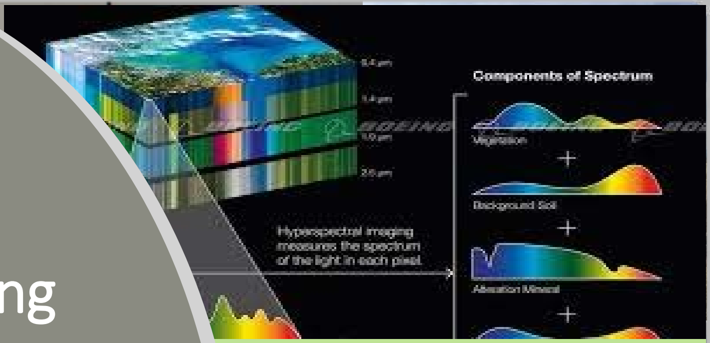


Dune Vegetation and Evolution Modeling for EWN: Linking Remote Sensing to Habitat Change and Ecological Process

Safra Altman, Todd Swannack, Molly Reif

Environmental Laboratory

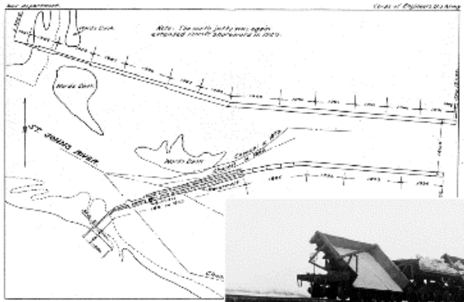
Jim Westervelt

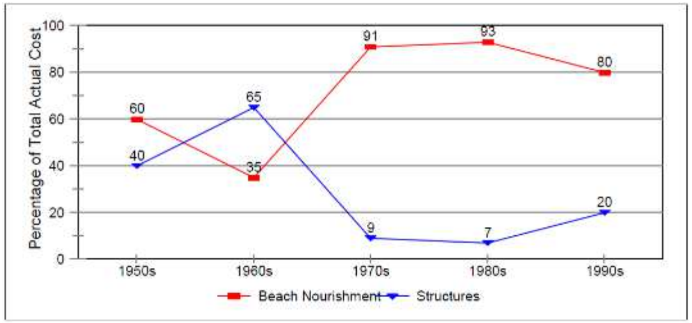
Construction Engineer Research Laboratory

Coastal defense: USACE perspective

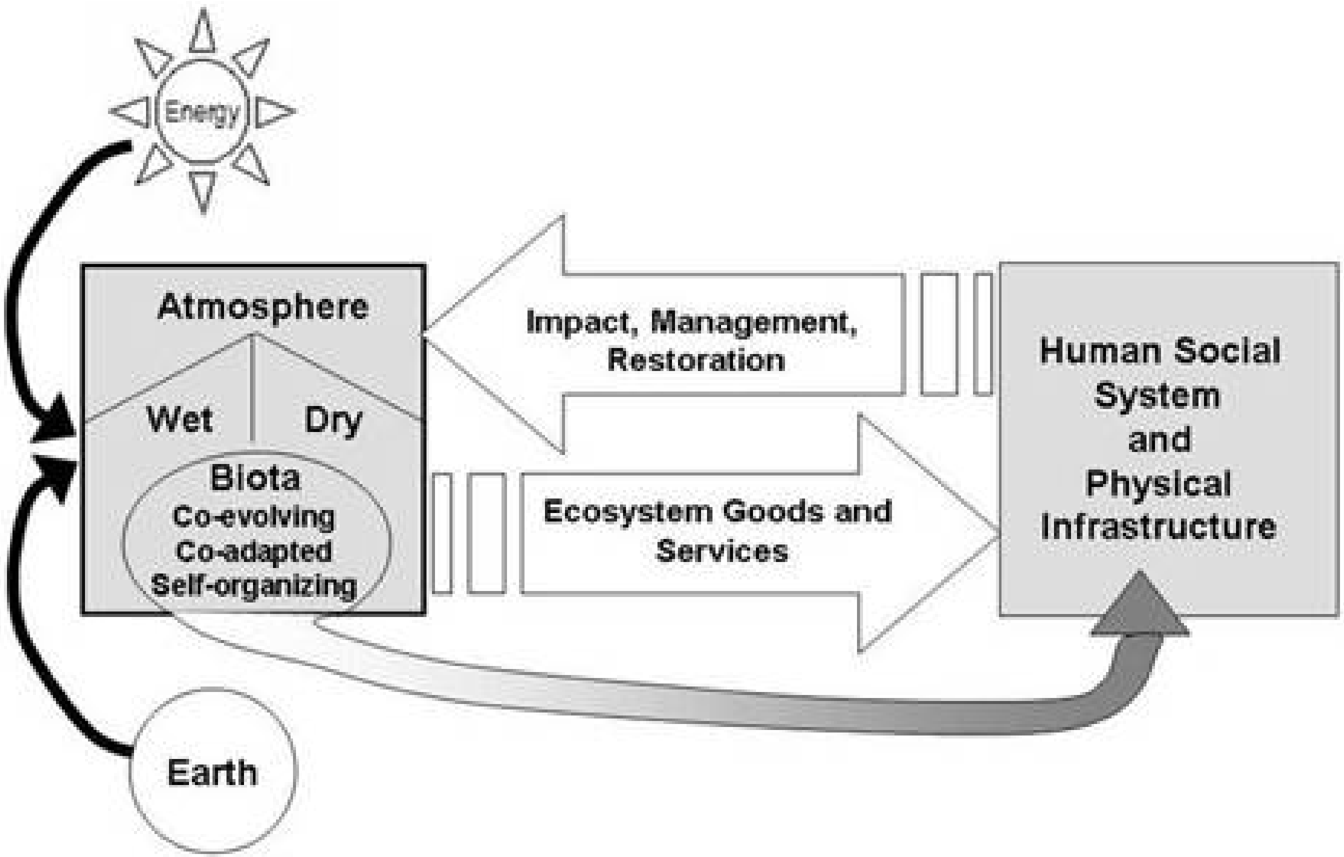
- 1824 – First Corps of Engineers coastal project: Long Beach in Plymouth, MA
- 1878 – Captain James B. Eads developed converging jetty design for St. Johns River, Jacksonville, FL
- Early to mid-20th century – Coastal development and structures proliferate (breakwaters, groynes, jetties, seawalls, dikes)
- Mid to late 20th century – shift to beach nourishment and artificial dunes
- Early 21st century – shifting away from traditional engineering approach towards a systems approach

"…triangular frames of timber filled in with stones, around and over which the sand gathers and forms a new brest. In other places large bodies of brush are laid, which have produced the desired effect, accumulating sand into cliffs and helping the growth of beach grass." –Howard P. Barnes 1958





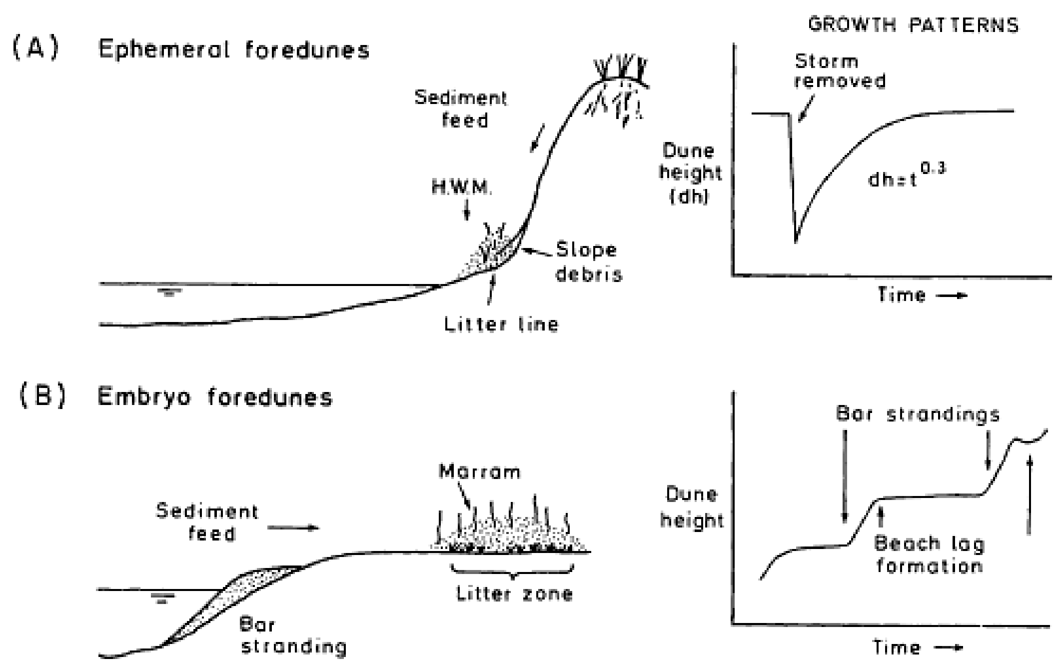
Ecological Modeling for Landscape Change Analysis



