Photo Credit: FWS 2014

Estimating the Societal Benefits of Carbon Dioxide Sequestration through Peatland Restoration

Emily Pindilli, Rachel Sleeter, Dianna Hogan

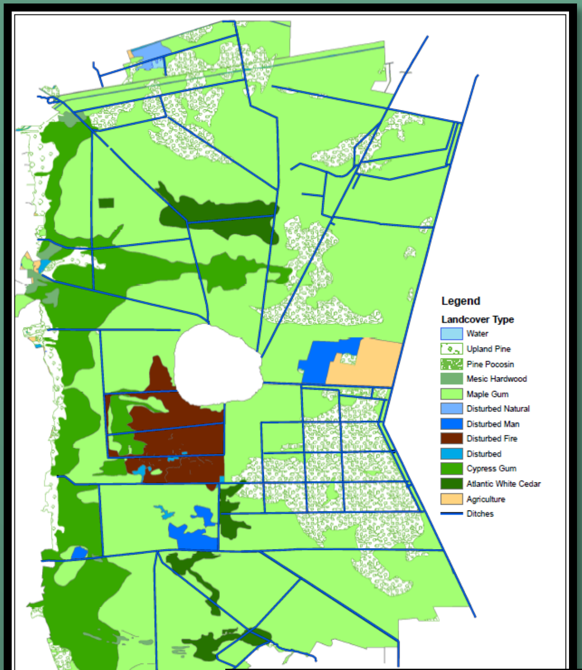
A Community on Ecosystem Services
December 2018

U.S. Department of the Interior
U.S. Geological Survey

Great Dismal Swamp Project

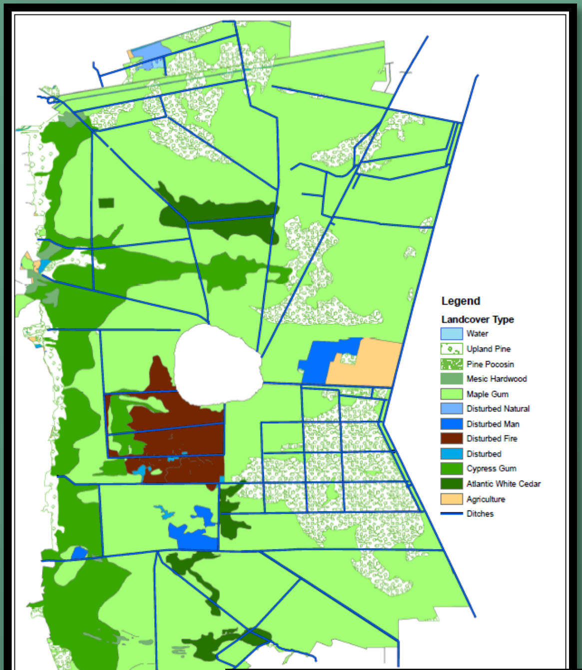
Background

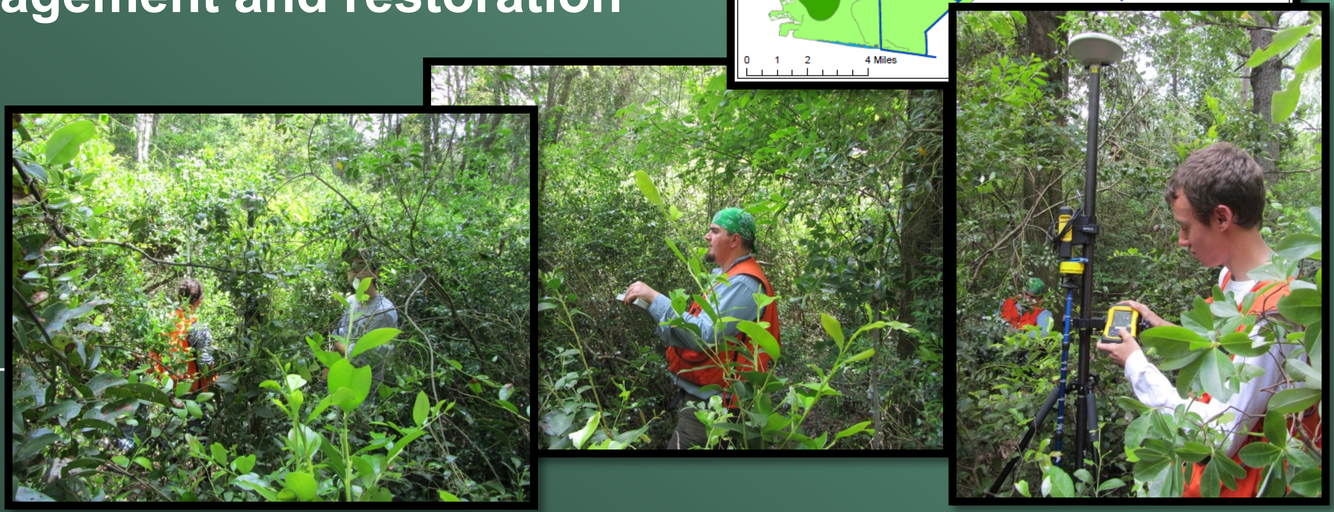
- Application of USGS LandCarbon
  - Produce regional- and local-scale C estimates (fluxes, ecosystem balance, and long-term sequestration rate) to include in ecosystem service evaluations in support of DOI land management
- Multi-partner project
  - FWS; TNC; USGS; George Mason, Southern Methodist, and Clemson Universities



