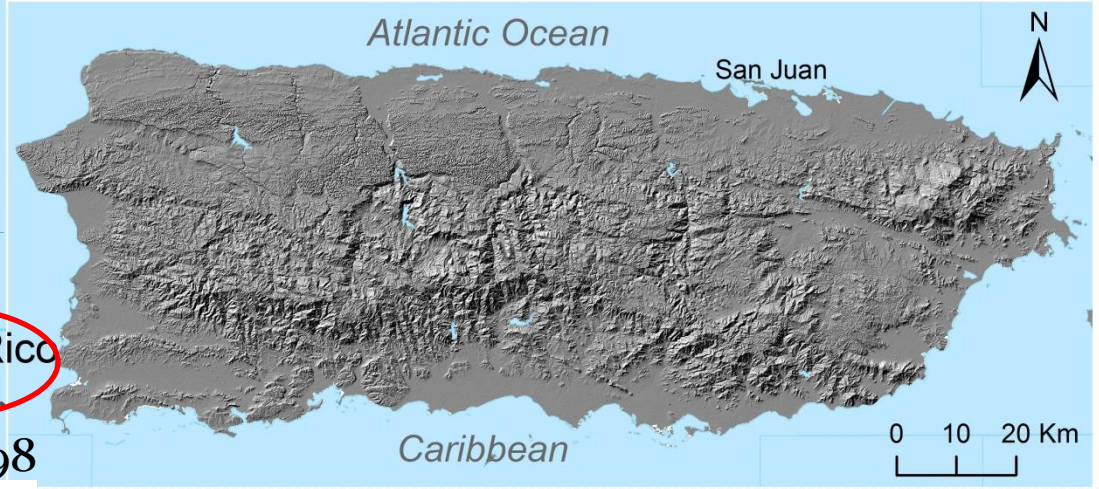
Vulnerability and Adaptive Management of Tropical Coastal Wetlands in the context of Land Use and climate Changes

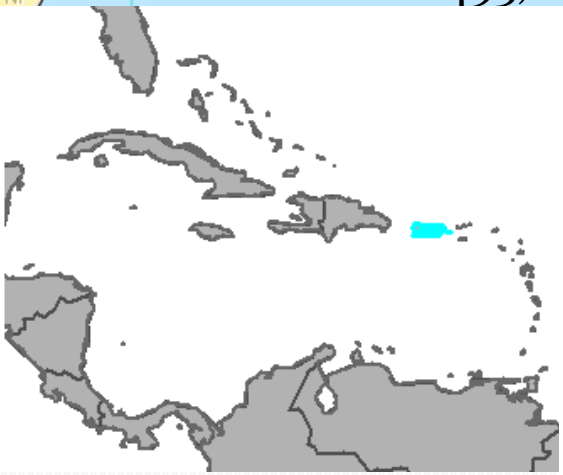
Mei Yu and Qiong Gao
Department of Environmental Science,
University of Puerto Rico, Rio Piedras

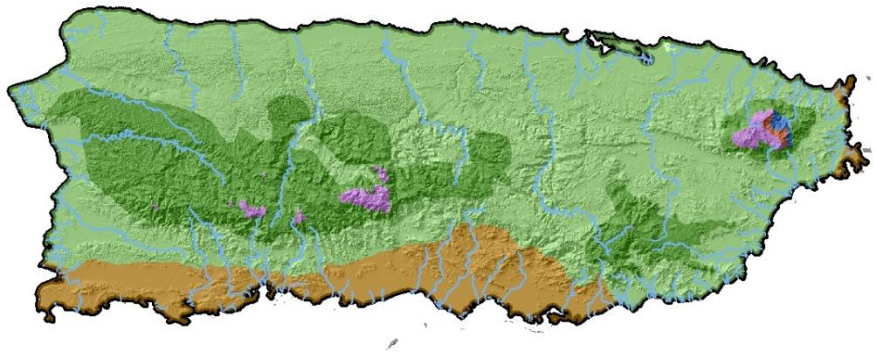
NASA LCLUC
Land-Cover / Land-Use Change Program

ITES

1493, 1898

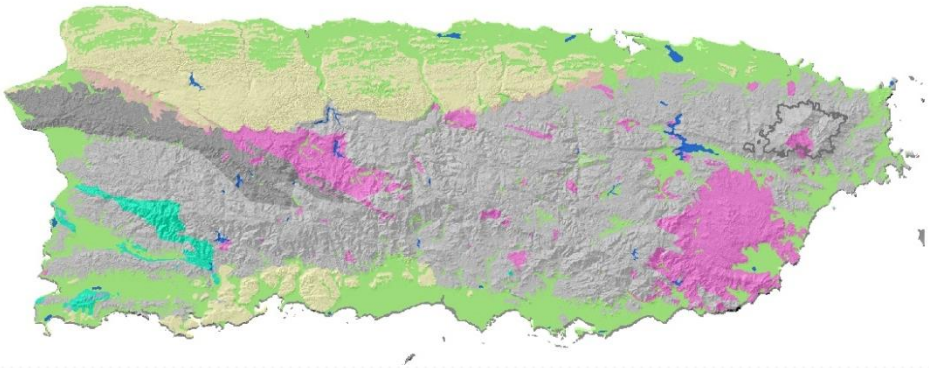






Life zone

- Subtropical Dry Forest
- Subtropical Moist Forest
- Subtropical Wet Forest
- Subtropical Rain Forest
- Lower Montane Wet Forest
- Lower Montane Rain Forest

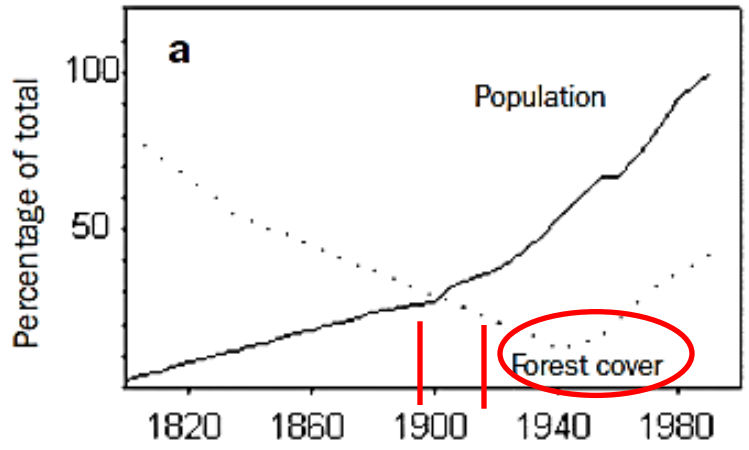


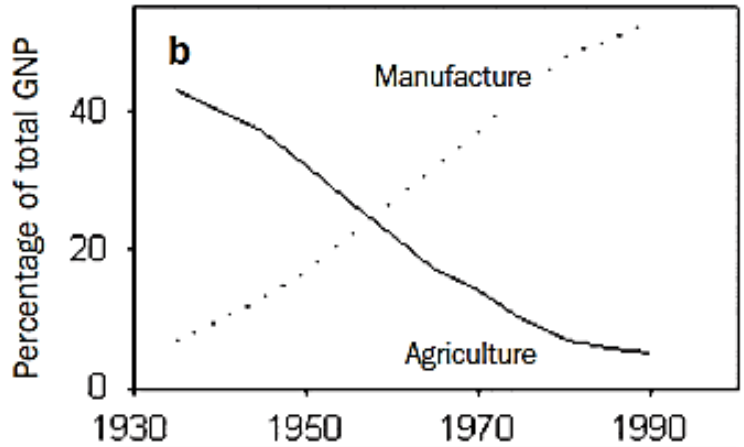
Geology

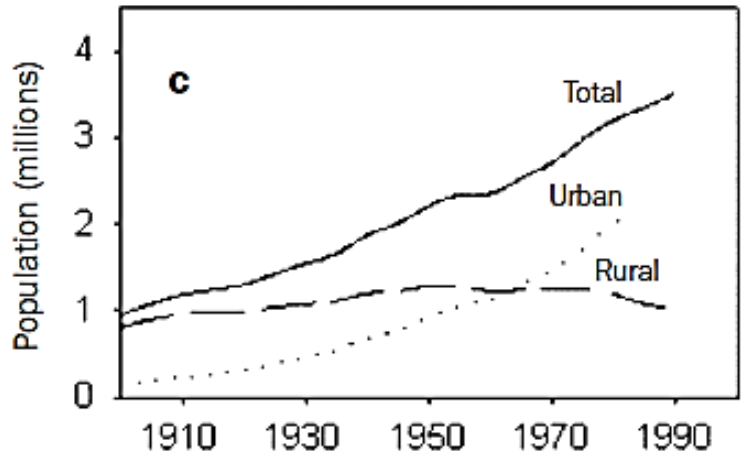
- Alluvial
- Limestone
- Sandstone
- Volcanic
- Volcaniclastic
- Plutonic
- Serpentinite
- Water

