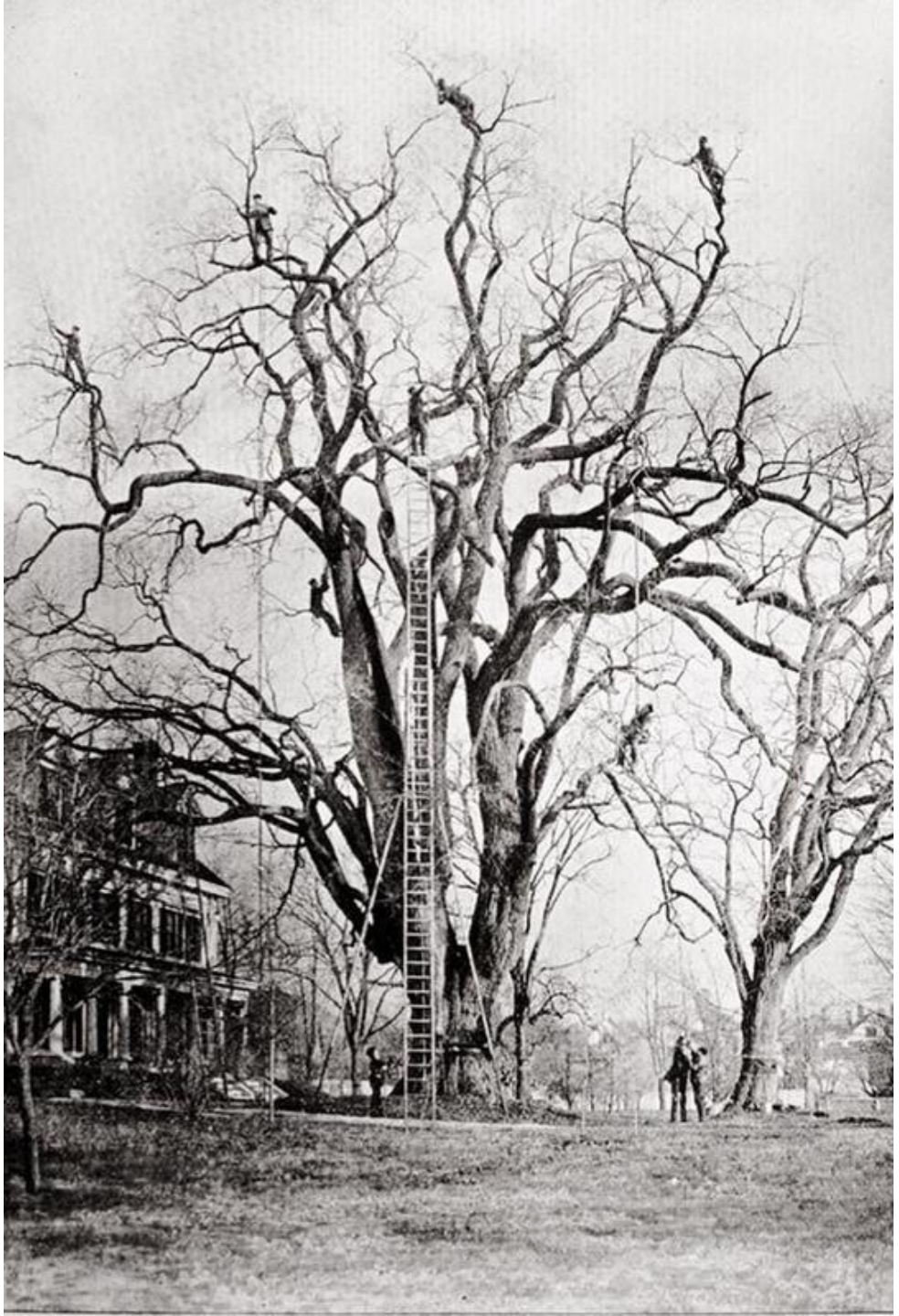
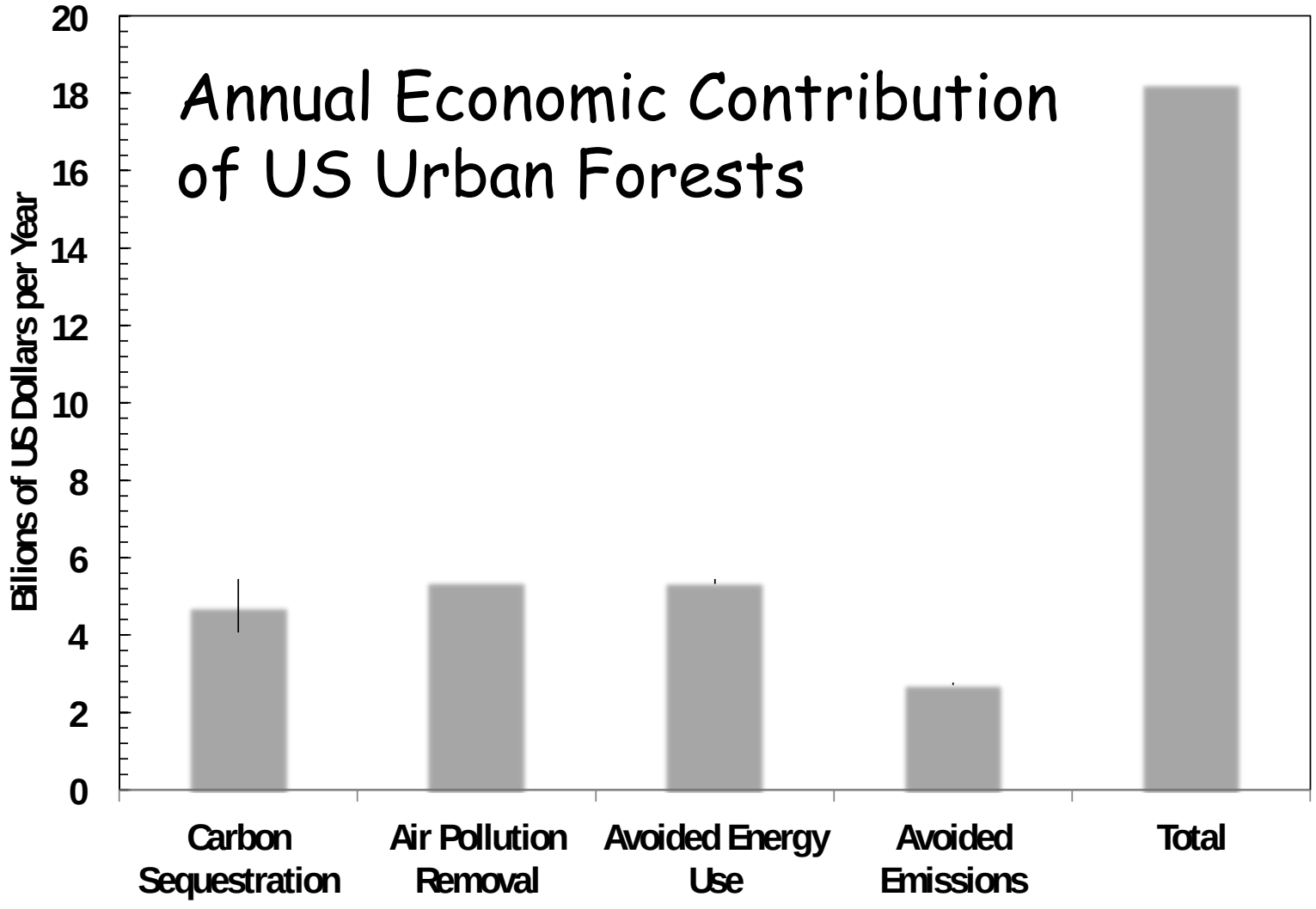
Clarifying Myths About Caribbean Cities and Using Vegetation for Making Them Adaptable and Resilient to Extreme Events

