Pricing the Carbon right: The case of the Everglades mangroves

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Introduction

- Mangroves and ecosystem services
  - Global primary production 218 ± 72 Tg C yr^{-1}
- Carbon storage (C stock) and sequestration (rate of removal)
  - Mitigates climate change effects
- Global threats to mangroves
  - deforestation, global warming
- Economic valuation of carbon sequestration and storage

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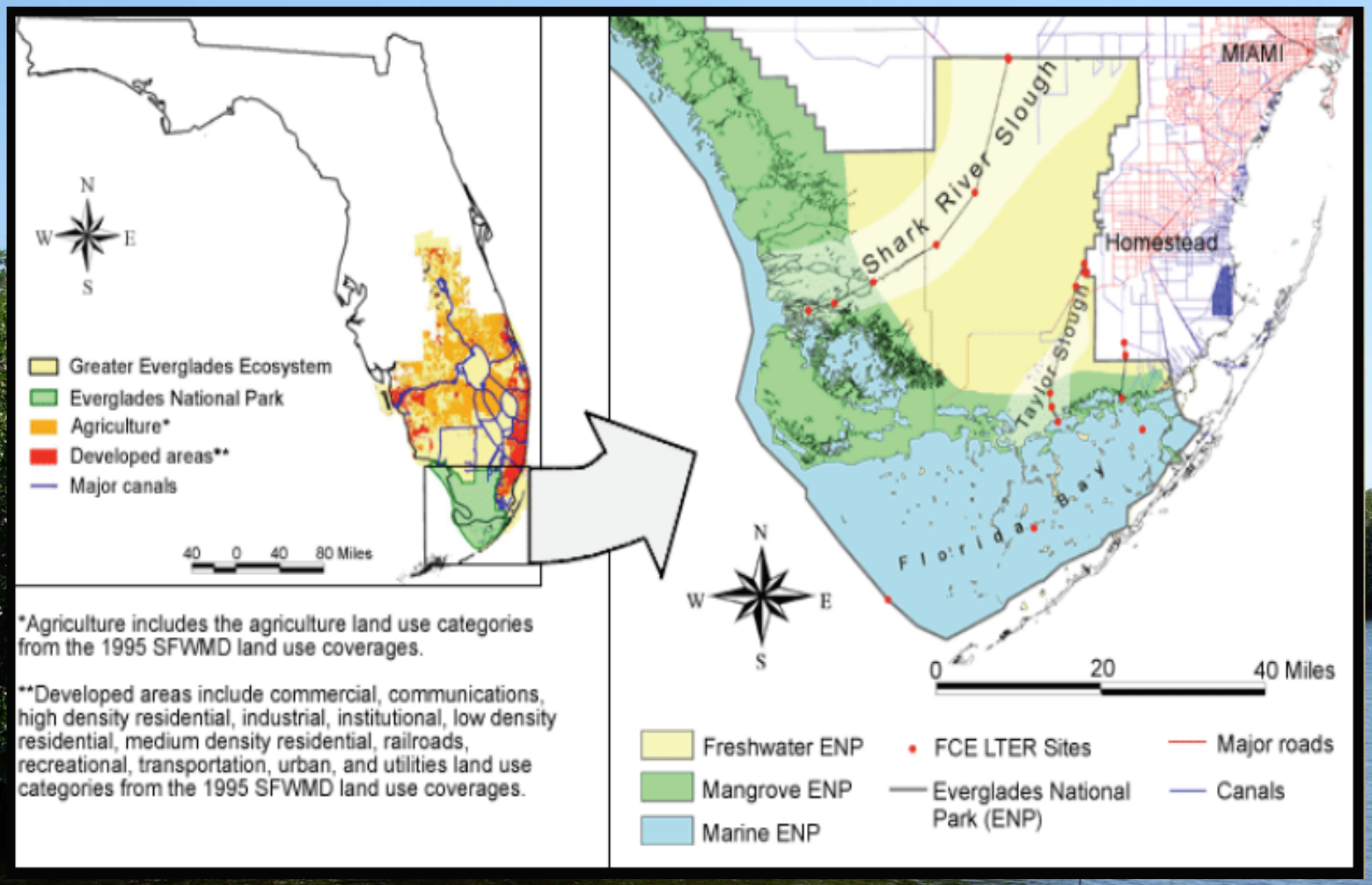
Mangrove forests of Everglades National Park