Miller et al 2010

Dune Development

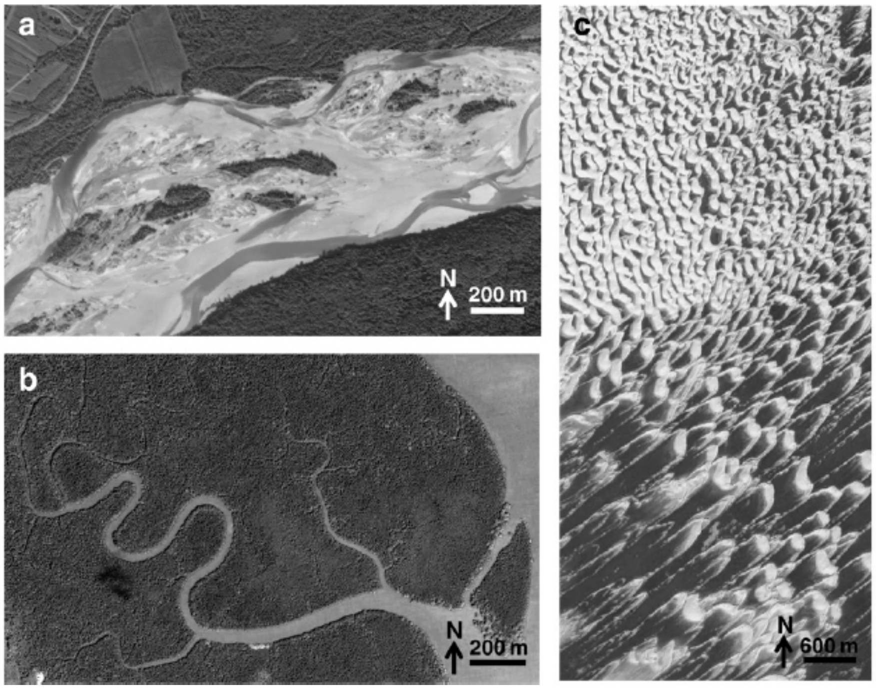
- **Sediment** - type and supply
  Wind field – wind presence above sediment entrainment threshold
  Vegetation - provide initial stabilization, growth
- Vertical and horizontal dune growth relies on interaction of these 3 factors
- Local controls
  - Topography
  - Wave climate
  - Tidal range, tidal litter
  - Sea level
- Limiting factor
  - Nitrogen



Vertical surface accumulation patterns in ephemeral and embryonic foredunes. Carter, 2013.

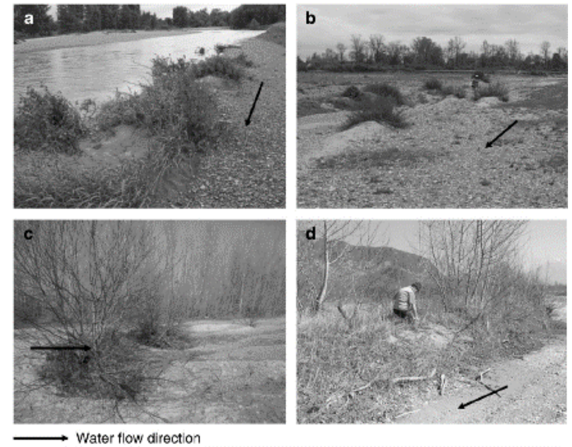
Vegetation shapes landscapes in dynamic environments

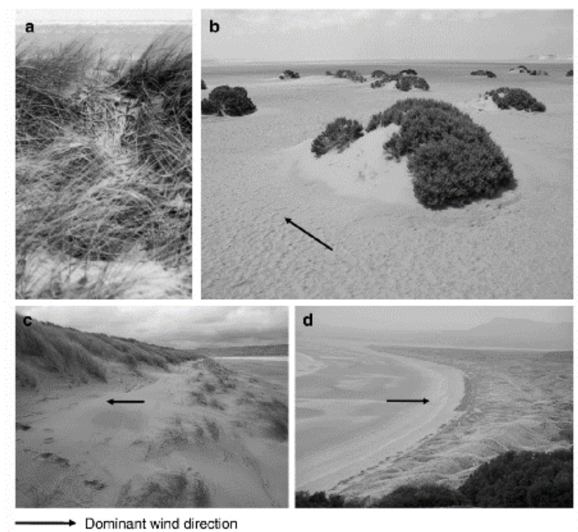
Islands



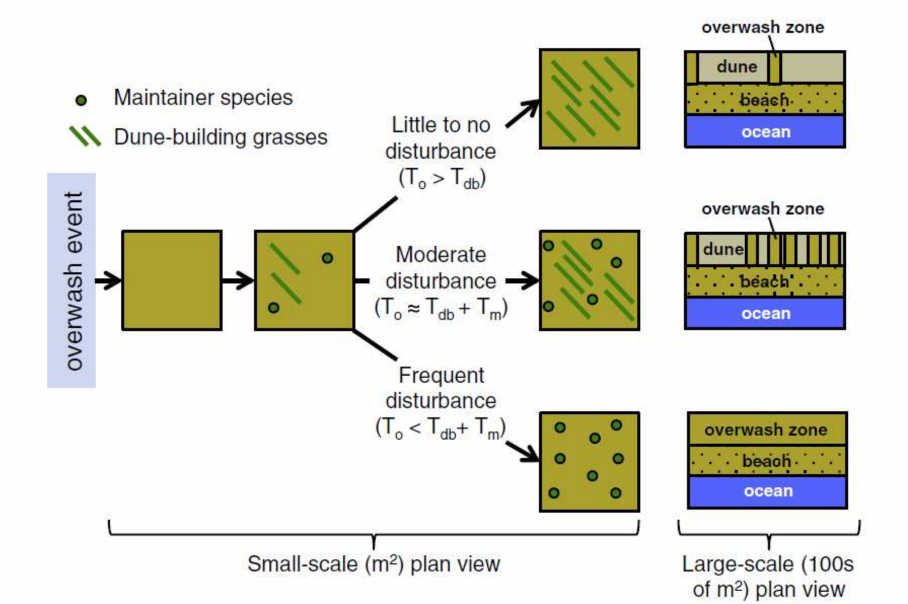
River networks

Desert dunes





Role of vegetation in dune storm response and recovery



Wolner et al., 2013

- Vegetation & storms
  - Dune erodibility
    - Root reinforcement of dunes
    - Mycorrizhal fungi
    - Organic matter
    - Surface protection
  - Wave attenuation
- Vegetation & dune recovery
  - Trapping wind-blown sand particles

Ecological Modeling for Landscape Change Analysis

How do we link landscape pattern to process?

How do we optimize planning and designing EWN features with respect to ecological processes?

