Louisiana’s 2012 Coastal Master Plan

Spatial Modeling of Land Change and Relative Elevation to Assess Restoration Priorities in Coastal Louisiana

Dr. Greg Steyer - U.S. Geological Survey

9th INTECOL International Wetlands Conference
Model Overview: Team Members

Wetland Morphology

- Greg Steyer, PhD, United States Geological Survey
- Brady Couvillion, United States Geological Survey
- Hongqing Wang, United States Geological Survey
- Bill Sleavin, United States Geological Survey
- John Rybczyk, PhD, Western Washington University
- Nadine Trahan, United States Geological Survey
- Holly Beck, United States Geological Survey
- Craig Fischenich, PhD, United States Army Corps of Engineers - ERDC
- Ron Boustany, Natural Resources Conservation Service
- Yvonne Allen, United States Army Corps of Engineers - ERDC
Historic Wetland Change

- Net land area change 1932-2010 is 4,877 km²
- 1985 – 2010 trend is 42.9 km²/yr
Model Overview: Historic Wetland Change

Coastal Louisiana
1985 to 2010

1985 to 2004 = -30.46 ± 11.58 sq.km/year $r^2 = 0.4969$

1985 to 2010 = -42.92 ± 9.814 sq.km/year $r^2 = 0.7208$

Katrina/Rita

Gustav/Ike

Land Area (sq.km.)

17,000
16,000
15,000
14,000


- Land area
- Excluded data points, 2005–8
- Regression trend line, 1985–2010
- Regression trend line, 1985–2004
- 95 percent confidence band, 1985–2010
Baseline loss rates unassociated with inundation due to RSLR are represented using multi-criteria weighting.

Water depths tracked using mean water level provided by Ecohydro models, SLR and subsidence from uncertainty scenarios, and calculating water depths based on bathy/topo.

The model utilizes a raster-based probability weight and cost surface to distribute sediment within Ecohydro box.

Surface elevation change relative to water level is tracked in relative elevation model: 
\[ \Delta E = \text{Accretion} - \text{ESLR} - \text{Subsidence} \]

Utilize adjusted salinity, water level, and sediment inputs from Eco-hydro to account for project effects.
Project performance was evaluated across a range of possible future scenarios (moderate and less optimistic presented) which reflect specific environmental uncertainties that impact coastal planning, including:

- SLR (0.3m; 0.5m),
- Subsidence (spatially variable),
- Mississippi River discharge,
- Rainfall,
- Evapotranspiration,
- Marsh collapse threshold (salinity/inundation).
Model Mechanics: Assumptions

Relative Elevation

- Organic matter accumulation rate $Q_{org} = Q_{sed} \times \frac{Org_{frac}}{Min_{frac}}$ based on fraction of organic matter mass in total soil mass.
- Calibrated BD/OM values for each basin-vegtype group are representative and conservative to describe the long-term soil accretionary processes.
- BD assumption that sands settle in open water and fine materials (silts/clay) settle on marsh surface.

Landscape Change

- With the exception of loss related to RSLR, the model assumes loss related to other factors will continue at rates similar to those observed during the 1984-2010 time period.
- With the exception of loss related to RSLR, land loss is assumed to take place in a linear fashion.
- Assumes 1,000 g/m2/yr delivered to each of the Eco-hydro boxes based on Nyman et al. (1995).
- Sediment delivery to a particular area is limited based on maximum stage exceeding elevation.
- The upper limit of vertical accretion was assumed to be 2.26 cm/yr based on historical field observations across coastal Louisiana (e.g., Rybcyzk 2002; Jarvis 2010).
**Calibration Data**

- CRMS 2006-2010 soil data (to 24 cm depth): bulk density, OM%, mineral matter %, pore space;
- CRMS 2006-2010 soil data: accretion (feldspar) and elevation (SET);
- CRMS 2007-2010 hydrology data (salinity and inundation);
- CRMS 2007 marsh type classification and dominant species;
- USDA SURRGO Soils (Soil type, bulk density and OM%);
- LCA S&T Task II 2006-2007 data (~50cm depth): BD, OM%, OC%, accretion;
- Historic Cesium cores (accretion since 1963)
Inputs provided by the Eco-hydrology Team

- Stage Change (STG)
- Stage Maximum (STG)
- Salinity ppt (SAL)
- Sediment Load (ACC)
Results: Model Outputs

- Percent Land (PCL)
- Elevation (ELV)
- Edge (EDG)
- Soil Organic Carbon (SOC)
Validation

**Accretion Validation**

(14 basin-vegtype groups, Overall Relative Error (RE) = -22%)
## Validation: Future without Action - Moderate Scenario