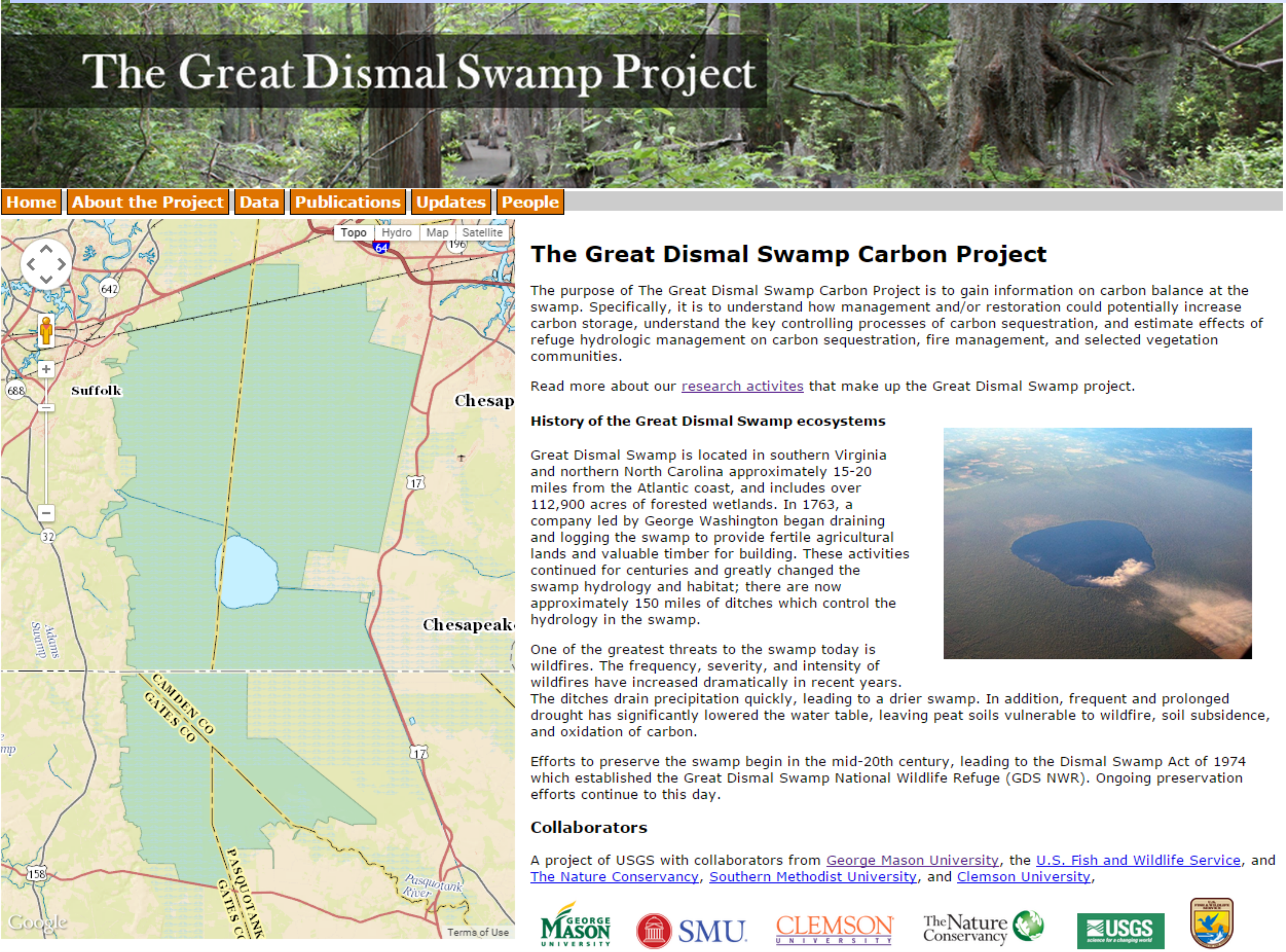
Great Dismal Swamp Project

- Estimate local-scale C storage and flux:
  - Carbon and hydrologic research: sequestration and peat storage, CO_2 CH_4 flux, soil moisture, hydrology (groundwater, and carbon flux through water)
  - Remote sensing: aboveground biomass (field verification), properties such as soil moisture and peat depth, and wildfire burn severity
- Assess ecosystem services in relation to selected management and restoration actions





http://www.usgs.gov/climate_landuse/lcs/great_dismal_swamp/default.asp



The Great Dismal Swamp Carbon Project

The purpose of The Great Dismal Swamp Carbon Project is to gain information on carbon balance at the swamp. Specifically, it is to understand how management and/or restoration could potentially increase carbon storage, understand the key controlling processes of carbon sequestration, and estimate effects of refuge hydrologic management on carbon sequestration, fire management, and selected vegetation communities.

Read more about our research activites that make up the Great Dismal Swamp project.

History of the Great Dismal Swamp ecosystems

Great Dismal Swamp is located in southern Virginia and northern North Carolina approximately 15-20 miles from the Atlantic coast, and includes over 112,900 acres of forested wetlands. In 1763, a company led by George Washington began draining and logging the swamp to provide fertile agricultural lands and valuable timber for building. These activities continued for centuries and greatly changed the swamp hydrology and habitat; there are now approximately 150 miles of ditches which control the hydrology in the swamp.

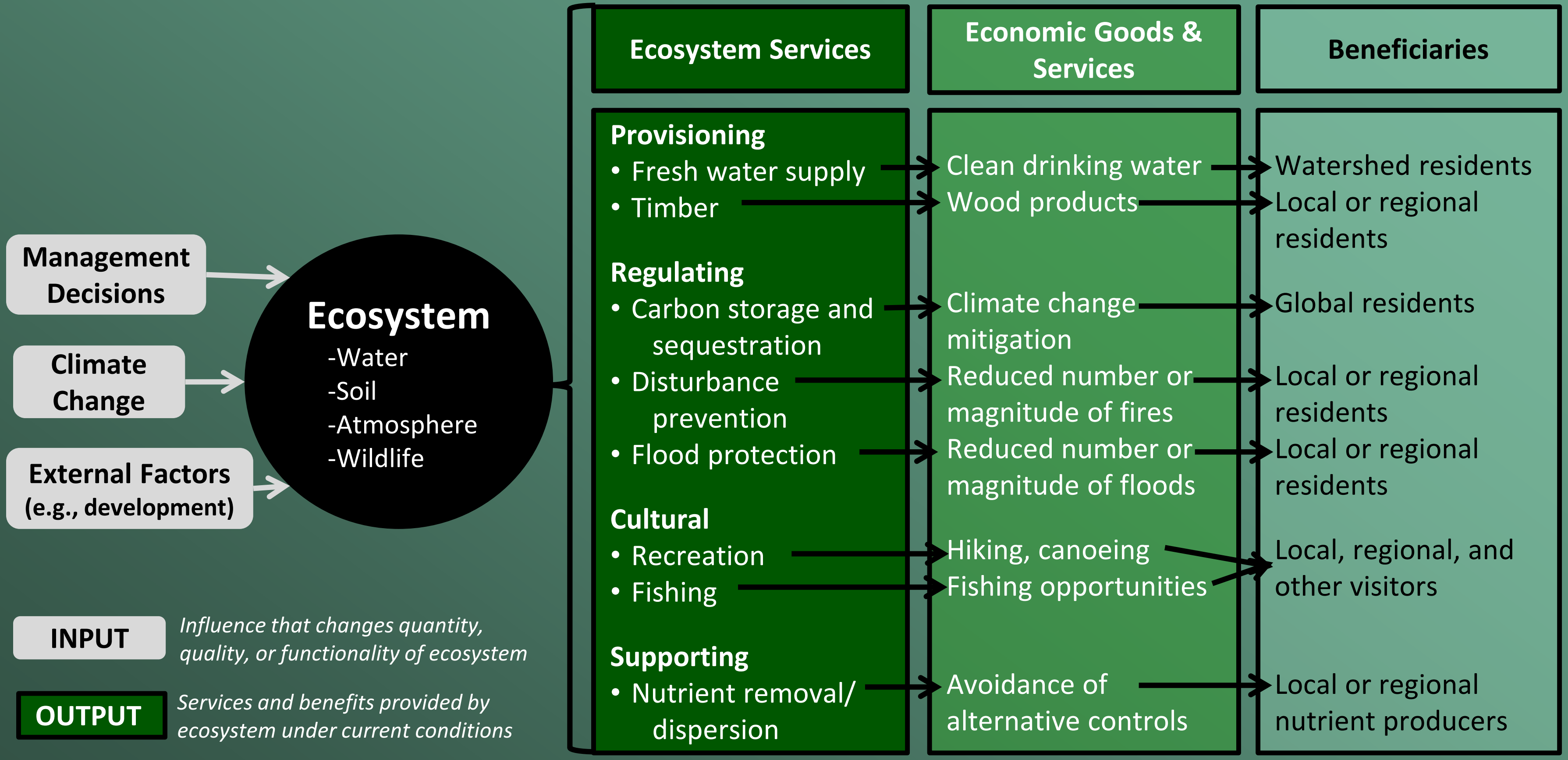
One of the greatest threats to the swamp today is wildfires. The frequency, severity, and intensity of wildfires have increased dramatically in recent years. The ditches drain precipitation quickly, leading to a drier swamp. In addition, frequent and prolonged drought has significantly lowered the water table, leaving peat soils vulnerable to wildfire, soil subsidence, and oxidation of carbon.