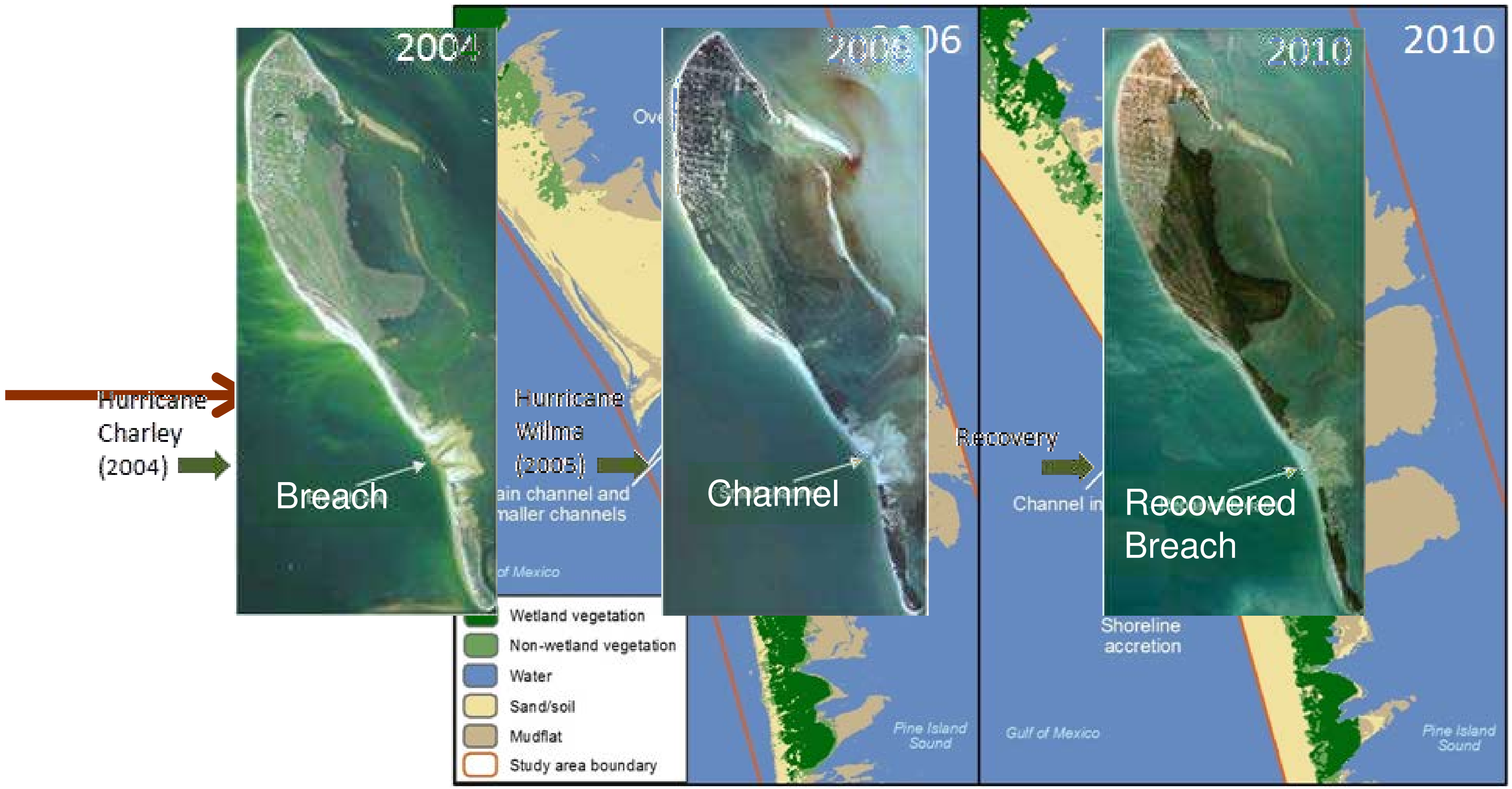
Goals:

Synthesize remote sensing imagery, landscape analyses, and ecological simulation

- factors that influence landscape change
- model how landscape structure will change as a result of project activity
- model how ecological processes will change

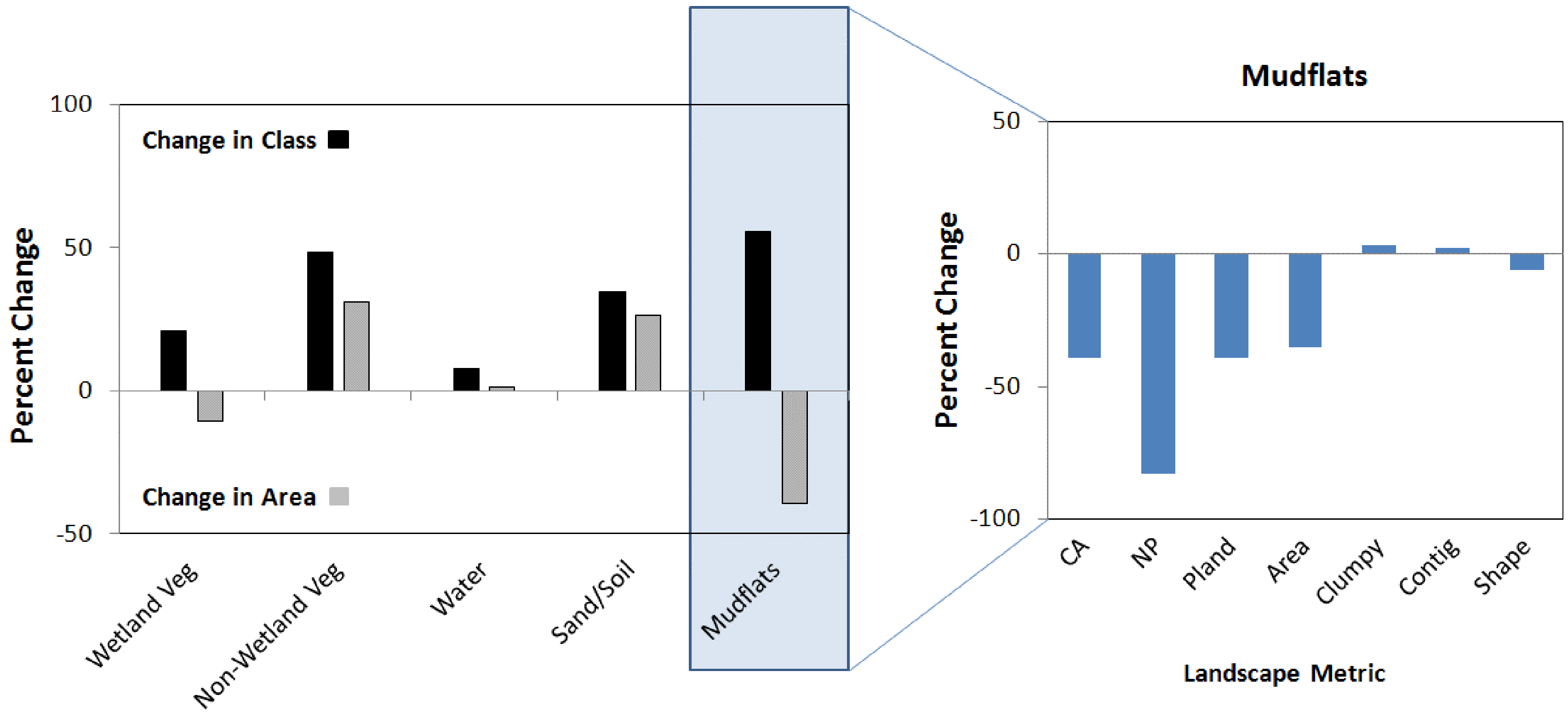
Ecological Modeling for Landscape Change Analysis

1) Identify changes to habitat
   - multi-temporal imagery
   - Light Detection and Ranging (Lidar) data



Ecological Modeling for Landscape Change Analysis

2) Derive landscape metrics associated with landscape patterns



Ecological Modeling for Landscape Change Analysis

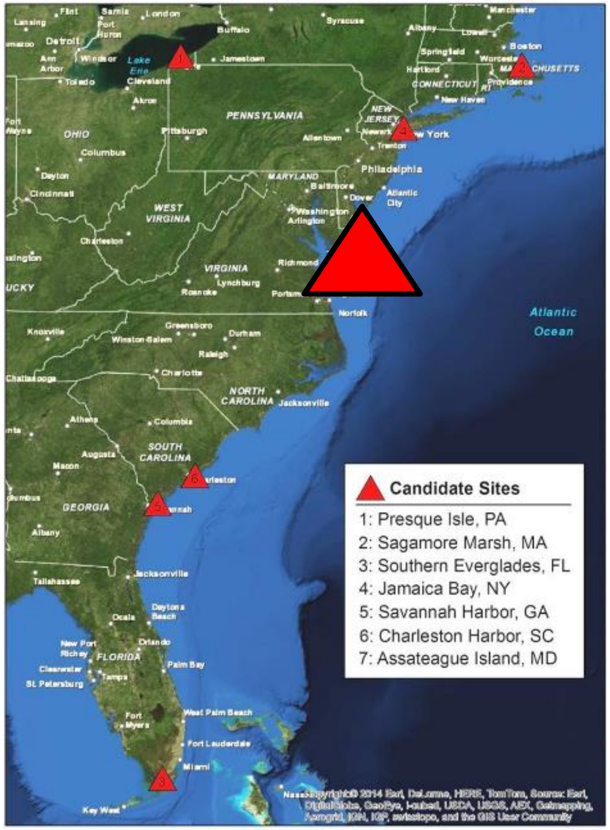
3) Integrate with ecological simulation
- Better understand factors influencing change
- Assess project level impacts & benefits

