
Photo Credit: FWS 2014

Ecosystem Service Assessments at Three National Wildlife Refuges: Methods, Results, and Lessons

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National Ecosystem Services Partnership Webinar

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

USGS

Discussion Overview

- USGS Landcarbon Applications Overview
- Great Dismal Swamp NWR Case Study
  - Carbon sequestration, fire mitigation, recreation
- Ding Darling NWR Case Study
  - Carbon sequestration, recreation, sea-level rise mitigation
- Nisqually NWR Case Study
  - Carbon sequestration, recreation, commercial fishing

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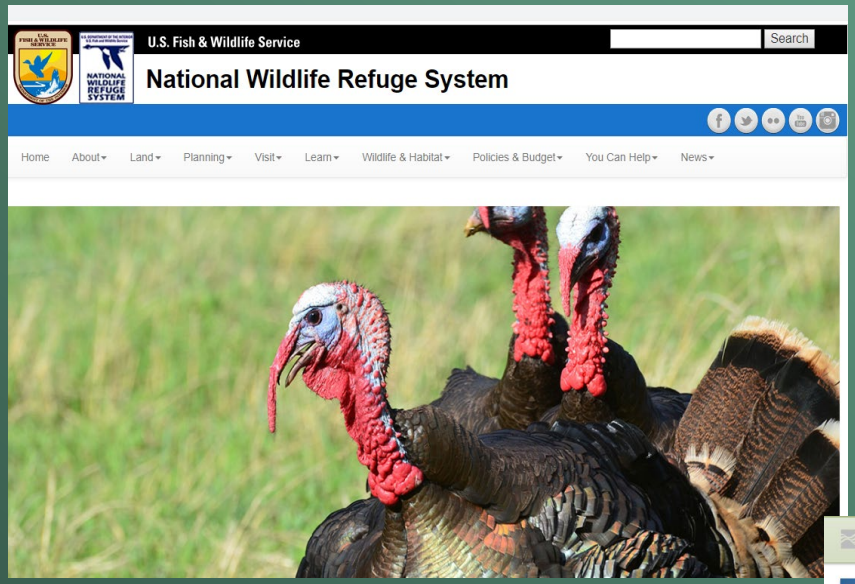
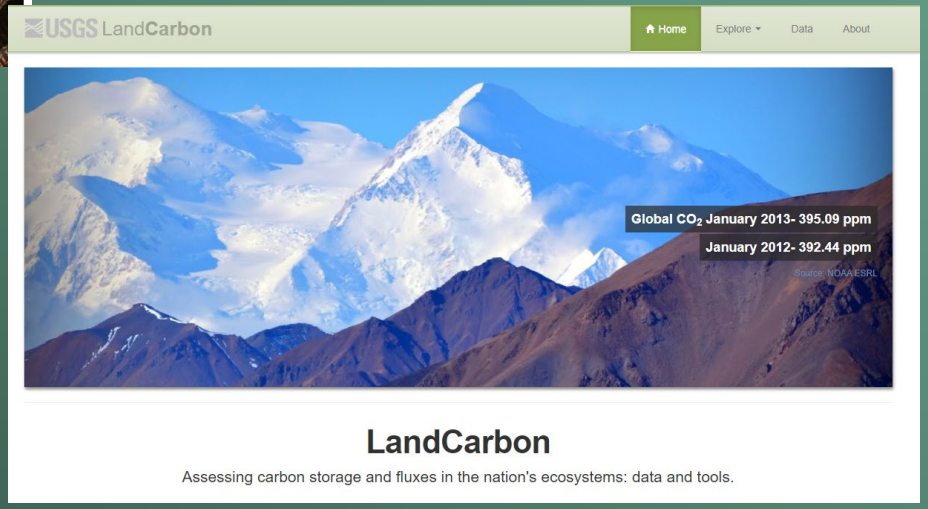
USGS Landcarbon Applications



- USGS Landcarbon program assesses ecosystem carbon storage/flux
  - Remote sensing
  - In-situ research
- Partnership with US Fish and Wildlife Service National Wildlife Refuges (NWR)
  - Applications provide site specific research on carbon storage/flux
  - Address management relevant issues
  - May include Ecosystem Service Assessment

- Landcarbon Applications Ecosystem Service Assessments on NWRs:
  - Great Dismal Swamp
    - Status: complete
  - Ding Darling
    - Status: ongoing
  - Nisqually
    - Status: ongoing



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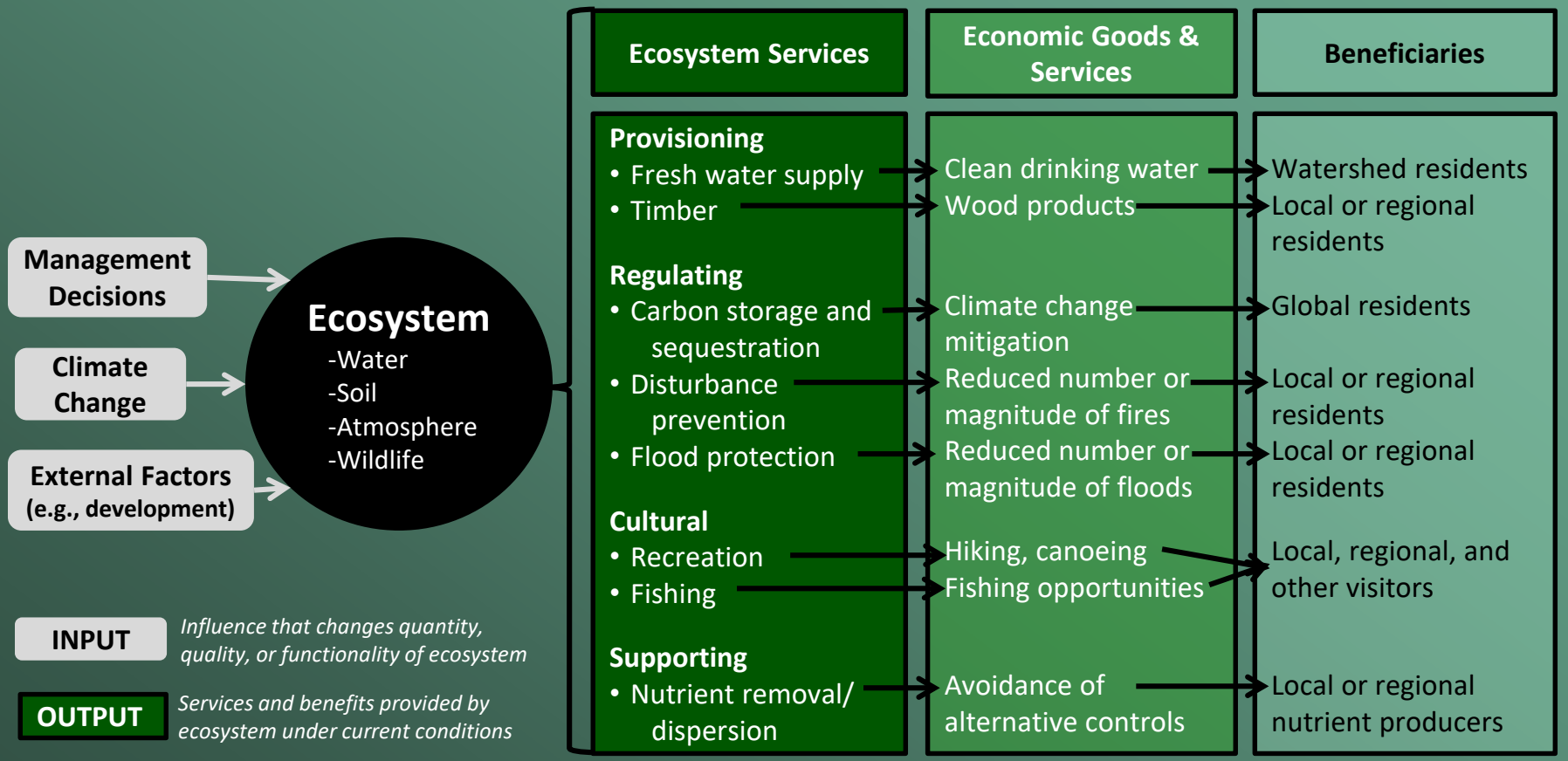
Ecosystem Services Framework