Efforts to preserve the swamp begin in the mid-20th century, leading to the Dismal Swamp Act of 1974 which established the Great Dismal Swamp National Wildlife Refuge (GDS NWR). Ongoing preservation efforts continue to this day.

Collaborators

A project of USGS with collaborators from George Mason University, the U.S. Fish and Wildlife Service, and The Nature Conservancy, Southern Methodist University, and Clemson University,

Ecosystem Services Framework



Management Decisions

Climate Change

External Factors (e.g., development)

Ecosystem
- -Water
- -Soil
- -Atmosphere
- -Wildlife

Ecosystem Services	Economic Goods & Services	Beneficiaries
Provisioning		
• Fresh water supply	Clean drinking water	Watershed residents
• Timber	Wood products	Local or regional residents
Regulating		
• Carbon storage and sequestration	Climate change mitigation	Global residents
• Disturbance prevention	Reduced number or magnitude of fires	Local or regional residents
• Flood protection	Reduced number or magnitude of floods	Local or regional residents
Cultural		
• Recreation	Hiking, canoeing	Local, regional, and other visitors
• Fishing	Fishing opportunities	Local, regional, and other visitors
Supporting		
• Nutrient removal/ dispersion	Avoidance of alternative controls	Local or regional nutrient producers

INPUT *Influence that changes quantity, quality, or functionality of ecosystem*

OUTPUT *Services and benefits provided by ecosystem under current conditions*

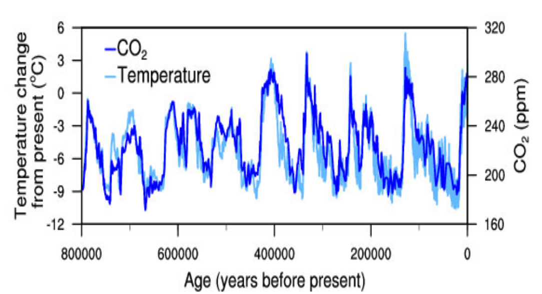
USGS

Priority Ecosystem Services

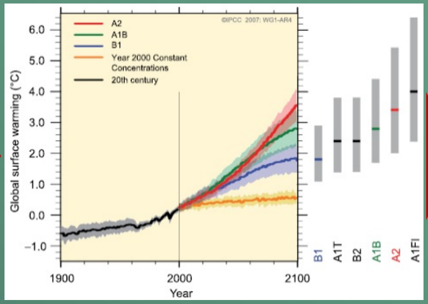
Ecosystem Service	Rank
Biodiversity	1
Wildlife Viewing	2
Education	3
Nutrient Cycling	4
Flood Protection	5
Carbon Sequestration	6
Fire Mitigation	7
Recreation (biking, hiking, boating)	8
Cultural Heritage	9
Recreational Hunting	10
Aesthetic	11
Recreational Fishing	12
Timber	13
Fresh Drinking Water	14

Carbon Sequestration Ecosystem Service Logic Flow

Photo Credit: USGS



Source: Jouzel et al. 2007; Lüthi et al. 2008



Source: IPCC 2007

Physical impacts include:
- higher air temps,
- increased ocean/freshwater temps,
- more frost-free days,
- more frequent heavy downpours,
- sea level rise,
- less snow-cover,
- shrinking glaciers, and
- reduced sea ice (Melillo et al., 2014).

Carbon sequestration:
- **in vegetation**
- **in soil (peat)**
- **in water**

Lower atmospheric carbon

Reduced climate change

Reduced damages:
- **health effects**
- **property damage**
- **loss of life**
- **loss of ecological functions**
- **lost agricultural yield (Tufts, 2017)**