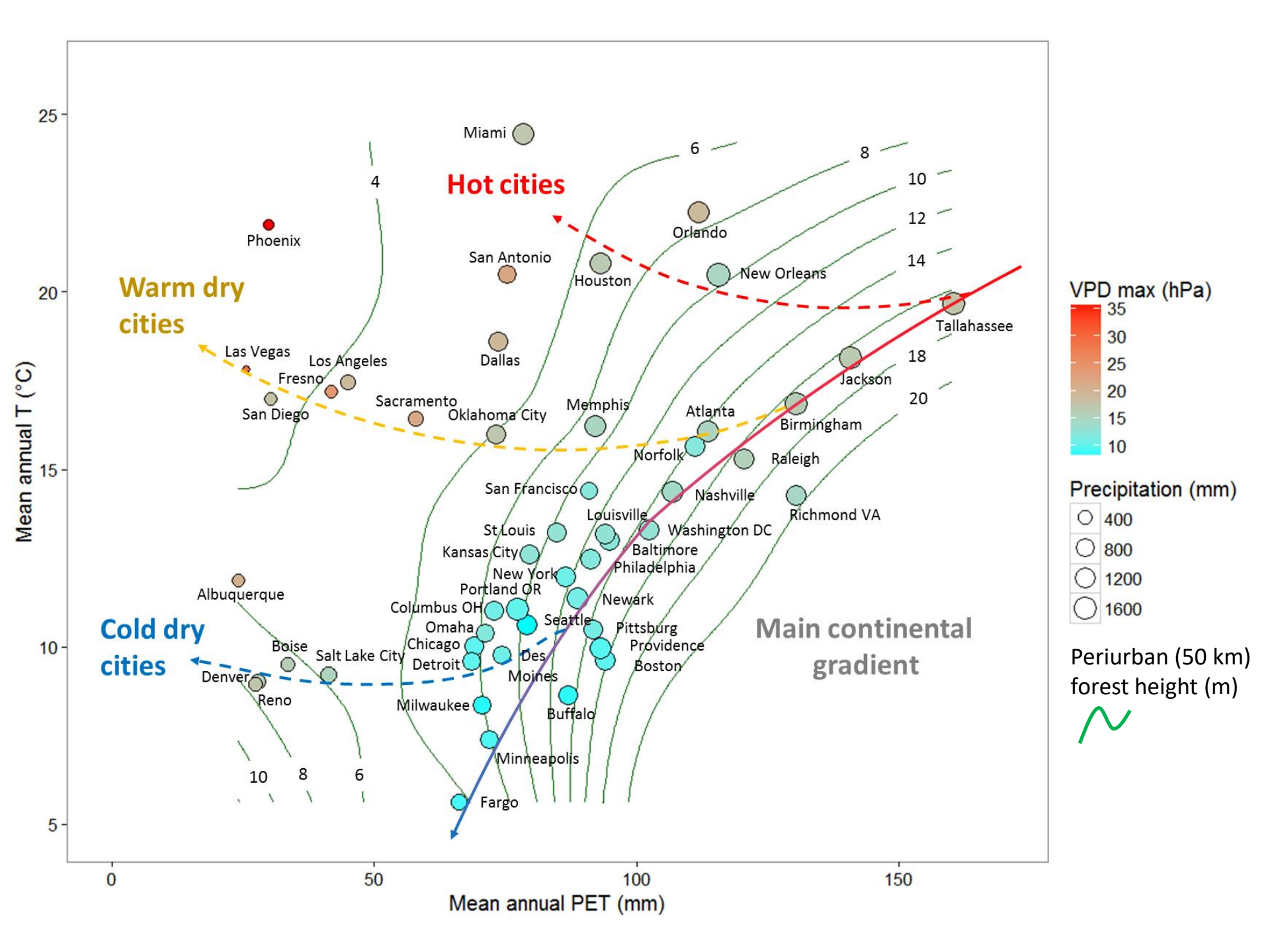
Ariel E. Lugo

USDA Forest Service

Contributions from Alonso Ramírez, Omar Pérez Reyes, Olga Ramos González, Sebastián Martinuzzi, Thomas J. Brandeis, Gabriela Morales Nieves, and natural and social scientists in San Juan ULTRA




Annual Economic Contribution of US Urban Forests
Billions of US Dollars per Year
20
18
16
14
12
10
8
6
4
2
0
Carbon Sequestration
Air Pollution Removal
Avoided Energy Use
Avoided Emissions
Total


Hot cities
Warm dry cities
Cold dry cities
Main continental gradient
Miami
Phoenix
San Antonio
Houston
Orlando
New Orleans
Tallahassee
Las Vegas
Los Angeles
Fresno
San Diego
Sacramento
Dallas
Oklahoma City
Memphis
Atlanta
Jackson
Birmingham
Norfolk
Raleigh
San Francisco
Nashville
Richmond VA
Louisville
St Louis
Washington DC
Kansas City
Baltimore
Philadelphia
New York
Portland OR
Albuquerque
Newark
Columbus OH
Seattle
Omaha
Pittsburg
Providence
Chicago
Boise
Salt Lake City
Detroit
Des Moines
Boston
Denver
Reno
Milwaukee
Buffalo
Minneapolis
Fargo
4
6
8
10
12
14
18
20
10
8
6
Mean annual T (°C)
Mean annual PET (mm)
25
20
15
10
5
0
50
100
150
VPD max (hPa)
35
30
25
20
15
10
Precipitation (mm)
400
800
1200
1600
Periurban (50 km) forest height (m)

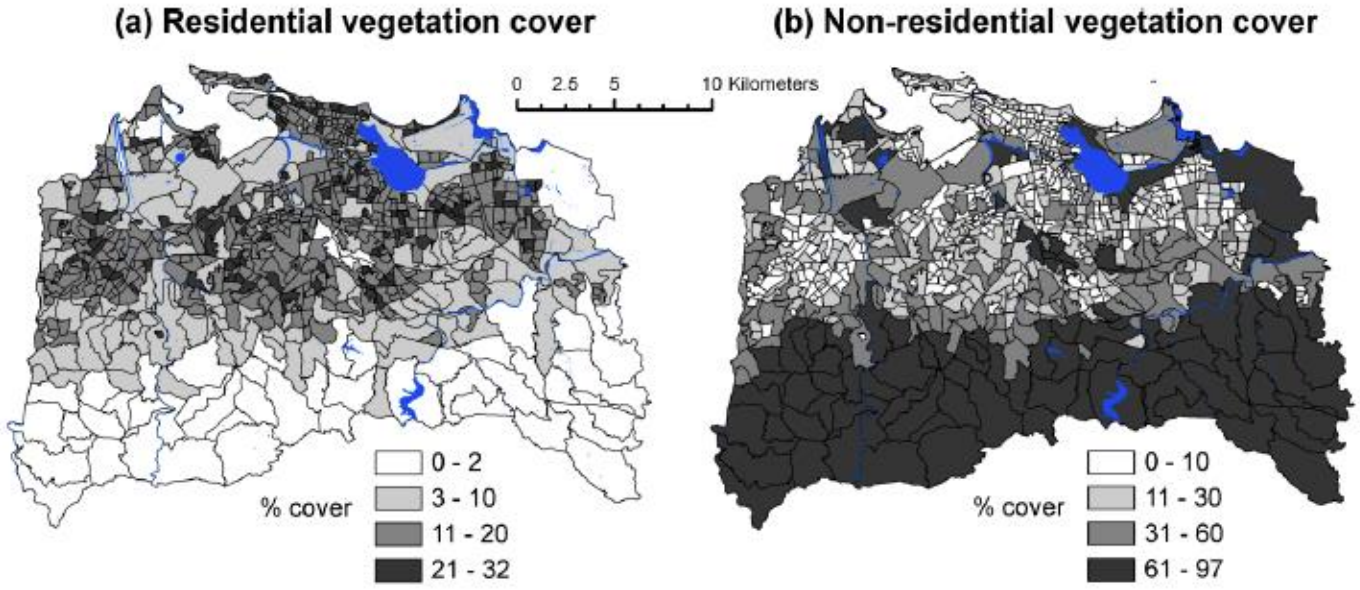
1. Low Area of Vegetation

Vegetation/non-vegetation based on 0.3-meter aerial photo

Martinuzzi et al (in rev)

Residential vegetation (yellow) vs. non-residential vegetation (green)

Martinuzzi et al (in rev)



Martinuzzi et al (in rev)

	Ha	% of total vegetation	Median cover by Census block group (%)
All vegetation	30,701		31.9
Residential vegetation	3,377	11.0	14.1
Non-residential vegetation	27,325	89.0	15.1

Martinuzzi et al (in rev)

1. Low Area of Vegetation
2. The Polluted River Had to be Depauperate in Species

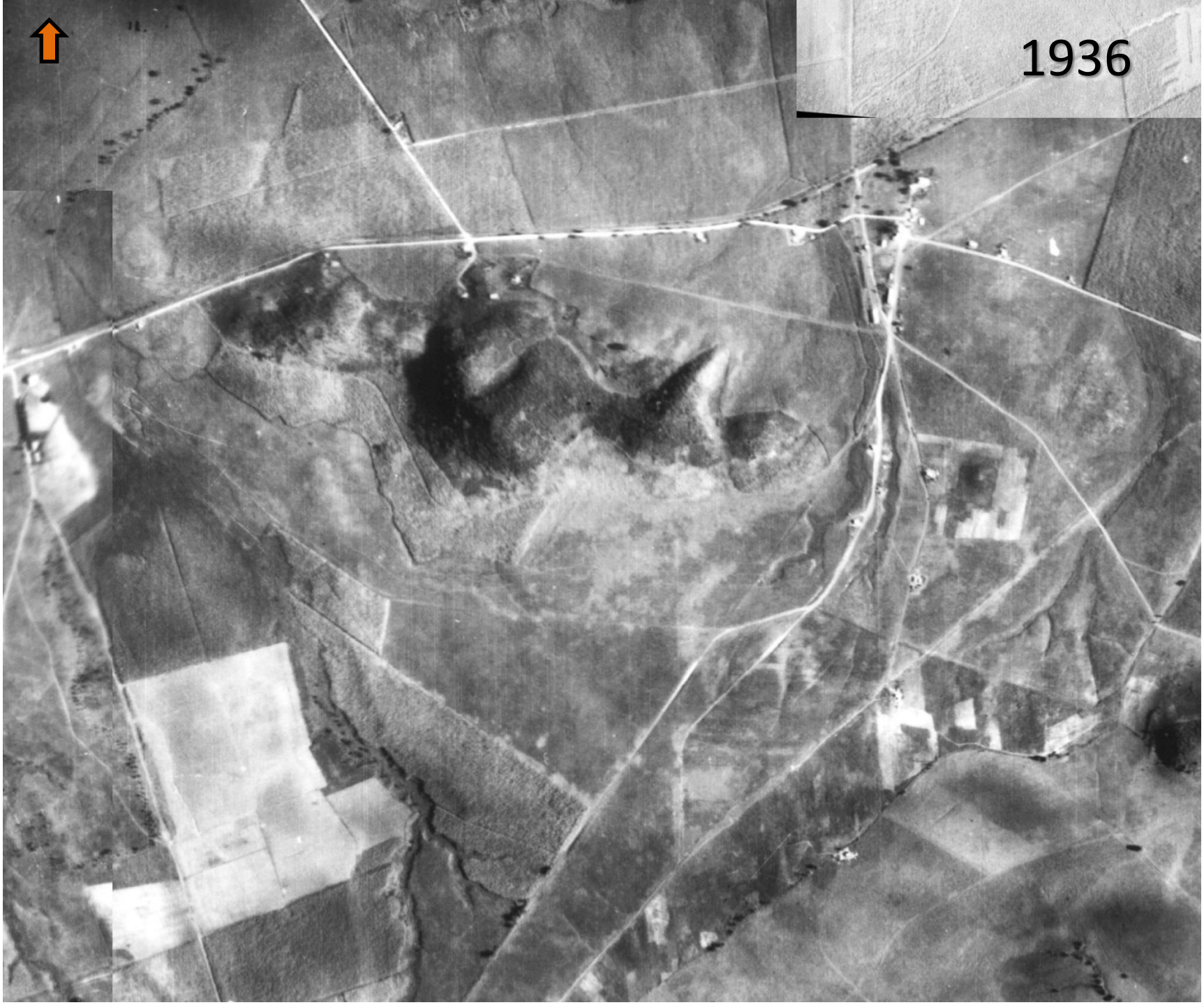
Actual Field Work

- Uncovered 120 taxa of aquatic organisms (fish [12 species], insects, crustaceans, other invertebrates, reptiles)
- High fish biomass
- A rare sponge (*Spongilla laba*)
- A shrimp species thought extinct (*Palaemon pandaliformis*) but actually common in this river.

