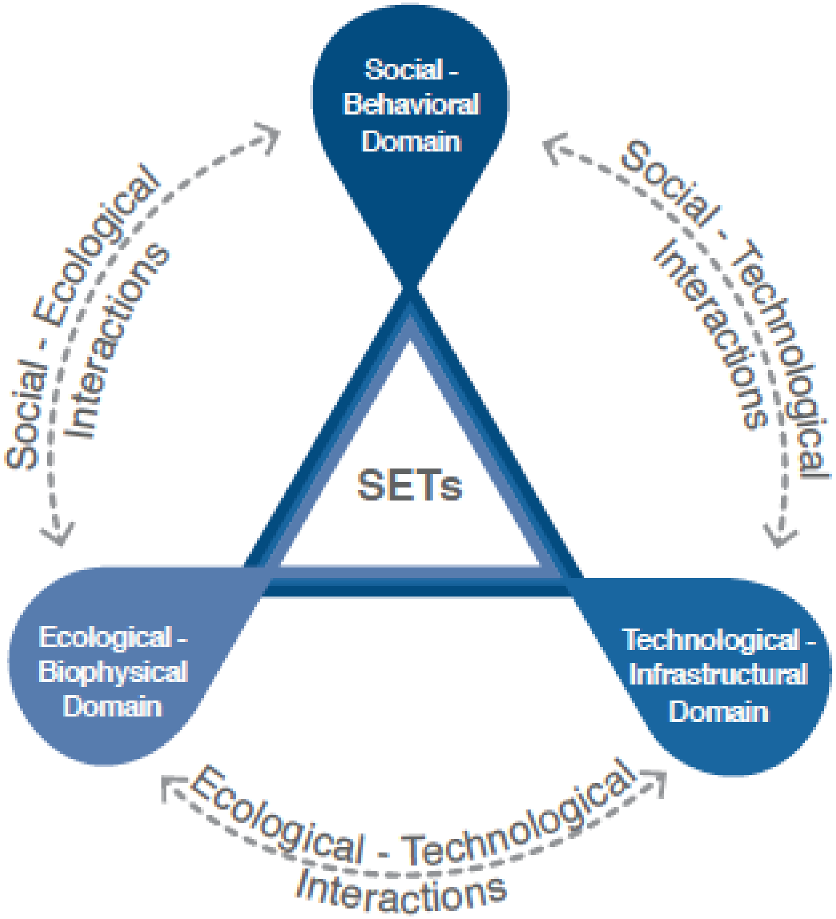
@DrNitrogen

@URExSRN

With thanks: Mikhail Chester, Elizabeth Cook, Melissa Davidson, David Iwaniec, Yeowon Kim, Lauren McPhillips, Timon McPhearson

Social-Ecological-Technical Systems (SETS)

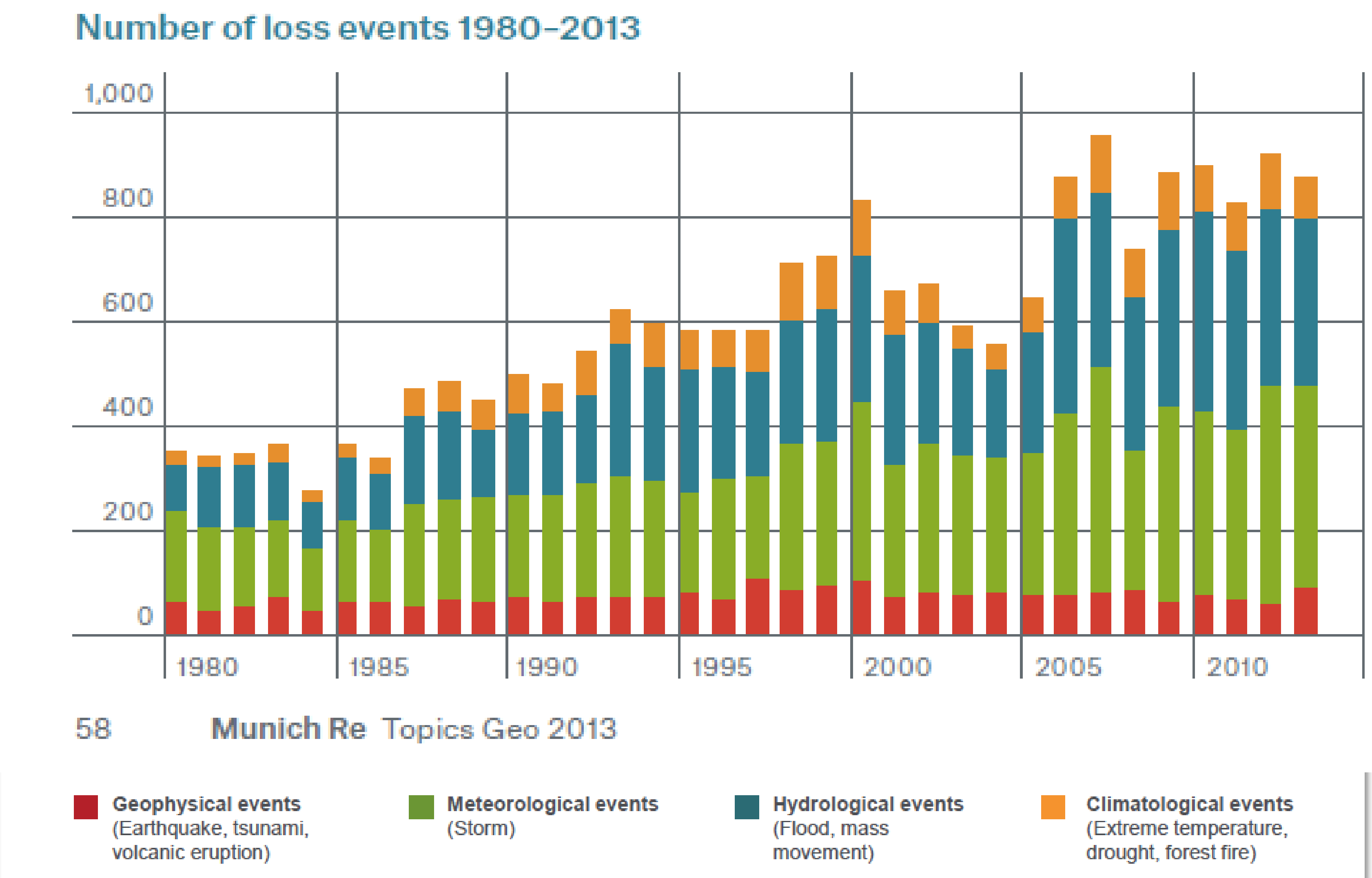
- What is SETS and why do we need this new concept?
- Infrastructure as SETS
- Services of SETS infrastructure
- SETS infrastructure as a resilient solution
- Application: building resilience in ten UREx network cities



(Depietri and McPhearson, in press)

Courtesy of Timon McPhearson

Anthropocene: an era of accelerating change



Anthropocene: an era of accelerating change

The Challenge

- Urbanization and climate change are on a collision course and infrastructure is their battlefield!
- ***Infrastructure***=Physical components of interrelated systems that provide commodities and services essential to enable, sustain, or enhance societal living conditions

Photo credit: Getty images

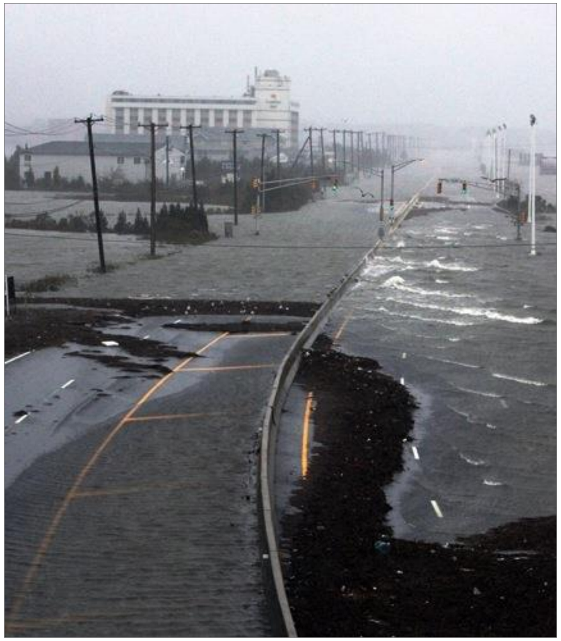


Photo credit: Tom Mihalek, Reuters

Built (technological) components (infrastructure), their functions, and services provided

Ecosystem component	Function	Service
Transportation network	Facilitating human movements	Provision of roadways, railways, and transport systems
Water delivery infrastructure	Water fluxes	Provision of water to users
Stormwater infrastructure	Water fluxes	Protection from flooding
Wastewater infrastructure	Water and sewage fluxes; physical and biogeochemical transformations	Sanitation, removal of wastes, improvement of water quality
Energy supply infrastructure	Heating, cooling, other work	Regulation of microclimate, provision of power for manufacturing, etc.
Housing and buildings	Structure and architecture	Provision of habitat

(Grimm et al. 2016, UGEC Handbook)

Infrastructure challenges in the Anthropocene (*esp gray infrastructure)

- inflexible, rigid
- in poor condition (ASCE reports)
- interdependent
- design based on probabilities that are not stationary
- decisions about infrastructure have social and ecological impacts
- expensive and inaccessible for rapidly growing cities in poor countries

Courtesy of Mikhail Chester

Urban infrastructure: a defining characteristic of cities

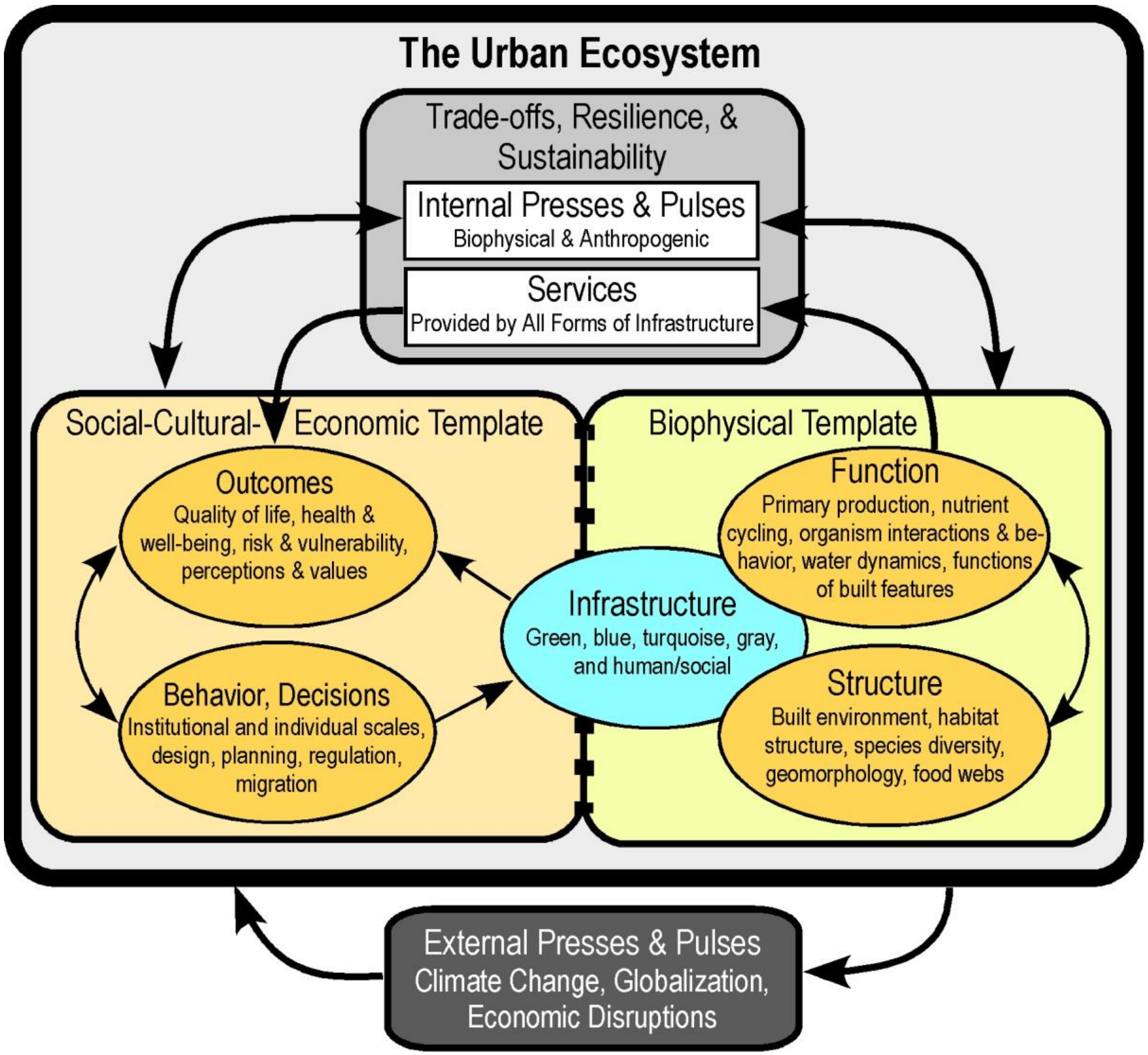
Urban infrastructure: a defining characteristic of cities

Urban infrastructure: bridging social-ecological domains

Service	Built Infrastructure	Non-Urban Nature
Water supply	Dams, wells, interbasin transfers (pipes, canals)	Streams, springs, rivers, lakes
Water delivery	Canals, pipes, plumbing	Streams, springs, rivers; gravity
Water quality assurance	Water treatment plants	Protected lakes and reservoirs, wetlands, rivers
Shelter	Housing, other buildings	Caves, trees*
Food provision	Food processing and storage plants, delivery systems	Farms, orchards, animal populations
Transportation	Roads, canals, public transit lines	Rivers, lakes, oceans*, land routes* and human-powered or passive transport systems
Energy supply	Power grid, power plants, delivery systems	Fire and biofuel*, sun*, wind*
Protection from flooding	Sea walls, river levees, drainage canals	Coastal wetlands, dunes, floodplains, natural terraces
Sanitation, waste removal and processing	Sewers, wastewater treatment plants, solid waste incinerators	Rivers*, soils*
Recreation and experience of nature	Parks, zoos, gyms, gardens, swimming pools, cinema, television, virtual reality	Forests, deserts, grasslands, rivers, lakes, streams, beaches, etc.

Grimm & Schindler, *in press*

CAP LTER New Conceptual Framework



Importance of infrastructure in bridging social and biophysical domains

Courtesy of Dan Childers et al.

