ERDC
Engineer Research and Development Center

# Process-Driven Ecological Modeling for Landscape Change Analysis

## RSM-EWN 2015 IPR

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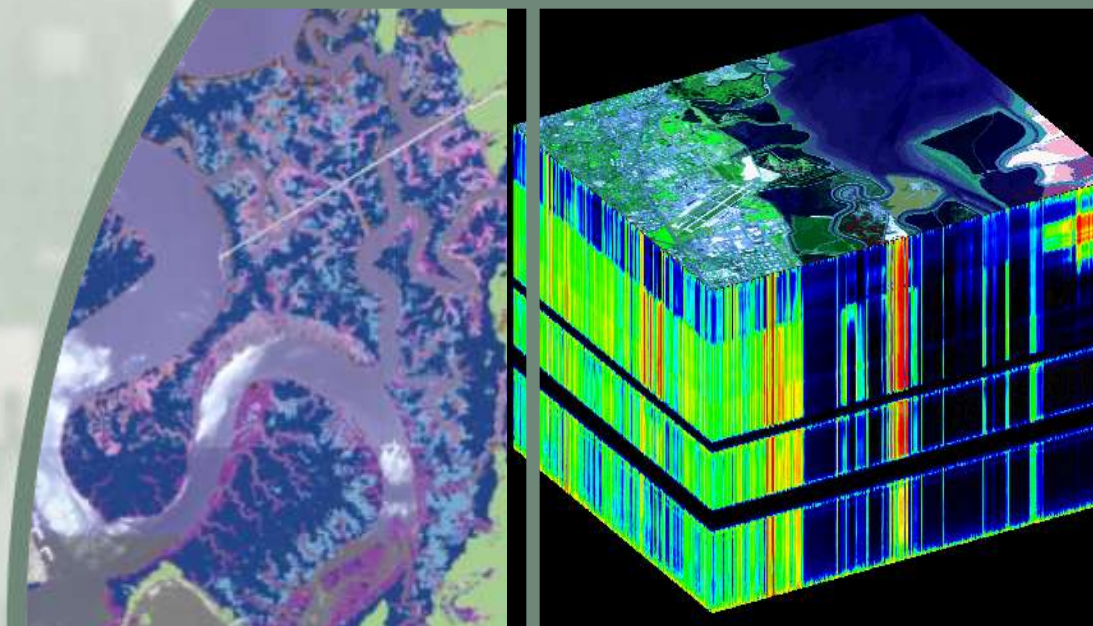
Research Geographer

Environmental Lab

20 August 2015



US Army Corps of Engineers®

NAVSYS
Navigation Systems Research Program

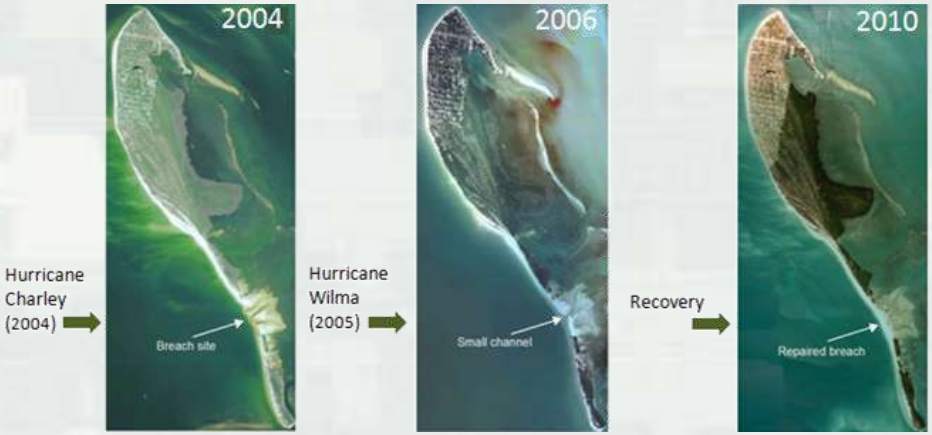
- **Tool:** Landscape Change Analysis Model