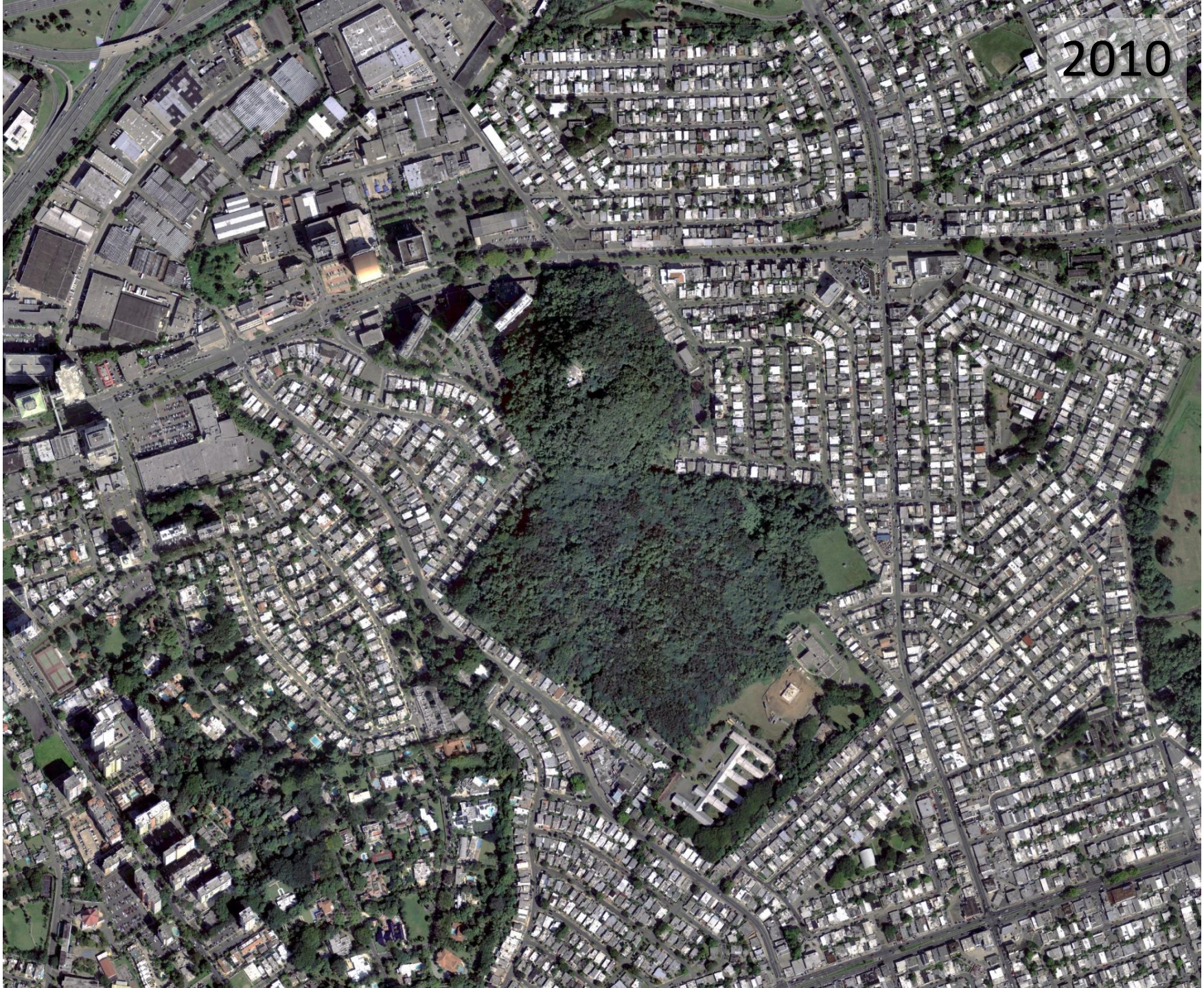
1. Low Area of Vegetation
2. The Polluted River Had to be Depauperate in Species
3. The City is Biologically and Ecologically Homogenized

Urban Forest Inventories for San Juan: Brandeis et al. 2014

- In 6.34 ha sampled at random in 2011: 86 tree and shrub species
- In 6.68 ha sampled at random in 2001: 75 tree and shrub species
- Shannon-Wiener Diversity index of 3.277 and 3.101, respectively (not bad!)