Change in Landscape Pattern

Change in Ecosystem Function

Metric	Process	Benefit
Clumpiness	Biodiversity	↑↓
Cohesion	Connectivity	↓↑

Site Selection

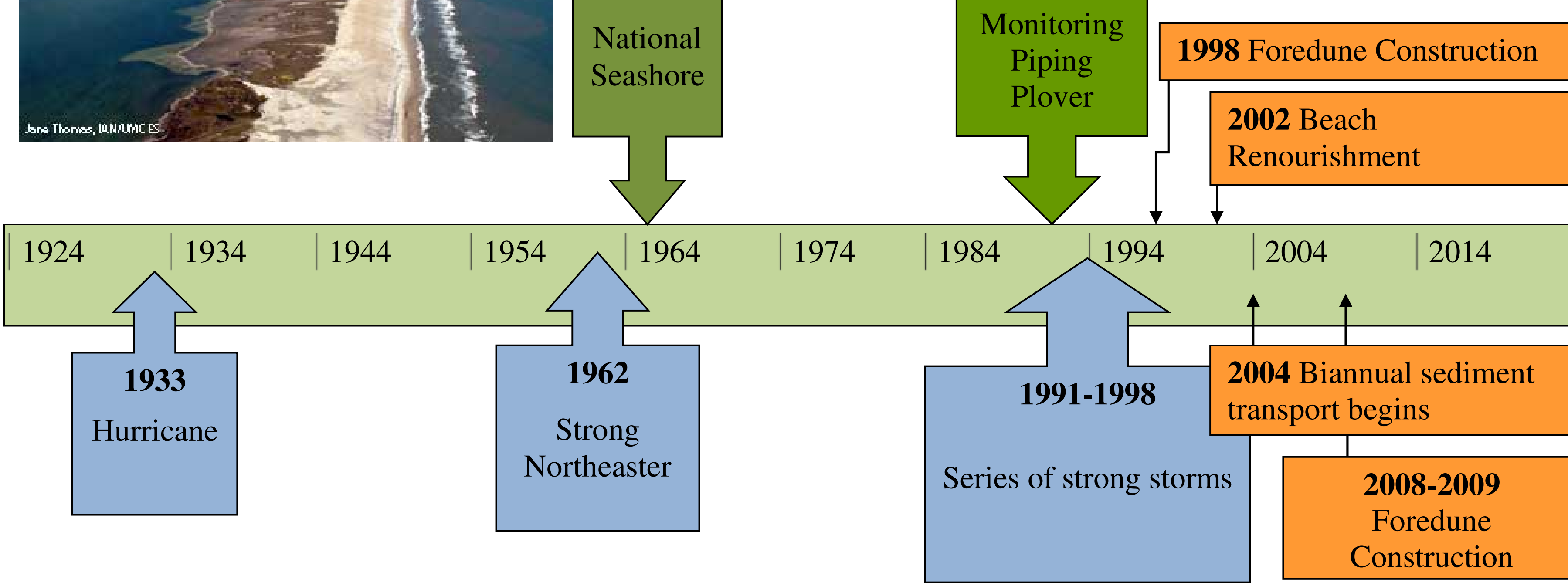


Criteria:

- *Coastal and dynamic*
- *O&M*
- *Ecosystem restoration*
- *Long project history*
- *Landscape changes*
- *Typical coastal project*

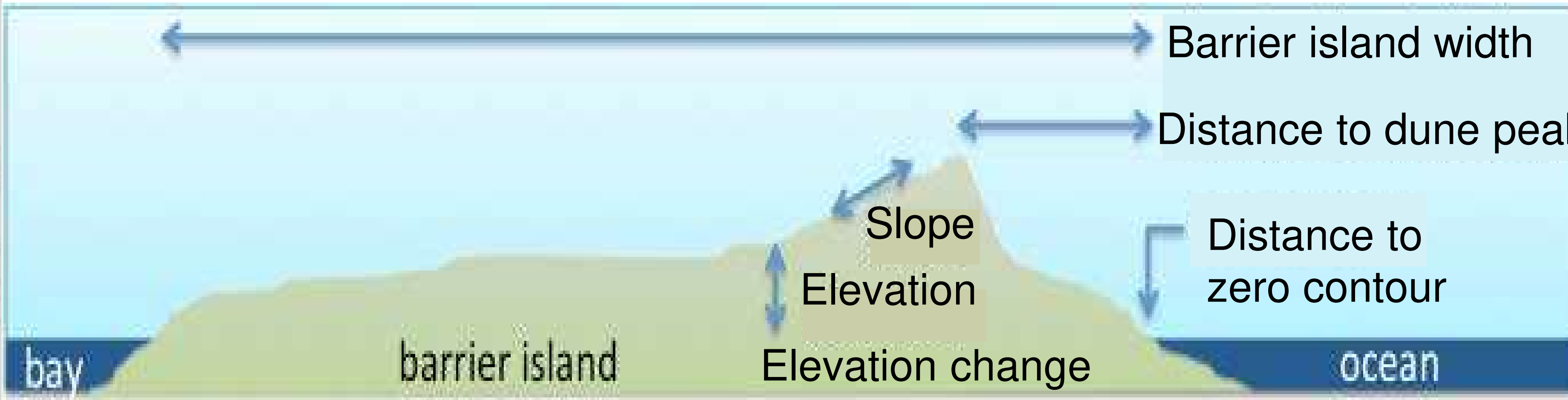
- Site: Assateague Island, MD
- Rich data and historical evaluation
- Time series of lidar data
- Habitat classification by the U.S. National Park Service

Site History
Assateague Island



Metrics Development

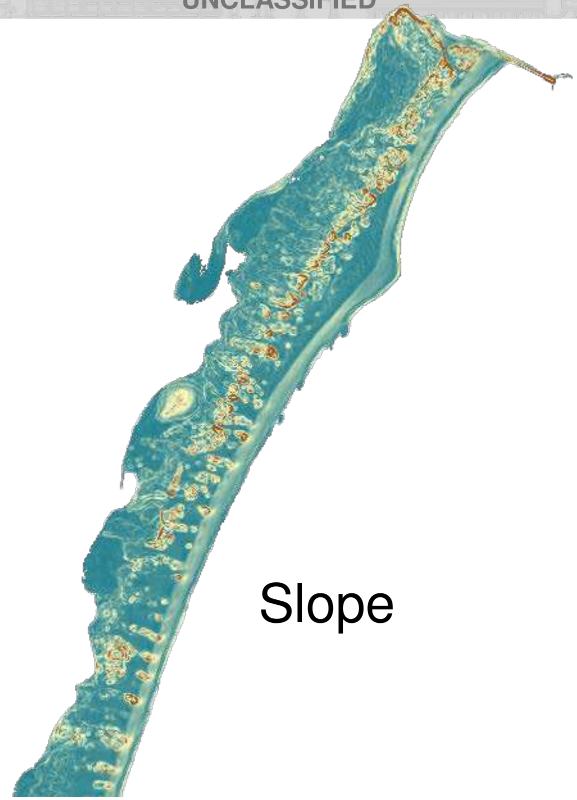
- Metrics identified from literature reviews
- Developed from lidar data (2000 - 2012) collected by the U.S. Geological Survey, NASA and The USACE National Coastal Mapping Program
- Focused on 6 metrics



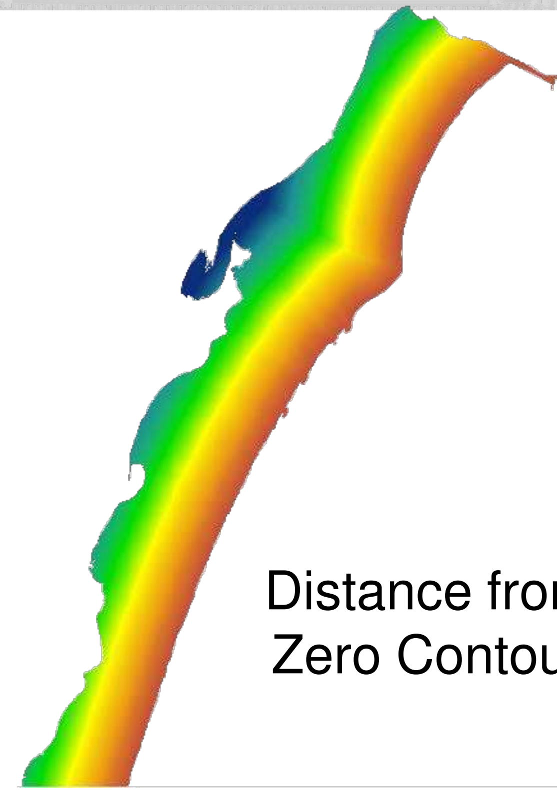
Distance to ocean	O	I	I	I	I		I
		Lucas and Carter, 2013 (would need further adjustment); Geider et al 2014; Tissier et al 2013					
Distance to sound	O	I	I		I		
		Geider et al 2014					
distance to dune crest	O	I	I				
		Geider et al 2014					
distance to dune toe	O	I	I				
		Grafals-Soto 2012; Geider et al 2014					
beach width	O						
zero contour to dune to	O						
dune field volume	O	I	I				
		Preistas and Fagherazzi 2010, implied					

