ADDRESSING THE CHALLENGE OF CLIMATE CHANGE IN THE GREATER EVERGLADES LANDSCAPE

Project Overview

"Addressing the Challenge of Climate Change in the Greater Everglades Landscape" is a research initiative funded by the U.S. Fish and Wildlife Service (USFWS) and the U.S. Geological Survey (USGS) and carried out by a group of researchers at the Department of Urban Studies and Planning at the Massachusetts Institute of Technology (MIT).

The study investigates possible trajectories of future transformation in the Greater Everglades Landscape relative to four main drivers: climate change, shifts in planning approaches and regulations, population change, and variations in financial resources. Through a systematic exploration at the landscape-scale, this research identifies some of the major challenges to future conservation efforts and illustrates a planning method which can generate conservation strategies resilient to a variety of climatic and socioeconomic conditions.

This project integrates the best available scientific information on climate change with local knowledge and expertise in order to create a suite of management-relevant scenarios for the Greater Everglades Landscape. Scenarios are conceived not as blueprints for the future, but rather as learning tools for management of uncertainty. The scenarios are internally-consistent bundles of assumptions with four dimensions. Each scenario is projected into the future using a computer simulation technique that creates land use visualizations called "Alternative Futures" (AF). Three future time intervals were simulated for each scenario: 2020, 2040, and 2060.

Each Alternative Future visualizes land use patterns and landscape changes such as coastal inundation, urbanization, and infrastructure expansion. Future changes in conservation lands are modeled and/or designed based on the input from local experts and managers and using the best available ecological information and data.

This research quantifies the complex range of conditions under which conservation strategies may operate, allowing today's managers to make strategic decisions despite considerable individual and compound uncertainties. It supports adaptive management by integrating the cumulative impacts of possible decisions across a range of scales. This allows managers not only to consider how to address those issues within their immediate purview, but also to form partnerships they may need to better prepare for future changes.

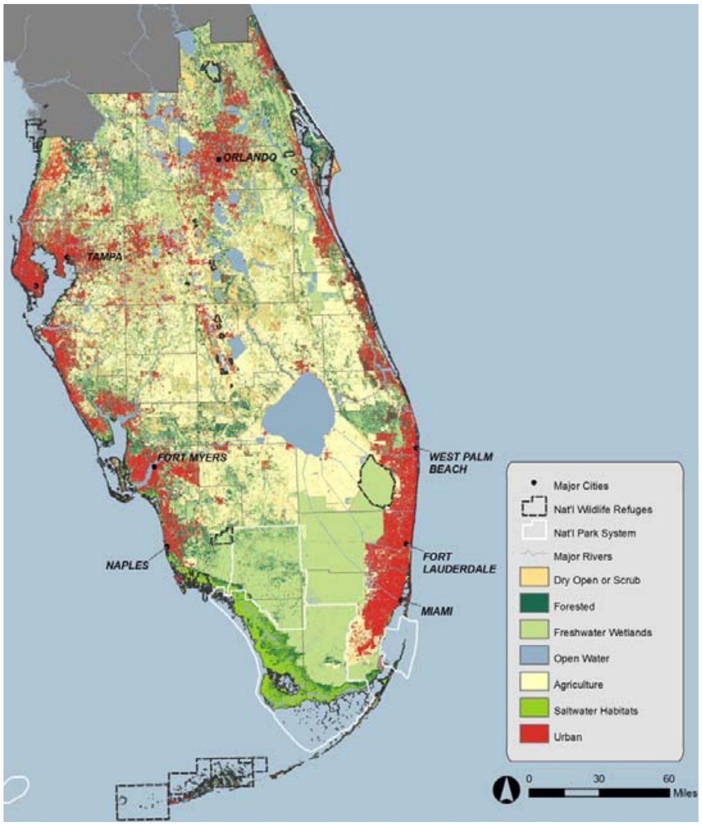


Figure 1. Study Region

The Greater Everglades Landscape: A Rapidly Changing Region

Study region characterization:
Area: 19.3 million acres (78,000 km^2)
Population: 15.3 million inhabitants.
Conservation units:

- *23 National Wildlife Refuges,*
- *2 National Parks,*
- *1 National Preserve,*
- *1 National Seashore,*
- *79 State Parks.*
- *30 Counties*

The specific counties included in this study are: Brevard, Broward, Charlotte, Collier, Desoto, Glades, Hardee, Hendry, Hernando, Highlands, Hillsborough, Indian River, Lake, Lee, Manatee, Martin, Miami-Dade, Monroe, Okeechobee, Orange, Osceola, Palm Beach, Pasco, Pinellas, Polk, St. Lucie, Sarasota, Seminole, Sumter, and Volusia.