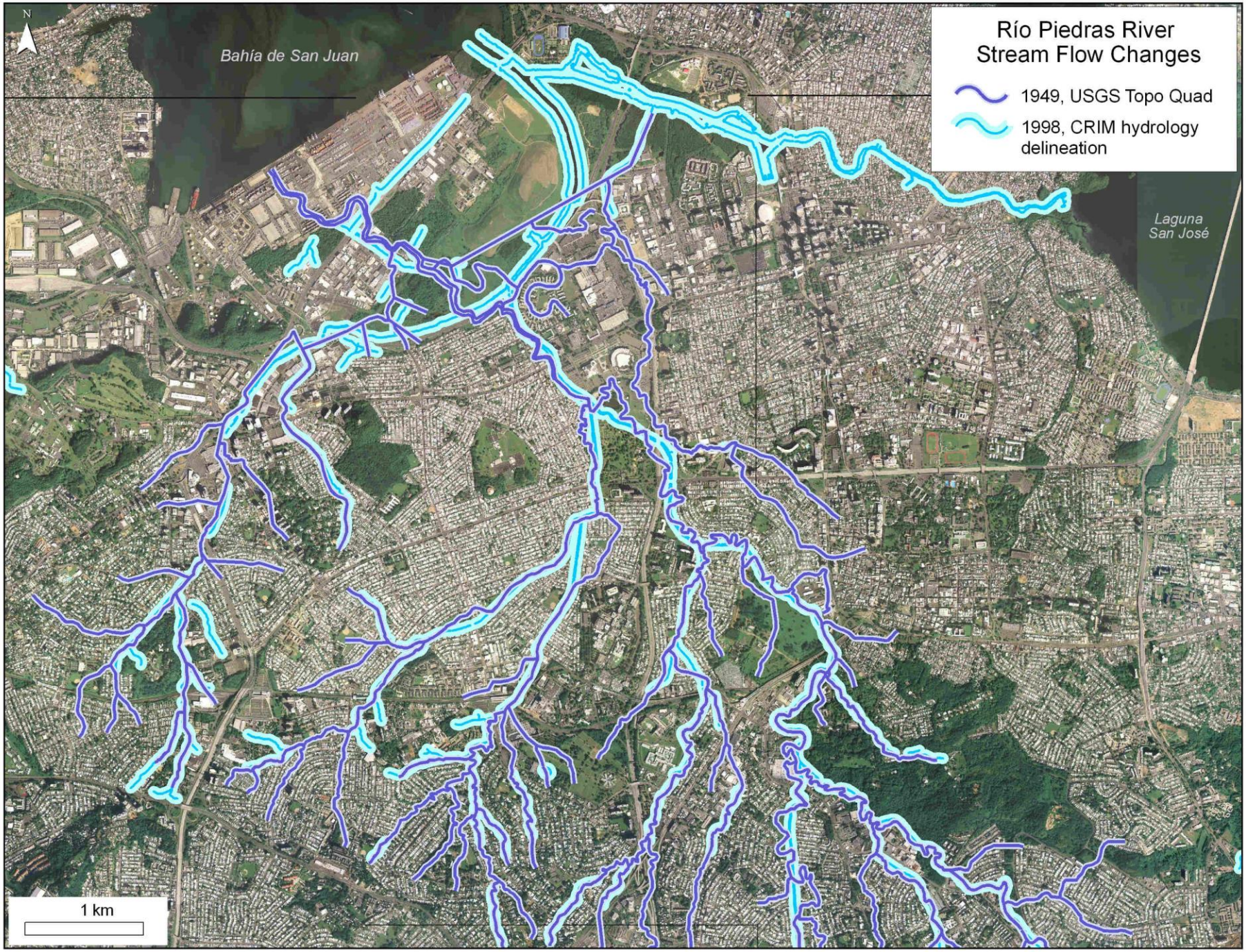

1936

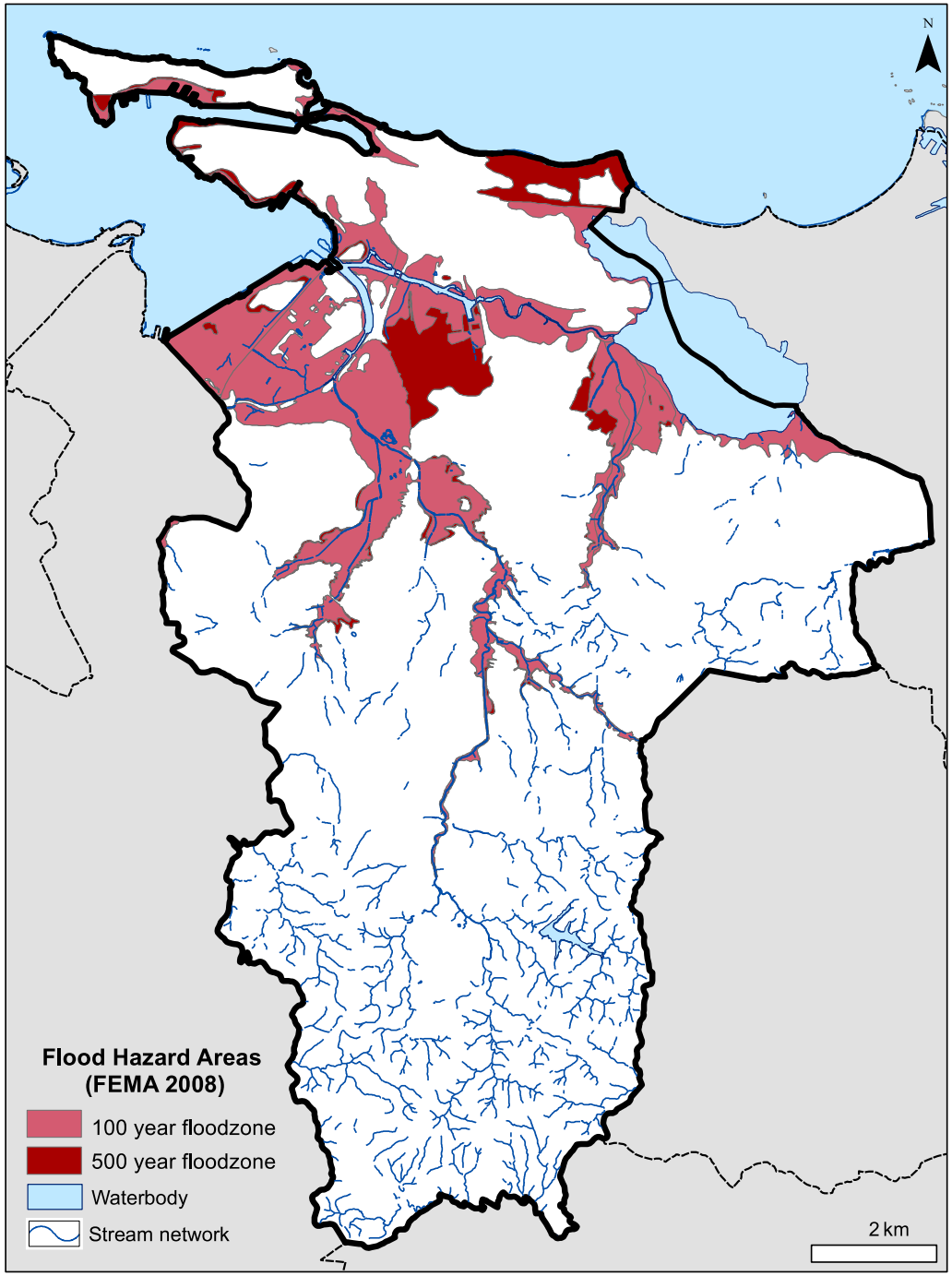

1952


2010

1. Low Area of Vegetation
2. The Polluted River Had to be Depauperate in Species
3. The City is Biologically and Ecologically Homogenized
4. Ecology Alone Can Solve the Flooding Problem

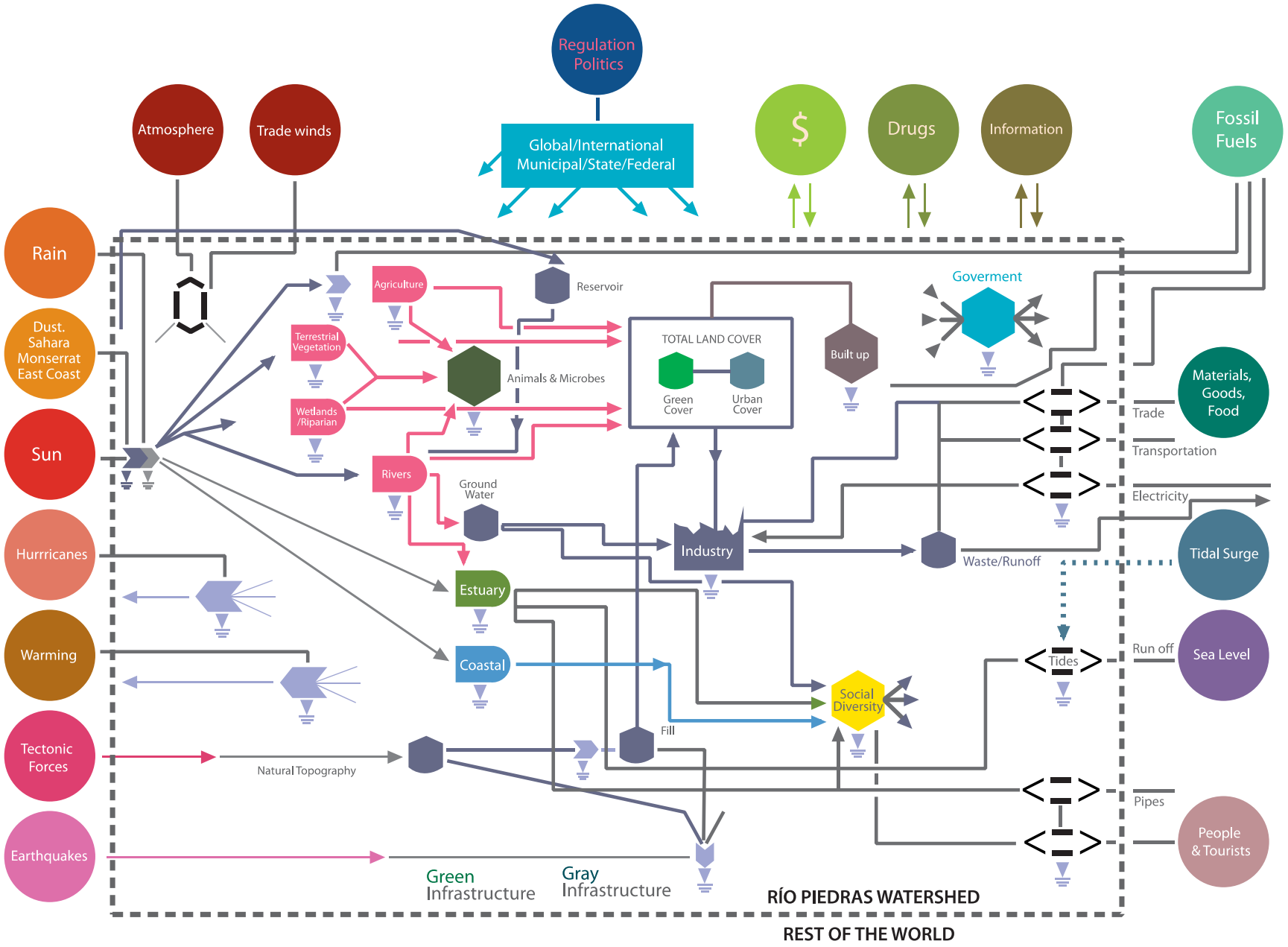

PUERTO DE SAN JUAN


N
Bahía de San Juan
Río Piedras River
Stream Flow Changes
1949, USGS Topo Quad
1998, CRIM hydrology
delineation
Laguna
San José
1 km