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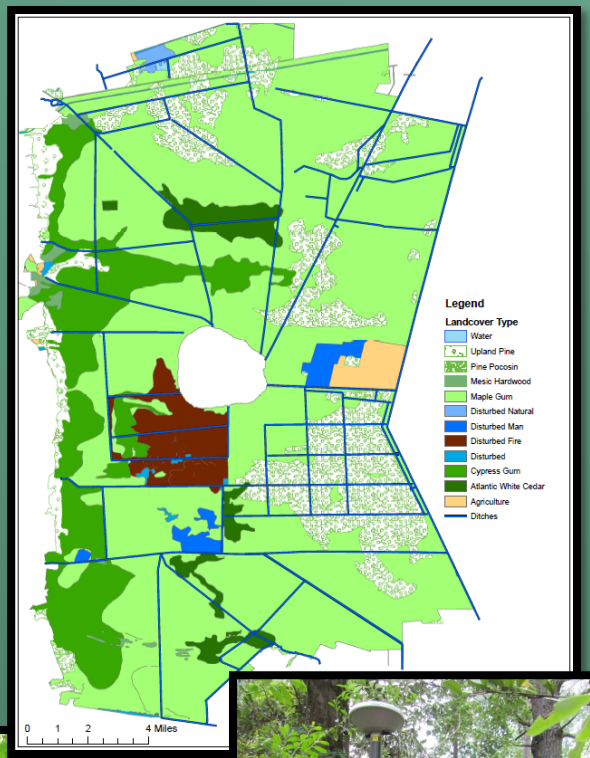
Great Dismal Swamp Project

- A forested peatland in southeastern Virginia and northeastern North Carolina
- Physical science:
  - Estimate local-scale carbon storage and flux
  - Hydrologic research
  - 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 actions
- Multiple partners: FWS; Nature Conservancy; George Mason, Southern Methodist, and Clemson Universities



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Stakeholder Engagement and Prioritization of 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

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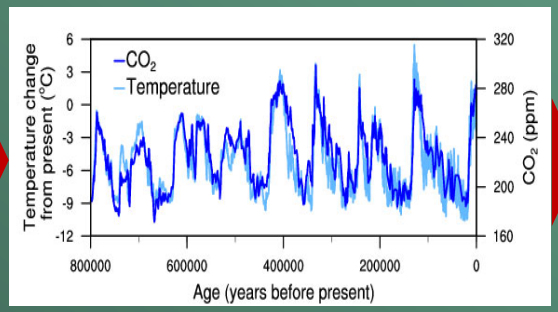
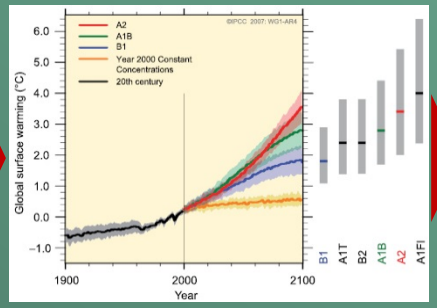
Carbon Sequestration Ecosystem Service Logic Flow

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)**

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Carbon Sequestration 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

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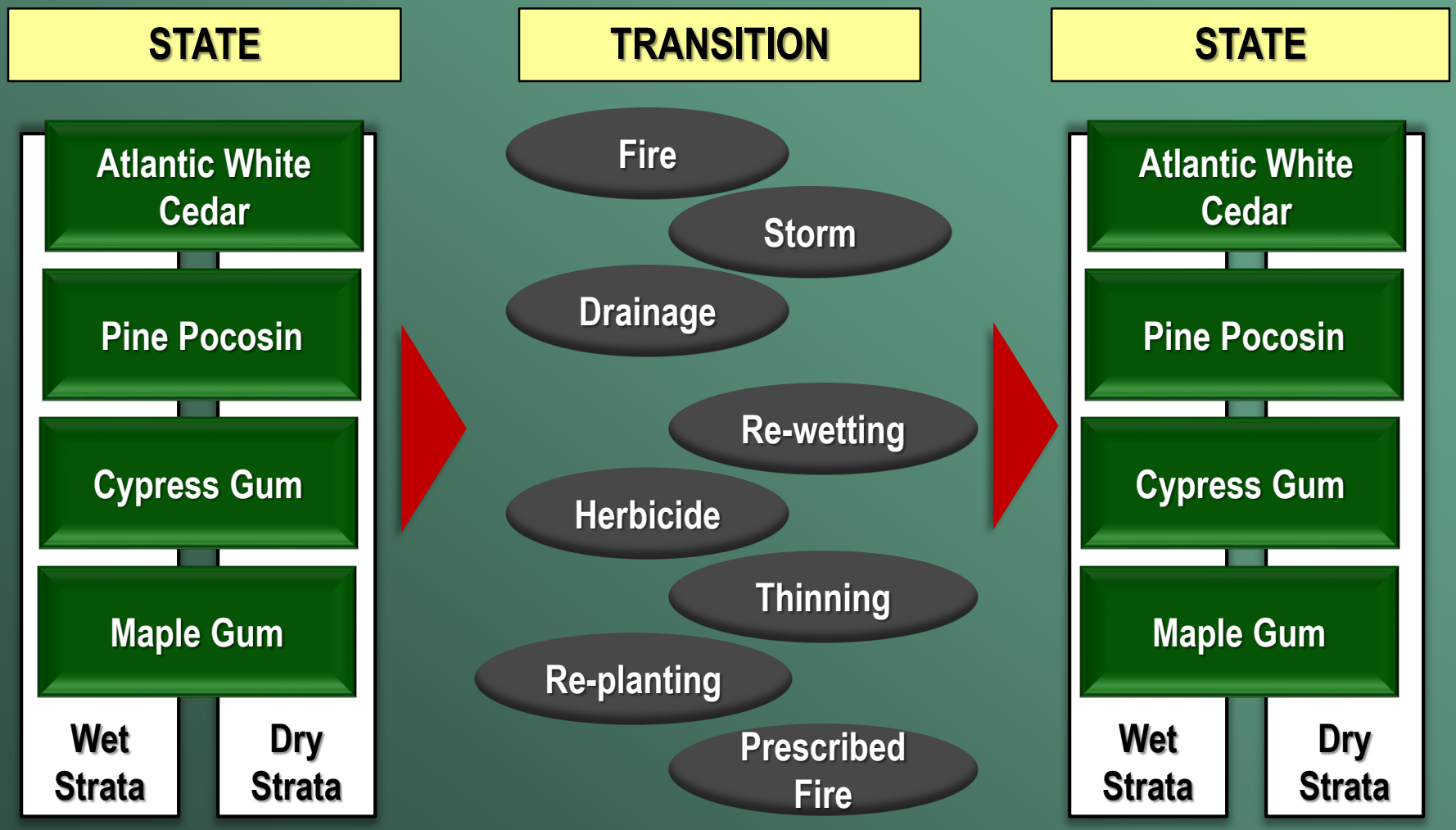
State-and-transition Model (ST-SIM)*