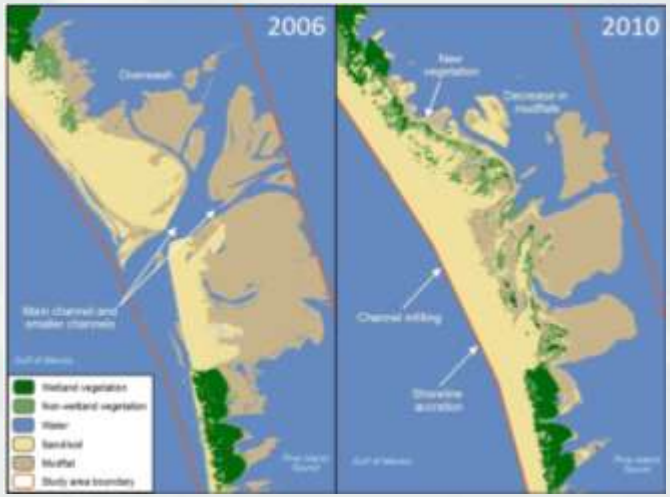
- **PIs:** Molly Reif, Todd Swannack and Safra Altman (EL)

- **GOAL:** To synthesize state-of-the-art remote sensing imagery, landscape analyses, and ecological simulation to develop not only a better understanding of the factors that influence landscape change, but also, a model that can be used to determine how landscape structure (e.g. vegetation pattern) will change as a result of project activity
- **Collaborators:** ERDC EL, CERL, NAB, and NPS
- **Status:** Evaluation phase

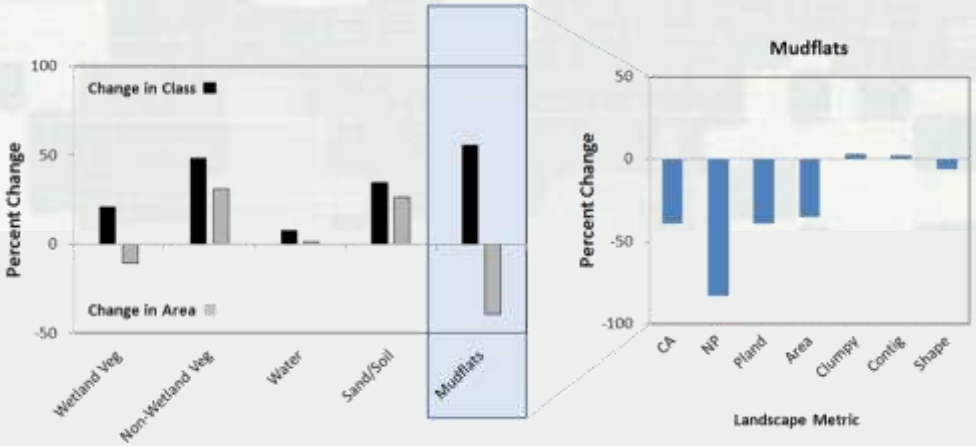
# Conceptual Model

1) Identify changes to critical habitat using multi-temporal imagery and lidar data




2) Derive landscape parameters associated with landscape patterns




3) Integrate with ecological simulation to develop a model for determining how landscape structure will change to assess project level impacts/benefits

*Change in Landscape Pattern*

*Change in Ecosystem Function*

| Metric | Process | Benefit |
|---|---|---|
| Clumpiness | Biodiversity | ↑↓ |
| Cohesion | Connectivity | ↓↑ |

# Ecological Process-Pattern Database

## Relational database

**Landscape Pattern**

| Pattern Type | Pattern Metric | Metric Category |
|---|---|---|
| Habitat Fragmentation | Clumpiness Index | Categorical Map Pattern, Surface Pattern |
| Landscape Configuration | Patch Area | Categorical Map Pattern, Linear Network Pattern |

