Carbon Cycling and Potential Soil Accumulation within Greater Everglades Forested Wetlands

By: W. Barclay Shoemaker and Frank Anderson

Photo taken by Bob Sobchek (BCNP)
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Science Questions

1. Are forested wetlands carbon sinks and methane sources?

2. Is the carbon-cycle building topography?

3. How do topography changes compare with sea-level rise?
Air flow can be imagined as a horizontal flow of numerous rotating eddies.
Each eddy has 3D components, including a vertical wind component.
The diagram looks chaotic but components can be measured from the tower.
EDDY-COVARIANCE SENSORS

- Sonic anemometer
- Gas analyzer
- CH₄ analyzer
Dwarf Cypress (55’ tower)

- Measures ET, NEE, CH$_4$
- Net radiation
- PAR
- Wind speed and direction
- SW/GW stage
- GW temperature
- SW temperature
- Air temperature
- Relative humidity
- Barometric pressure
- ORP
Cypress Swamp (120’)

- Measures ET, H, NEE
- Net radiation
- PAR
- Wind speed and direction
- Surface/groundwater stage
- Ground-water temperature
- Surface-water temperature
- Air temperature
- Relative humidity
- Soil temperature
- Soil heat flux
- Soil moisture
Pine upland (120’ tower)

- Measures ET, NEE
- Net radiation
- SW/GW stage
- GW temperature
- SW temperature
- Air temperature
- Relative humidity
- Soil moisture
- Soil temperature
- Soil heat flux
Carbon Cycling Conceptual Model

NEE is net ecosystem C exchange, measured with gas analyzer

Missing NEE gap-filled with Artificial Neural Networks (ANN)

ANNs are non-linear regression models based on season, time of day, net radiation, water temperature, air temperature, and vapor pressure deficit.

Missing weather data supplemented from nearby weather stations (Oasis Visitor Center, others).

Do \( i = 1, 20 \) (Repeat 20 times with different sets of weather data)

Do \( j = 1, 10 \) (Initialize starting values for ANN weights)  
Avoids local minima

Complexity increased

End Do (Initialize starting values for ANN weights)

Complex models with an NEE accuracy gain less than 5% are removed.

End Do (Repeat 20 times with different sets of weather data)

Missing NEE replaced with a median value from the 20 resultant predictions.

For more information, contact: 
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Variation of energy and carbon fluxes from a restored temperate freshwater wetland and implications for carbon market verification protocols

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Abstract. Temperate freshwater wetlands are among the most productive terrestrial ecosystems, stimulating interest in using restored wetlands as biological carbon sequestration projects for greenhouse gas reduction programs. In this study, we used the eddy covariance technique to measure surface energy carbon fluxes from a constructed, impounded freshwater wetland during two annual periods that were 8 years apart: 2002–2003 and 2010–2011. During 2010–2011, we measured methane (CH₄) fluxes to quantify the annual atmospheric carbon mass balance and its concomitant influence on global warming potential (GWP). Peak growing season fluxes of latent heat and carbon dioxide (CO₂) were greater in 2002–2003 compared to 2010–2011. In 2002, the daily net ecosystem exchange reached as low as −10.6 g C m⁻² d⁻¹, which was greater than 3 times the magnitude observed in 2010 (−2.9 g C m⁻² d⁻¹). CH₄ fluxes during 2010–2011 were positive throughout the year and followed a strong seasonal pattern, ranging from 38.1 mg C m⁻² d⁻¹ in the winter to 375.9 mg C m⁻² d⁻¹ during the summer. The results of this study suggest that the wetland had reduced gross ecosystem productivity in 2010–2011, likely due to the increase in dead plant biomass (standing litter) that inhibited the generation of new vegetation growth. In 2010–2011, there was a net positive GWP (675.3 g C m⁻² yr⁻¹), and when these values are evaluated as a sustained flux, the wetland will not reach radiative balance even after 500 years.
Dwarf Cypress

Stage, in m above (+) and below (-) LS

1400 mm rain
Year 1
-165 g C m\(^{-2}\) yr\(^{-1}\)
1480 mm rain
Year 4
-205 g C m\(^{-2}\) yr\(^{-1}\)

1270 mm rain
Year 2
-80 g C m\(^{-2}\) yr\(^{-1}\)

1400 mm rain
Year 3
-35 g C m\(^{-2}\) yr\(^{-1}\)


1400 mm rain Year 1
-165 g C m\(^{-2}\) yr\(^{-1}\)
1480 mm rain Year 4
-205 g C m\(^{-2}\) yr\(^{-1}\)

1270 mm rain Year 2
-80 g C m\(^{-2}\) yr\(^{-1}\)

1400 mm rain Year 3
-35 g C m\(^{-2}\) yr\(^{-1}\)

NEE, in g C m\(^{-2}\) d\(^{-1}\)

Year 1 Year 2 Year 3 Year 4
-165 g C m\(^{-2}\) yr\(^{-1}\) -80 g C m\(^{-2}\) yr\(^{-1}\) -35 g C m\(^{-2}\) yr\(^{-1}\) -205 g C m\(^{-2}\) yr\(^{-1}\)

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1270 mm rain Year 2
-80 g C m\(^{-2}\) yr\(^{-1}\)

1400 mm rain Year 3
-35 g C m\(^{-2}\) yr\(^{-1}\)

wet season

wet season

wet season

wet season

wet season

wet season

wet season

wet season

land surface
Dwarf Cypress - Methane (CH4)