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*Model developer – Rachel Sleeter, USGS

Scenario Development

SCENARIO ASSUMPTIONS:

VEGETATION AND CARBON BIOMASS

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

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

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

Initial vegetation quantities

Proportion of the refuge that is dry versus wet

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)

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)

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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.

$$NPV = B0 + d1B1 + d2B2 + \ldots + dn{-}1Bn{-}1 + dnBn$$

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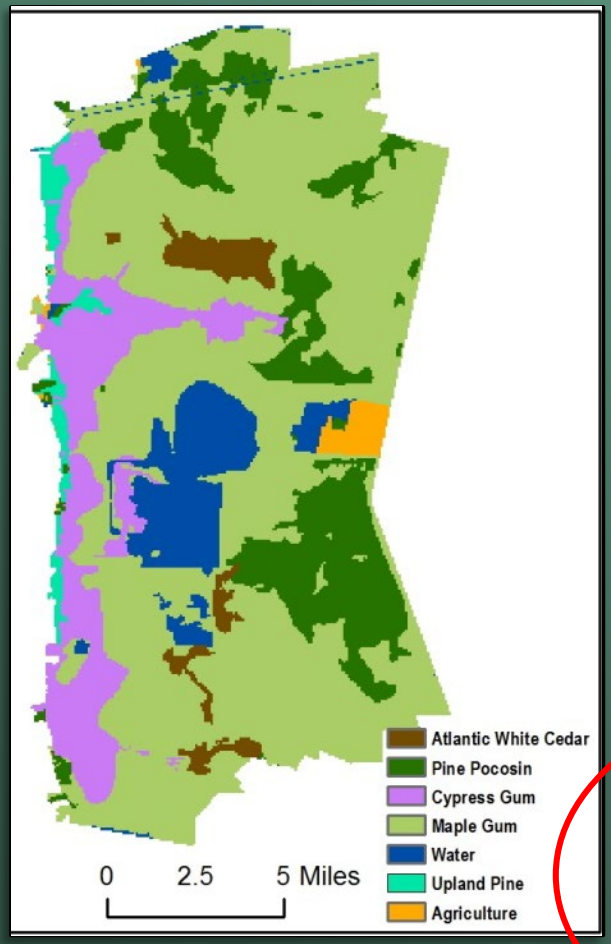
Scenario 1: Reference Conditions

2015 ← 50 YEARS → 2065



SCENARIO ASSUMPTIONS:

CURRENT VEGETATION AND CARBON BIOMASS

SOIL MOISTURE:

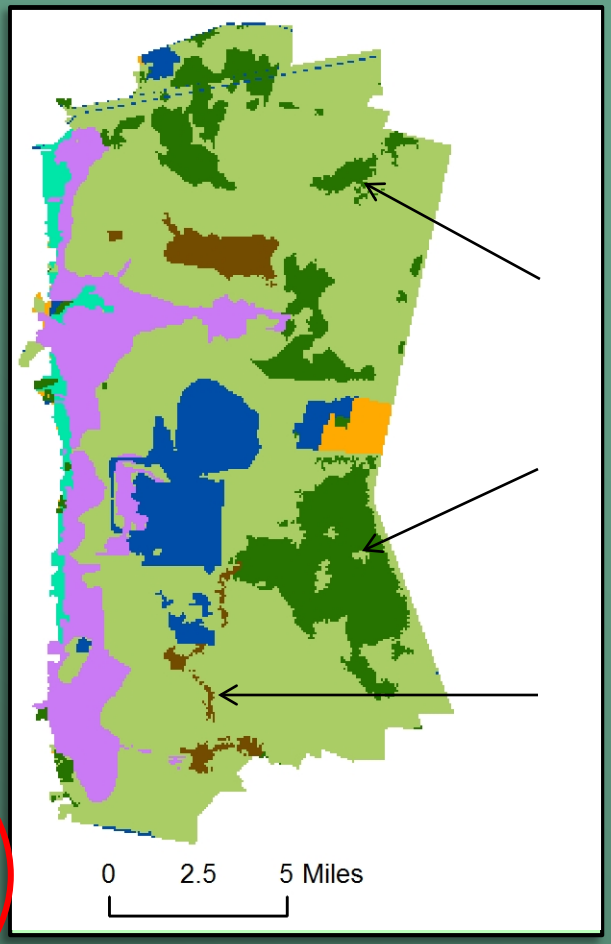
- ~ 65% DRIER; ~35% WETTER (RELATIVE)

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)



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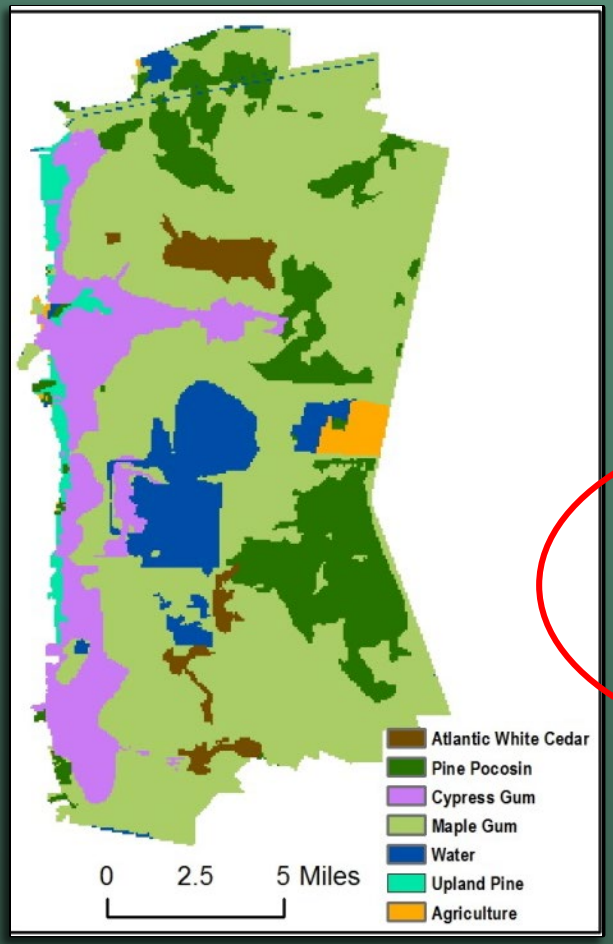
Scenario 2: Extreme Fire Event

2015 ← 50 YEARS → 2065



SCENARIO ASSUMPTIONS:

CURRENT VEGETATION AND CARBON BIOMASS

SOIL MOISTURE:

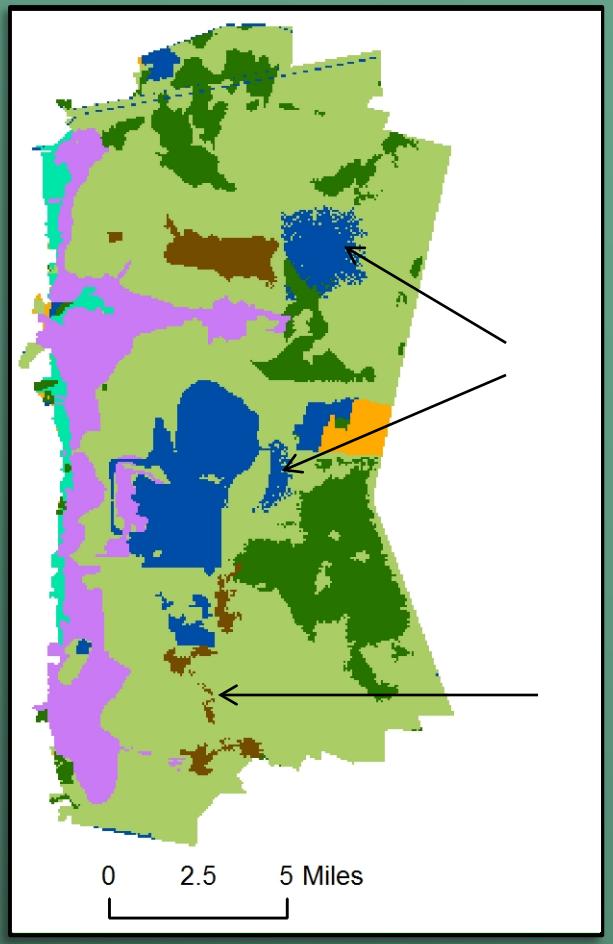
- ~ 65% DRIER; ~35% WETTER (RELATIVE)

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)



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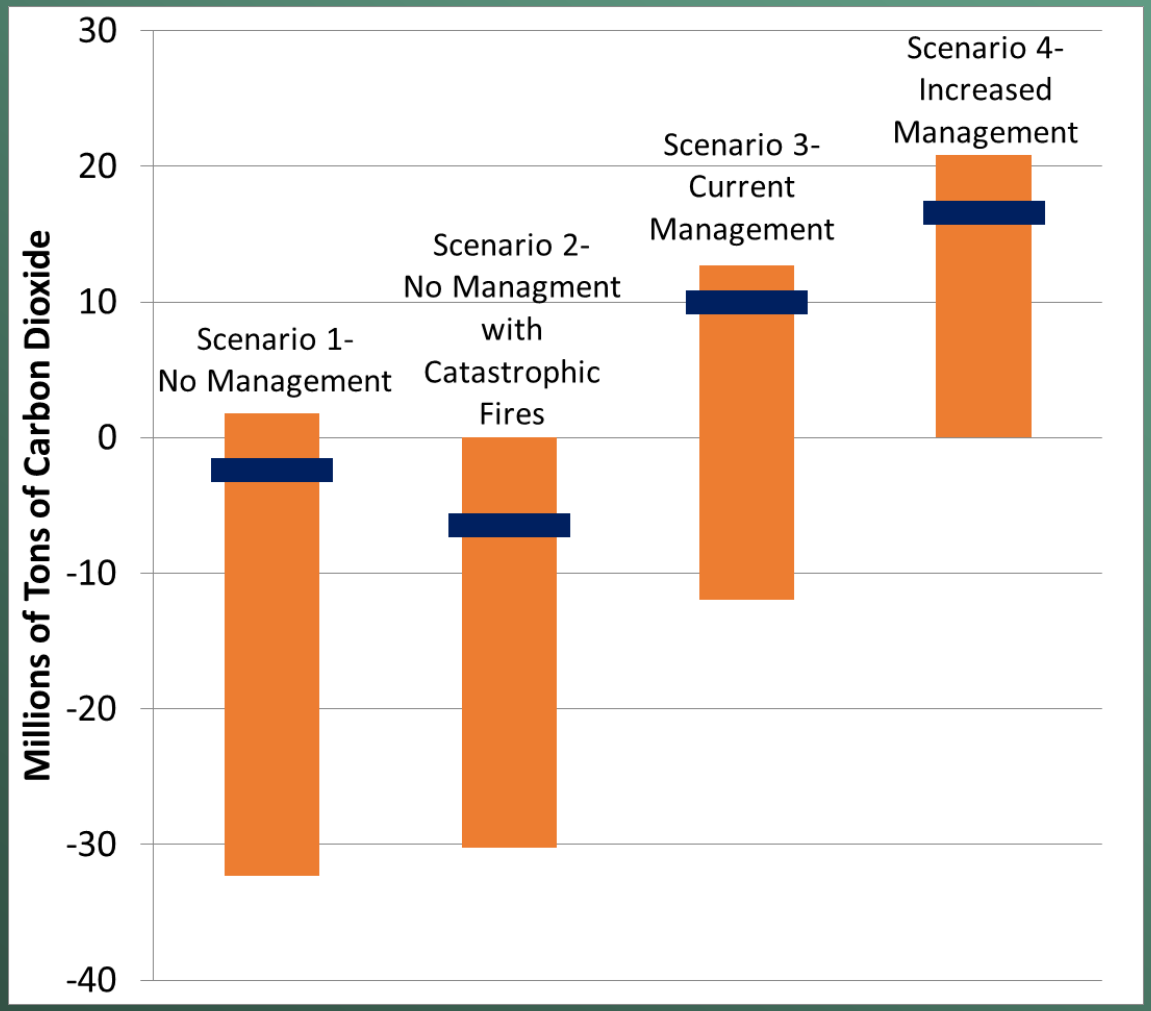
Results: Tons of CO_2 Sequestered



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

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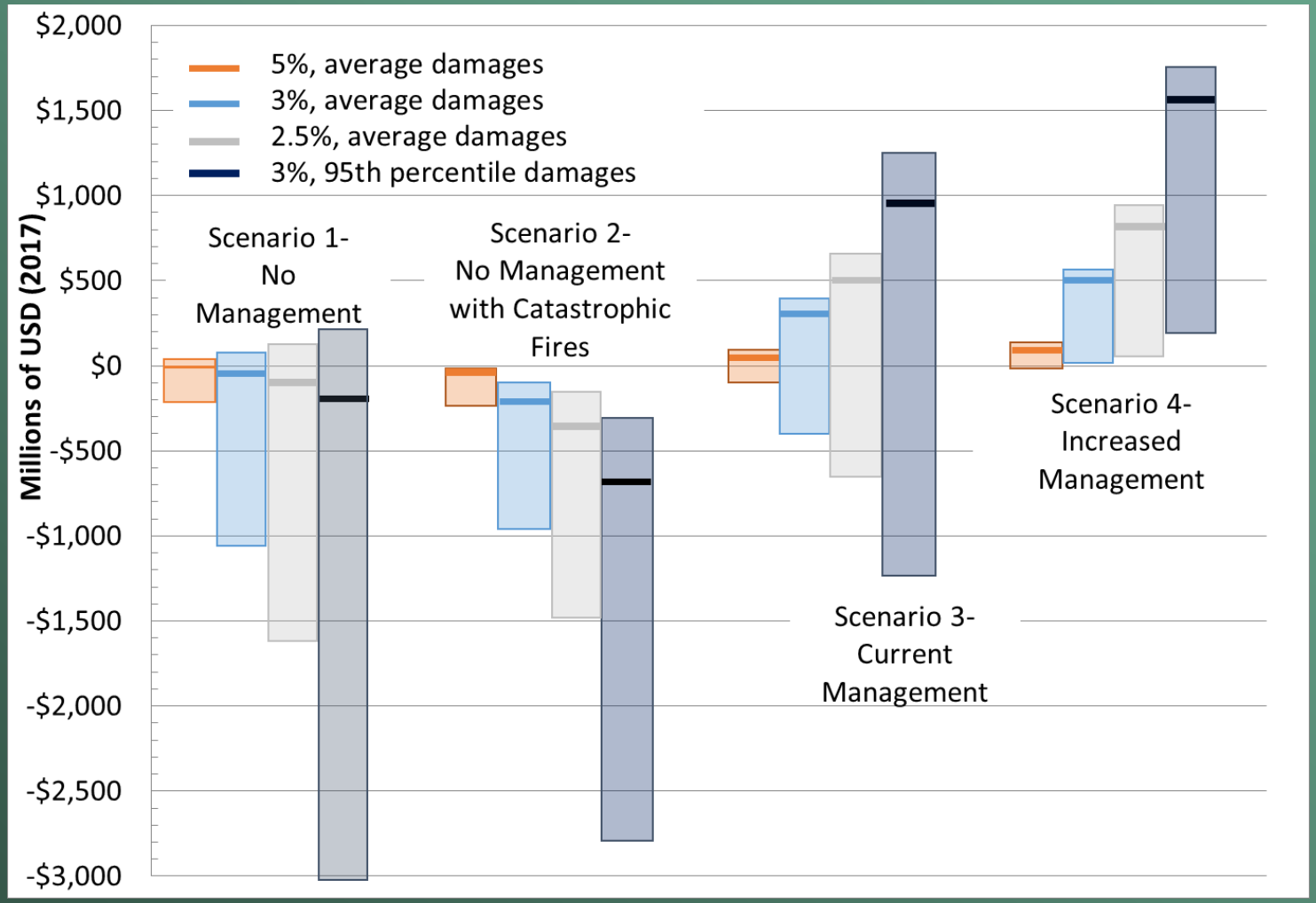
Results: Net Present Value of CO_2 Sequestered

