Photo Credit: FWS 2014

Carbon Balance Modeling for the Great Dismal Swamp Ecosystem

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A Community on Ecosystem Services

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Biological Sequestration (aka LandCarbon; Z. Zhu)

Objective: Conduct periodic assessments to understand the relative impact of the major controlling processes (e.g. land use, climate, fire, hydrology) on ecosystem carbon dynamics.

- Estimate carbon balance in relation to land management on public lands, to provide tradeoff analyses supporting increased carbon sequestration as one of many priority ecosystem services.

USGS

http://www2.usgs.gov/climate_landuse/land_carbon/default.asp

Great Dismal Swamp Project

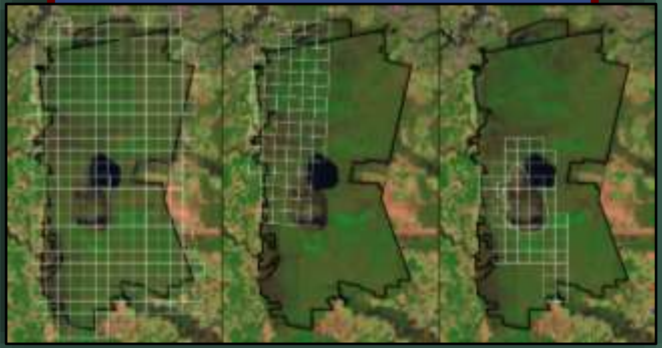
- Produce regional- and-local scale carbon estimates to understand how refuge management could potentially increase carbon storage

In Situ Measurements

- Hydrologic monitoring of groundwater and lateral flux of C
- Above Ground Biomass (AGB) Survey & Peat Depth (probes)
- Peat Cores (soil chemistry & age of peat)
- GHG Flux Chambers (CO_2 & CH_4)
- Rod Surface Elevation Tables RSET (soil subsidence)

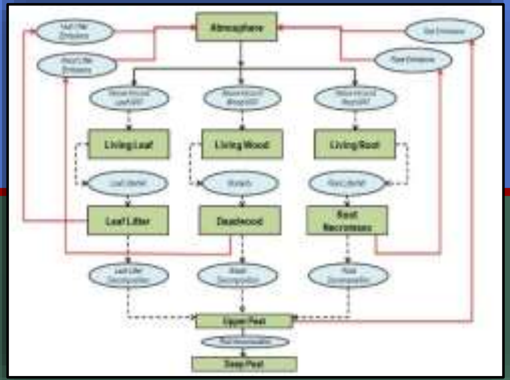
Remote Sensing & Spatial Data

- Airborne LiDAR field data
- Soil Moisture analysis using Radar
- AGB survey + LiDAR to create wall-to-wall Live Biomass Map
- Vegetation map of forest types
- Peat Depth Map
- Geo Spatial Data Library



Model Integration

- Scale-up *in situ* measurements for refuge-wide analysis
- Ecological conditions and management actions defined (spatial and probabilistic)
- Use Stakeholder Process
- Future scenarios modeled for Eco. Services Assessment
- Consistency with LandCarbon National Assessment