The Challenge

The Greater Everglades Landscape is one of the most vulnerable regions to climate change in the U.S. Its low elevation makes it very susceptible to sea level rise and its fragile ecosystems are sensitive to changes in temperature and precipitation. Some of the potential risks include population displacement, loss of economic assets, critical infrastructure failure, and an increased occurrence or severity of natural disturbances such as hurricanes and droughts.

In addition to the threats posed by climate change, the population of the Greater Everglades Landscape is expected to increase by 13.5 million inhabitants over the next 50 years, requiring as much as 1.7 million acres for urban land use. This demand will create unprecedented landscape changes that will produce significant challenges to ecological systems and human populations.

In particular, these forces pose a unique challenge to conservation management and planning in the region. Given the region's complex socioeconomic and ecological dynamics and the large number of governing agencies involved in conservation planning, the key research objective is to create a set of exploratory scenarios useful for decision-making across current conservation planning agencies and jurisdictions.

These scenarios are particularly valuable when used to simulate future land use and their associated impacts. The outputs of these scenarios will help USFWS and their partners to prioritize conservation and management efforts. The results will also allow them to address challenges early in the conservation planning process by forming partnerships and devising adaptation and mitigation measures.

Research Approach and Methods

The project uses two primary methodological approaches: first, *a stakeholder-based participatory process;* and second, a *scenario-based simulation modeling approach.*

The primary goal of the stakeholder-based participatory process was to integrate scientific information with local expertise and knowledge for scenario development. Input from participants was incorporated through a number of workshops over the course of two years. Participants included federal, state, and local stakeholders ranging from scientists and refuge managers to agricultural experts and county planners. The objective of the workshops was to share scientific information, explore its applications and impacts on local systems, discuss its relevance and applicability, and to explore participants' assumptions about the future dynamics of the region. The participatory process also allowed the research team to work with stakeholders to package assumptions and scientific information into scenarios.

The scenario-based simulation modeling approach supported the construction of a range of possible scenarios for the region (as formulated by the stakeholder-based participatory process). The input assumptions of each scenario were used as inputs to the AttCon land cover change model (Flaxman and Li, 2009). This model allocates potential future land use according to a set of scenario-specific demands, and rules. Scenarios are visualize at different points in time (2020, 2040, 2060). Once the scenarios were simulated, the projected impacts of each scenario were calculated in order to evaluate the potential outcomes.

This pair of methods combines qualitative judgment and quantitative modeling to generate alternative future scenarios which "downscale" broad global and regional assumptions into specific potential land use and management changes and their impacts.