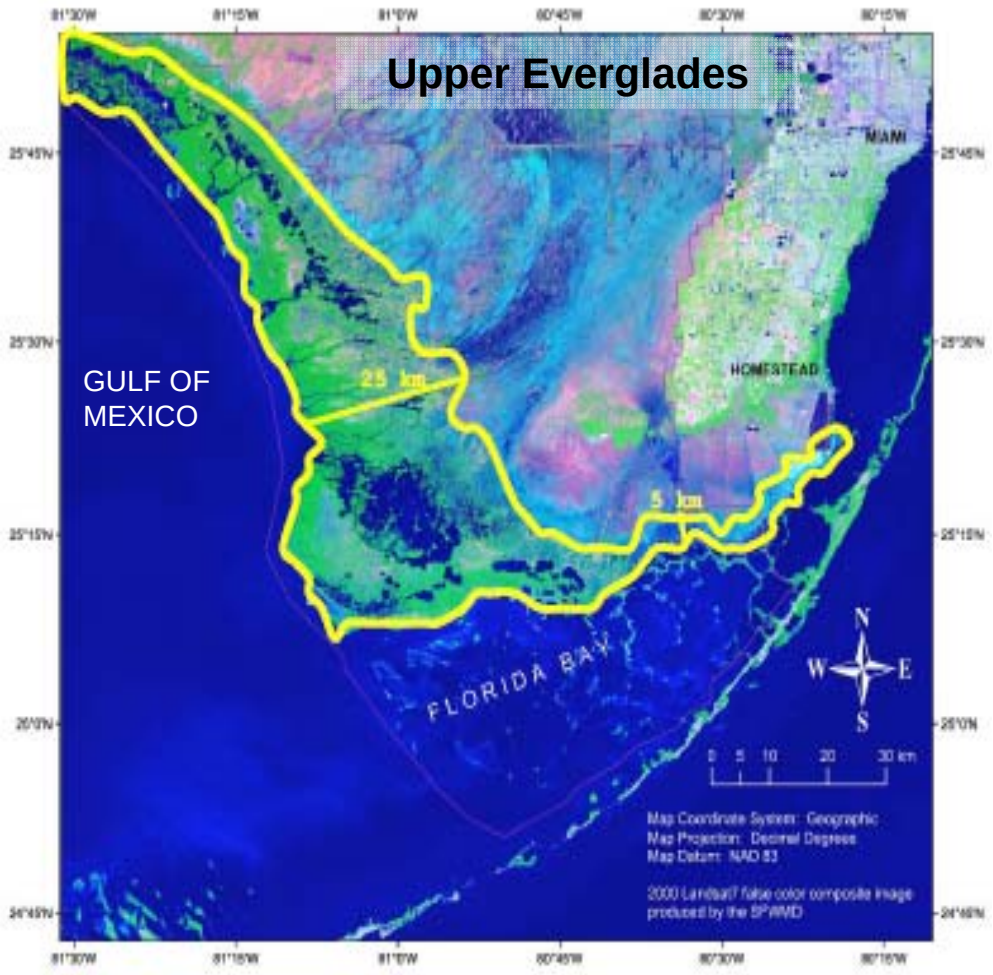
Total area 144,447 ha

Map source: F LTER

Mangrove Forests of ENP

Everglades Mangrove Ecotone Region (EMER)