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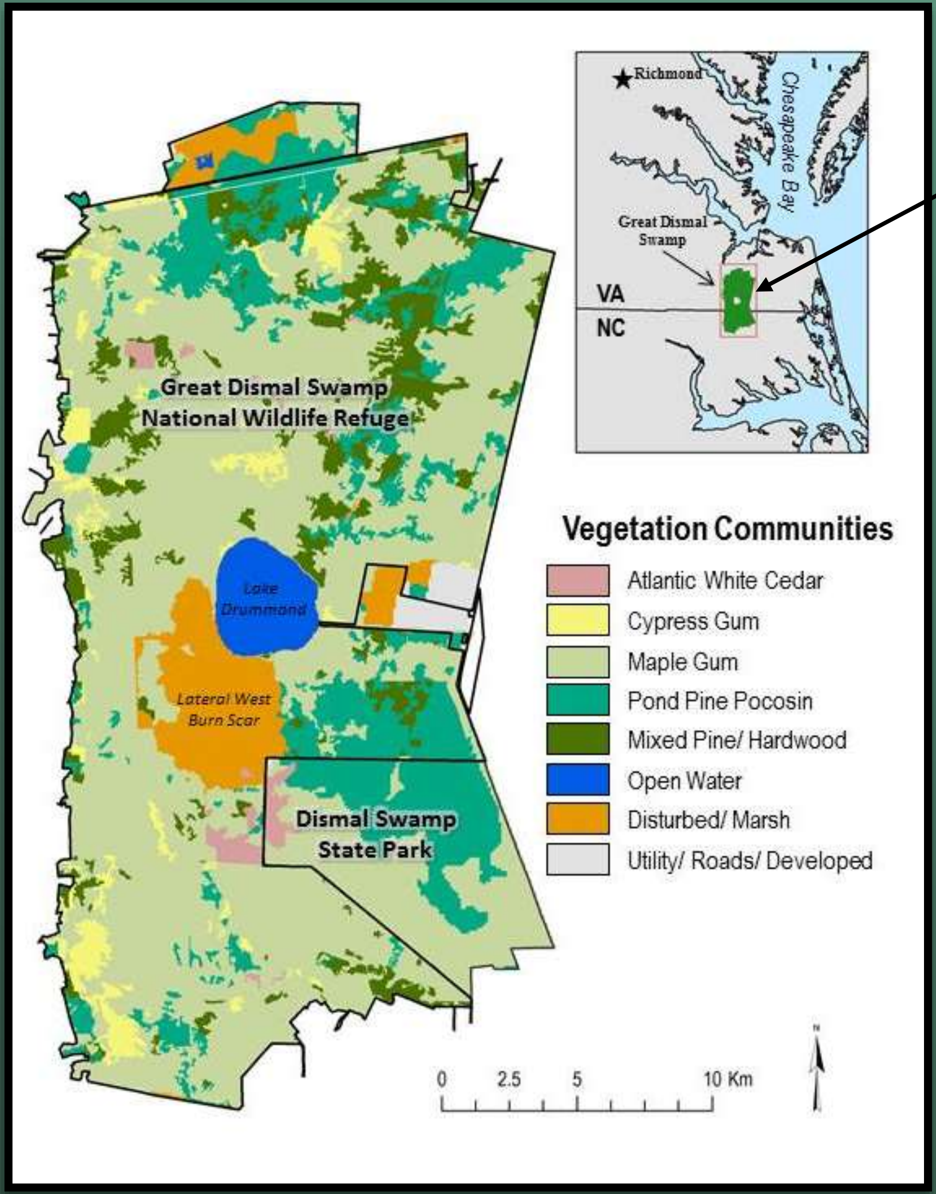
Great Dismal Swamp – Landscape and Geography