CAP LTER Central Arizona – Phoenix Long-Term Ecological Research

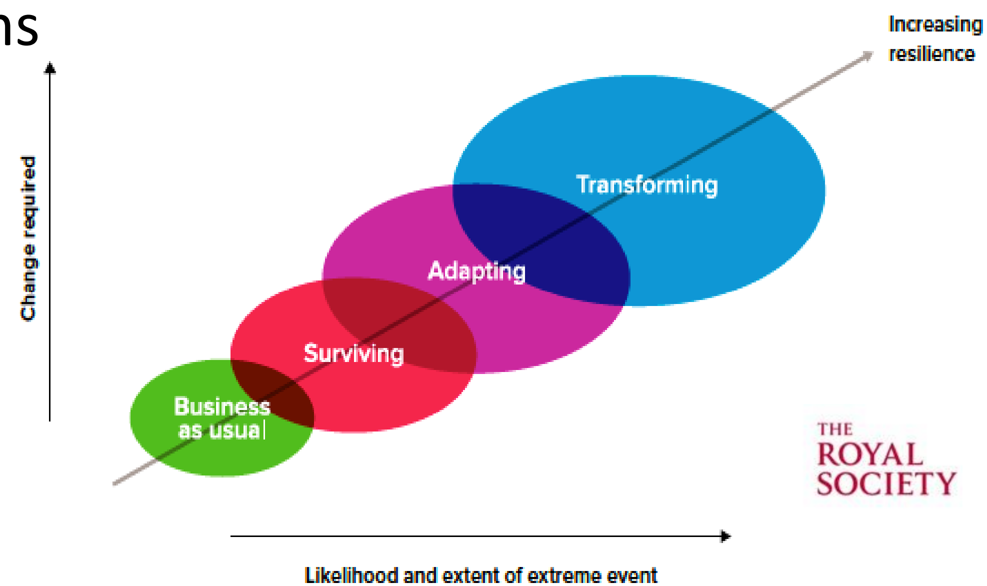
Extreme Events: the New Normal

- Immediate (local) impacts: ecological, social, infrastructural
- Impacts on supply chains/external systems
- Social/political strain from impacts
- Responses/solutions
    - Must be flexible, account for an uncertain future
    - Should incorporate social, ecological, technological elements – SETS!

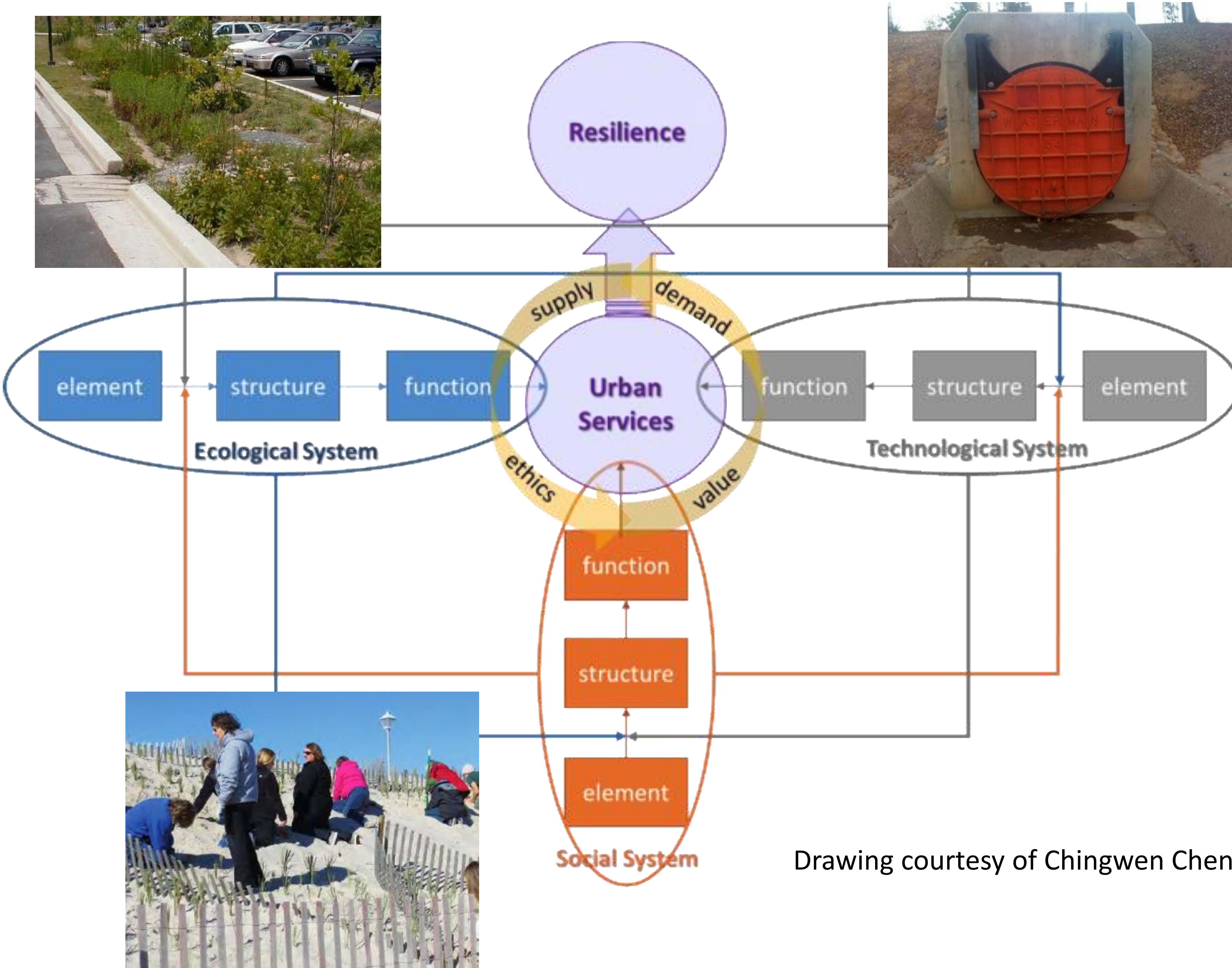
Resilience: an appropriate theoretical basis

- Resilience is 'the capacity of individuals, communities and systems to survive, adapt, and grow in the face of stress and shocks, and **even transform** when conditions require it'
  - *The Rockefeller Foundation, 2009, Building Climate Change Resilience*

- Qualities of resilient systems
  - Reflectiveness
  - Resourcefulness
  - Robustness
  - Redundancy
  - Flexibility
  - Inclusiveness
  - Integration
    - *The Rockefeller Foundation, 2014, Resilient Cities Framework*



THE ROYAL SOCIETY



Drawing courtesy of Chingwen Cheng

Resilient Infrastructure as SETS

Extreme Events

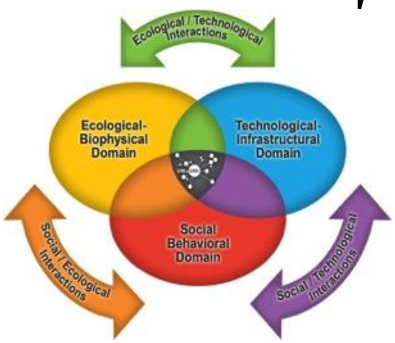
Capital inputs
Energy, extracted materials
Raw materials, land, ecosystems
Labor, knowledge, data, institutions

SETS Resilient Infrastructure

Outcomes
Risk management, persistence, adaptation, transformation
Ecological changes in local and distant systems (managed, maintained, transformed…)
Learning, altered expectations, reorganization, sense of place, transformation

Services provided
Disservices managed
Ecosystem services captured
Ecosystem services delivered
Jobs created and maintained

Technological
Ecological
Social



Developed from discussions in SETS WG of UREx SRN

A new design paradigm: "safe-to-fail"

(after Park, Seager et al. 2012 *Risk Analysis)*

	Risk management (traditona)	Resilience (ecological)
Design principles	Status quo: avoid failure or transformative change	Unknown hazards ok; adapt w/o loss of function. Some failure ok
Design objectives	Minimize probability of failure, allow rare catastrophic consequences (long RT)	Minimize consequence of failure, more frequent failure (short RT)
Design strategies	Armoring; strengthening; resistance; oversizing (gray)	Diversity, adaptability, regrowth flexibility, renewability, innovation
Response coordination	Centralized, hierarchical, coordinated per plans	Decentralized, autonomous response





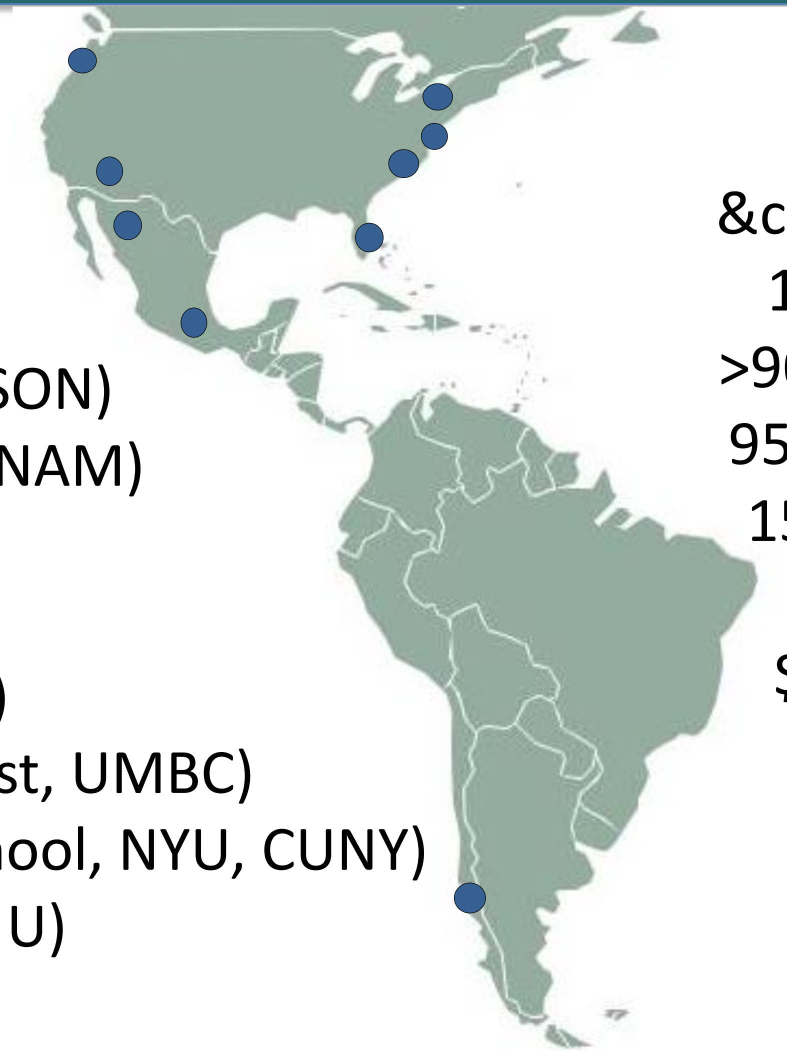


Allow some ecosystem function in hard-engineered structure
Develop new design that is a hybrid
Optimize the conditions for ecosystem development
Strengthen the existing ecosystem
A
Hard engineering
Structural engineering
Biotechnological engineering
Bioengineering
B
Grimm et al. 2016, UGEC Handbook
GRAY
BLENDED/HYBRID
GREEN

Coastal Flooding | Extreme Heat | Drought | Urban flooding

The UREx SRN

Portland, OR (PSU)
Phoenix, AZ (ASU)
Hermosillo, Mexico (ITSON)
Mexico City, Mexico (UNAM)
Valdivia, Chile (UACh)
San Juan, PR (UPR)
Miami, FL (FIU, Clark U)
Baltimore, MD (Cary Inst, UMBC)
New York, NY (New School, NYU, CUNY)
Syracuse, NY (Syracuse U)



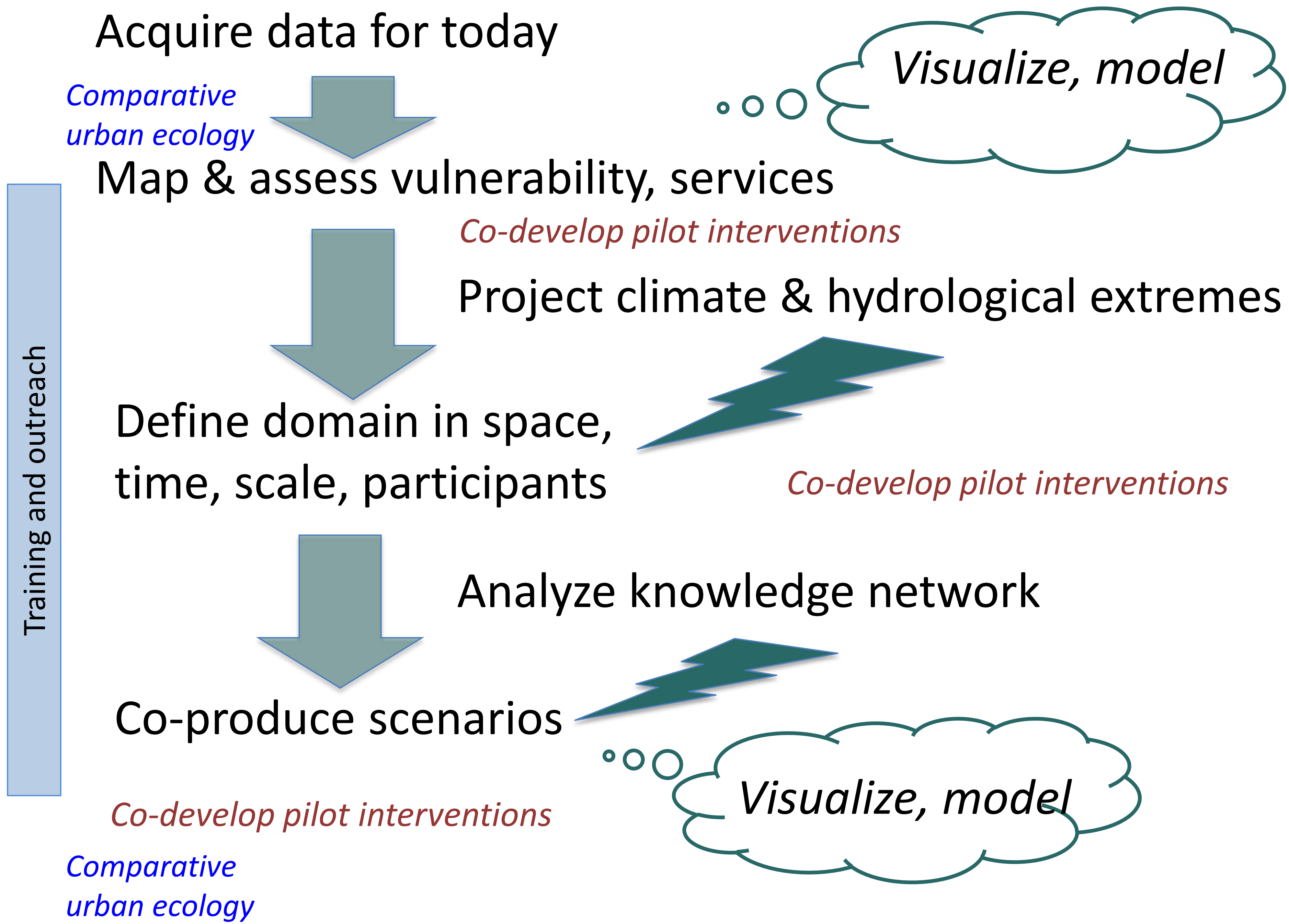
Ten cities in Latin America &continental US
17 institutions
>90 participants
95 practitioners
15 grad fellows
8 postdocs
$12M funding
2015-2021

