Valuing the Carbon Stocks in the Treasured Mangroves of the Everglades

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Florida International University
Hurricane Wilma
Benefits

Mark Spalding; The Nature Conservancy
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Benefits

- Timber & Fuel
- Fisheries
- Water Purification
- Tourism
Benefits

- Timber & Fuel
- Carbon Storage
- Fisheries
- Water Purification
- Tourism
“Ecosystem services are the benefits people obtain from ecosystems”

Millennium Ecosystem Assessment, 2005
Ecosystem Services and Mangroves

– **Provisioning**
  • Wood for fuel & construction; food (fish); fiber; leather; paper etc.

– **Cultural**
  • Recreational, aesthetic and spiritual benefits

– **Supporting**
  • Nutrient retention, water quality improvement through filtration of sediments and pollutants; Soil accretion

– **Regulating**
  • Flood mitigation; protection from strong winds & waves; soil stabilization & erosion protection; **Carbon sequestration & storage**
Introduction

Mangroves and various ecosystem services

- Global primary production: 218 ± 72 Tg C yr⁻¹

Carbon storage and sequestration

- Mangrove forests in the Indo-Pacific region: 1023 Mg/ha

- As a contrast, carbon storage in tropical upland, temperate, and boreal forests (200–400 Mg/ha)

- Mitigates climate change effects

Blue Carbon in Mangroves

- Direct herbivory
- Adjacent environments
- Atmosphere

Aboveground biomass
- Leaves
- Stem
- Wood

Belowground biomass
- Fine & coarse roots

C stored in kg = Biomass (kg) * C conversion factor

Diagram source: dem.qld.gov.au
Picture: IUCN report 2009
CRITICAL STORAGE
MANGROVES

50% LOSS
ON COVERAGE IN THE LAST 50 YEARS

Mangroves are being lost at a rate of 2% per year. Experts estimate that carbon emissions from mangrove deforestation account for up to 10% of emissions from deforestation globally, despite covering just 0.7% of land coverage.
Mangrove Forests of Everglades National Park

Meenakshi Jerath
Mangrove Forests of Everglades National Park

Total area 1,445 km² or 144,447 ha
Mangrove Forests of ENP
Everglades Mangrove Ecotone Region (EMER)

• Subtropical

• Known to have high productivity

• **Not** threatened by direct human impact
  (unlike other mangrove forests)
Water management

Sea level rise & salt intrusion

Urban development, agricultural impacts

Pulses

Presses

ENP Mangroves

Varying spatial and temporal scales

Simard et al. (2006)

(Photograph: FCE LTER)
Why this research?
Objectives

Assess quantity and economic value of legacy carbon in Everglades mangroves
Ecological Challenges for Valuation

• Uncertainty in accurate estimations of C sequestration and storage
  – Complex, dynamic C cycling in wetlands
  – Variability in primary production and C accumulation through space and time
  – Short-term storage or sequestration is more uncertain
  – Human impacts on wetlands
  – But
    • Keep in mind the unique protected nature of Everglades mangroves
    • Can still serve as a sink for long-term storage
Economic Challenges for Valuation

- Various methodologies for valuation
- Carbon prices influenced by several technological, regulatory, economic and social factors
- C prices vary across countries and markets.
What is the Purpose of Valuation of Carbon?

• **Not** necessarily to promote a market for carbon

• Policy relevance:
  – Justification for long-term restoration funds
  – Baseline for carbon benefits of future restoration efforts
  – US commitment to the 2015 Paris Agreement
  – Mangroves potential to be included in national climate strategy
“Under the Paris Accord the US 2025 GHGs target is at 26% to 28% below 2005 levels.

US emissions in 2005 ~ 7 billion metric tons (EPA report)

With all current and proposed policies, the US will MISS the target by 1.5 billion metric tons or 20% of the target.”

The role of economic, policy, and ecological factors in estimating the value of carbon stocks in Everglades mangrove forests, South Florida, USA

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Study Area

Mark Spalding; The Nature Conservancy
Spatial distribution and location of the Taylor and Shark River sloughs in the Everglades National Park

Source: FCE LTER
Environmental gradients

Hurricane events

Riverine Mangroves
Shark River Slough (SRS)

Taylor River Slough (TS)

Scrub mangroves

Pictures: FCE LTER, Bhat & Victor Rivera-Monroy

Biodiversity: Meenakshi Jerath obtains samples of a mangrove forest in the Shark River Estuary

Credit: Victor H. Rivera-Monroy

Castaneda-Moya et al. (2010)
Total Organic Carbon in the EMER

\[ \text{TOC} = \text{C}_{\text{AGR}} + \text{C}_{\text{BGR}} + \text{C}_{\text{BGS}} \]

*Total Organic Carbon  = C in Aboveground biomass + C in Roots + C in Soils*
Map of mean tree height of mangroves of ENP

- Simard et al. 2006
- Shuttle Radar Topography Mission (SRTM), Light Detection and Ranging (LiDAR) data, and field data
- Most mangroves in scrub category
- Mean tree height of scrubs: 3.2 ± 1.3m
Belowground C: Roots and Soil