NASA LCLUC

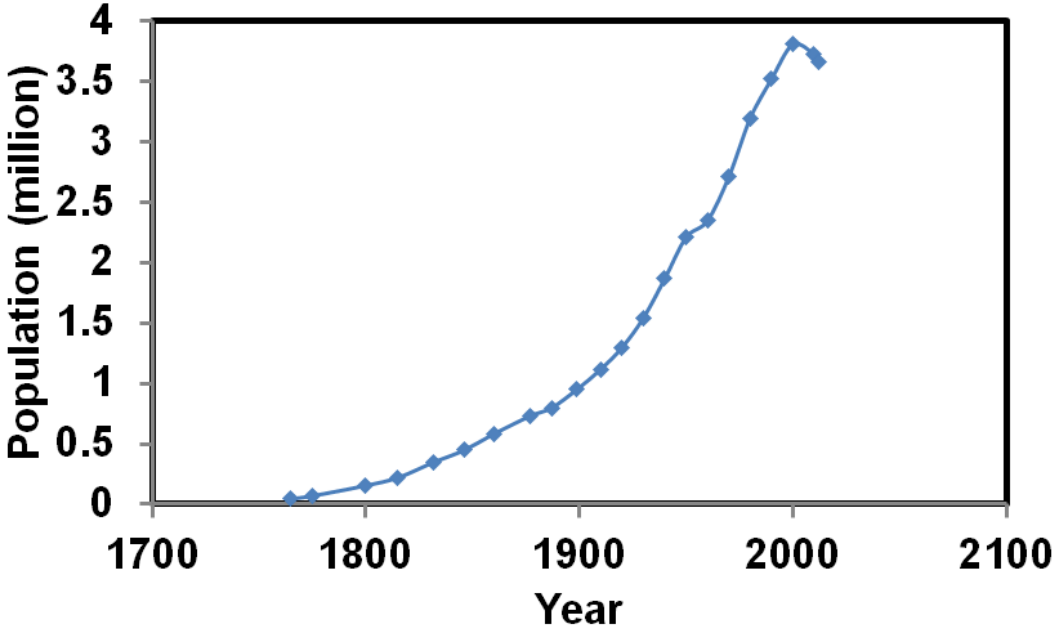
Land-Cover / Land-Use Change Program



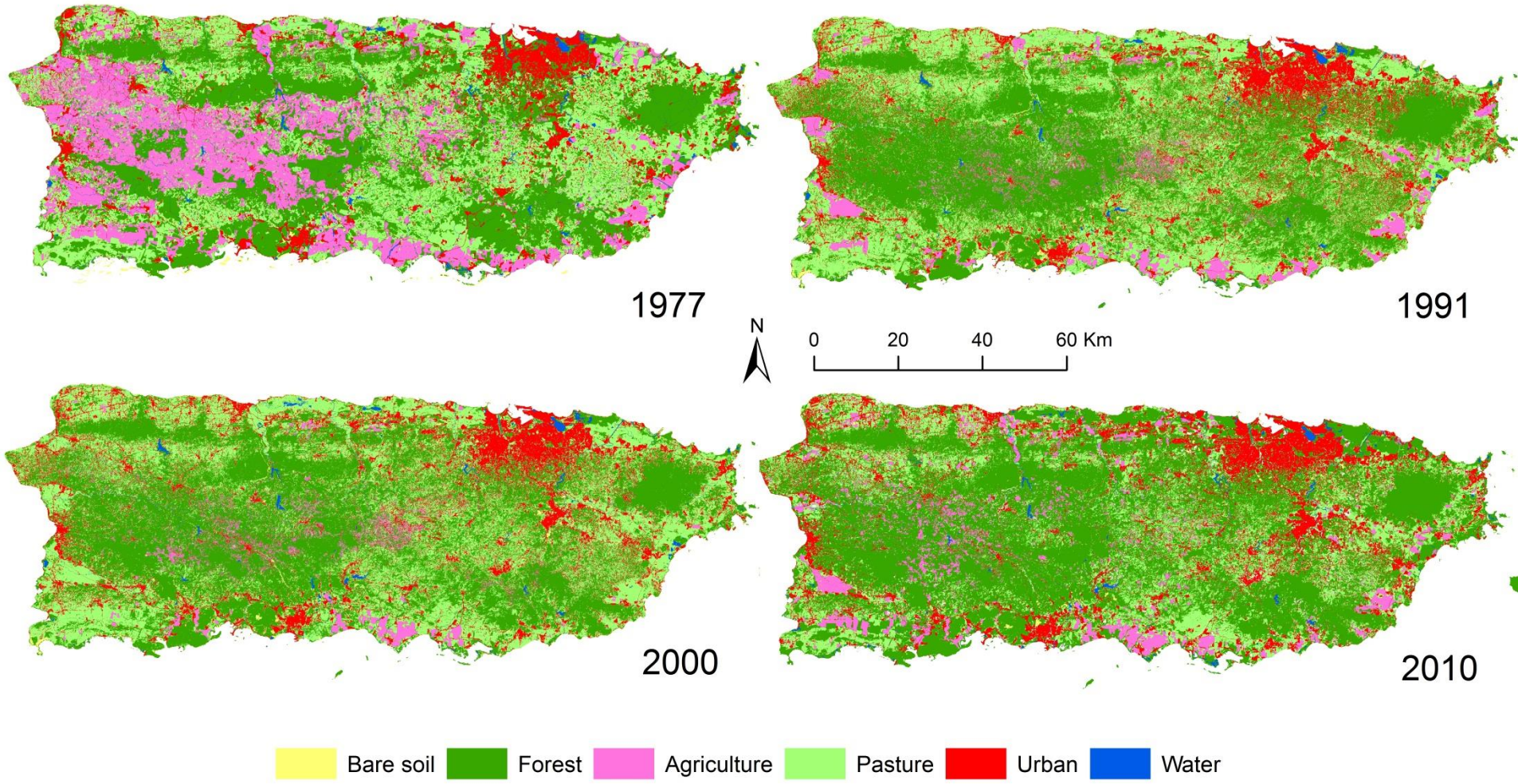




Grau et al. 2003 Bioscience



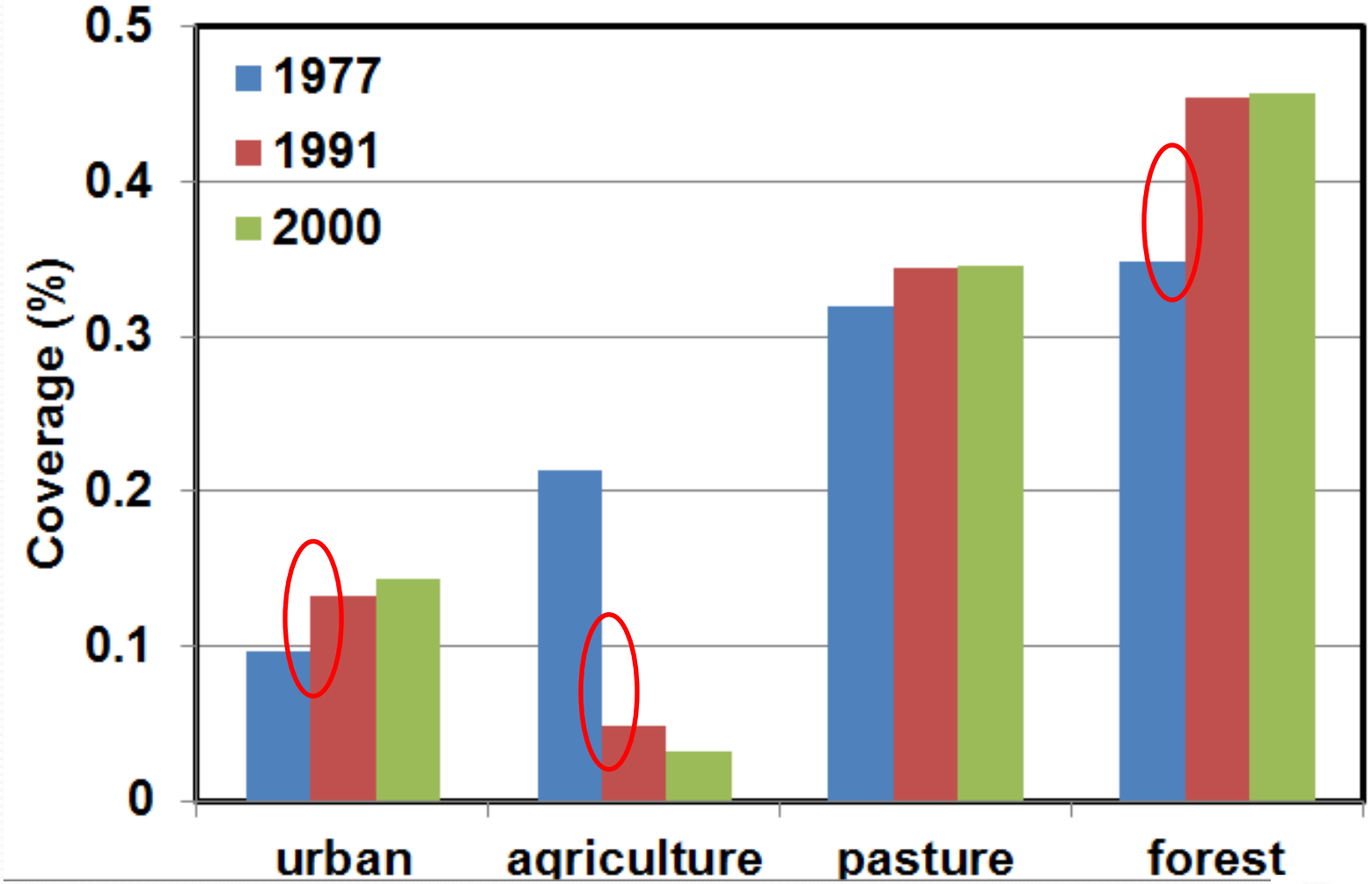
Land Cover changes



Land-Cover / Land-Use Change Program

ITES

Land Cover changes

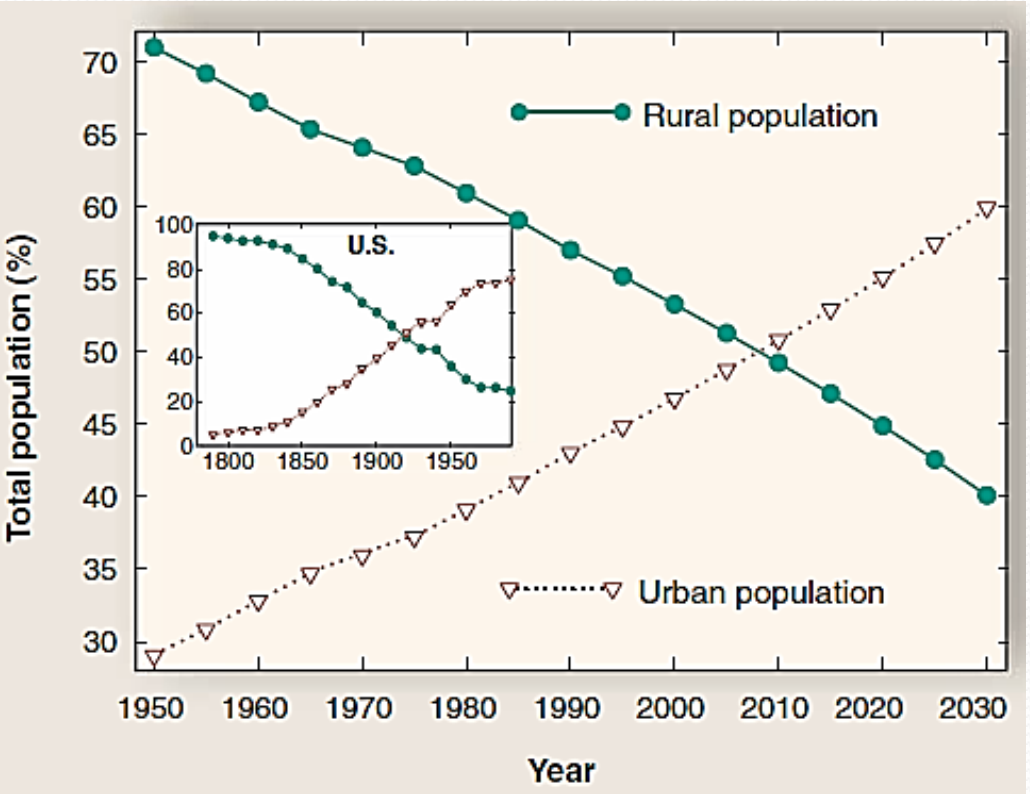


Land-Cover / Land-Use Change Program

ITES

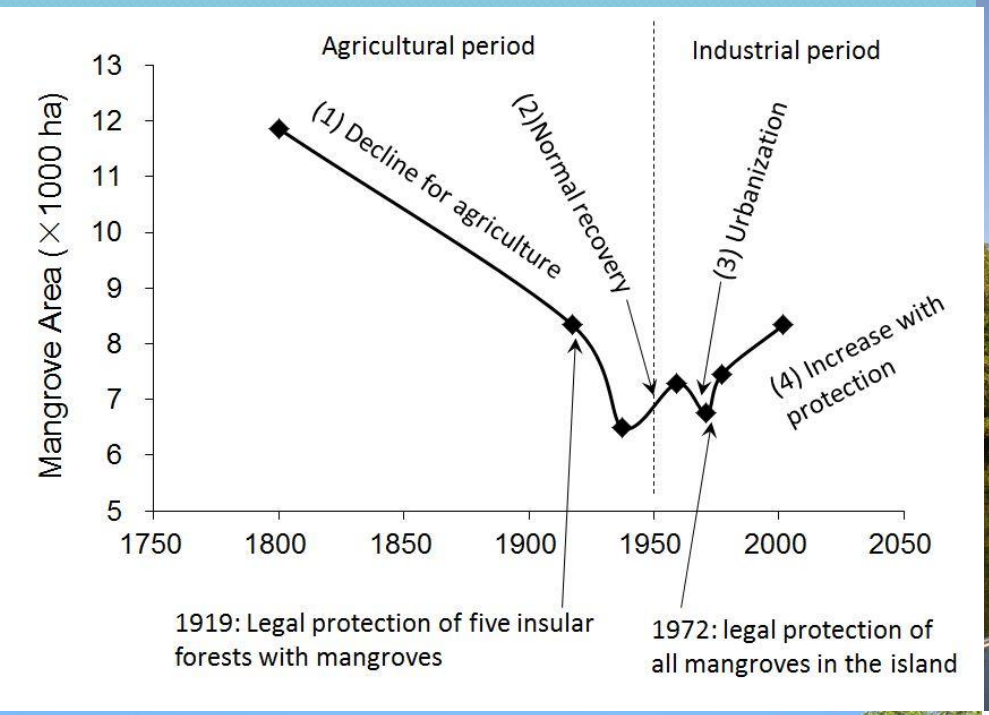
Land Cover changes

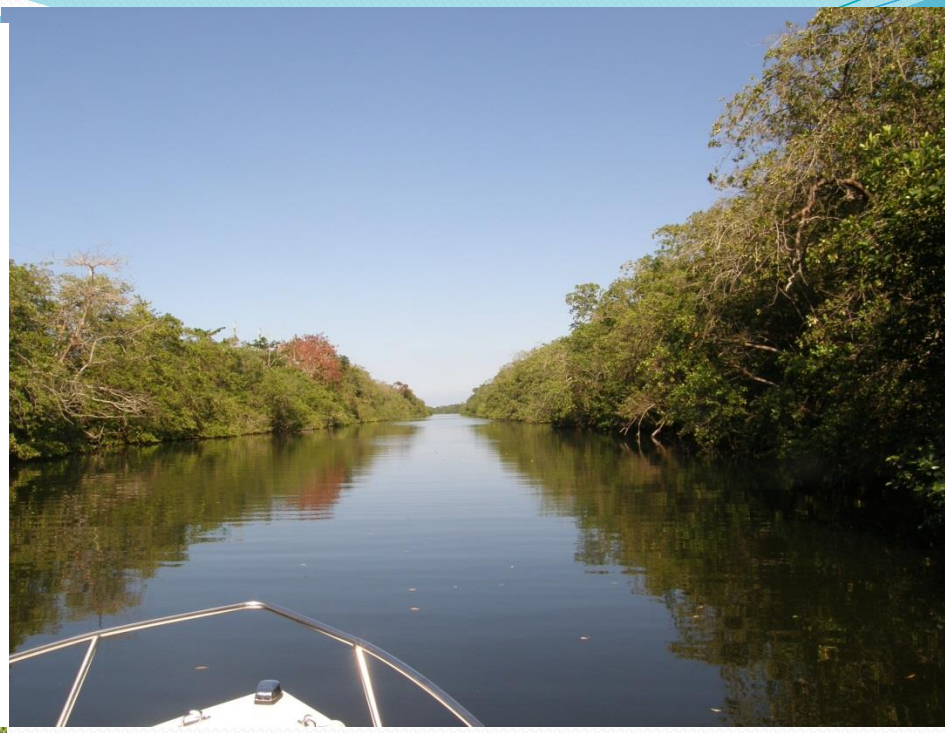