- Subtropical
- Carbonate platform
- Oligotrophic
- P- the limiting nutrient
- **“Upside down estuary”**
  (Childers et al. 2006)
- **High productivity**
- **Not threatened by direct human impact**
  (unlike other mangrove forests)



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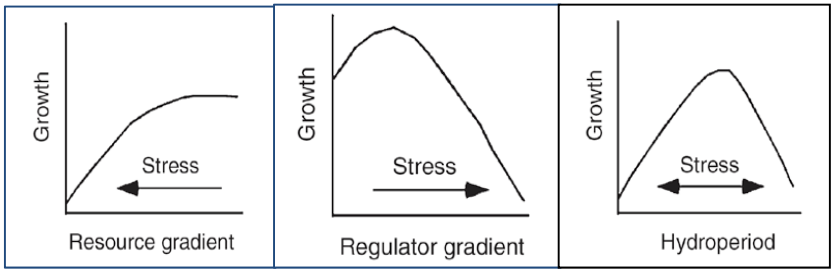
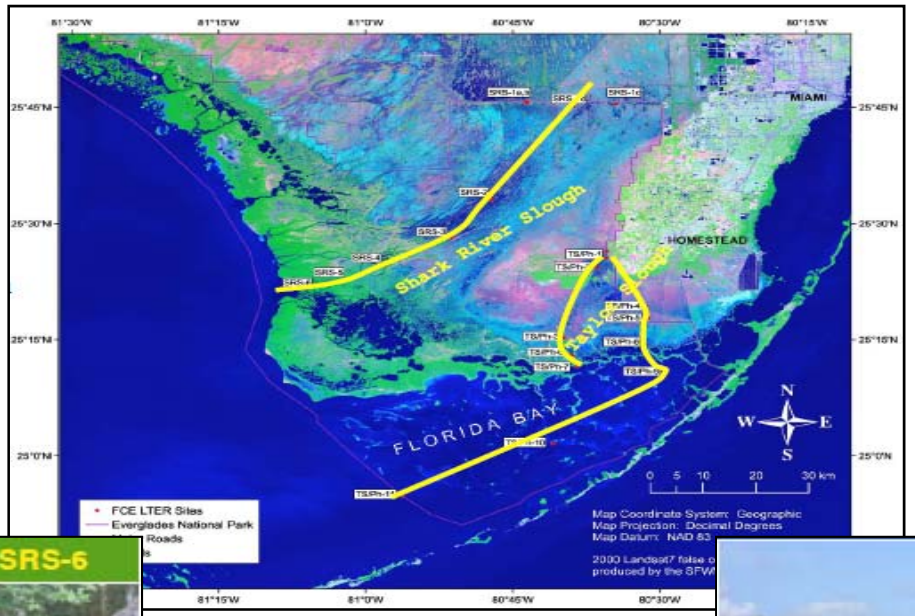
Environmental gradients



Hurricane events



Riverine Mangroves

Shark River Slough (SRS)

Scrub mangroves

Taylor River Slough (TS)

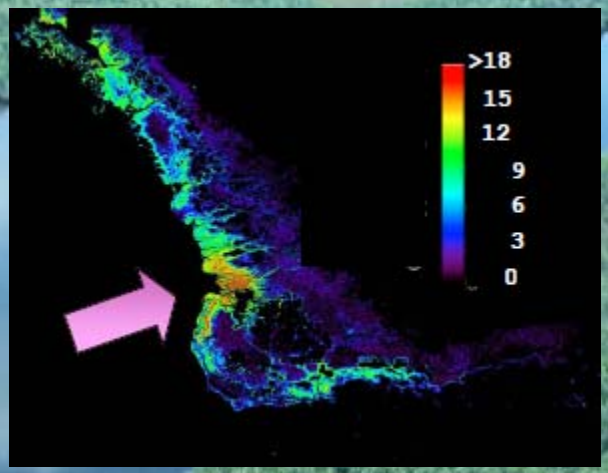
Pictures: FCE LTER

ENP Mangroves

Pulses

Presses

FCE-LTER



Simard et al. (2006)