Metrics Analysis

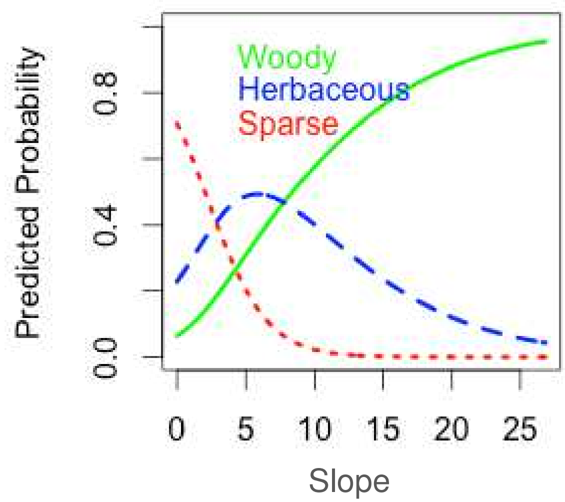
- Predicted probability of vegetation type determined using multinomial logistic regression
- Influence of interactions between metrics investigated
- Relationships incorporated into spatial model

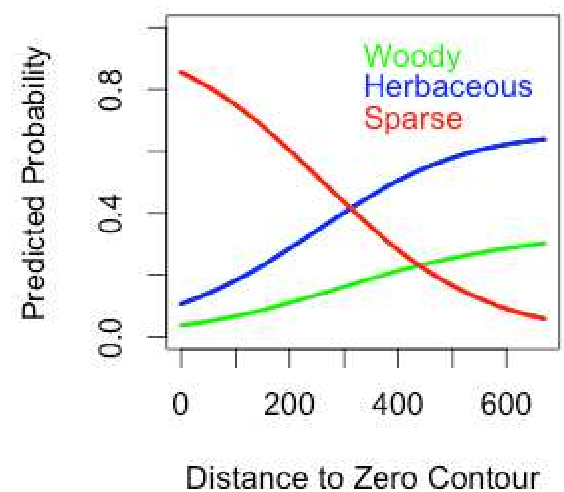


Slope



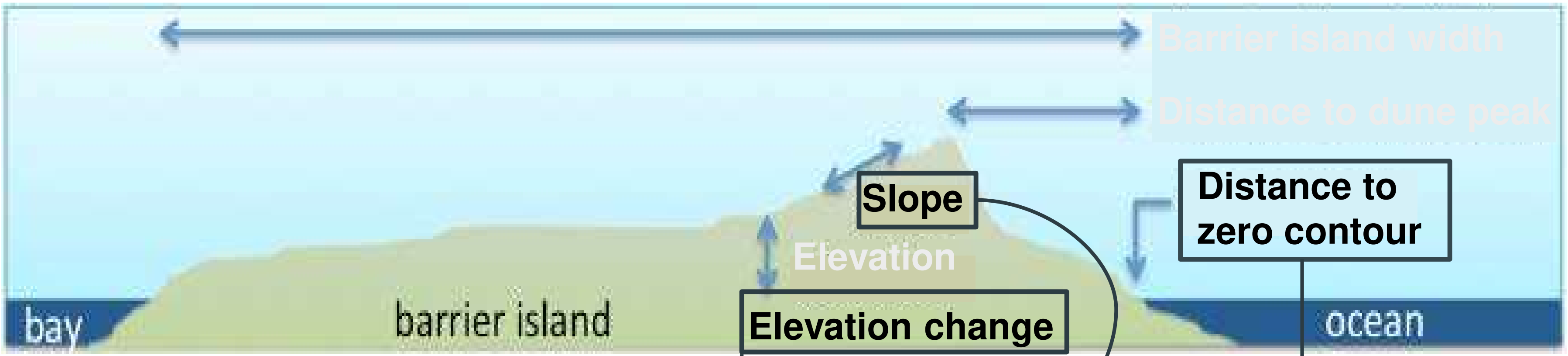
Distance from Zero Contour





.

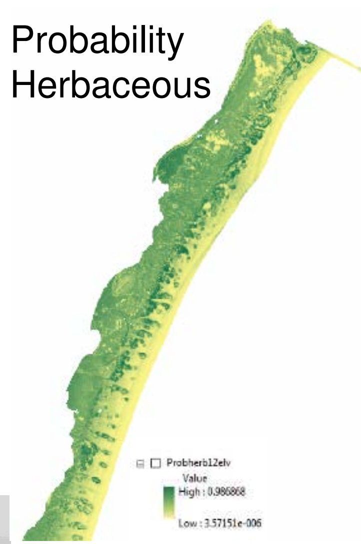
Probabilities

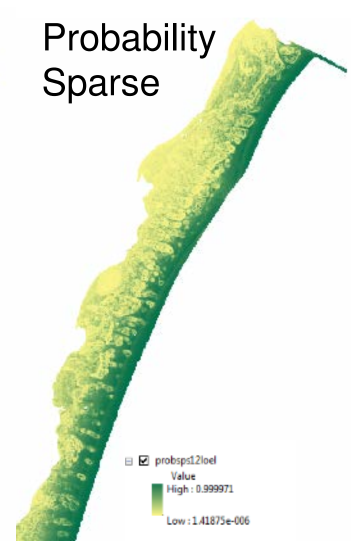


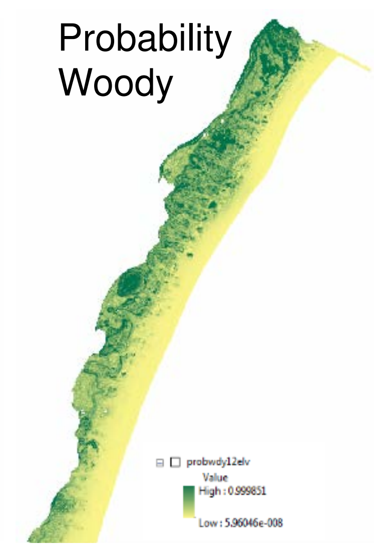
$$
\mathrm{L}_{\text{herbaceous}} = \ln\left(\frac{p(herbaceous_{2012})}{p(woody_{2012})}\right)
$$
$$
= -6.07 + 1.59(elevation\ change) + 8.26\left(slope^{\frac{1}{3}}\right) + 1.13\left(dist.\ zero\ contour^{\frac{1}{3}}\right)
$$
$$
+ 1.39\left(slope^{\frac{1}{3}} * dist.zero\ contour^{\frac{1}{3}}\right)
$$