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



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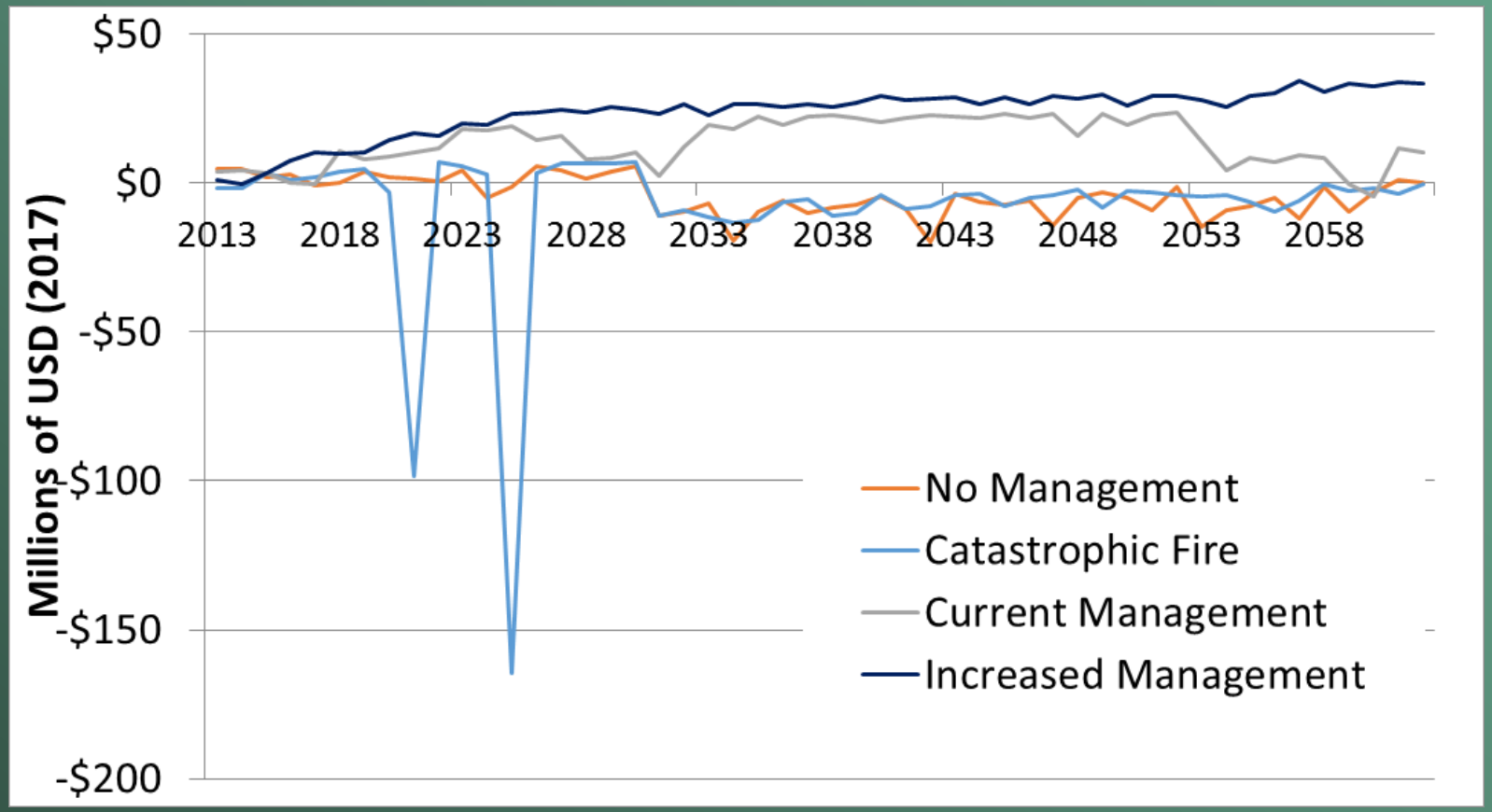
Results: Value of CO_2 Sequestered Over Time



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

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Fire Mitigation Ecosystem Service*

- **Ecological Function: hydrologic regime**
- **Economic Goods and Services: fire mitigation**

Hydrologic balance:
- **reduces dry vegetation/ ignition material**
- **reduces infiltration of fire to deep peat**
- **allows for prescribed burn**

Fire probability reduced
- **magnitude, and/or**
- **frequency**

Fire damages reduced
- **Air quality/human health impacts**
- **Carbon emissions**
- **Recreation lost**
- **Tourism lost**

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*PI – Bryan Parthum, USGS SDC

Biophysical Evaluation of Fire Mitigation ES

- Fire mitigation ES assessment only considers "catastrophic fire"
  - Fires of sufficient economic and ecological magnitude
- Two high-level factors considered in biophysical evaluation of catastrophic fires
  - Probability of catastrophic fire (annually)
  - Effects of catastrophic fire
- Effects considered:
  - Air quality/human health impacts
  - Carbon emissions
  - Recreation lost
  - Tourism lost

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Quantifying Human Exposure to Wildfire Smoke

- Estimating human health impacts using method developed by Rappold et al. (2011)[1]
  - Aerosol Optical Depth (AOD) readings from satellite imagery provide areas of concern and duration of impacts
  - During periods above AOD threshold, Rappold study observed an increase in hospital visitation for respiratory and cardio-pulmonary symptoms
- Methods are being applied to GDS using local hospital visitation data and AOD readings during 2008 South One Fire
- Study is being taken another step by assigning monetary value to health outcomes

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1. Rappold et al. (2011). *Peat Bog Wildfire Smoke Exposure in Rural North Carolina*. Environmental Health Perspectives, Vol 119, No.10, October 2011.