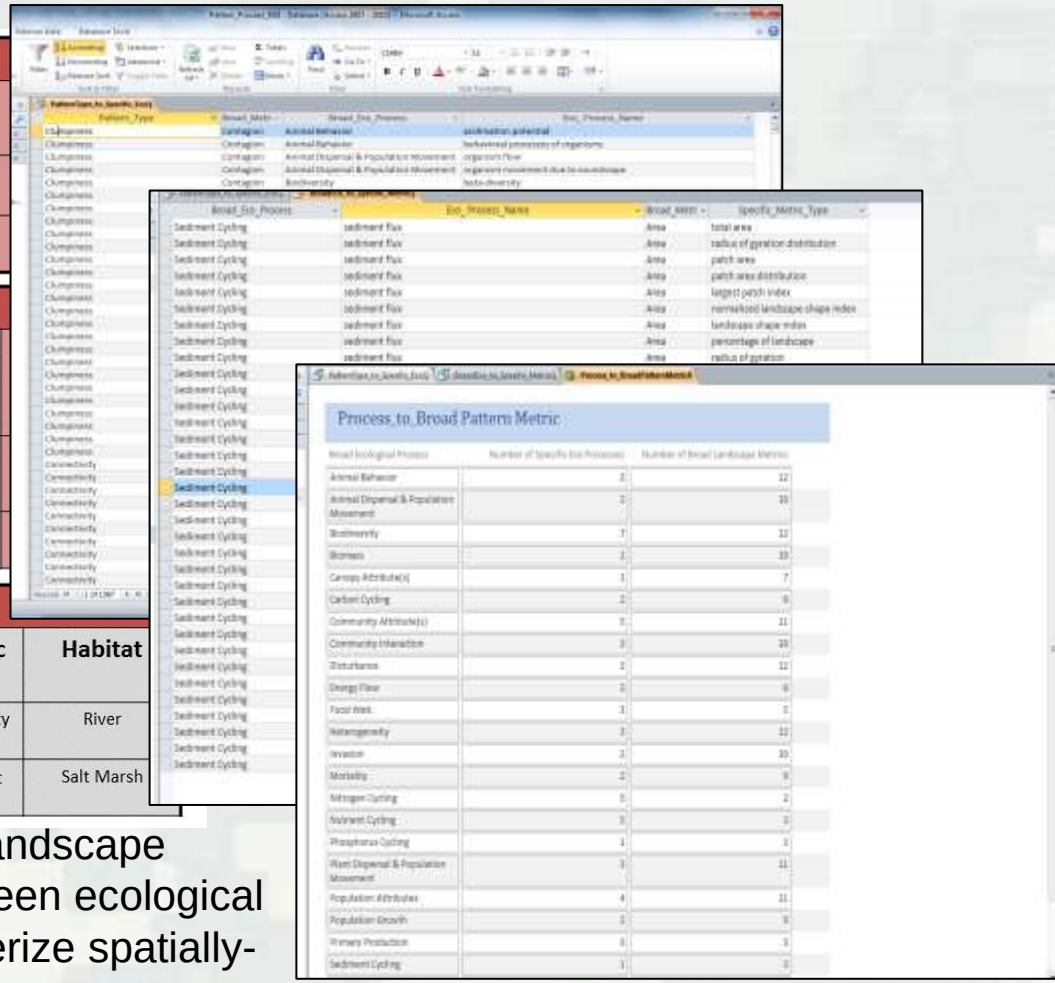
**Ecological Process**

| Broad Process | Process Name | Ecosystem Goods & Services Category (UNEP) | Process Category | Spatial Scale |
|---|---|---|---|---|
| Biodiversity | Species Richness | Supporting/Provisioning | Community Dynamics | Local - Global |
| Sediment Cycling | Sediment Flux | Supporting/ Regulating | Other | Local - Global |

**Study**

| Study ID | Process Name | Temporal Scale | Spatial Scale | Study Metric | Habitat |
|---|---|---|---|---|---|
| 3 | Species Richness | 1 week | 30 $Km^2$ | Shannon's Diversity Index | River |
| 8 | Sediment Flux | Daily tidal cycles | 14,500 $Km^2$ | $VS=\int^{thigh}_{tlow} CsQdt$ | Salt Marsh |