Probability(herbaceous)=

$$
\frac{e^{L_{herbaceous}}}{1 + e^{L_{herbaceous}} + e^{L_{sparse}}}
$$

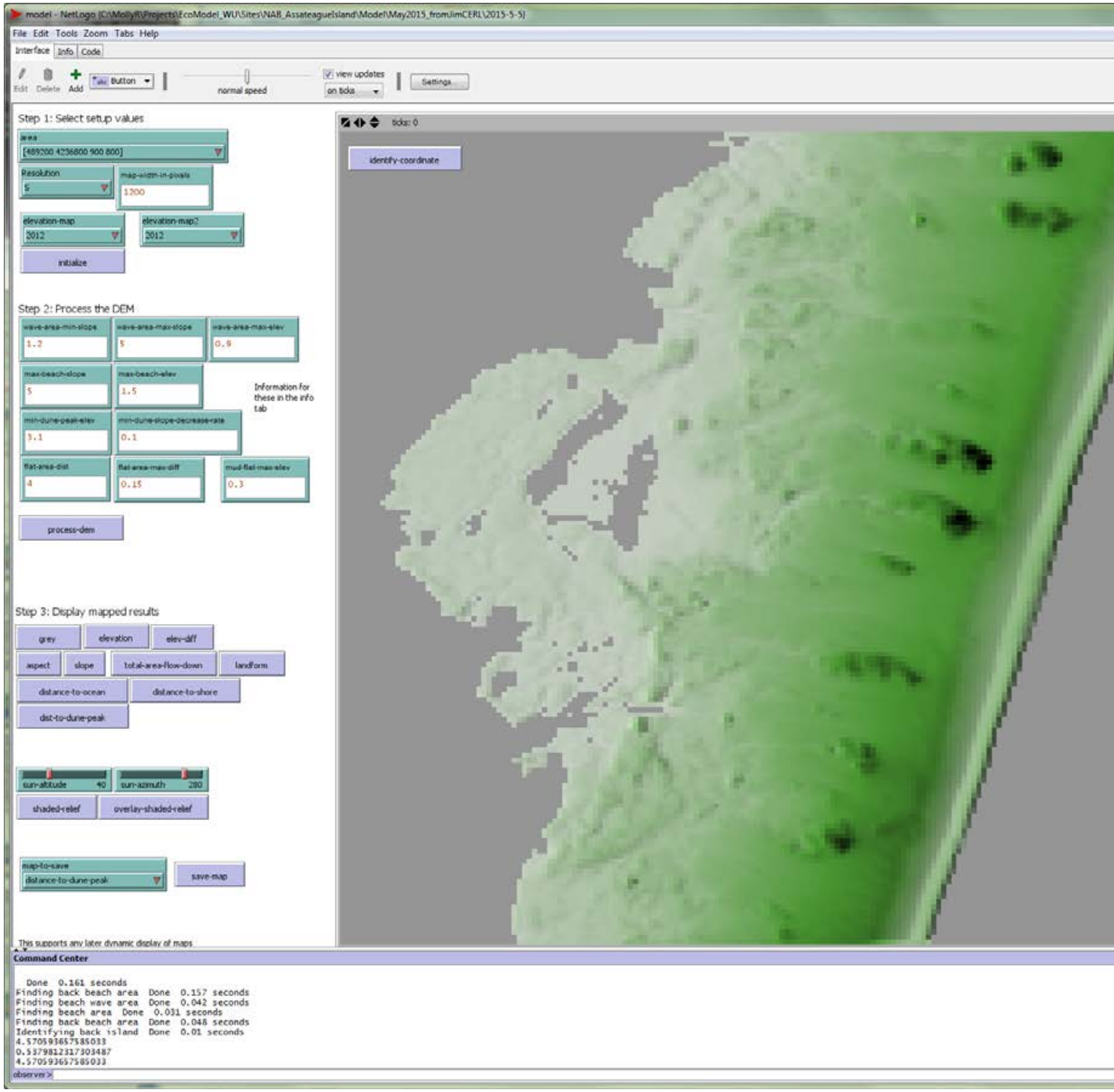


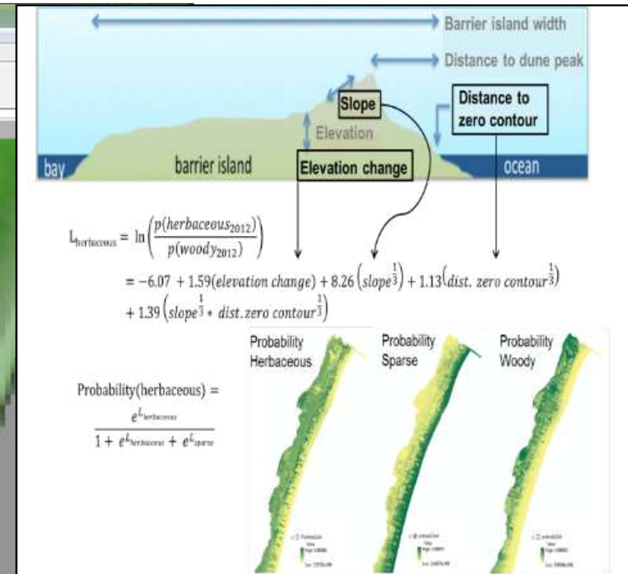




.

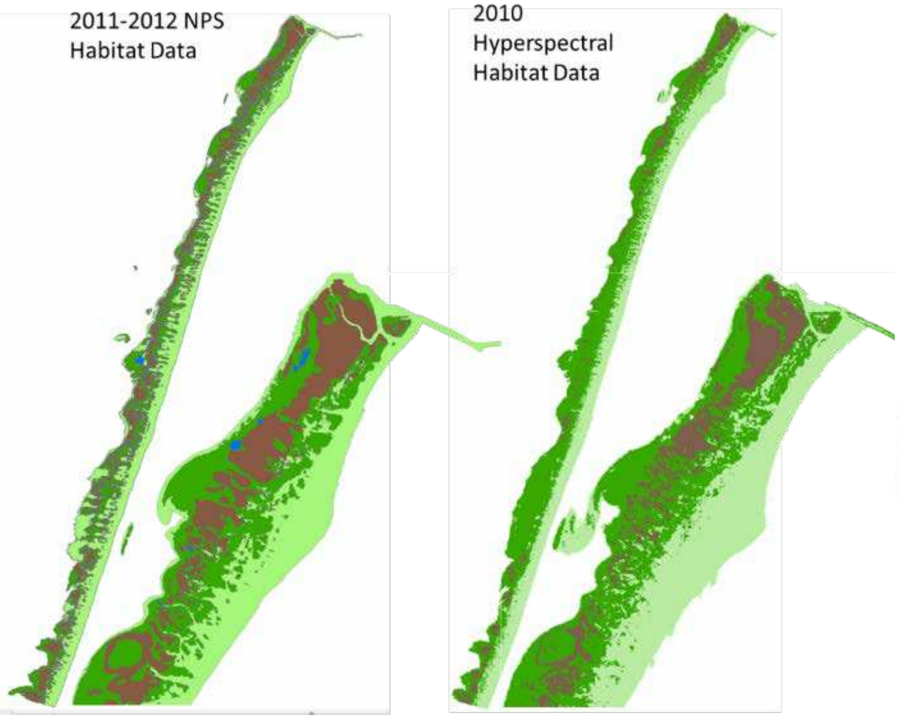
Model Evolution

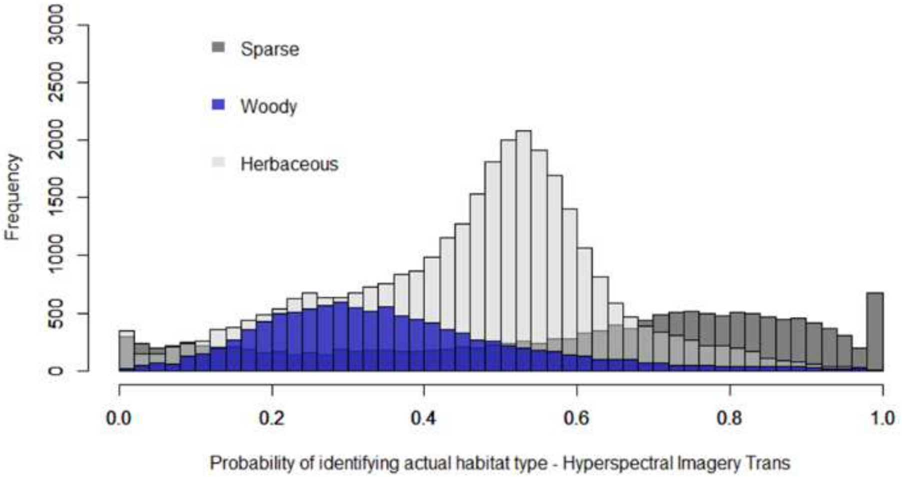




Validation Analysis

- Created additional Hyperspectral dataset to classify habitat types
- Compared habitat probabilities across years and across data type
- Standard statistical and sensitivity analysis

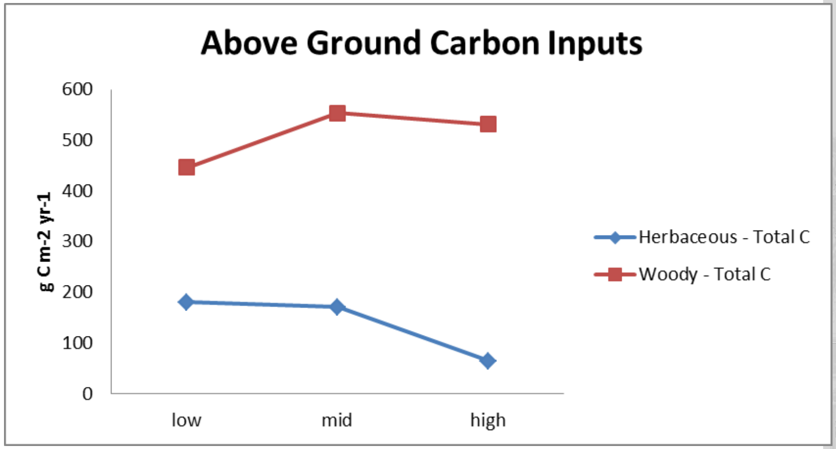


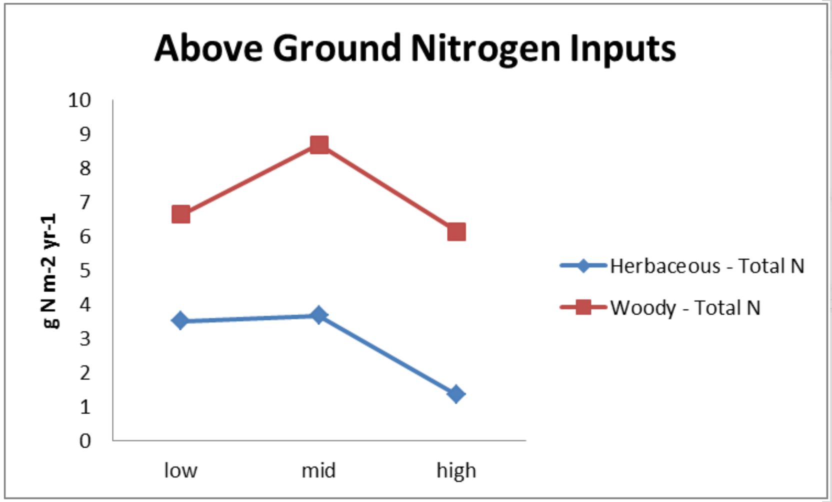


Incorporating Ecological Processes

- Site specific analysis of pedogensis and hydromorphology (Rossi, 2015)
- Estimates Carbon and Nitrogen sequestration based on habitat and elevation

