Decadal Variation in Everglades Peat Soil at the Landscape Scale: Results of REMAP 1995-2014

Greater Everglades Ecosystem Restoration (GEER) 2015

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Scientific Approach: REMAP
Regional Environmental Monitoring & Assessment Program

- Random Sampling approach: probability-based design; every point has an equal chance of being sampled.
- Description of the whole by sampling parts.
- Can estimate, with known confidence, the status of ecological resources across the landscape: ie, as of 2005, 25.1 +/- 2.0% of the EPA had soil thickness < 1 foot (Scheidt and Kalla, 2007).
- sampled ~1000 locations from the 1990s to present
Everglades REMAP
Marsh Sampling Events

Soil, Surface Water, Periphyton, Pore Water, Mosquitofish
Performed Macrophyte and Aquatic Food Web Analyses

>100,000 Biogeochemical Analyses

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<tbody>
<tr>
<td>Dry Season</td>
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</tr>
<tr>
<td>Number of stations*</td>
<td>102</td>
<td>105</td>
<td>114</td>
<td>109</td>
<td>-</td>
<td>-</td>
<td>430</td>
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<tr>
<td>Wet Season</td>
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<tr>
<td>Number of stations</td>
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<td>102</td>
<td>112</td>
<td>119</td>
<td>51</td>
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<td>Phase</td>
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<tr>
<td>Number of stations</td>
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<td>207</td>
<td>226</td>
<td>228</td>
<td>51</td>
<td>119</td>
<td>1039</td>
</tr>
<tr>
<td>Big Cypress</td>
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</tbody>
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*based on soil thickness data
2014 Sampling Partners

85 people

- EPA Region 4 SESD (30 people)
- EPA Region 4 WPD (6)
- EPA Region 4 OPM (1)
- EPA ORD (2)
- EPA Contractors: ILS / Alion, Inc. (ESAT) (9)
- FIU (18)
- ENP (10)
- NPS (4)
- FWS (2)
- HMC Helicopters, Inc. (3)
Soil Parameters

- Field: measure thickness, pH, redox potential
- Collect 3 cores per site
- Photodocumentation
- Separate the benthic periphyton mat, floc, 0–10 cm soil profile.
- FIU labs determine TP, TN, TC, THg, MeHg, % Organic Matter, Bulk Density, Mineral Content, CH$_4$, CO$_2$
Soil Thickness Method

• Insert a metal probe through the soil profile to point of refusal. Measure to 0.05 inches

Soil core collection in sawgrass
Everglades Soils

• **Peat**
  - Derived from decaying plant matter with inundation
  - Forms at ~ 1 inch/100 years
  - Largest expanse of peat soil in the world
    (Stephens 1956)

• **Marl-** calcitic mud in shorter hydroperiod portions of Everglades National Park

• **Subsidence** is the drop in ground surface due to:
  - shrinkage from drying; biogeochemical oxidation; wind; fire
  - C loss to air as CO₂.
  - Depth of soil surface to water table critical

• **Soils** are vital to maintenance of wetland vegetation communities and wildlife habitat
Soil Subsidence in The Everglades

- EAA soils and subsidence have been often studied over the last century—agricultural sustainability.
  - EAA was established where soil was thickest ~ 17 feet.
  - First canals cut in 1906.

- Public Everglades ~ soil thickness, subsidence have been studied less
  - Davis, 1946, Jones 1948,
  - REMAP 1990s to present [Scheidt et al 2001; Scheidt and Kalla 2007],

  ➤ EAA subsidence post- ~5 feet lost from 1924-1984 (1 in/yr).
Peat Thickness ~ 1946

- Earliest quantitative information about soil thickness.
- “several hundred soundings of depth by rods” “reliable enough for general estimates of average conditions.” p. 121.
- Limitation: sampling points and data are not reported.; 2 foot intervals, the best we have.

“...experiments to determine whether or not Everglades peat...could be economically used for fuel for generating heat and power, or for making plastics, were undertaken.” p. 1

“...an area in the Everglades of 36 square miles and 6 feet deep peat might be used to develop 23,000,000,000 kilowatt hours. This is enough power to supply a city of 200,000 people over 40 years.” p. 223.
Soil Thickness

1940s No WCA levees
Sheet flow from EAA

REMAP
1995-96, n = 479

(Davis, 1946) (Scheidt et al 2000)

Canals in place by 1917
With drainage, subsidence began
REMAP Findings 1999

- Soil Subsidence
  - From 1946 to 1996 northern WCA3A lost 39% to 69% of its soil, depending on assumptions about Davis 1940s depth.
  - $2 \times 10^8$ to $6 \times 10^8$ m$^3$ loss

- Decreased inundation leads to
  - Soil subsidence, oxidation
  - Soil becomes less organic, more mineral
  - Relative increase in soil TP due to decrease in soil mass, and volume
  - Vegetation change is associated with higher phosphorus

(Scheidt et al 2000)
Hydroperiod Restoration

- Brown is dry, April 2012
- A Central Everglades Planning Project (CEPP) restoration goal:
  - Correct over-drainage in Northern WCA3A, WCA3B, Northeast Shark Slough
  - Re-establish peat accretion
Soil Thickness (feet) 1995-96 vs 2014
Is there evidence of change in areas most vulnerable to subsidence?