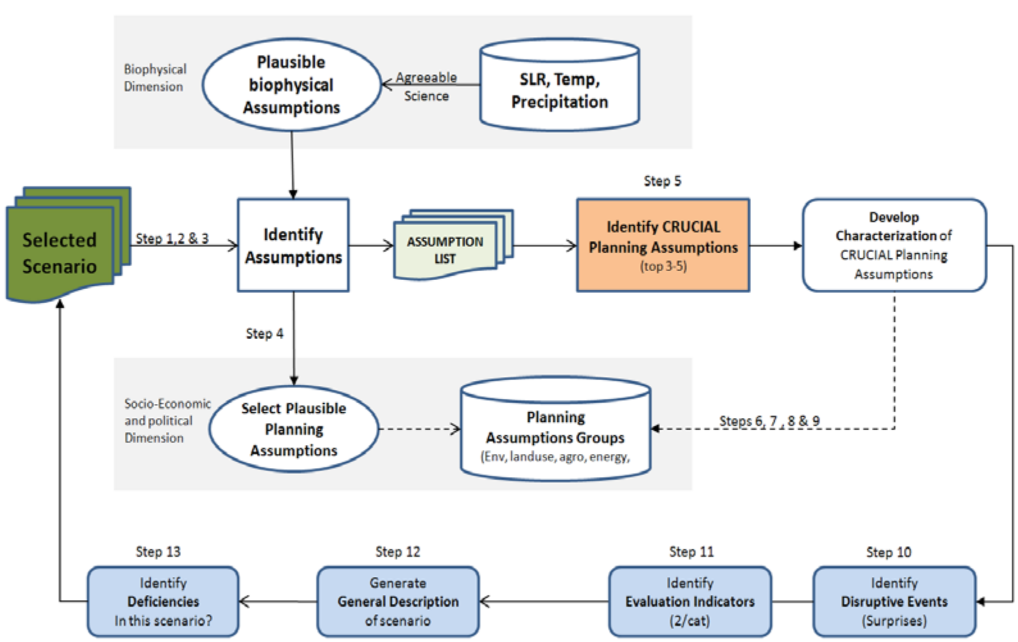


Figure 2. Assumption-based scenario planning process (Vargas-Moreno, 2009)

Stakeholder-based Participatory Process

The scenario creation process has been developed in a stakeholder-driven participatory format. Each scenario is structured by four different dimensions (climate change, shifts in planning approaches and regulations, population change, and variations in financial resources).

The scenarios were developed following the framework of Vargas-Moreno (2009). See Figure 2.

A total of five primary scenarios for the Greater Everglades Landscape were identified. See Figure 4.

Note: An Additional 19 scenarios have been developed and modeled.

MIT Bounding Scenarios

The MIT scenarios consider how climate change (primarily sea level rise), water management, conservation, urban growth, and land use regulation and planning affect the landscape (see Figure 3). Each scenario is made up of a set of input assumptions that determine how these major factors may vary over time. The trajectories of change that each scenario illustrates are relevant for strategic planning. These trajectories also have implications for policy and management decisions at local, state, and federal levels.

Scenario Impact Evaluation

Following the generation of future land use maps, a conflict analysis was performed for a number of key species' habitats. The output identifies the location and degree of impact that may affect each species' habitat in the future for all scenarios (see Figure 6).The conflict analysis was developed using the following datasets:

- Black bear, scrub jay, panther, caracara, & crocodile potential habitats (FFWCC)
- The FNAI Endangered Natural Communities
- FEGN Critical Linkages

Bounding Scenario Results

- Identification of key drivers of change and their potential trajectories based on the best available science and local expertise
- Development of nine different scenarios and alternative futures created from a two-year, eight workshop participatory planning process (see Figure 4)
- A series of impact assessments developed for specific species' habitats, natural communities, and conservation areas under each scenario
- Estimates of land use change by category
- Estimates of sea level rise impacts on protected areas

Climate Change	Population (in millions)	Plannning Assumptions	Financial Resources
Low (+3.6" SLR)	Trend (25)	Business as Usual (B.A.U.)	Low ($)
Medium (+18.4" SLR)			
High (+39.1" SLR)	Double (29)	Proactive	High ($$$)

Figure 3. Scenario dimensions and corresponding values and units

Scenario	Climate Change	Population	Planning Assumptions	Financial Resources
A	LOW	DOUBLE	Business as Usual (B.A.U.)	LOW $
B	LOW	TREND	PROACTIVE	HIGH $$$
C	HIGH	DOUBLE	B.A.U.	LOW $
E	MEDIUM	DOUBLE	B.A.U.	HIGH $$$
I	HIGH	DOUBLE	PROACTIVE	LOW $

Figure 4. Top 5 MIT scenario bundles for the Greater Everglades Landscape. NOTE: An additional 19 scenario bundles have been modeled as well, but are not included in this Project Summary Sheet.