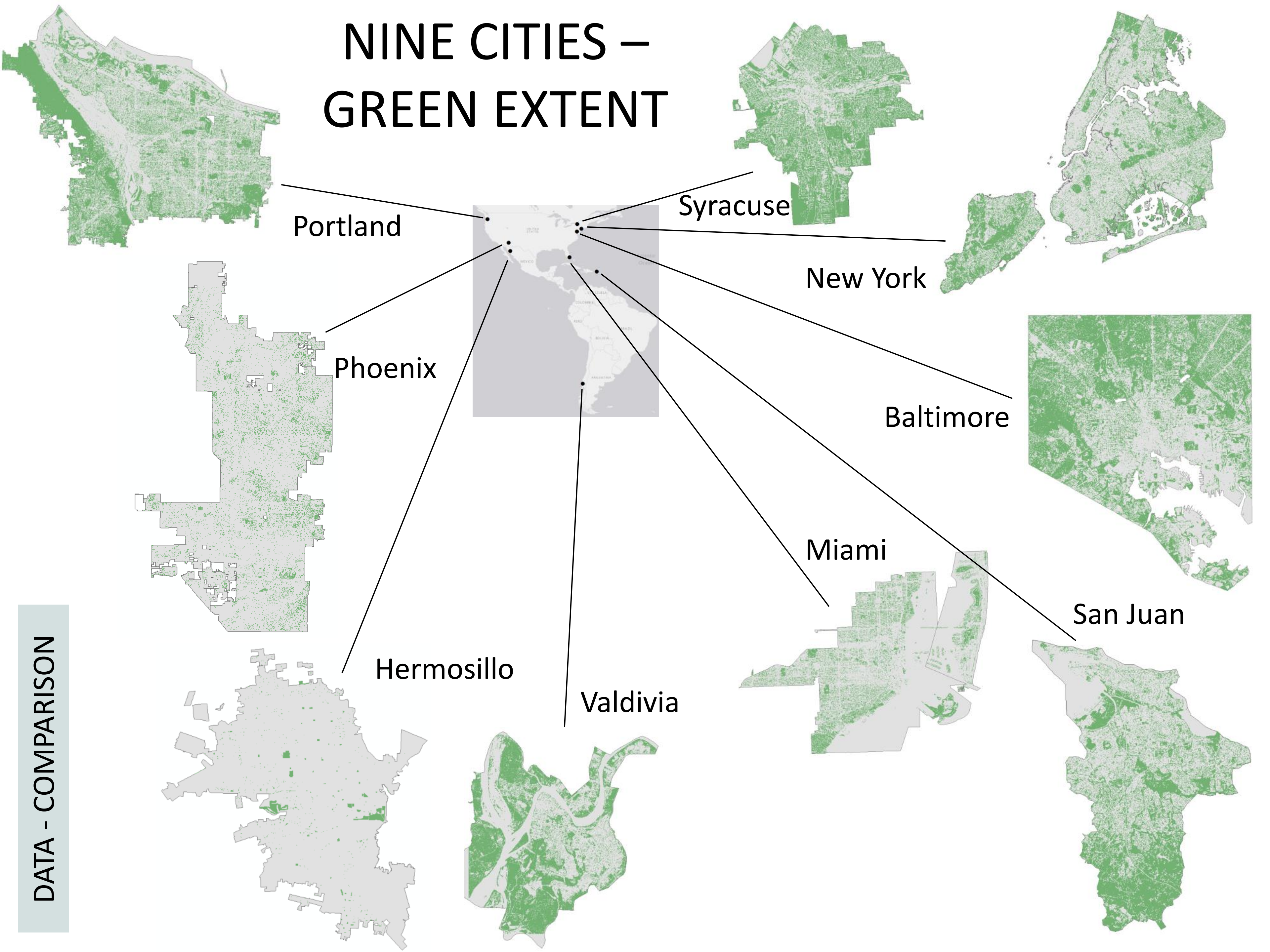
Urban Resilience to Extremes Sustainability Research Network

Our vision

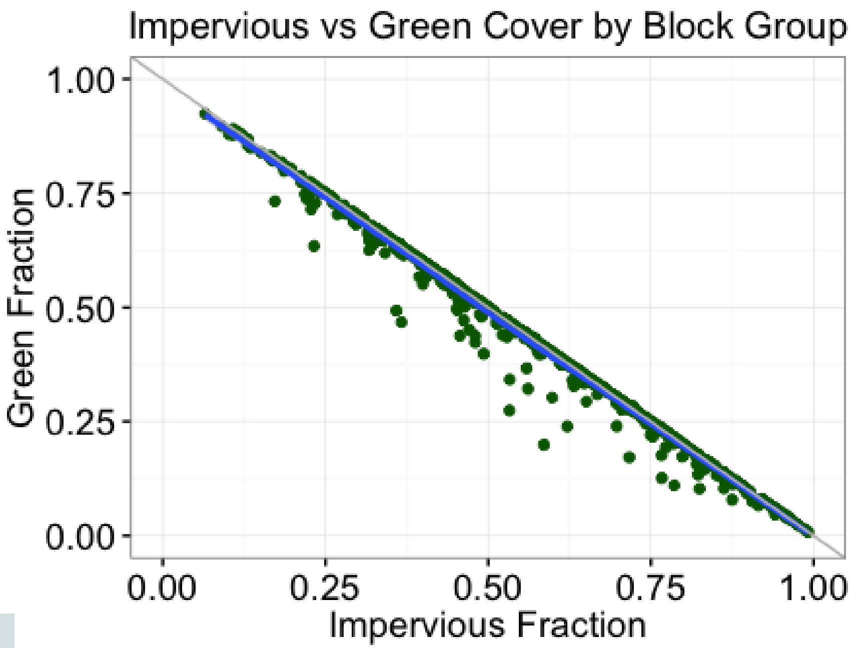
A network of collaborating interdisciplinary scientists and practitioners from diverse world cities working together to promote, design, and implement urban infrastructure that is resilient in the face of future extreme events, provides ecosystem services, improves social well being, and exploits new technologies in ways that benefit all segments of urban populations.

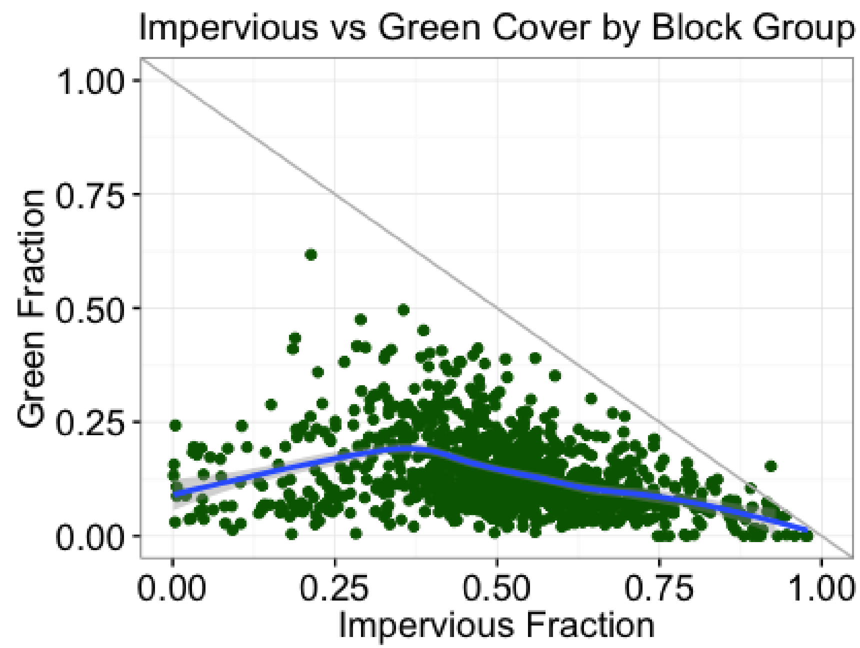
UREx SRN


Acquire data for today
Comparative
urban ecology
Visualize, model
Map & assess vulnerability, services
Co-develop pilot interventions
Project climate & hydrological extremes
Training and outreach
Define domain in space,
time, scale, participants
Co-develop pilot interventions
Analyze knowledge network
Co-produce scenarios
Visualize, model
Co-develop pilot interventions
Comparative
urban ecology


NINE CITIES –
GREEN EXTENT
Portland
Syracuse
New York
Phoenix
Baltimore
Miami
San Juan
Hermosillo
Valdivia
DATA - COMPARISON

Baltimore and Phoenix contrasts

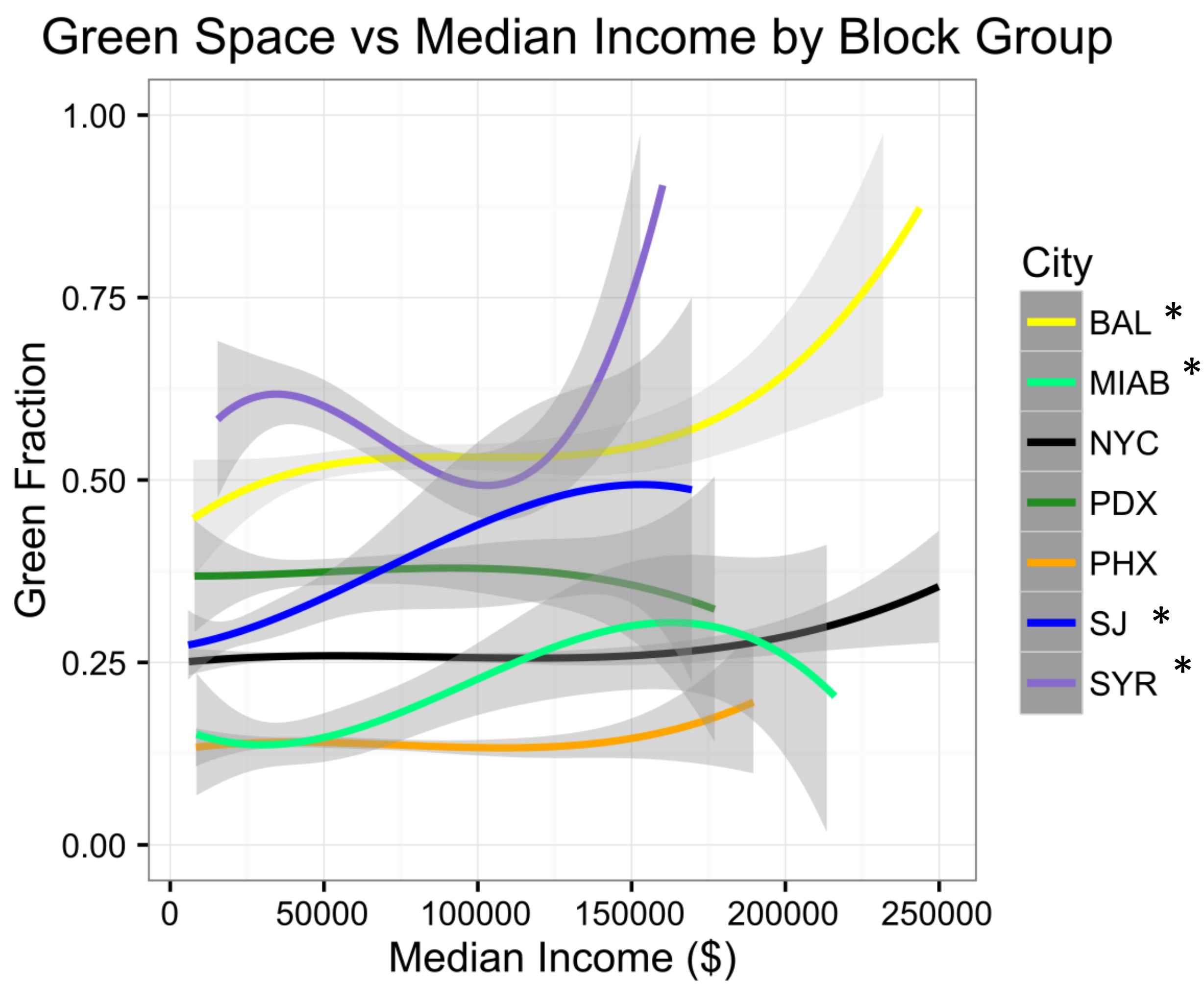




- Caution in assuming relationships based on better-studied mesic systems
- Context matters! (geographical, physical, ecological, social)