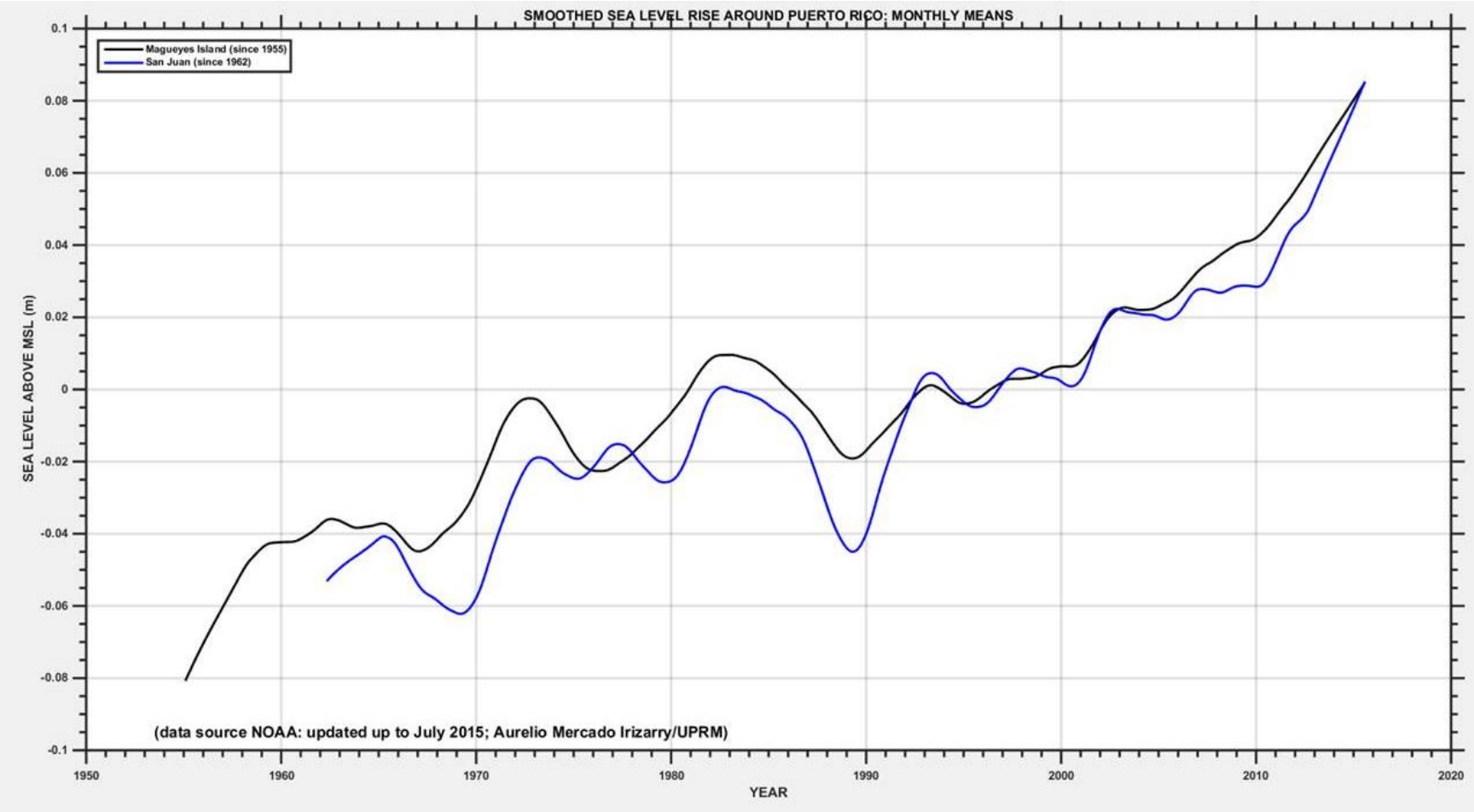

N
Flood Hazard Areas
(FEMA 2008)
100 year floodzone
500 year floodzone
Waterbody
Stream network
2 km

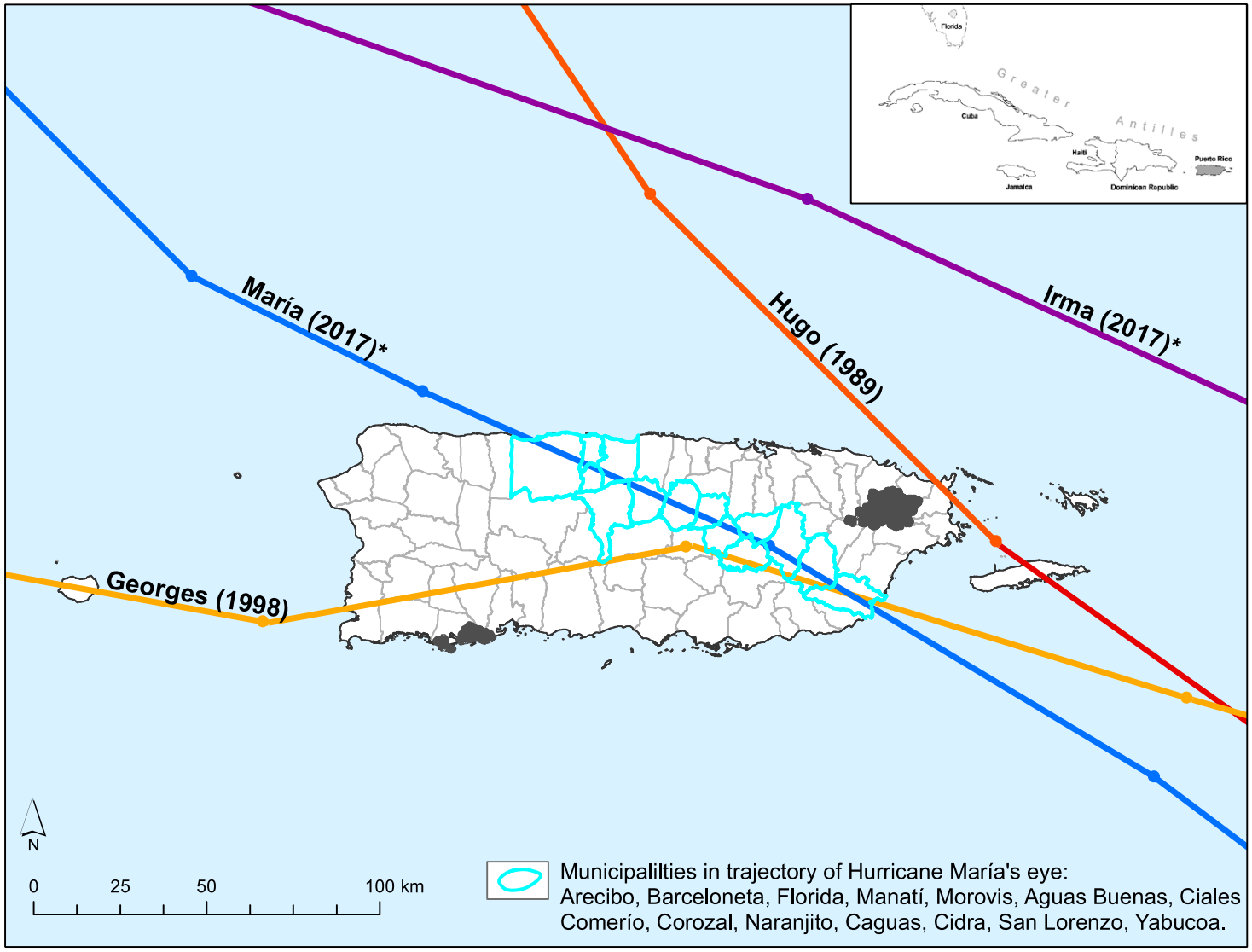
1. Low Area of Vegetation
2. The Polluted River Had to be Depauperate in Species
3. The City is Biologically and Ecologically Homogenized
4. Ecology Alone Can Solve the Flooding Problem
5. The City is a Simple System

A SOCIAL-ECOLOGICAL-TECHNOLOGICAL SYSTEM (SETS)



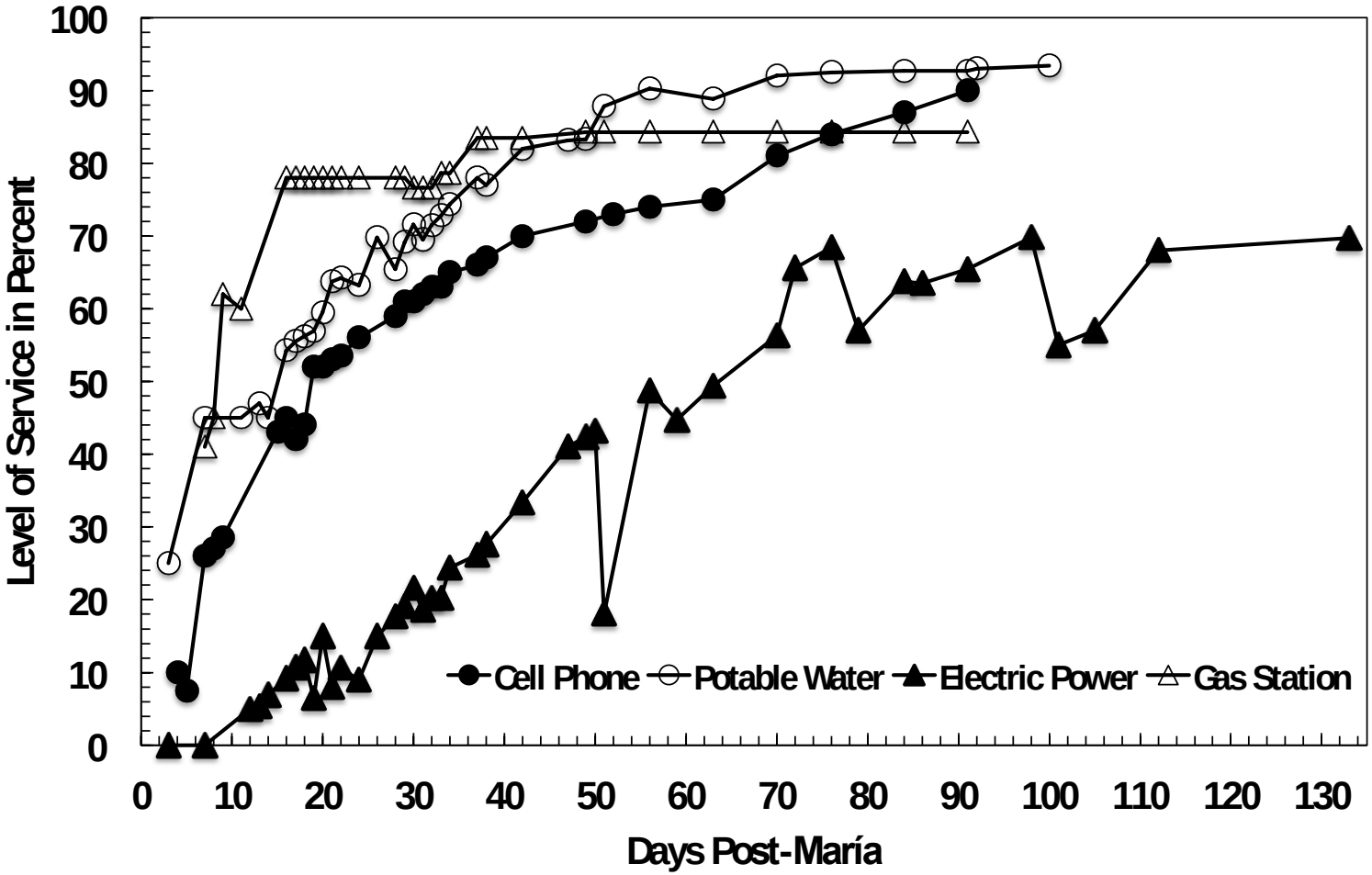
Rising Sea Level





* Preliminary trajectory (Source: NOAA National Hurricane Center)

Category and Unit	Total Number	Percent Functioning
Banks (number of branches)	313	0
Containers (dispatched daily at ports)	1,400	0
Gasoline Stations (number)	1,100	40
Post Offices (number)	132	0
Pharmacies (number)	1045	0
Roads (miles)	5,073	8
Supermarkets (number tracked)	456	0
Telecommunication Antennas (number)	2,671	<10
Telecommunication Towers (number)	1,619	20


Level of Service in Percent
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
Days Post-María
Cell Phone
Potable Water
Electric Power
Gas Station

How did Urban Forests do?