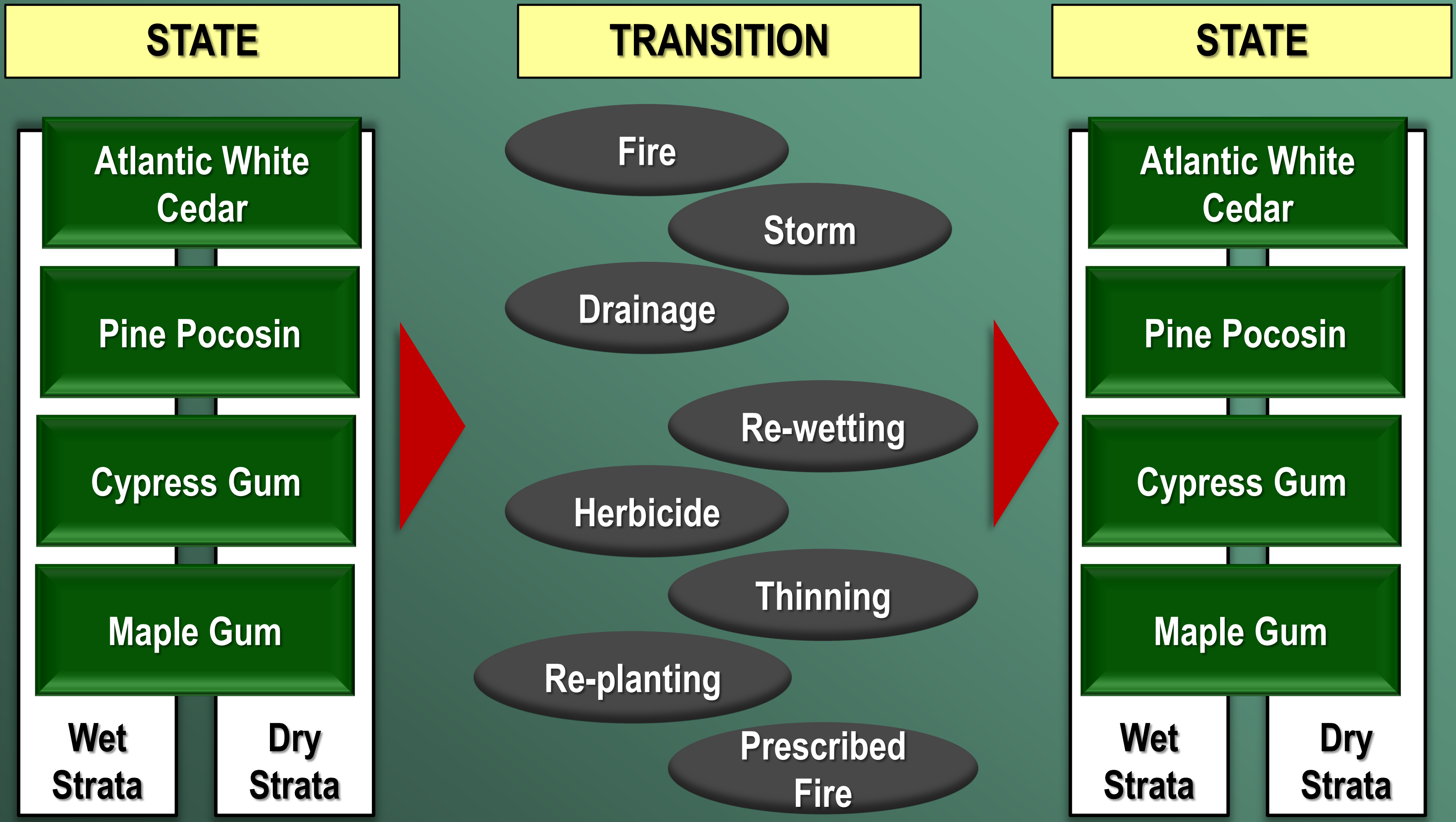
Methods Overview

- Biological Sequestration
  - LiDAR and field validation to derive above-ground biomass
  - Extrapolated to entire refuge (45,000 hectares)
  - Below ground biomass research still underway; literature utilized to fill in gaps

- Modeling
  - Land Use and Carbon Scenario Simulator (LUCAS Model)
  - State and transition model simulates carbon pools and fluxes under baseline and alternative scenario conditions

- Valuation
  - Interagency Working Group on Social Cost of Carbon
  - Four discount rates, 50 year period

State-and-transition Model (ST-SIM)



STATE

- Atlantic White Cedar
- Pine Pocosin
- Cypress Gum
- Maple Gum

Wet Strata | Dry Strata

TRANSITION

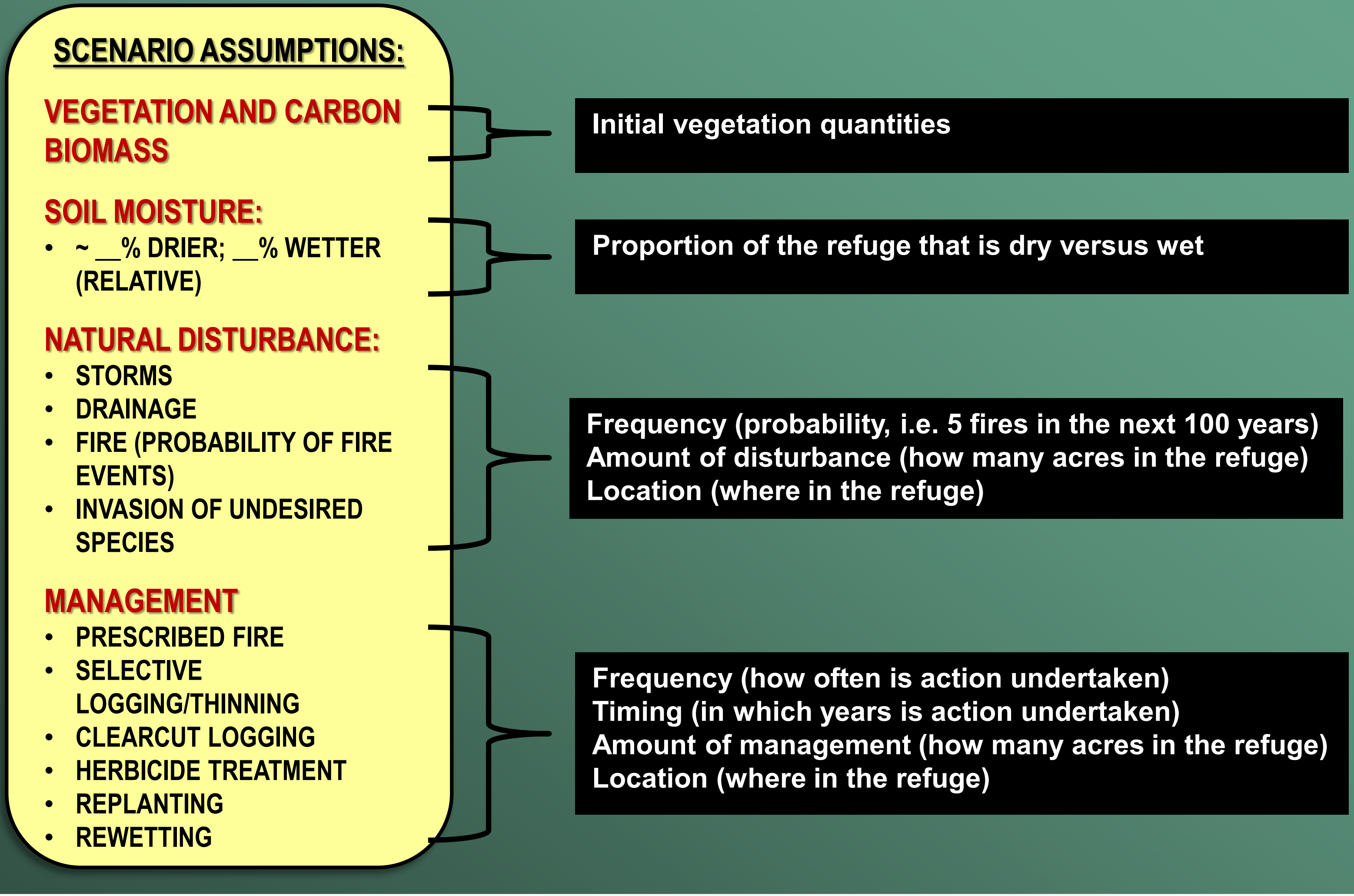
- Fire
- Storm
- Drainage
- Re-wetting
- Herbicide
- Thinning
- Re-planting
- Prescribed Fire