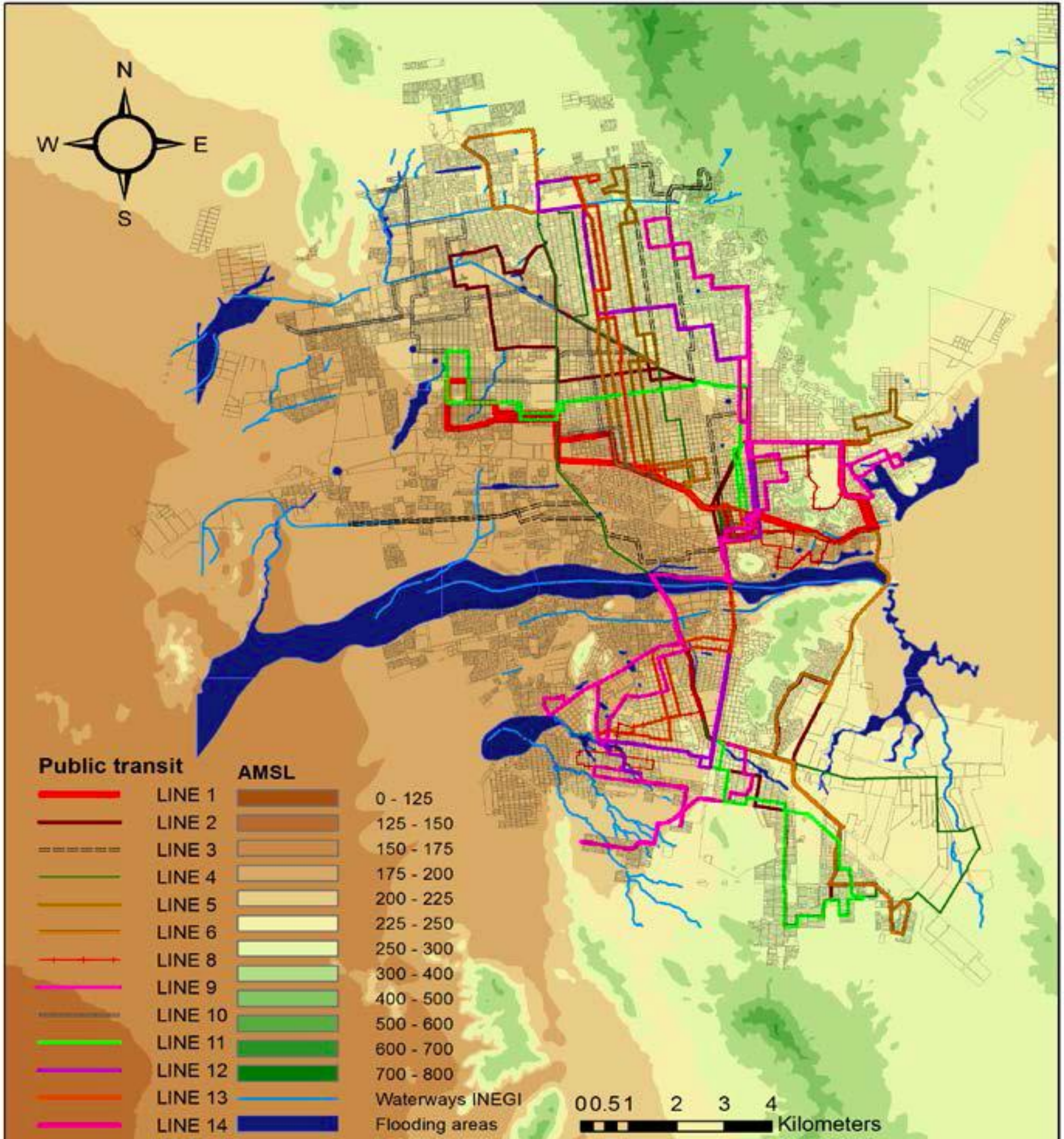
DATA - COMPARISON

Inequality in access to green space



DATA - COMPARISON

Public transit and flooding in Hermosillo

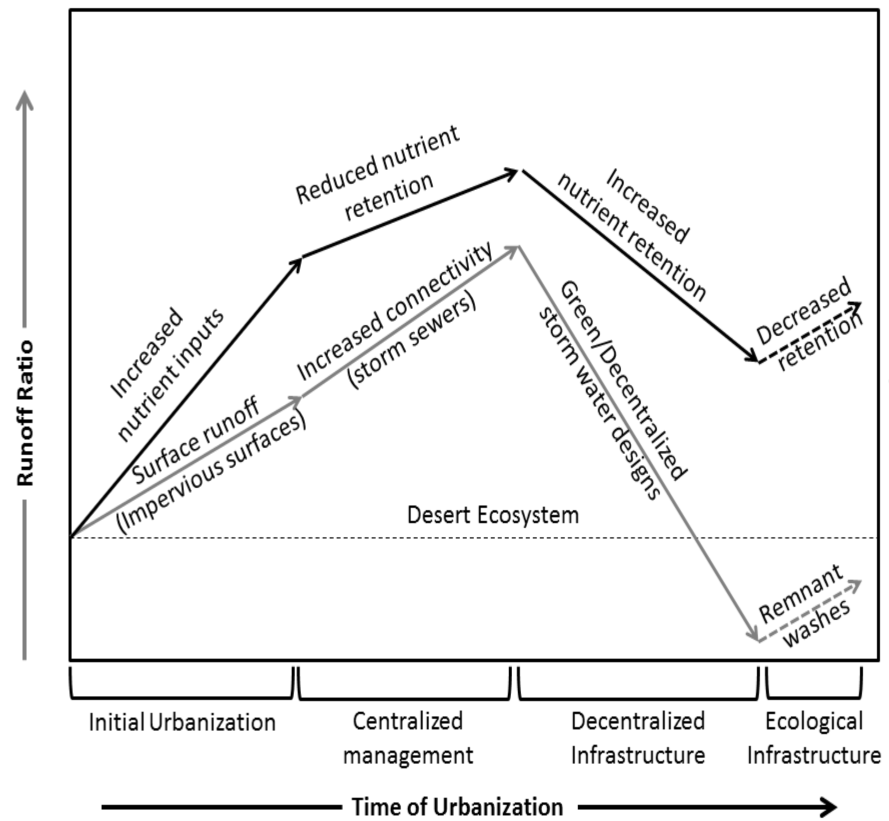


MAP - ASSESS

Phoenix: from fail safe to safe-to-fail

- Indian Bend Wash watershed, Scottsdale
- Changes in nutrient retention & hydrologic connectivity are closely tied to changes in stormwater infrastructure

- A changing vision:



Roach et al. 2008; Hale et al. 2015

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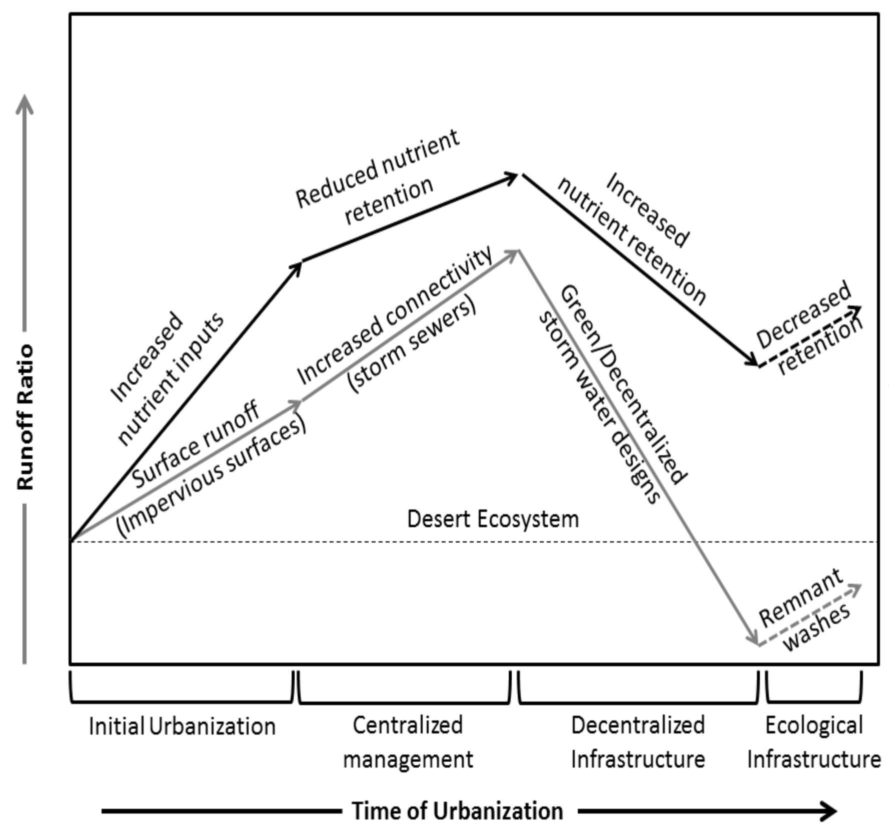


Roach et al. 2008; Hale et al. 2015

Baltimore: Can you find the detention basins in this suburban landscape?

½ mile x ¾ mile area

Source: Neil Bettez

MAP - ASSESS

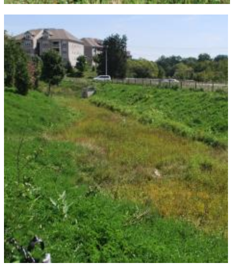
Baltimore: Can you find the detention basins in this suburban landscape?

½ mile x ¾ mile area

MAP - ASSESS

Source: Neil Bettez

Stormwater Management Structures in the Gwynns Falls (Baltimore)



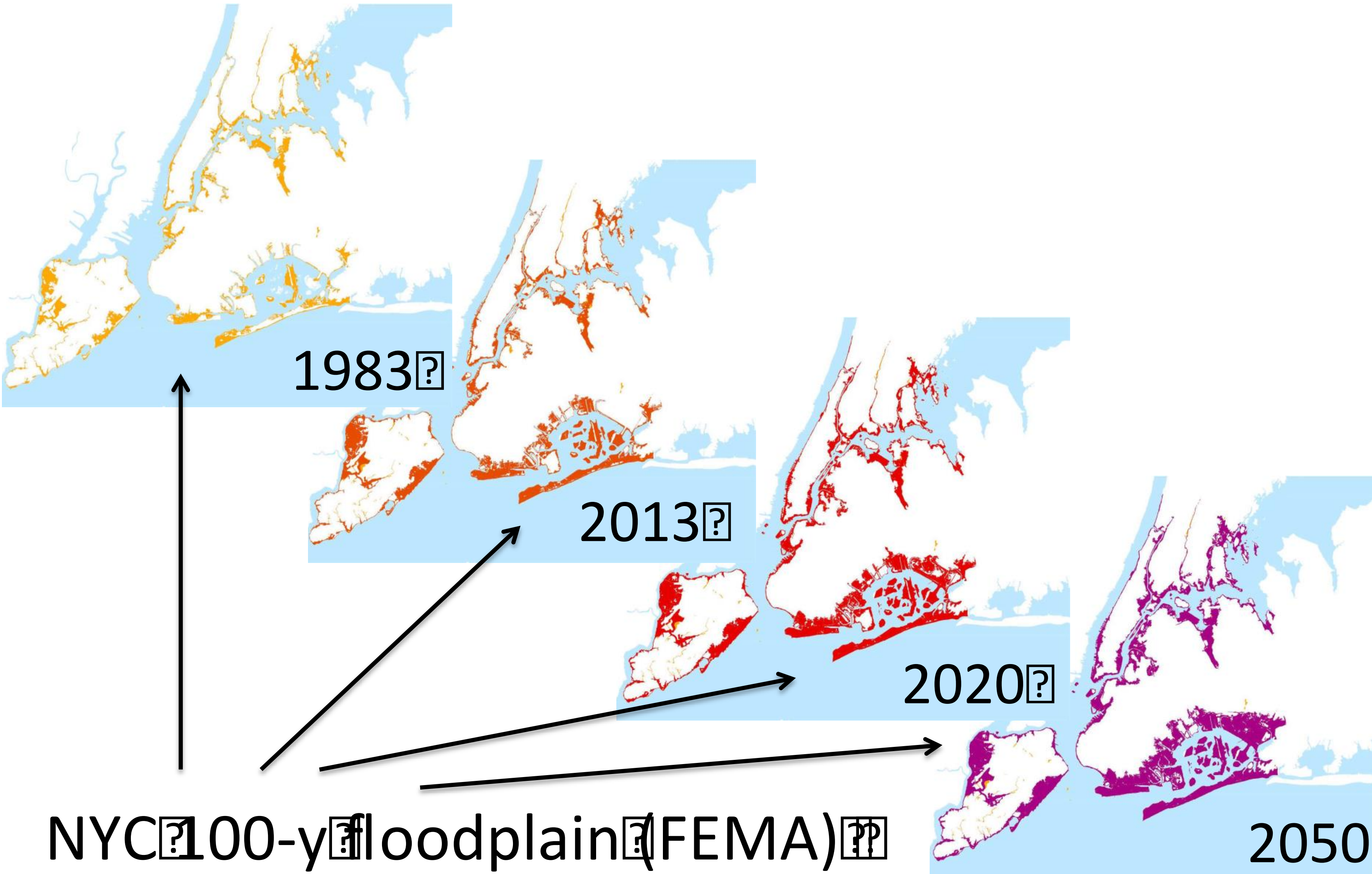
Type	Structure Type (TN removal efficiency)	Count	Percent of total	Percent of Drainage Area	Area weighted removal	Type of Structure
A	Wet Ponds and Wetlands (30%)	23	3%	1	0.33	shallow marsh Retention Pond
B	Dry Detention & Hydrodynamic structure (5%)	275	33%	10	0.48	Bay Separator Oil & Grit Separator Still Basin Underground storage Detention Pond
C	Dry Extended Detention (30%)	272	33%	8	2.39	Dry Ext Detention Pond Ext Det Pond
D	Infiltration Practices (50%)	90	11%	0.34	0.14	Porous Pavement Swale Infiltration Trench Infiltration basin
E	Filtering Practices (40%)	167	20%	1.79	0.72	Dry Well BIO-Retention Sand filter

(Stormwater workgroup: BMP Pollutant Removal Efficiencies.PDF)