<table>
<thead>
<tr>
<th>Basin</th>
<th>Modeled Accretion (cm/yr) Mean</th>
<th>Accretion Range from Literature (cm/yr)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcasieu/Sabine</td>
<td>0.283</td>
<td>0.36-0.9</td>
<td>DeLaune et al., 1989; Bryant &amp; Chabreck, 1998; Steyer, 2008</td>
</tr>
<tr>
<td>Mermentau</td>
<td>0.536</td>
<td>0.12-0.98</td>
<td>Cahoon, 1994; Bryant &amp; Chabreck, 1998</td>
</tr>
<tr>
<td>Teche/Vermilion</td>
<td>0.578</td>
<td>0.29-0.70</td>
<td>Bryant &amp; Chabreck, 1998</td>
</tr>
<tr>
<td>Atchafalaya</td>
<td>1.600</td>
<td>0.07-0.99</td>
<td>Day et al., 2011</td>
</tr>
<tr>
<td>Terrebonne</td>
<td>0.660</td>
<td>0.59-1.4</td>
<td>DeLaune et al., 1989; Nyman et al., 1993</td>
</tr>
<tr>
<td>Barataria</td>
<td>0.891</td>
<td>Not Available</td>
<td>Hatton et al., 1983; DeLaune et al., 1989</td>
</tr>
<tr>
<td>Mississippi River Delta</td>
<td>0.733</td>
<td>Not Available</td>
<td>NA</td>
</tr>
<tr>
<td>Breton Sound</td>
<td>0.874</td>
<td>0.42-1.72</td>
<td>DeLaune et al., 2003</td>
</tr>
<tr>
<td>Pontchartrain</td>
<td>0.668</td>
<td>Not Available</td>
<td>NA</td>
</tr>
<tr>
<td>LA Coastwide</td>
<td>0.689</td>
<td>0.25-1.78</td>
<td>Nyman &amp; DeLaune, 1999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.46-0.76</td>
<td>Piazza et al., 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.59-0.98</td>
<td>Nyman et al., 2006</td>
</tr>
</tbody>
</table>
Over the next 50 years, a total loss of 2054 Km$^2$ (793 mi$^2$)

Over the next 50 years, a total loss of 4533 Km$^2$ (1750 mi$^2$)

Moderate Scenario

Less Optimistic Scenario
Results: Potential Land Area Change

Future Without Action - Projected Land Area Change 2010 - 2060

<table>
<thead>
<tr>
<th>Year</th>
<th>Land Area (sq. mi.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>3000</td>
</tr>
<tr>
<td>2010</td>
<td>3200</td>
</tr>
<tr>
<td>2020</td>
<td>3400</td>
</tr>
<tr>
<td>2030</td>
<td>3600</td>
</tr>
<tr>
<td>2040</td>
<td>3800</td>
</tr>
<tr>
<td>2050</td>
<td>4000</td>
</tr>
<tr>
<td>2060</td>
<td>4200</td>
</tr>
<tr>
<td>2070</td>
<td>4400</td>
</tr>
</tbody>
</table>

Moderate
Less optimistic
<table>
<thead>
<tr>
<th>Year</th>
<th>Percent Land: FWOA – Moderate Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021</td>
<td></td>
</tr>
<tr>
<td>2031</td>
<td></td>
</tr>
<tr>
<td>2041</td>
<td></td>
</tr>
<tr>
<td>2051</td>
<td></td>
</tr>
<tr>
<td>2061</td>
<td></td>
</tr>
</tbody>
</table>
By 2061, average Percent Land in the upper basin would Increase from <40% under FWOA to ~84% with 250K diversion.
Results: Model Outputs: Upper Breton Diversion (max 250K cfs)

Moderate and Less Optimistic Scenarios

- **FWP – Moderate Scenario**
  - Loss rate: 10.34%

- **FWP – Less Optimistic Scenario**
  - Loss rate: 16.49%

- **FWOA – Moderate Scenario**
  - Loss rate: 46.30%

- **FWOA – Less Optimistic Scenario**
  - Loss rate: 54.12%
Potential Land Area Change

Potential Land Area Change Over Next 50 Years
Moderate Scenario

Potential Land Area Change Over Next 50 Years
Less Optimistic Scenario
**Strengths**

- Addresses uncertainties.
  - Eustatic sea-level rise [ESLR],
  - Subsidence
  - Freshwater and mineral sediment supply
  - Marsh Collapse Thresholds
- **Directly incorporates the affect of accretion on landscape change projections.**
  - Improves upon so-called “bathtub” model projections by considering wetland elevation maintenance through accretion
- Enables the projection of changes in elevation which can then be utilized by other models.
- Can be used to project soil organic carbon sequestration under RSLR and restoration.
Limitations

• Effectively address how much sediment is delivered to the marsh surface at finer resolutions than the box scale

• Reflect the spatial variation in sediment accumulation brought by hurricanes/storms of different categories.

• Estimate vertical soil loss depth by erosive forces (e.g., wind/wave at marsh open water interface and by biological factors e.g., vegetation mortality).

• Capture OM inputs from wetland productivity and elevation change based on changes in below-ground processes
Next Steps

• Further testing of multi-criteria weightings of marsh loss

• Distribution of sediment to marsh surface
  • More spatially explicit sediment transport model

• **Spatially-distributed sediment delivery from hurricanes**
  • Inclusion of variable storm surge sedimentation rate across coast for modeled storms scaled to surge water depth and based on maximum sedimentation from literature

• **Changes in bulk density associated with restoration**
  • Temporal - Marsh creation (Bayou LaBranche 1.16 – 0.6 in 6 yrs)

• **Feedback between eco-hydrology, vegetation, and landscape/elevation modeling**
  • At five-year interval (currently at 25-year interval)
  • Coupling for efficiency
Thank You!