STATE

- Atlantic White Cedar
- Pine Pocosin
- Cypress Gum
- Maple Gum

Wet Strata | Dry Strata

Scenario Development



SCENARIO ASSUMPTIONS:

VEGETATION AND CARBON BIOMASS

Initial vegetation quantities

SOIL MOISTURE:

- ~ __% DRIER; __% WETTER (RELATIVE)

Proportion of the refuge that is dry versus wet

NATURAL DISTURBANCE:

- STORMS
- DRAINAGE
- FIRE (PROBABILITY OF FIRE EVENTS)
- INVASION OF UNDESIRED SPECIES

Frequency (probability, i.e. 5 fires in the next 100 years)
Amount of disturbance (how many acres in the refuge)
Location (where in the refuge)

MANAGEMENT

- PRESCRIBED FIRE
- SELECTIVE LOGGING/THINNING
- CLEARCUT LOGGING
- HERBICIDE TREATMENT
- REPLANTING
- REWETTING

Frequency (how often is action undertaken)
Timing (in which years is action undertaken)
Amount of management (how many acres in the refuge)
Location (where in the refuge)

Valuation

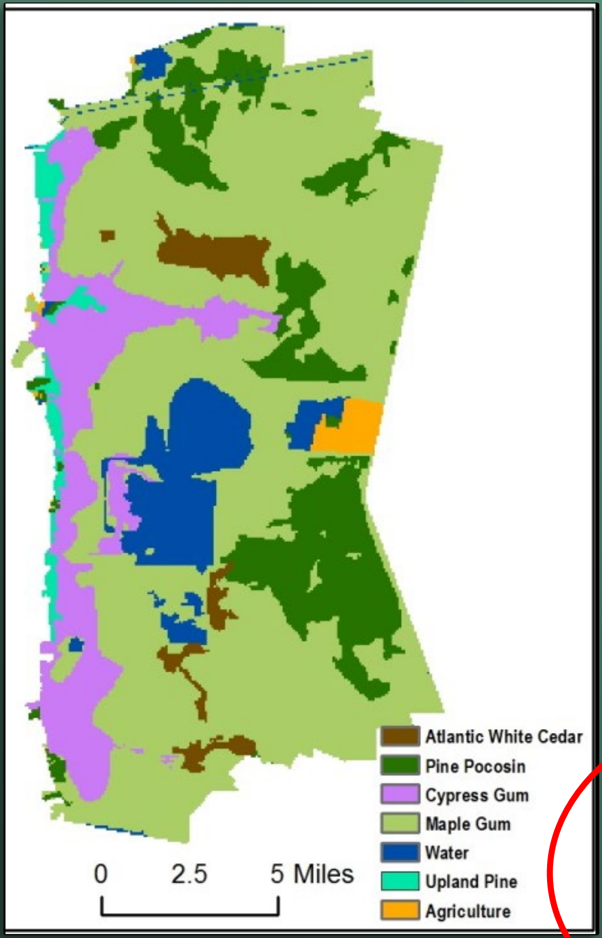
Year	5% Average	3% Average	2.5% Average	High Impact (95th Percentile at 3%)
2010	$12	$38	$61	$104
2015	$13	$44	$68	$127
2020	$15	$51	$75	$149
2025	$17	$56	$82	$167
2030	$19	$61	$88	$184
2035	$22	$67	$94	$203
2040	$25	$73	$102	$221
2045	$28	$77	$108	$238
2050	$31	$83	$115	$257
2060	$44	$96	$127	$293

Notes: original source is IWG 2016; values are escalated using CPI from 2007 to 2017. Values for 2060 are estimated based on rate of increase from 2040-2050.

$$NPV = B0 + d1B1 + d2B2 + \dots + dn-1Bn-1 + dnBn$$

Scenario 1: Reference Conditions

2015 ← **50 YEARS** → **2065**



SCENARIO ASSUMPTIONS:

CURRENT VEGETATION AND CARBON BIOMASS

SOIL MOISTURE:

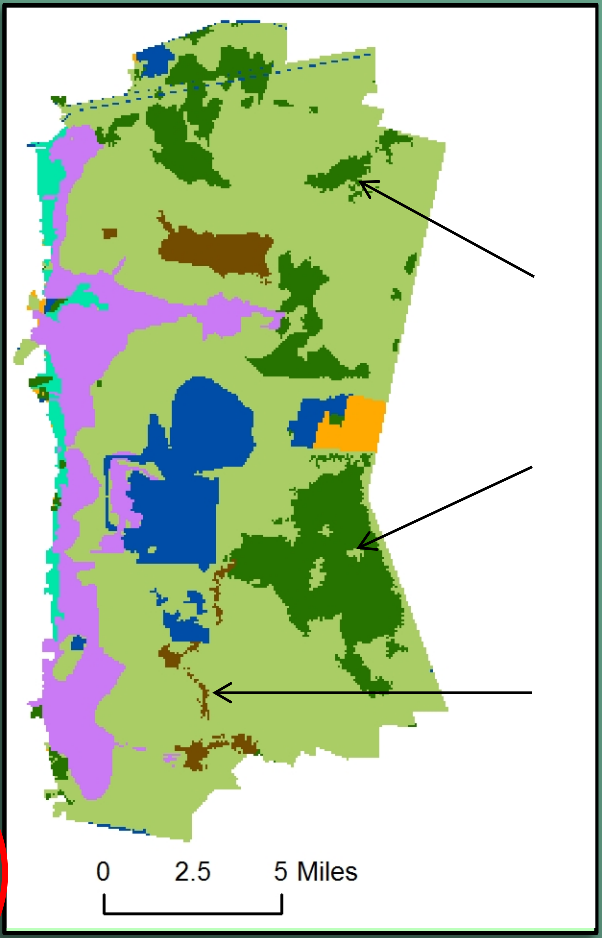
- ~ 65% DRIER; ~35% WETTER (RELATIVE)