MAP - ASSESS

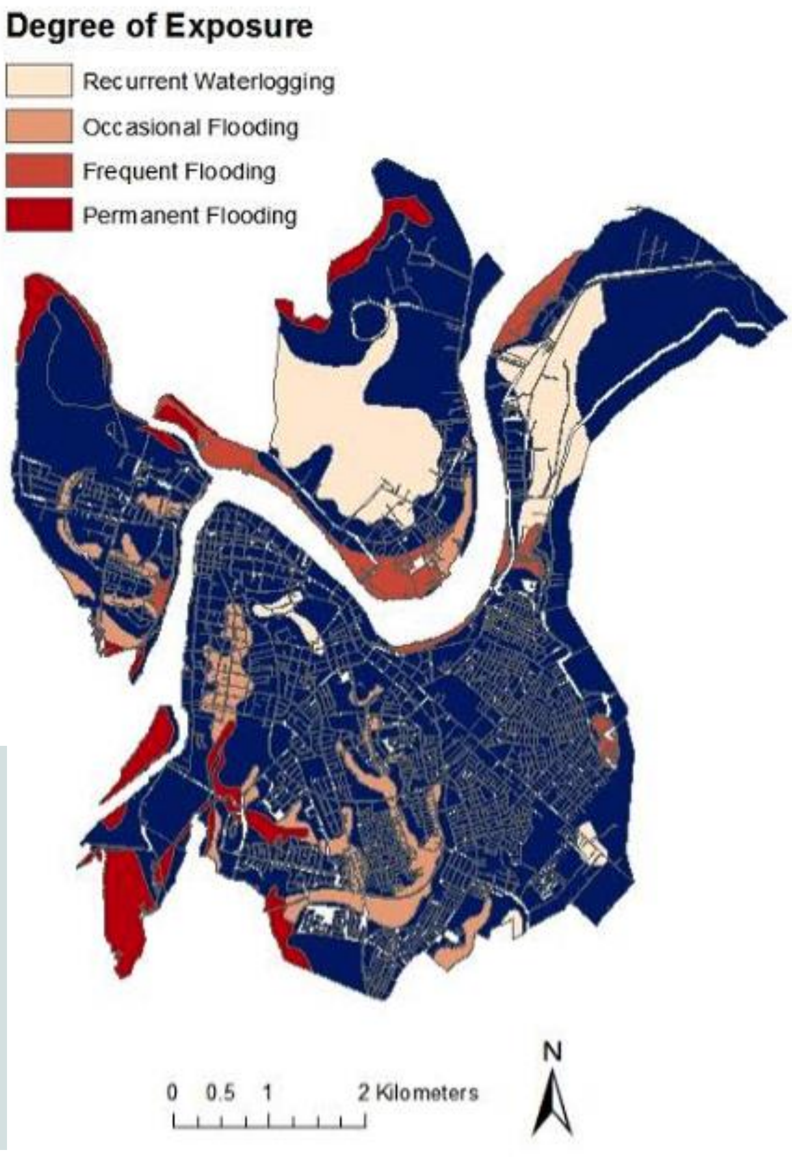
Courtesy of Peter Groffman, Neil Bettez

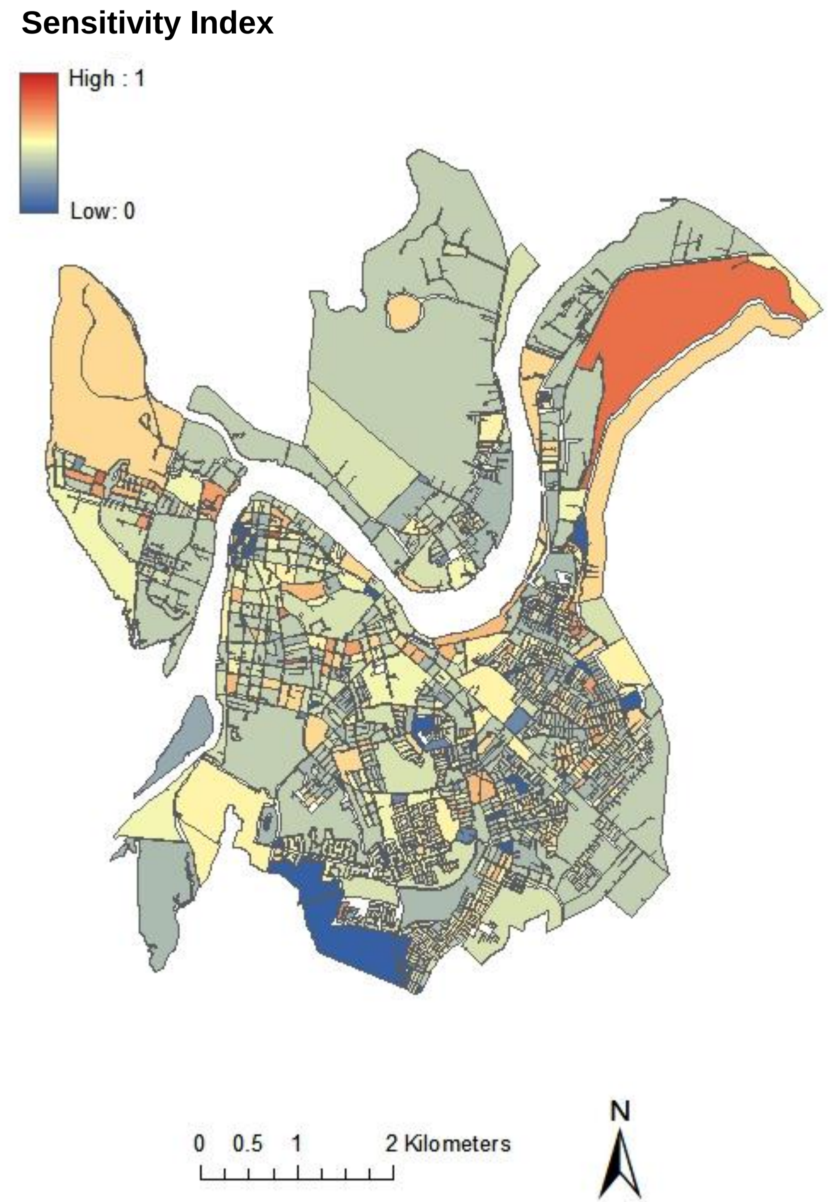
New York: Projecting future changes



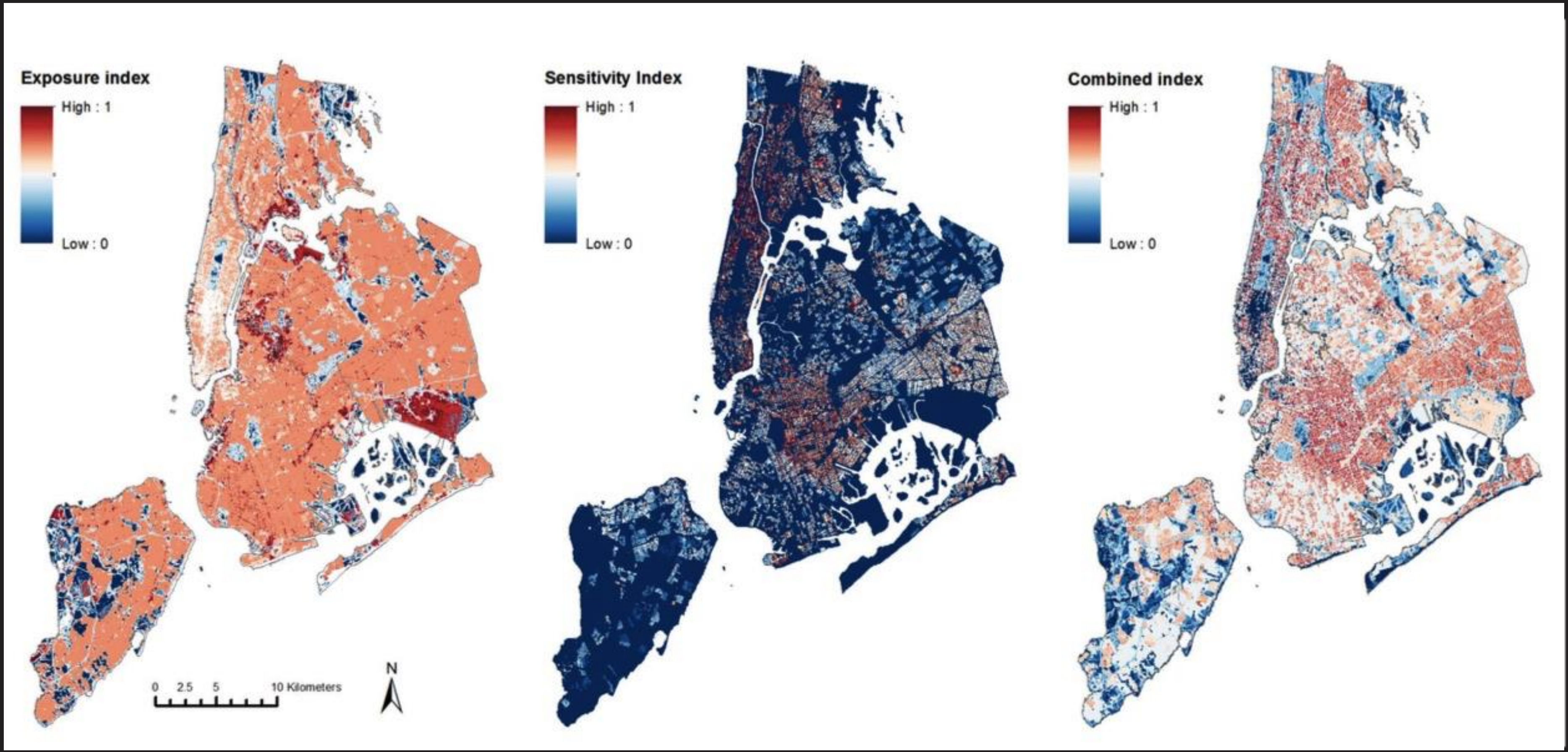
Valdivia Flooding:

Can we incorporate SETS thinking into the assessment of vulnerability?





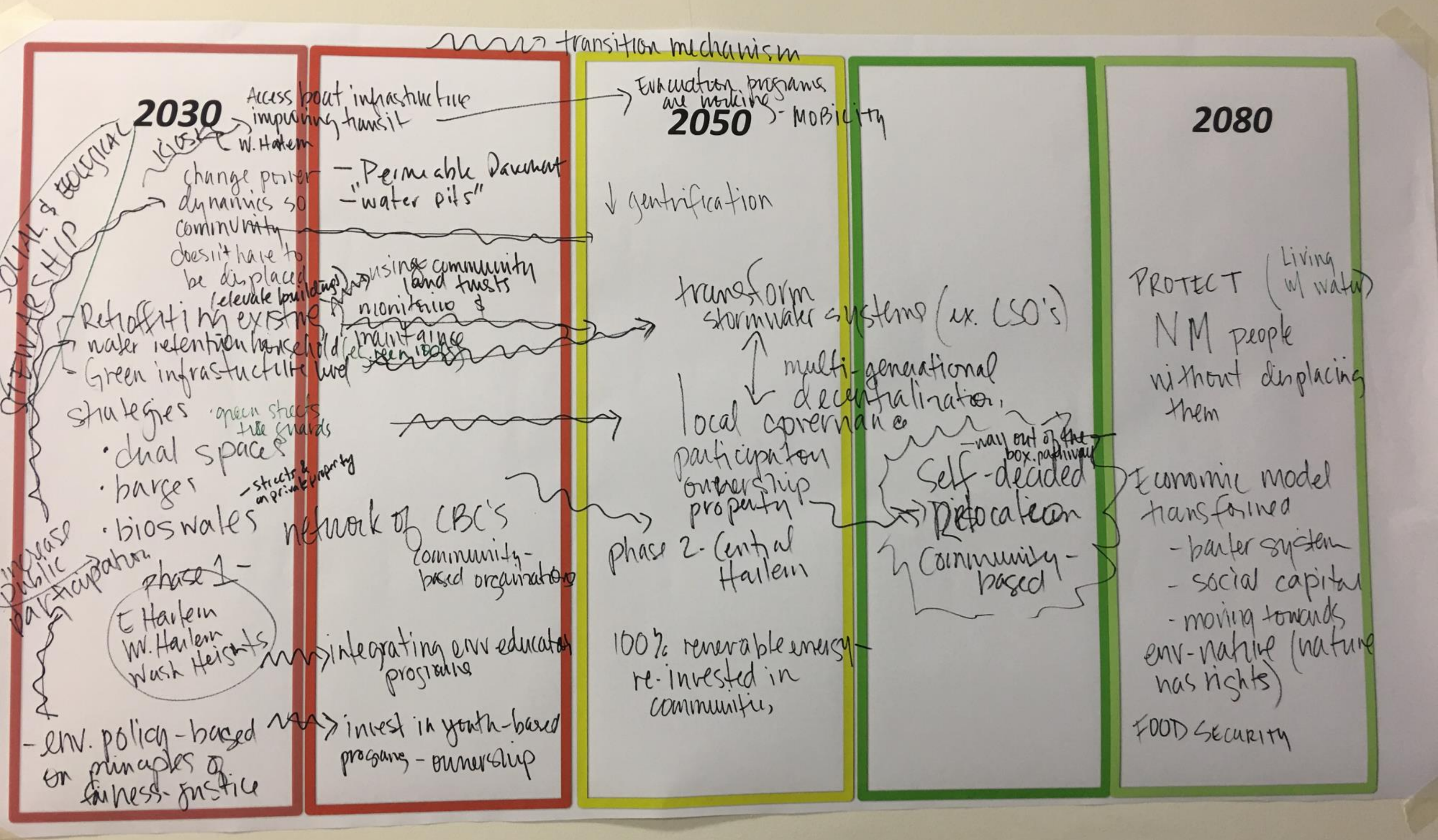
MAP - ASSESS



New York

COMBINING URBAN SOCIAL, ECOLOGICAL, AND TECHNICAL-INFRASTRUCTURAL SYSTEM (SETS) DATA

HEAT VULNERABILITY



New York: participatory visioning

Miami-Dade County OCTOBER 7, 2014

86° Sign In | Subscribe Miami Herald

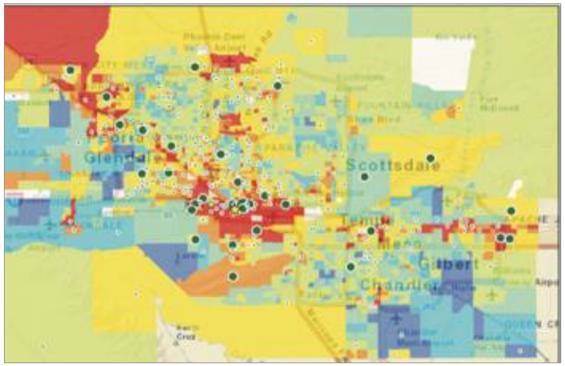
Report: Tidal flooding to be more frequent in Miami, Key West as seas rise

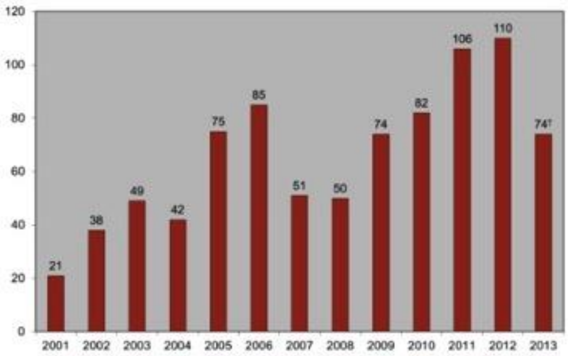
HIGHLIGHTS

A new look at the nation's climate concludes that flooding in Miami and Key West will happen more often and more severely as seas continue to rise.

San Juan: building resilience but avoiding gentrification

Phoenix: How can we build resilience to heat?