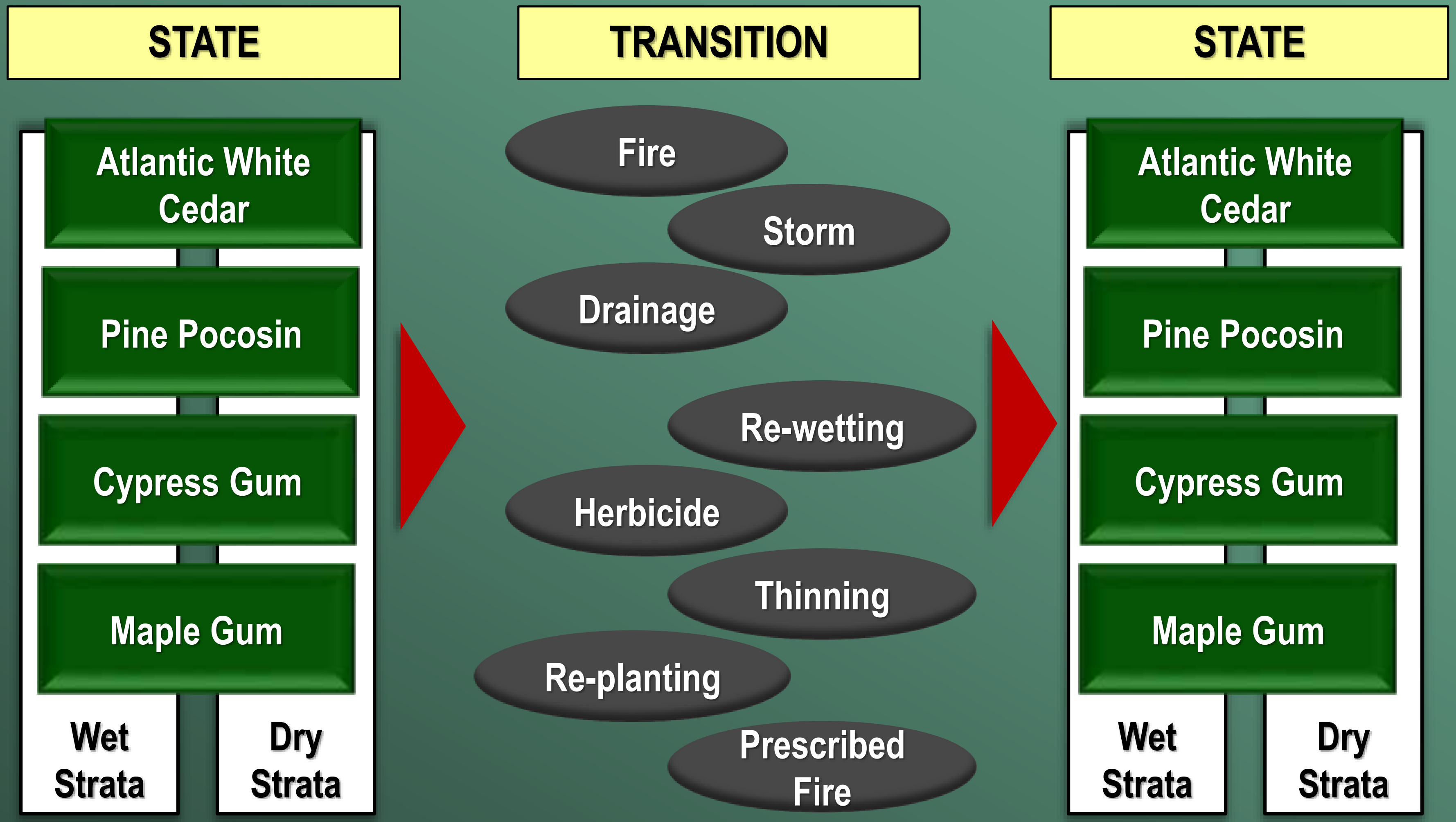


- Located southern VA/ northern NC
- 25 -30 km from coast
- 1763: George Washington began draining/logging - greatly altered hydrology and native vegetation
- Dismal Swamp Act of 1974 est. Great Dismal Swamp NWR
- > 45,000 ha (112,000 ac) of forested wetlands
- 240 km (150 mi) of ditches
- Forest Types of interest: Atlantic White Cedar, Pine Pocosin, Cypress Gum and Maple Gum

Ecosystem Departure and Dynamics

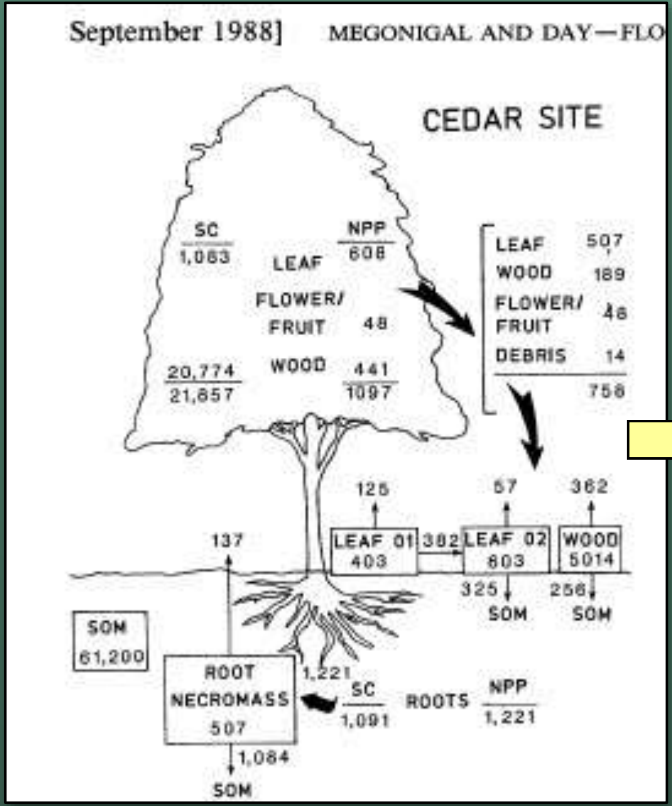
USGS

State-and-transition Model (ST-SIM)