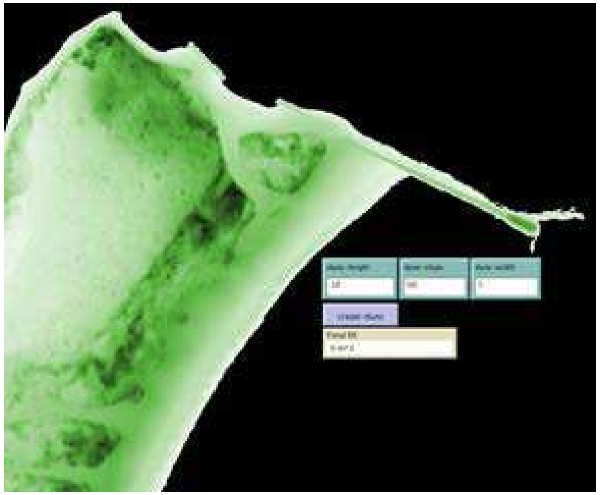
Vegetation	Elevation	elevation range (m)	mean total_C *	SE Total C	mean total_N **	SE Total N
herb	low	0.29-0.66	181.040	15.738	3.524	0.327
herb	mid	0.67 - 1.04	171.248	30.666	3.675	0.716
herb	high	1.05-1.41	65.278	11.965	1.357	0.271
herb	Island Avg	Average - use for above 1.41	112.000	14.000		
woody	low	-0.02 to 0.38	447.289	56.091	6.650	0.927
woody	mid	0.39 -0.79	553.900	87.969	8.698	1.592
woody	high	0.8-1.2	531.967	41.882	6.140	0.758
woody	Island Avg	Average - use for above 1.2	497.000	43.000		

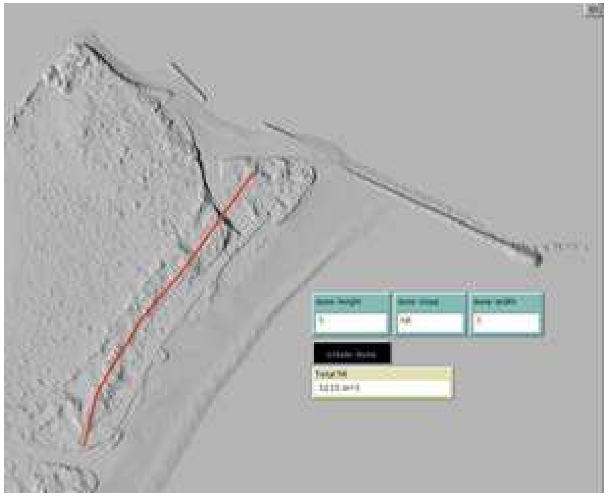


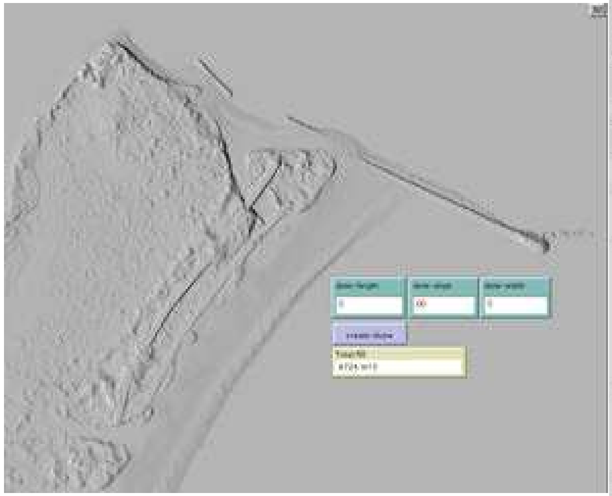


Feature tool

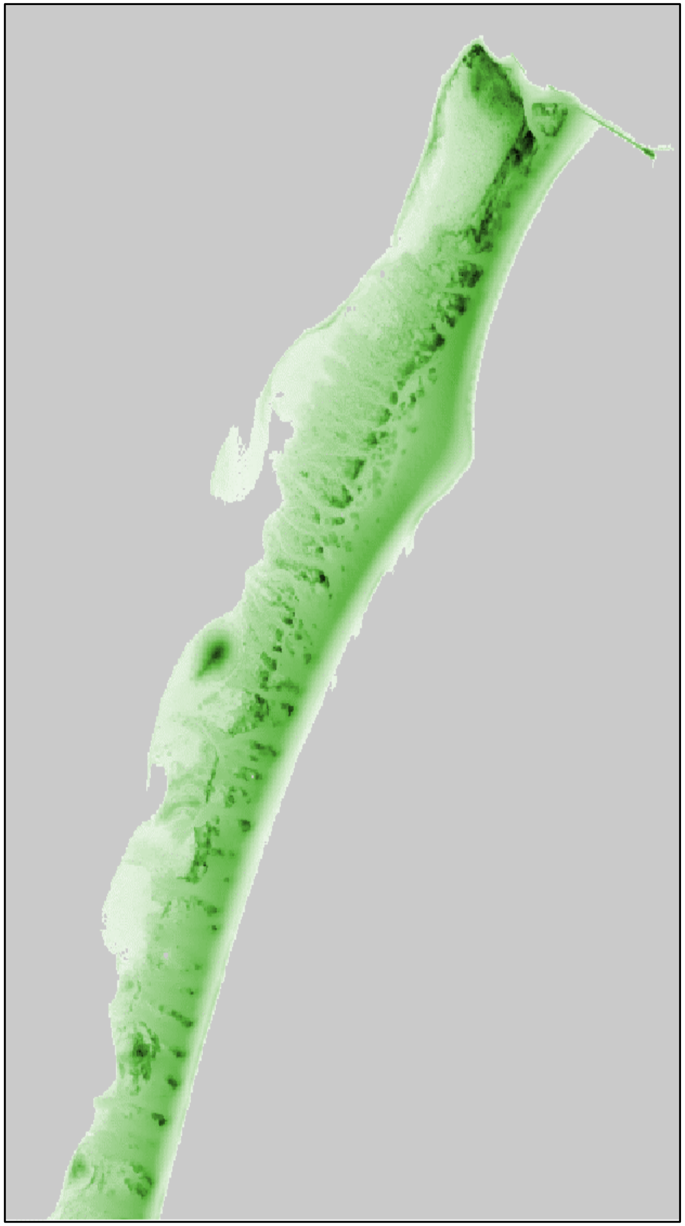
- User controlled
  - Height, Slope, Width
  - Location and Length
- Creates feature and new Digital Elevation Model

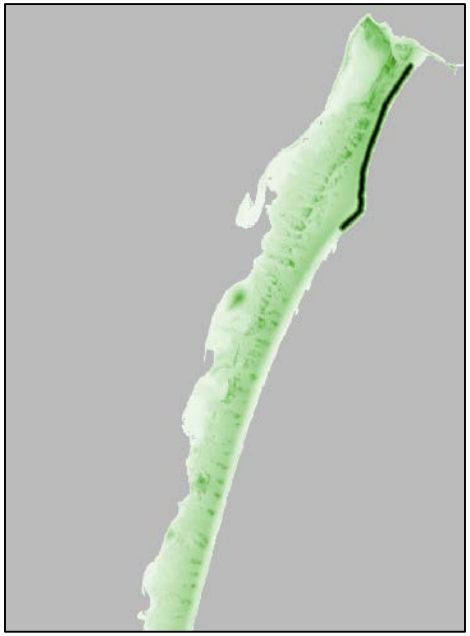




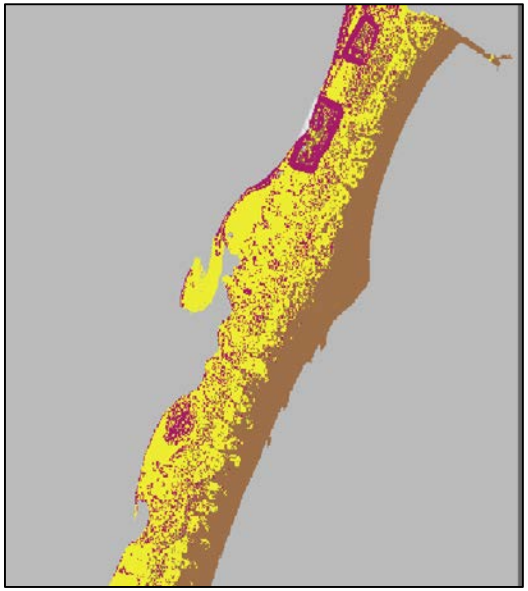


- Updates landscape parameter values, vegetation probabilities, and C and N storage in project footprint