- Water management
- Sea level rise
- Urban development

Varying spatial and temporal scales

(Photograph: FCE LTER)

Economic valuation of C storage

- Challenges
  - Large uncertainty in C storage estimations of coastal wetlands (Hopkinson et al, 2012)
    - Variability and uncertainty in mangrove production and C accumulation through space and time (Alongi, 2011)
    - C storage temporary
    - C cycling dynamic: hydrological conditions regulate exchange of organic and inorganic C b/w land and water
    - Wetland expansion reduced by human impacts
    - ***But*** keep in mind the unique protected nature of Everglades mangroves

Our estimation of C storage , therefore, a rental value of "parking" the organic C, not the fixed value of C in the biological pool

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Economic valuation of C storage

- Challenges
  - Lack of well developed C markets
  - Economic valuation varies with methodologies
  - C prices influenced by technological, regulatory, economic, social factors
  - Value transfer inappropriate
    - Distinct geographical location, ecogeomorphic characteristics, nature of presses and pulses that affect mangrove functions

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Economic valuation of C storage

- Challenges
  - Market failure problem of a global public good
  - Under valuation in private markets
  - Contested ecosystem service policy
  - Ignored by policy makers

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Purpose of our study

- First estimation of total organic C storage in mangrove forests of the Everglades National Park
- Economic valuation of the total organic C storage
- Hypotheses:
  - Significant organic C storage, particularly belowground
  - Higher economic value because of protected nature of the forest and ecogeomorphic attributes

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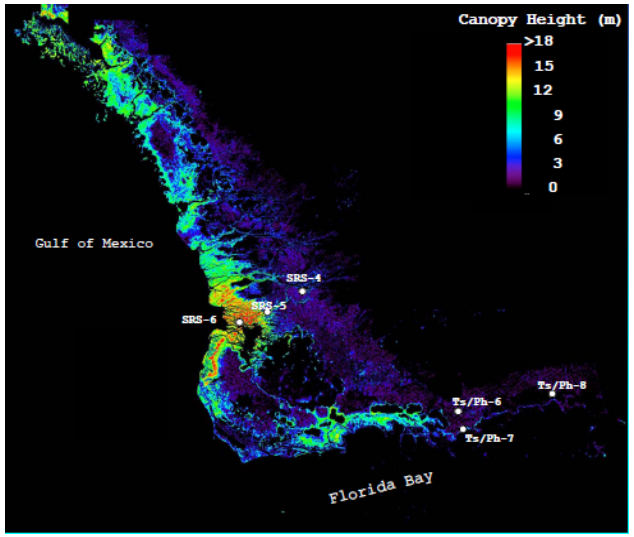
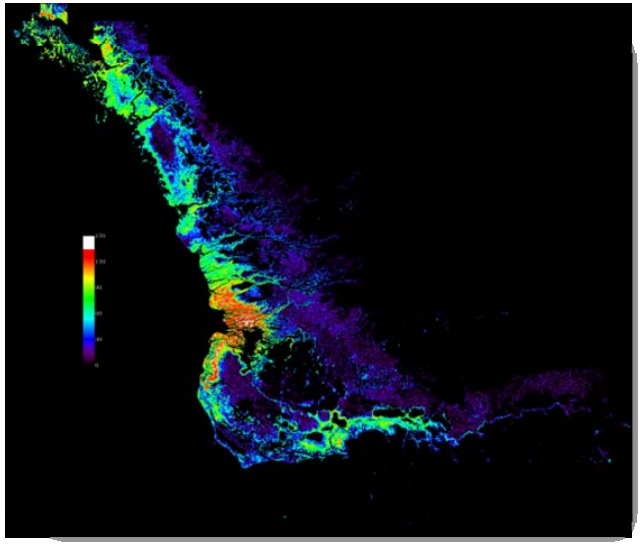
Estimation of Total Organic Carbon (TOC)