- Deforestation → Reforestation
- Urbanization → Urban Sprawl



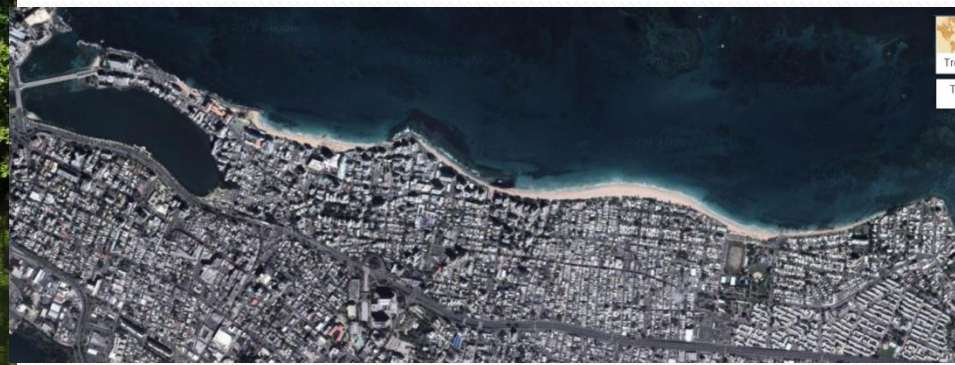
Grimm et al. 2008 Science

Land-Cover / Land-Use Change Program



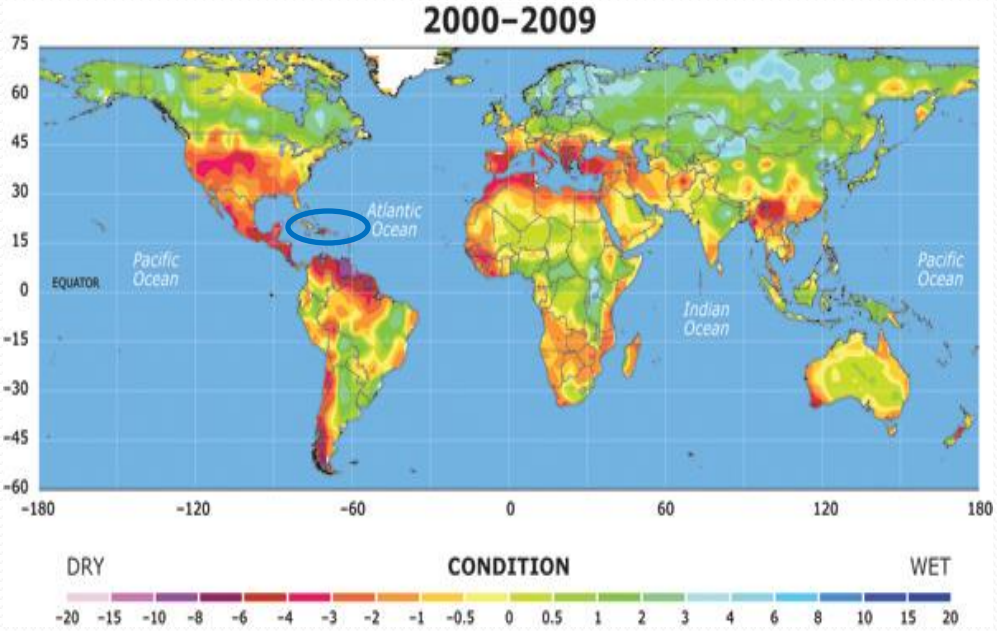


Mangrove distribution, (Martinuzzi et al. 2009)



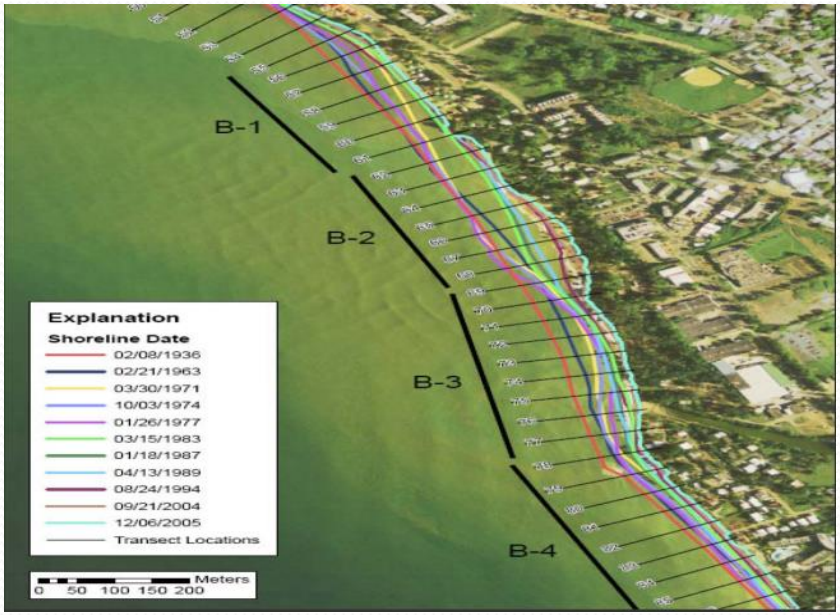
Climate changes

- Drought



Annual Palmer Drought Severity Index, Dai 2010

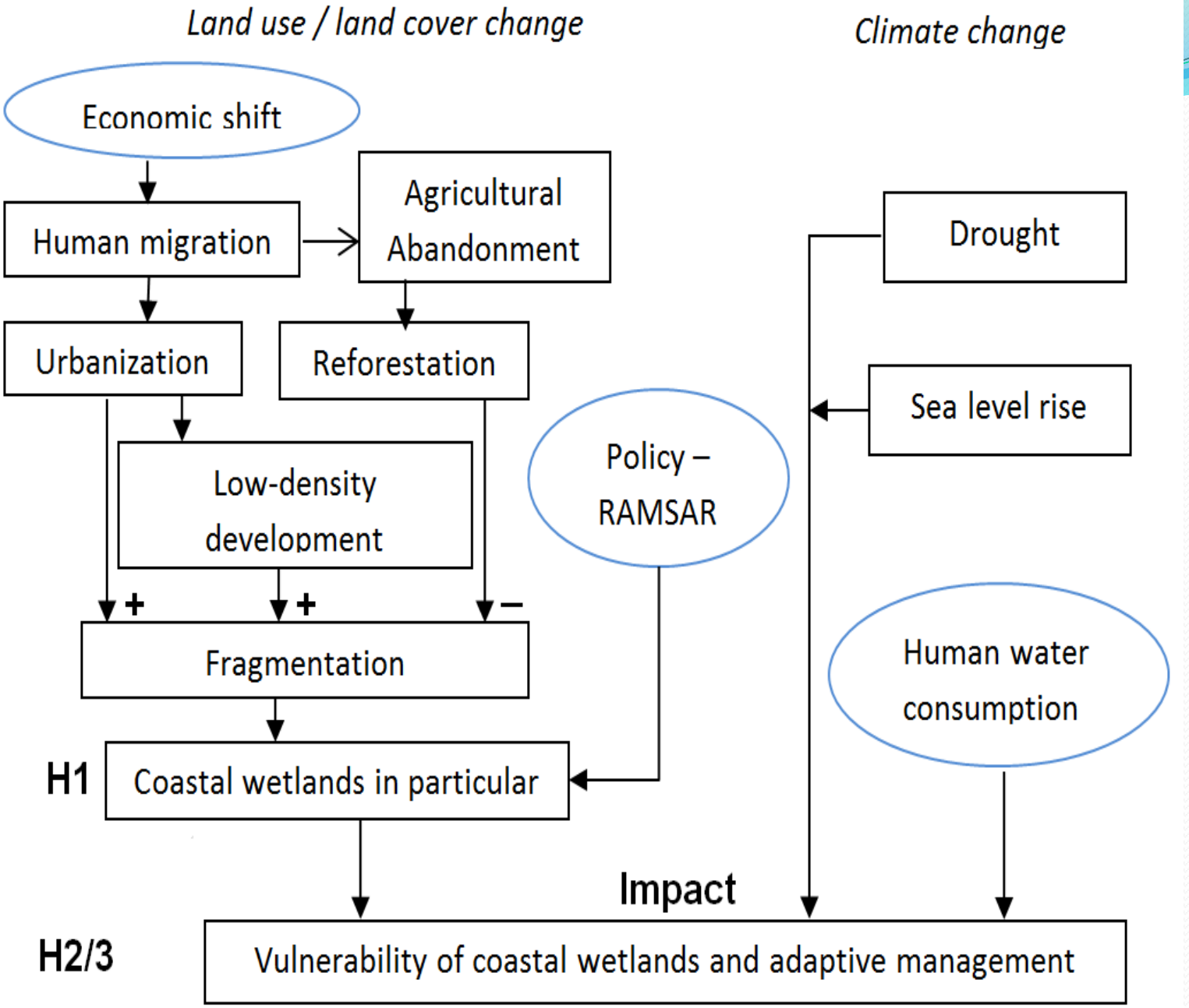
- Sea Level Rise



Shoreline retreats in Southern Puerto Rico (1936~2005, Diaz 2008)