SCENARIO C (2060)

- High Sea Level Rise
- Low Financial Resources
- Business as Usual Planning
- Double Population Growth

SCENARIO B (2060)

- Low Sea Level Rise
- High Financial Resources
- Proactive Planning
- Trend Population Growth

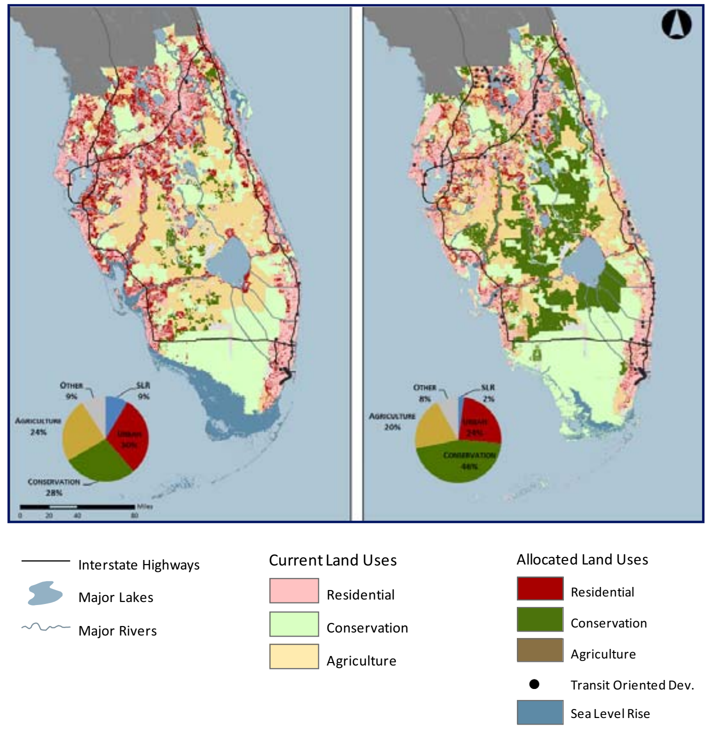


Figure 5. Bounding MIT Scenarios "C "and "B" in 2060.

SCENARIO C **SCENARIO B**

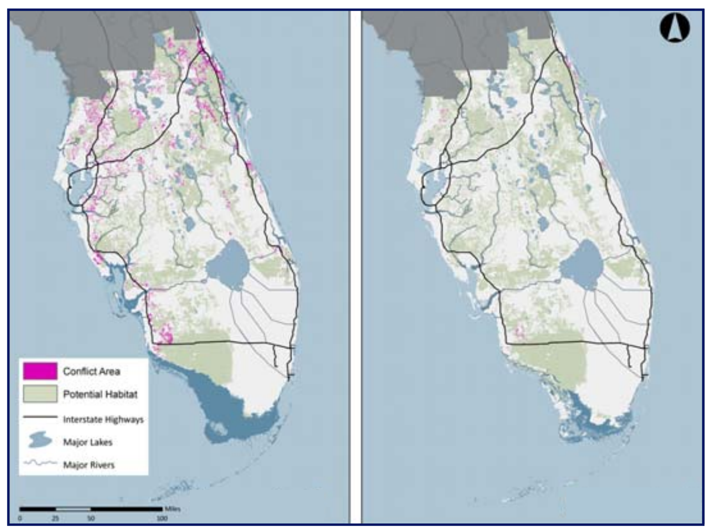


Figure 6. Example potential black bear habitat development conflict

Scenario Simulation Process

Each of the five scenarios assembled by the stakehholders was expressed spatially using a series of Geographic Information System (GIS) models in order to simulate the driving forces of the region.

The models match the most desirable portions of land (50m x 50m cells) with the demands derived from different demographic projections. Additionally, urban density assumptions and regulations of protected resources and areas are incorporated in the models.

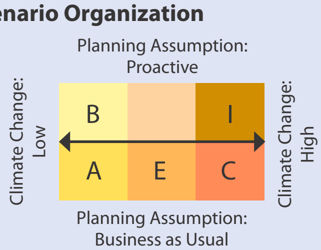
MIT Scenario Organization

The long term future is inherently uncertain, not only because of scientific uncertainty, but also because of human decision-making. We developed a set of alternative future scenarios not as an attempt to predict the future, but to help bound these uncertainties in a way which helps to inform choices and actions occurring today.

Our process was one of broad consultation, attempting to reflect a wide range of views and make use of professional expertise from many disciplines. Each scenario is composed of two elements. This first is a set of internally-consistent and explicit assumptions. The second is a set of rules for simulating the consequences of these assumptions, in the form of a spatial model.