- 229 soil cores from 6 FCE-LTER sites
- Root cores 0–0.9m, <20mm diameter
- Plant C conversion ~44% (Ewe et al. 2006)
- 4 soil cores each from the 6 FCE-LTER sites
- Depth 0.45m

Castañeda Moya et al. 2011; 2013
Comparison of Carbon Stocks in Terrestrial Ecosystems and Mangroves

<table>
<thead>
<tr>
<th>Ecosystem</th>
<th>Mean Estimate of C (Mg C per hectare)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical</td>
<td>242</td>
<td>Pan et al., 2011</td>
</tr>
<tr>
<td>Temperate</td>
<td>155</td>
<td>Pan et al., 2011</td>
</tr>
<tr>
<td>Boreal</td>
<td>239</td>
<td>Pan et al., 2011</td>
</tr>
<tr>
<td>Tropical Mangroves</td>
<td>1023</td>
<td>Donato et al., 2011</td>
</tr>
<tr>
<td>ENP Mangroves</td>
<td><strong>335.6</strong></td>
<td>This study</td>
</tr>
</tbody>
</table>

Carbon Stored in Different Ecosystems

![Graph showing carbon storage in different ecosystems](image-url)
Selection and Development of Carbon Prices
Selection and Development of C Prices

- Three methods:
  - Social Cost of Carbon Emission or the Damage Cost that People want to avoid
  - Cost of Abatement of Carbon Loss or Cost of Mangroves Restoration
  - Market Value of Carbon
<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total CERP cost 1998</td>
<td>7,800,000,000</td>
<td>182,000,000</td>
</tr>
<tr>
<td>compounded to 2010 at 3%</td>
<td>12,892,211,532</td>
<td>300,818,269</td>
</tr>
<tr>
<td>80% of the above CERP-related</td>
<td>10,313,769,225</td>
<td>240,654,615</td>
</tr>
<tr>
<td>cost for freshwater for natural system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(the rest for urban and agr. area)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Everglades mangroves area (ha) | 144,447 |

in Acres                                 | 356,784 |

Mean current C (MgC/ha)                  | 335.7   |
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial cost of projects 2010</td>
<td>10,313,769,225</td>
</tr>
<tr>
<td>Annual maintenance cost ($/year)</td>
<td>240,654,615</td>
</tr>
<tr>
<td>Total PV cost over the life of the project</td>
<td>8,021,820,509</td>
</tr>
<tr>
<td>Discounted at 3%</td>
<td></td>
</tr>
<tr>
<td>Total cost of preservation (Initial + annual maintenance)</td>
<td>18,335,589,734</td>
</tr>
<tr>
<td>Total &quot;GREEN ACRES&quot; promised by CERP</td>
<td>2,400,000</td>
</tr>
<tr>
<td>Total CERP area</td>
<td>971,660</td>
</tr>
<tr>
<td>Percent of mangroves to Everglades area</td>
<td>14.86</td>
</tr>
<tr>
<td>(Mangroves to total CERP area)</td>
<td></td>
</tr>
<tr>
<td>Cost of preservation prorated to mangroves area</td>
<td>2,725,769,457</td>
</tr>
<tr>
<td>Per hectare preservation cost</td>
<td>18,870</td>
</tr>
<tr>
<td>Per Ton cost ($)</td>
<td>56</td>
</tr>
</tbody>
</table>
Selection and Development of C Prices

- Maximum Value People are Willing to Pay which is equal to the Social Cost of Carbon Emission
- Market price of Carbon
- Cost of Provision of a Service or Maintaining the Existing Carbon
- Actual Current Market price of Carbon (effect of undervalued carbon)
Selection and Development of C Prices

- Avoided Social Cost = $56,045 /ha
- Cost of Provision of a service $18,794 /ha
- Market price of Carbon $6,041 /ha
## Economic Valuation of the Carbon Stored in EMER

<table>
<thead>
<tr>
<th>Valuation Method</th>
<th>Price ($/ton)</th>
<th>Carbon (ton/ha)</th>
<th>Carbon Value ($/ha)</th>
<th>Total Area</th>
<th>Total ENP C Value (Billion $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Cost Method</td>
<td>167</td>
<td>335.6</td>
<td>56,045</td>
<td>144,447</td>
<td>8.10</td>
</tr>
<tr>
<td>Abatement Cost Method</td>
<td>56</td>
<td>335.6</td>
<td>18,794</td>
<td>144,447</td>
<td>2.71</td>
</tr>
<tr>
<td>Market Price Method</td>
<td>18</td>
<td>335.6</td>
<td>6,041</td>
<td>144,447</td>
<td>0.87</td>
</tr>
</tbody>
</table>
# Economic Valuation of the Carbon Stored in EMER