Landscape level estimation of Total Organic Carbon

$$TOC = Aboveground\ TOC + Belowground\ TOC\ (Roots + Soil)$$



Mean tree height
(Simard et al., 2006)



Standing Biomass distribution
(Rivera-Monroy et al., 2011)

Carbon Conversion factor = 0.44
(Ewe et al., 2006)

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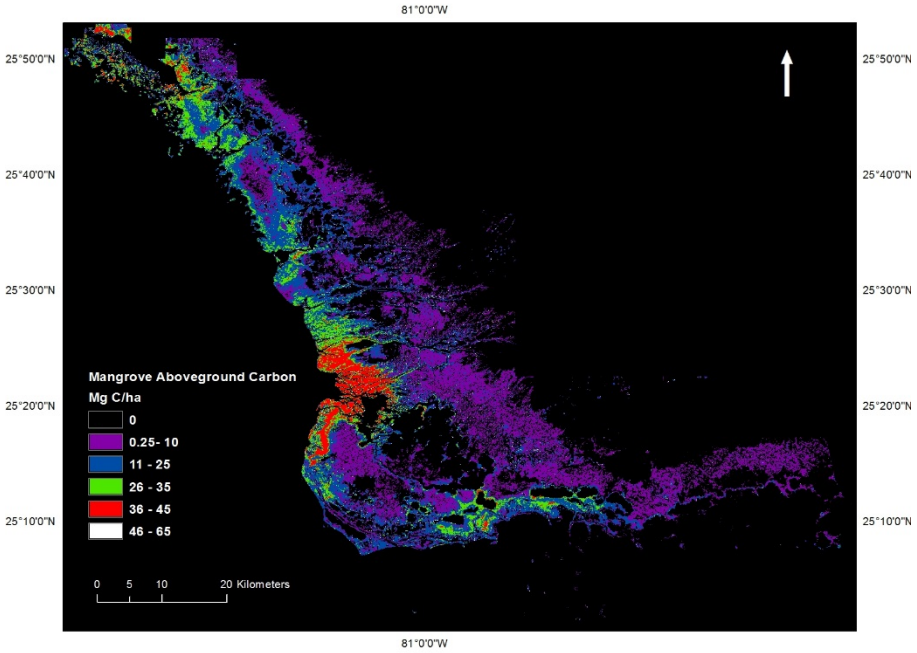

Aboveground Carbon in Standing Biomass of ENP mangroves

Carbon Conversion factor = 0.44

(Ewe et al., 2006)

FCE-LTER Study Site	Soil Organic Carbon MgC/ha (0.9m)	Total Organic Carbon MgC/ha
SRS-4	373.5 ± 23.8	421
SRS-5	476.1 ± 14.2	518
SRS-6	365.4 ± 7.7	437
TS/Ph-6	28.8 ± 3.8(.12m)	34
TS/Ph-7	450 ± 27.7	456
TS/Ph-8	291.4 ± 18.3	293
Mean	**330.87 ± 66.1**	