The five scenarios judged by our stakeholder group to be the most important relative to their management concerns were simulated by MIT using a set of spatial models built within a Geographic Information System (GIS). It should be emphasized that these scenarios were not generated based on their likelihood or desirability - they are not plans or policies. They are possible futures representing in many cases extremes in which major driving forces lead towards unbalanced and unsustainable paths. No endorsement of such scenarios by either MIT or our sponsors should be inferred or implied.

Scenario Organization



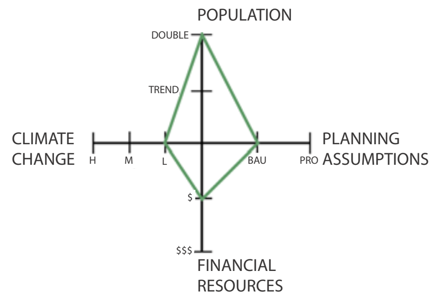
Scenario Dimensions Table

Climate Change	Population (millions)	Planning Assumptions	Financial Resources
Low (+3.6" SLR)	Trend (25)	Business as Usual (BAU)	Low ($)
Med. (+18.4" SLR)			
High (+39.1" SLR)	Double (29)	Proactive (PRO)	High ($$$)

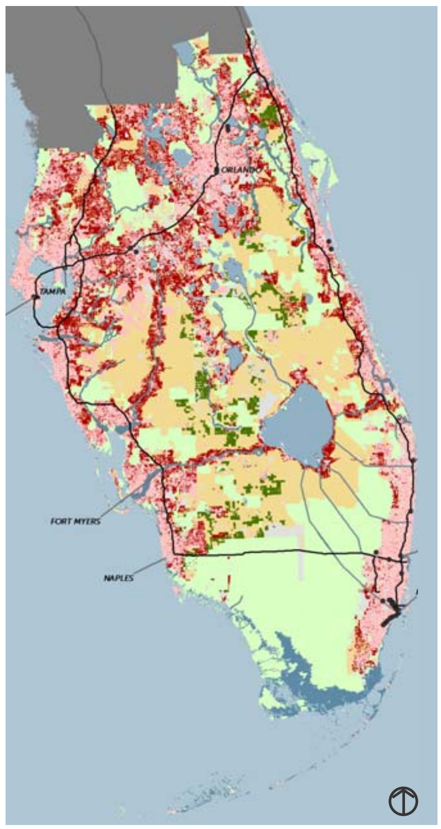
Map Legend

Current Land Use	Projected Land Use
Agriculture	Agriculture
Conservation	Conservation
Urban	Urban