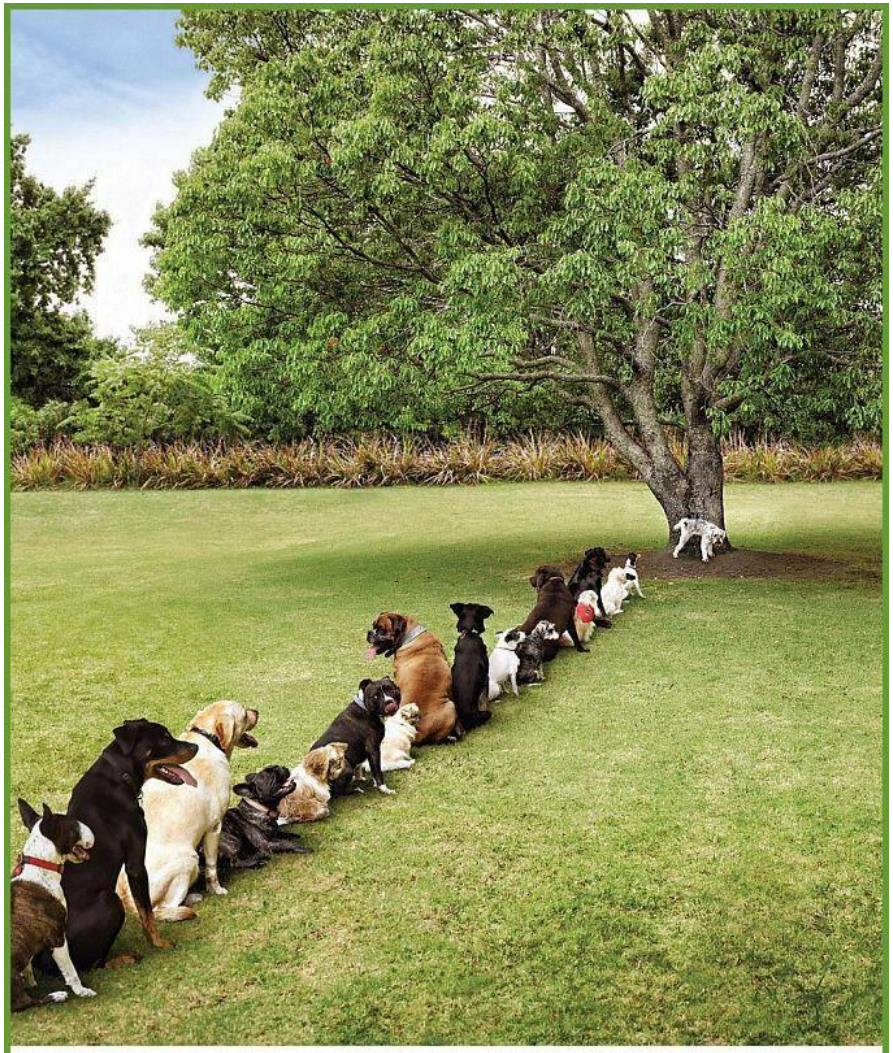
- Those trees that were planted in the wrong place perished.
- Urban forests experienced similar effects as rural forests and they recovered as fast.
- The city was hotter because of the loss of forest canopy and leaves.
- People recognized the importance of vegetation for water quality and advocated reforestation.

Moving Forward: María Was An Experiment That Can Benefit Other Countries

- Complex adaptive system's thinking along the lines of SETS.
- A focus on learning.
- Increased participation.
- Inclusivity, connectivity, and transparency.
- Polycentric governance.

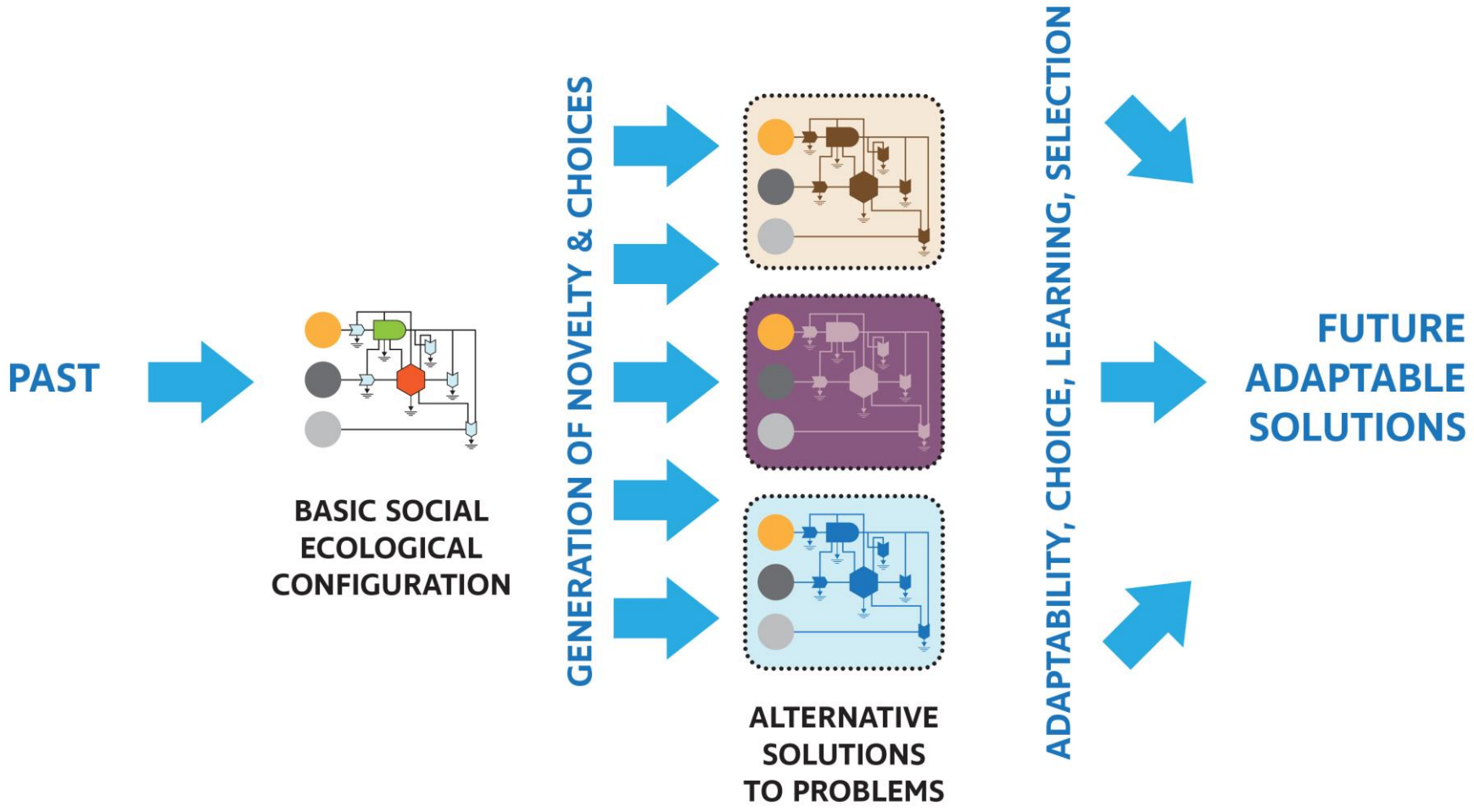
Surprised by Deforestation

¿Questions?