NATURAL DISTURBANCE:

- WIND/STRESS
- FIRE (Probability of 1 Extreme Fire Event within 100 YRS)
- INVASION OF UNDESIRED SPECIES (MAPLE GUM)

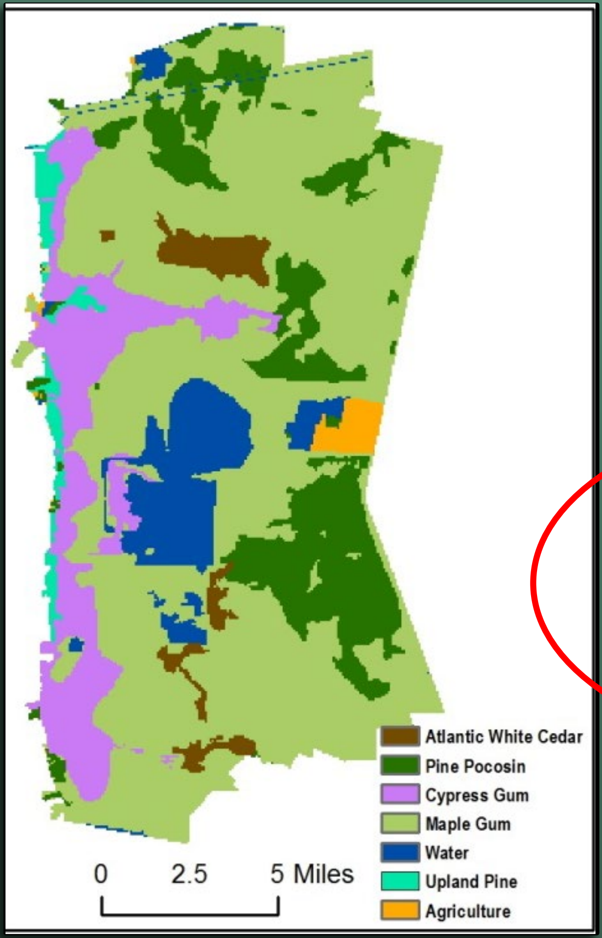
NO MANAGEMENT

- NO FIRE SUPPRESSION (PRESCRIBED FIRES OR THINNING)
- NO REWETTING
- NO FOREST RESTORATION (THINNING, REPLANTING, HERBICIDE)



Scenario 2: Extreme Fire Event

2015 ← **50 YEARS** → **2065**



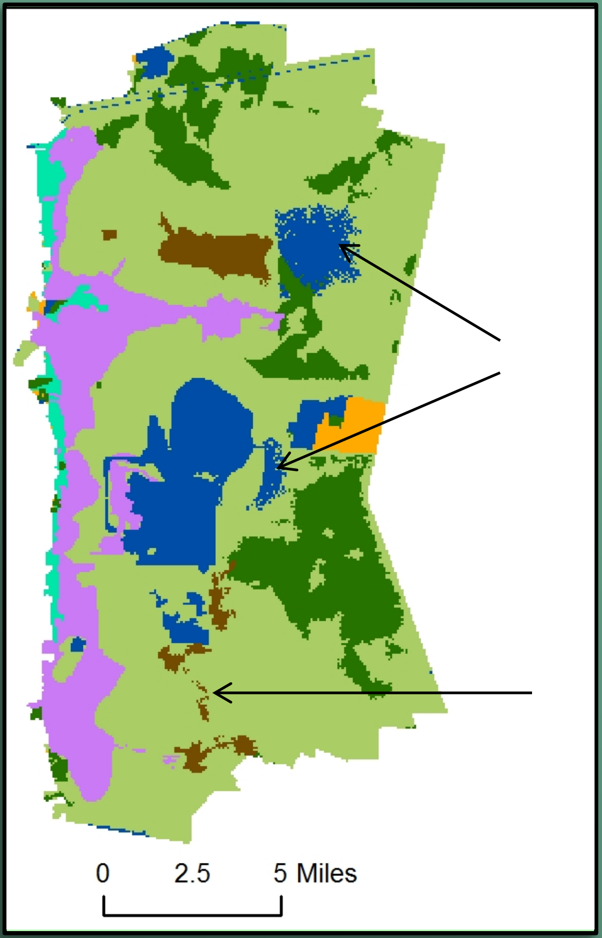
SCENARIO ASSUMPTIONS:

CURRENT VEGETATION AND CARBON BIOMASS

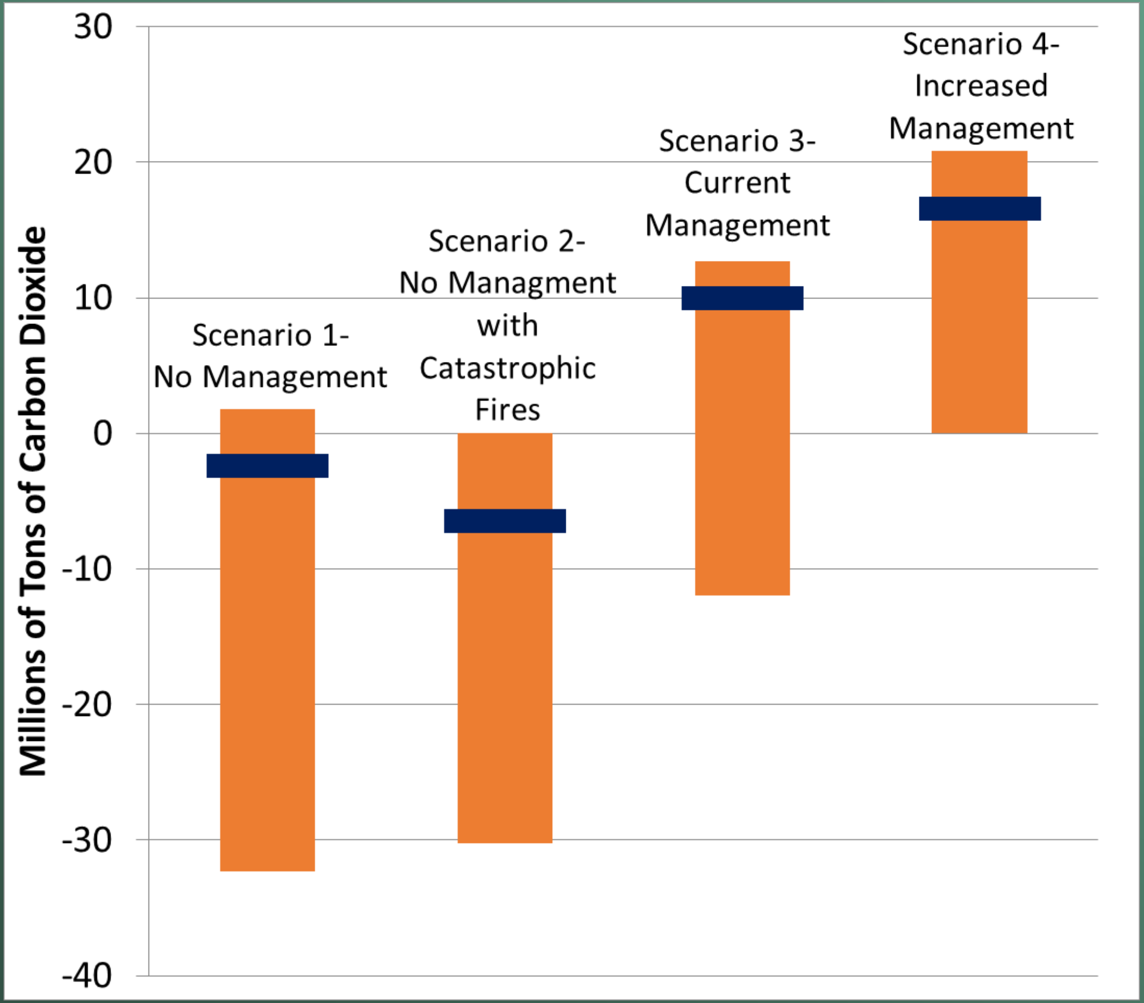
SOIL MOISTURE:
- ~ 65% DRIER; ~35% WETTER (RELATIVE)

NATURAL DISTURBANCE:
- WIND/STRESS
- **FIRE – 2 LARGE FIRES OCCUR ON SAME PATCH WITHIN 5 YRS**
- INVASION OF UNDESIRED SPECIES (MAPLE GUM)

NO MANAGEMENT
- NO FIRE SUPPRESSION (PRESCRIBED FIRES OR THINNING)
- NO REWETTING
- NO FOREST RESTORATION (THINNING, REPLANTING, HERBICIDE)