## Queries and Forms



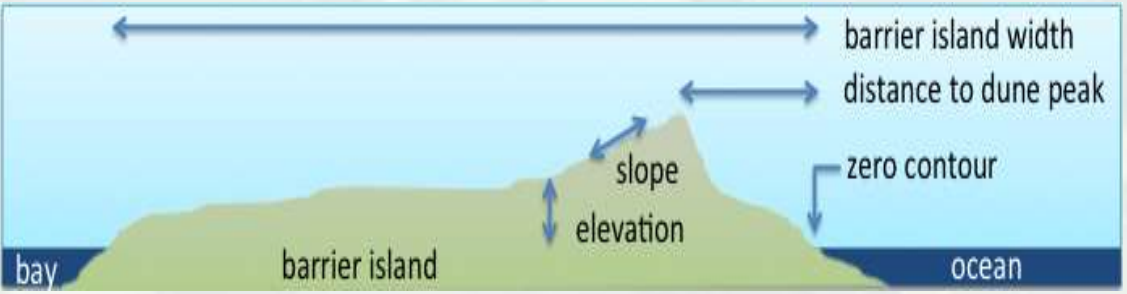

- Database serves as a foundation for the landscape model by providing key relationships between ecological process and pattern and used to parameterize spatially-explicit model
- Describing: 1) relevant landscape patterns and metrics, 2) ecological processes, 3) specific studies, and 4) linkage of patterns, processes, and studies

# Site Selection


- Sites selected as a result of feedback from the Coastal Working Group and Environmental Chiefs
- Sites evaluated based on selection criteria:
  - *Coastal and dynamic*
  - *O&M activity*
  - *Ecosystem restoration activity*
  - *Long project history with visible landscape changes*
  - *Represents typical coastal project*


- **Site selected:** Assateague Island, MD due to data richness and historical evaluation
- Includes time series of lidar data and habitat classification by the National Park Service

# Tool Input: Parameter Development




| | | | | | |
|---|---|---|---|---|---|
| **Distance to ocean** | O | I I I<br>Lucas and Carter, 2013 (would need further adjustment); Geider et al 2014; Tissier et al 2013 | I | | I |
| **Distance to sound** | O | I I<br>Geider et al 2014 | I | | |
| **distance to dune crest** | O | I I<br>Geider et al 2014 | | | |
| **distance to dune toe** | O | I I<br>Grafals-Soto 2012; Geider et al 2014 | | | |
| **beach width** | O | | | | |
| **zero contour to dune to** | O | | | | |
| **dune field volume** | O | I I<br>Preistas and Fagherazzi 2010, implied | | | |
| **beach slope** | O | I I | | I | |
| **barrier island width** | O | I I I<br>Claudino-Sales et al 2008; background: Houser and Hamilton, 2009; Smith et al 2008 | | O | |
| **elevation** | O | I I I<br>Lucas and Carter, 2013; Geider, 2014; Judd et al, 2008; Miller et al, 2010; Sellars and Jolls, 2007 *(Amaranthus)*; Priestas and Fagherazzi, 2010 | I | | I |
| **slope** | O | Tisser et al 2013, slope angle | | | |
| **aspect** | O | | | | |
| **foredune continuity (?)** | O | I I I<br>Preistas and Fagherazzi 2010; Miller et al 2010 | | | |

- Parameters identified from literature reviews and developed from a time series of lidar data (2000 - 2012) collected by the USGS, NASA, and the USACE NCMP

- Focused on 6 parameters:
  - **Elevation**
  - **Slope**
  - **Barrier island width**
  - **Distance to zero contour**
  - **Distance to dune peak**
  - **Elevation change**