Land-Cover / Land-Use Change Program

ITES

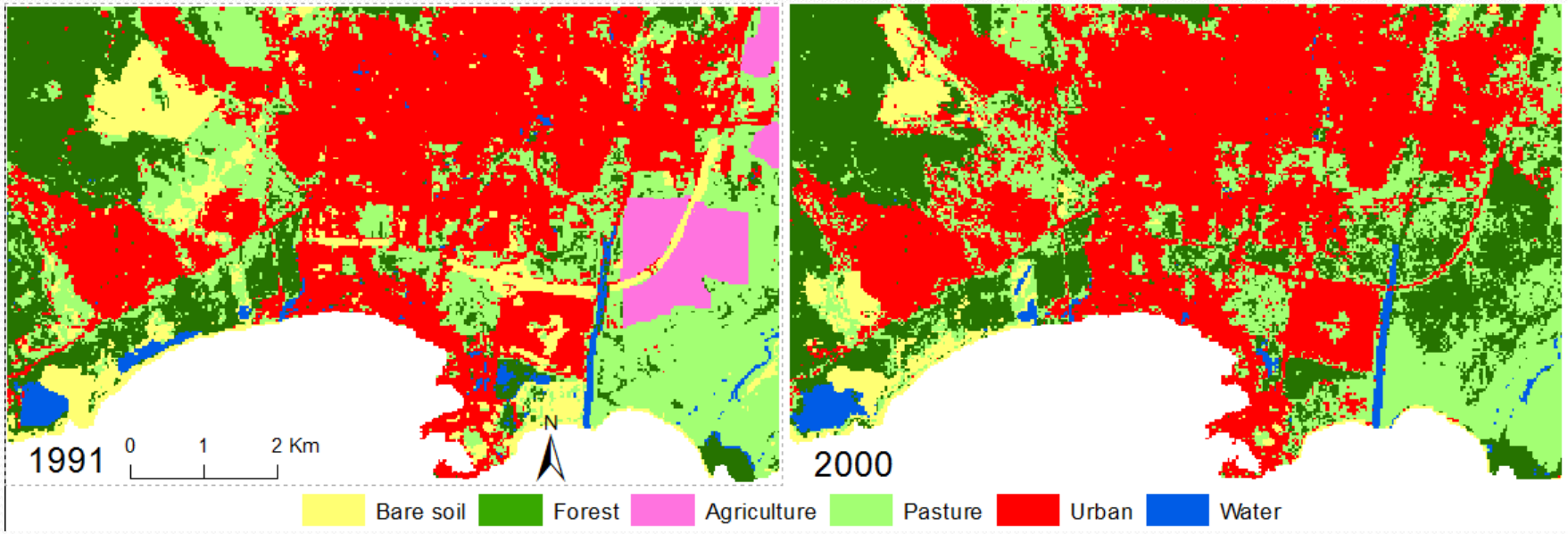

Land use / land cover change
Climate change
Economic shift
Human migration
Agricultural Abandonment
Drought
Urbanization
Reforestation
Sea level rise
Low-density development
Policy – RAMSAR
+
+
–
Fragmentation
Human water consumption
H1
Coastal wetlands in particular
Impact
H2/3
Vulnerability of coastal wetlands and adaptive management

Overarching scientific questions

- *How do the land use changes (reforestation and urbanization), interacting with climate change (drought and sea level rise), impact the vulnerability and the adaptation capacity of tropical wetlands spatiotemporally during the past 33 years in Puerto Rico? and*
- *What are the potential adaptive management plans for sustainable coastal wetlands in the context of climate change?*

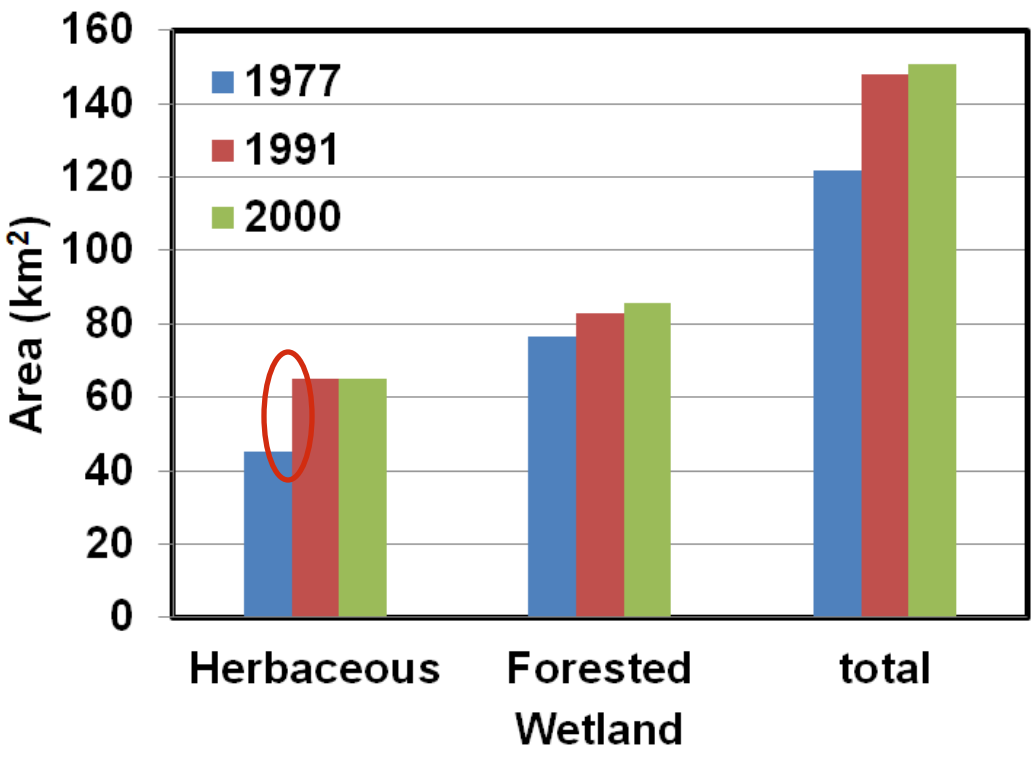
Hypothesis 1

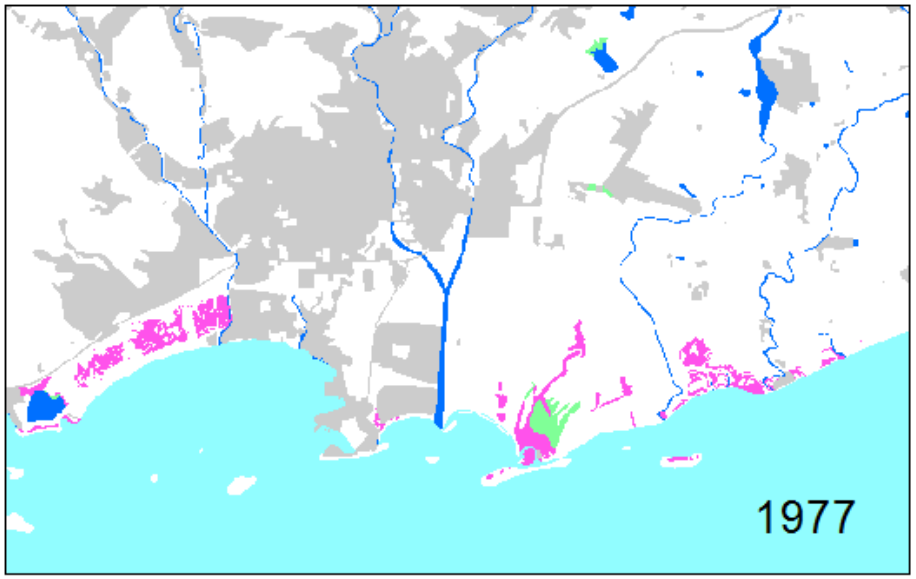
- *In spite of reforestation, island wide forests were fragmented by the urban sprawl, especially the low-density residential development. However, the coastal wetlands may aggregate due to the policy change, e.g., the implementation of The RAMSAR Convention on Wetlands.*