Human Health Effects of Wildfire Smoke Exposure

- Wildfire smoke exposure increases incidence of:
  - Asthma
  - Chronic Obstructive Pulmonary Disease (COPD)
  - Pneumonia/acute bronchitis
  - Heart failure (CHF)
  - Cardiopulmonary symptoms

- Valuation uses Cost of Illness (COI)[1]
  - Focuses on HIGHEST costs
  - Includes actual costs incurred (medical bills)
  - Includes opportunity cost (lost wages/value of time lost)

- Other studies have indicated a willingness to pay to avoid health effects to be substantially higher than COI

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1. Localized COI values derived using EPA's BenMAP estimates

Wildfire: Preliminary Results

- Preliminary results suggest catastrophic wildfire has COI of $2.2 million (currently only direct costs)*
- Catastrophic wildfire has annual probability of 2% (2 events in 100-year period)
- Annual COI under current conditions $44,000*
- Does not include other costs of catastrophic wildfire:
  - Reduced tourism (nearby)
  - Reduced recreation (on refuge)
  - Carbon emissions
- Management (rewetting) can reduce the risk of catastrophic wildfire

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*These data are preliminary and are subject to revision. They are being provided to meet the need for timely 'best science' information. The assessment is provided on the condition that neither the U.S. Geological Survey nor the United States Government may be held liable for any damages resulting from the authorized or unauthorized use of the assessment.

Wildlife Viewing Ecosystem Service

- Ecological Function: natural environment, habitat
- Economic Goods and Services: recreation, wildlife viewing

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Biophysical Evaluation of Wildlife Watching ES

- Visitation (indication of human benefits) is a function of:
  - habitat conditions
  - species abundance
  - recreational access
- 2014 GDS NWR visitation rates[1]:

Purpose (self-report)	Co
Wildlife observation	
Fishing	
Hunting	272
Photography	10,999
Environmental Education	432
Interpretation	5,994
Special event	1,103
Visitor center	5,200
Auto tour	9,281
Total*	**92,768**
*Total does not equal sum of categories	

Biodiversity is an important factor in desirability of visitation to a specific location. Species abundance and variety in GDS both contribute to visitation numbers. The value of biodiversity as it contributes to wildlife viewing is captured in this analysis.

1. Source: GDS NWR Staff personal communication. (January 2015).

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Economic Valuation of Wildlife Watching

- Valuation based on travel-cost consumer surplus
  - Consumer surplus is difference in visitors' "willingness to pay" and actual travel costs incurred
  - Values from FWS 2015 survey for wildlife watching values in the state of Virginia
  - Residential values and non-residential values

- Analysis assumes all non-consumptive visitation using 2014 visitation rates
  - Residential versus non-residential visitation is derived using FWS 2013 Banking on Nature Report

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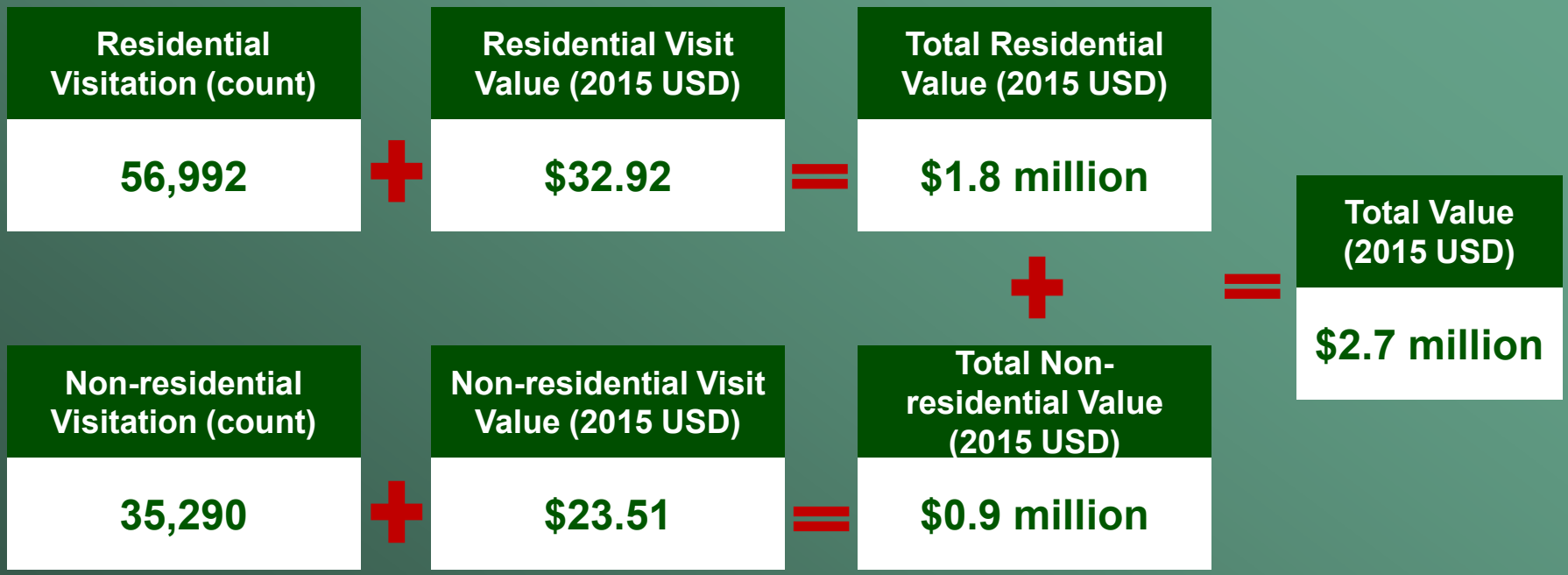
Wildlife Watching ES Results Summary



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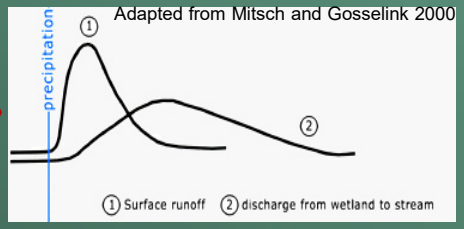
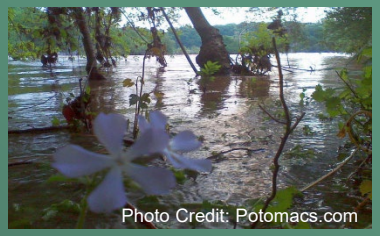
Flood Protection Ecosystem Service

- Ecological Function: flood and flow control
- Economic Goods and Services: flood protection

Wetlands act as 'sink' during precipitation events



Reduces peak flow



Flood probability reduced
- magnitude, and/or
- frequency

Flood damages reduced
- property damage
- safety implications

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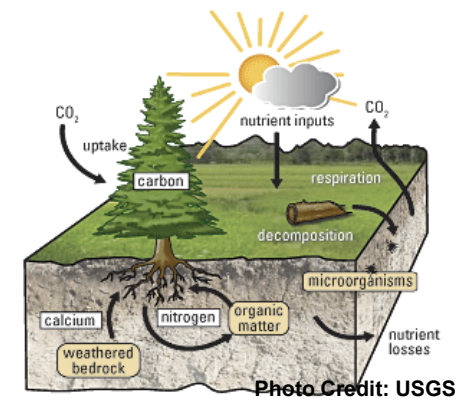
Nutrient Cycling Ecosystem Service

- Ecological Function: water quality maintenance/nutrient retention
- Economic Goods and Services: improved water quality



Wetlands act as nutrient sink

Reduces nutrients and other pollutants from reaching water bodies

Increases water quality, may reduce need to purify water, may reduce need to decrease nutrients from other sources

