Green Infrastructure: A Climate Change Adaptation Strategy for Cities in Arid Lands

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AQUASEC: Center of Excellence for Water Security

- Virtual center
- Network
- Umbrella

- NSF-CNH
- IAI Aguascapes
- Lloyd’s IWSN – Arid Americas
Overview

1. Cities in drylands
2. Climate change projections for cities in drylands
3. Green infrastructure
4. Research project
1. Cities in Drylands
Drylands

41% of the land area in the world\(^1\)

Drylands:\(^2\)
- Hyperarid
- Arid
- Semi-arid
- Subhumid

Water scarcity\(^1\)

Scientists = Coupled social-ecological system\(^3\)

Social-Ecological Systems

Fig. 1. The core subsystems in a framework for analyzing social-ecological systems.

(Ostrom 2009)
Cities in Drylands

- Rapidly expanding
- The drier the land, the larger the fraction of population will be living in urban areas

Change in world rural and urban population (%) from 1950 to 2030

Cities in Drylands

The growth of cities in drylands:

- Adds pressure to the ecological systems\(^1\)
- Alters the biogeochemical cycles\(^1\)

(1: Grimm et al. 2008)
2. Climate change projections for cities in drylands
Climate Change

Climate change projections for drylands\(^1\):

- Increase in temperatures
- More prolonged droughts
- More frequent severe storm events

(1: Maliva and Missimer 2012)
Climate Change

Increase in temperatures:

- Exacerbates the *urban heat island* effect
- Poses a serious health risk to people living in hot regions
Climate Change

Prolonged droughts:

- Groundwater is an important water source for cities in drylands
- Climate change threatens water security in arid lands
Climate Change

More frequent severe storm events:

- Produce flooding
- Damage the urban infrastructure
- Decrease water quality – nonpoint source pollution
Drainage Systems in Drylands

Low frequency in rain events makes it cheaper to repair urban infrastructure than install drainage system

Hermosillo: Ciudad alérgica a la lluvia.
Nonpoint source pollution

**Definition:** Pollution that comes from different sources

Water flow across paved streets pick up oil left by vehicles, resulting in polluted runoff.
Sustainability in Cities

Cities provide opportunities for sustainability\(^1\)

(1: Ernstson et al. 2010)
3. Green Infrastructure
Greenspace

Definition:

*Public outdoor space dominated by vegetation*
Green Infrastructure

Definition:

Areas dominated by vegetation and covered by natural pervious surfaces where rainwater is directed for retention/detention allowing water infiltration into the aquifers in the place (in situ).

Green infrastructure considers the water cycle

Green infrastructure in the University of Arizona main campus
Greenspace

Greenspace in rural vs. urban environments

**Natural System Conditions**
- High plant cover
- Low runoff production
- Low nutrient export
- Low plant cover
- High runoff production
- High nutrient export

**Human System Conditions**
- Low population density
- Sparse social networks
- Highly visible ecosystem services
- High population density
- Dense social networks
- Low visibility ecosystem services

(From NSF Proposal by Meixner et al. 2015)
Green Infrastructure

Runoff with green infrastructure vs. without

(From NSF Proposal by Meixner et al. 2015)
Green Infrastructure

Through slope, curb cuts, and detention basins, rainwater is infiltrated into the aquifer, while providing a greenspace for the people.
Green Infrastructure

Boulevards may function as green infrastructure

Curb cuts, slope, and swales are combined to direct rainwater to small basins - infiltration areas
Green Infrastructure

Circles at street intersections slow down traffic and prevent flooding.
Green Infrastructure

There are multiple opportunities for developing green infrastructure in cities

Slope of paved areas  Infiltration areas  Slope of paved areas
Green Infrastructure

There are multiple opportunities for developing green infrastructure in cities

Street in Hermosillo after a rain event

(Photo by Kacey Ernst)
Green Infrastructure

Greenspace can be modified so it can function as green infrastructure:

1. Identify the natural drainage systems
2. Delineate the project area
3. Design retention/detention areas and basins
Green Infrastructure

It is important to consult with experts before implementation.
Green Infrastructure

Photo from Conserve 2 Enhance Grant Workshop 2015
Green Infrastructure

Photos from Conserve 2 Enhance Grant Workshop 2015
Green Infrastructure

Photos from Conserve 2 Enhance Grant Workshop 2015
Green Infrastructure

Opportunities for community interaction
Green Infrastructure & Climate Change

• **Drought**
  • Recharges aquifers\(^1\)
  • Reduces run off\(^1\)
  • Increases water quality