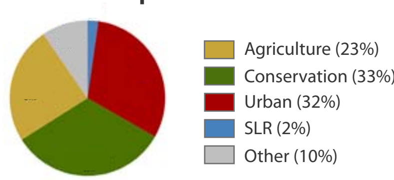
Scenario A



Land Use / Land Cover 2060

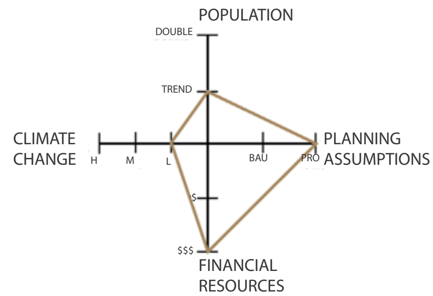


Land Use Composition 2060

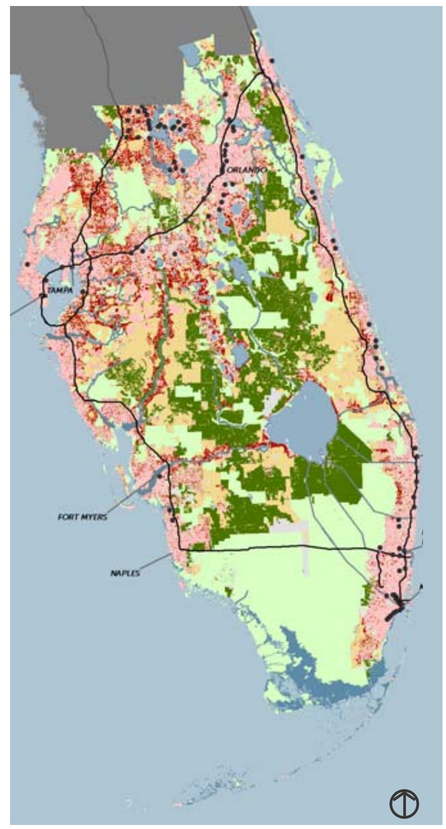


Total Land Use Area (in millions of acres)	2020	2040	2060
Agriculture	6.13	5.32	4.36
Conservation	6.00	6.16	6.32
Urban	4.53	5.30	6.16
Sea Level Rise	0.33	0.38	0.44
Other	2.30	2.13	2.01

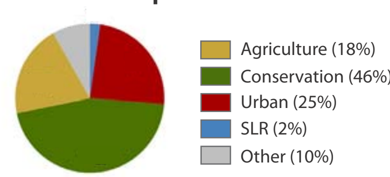
Scenario B



Land Use / Land Cover 2060

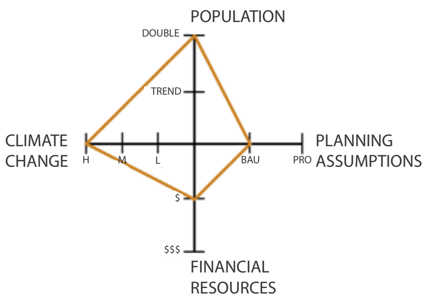


Land Use Composition 2060

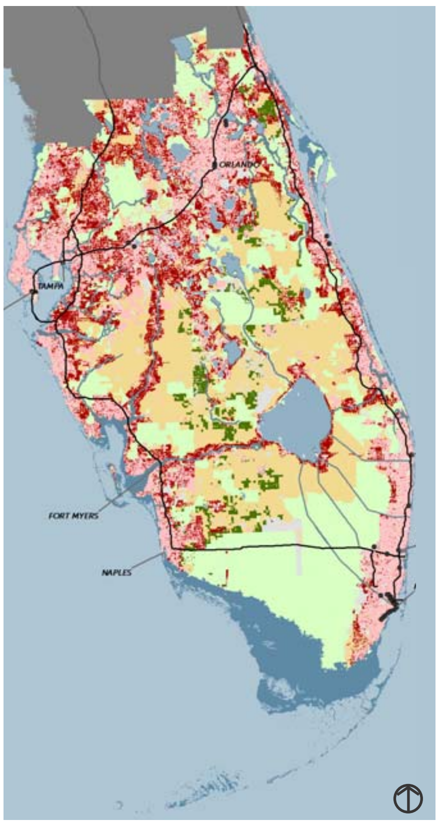


Total Land Use Area (in millions of acres)	2020	2040	2060
Agriculture	5.93	4.78	3.41
Conservation	6.50	7.66	8.80
Urban	4.29	4.48	4.78
Sea Level Rise	0.33	0.38	0.44
Other	2.24	2.00	1.87