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J.N. Ding Darling Project

- A mangrove forest off the western coast of Florida (on Sanibel Island)
- Physical science:
  - Estimate local-scale carbon storage and flux
  - Remote sensing: aboveground biomass (field verification)
- Assess ecosystem services (baseline) and under scenarios (exogenous factors)

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Mangrove Ecosystem Services

- Carbon Sequestration – methods same as GDS
- Sea Level Rise Protection
  - Coastal Protection (storm surge)
  - Coastal Erosion Mitigation
- Recreation (Wildlife Viewing, Fishing, Boating, etc.) – methods same as GDS
- Commercial Fishing
- Pollution Abatement
- Wood and Timber
- Aesthetic Value

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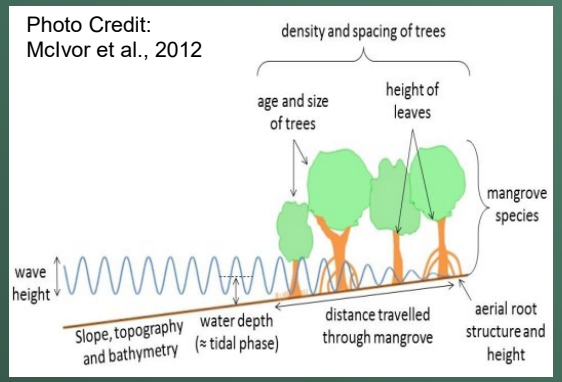
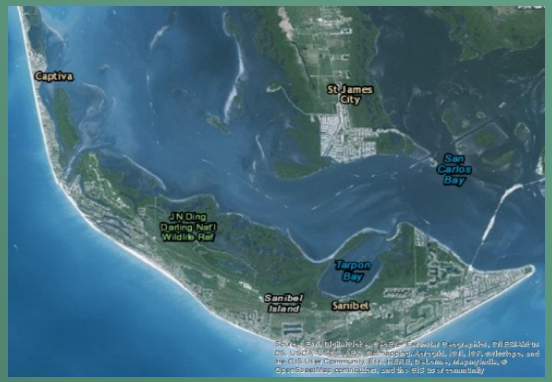
Sea Level Rise Ecosystem Service

- Ecological Function: wave attenuation
- Economic Goods and Services: coastal protection



Wave energy dissipation

Coastal protection from
- wind and swell waves
- storm surges
- tsunamis
- erosion



Reduced damages
- reduced property damage
- reduced loss of life
- reduced loss of agricultural yield

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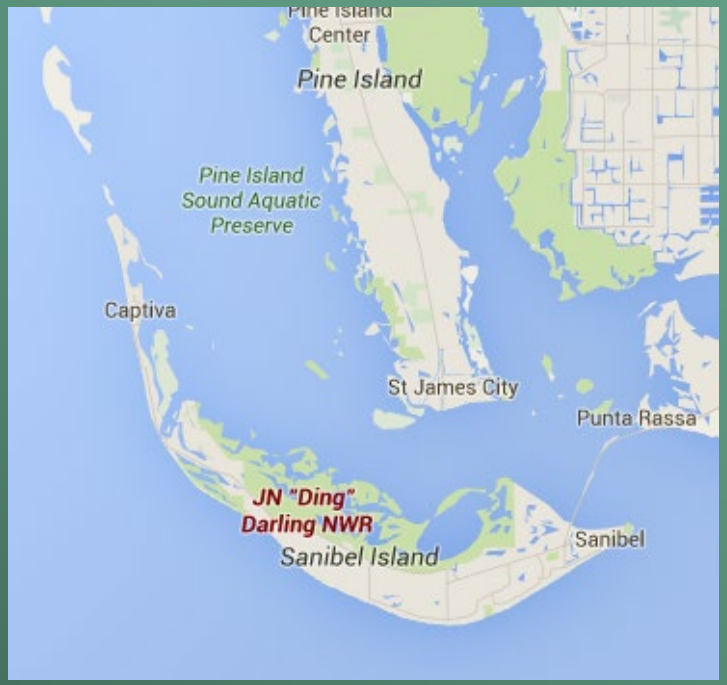
Coastal Protection from Catastrophic Events

- On average, mangroves provide $3,116 /Ha/yr in coastal protection[1]
  - Based on mangrove forests capacity to protect landmasses from open water, i.e. waves generated from long fetch distances

- DD NWR's mangroves are located on the eastern coast

- *Unlikely* to provide Sanibel Island protection from open water during storm events



1. 2012. Marwa E. Salem and D. Evan Mercer. The Economic Value of Mangroves: A Meta-Analysis.

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Coastal Protection from Erosion

- Mangroves *may* protect Sanibel Island from soil erosion and inundation, especially with sea level rise
- Mean sea level rise near Fort Myers, Florida is estimated at 2.85 mm/yr +/- 0.49 mm/yr (1965 to 2015)[1]
- Elevation surplus/deficit = surface elevation change – relative sea level rise

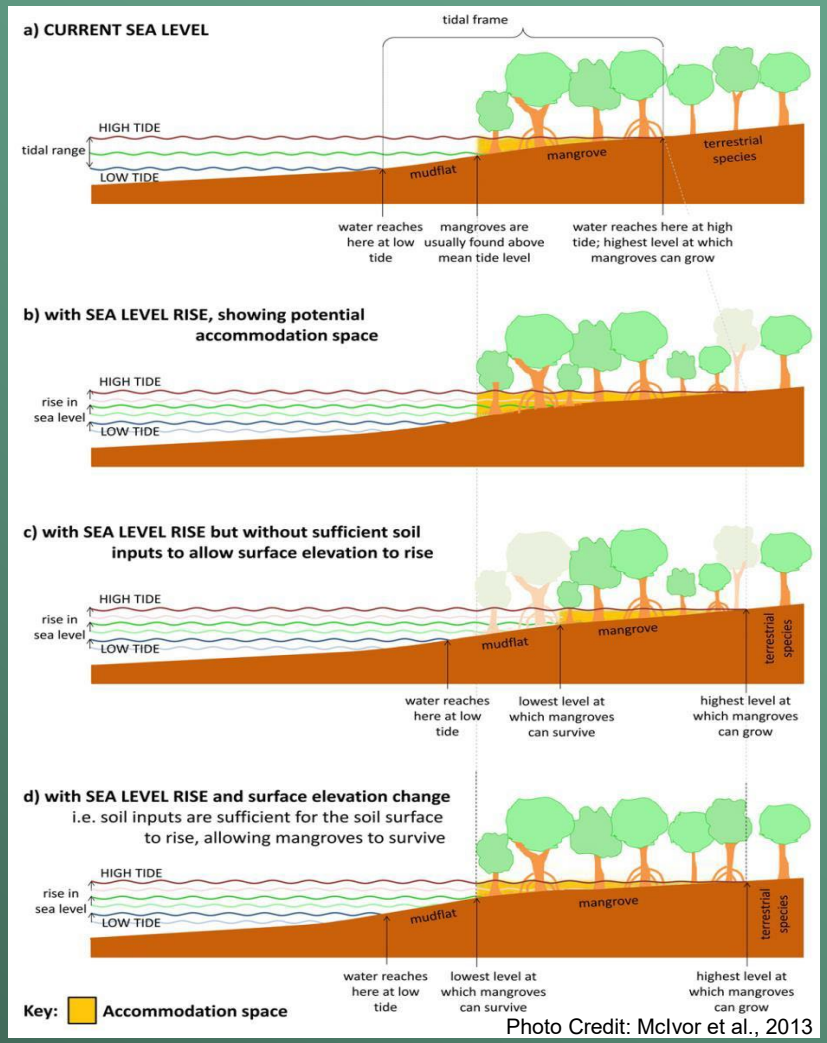

Photo Credit: McIvor et al., 2013

1. National Oceanic and Atmospheric Administration. (2016). Tides & Currents. Available at: https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8725520

