Carbon Budget Estimation from Everglades Tree Islands: Balancing Soil Accretion and CO₂ Efflux

Leonard J. Scinto¹
Robert Schroeder¹
Andrés Rodríguez¹
Alexandra Serna¹

Eric Cline²
Thomas Dreschel²
Fred Sklar²

¹Southeast Environmental Research Center and Department of Earth and Environment, Florida International University, Miami, FL  scintol@fiu.edu
²South Florida Water Management District, Everglades Systems Assessment Section, West Palm Beach, FL
Drainage of the Everglades results in loss of stored Soil Carbon
Our objective is to develop a model based on empirical data for tree island soil carbon sequestration/release relative to water depth fluctuations.

From Fig. 4 Larsen et al., 2011 Crit Rev Environ Sci Technol. 41 (S1):344-381
Loxahatchee Impoundment Landscape Assessment

LILA

Aich et al., 2011 J. Environ Sci Engineer 5:289-302
Tree island planting 2006

2010
Net soil C accumulation in tree islands is a balance between production and respiration.
Organic matter respiration will be greater at higher elevations because of reduced inundation

Atmospheric CO₂ → Above ground biomass

Litter fall → Decomposition → Litter bags

Feldspar markers

Accretion

LICOR

CO₂ efflux

SETs
Litter production and soil building will be higher at high elevations because of higher biomass growth.
Tree island will increase in elevation if soil building occurs at a rate greater than decomposition.

Atmospheric CO₂ → Above ground biomass → Litter bags → Decomposition → Litter traps → 50x50cm² → Accretion → Feldspar markers → SETs → CO₂ efflux → LICOR
Above ground biomass

LICOR

Litter traps

Litter bags

Feldspar markers

SETs
Soil CO$_2$ Efflux measured using a LICOR LI-8100 Infra-red Gas Analyzer (IRGA) with Multiplexer and Long-term automated chambers (4 - model 104 chambers) with 20 cm diameter collars.

Collars georectified in x, y, and z at each location. Soil elevation at each collar was determined and combined with daily stage to calculate relative water depth (RWD).

Collars sampled once quarterly for approximately 24 h.
CO₂ efflux was significantly and negatively correlated to Relative Water Depth (RWD)

ALL: \( y = -5.46x + 3.85, r^2 = 0.21, n = 293, p < 0.001 \) (solid)

W/O Limestone: \( y = -7.54x + 3.86, r^2 = 0.30, n = 225, p < 0.001 \) (dashed)
Efflux varied seasonally with RWD. Lower elevations saturated or flooded approximately 50% of the year while High elevations were not inundated.
Annual Soil efflux was determined for individual sites, all of which showed significant, negative linear relationships with RWD. Efflux estimates were in the range of other published values.

<table>
<thead>
<tr>
<th>Estimated C efflux (g C m⁻² yr⁻¹)</th>
<th>m</th>
<th>b</th>
<th>r²</th>
<th>N</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1HH</td>
<td>2278 ± 171</td>
<td>-8.83 ± 2.94</td>
<td>3.20 ± 1.39</td>
<td>0.09</td>
<td>90</td>
</tr>
<tr>
<td>M1HL</td>
<td>970 ± 234</td>
<td>-14.09 ± 2.15</td>
<td>4.63 ± 0.30</td>
<td>0.33</td>
<td>83</td>
</tr>
<tr>
<td>M2HH</td>
<td>1419 ± 95</td>
<td>-3.84 ± 1.09</td>
<td>2.45 ± 0.63</td>
<td>0.16</td>
<td>63</td>
</tr>
<tr>
<td>M2HL</td>
<td>1066 ± 109</td>
<td>-6.94 ± 1.06</td>
<td>2.36 ± 0.36</td>
<td>0.40</td>
<td>57</td>
</tr>
<tr>
<td>ALL</td>
<td>970-2278</td>
<td>-5.46 ± 0.46</td>
<td>3.85 ± 0.25</td>
<td>0.21</td>
<td>293</td>
</tr>
</tbody>
</table>

Hirano et al., 2009: 2592 – 4794 g C m⁻² yr⁻¹  
Savage and Davidson, 2003: 1636 g C m⁻² yr⁻¹
Litter fall adds material to surface soil

Mean leaf litter (g m\(^{-2}\))

Litter traps

0.5x0.5m²

Planted in 2006

Planted in 2007

Planted in 2007

Planted in 2006

Elevation

HH

HL

mean ± SD

n=3
Litter fall adds material to surface soil

Mean leaf litter (g m\(^{-2}\))

**Litter traps**

- **M1**
  - 363 g C m\(^{-2}\) y\(^{-1}\)
  - 169 g C m\(^{-2}\) y\(^{-1}\)

- **M2**
  - 153 g C m\(^{-2}\) y\(^{-1}\)
  - 66 g C m\(^{-2}\) y\(^{-1}\)

- **M3**
  - Planted in 2007

- **M4**
  - Planted in 2006
  - mean ± SD
  - n=3

- **Elevation**
  - HH
  - HL

- **Dimensions:** 0.5x0.5 m\(^2\)
Litter production increases with increase in biomass mean \( \pm \) SD

<table>
<thead>
<tr>
<th>Crown area (m(^2))</th>
<th>Leaf litter (g C m(^{-2}) y(^{-1}))</th>
</tr>
</thead>
</table>

Litter production and biomass were greater at higher elevations.
Litter decomposition was similar for all tree islands and elevations.
Litter decomposition was similar for all tree islands and elevations.

