Landscape Effect of Mississippi River Diversions on Soil Organic Carbon Sequestration in Louisiana Deltaic Wetlands

Hongqing Wang, Gregory D. Steyer, Brady R. Couvillion, Holly J. Beck, John M. Rybczyk, Victor H. Rivera-Monroy

U.S. Geological Survey, National Wetlands Research Center

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Outline

• **Background** (loss of wetland and SOC)
• **Methods** (the Wetland Morphology Model)
• **Results** (discharge rate and location of diversions on SOC sequestration rates)
• **Conclusions**
Historic Wetland Change

- Net land area change 1932-2010 is 4,877 km²
- 1985 – 2010 trend is 42.9 km²/yr

(Couvillion et al., 2011)
Historic Distributary Flow Paths

Historic distributaries before the flood protection levees of the MR&T delivered freshwater and sediment to the wetlands.

Contemporary Distributary Flow Paths

(Source: Blum & Roberts, 2009)

400 – 500 MMT/yr

~205 MMT/yr
False-color image taken from Aqua MODIS on May 17, 2011 (Source: NASA)
Coastal Louisiana SOC loss during 1978-2000

- Lost rate: 1000-2050 g C/m²/yr
- Sequestration rate: 100-380 g C/m²/yr

Currently, LA coast is still a carbon “Sink” due to remaining wetland area is larger than loss area. But, when loss area is larger than remaining area, with much higher SOC loss rate, LA coast will be a carbon “Source”.

Source: Markewich et al. (2007)
Methods: Modeling in a Systems Context

Stage, Salinity, Water Quality

Land Configuration, Elevation

Surge, Waves

Risk Assessment

Stage

Land Configuration, Elevation

Dominant Vegetation

Island Configuration

Stage, Salinity, Sediment

Eco-hydrology

Wetland Morphology

Dominant Vegetation

Vegetation

Storm Surge/Waves

Barrier Shoreline Morphology

Ecosystem Services
<table>
<thead>
<tr>
<th>Uncertainty</th>
<th>Moderate</th>
<th>Less Optimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level Rise</td>
<td>0.27m over 50 yrs</td>
<td>0.45m over 50 yrs</td>
</tr>
<tr>
<td>Subsidence</td>
<td>0-19 mm/yr, spatially variable</td>
<td>0-25 mm/yr, spatially variable</td>
</tr>
<tr>
<td>Storm Intensity</td>
<td>+10% of current</td>
<td>+20% of current</td>
</tr>
<tr>
<td>Storm Frequency</td>
<td>Current - One Category 3 or greater storm every 19 years</td>
<td>+2.5% of current</td>
</tr>
<tr>
<td>River Discharge / Sediment Load</td>
<td>Mean annual discharge (534,000 cfs)</td>
<td>-5% of mean annual discharge</td>
</tr>
<tr>
<td>Mississippi River Nutrient Concentration</td>
<td>-12% of current</td>
<td>Current (mg/L) – Phosphorus (0.22); Nitrite+Nitrate (1.3); Ammonium (0.044); Org. Nitrogen (0.77)</td>
</tr>
<tr>
<td>Rainfall</td>
<td>Percent of historic mean</td>
<td>Percent of historic mean</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>Historic monthly mean</td>
<td>0.45D from historic</td>
</tr>
</tbody>
</table>

**Uncertainty Scenarios**

- **Moderate**: lower 20th percentile of the plausible range
- **Less Optimistic**: 50th (mid-point value) of the plausible range
Soil Organic Carbon (SOC):

SOC Sequestration Rate:

$$\Delta SOC = (BD \times OM\%/2.2) \times H$$

Modification of Van Bemmelen Factor

- Coastal Louisiana wetland soil organic matter contains 45.4% organic carbon, not 58%.
- Conversion factor should be 2.2 instead of 1.724.
A total of 49 individual diversion projects with different locations and operation schemes have been proposed by CPRA and were simulated in the 2012 Coastal Master Plan modeling study.

Source: http://www.coastalmasterplan.louisiana.gov/
Results

Basin-wide SOC Sequestration:

1. Diversion Discharge
2. Diversion Location

Moderate Scenario
(RSLR= 1.24, 1.14 cm/yr)
Less Optimistic Scenario
(RSLR=2.0, 1.8 cm/yr)

BA = Barataria Basin
BS = Breton Sound Basin

Diversion Scales (e.g., Allison and Meselhe, 2010):

Large:  > 1416-7080 cms (50K cfs)
Medium: 283-1416 cms (10K - 50K cfs)
Small:  ≤ 283 cms (10K cfs)
Discharge Effect

Myrtle Grove, BA

Caernarvon, BS

Barataria Basin

SOC Sequestration (g m\(^{-2}\) yr\(^{-1}\))

- Moderate
- Less Optimistic

Diversion Discharge (m\(^3\) s\(^{-1}\))

- 0 (FWOA)
- 142
- 1416
- 7080

Breton Sound Basin

SOC Sequestration (g m\(^{-2}\) yr\(^{-1}\))

- Moderate
- Less Optimistic

Diversion Discharge (m\(^3\) s\(^{-1}\))

- 0 (FWOA)
- 142
- 1416
- 7080
Barataria Basin

\[ y = -3 \times 10^{-6}x^2 + 0.0251x + 217.82 \]
\[ R^2 = 0.9947 \]

\[ y = -3 \times 10^{-6}x^2 + 0.0105x + 157.15 \]
\[ R^2 = 0.9931 \]

Breton Sound Basin

\[ y = -4 \times 10^{-6}x^2 + 0.0254x + 191 \]
\[ R^2 = 0.979 \]

\[ y = -4 \times 10^{-6}x^2 + 0.0261x + 166.51 \]
\[ R^2 = 0.8613 \]
\[ \Delta \text{SOC} = (\text{BD} \times \text{OM}\% / 2.2) \times H \]

Increases in H from 7080 cms diversion <20%

Source: Wang et al. (2014)
ΔSOC = (BD * OM%/2.2) * H

OC density (g/cm³) based on CRMS soil data
Predicted Land Area Change (2010-2060)
Location Effect: BA at 1416 cms (50K cfs)

Baratia Basin

SOC Sequestration (g m⁻² yr⁻¹)

- Moderate
- Less Optimistic

Myrtle Grove  West Pointe a la Hache  Empire
Location Effect:
BS at 7080 cms (250K cfs)

Breton Sound Basin

SOC Sequestration (g m\(^{-2}\) yr\(^{-1}\))

- **Moderate**
- **Less Optimistic**

Caernarvon

Black Bay
Topography & Bathymetry Characteristics within a Hydrologic Basin

- **Upper ➔ Middle -➔ Lower Estuary:**
  - Lower retention of diverted sediments and decreased vertical accretion due to decreases in land area, % of vegetated area, marsh elevation; and increase in water depth.
Conclusions

• Basin-wide diversion benefits vary with diversion discharge rate and location:
  ➢ An optimal increase in SOC sequestration could likely be achieved with medium- to large-scale diversions along the upper section of the lowermost Mississippi River;

• Decisions on the implementation of new diversion projects should consider the optimization (not maximization) of these basin-wide benefits due to the “trade-offs” between elevation gain and SOC sequestration reduction under large-scale diversions.
Questions?