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Wildlife Viewing Ecosystem Service

- Ecological Function: natural environment, habitat
- Economic Goods and Services: recreation, wildlife viewing

Unique ecosystem provides habitat, food, and nursery for flora and fauna

Abundance and diversity of species attract recreationists including wildlife viewers

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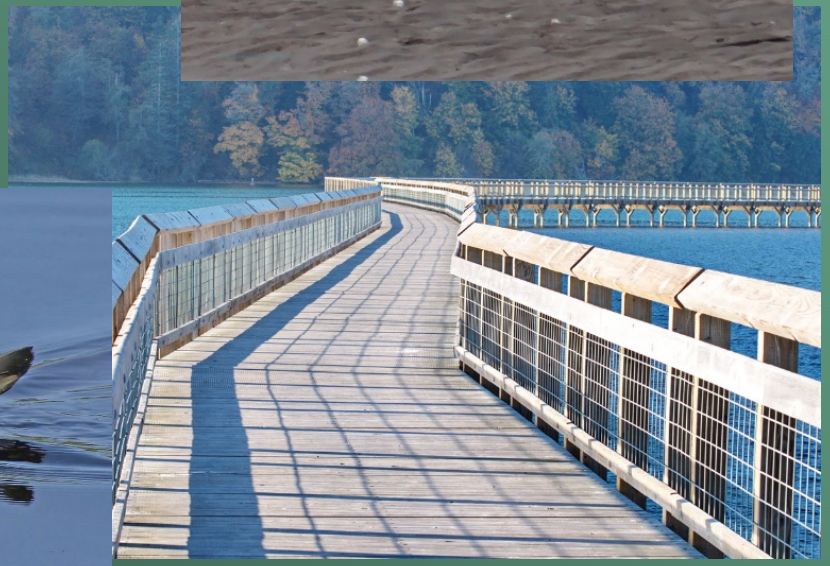
Billy Frank Jr. Nisqually Project

- An estuarine system located at the southern end of Puget Sound in Washington state
- Physical science:
  - Estimate local-scale carbon storage and flux
  - Food web energetics
  - Marsh equilibrium modelling
- Assess ecosystem services (baseline) and under scenarios (exogenous factors)



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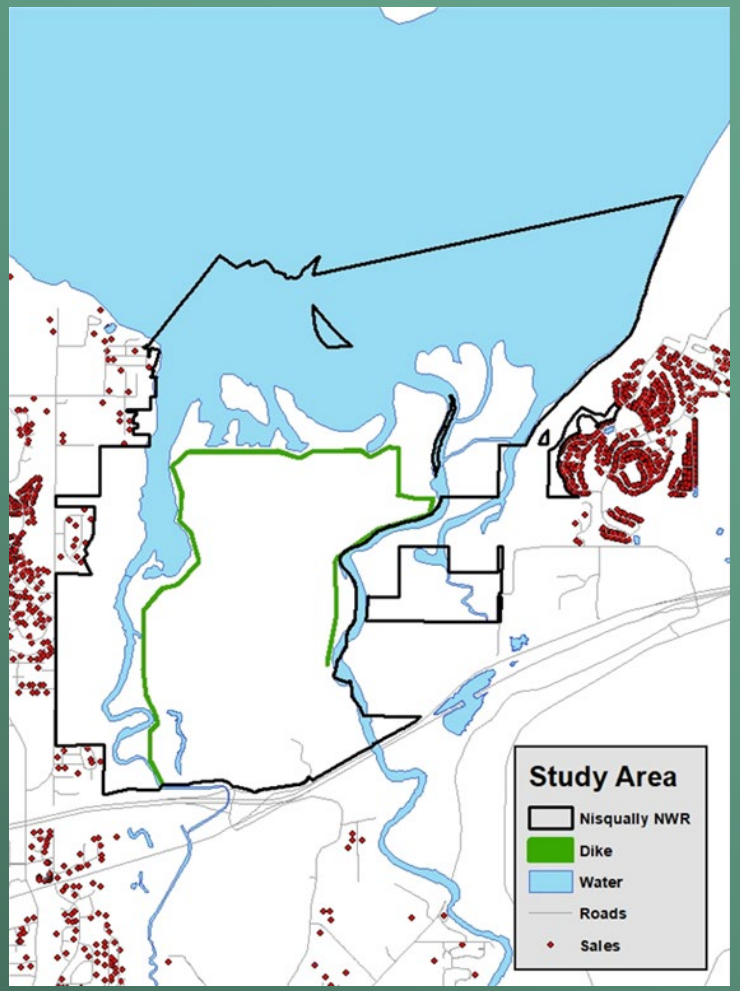
Estimating Benefits of Tidal Marsh Restoration

- Study in progress* - benefits of Brown Farm Dike removal
- Hedonic Price Model

$$\ln(P_{it}) = \alpha_0 + \sum \alpha_i S_{ji} + \sum \alpha_i E_{ki} + \sum \alpha_i N_{li} + \varepsilon_{it}$$

- P_i is the price of property *i at time t*
- S_{ji} is the *j*th structural attribute
- E_{ki} is the *k*th environmental amenity
- N_{li} is the *l*th neighborhood characteristics
- ε_{it} is the error term



*PI – Anthony Good, USGS SDC

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Valuing Salmon Habitat in the Nisqually River Delta

- Assess value of salmon habitat in Nisqually River delta under various sea level rise scenarios
- Development of a bioeconomics model in progress*
  - Integrates ecology, resource biology, and economics of fisher behavior

*PI – Anthony Good, USGS SDC

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Acknowledgements

- **This work represents multi-disciplinary, multi-agency partnerships. The following individuals provide substantial contributions to the projects:**

- **Great Dismal Swamp Project**
  - **Dianna Hogan,** Zhiliang Zhu, Brad Reed, John Schmerfeld, Sara Ward, Chris Lowie, Fred Wurster, Christine Pickens, Chuck Peoples, Brian van Eerden, Ken Krauss, Nicole Cormier, Rebecca Moss, Courtney Lee, Jamie Duberstein, Josh Salter, Laurel Gutenberg, Chris Wright, Judy Drexler, Gary Speiran, Todd Hawbaker, Zhong Lu, John Qu, Laurel Gutenberg, Bryan Parthum, Rachel Sleeter, Kim Angeli, and Gary Fisher

- **Ding Darling Project**
  - **Ken Krauss,** Nicole Cormier, Judith Drexler, Anthony Good, Dianna Hogan, Elitsa Peneva-Reed, Eric Bullock, Jeremy Conrad, Jamie Duberstein, Chandra Giri, Kurt Johnson

- **Nisqually Project**
  - **Kristin Byrd,** Travis Poitras, Monica Moritsch, Isa Woo, Melanie Davis, Susan De La Cruz, Lisamarie Windham-Myers, Judith Drexler, Ken Krauss, Frank Casey, and Anthony Good

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Associated Publications

- **Great Dismal Swamp:**
  - 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
  - See http://www.ss-pub.org/wp-content/uploads/2019/11/AEER2019080701.pdf for details on the portfolio of services

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