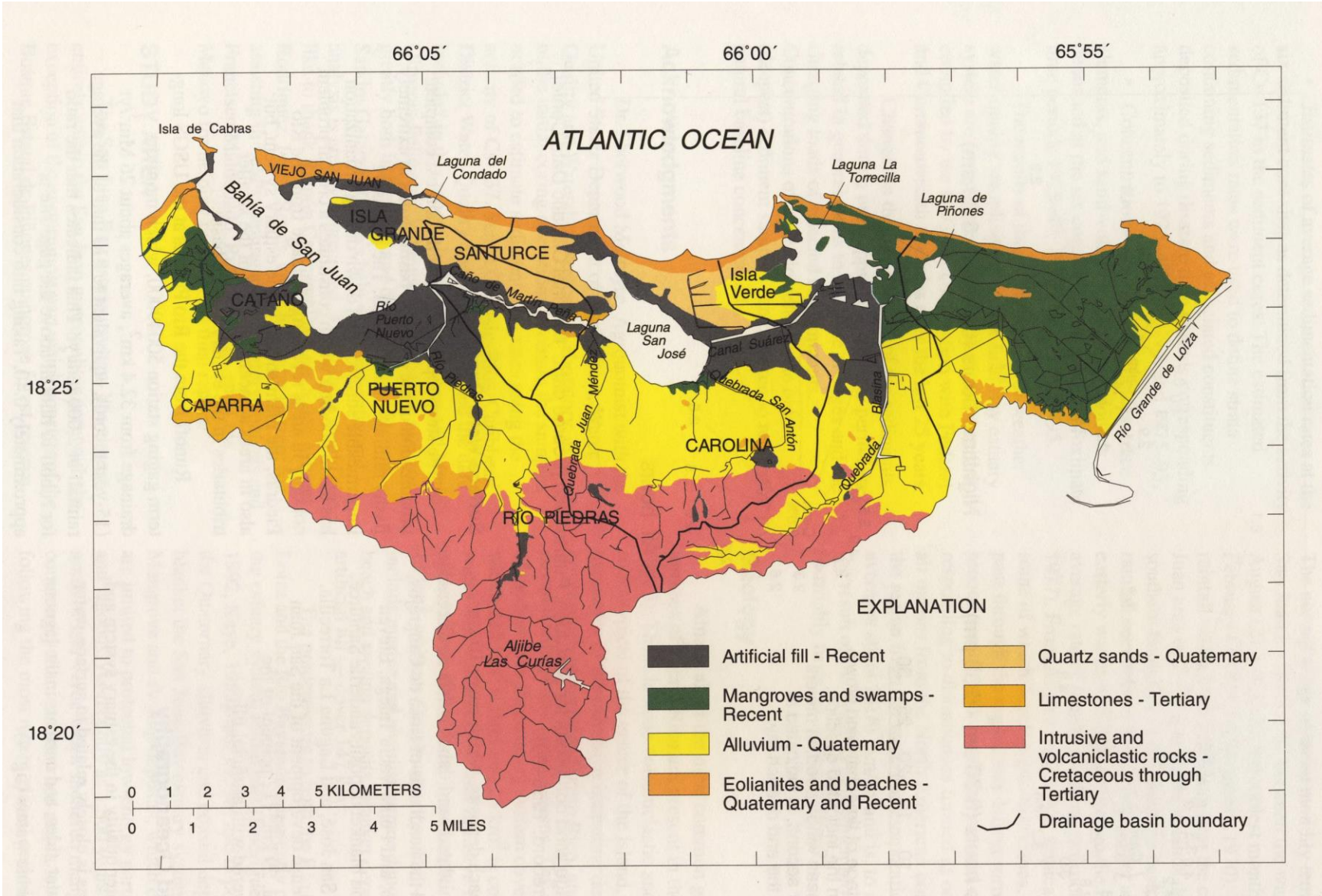


Another problem caused by deforestation

ADAPTING TO ENVIRONMENTAL CHANGE

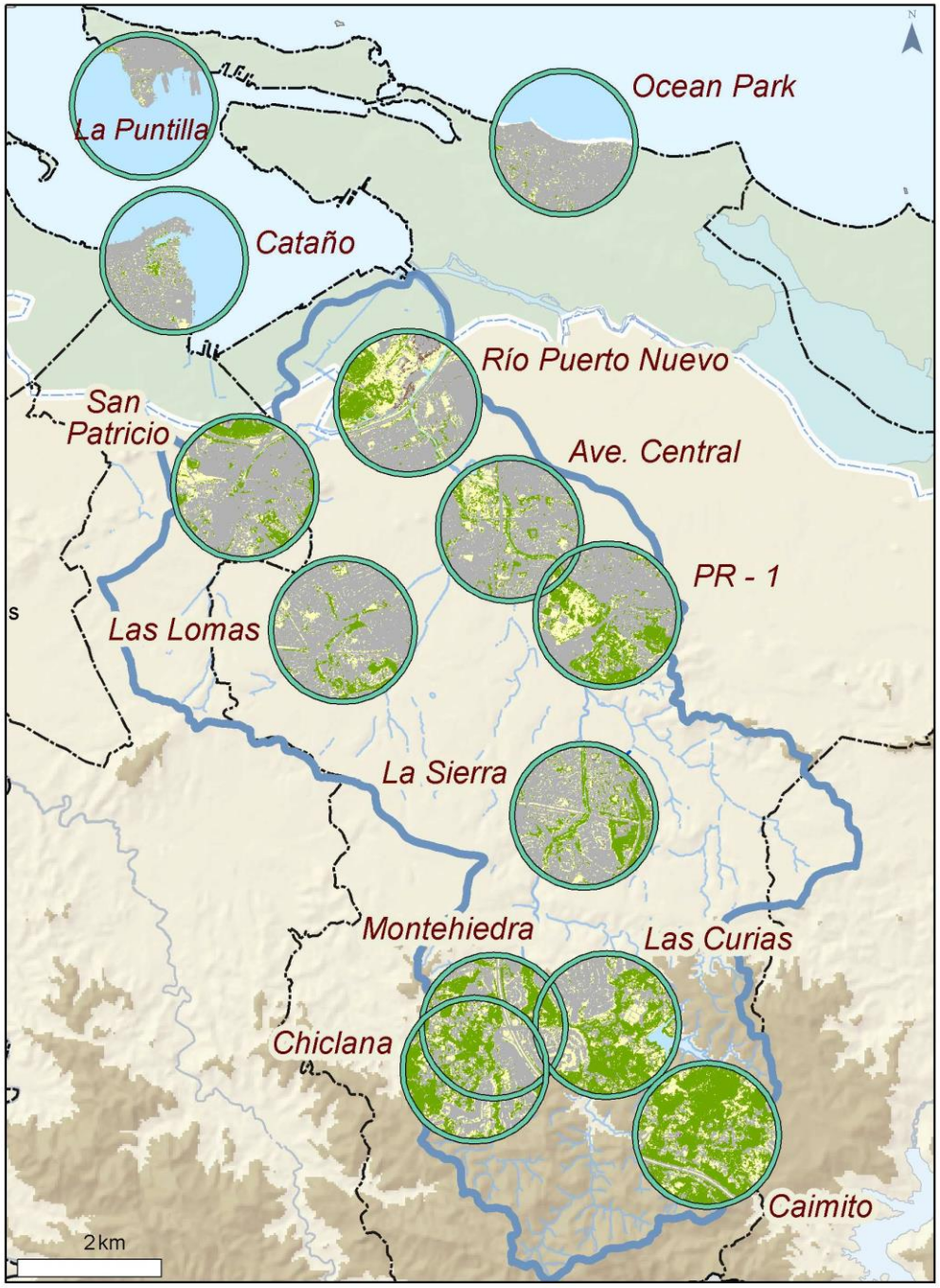


Generalized Surficial Geology (Webb and Gomez Gomez 1998)




2015

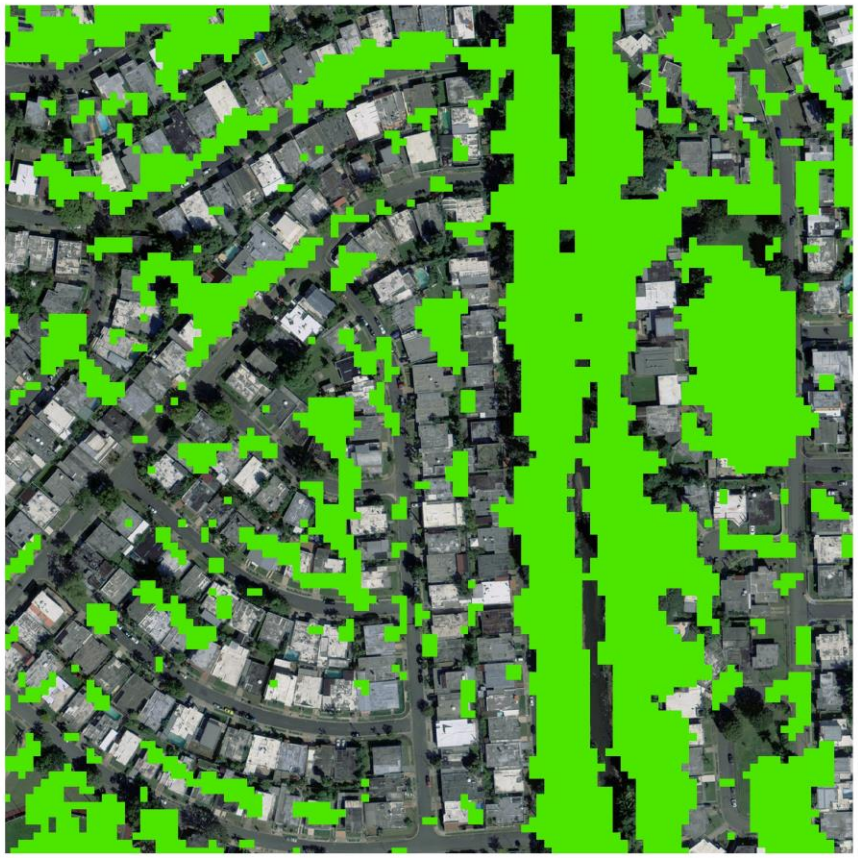

2007



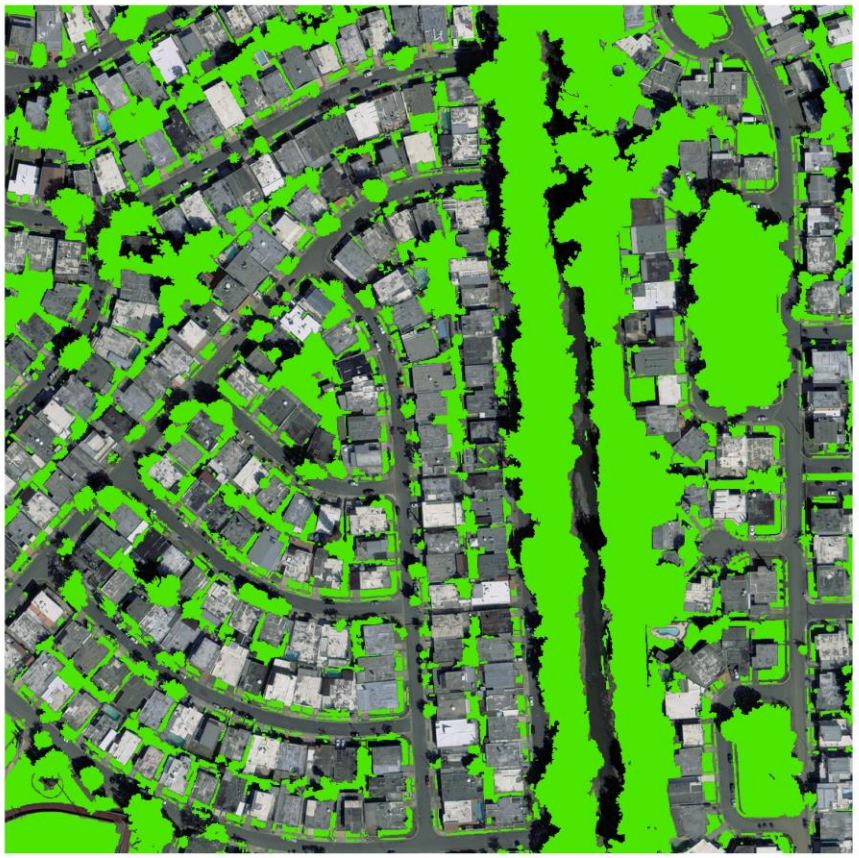
Land Cover (IKONOS 2002, American Forests)