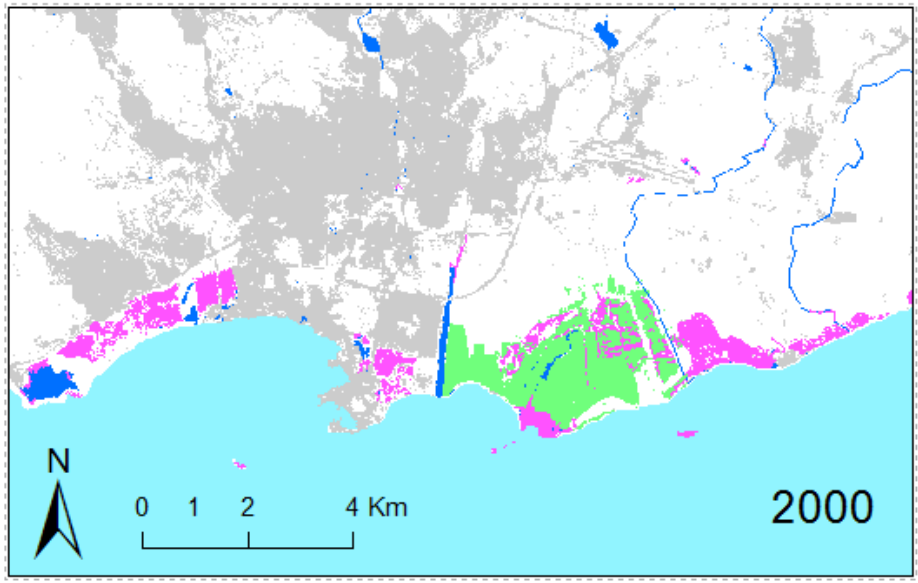


Land-Cover / Land-Use Change Program

ITES



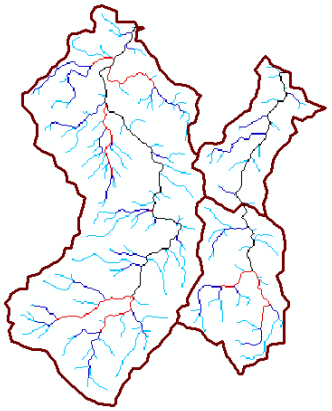


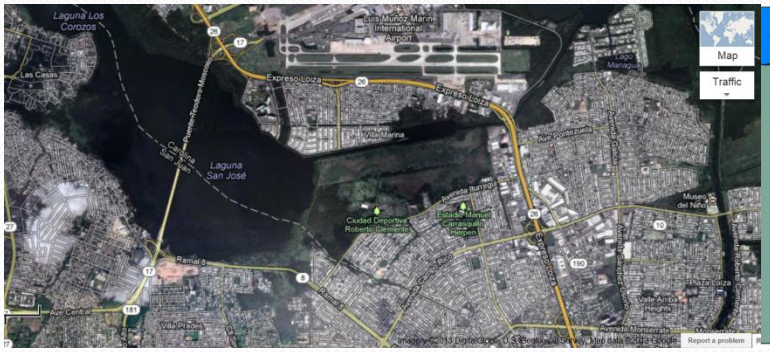


Ocean Urban Herbaceous Wetland Forested Wetland Water

Hypothesis 2

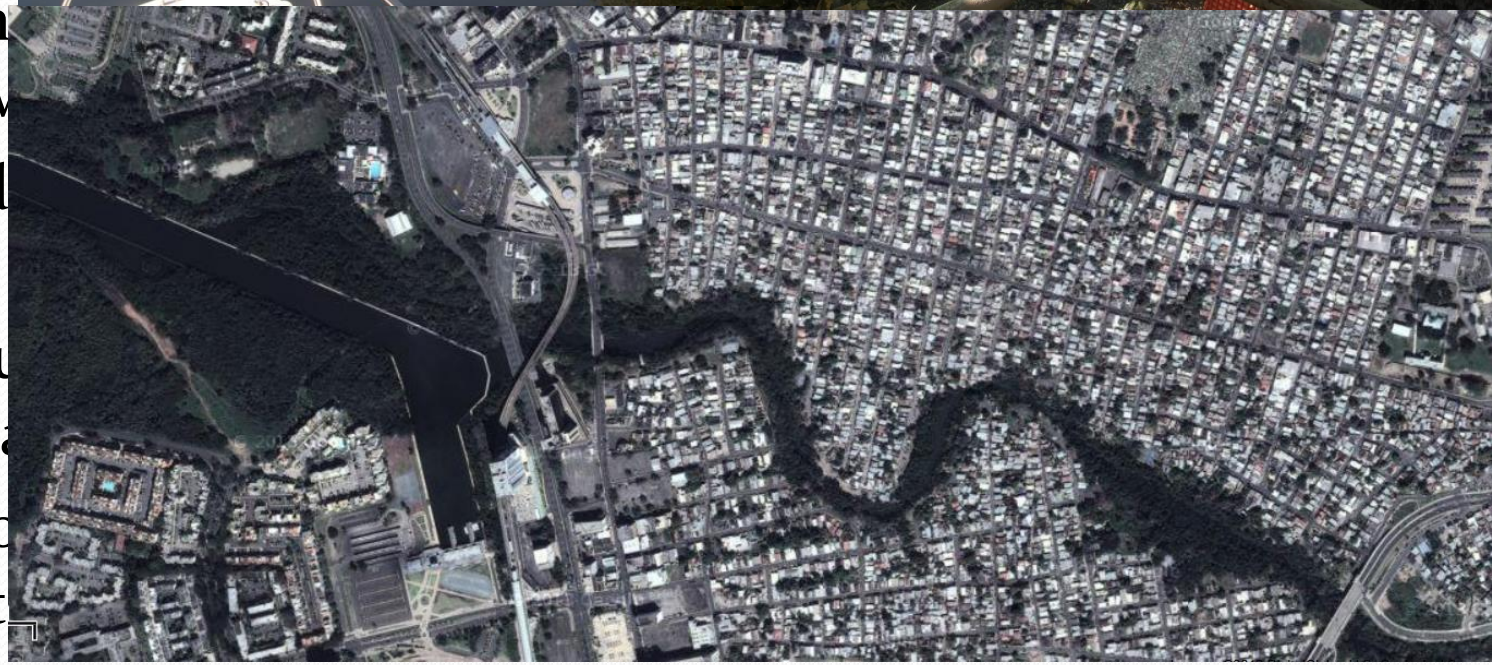
- *Land use and future climate changes will make coastal wetlands more vulnerable by reducing water supply, decreasing water quality, and retreating shoreline due to sea level rise.*
  - Integrated analysis at Watershed scale
  - SWAT (Soil and Water Assessment Tools)
    CLUEs (Conversion of Land Use and its Effects)
  - Drought
    Consumption
    Sea level rise
    → water quantity
    water quality





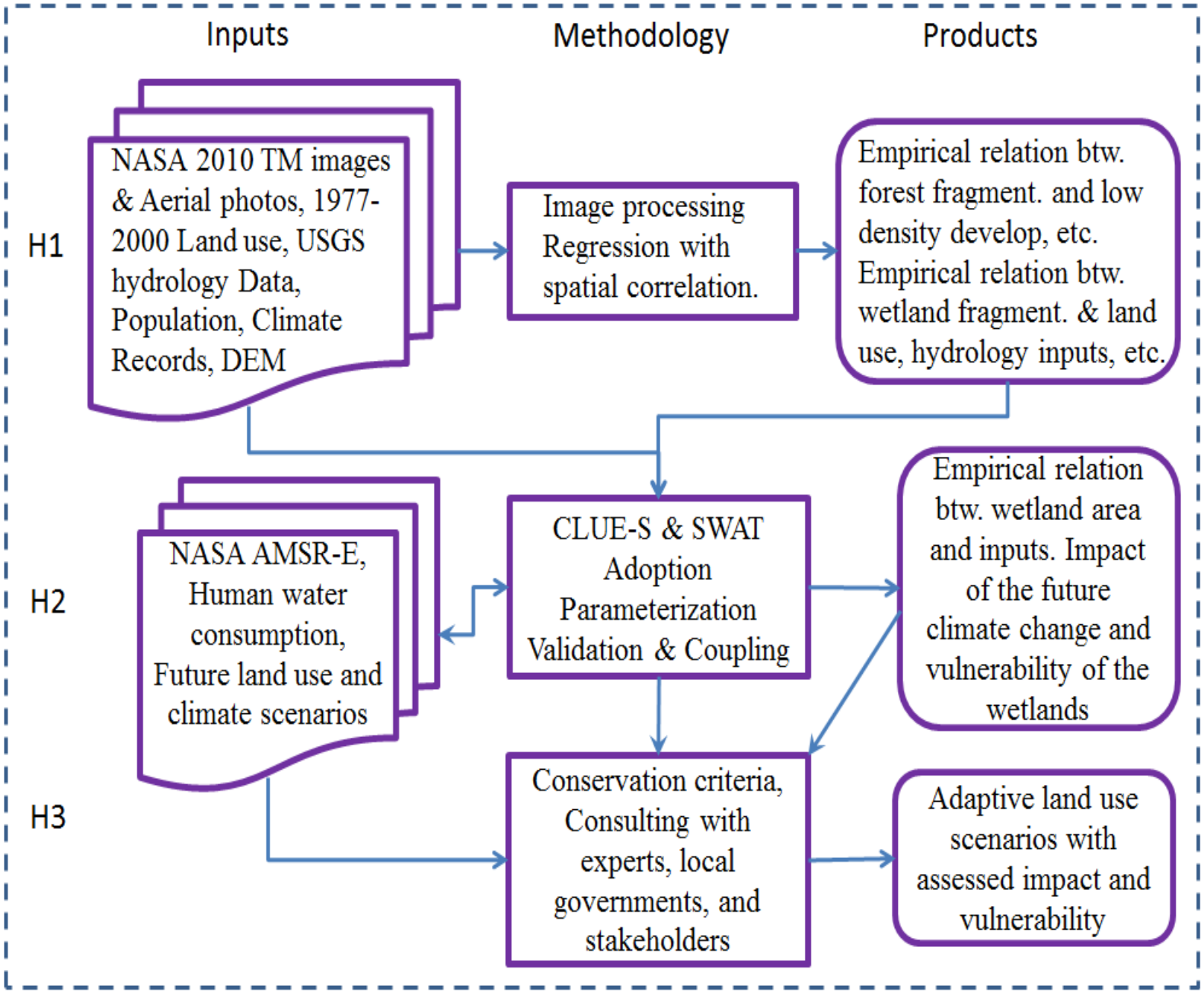
Hypothes

- *Adaptive sc*
  as restricte
  and wetlan
  wetlands in
- Rational an
  upstream w
  - Wetland
    doubled
  - Water qu
    + vulnera
  - Buffer zo
    + potent
  - Selection of conservative scenarios + socioeconomic analysis



Land-Cover / Land-Use Change Program

ITES


Inputs
Methodology
Products
H1
NASA 2010 TM images & Aerial photos, 1977-2000 Land use, USGS hydrology Data, Population, Climate Records, DEM
Image processing Regression with spatial correlation.
Empirical relation btw. forest fragment. and low density develop, etc. Empirical relation btw. wetland fragment. & land use, hydrology inputs, etc.
H2
NASA AMSR-E, Human water consumption, Future land use and climate scenarios
CLUE-S & SWAT Adoption Parameterization Validation & Coupling
Empirical relation btw. wetland area and inputs. Impact of the future climate change and vulnerability of the wetlands
H3
Conservation criteria, Consulting with experts, local governments, and stakeholders
Adaptive land use scenarios with assessed impact and vulnerability

Patterns in Land Cover Change

Changes in total coverage

- 1977-1991 – Rapid urbanization (39% increase)
  + reforestation (32% increase)
  1991-2000 – Reforestation slowed down,
  urbanization mostly in the form of urban sprawl.
- 1977-1991 – Vegetated wetlands expanded by 22% with significant increase in emergent wetland (45%)
  ← partly due to the abandoned agriculture in lowlands (agriculture decreased by 78%).
  1991-2000 – vegetated wetlands kept slowly increasing.

Patterns in Land Cover Changes – Fragmentation

- Total areas of both forest and vegetated wetlands increase.
- 1991-2000
  Reforestation (-) and Urbanization (+)
  → more fragmentation in forests
  RAMSAR, enforced conservation
  → reduced fragmentation in vegetated wetlands

	Forests		Wetlands	
	1991	2000	1991	2000
Area (ha)	403,941	406,975	14,800	15,093
# patches	88,974	103,170	7,252	3,908
Mean patch size (ha)	4.54	3.94	2.0	3.9
Normalized landscape shape index	0.13	0.14	0.18	0.14

Fragmentation – local scale

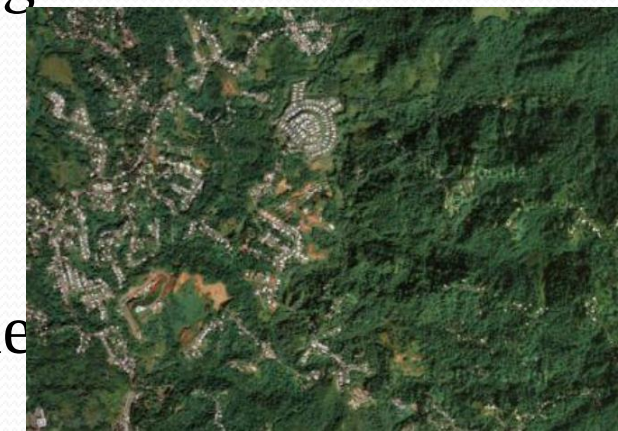
- Land covers of Urban, Forest, and Wetland in 1977, 1991, 2000
- Scale: 3 km × 3 km
- Fragmentation index
  - Boundary edge length per focal type area

$$p_1 = L \bullet \sum e_i / \sum a_i$$

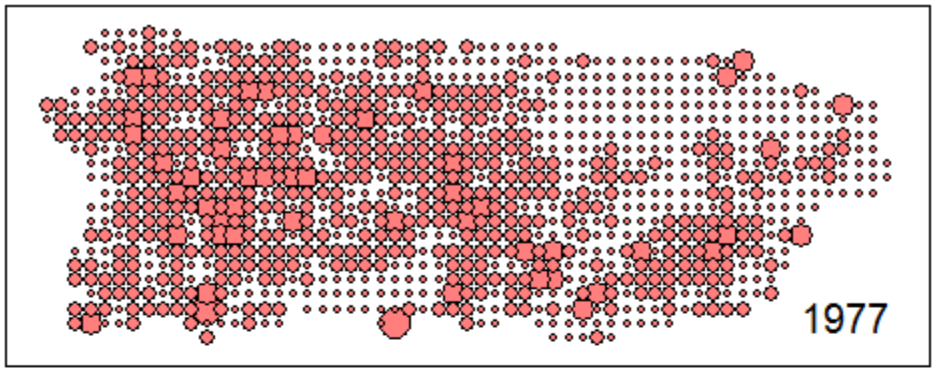
  - Boundary edge length to Inner pixel length