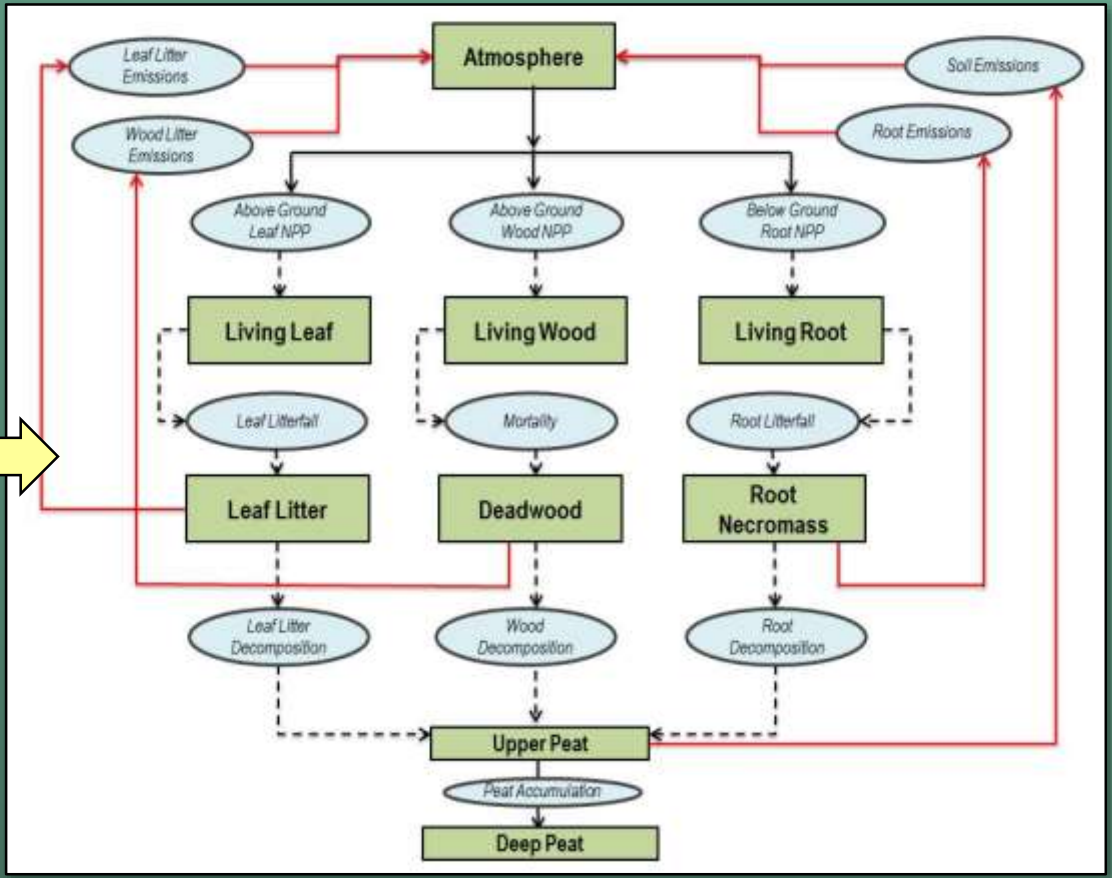
Carbon Stock-Flow Model Development

Literature Values



Megonigal & Day, (1988) Organic matter dynamics in four seasonally flooded forest communities of the dismal swamp. Amer J Bot.1988; 75(9): 1334-1343.

Stock-Flow Pathway Diagram



Carbon stock-flow model: 8 stock types and 14 flow/flux types are simulated annually, running in tandem, with the landscape ST-Sim model