- Tree cover
- Cropland, pasture, grassy areas
- Impervious surfaces
- Bare areas
- Water

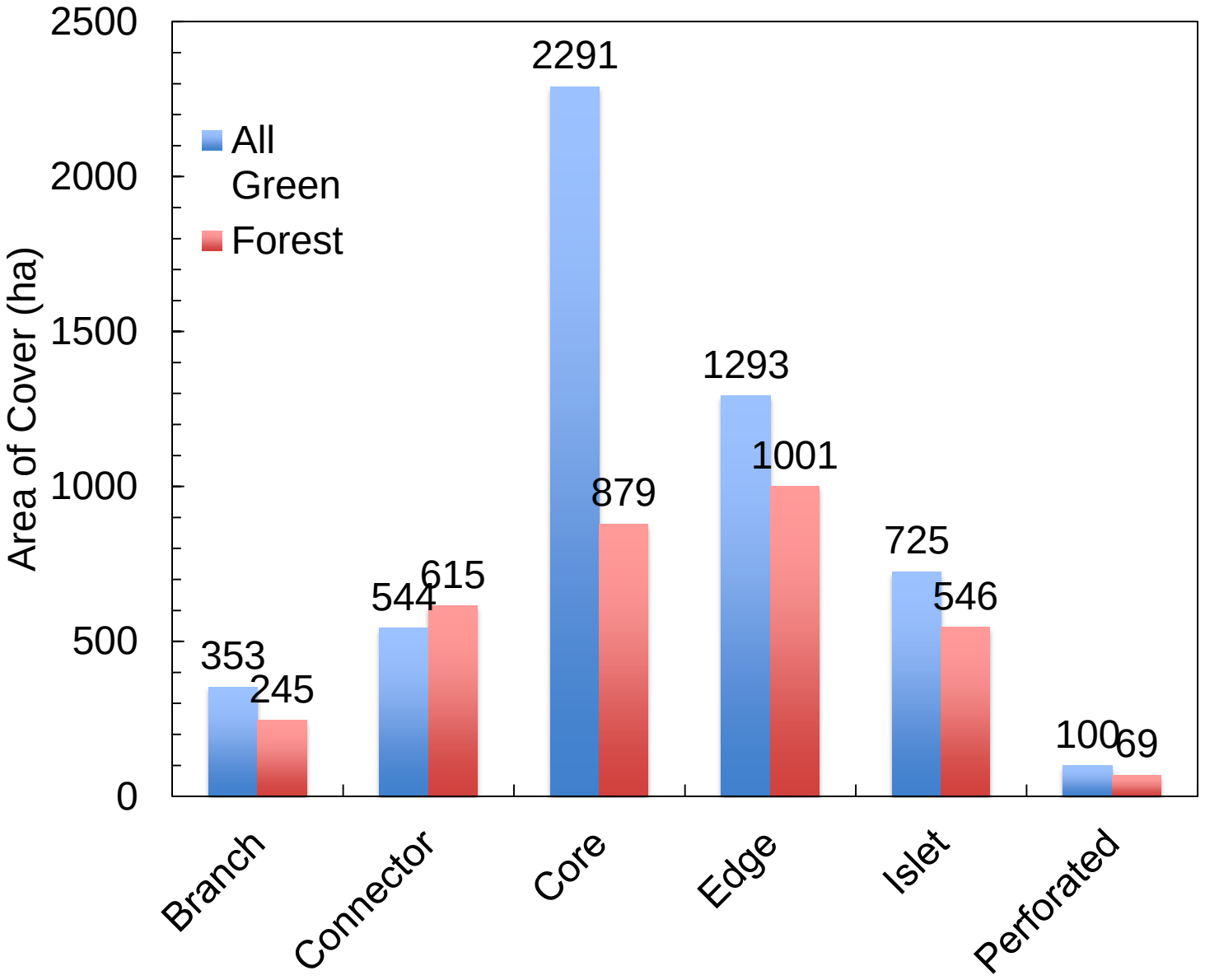
Detail of the Green Infrastructure at La Sierra ULTRA Circle

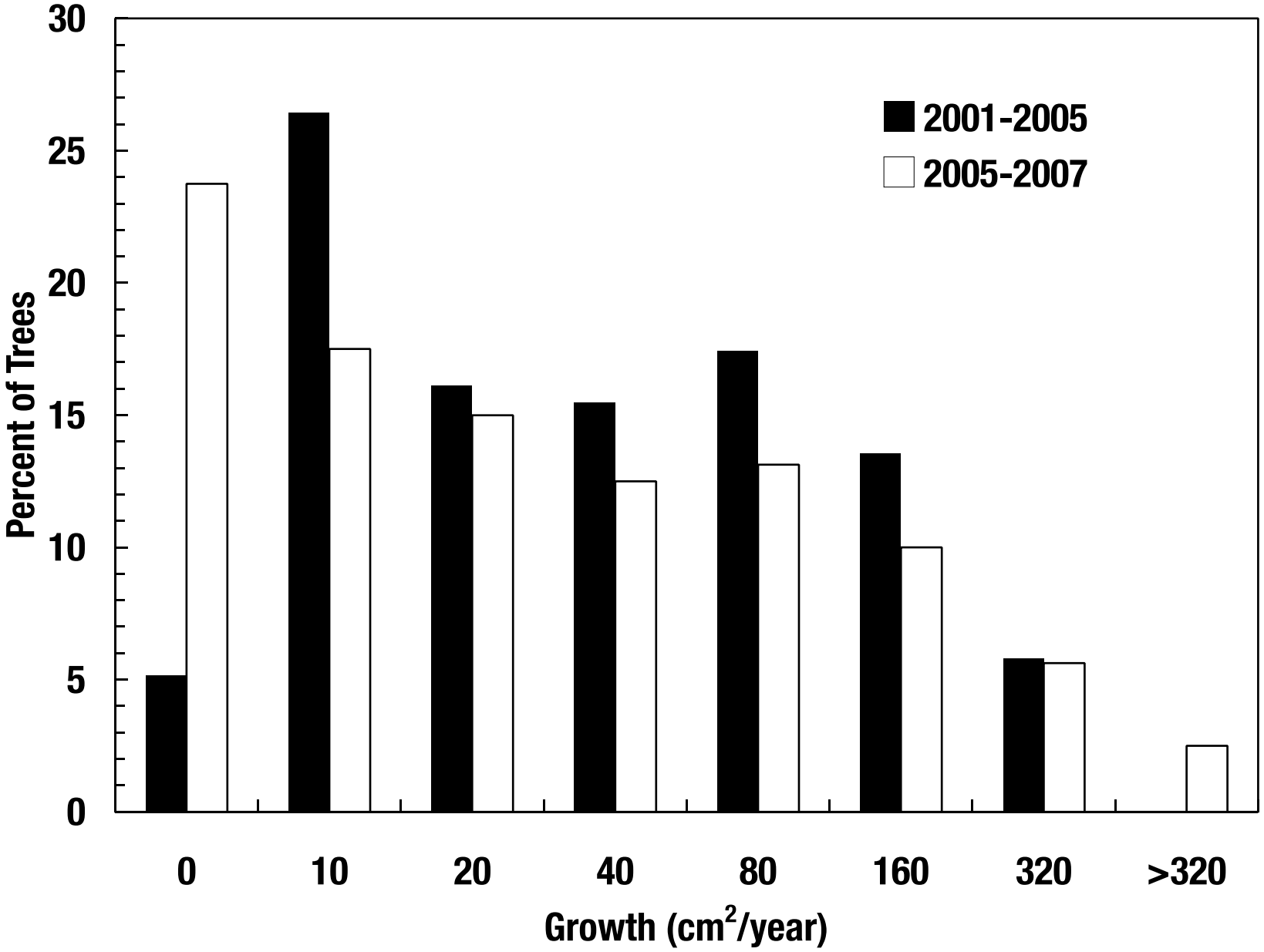


2002 - 4 meters spatial resolution



2010 - 0.3 meters spatial resolution


2500
2000
1500
1000
500
0
Area of Cover (ha)
All Green
Forest
353
245
544
615
2291
879
1293
1001
725
546
100
69
Branch
Connector
Core
Edge
Islet
Perforated


30
25
20
15
10
5
0
Percent of Trees
2001-2005
2005-2007
0
10
20
40
80
160
320
>320
Growth (cm2/year)

Social-Ecological-Technological (SETS) Effects of María

- Changed the social, ecological and technological conditions under which systems had to function.
- Set organisms, institutions & organizations in motion.
- Reduced the connectivity among all subsystems, isolating their components and retarding recovery.
- Increased heterogeneity of conditions.
- Induced creativity and innovation (legal and illegal).
- Exposed social and technolgical weaknesses, particularly governance.
- Few weaknesses in forests.

The Anthropocene Challenges Cities

- By exposing them to novel changing conditions.
- This includes extreme events such as heat islands, rising sea levels, intense rainfalls, long-lasting droughts, stronger hurricanes.
- Extreme events expose the weaknesses of our social-ecological and technological systems (SETS).
- They test our adaptability and resilience.