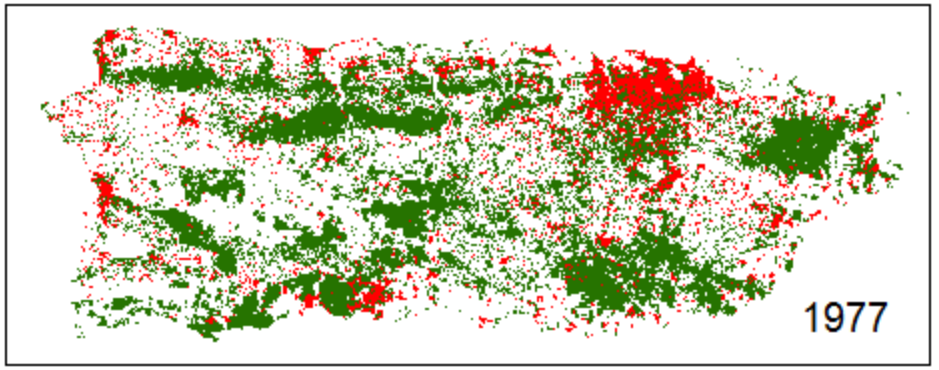
$$p_3 = \sum e_i / \sum e_c$$

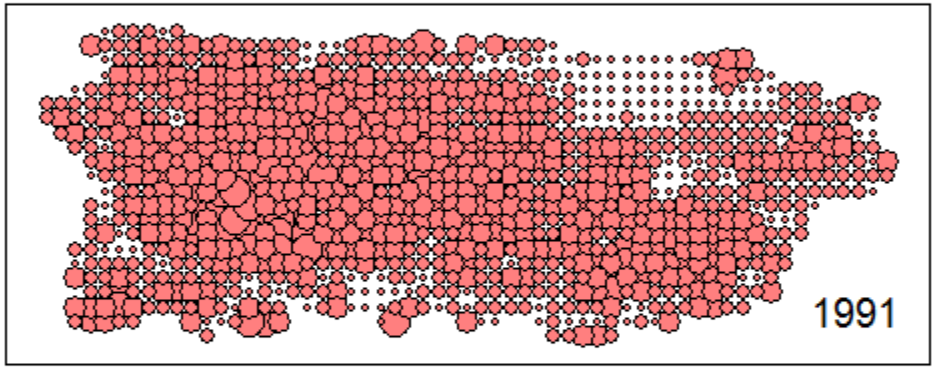
- Spatial error models
  – biophysical and socioeconomic variable