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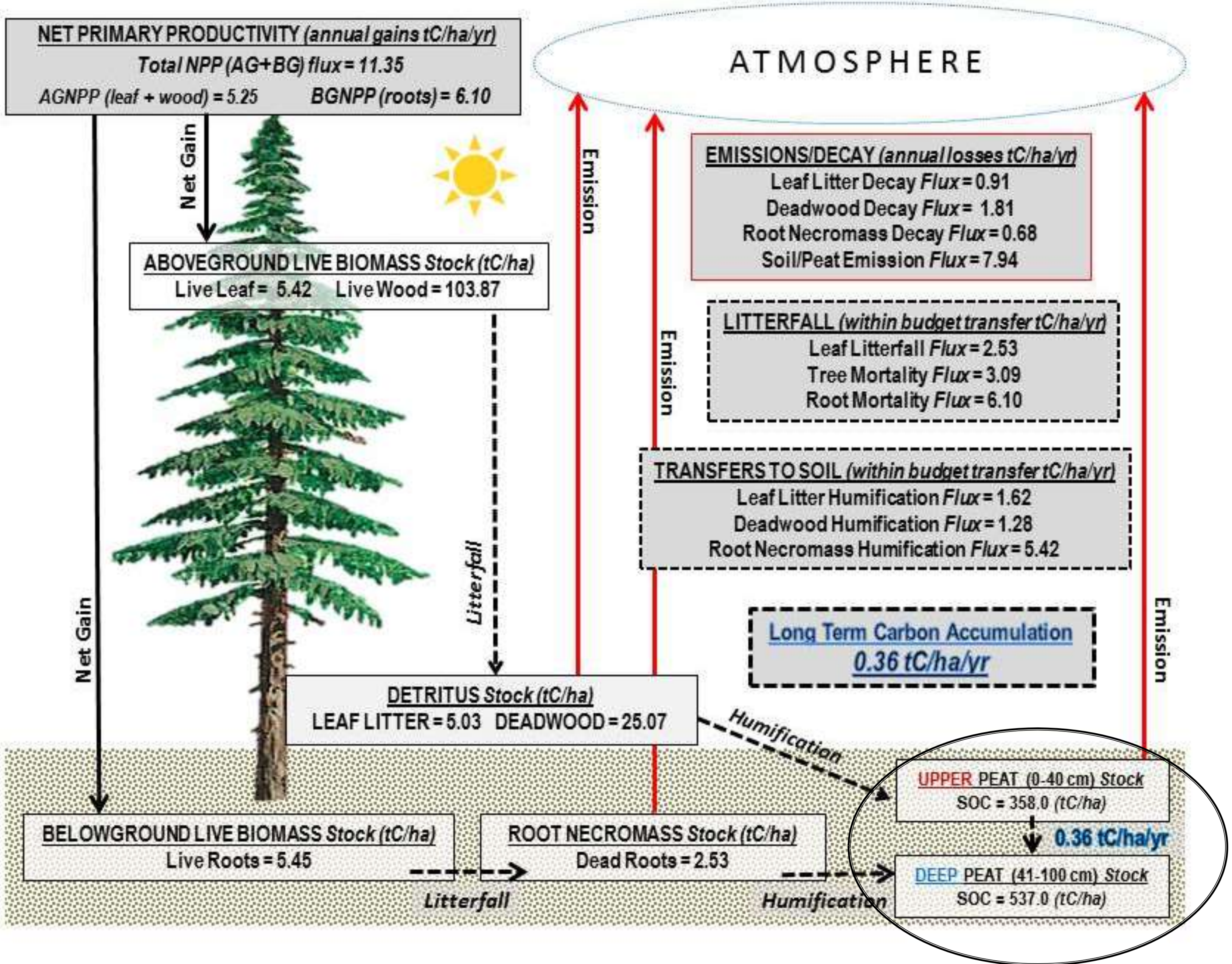
Data Correspondence: Literature and USGS 2014 Survey

GDS Average	Living Wood	Living Leaf	Living Root	Dead wood	Leaf Litter	Dead Roots	Soil/Peat (0-100 cm)	TOTALS	Totals W/O Soil
C Stocks Literature	122.7	3.8	4.5	20.4	4.6	2.1	**896.0	1054.0	158.0
C Stocks USGS	114.0	6.0	6.0	31.0	2.0	3.0	**896.0	1058.0	162.0

Values are in metric tons carbon per hectare (t C/ha)
Peat carbon is calculated refuge wide with the assumed depth of 100 cm

Carbon Budget for Atlantic White Cedar in the Great Dismal Swamp, VA.



LUCAS Model Testing
Historic Fire Simulation (1985-2015)

Repeat Disturbance for the Atlantic White Cedar

Hurricane Isabel (2003) – 1,500 (ha) blown down

- Largest pure stands remaining in the Atl. Coastal Plain
- GDS NWR began large Atl. White Cedar restoration project