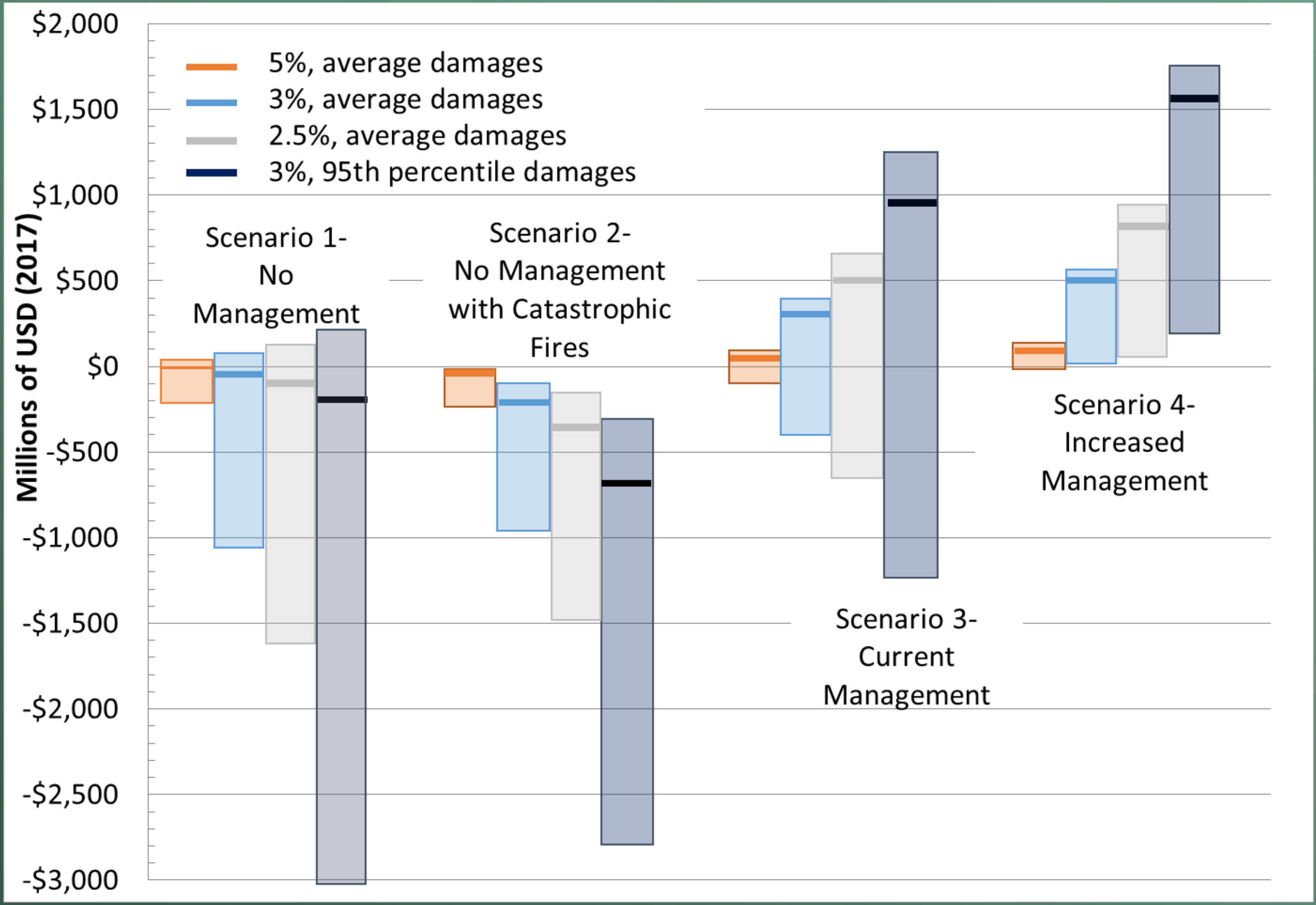
Results: Tons of CO_2 Sequestered



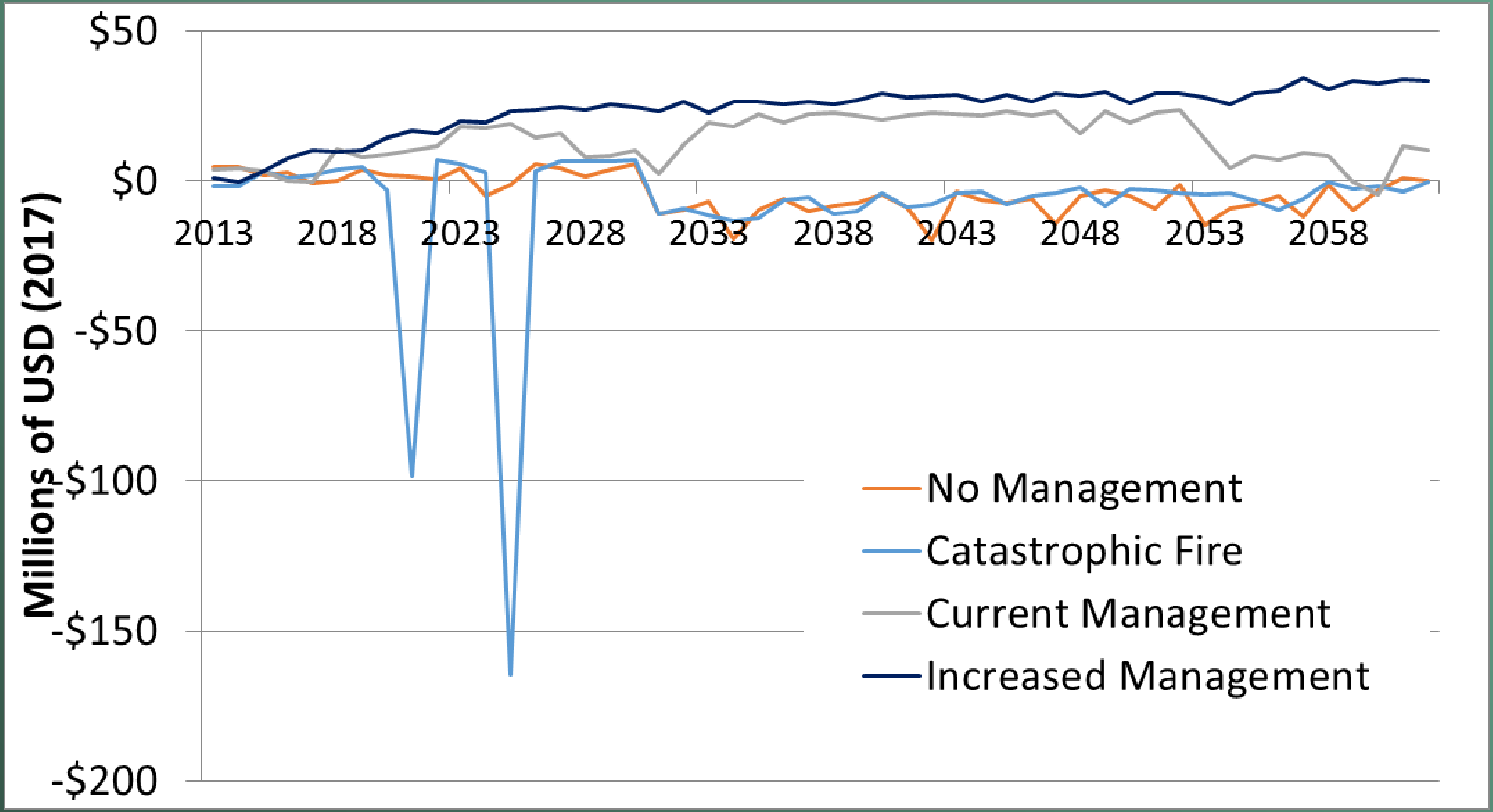
Range and Mean Total Carbon Sequestered (positive) or Emitted (negative) from 2013-2062. The range of total CO2 emissions for the entire simulation period is shown in orange with the mean represented in blue

Results: Net Present Value of CO_2 Sequestered

Minimum, Mean, and Maximum Net Present Value of Social Cost of Carbon Associated with Scenarios at 2.5, 3, and 5% discount rates and at the 95th percentile at 3% for 2013-2062



Results: Value of CO_2 Sequestered Over Time



Annual Value of Carbon Sequestration for Four Scenarios in GDS (at the 3% discount rate); note that values differ in the first year due to the incorporation of uncertainty in the model

Conclusions

- Management actions expected to influence GDS's capacity to sequester carbon
- Additional drivers also impact ecosystem services
- Managing for one service may have unintended consequences
- A portfolio approach increases information to decision-makers on how management effects people
- See https://doi.org/10.1016/j.ecolecon.2018.08.002 for details on the carbon sequestration analysis
- See https://doi.org/10.1016/j.jenvman.2017.08.018 for details on benefits of fire mitigation

Acknowledgements

- **This work is a multi-disciplinary, multi-agency partnership. The project relies on the extensive expertise of all of the team members, with leadership and integration by Dr. Dianna Hogan.**

Ecosystem Services Assessment and Carbon Monitoring Team	
Coordination Team	• FWS (John Schmerfeld, Sara Ward), USGS (Zhiliang Zhu, Brad Reed, Dianna Hogan), NWR managers (Chris Lowie, Fred Wurster, Howard Phillips), State Park (Joy Greenwood, Adam Carver), TNC (Christine Pickens, Chuck Peoples, Brian van Eerden)
Dianna Hogan	• Coordination and communications, ecosystem services analysis, model development, field research
Ken Krauss, Nicole Cormier, Rebecca Moss, Courtney Lee, Jamie Duberstein, Josh Salter, Laurel Gutenberg, Chris Wright	• Field research – carbon storage and flux
Judy Drexler	• Field and lab research – carbon storage in soils (peat)
Gary Speiran	• Field research – hydrologic measurements
Todd Hawbaker, Zhong Lu, John Qu, Laurel Gutenberg	• Biomass and soil moisture measurements and fire characterization
Emily Pindilli, Bryan Parthum	• Economics analysis, model development
Rachel Sleeter	• ST-SIM model development
Kim Angeli, Gary Fisher	• Remote sensing

Questions?