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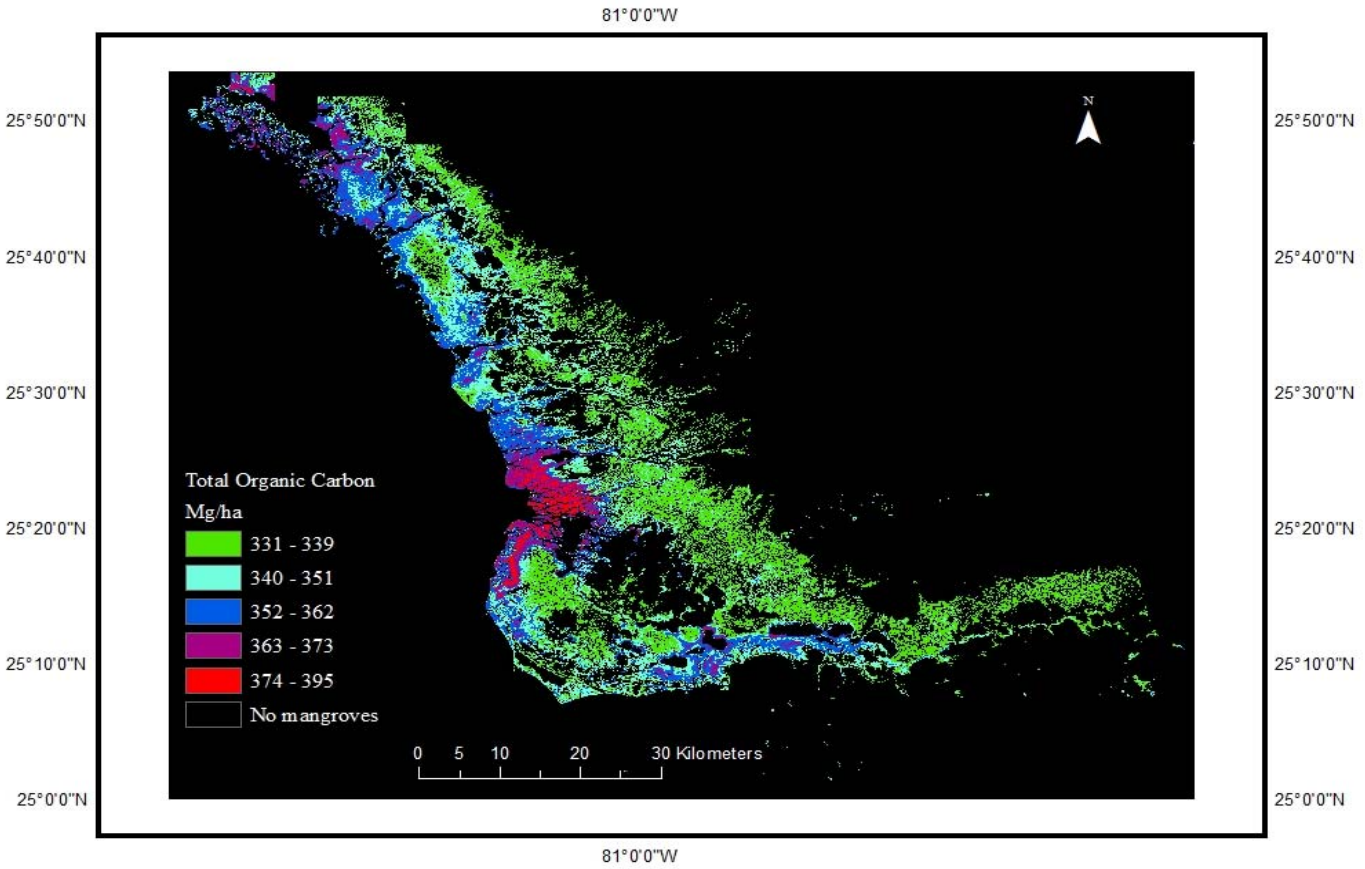

Estimation of Total Organic Carbon (TOC)

Landscape level estimation of Total Organic Carbon

$$TOC = Aboveground\ TOC + Belowground\ TOC\ (Roots + Soil)$$

Mangrove Forest Component	Mean Estimate (Mg C/ha)	Standard Deviation	Total Organic Carbon (Mg C)
Aboveground Organic Carbon	14.15	11.29	1,792,019
Belowground Organic Carbon	330.87	161.92	
Total Organic Carbon	**345.01**	162.31[d]	43,705,154 (23,144,243 – 64,266,065)

Mangrove Forest Carbon Storage in ENP, Florida

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Comparison of Carbon Stocks in Terrestrial Ecosystems and Mangroves