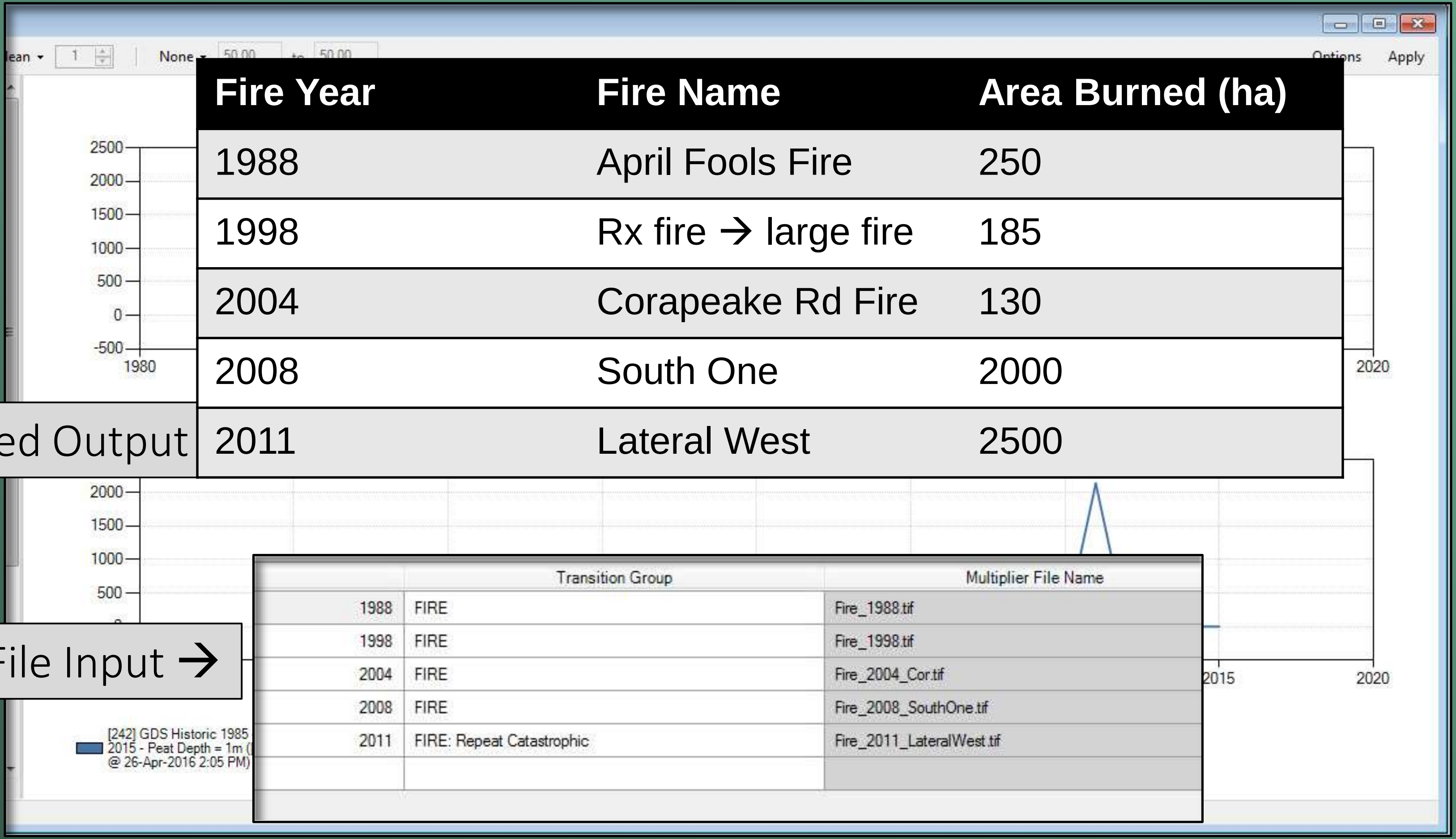
South One (2008) – 2,000 (ha) burned

- Fire burned for 121 days (drought conditions, dry soils)
- 350 ha Atl. White Cedar restoration lost
- Restoration efforts continued in 2010…

Lateral West (2011) – 2,500 (ha) burned

- High fuel loads from 2008, 111 days of burning
- 300,000 seedlings Atl. White Cedar restoration lost
- Deep peat burns with massive CO_2 emissions

Model Testing -Historic Fires (1985 – 2015)



Modeled Output

Fire Year	Fire Name	Area Burned (ha)
1988	April Fools Fire	250
1998	Rx fire → large fire	185
2004	Corapeake Rd Fire	130
2008	South One	2000
2011	Lateral West	2500