CH4, in g CH4 m⁻² d⁻¹

Year 1
16 g CH₄ m⁻² yr⁻¹

Year 2
9 g CH₄ m⁻² yr⁻¹

Year 3
7 g CH₄ m⁻² yr⁻¹

Year 4
16 g CH₄ m⁻² yr⁻¹

Stage, in m above (+) and below (-) LS

CH₄, in g CH₄ m⁻² d⁻¹

wet season

land surface
Cypress Swamp

Stage, in m above (+) and below (-) LS

1400 mm rain
Year 1
-305 g C m² yr⁻¹
wet season

1270 mm rain
Year 2
-190 g C m² yr⁻¹
wet season

1400 mm rain
Year 3
-100 g C m² yr⁻¹
wet season

1480 mm rain
Year 4
-355 g C m² yr⁻¹
wet season

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>wet</td>
<td></td>
<td></td>
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<tr>
<td>1400 mm rain</td>
<td>1270 mm rain</td>
<td>1400 mm rain</td>
<td>1480 mm rain</td>
</tr>
<tr>
<td>-305 g C m² yr⁻¹</td>
<td>-190 g C m² yr⁻¹</td>
<td>-100 g C m² yr⁻¹</td>
<td>-355 g C m² yr⁻¹</td>
</tr>
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</table>

NEE, in g C m⁻² d⁻¹
Pine Upland

Stage, in m above (+) and below (-) LS

<table>
<thead>
<tr>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>-470 g C m(^{-2}) yr(^{-1})</td>
<td>-410 g C m(^{-2}) yr(^{-1})</td>
<td>-233 g C m(^{-2}) yr(^{-1})</td>
<td>-440 g C m(^{-2}) yr(^{-1})</td>
</tr>
</tbody>
</table>

1400 mm rain 1270 mm rain 1400 mm rain 1480 mm rain


NEE, in g C m\(^{-2}\) d\(^{-1}\)

-4.0 -3.0 -2.0 -1.0 0.0 1.0 2.0 3.0 4.0

wet season

Hansen Fire

land surface

1400 mm rain 1270 mm rain 1400 mm rain 1480 mm rain

ΔC = -NEE - F_{net} - F_{CH_4}.

Is the carbon cycle accumulating soil?

How do soil accumulation rates compare with sea-level rise?
$\Delta C / \text{soil bulk density} = \text{topographic gain or loss}$
Soil bulk density

Samples Before Drying

Samples After Drying

Samples After Furnace

Slide and analysis provided by Matt Sirianni (FAU)
# Soil bulk density

<table>
<thead>
<tr>
<th>Count</th>
<th>Sample</th>
<th>Porosity</th>
<th>Bulk Density</th>
<th>Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DC_1A</td>
<td>0.84</td>
<td>0.199</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>DC_2A</td>
<td>0.82</td>
<td>0.233</td>
<td>21</td>
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<tr>
<td>3</td>
<td>DC_3A</td>
<td>0.69</td>
<td>0.401</td>
<td>14</td>
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<tr>
<td>4</td>
<td>DC_1P</td>
<td>0.68</td>
<td>0.45</td>
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<tr>
<td>5</td>
<td>DC_2P</td>
<td>0.70</td>
<td>0.38</td>
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<tr>
<td>6</td>
<td>DC_1D</td>
<td>0.77</td>
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<tr>
<td>7</td>
<td>DC_2D</td>
<td>0.72</td>
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<tr>
<td>8</td>
<td>CS_1A</td>
<td>0.93</td>
<td>0.092</td>
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<tr>
<td>9</td>
<td>CS_2A</td>
<td>0.81</td>
<td>0.24</td>
<td>41</td>
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<tr>
<td>10</td>
<td>CS_3A</td>
<td>0.81</td>
<td>0.243</td>
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<td>11</td>
<td>CS_1MF</td>
<td>0.83</td>
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<tr>
<td>12</td>
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<td>0.81</td>
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<tr>
<td>13</td>
<td>CS_1D</td>
<td>0.79</td>
<td>0.27</td>
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</tr>
<tr>
<td>14</td>
<td>CS_2D</td>
<td>0.87</td>
<td>0.16</td>
<td></td>
</tr>
</tbody>
</table>

- Weighted average bulk density = 0.28 g/cm³

Calcitic soils due to periphyton

60% 40%  

Slide and analysis provided by Matt Sirianni (FAU)
Loop Road - carbon budget and potential topography changes

- Wet season
- Bulk density = 0.28 g cm⁻³
- Bulk density = 0.15 g cm⁻³
Key Findings

1. Cypress and pine forested wetlands are carbon (C) sinks and methane (CH4) sources.
   - Cypress Swamp = -260 g C m$^{-2}$ year$^{-1}$
   - Dwarf Cypress = -120 g C m$^{-2}$ year$^{-1}$; +12 g CH4 m$^{-2}$ year$^{-1}$
   - Pine Upland = -390 g C m$^{-2}$ year$^{-1}$

2. Seasonality in C uptake is primarily driven by photosynthesis and respiration.
   - Flooding reduces respiration (soil oxidation) but increases CH4 emission.
   - Hansen fire suppressed peak photosynthesis at Pine Upland in 2015

3. Carbon uptake (NEE) rates are equivalent to ~1 mm per year of topography gains in forested wetlands.
   - Accumulation rate is very sensitive to peat bulk-density.
   - Accumulation rate < sea level rise

Conclusions are provisional and subject to change during peer review
THANKS!