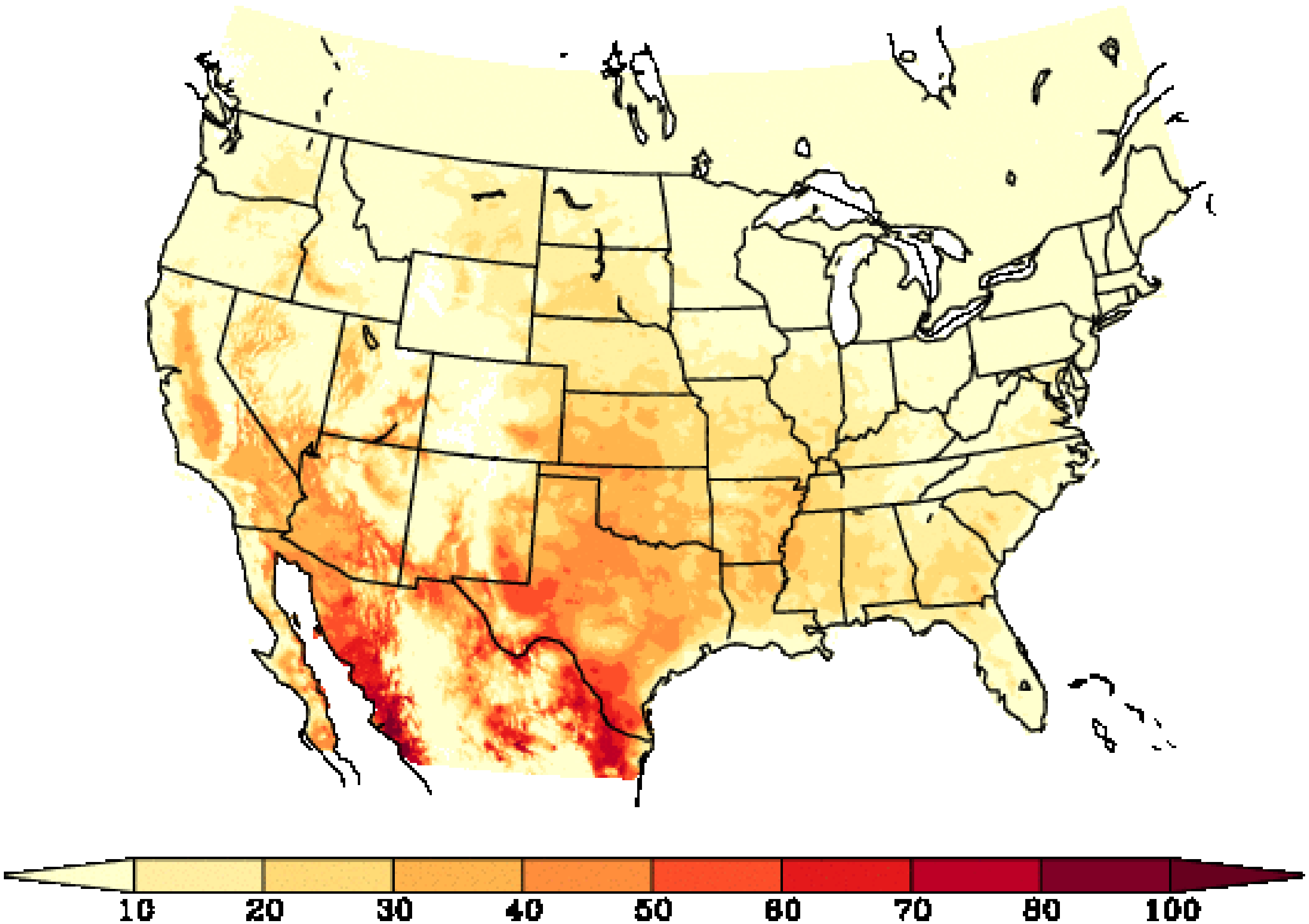


SOCIAL VULNERABILITY

EXTREME HEAT & UHI

VEGETATION & GI

Annual count of days when max temperature > 100F
RCP8.5: 2036-2065

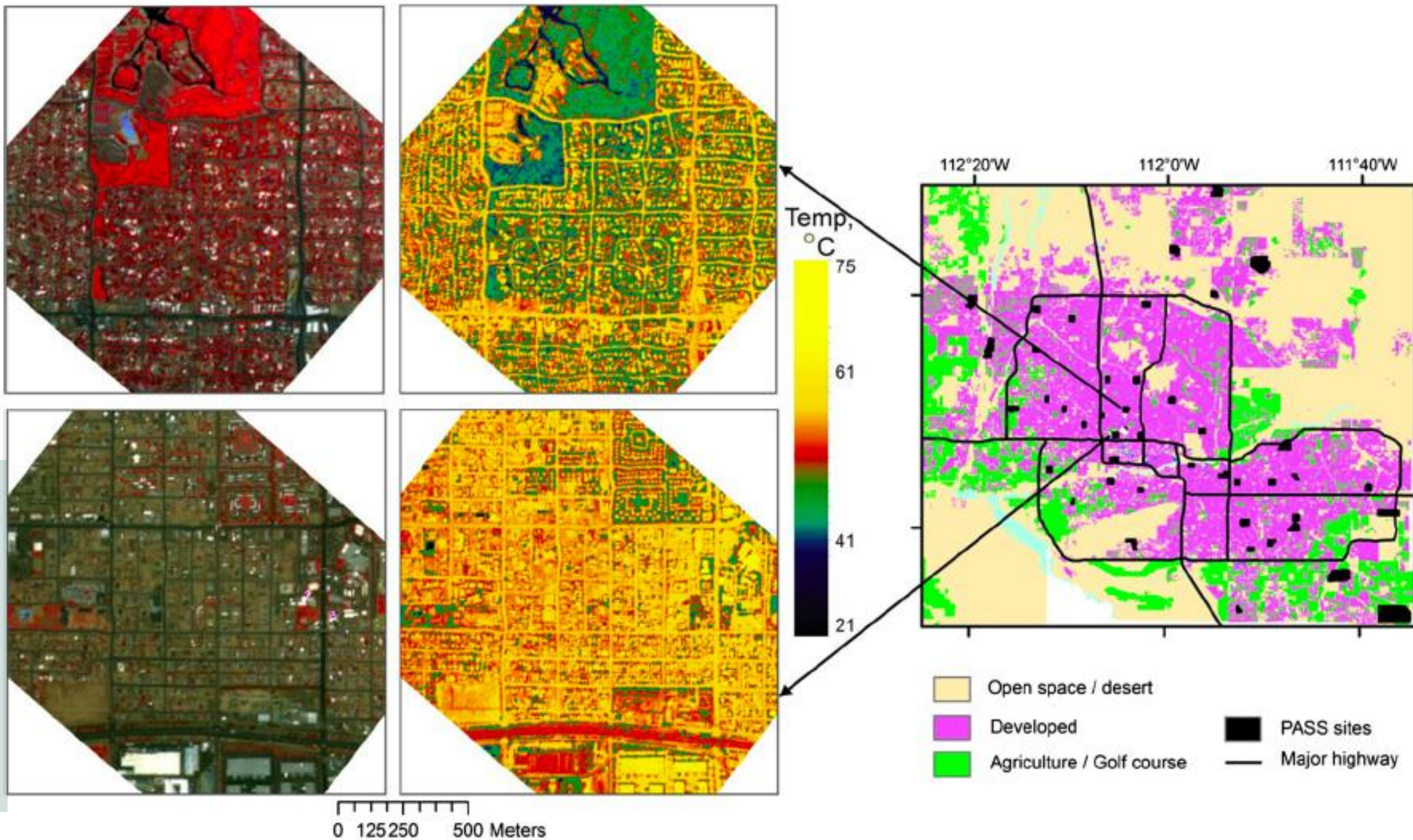


PROJECT FUTURE CLIMATE

Vegetation cover-heat relationship

Landscape Ecol (2016) 31:745–760

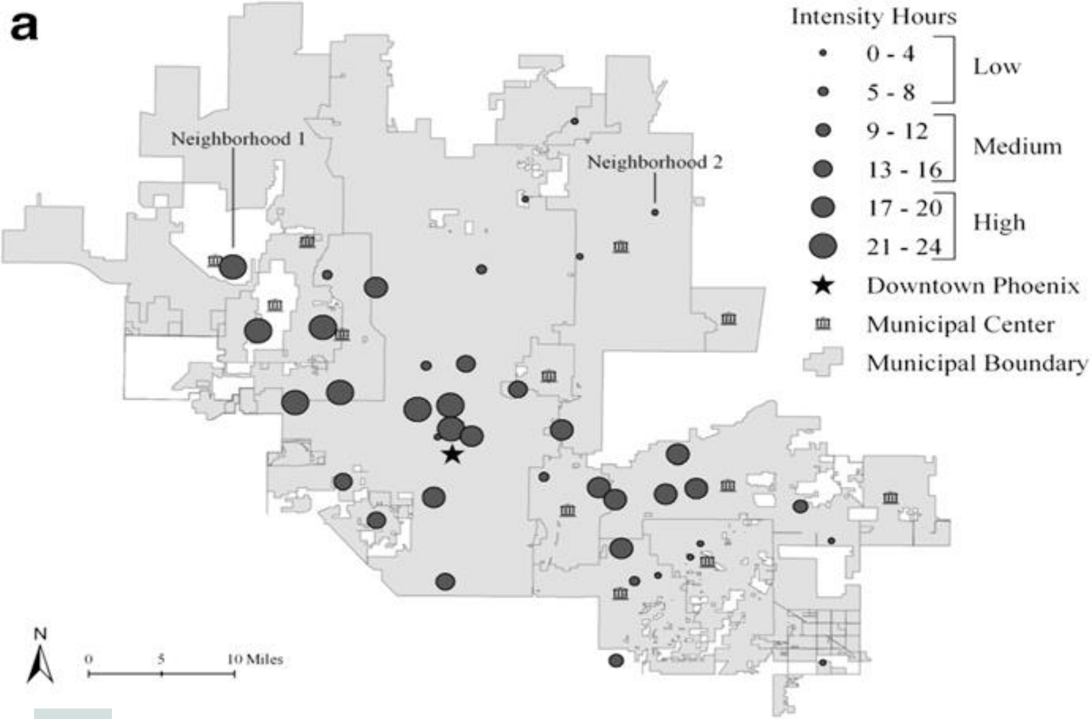
Jenerette et al. 2016



DATA - MAPPING

People are differentially affected by urban heat

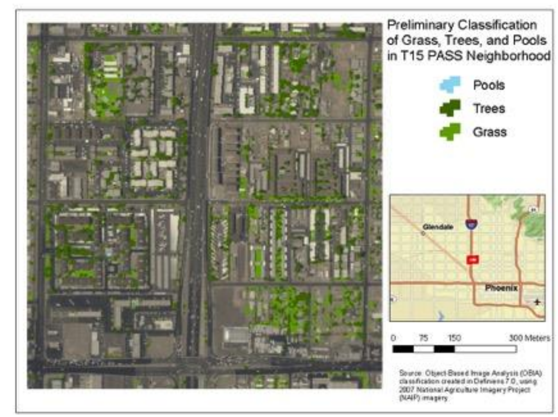
a



b

US Census	Exposure to High Heat Low	Medium	High
N Neighborhoods	15	10	15
Population/mi²	3,569	3,757	7,550
Income	$71,903	$62,669	$38,621
% minority	20.7	25.9	44.7
% over age 65	9.8	20.4	17.5

ASEESS VULNERABILITY



Spatial heterogeneity in neighborhood vegetation explains much of the variance in heat exposure risk

Ruddell et al. 2012

Co-Production with Communities

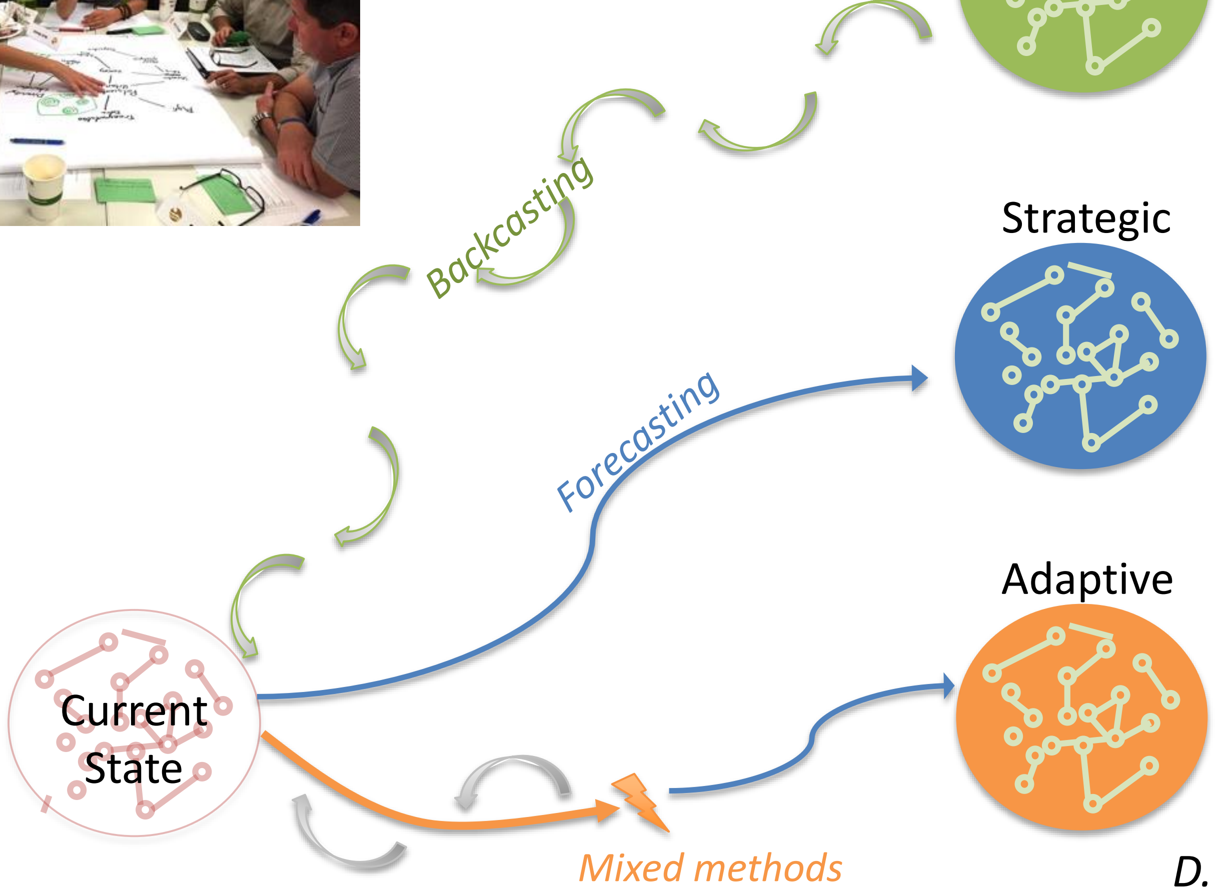
- Input from community members from outset
- Investigate local knowledge networks and decision processes
- Examine vulnerability and resilience within local context
- Scenarios workshops to share visions and propose interventions