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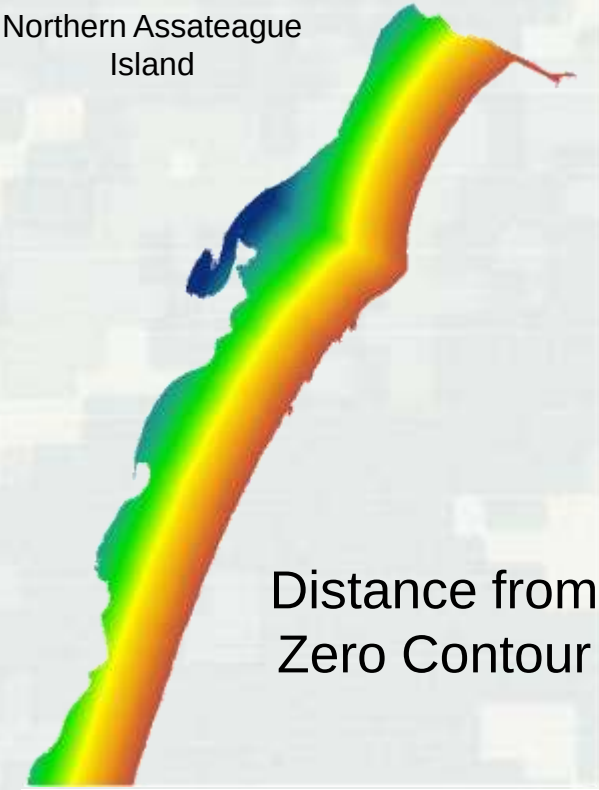
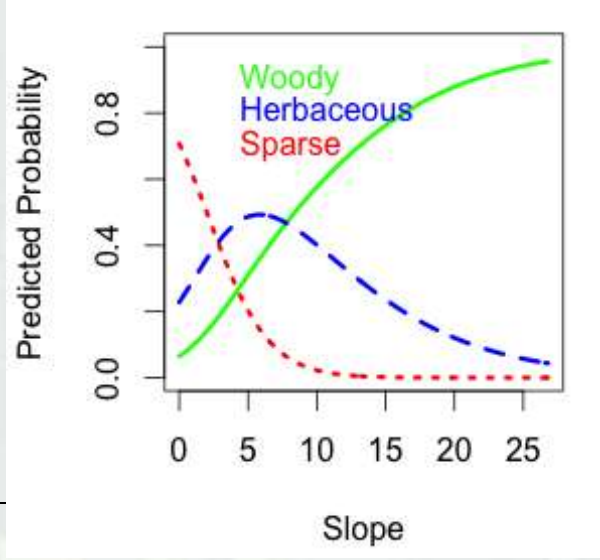
# Parameter Analysis

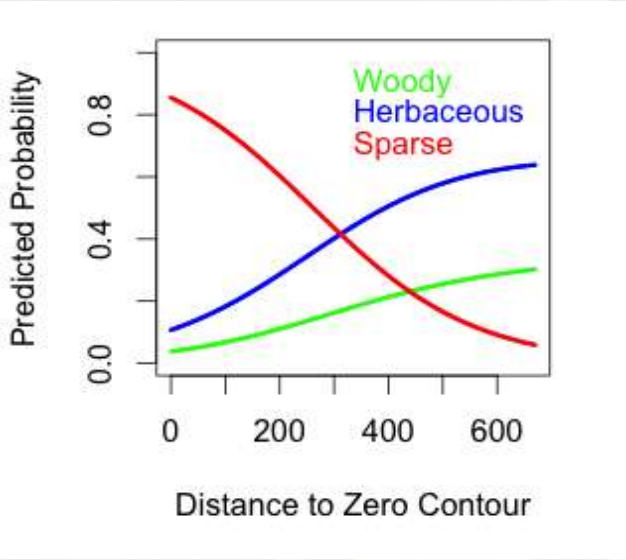
- Predicted probability of vegetation type for each parameter determined using multinomial logistic regression
- Influence of interactions between metrics investigated
- Identified significant parameters and incorporated relationships into spatial model
  - **Slope**
  - **Distance to Zero Contour**
  - **Elevation Change**