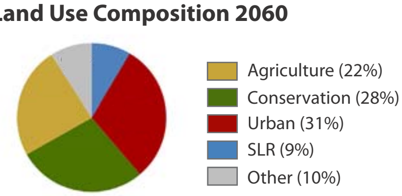
Scenario C



Land Use / Land Cover 2060

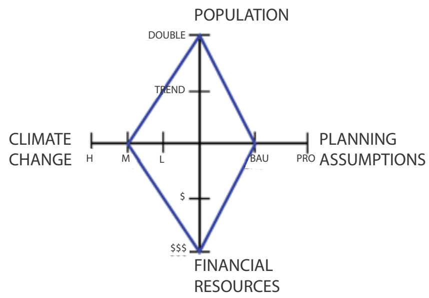


Land Use Composition 2060

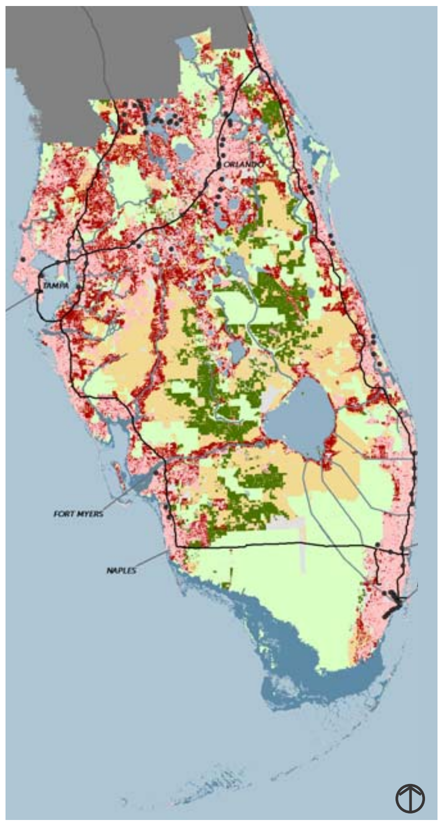


Total Land Use Area (in millions of acres)	2020	2040	2060
Agriculture	6.13	5.31	4.33
Conservation	5.77	5.40	5.40
Urban	4.50	5.20	6.00
Sea Level Rise	0.63	1.34	1.64
Other	2.26	2.05	1.92

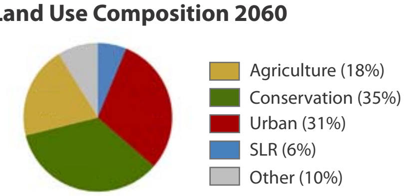
Scenario E



Land Use / Land Cover 2060

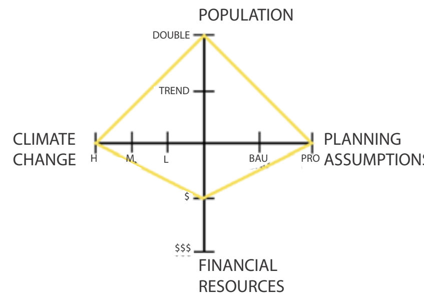


Land Use Composition 2060

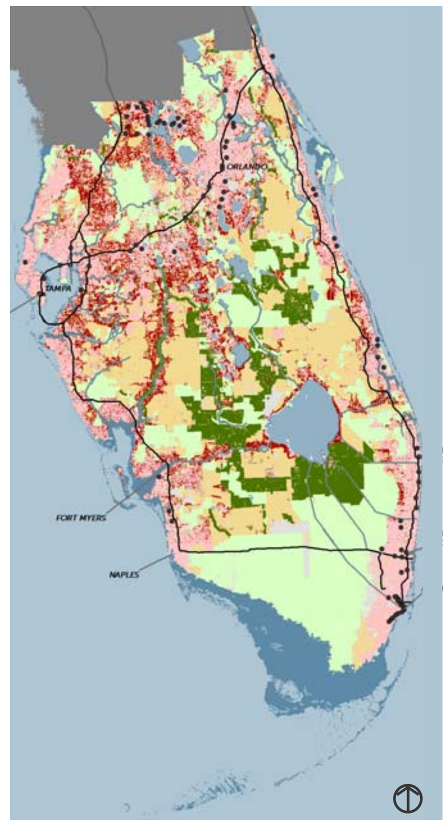


Total Land Use Area (in millions of acres)	2020	2040	2060
Agriculture	5.98	4.84	3.53
Conservation	6.12	6.40	6.69
Urban	4.50	5.20	6.01
Sea Level Rise	0.44	0.82	1.20
Other	2.25	2.03	1.86

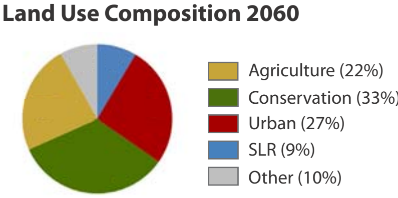
Scenario I



Land Use / Land Cover 2060



Land Use Composition 2060



Total Land Use Area (in millions of acres)	2020	2040	2060
Agriculture	6.06	5.19	4.18
Conservation	5.97	5.99	6.39
Urban	4.39	4.76	5.16
Sea Level Rise	0.63	1.34	1.64
Other	2.25	2.01	1.91