• **Increased temperature**
  • Reduces temperatures in cities\(^2\)
  • Alleviates the urban heat island effect\(^1\)

• **More frequent severe storm events**
  • Reduces flooding risk\(^1\)
  • Prevents damage to urban infrastructure

Coupled social – ecological systems\(^3\)

Social-Ecological Systems

(Fig. 1. The core subsystems in a framework for analyzing social-ecological systems. (Ostrom, 2009))
Greenspace & Wellbeing

Greenspace improves human wellbeing:

- **Physical health**¹:
  - Provides opportunities for recreational activities
  - Improves air quality

- **Mental health**²:
  - Reduces stress, noise, and overcrowding feelings

- **Social health**³:
  - Provides opportunities for social interaction

¹ Herrick 2009; Samet 2011; ² Chu et al. 2004; ³ Francis et al. 2012

Santa Cruz River Park
Conclusions from Dissertation

Walkable neighborhoods with access to greenspace:

- Improve wellbeing in urban residents.
- Enhance conservation support.
- Increase the number of users of greenspace.

Sabino Canyon – Coronado National Forest

(1: Zuniga-Teran 2015)
Social-Ecological Systems

Postdoctoral Research

Fig. 1. The core subsystems in a framework for analyzing social-ecological systems.

(Ostrom, 2009)
4. Research Project
Research Project

*Green infrastructure as a climate change adaptation strategy in Hermosillo, Mexico*
Adriana Zuniga-Teran and Rolando Diaz Caravantes

**METHODS:**

1. Analysis of vegetation abundance and temperature
2. Stormwater management and vegetation abundance
3. Survey to the residents

Hermosillo, Sonora
Research Project

METHODS

SECTION 1: Analysis of vegetation abundance and temperature

• Vegetation abundance: Normalized Difference Vegetation Index – NDVI¹

\[
NDVI = \frac{(NIR - Red)}{(NIR + Red)}
\]

¹ Halper et al. 2012

Landsat Satellite

NDVI
Research Project

METHODS

SECTION 1: Analysis of vegetation abundance and temperature

- Vegetation abundance: NDVI

- Temperature:
  1. Above canopy – Landsat thermal band with emissivities from NDVI¹
  2. Below canopy – HOBO Data Loggers

(1: Halper et al. 2012)
Research Project

METHODS

SECTION 2: Stormwater management

1. Using a Digital Elevation Model (DEM)\(^1\), identify flood-risk areas

2. Identify flood-prone areas in the city – GIS shapefile\(^1\)

3. Spatial analysis between flood prone areas and vegetation abundance - NDVI

(1: “Shuttle Radar Topography Mission” 2015; 2: INEGI)
SECTION 3: Survey of the residents

1. Thermal comfort\(^1\)
2. Mood\(^2\)
3. Perception of crime\(^3\)
4. Wellbeing -12-ISFHS\(^4\)
5. Experience flooding during rainy season

Research Project

METHODS

- Spatial analysis – GIS²
- Statistical analysis – SPSS³
  - Bivariate correlation
  - Analysis of variance (ANOVA)

Spatial analysis example in Hermosillo¹

Research Project

HYPOTHESES:

1. Areas that have a higher level of vegetation (NDVI) will be related to lower temperatures

2. People who live in areas with higher level of vegetation will report higher levels of thermal comfort, better mood, less crime in the neighborhood, and better health

3. Areas that have higher level of vegetation will be correlated with fewer and smaller areas affected by floods

4. People who live in neighborhoods with higher level of vegetation will report less floods in their neighborhood
Research Project

BROADER IMPACT:

1. Green infrastructure can act as a climate change adaptation strategy – temperature, droughts, storm events

2. Green infrastructure can mitigate climate change:
   - Vegetation – carbon sink
   - Enhanced thermal comfort - walking & biking – less use of car
   - Less energy load for HVAC systems in buildings

3. Increase water security – replenish aquifers, enhance water quality

4. Improve quality of life in cities – comfort, mood, crime, wellbeing

5. Provide habitat for species – ecosystem services
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For more information, see: [www.lrfoundation.org.uk](http://www.lrfoundation.org.uk)
References