Slope

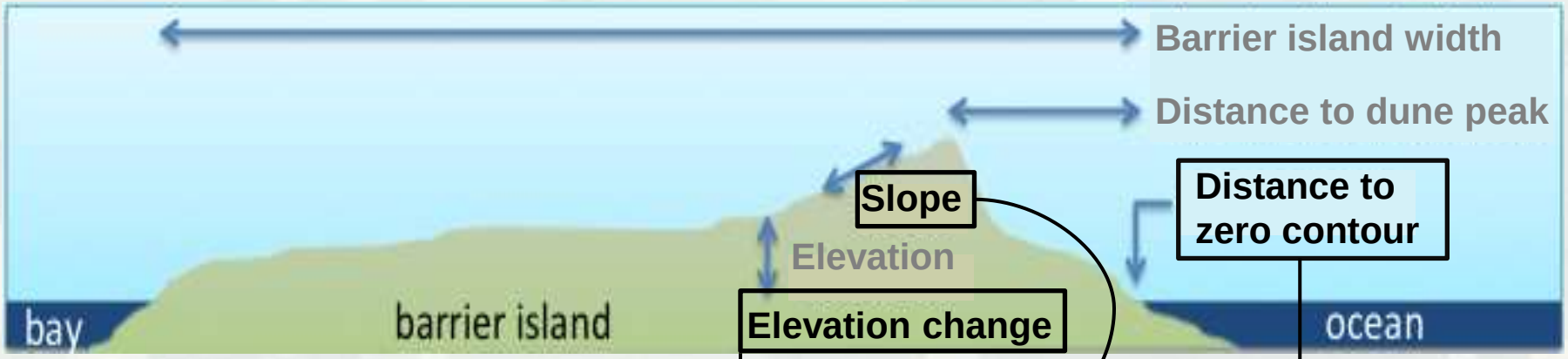



Distance from Zero Contour



# Parameter Analysis




$$L_{herbaceous} = \ln\left(\frac{p(herbaceous)}{p(woody)}\right)$$

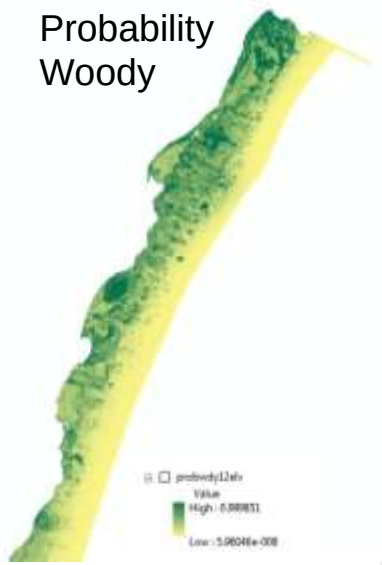
$$= -6.07 + 1.59(elevation\ change) + 8.26\left(slope^{\frac{1}{3}}\right) + 1.13\left(dist.\ zero\ contour^{\frac{1}{3}}\right) + 1.39\left(slope^{\frac{1}{3}} * dist.zero\ contour^{\frac{1}{3}}\right)$$

$$\text{Probability(herbaceous)} = \frac{e^{L_{herbaceous}}}{1 + e^{L_{herbaceous}} + e^{L_{sparse}}}$$