Future Conservation Scenarios

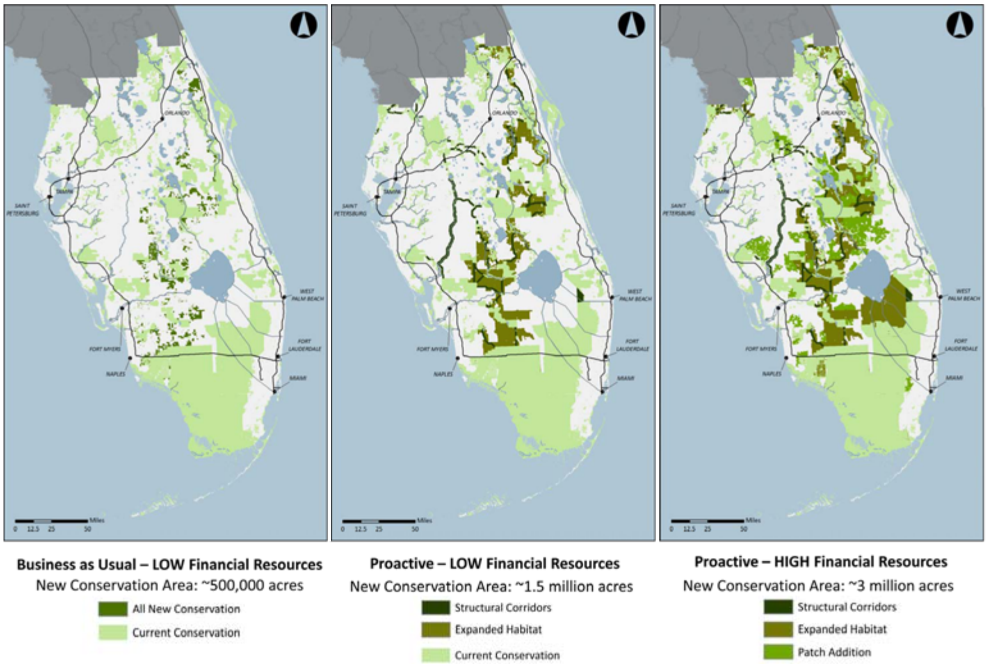


Figure 7. Conservation trajectories under different scenarios

Exploring Conservation Trajectories

MIT is using the scenarios and alternative futures to explore different trajectories of conservation under various financial and strategic conservation principles assumptions.

The image to the left shows a preliminary simulation of the conservation network based on three different scenarios (see description below images).

Conservation under Business as Usual is derived from a computer model that simulates a trend scenario of land acquisition.

Conservation under the Proactive Low and High-Financial Resources is created by design according to principles and spatial concepts informed by landscape ecology while reflecting different levels of financial resources.

Future Research Directions

1) Improved Species and Habitat Impact Modeling. Our initial impact models have been based on simple GIS overlays. These are sufficient to capture direct habitat conversions. However, we are currently working with the Florida Wildlife Commission and the Defenders of Wildlife on adapting The Nature Conservancy's Climate Vulnerability Index approach for use with our scenarios. We are also working with USGS, USFWS and University of Florida scientists conducting "climate envelope modeling."

2) Supporting Landscape Conservation Cooperatives (LLCs). LCCs are a new Dept. of Interior initiative expected to be our nation's primary mechanism for developing climate-sensitive conservation strategies. We see our work as providing a research base and methodological toolbox for such efforts. In preparation for this, we plan to extend our scenarios to include the full geography of the Peninsular Florida LCC. We hope to begin working shortly with researchers from University of Florida on updates to their Critical Lands and Waters Identification Project (CLIP) conservation prioritization system which use our scenarios to consider climate change, urbanization and policy choices.

3) Broadening Access to Spatial Scenarios. We are currently developing a web services platform to provide access to our study results and supporting data sets. Our system will provide a web-page interface for graphical scenario comparison. For those interested in incorporating our scenario simulations in their work, it will also provide GIS layer download capability.

Participants

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Holly Moeller (PhD Candidate)
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US Geological Survey (USGS) Team
Dr. Ronnie Best (Coordinator, USGS)

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Vargas-Moreno, J.C. "An Assumption-Based Scenario Planning Process for Landscape Planning". Research Report. Department of Urban Studies and Planning. MIT. August 2009.

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