Box and whisker graph shows no indication of further subsidence between 1995-96 & 2014

Caveat: smaller sample size in 2014
Soil Thickness (feet)

1995 – 2014
n = 977

Soil Thickness (feet) 1995 to 2014

- Median
- 25%-75%
- Non-Outlier Range
- Outliers
- Extremes

Legend:
- LNWR
- WCA 2
- WCA 3AN
- WCA 3AS
- WCA 3B
- SRS
- NESS
- OM
- EMM
- TS

Map showing soil thickness distribution with boxplots for various locations.
REMAP
11 Sub-Areas

Study Area
- ENP-EASTERN MARL
- ENP-NESS
- ENP-OCHOPEE MARL
- ENP-SRS
- ENP-TAYLOR SLOUGH
- LOX
- WCA2
- WCA3-N
- WCA3-SW
- WCA3B

Canals
Miccosukee

Current Everglades Footprint (Everglades Protection Area and EAA)

(Hohner & Dreschel 2015; McVoy et al 2011)
Current Soil Volume

- Soil Volume = Area x Median Thickness ~ method A
- EPA soil volume $4.69 \times 10^9$ m$^3$ \( (n= 977) \)
- Soil Thickness: median = 2.3 feet

<table>
<thead>
<tr>
<th></th>
<th>Area (km$^2$)</th>
<th>n</th>
<th>Median Soil Thickness (m)</th>
<th>Volume (m$^3$)</th>
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<tbody>
<tr>
<td>LNWR</td>
<td>567</td>
<td>105</td>
<td>2.62</td>
<td>$1.49 \times 10^9$</td>
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<tr>
<td>WCA2</td>
<td>539</td>
<td>104</td>
<td>1.28</td>
<td>$0.69 \times 10^9$</td>
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<td>WCA 3AN</td>
<td>715.8</td>
<td>129</td>
<td>0.49</td>
<td>$0.35 \times 10^9$</td>
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<tr>
<td>WCA 3AS</td>
<td>1288</td>
<td>224</td>
<td>0.88</td>
<td>$1.14 \times 10^9$</td>
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<td>WCA 3B</td>
<td>401.4</td>
<td>78</td>
<td>1.01</td>
<td>$0.40 \times 10^9$</td>
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<td>ENP SRS</td>
<td>357.6</td>
<td>67</td>
<td>0.46</td>
<td>$0.16 \times 10^9$</td>
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<td>ENP NESS</td>
<td>251.1</td>
<td>44</td>
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<td>$0.12 \times 10^9$</td>
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<td>ENP OM</td>
<td>437.6</td>
<td>79</td>
<td>0.24</td>
<td>$0.11 \times 10^9$</td>
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<td>ENP EMW</td>
<td>693.4</td>
<td>115</td>
<td>0.21</td>
<td>$0.15 \times 10^9$</td>
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<td>ENP EME</td>
<td>137.1</td>
<td>19</td>
<td>0.21</td>
<td>$0.03 \times 10^9$</td>
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<td>ENP TS</td>
<td>59.1</td>
<td>13</td>
<td>0.91</td>
<td>$0.05 \times 10^9$</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>5447.1</strong></td>
<td><strong>977</strong></td>
<td></td>
<td><strong>$4.69 \times 10^9$</strong></td>
</tr>
</tbody>
</table>

Hohner & Dreschel 2015 ~ method B GIS based approach: surface elevation – bedrock elevation

$4.7 \times 10^9$
Soil Organic Matter & Bulk Density

Soil Organic Matter 1995-2014

Soil Bulk Density 1995 - 2014

78%

14%
Summary

• REMAP Program has documented landscape conditions at ~1000 locations (1995-6, 1999, 2005, 2014)
  • soil characteristics (thickness, organic matter, bulk density, P, N, C, Hg), & associations with water conditions, macrophytes and periphyton.
• Soil Thickness: median 2.3 feet
• Soil Volume: $4.7 \times 10^9 \text{ m}^3$
• Soil Subsidence: no indication of further subsidence from 1996 to 2014.
• REMAP Program provides CEPP baseline
• REMAP helps satisfy restoration monitoring: status and trends.
• Soil perpetuation is critical to ecosystem restoration, and is a goal of hydrologic restoration efforts
QUESTIONS?

REMAP Program data are featured in over 20 publications.
Over 30 co-authors, many agencies and universities

*Environmental Science & Technology; Environmental Pollution; International Journal of Plant Science; Aquatic Botany; Journal of Freshwater Biology; Marine & Freshwater Research; Reviews in Environmental Science & Technology*

Acknowledgements: Derek Little, Jon McMahan USEPA; Paul Conrads, USGS EDEN

Sources:
Soil Organic Matter & Bulk Density

PERCENT ORGANIC MATTER 1995 to 2014

BULK DENSITY (g/cc)
WCA3A South

- Soil Thickness = 2.9 ft (median, n=224)
- Bulk density = 0.11 g/cc
- Organic matter = 88%
- Water depth (1991-2014)* = 2.2 ft
- % of days dry* = 0%
- Abundant floculant matter

* Site 65, data from EDEN
Eastern Marl Marsh – Rocky Glades

- Soil Thickness = 0.7 ft (median, n=134)
- Bulk density = 0.45 g/cc
- Organic matter = 21%
- Water depth (1991-2014)* = 0.14 ft
- Days dry* = 42%
- Benthic periphyton mat

* NP206, data from EDEN