Dry mass remaining (%) over days of decomposition for different sites:

- **M1**: 11% and 31%
- **M2**: 31% and 40%
- **M3**: Mean ± SD, n = 3
- **M4**: HH and HL

**Graphs** showing dry mass remaining over time with SD error bars.
Balance between litter production and litter decomposition results in a net gain

<table>
<thead>
<tr>
<th>Parameter</th>
<th>M1WHH</th>
<th>M1WHL</th>
<th>M2WHH</th>
<th>M2WHL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf litter input</td>
<td>363</td>
<td>169</td>
<td>153</td>
<td>66</td>
</tr>
<tr>
<td>Litter bag mass loss</td>
<td>-40</td>
<td>-52</td>
<td>-48</td>
<td>-27</td>
</tr>
<tr>
<td>Net Gain</td>
<td>323</td>
<td>117</td>
<td>106</td>
<td>40</td>
</tr>
</tbody>
</table>
Feldspar markers determine surface accretion and SETs show overall changes in elevation.

From Fig. 12.7 Brinson in Batzer and Sharitz, 2006
Markers showed cumulative Accretion over time

<table>
<thead>
<tr>
<th>Year</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
</tr>
</thead>
<tbody>
<tr>
<td>'09-'10</td>
<td>0±0.5</td>
<td>0±1.0</td>
<td>0±0.5</td>
<td>0±1.0</td>
</tr>
<tr>
<td>'10-'11</td>
<td>1±0.5</td>
<td>1±1.0</td>
<td>1±0.5</td>
<td>1±1.0</td>
</tr>
<tr>
<td>'11-'12</td>
<td>2±0.5</td>
<td>2±1.0</td>
<td>2±0.5</td>
<td>2±1.0</td>
</tr>
</tbody>
</table>

Note: mean ± SD
n = 3
Markers showed cumulative Accretion over time

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean (g C m⁻² y⁻¹)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>'09-'10</td>
<td>2183</td>
<td>-</td>
</tr>
<tr>
<td>'10-'11</td>
<td>499</td>
<td>-</td>
</tr>
<tr>
<td>'11-'12</td>
<td>743</td>
<td>-</td>
</tr>
</tbody>
</table>

Mean ± SD
n = 3
SETs generally show negative elevation change.
Net elevation change suggests a loss in net carbon.
Although soil material showed surface Accretion there was generally a NET loss of soil resulting in a negative change in Elevation.
Loss of soil elevation suggests NET loss of soil Carbon. Loss of soil C estimated from change in elevation, soil bulk density, and soil total C content.

<table>
<thead>
<tr>
<th>Soil field bulk density (g dw cm(^{-3}))</th>
<th>Soil total carbon (mg g(^{-1}) dw)</th>
<th>SET gain/loss (cm)</th>
<th>Feldspar accumulation (cm)</th>
<th>Calculated gain/loss (cm)</th>
<th>NET gain/loss (g C m(^{-2}) y(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1HH</td>
<td>0.39 ± 0.05</td>
<td>151.7 ± 54.5</td>
<td>-1.5 ± 1.3(^a)</td>
<td>3.7 ± 1.4(^a)</td>
<td>-5.2 ± 1.4</td>
</tr>
<tr>
<td>M1HL</td>
<td>0.47 ± 0.08</td>
<td>99.2 ± 24.6</td>
<td>-0.5 ± 1.5(^b)</td>
<td>1.1 ± 0.6(^b)</td>
<td>-1.6 ± 0.6</td>
</tr>
<tr>
<td>M2HH</td>
<td>0.52 ± 0.01</td>
<td>95.5 ± 36.4</td>
<td>0.0 ± 0.8(^c)</td>
<td>1.5 ± 0.6(^b)</td>
<td>-1.5 ± 0.6</td>
</tr>
<tr>
<td>M2HL</td>
<td>0.46 ± 0.23</td>
<td>145.4 ± 74.1</td>
<td>-0.7 ± 0.9(^b)</td>
<td>1.7 ± 0.8(^b)</td>
<td>-2.4 ± 0.8</td>
</tr>
</tbody>
</table>
Carbon budget estimation

**M1HH**

- 2183\text{FM}_{LT-LB}
- 323\text{LT-LB}
(1860) g C m\textsuperscript{-2} y\textsuperscript{-1}

**M2HH**

- 743\text{FM}_{LT-LB}
- 106\text{LT-LB}
(640) g C m\textsuperscript{-2} y\textsuperscript{-1}

**M1HL**

- 499\text{FM}_{LT-LB}
- 117\text{LT-LB}
(382) g C m\textsuperscript{-2} y\textsuperscript{-1}

**M2HL**

- 1138\text{FM}_{LT-LB}
- 40\text{LT-LB}
(1098) g C m\textsuperscript{-2} y\textsuperscript{-1}

LT: litter traps, FM: feldspar markers, LB: litter bags
Conclusions

• CO₂ efflux was significantly and negatively correlated to Relative Water Depth at all locations.

• Annual efflux from LILA tree island soils are comparable to other studies conducted in similar ecosystems (Savage and Davidson, 2003; Hirano et al., 2009).

• Within a Tree Island the higher elevations generally had higher Respiration, Biomass, Litter Fall, and NET Litter inputs.

• Accretion is less than Subsidence resulting in NET elevation loss on “young” LILA Tree Islands.
Conclusions

• Respiration, Litter inputs, Accretion and Subsidence were “Balanced” for a one-year period 2010 to 2011.
• At this point, outputs are greater than inputs.
• Currently, 77-96% of inputs and 54-97% of outflows are unaccounted.
• To improve our estimates:
  – A laboratory core study is being conducted to determine effects of Live Root Respiration.
  – Fine scale soil sampling and nutrient analysis.
  – Evaluate over a longer time-frame.

scintol@fiu.edu