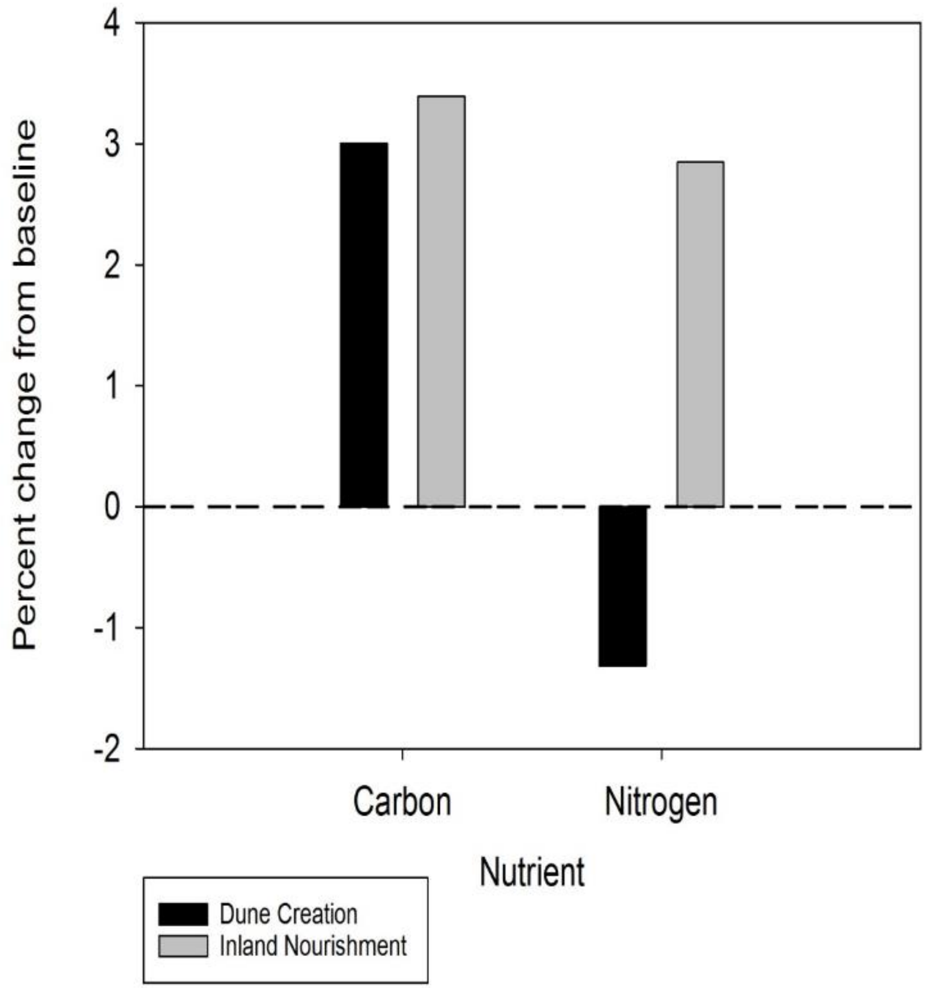


Creating Feature



Creating Vegetation

Nutrient sequestration as result of EWN feature on landscape



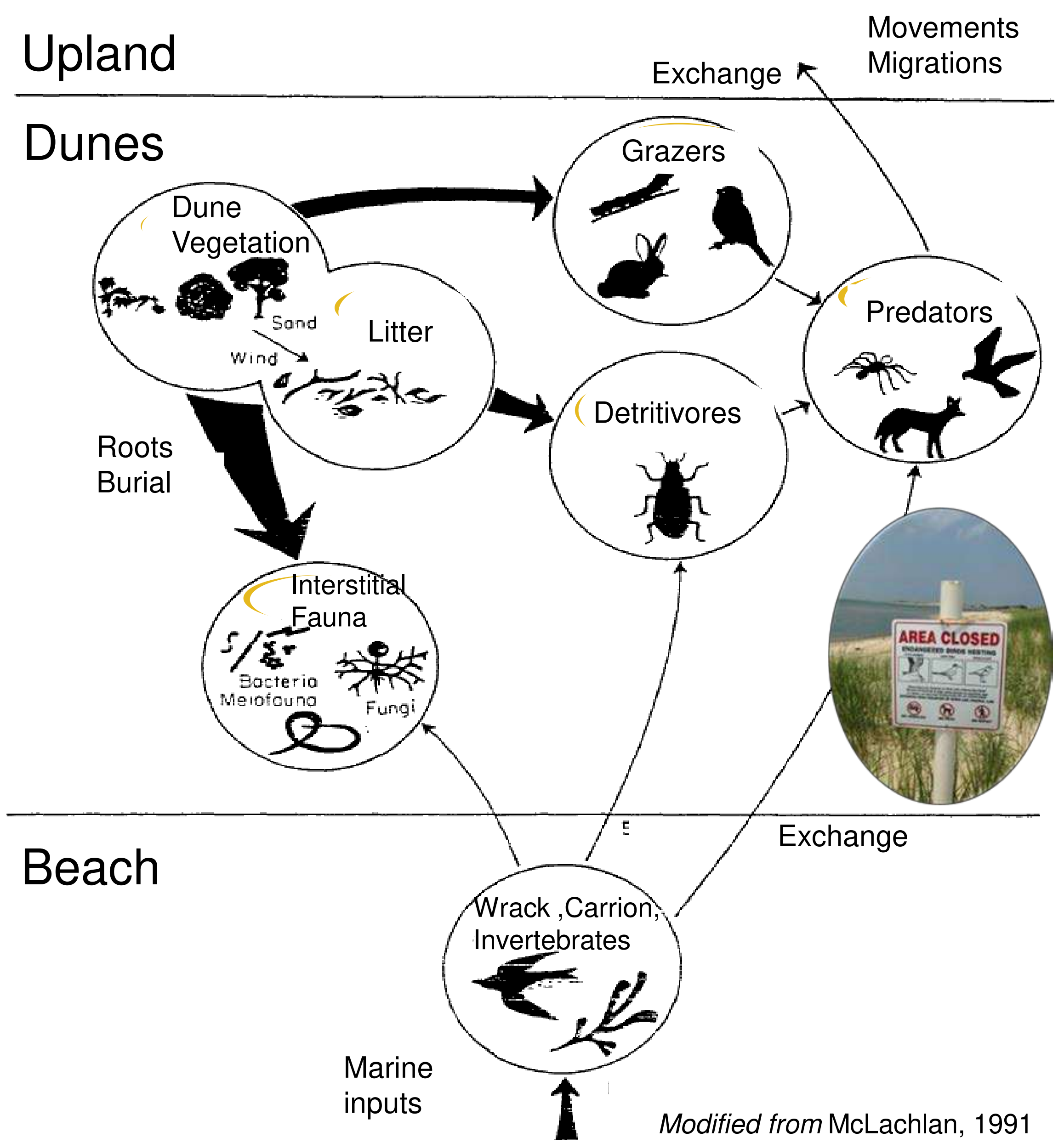
Value to EWN in Dune Systems

- Evaluate potential impacts of project activities to increase environmental benefit
- Evaluate alternative project designs and describe benefits/impacts outside of habitat unit creation
- Evaluate landscapes for better understanding of ecological impacts

Considerations and Research Needs

Food web dynamics

- Vegetation and early succession
- Importance of belowground biomass and microbial community
- High diversity and endemism
- Connectivity between habitats
- Significance of marine inputs
- Nesting grounds



Modified from McLachlan, 1991

Acknowledgements

Tosin Sekoni, US Army Environmental Laboratory

Eric Gulledge, Jackson State University

USACE Baltimore District

U.S. National Parks Service

NAVSYS
Navigation Systems Research Program

Questions??

Barry Long, 2012