## Table 2

<table>
<thead>
<tr>
<th>Total Organic Carbon in ENP Mangroves (MgC/ha)</th>
<th>Average Abatement Cost for ENP mangroves ($/tC(^a))</th>
<th>Economic Valuation of C stored in ENP mangroves per ha ($/ha)</th>
<th>Economic Valuation of total C storage in ENP mangrove forests(^b)($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median + SE Value</td>
<td>247.5</td>
<td>56</td>
<td>13,860</td>
</tr>
<tr>
<td>Median Value</td>
<td>335.6</td>
<td>56</td>
<td>18,794</td>
</tr>
<tr>
<td>Median - SE Value</td>
<td>423.7</td>
<td>56</td>
<td>23,727</td>
</tr>
</tbody>
</table>

Total Organic Carbon (median value) in ENP mangroves: 335.6 MgC/ha * 144,447 ha = 48,476,413 MgC.

The median economic value for ENP mangroves based on:
- SCC ($167/tC) = $56,045/ha.
- RGGI market price ($18/tC) = $6041/ha.
- International voluntary market price ($14.36/tC) = $48,199/ha.

\(^a\) 1tC = 1 metric ton Carbon = 1 MgC.
\(^b\) ENP mangrove forest area: 144,447 ha.
## Benefit Cost Analysis

<table>
<thead>
<tr>
<th></th>
<th>Per Unit area Value of ENP Mangrove Carbon based on Social Cost of Carbon/Per Unit area Value of ENP Mangrove Carbon based on CERP Abatement Cost</th>
<th>$56,045/$18,794</th>
<th>2.98</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Social BCA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Economic BCA</strong></td>
<td>Per Unit area Value of ENP Mangrove Carbon based on Market Price/Per Unit area Value of ENP Mangrove Carbon based on CERP Abatement Cost</td>
<td>$6,041/$18,794</td>
<td>0.32</td>
</tr>
</tbody>
</table>

*Making a case for public funding to protect carbon storage in the ENP Mangroves*
Ecological criteria for valuation

• Forest age
  – Mature and intact forest has interconnectivity, functional redundancy, richness of ecosystem services
  – Variability in ecosystem services and function
  – The status of the forest as a protected area
Economic criteria for valuation

• Type of Carbon valued—short vs long term storage
  – Sequestered C: SCC or Market price
  – Stored C: Abatement cost

• Robustness of C markets
  – C markets and REDD+ schemes designed for C sequestration, plantations
  – Protected area C not included as yet

• Stage of policy cycle: Economic and political environment
  – Willingness to Pay—reflected in policy?
Conclusions

• Change in public perception about C storage, global benefits
• Foster robust C markets
• Effective management strategies
• Assist policy dialogues
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• NASA-JPL project
  • Vulnerability Assessment of Mangrove Forest Regions of the Americas (LSU Subcontract# 1452878)

• Dr. Keqi Zhang, Daniel Gann, and Himadri Biswas of Florida International University for their valuable support in using GIS methodology.
Coastal resiliency utilizing trees and living shorelines

Michael Houle  RLA, CGC

Miami Dade Parks Recreation and Open Spaces Department
Atoll pool

Atoll walking path @ low tide

Atoll walking path @ King tide
Atoll pool

Dead Calophyllum trees

Conocarpus erectus var. sericeus
Silver buttonwood

Conocarpus erectus
Green buttonwood

Coccoloba uvifera
Sea grape

Beach erosion / Die back

Conocarpus erectus var. sericeus
Silver buttonwood
South Matheson Park – Kayak launch

Hose bib @ low tide

Hose bib @ high tide

Laguncularia racemosa
White mangrove

Avicennia germinans
Black mangrove

Rhizophora mangle
Red mangrove

Laguncularia racemosa
White mangrove
Typical Tree Planting Detail

WOOD BRACE
LAYOUT:
WOOD BRACE
SPACED AT 90°
APART

90°
90°
90°
90°

NOTE:
LANDSCAPE CONTRACTOR TO
REMOVE ALL STAKES / GUYS 1
YEAR AFTER FINAL ACCEPTANCE

DRIP LINE

ARBORLOCK STAKING
SYSTEM WITH 3" THICKNESS
OF BURLAP WRAPPED
AROUND TRUNK

TO BE OF SUCH
HEIGHT AS TO
PROVIDE PROPER
SUPPORT

1/8" BURLAP TURNED DOWN
(B&B)

COMPACTED
SOIL AS
NEEDED

TREE PROTECTION
4 - 2" x 4" BRACES EQUALLY SPACED AROUND TRUNK
2" MELALEUCA MULCH (FLORA MULCH OR
EQUAL) INSTALLED TO CREATE A 6" MINIMUM
DIAMETER RING AROUND THE TREE.
2" x 4" AT BASE OF EACH BRACE TO
PREVENT FROM KICKING OUT
FINISH GRADE

RAISED ROOT BALL 3" ABOVE GRADE

6" SOIL BERM (TYP.)
EXISTING SOIL
BACK FILL WITH LOOSE EXISTING SOIL
2017 LEAF SUMMIT

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