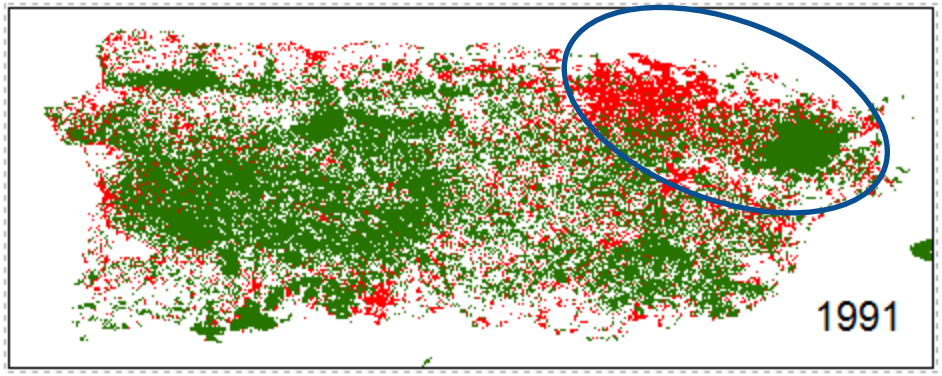


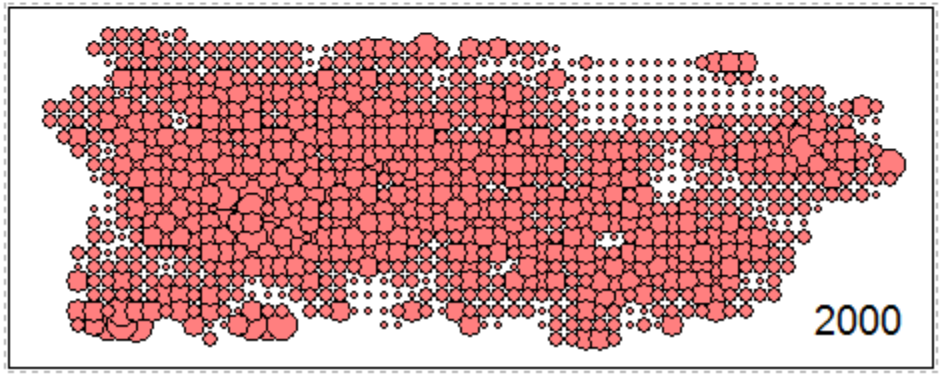
Urban Fragmentation

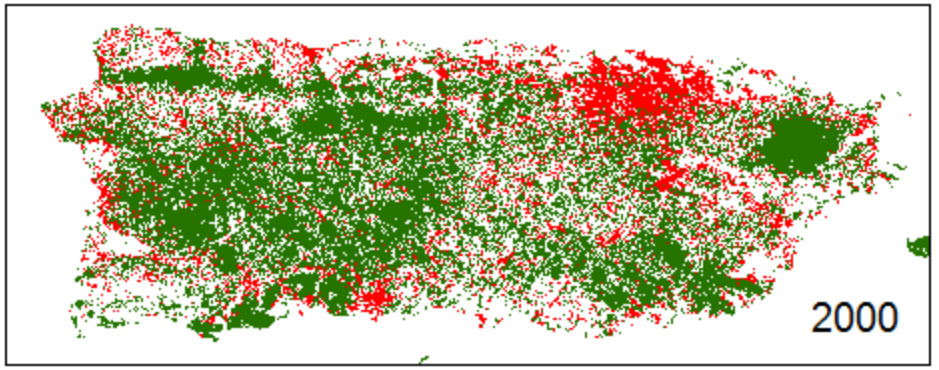


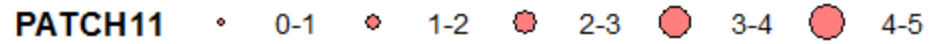




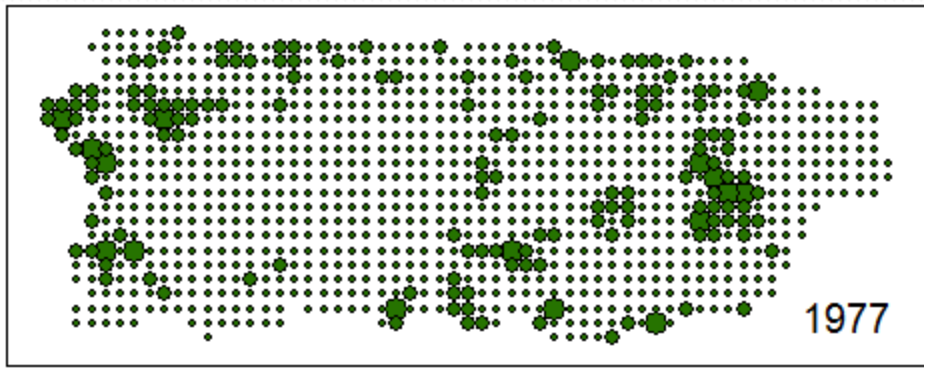


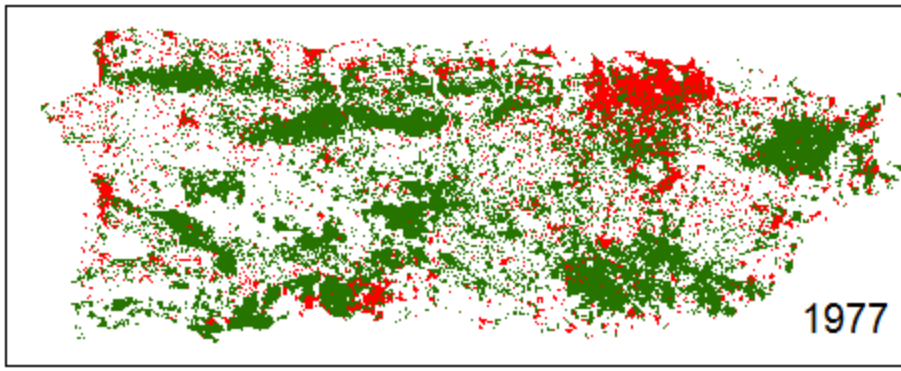


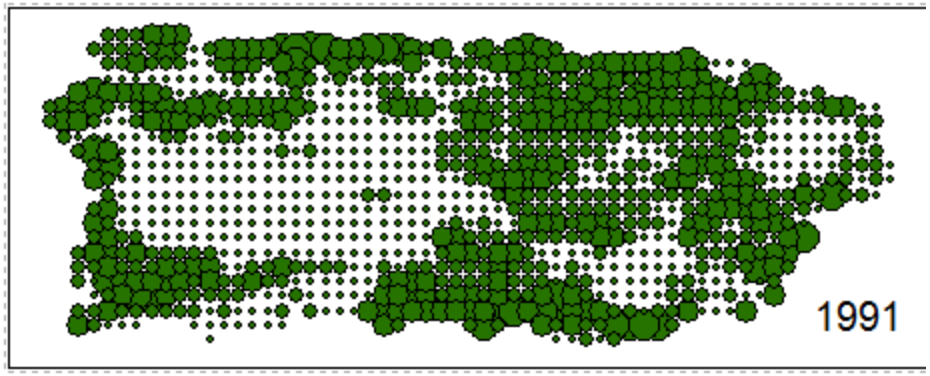


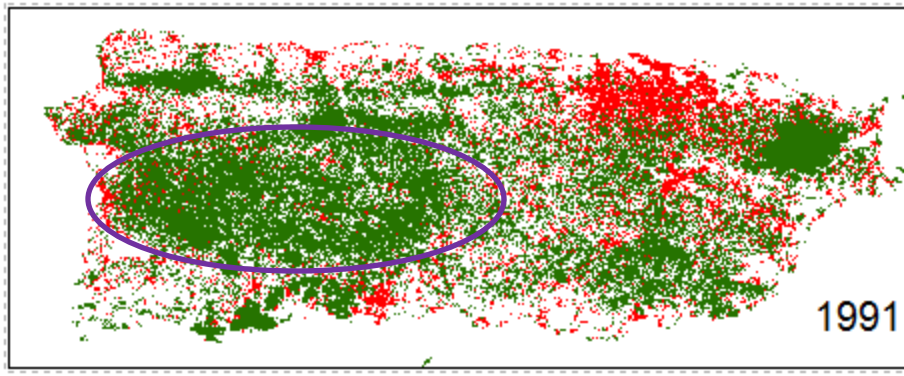


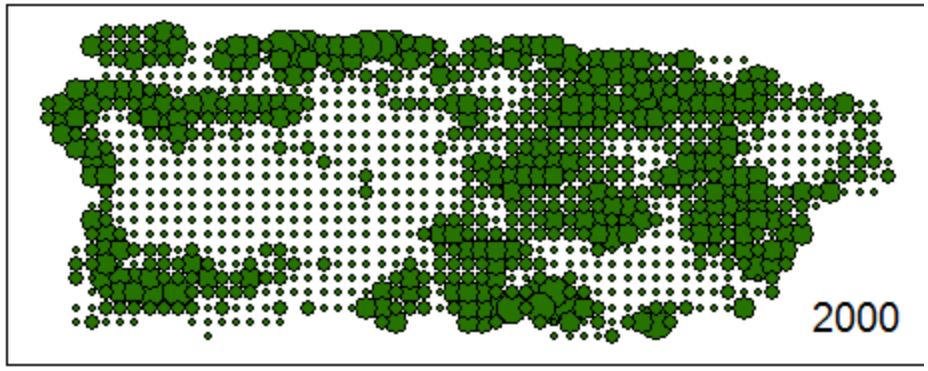
Forest Fragmentation

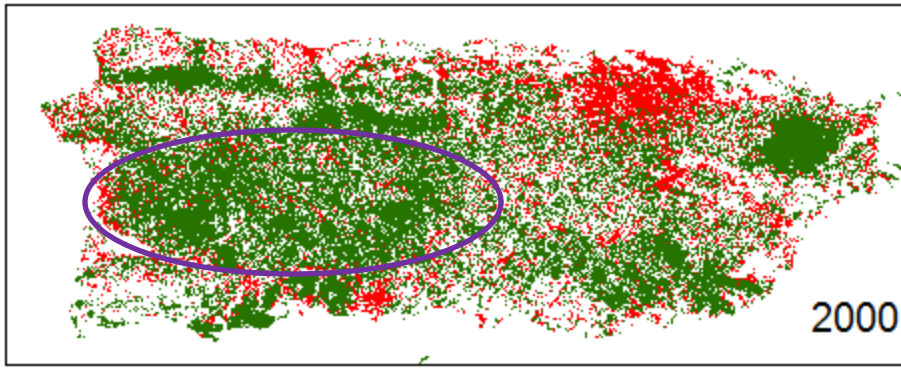






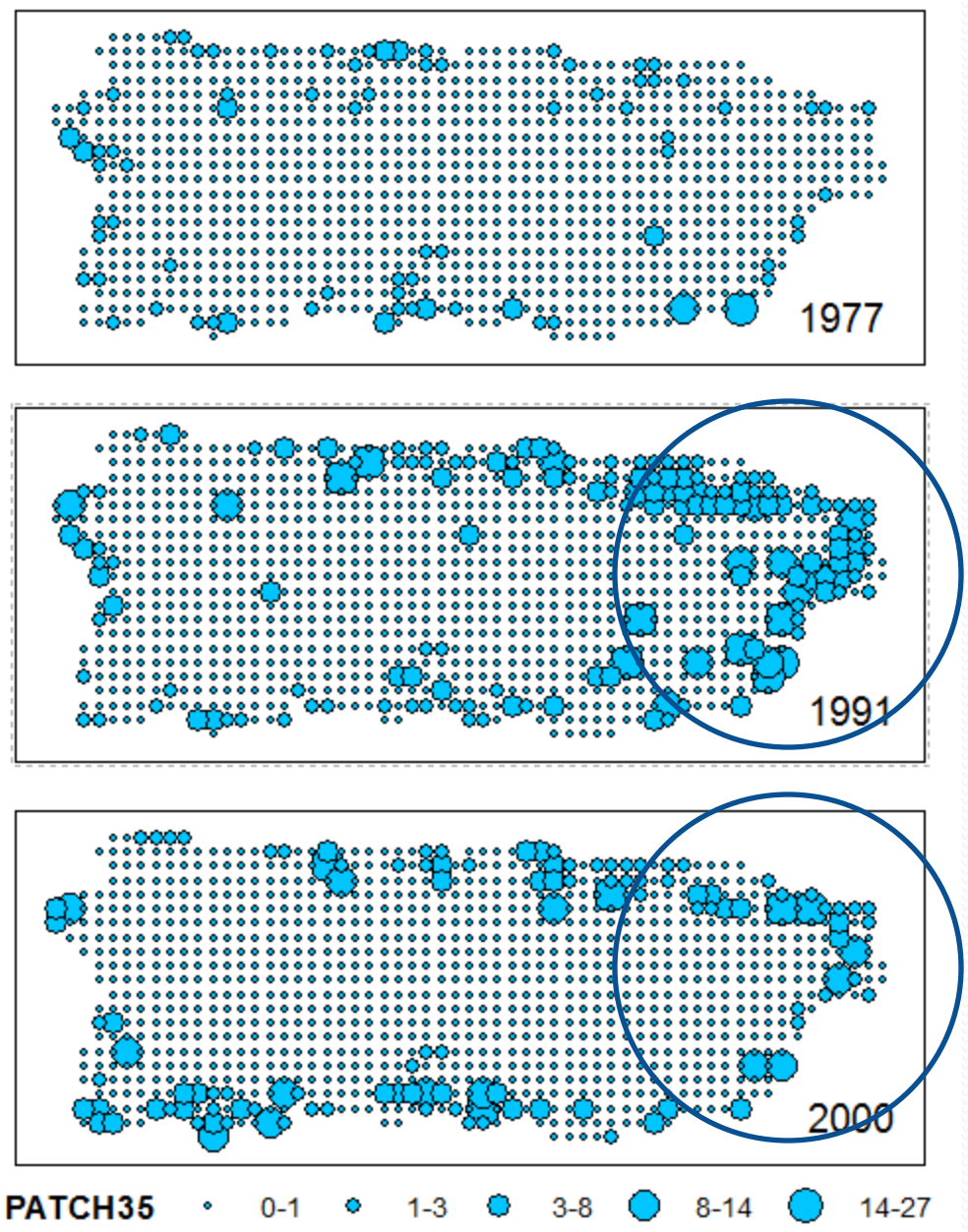


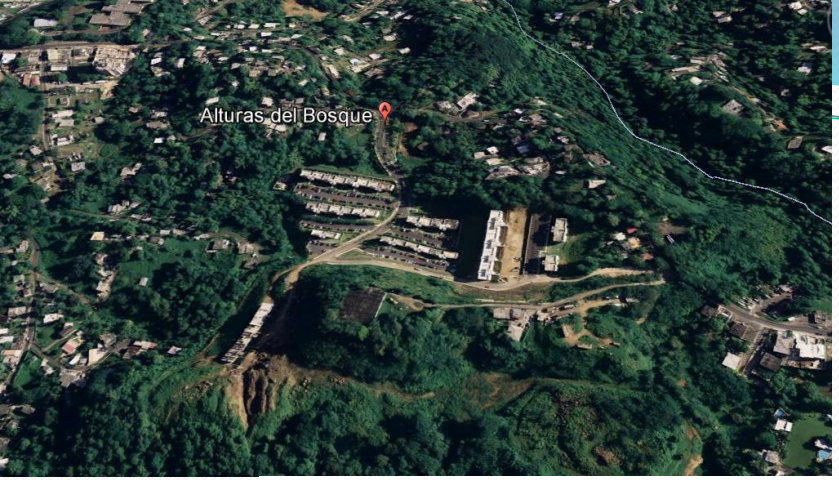




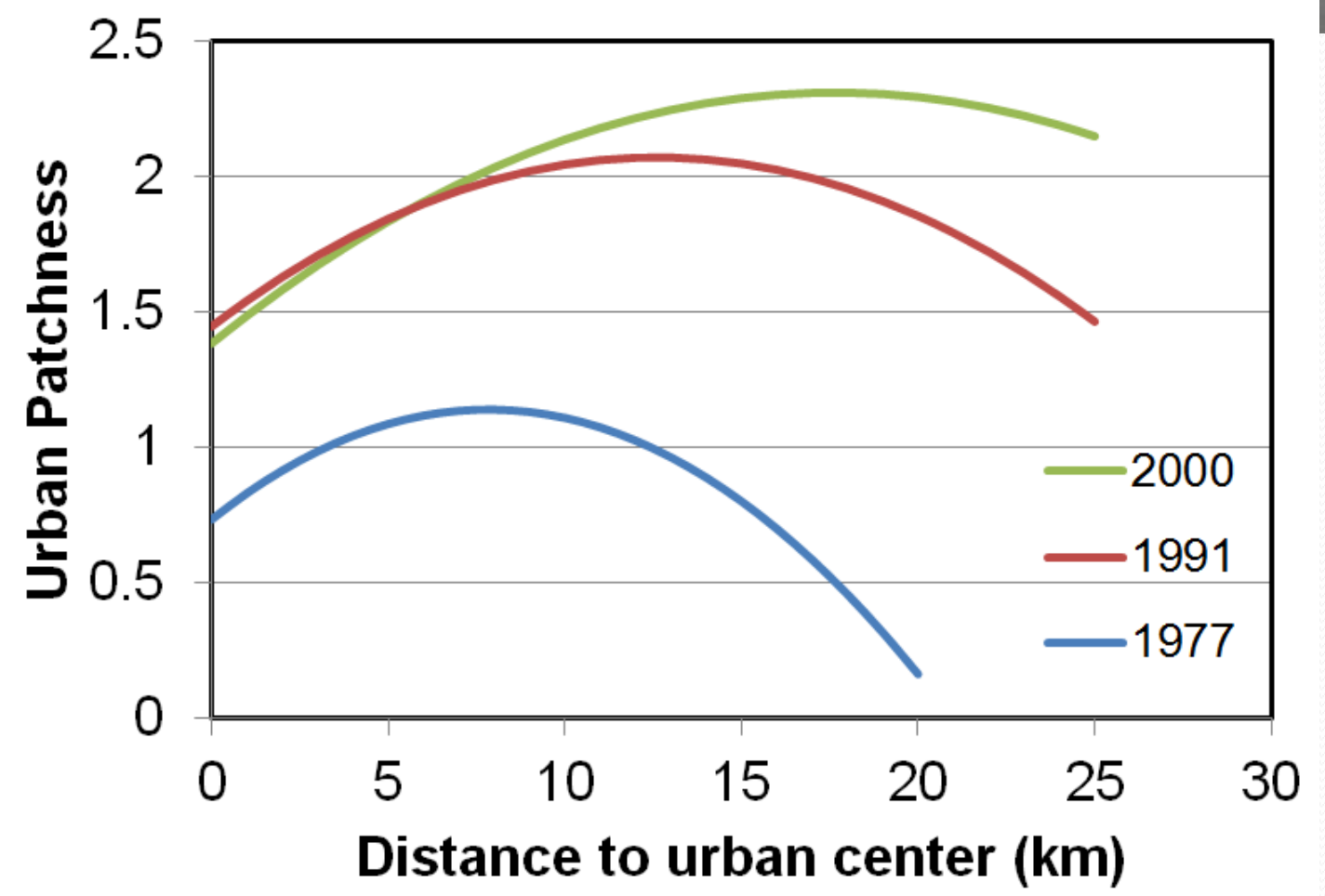
PATCH34 • 0-0.75 • 0.75-1.5 • 1.5-3 • 3-7 • 7-16.1

Wetlands Fragmentation




Alturas del Bosque


Grand
Homes


Urban Patchness
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
Distance to urban center (km)
2000
1991
1977