File Input →

	Transition Group	Multiplier File Name
1988	FIRE	Fire_1988.tif
1998	FIRE	Fire_1998.tif
2004	FIRE	Fire_2004_Cor.tif
2008	FIRE	Fire_2008_SouthOne.tif
2011	FIRE: Repeat Catastrophic	Fire_2011_LateralWest.tif

Major Findings from Historic Fire Simulation

- Net Ecosystem Production (NEP) for the GDS for the historic 30 year period (1985-2015) was estimated at an average annual rate of **0.64 t C/ha^{-1}/yr^{-1}** (64 g C/m^{2}/yr^{-1}) OR a net sink of 0.97 Tg C.
  - **Growth (14.73 Tg C) - Rh (13.76 Tg C) = 0.97 Tg C**

- When the six historic fire events were modeled during (1985-2015), including the South One and Lateral West, the GDS became a net source of 0.89 Tg C (NECB = - 0.89 Tg C)
  - **Growth (14.73 Tg C) – Rh (13.76 Tg C) – Management (0.01 Tg C) - Fire Emissions (1.86 Tg C) = - 0.89Tg C**
  - **Fire Emissions = South One (0.66 Tg C) + Lateral West (1.04 Tg C) + Other (0.16 Tg C)**

- Cumulative above and belowground C loss estimated from the South One and Lateral West fire events totaled **1.70 Tg C**. The C loss in belowground biomass alone totaled **1.38 Tg C**, with the balance (**0.31 Tg C**) coming from above-ground biomass.

Comparison to recent USGS published work

Results Comparison	South One Fire (2008)		Lateral West Fire (2011)			Cumulative	
	Hawbaker (2016)	**LUCAS Historic**	Hawbaker (2016)	Reddy (2015)	**LUCAS Historic**	Hawbaker (2016)	**LUCAS Historic**
Below-ground carbon loss (Tg)	0.38	**0.42**	1.09	N/A	**0.95**	1.47	**1.38**
Above-ground carbon loss (Tg)	0.22	**0.23**	0.14	N/A	**0.09**	0.36	**0.31**
Deadwood removal: Carbon loss from Management (Tg)	N/A	**0.01**	N/A	N/A	**0.00**	N/A	**0.01**
Total carbon loss (Tg)	0.60	**0.66**	1.23	1.10	**1.04**	1.83	**1.70**
Soil elevation loss (m)	0.17	**0.20**	0.46	0.47	**0.50**	0.63	**0.70**

Reddy A, et al. (2015) Quantifying soil carbon loss and uncertainty from a peatland wildfire using multi-temporal LiDAR. Remote Sensing of Environment, 170: 306-316.

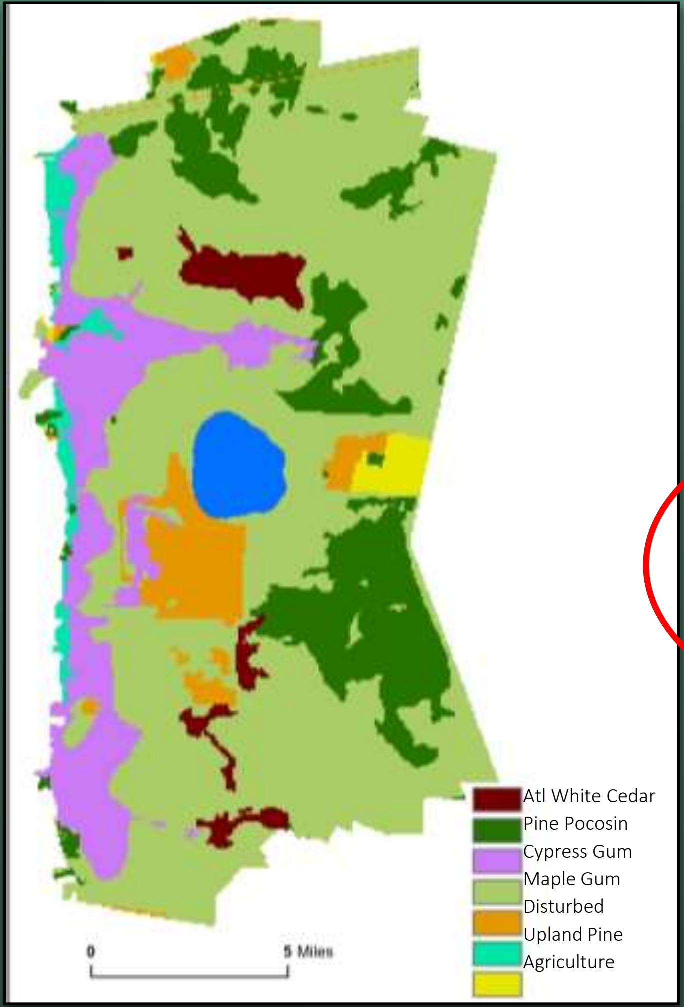
Hawbaker T, et al. (2016) Quantifying above and belowground carbon loss following wildfire in peatlands using repeated lidar measurements, Proceedings: 15th International Peat Congress, 2016, Malaysia