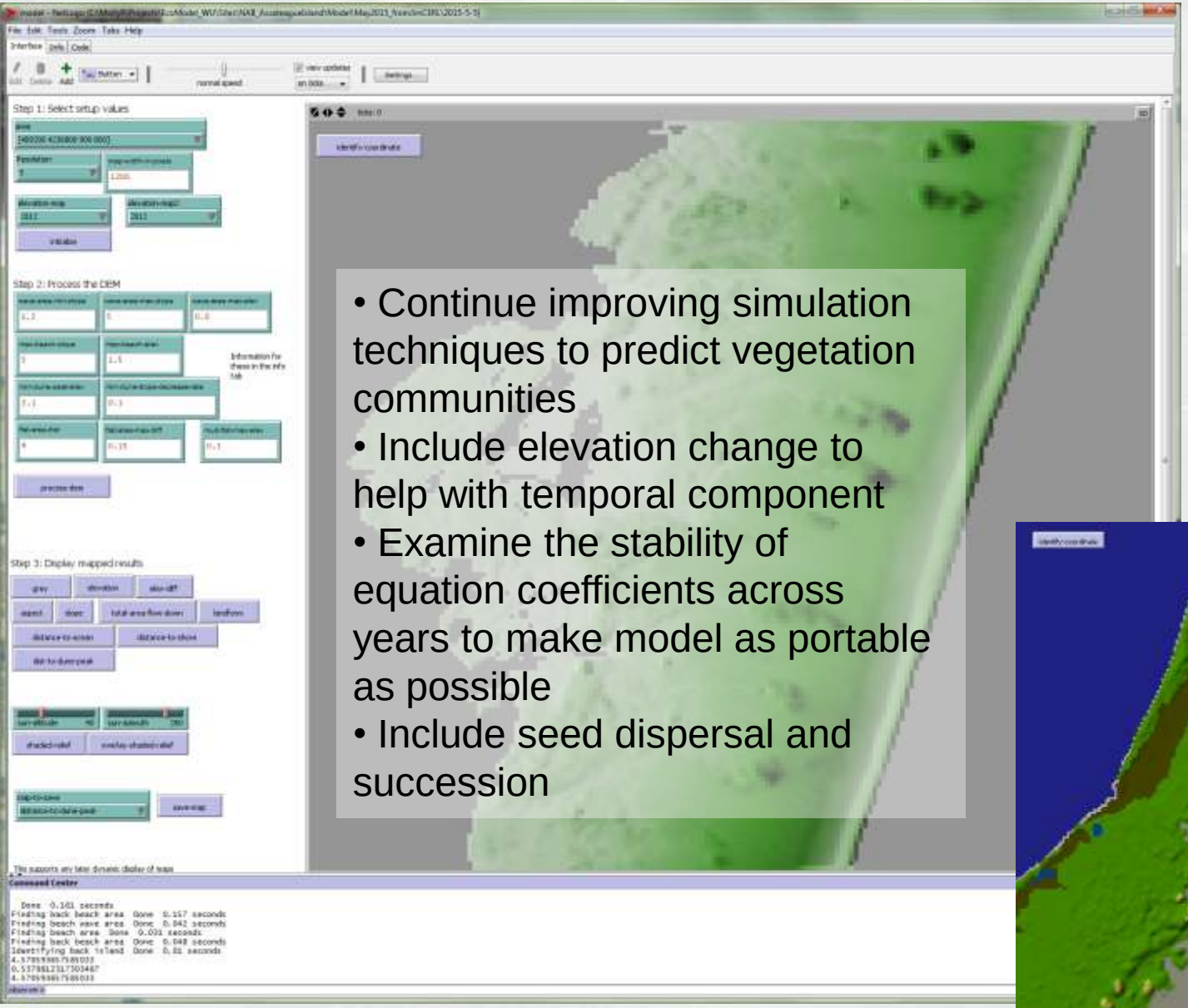
Probability Herbaceous

Probability Sparse

Probability Woody



# Model Evolution




- Continue improving simulation techniques to predict vegetation communities
- Include elevation change to help with temporal component
- Examine the stability of equation coefficients across years to make model as portable as possible
- Include seed dispersal and succession

Using the results from the statistical analysis, develop a Monte Carlo based probabilistic approach that simulates changes in the distribution of the vegetative communities

# Project Value

- **Operations**: For design engineers to evaluate potential impacts of operational activities to maximize environmental benefit
- **Planning**: For planners to evaluate alternative scenarios as they relate to vegetation change and describe benefits/impacts outside of habitat unit creation (i.e. how do changes tie back to ecological processes?)
- **R&D**: For researchers/modelers to evaluate landscapes for better understanding of ecological impacts

# FY16 Proposed Activities

- This WU will segue into a new work unit that will focus on:
  1) Model implementation (tech transfer/operationalization strategy)
  2) Quantitative integration with specific ecological processes to identify project benefits or potential impact on both landscape change as well as ecological processes over time
  3) Testing model robustness (through application of model at a different site and/or coordination with a physical model)