Spatial Error Model for Urban

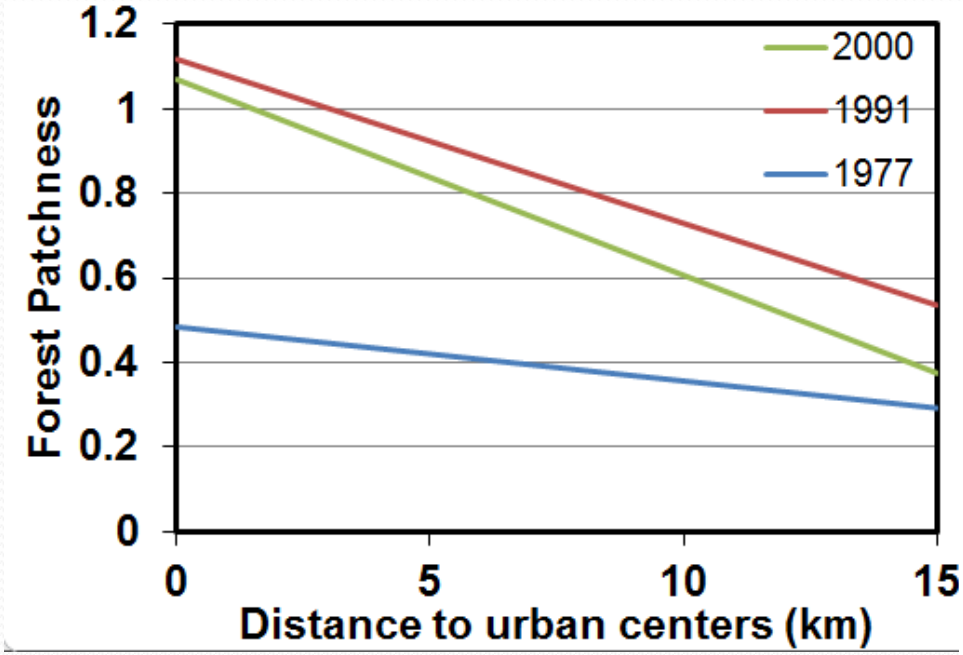
$$p_{1,77} = 0.8354 + 0.1036D - 0.00661D^2 + 0.01574S - 0.01926\sigma_s - 0.000465P_g$$

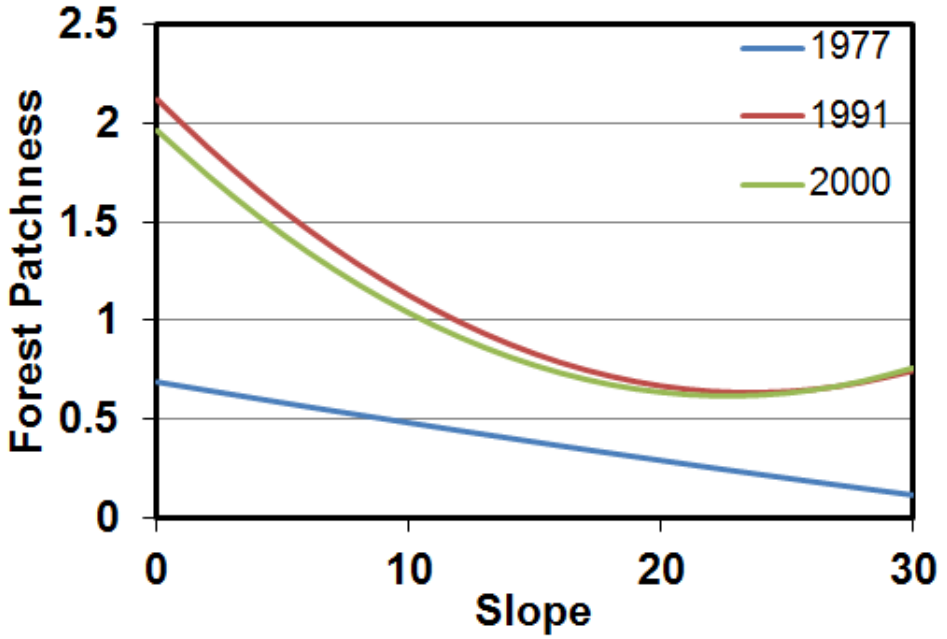
$$p_{1,91} = 1.5691 + 0.0992D - 0.00394D^2 + 0.05690S - 0.09123\sigma_s - 0.000855P_g$$

$$p_{1,00} = 1.5611 + 0.1051D - 0.00298D^2 + 0.05464S - 0.10045\sigma_s - 0.000812P_g$$

- D – distance to urban centers
  S – slope
  σ_s – standard deviation of slope
  P_g – population density

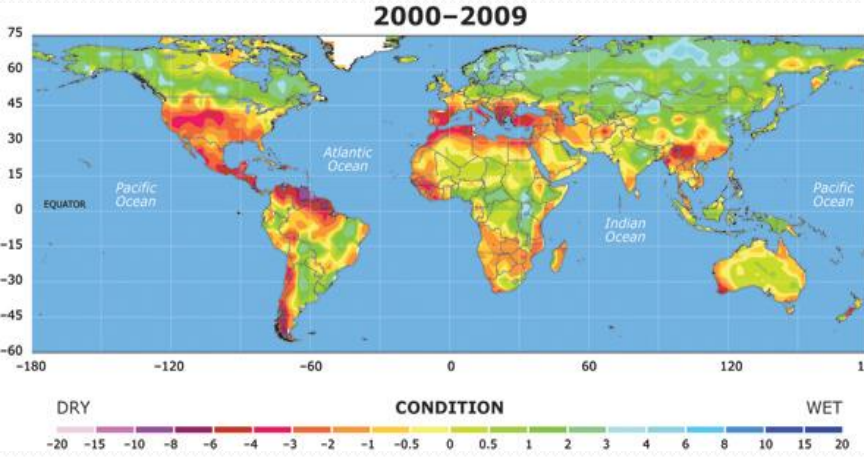
Spatial Error Model for Forest

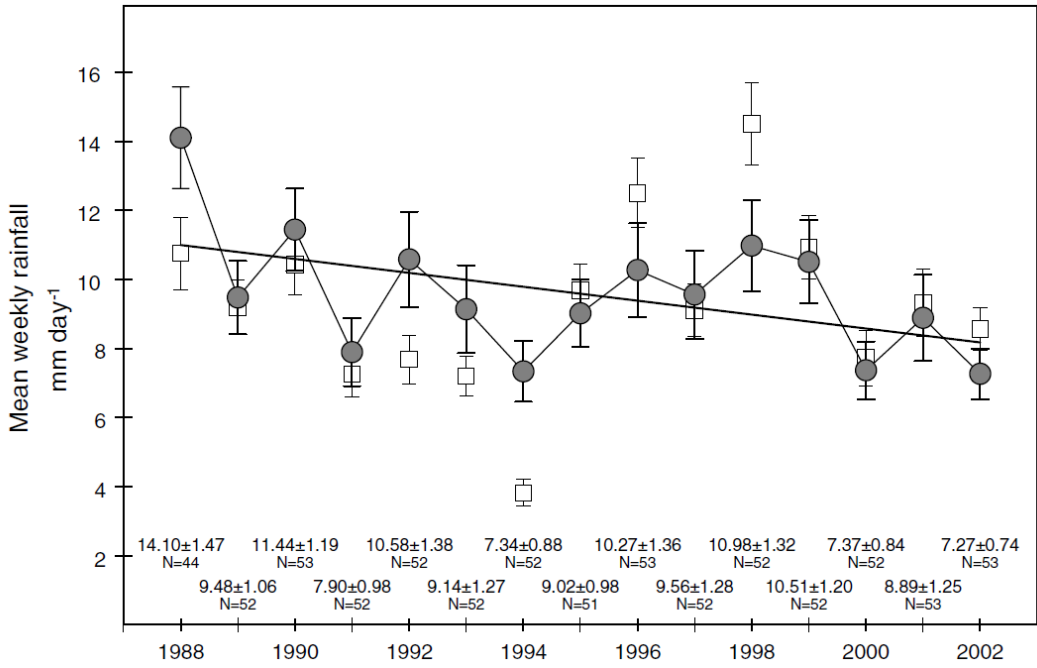




Trends in Climate Change

- Drought detection in 2000-2009 (Dai, 2010)
- Rainfall decrease trend detected at El Yunque in 1988-2002 (Heartsill et al. 2007)

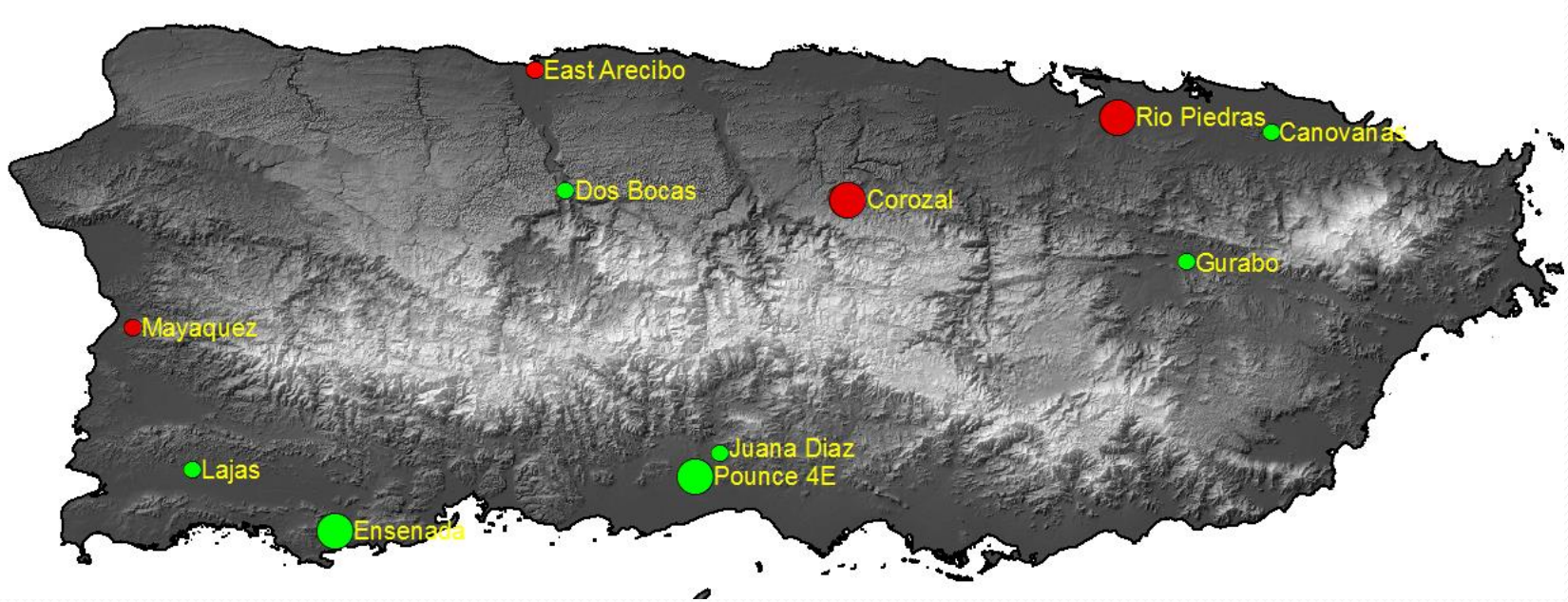




Land-Cover / Land-Use Change Program

Trends in Climate Change

- Time series analysis on local meteorological records from 1970 to 2011



- Great uncertainty / discrepancy between global prediction and regional reality due to the complex interactions between regional ecosystems and the microclimate system

Thank you!