CO-PRODUCE SCENARIOS

Sustainable Future Scenarios

CAP LTER
Central Arizona – Phoenix Long-Term Ecological Research

CO-PRODUCE SCENARIOS



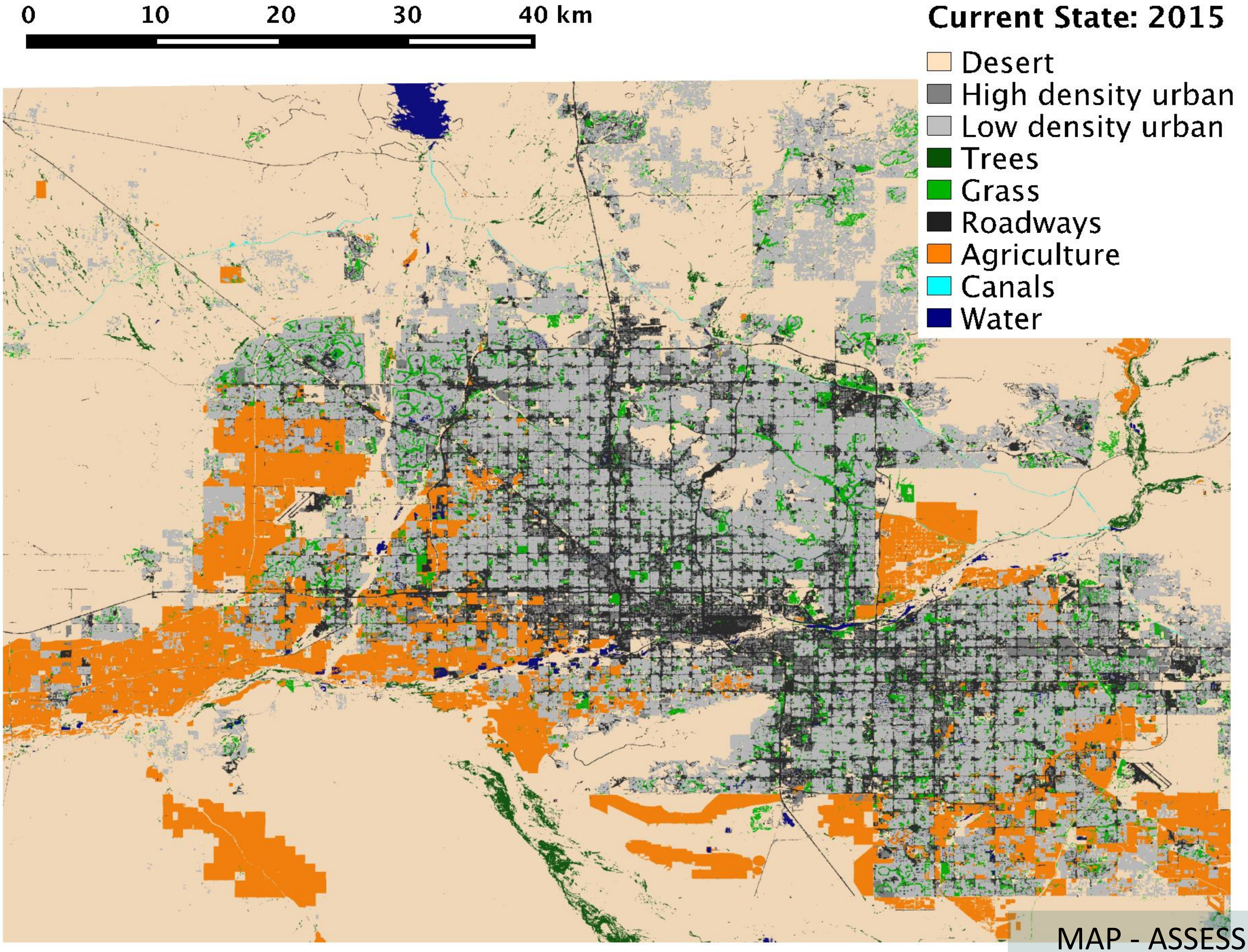
Based on:

Desired outcomes (co-produced)

Existing strategies and goals

In response to extreme events (co-produced)

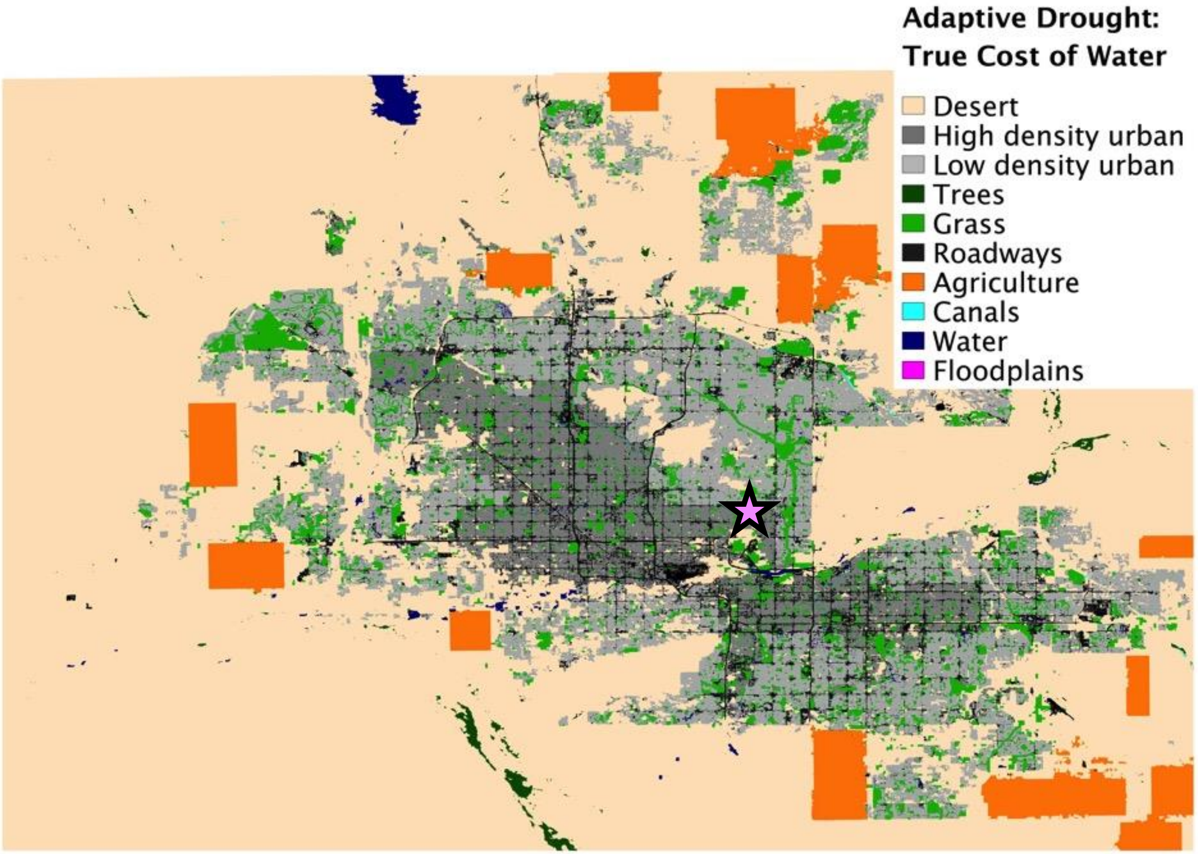
D. Iwaniec et al., in progress


0
10
20
30
40 km
Current State: 2015
Desert
High density urban
Low density urban
Trees
Grass
Roadways
Agriculture
Canals
Water

MAP - ASSESS

Adaptive Drought: “The True Cost of Water”

- Rainwater & stormwater harvesting
- Urban infill & increase density
- Large → smaller scale agriculture
- Shift in energy sourcing
- Education about water conservation



Zooming in to Vignette (different scale)

ENVISION

Adaptive Drought: “The True Cost of Water”

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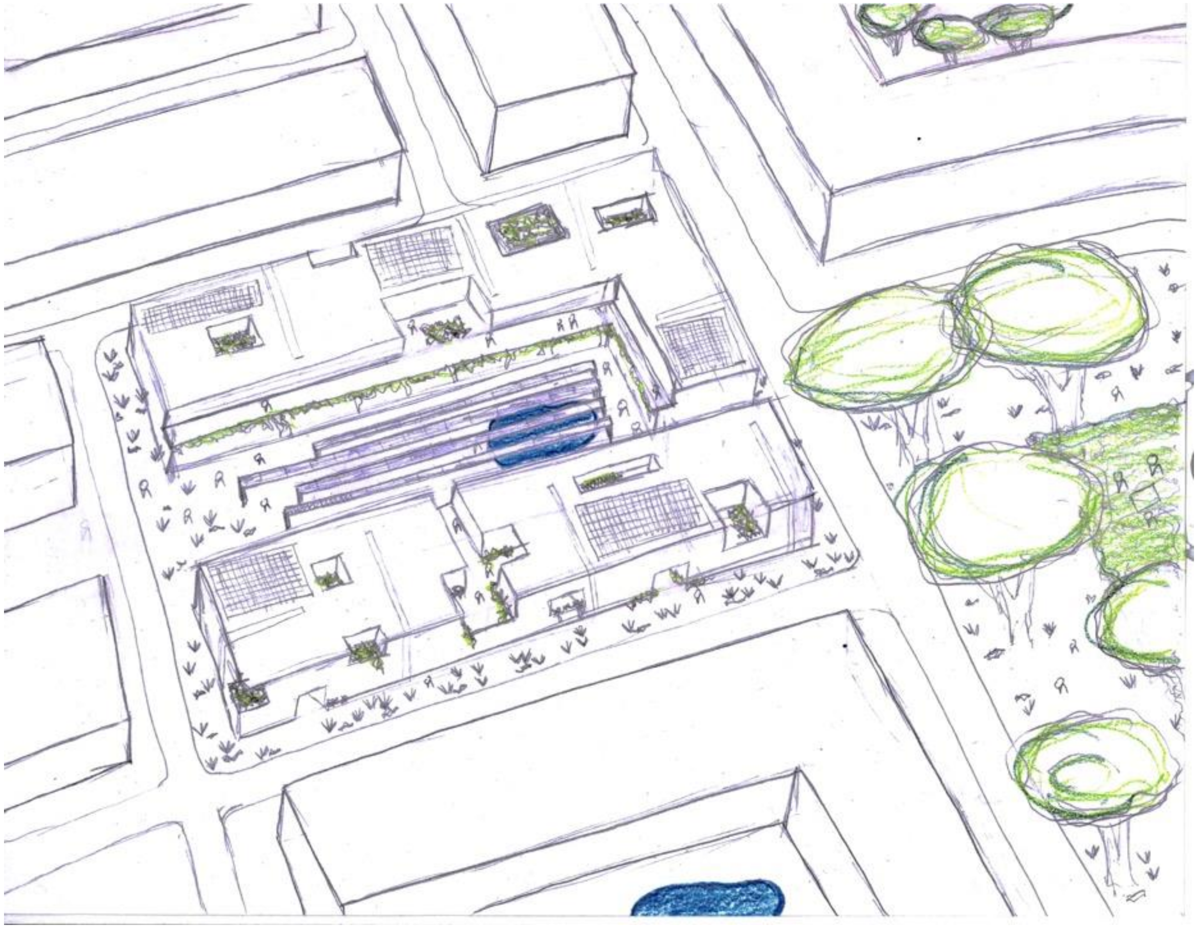
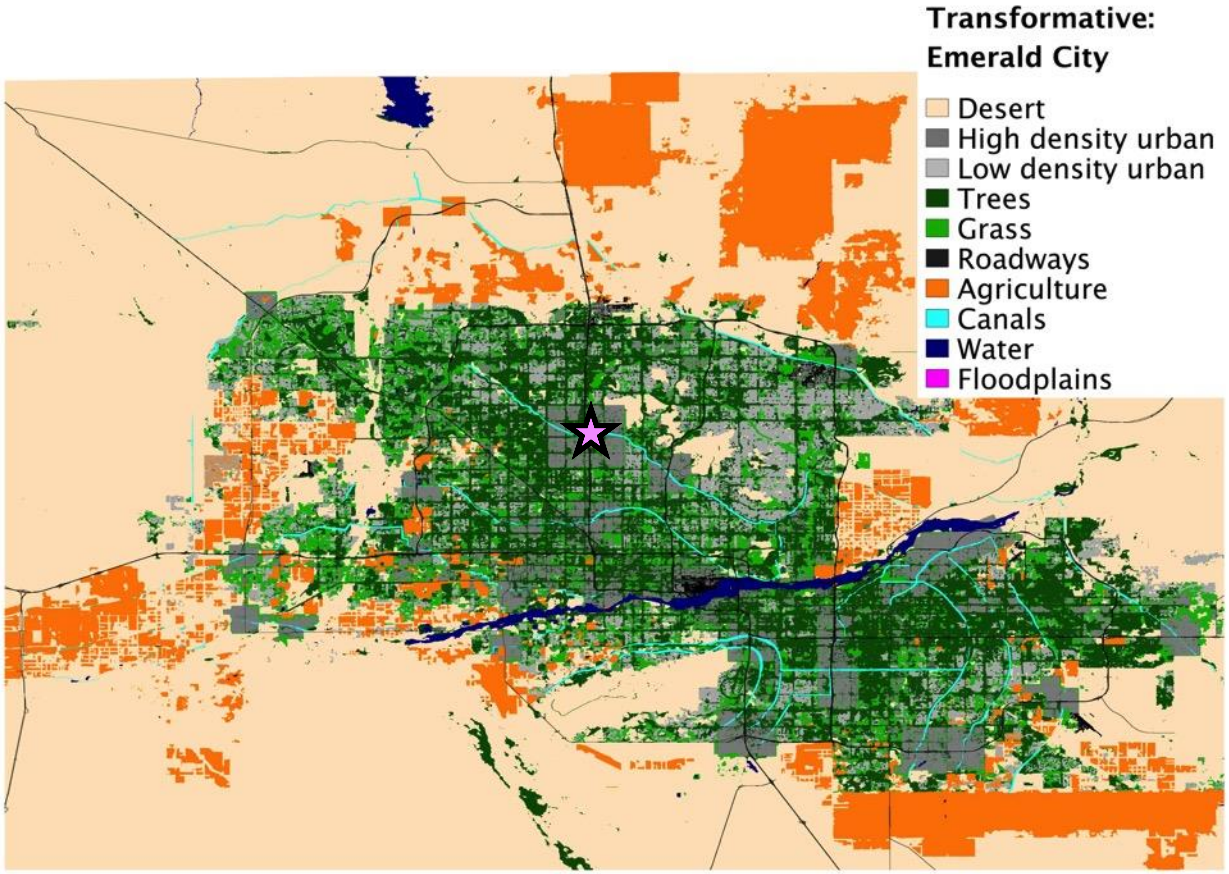