Priority Ecosystem Services and Evaluation Methods

Ecosystem Service	Methodology	
	Biophysical	Economic
Carbon Sequestration	• Plot data on biomass scaled up to GDS NWR via ST-SIM • Converted to carbon biomass using literature values • Will be improved with carbon values from monitoring as available	• Interagency Working Group on Social Cost of Carbon (SCC) applied to INCREMENTAL CO_2 emissions (tons per year) • 2014 value is $42.55 (adjusted using BLS info)
Wildlife Viewing	• Using visitation rates provided by GDS NWR (2014) • Assuming all “non-consumptive” visitation	• Valuation based on consumer surplus or “willingness to pay” above actual costs incurred • Using FWS survey (2006) data
Fire Mitigation	• Only considers “catastrophic fire” • Determined by annual probability of fire and effects of catastrophic fire • Effects considered: air quality/human health impacts, carbon emissions, recreation lost, and tourism lost	• Human health impacts value based on Cost of Illness • Carbon emissions - SCC • Recreation lost due to full or partial closures during event • Tourism lost in communities considered qualitatively

Scenario Example: Extreme Fire Event

2015 ← **50 YEARS** → **2065**



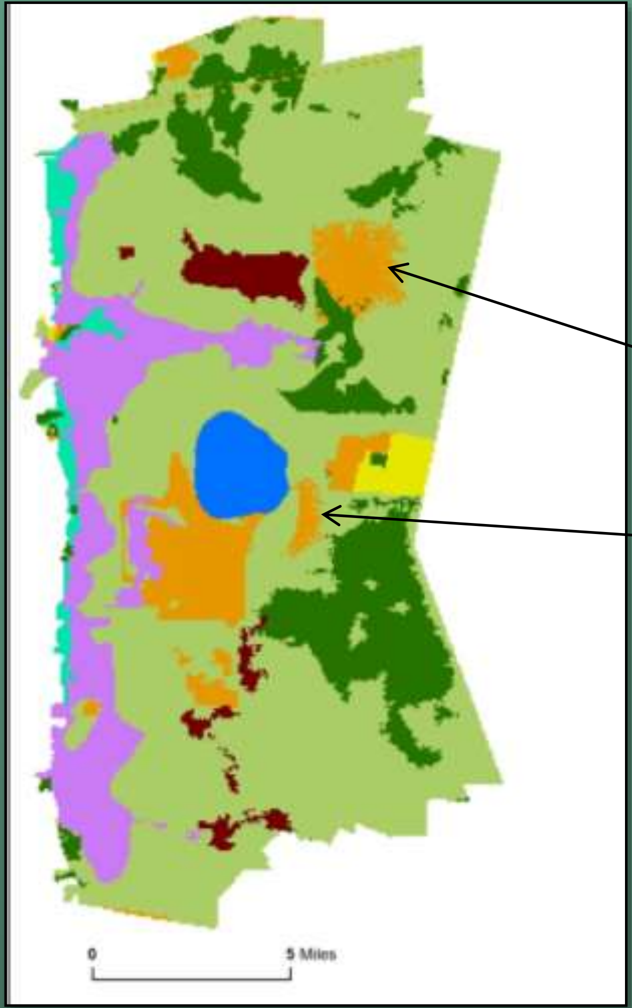
SCENARIO ASSUMPTIONS:

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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Next Steps

- Model integration of *in situ* field data as it becomes available
- Build the ecosystem services scenarios into model parameters
- Run the LUCAS model iteratively (50-100 Monte Carlo iterations per year) in order to measure model uncertainty
- Present the scenarios with tradeoff analysis to the stakeholders in Fall 2017

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Emily Pindilli, Bryan Parthum	• Economics analysis, model development
Rachel Sleeter	• ST-SIM model development
Kim Angeli, Gary Fisher	• Remote sensing

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Questions?

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