VISUALIZE

Transformative: "Emerald City / Necklace"

- Repurposed freeways; reduced reliance on cars
- Hubs where canals & freeways cross
- Concentrated city centers
- Water harvesting to support green hubs
- Social change in sense of place priorities



ENVISION

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- Repurposed freeways; reduced reliance on cars
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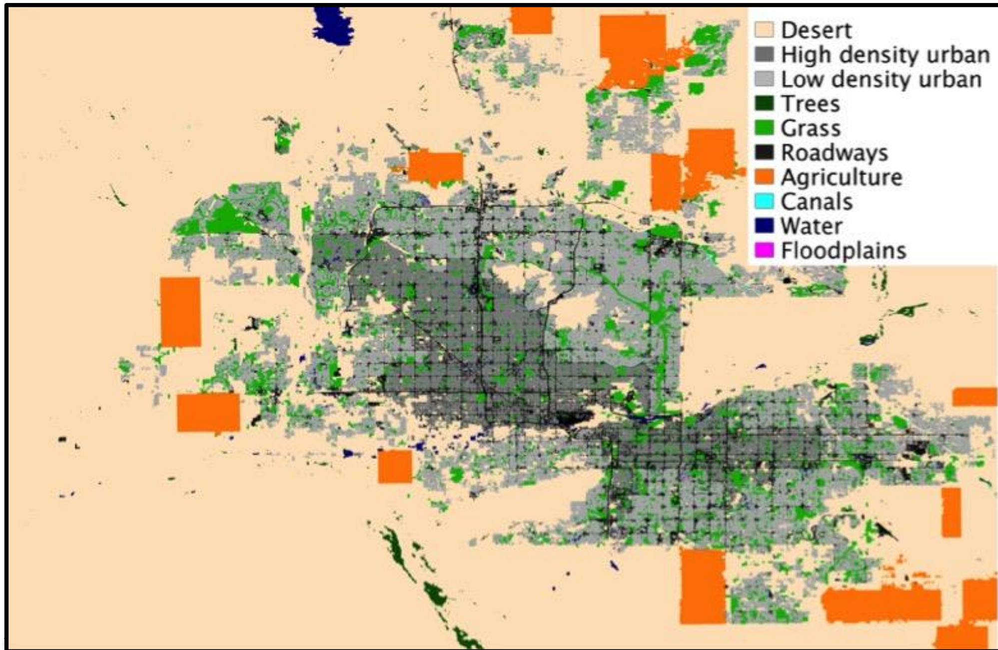
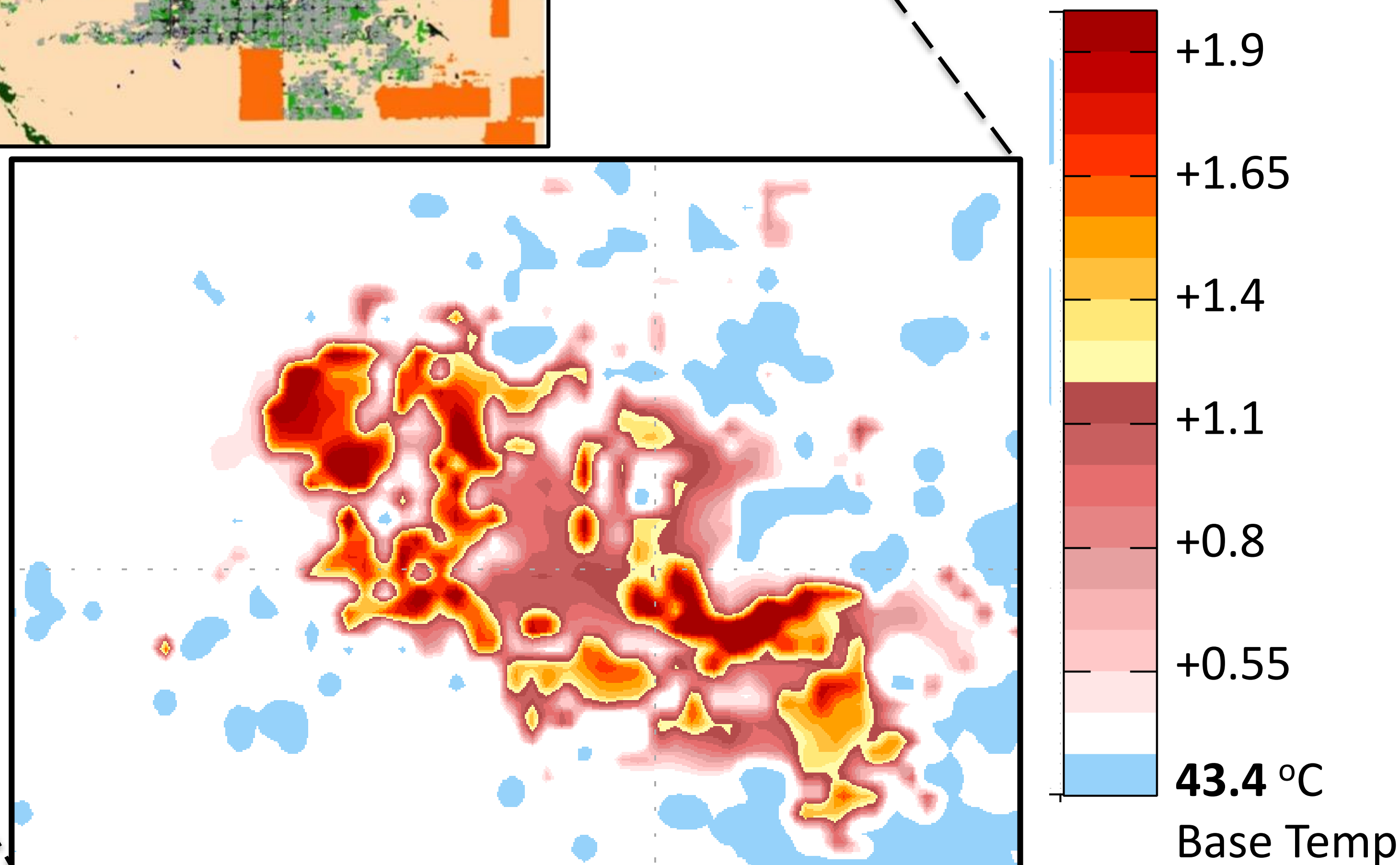
VISUALIZE

2060 Adaptive Drought: True cost of water scenario



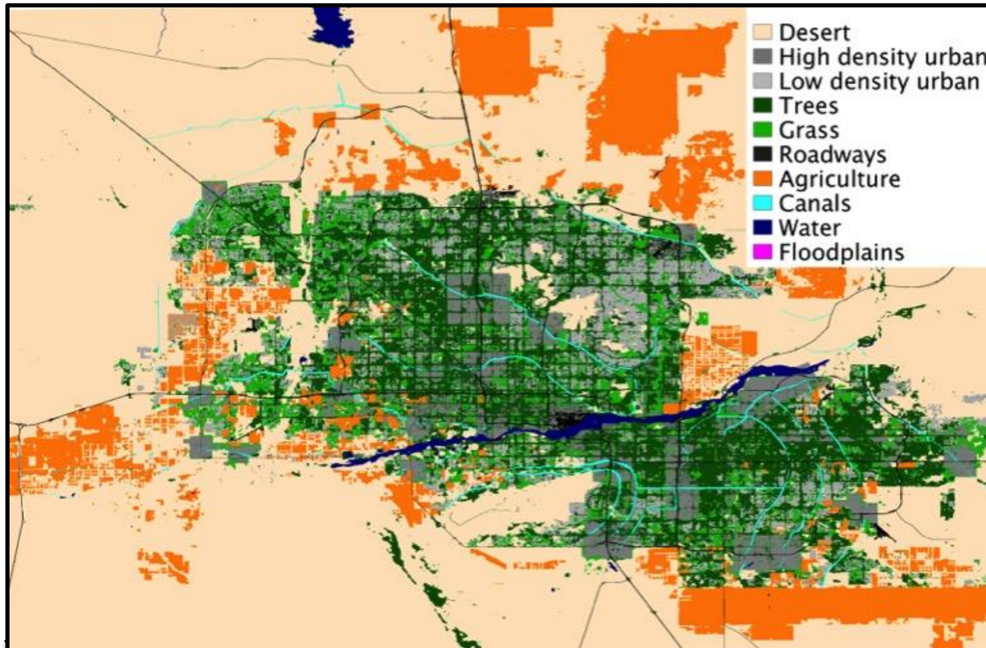
2060 Regional Temperature (^oC)



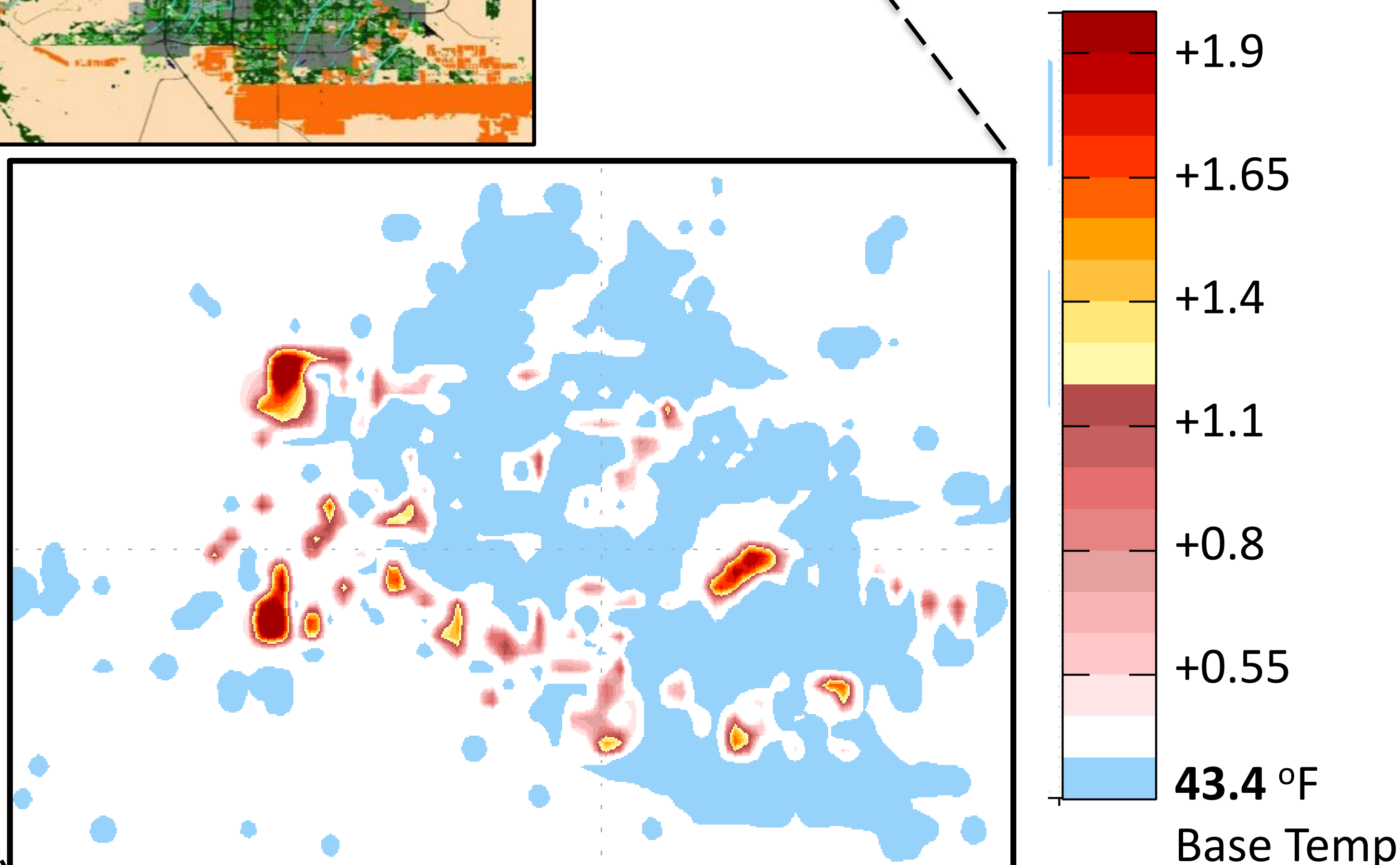
MODEL

LULC, Xiaoxiao Li (School of Geographical Sciences and Urban Planning, ASU); Weather Research and Forecasting (WFR) model, Matei Georgescu (School of Geographical Sciences and Urban Planning, ASU)

2060 Emerald City: Transformative scenario



2060 Regional Temperature (°C)



MODEL

LULC, Xiaoxiao Li (School of Geographical Sciences and Urban Planning, ASU); Weather Research and Forecasting (WFR) model, Matei Georgescu (School of Geographical Sciences and Urban Planning, ASU)

Visualization and Pilot Interventions


PHOENIX
SUNRISE
MOTEL
VACANCY


PHOENIX
SUNRISE
MOTEL
VACANCY


PHOENIX
SUNRISE
MOTEL


PHOENIX
SUNRISE
MOTEL


PHOENIX
MOTEL
java
man


PHOENIX
java man


PHOENIX
SUNRISE DINER
java man


SUNRISE DINER
java man

COST FP1204 GREEN INFRASTRUCTURE

Nature based solutions for sustainable and resilient cities

ORVIETO, ITALY 4-7 April 2017

- Infrastructure – defining characteristic – bridging social-ecological systems
- SETS solutions needed in uncertain world of the Anthropocene
- SETS solutions leverage services, improve well-being
- Resilience-building
- Technologically advanced
- Equitable and fair
- Context-appropriate

- UREx SRN –comparative urban research, network of city researchers and practitioners
- Investigating SETS solutions in the face of extreme events
- Co-producing visions for resilient futures with city practitioners
- Models, visualizations, implementation
- Transdisciplinary training

UREx SRN

COST FP1204 GreenInUrbs GREEN INFRASTRUCTURE
Nature based solutions for sustainable and resilient cities
ORVIETO, ITALY 4-7 April 2017

THANKS FOR YOUR ATTENTION!

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- Context-appropriate

- UREx SRN –comparative urban research, network of city researchers and practitioners
- Investigating SETS solutions in the face of extreme events
- Co-producing visions for resilient futures with city practitioners
- Models, visualizations, implementation
- Transdisciplinary training