Ecosystem	Mean Estimate of C (Mg C per hectare)	Source
Tropical	242	Pan et al., 2011
Temperate	155	Pan et al., 2011
Boreal	239	Pan et al., 2011
Tropical Mangroves	1023	Donato et al., 2011
ENP Mangroves	**345 ± 162.31**	This study

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Selection and Development of C Prices

Valuation methodology	Source	Cost of Carbon ($/ton)	Value of C Storage ($/ha)	Mean estimate ($/ha)	Total Value ($)	Mean estimate (billion $)
Social Cost of Carbon	Peer reviewed[a] (Tol, 2011)	80	27,601	22,426	3,496,412,321	**2.84**
	U.S. Interagency report[b], 2010	86	29,671		3,758,643,245	
	Tol, 2011	59	20,356		2,578,604,087	
	Nordhaus	35	12,075		1,529,680,390	

Social Cost of Carbon

WTP of society to avoid damages caused by C emissions

Every unit of sequestered C has the ability to prevent damage from occurring

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Selection and Development of C Prices

Valuation methodology	Source	Cost of Carbon ($/ton)	Value of C Storage ($/ha)	Mean estimate ($/ha)	Value of C storage ($)	Mean estimate (billion $)
Marginal Abatement Cost	Globalized MAC[c]	233	80,387	41,211	10,183,300,884	**5.22**
	Fisher and Nakicenovic et al., 2007[d]	129	44,506		5,637,964,867	
	Stavins and Richards, 2005	70	24,151		3,059,360,781	
	CERP	**45.8**	**15,801**		**2,001,696,054**	

Marginal Abatement Cost

Cost of maintaining/reducing C emissions

Cost of restoring/preserving existing mangrove, stored Carbon

Selection and Development of C Prices

Valuation methodology	Source	Cost of Carbon ($)	Value of C Storage ($/ha)	Mean estimate ($/ha)	Value of C storage ($)	Mean estimate (billion $)
Market price	EU ETS[g]	79	27,256	12,190	3,452,707,167	**1.54**
	CER[h]	46	15,870		2,010,437,084	
	secondary CERs	40	13,800		1,748,206,160	
	RGGI[i]	**7**	**2,415**		**305,936,078**	
	VER[j]	22	7,590		961,513,388	
	REDD[k]	18	6,210		786,692,772	

Market Price of Carbon

Individual WTP for Carbon storage/ sequestration

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Ecological Criteria for Valuation

- Variability in ecosystem services and functions
  - Sequestration non-linear, varies with time and space in coastal ecosystems
  - Distinct geomorphic settings (e.g., delta vs. karstic)
  - Landscape level disturbances
- Forest age
  - Mature, intact forests
    - Interconnectivity, functional redundancy, variety of ecosystem services (Alongi, 2012; Rivera-Monroy et al., 2013)
- Status of ENP mangroves as a protective area
  - Regulate climate through C storage
  - Limited/no extractive uses → significant sinks of C
  - ENP mangroves unique
    - Not influenced by direct or indirect extractive uses
    - Higher restrictive IUCN management category, more effective

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Economic Valuation of the Carbon Stored in EMER

Valuation Methodology	Type	$/ton C	$/ha	Total Value of Everglades mangrove C
Market Price	RGGI	7	**2,415** (1,281–3,549)	**$306 million** ($162 – 450 million)
Marginal Abatement Cost	Average abatement cost of C for the Everglades mangroves	45.8	**15,801** (8,381–23,221)	**$2 billion** ($1.06– 02.94 billion)

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Conclusion

- Landscape level C value of Everglades mangroves
  - Ecological attributes
  - Status as a protected area
  - Economic and political environment
- Change in public perception about C storage, global benefits
- Foster robust C markets
- Effective management strategies
- Assist policy dialogues
- Cost of inaction derived from social cost of C ($22,426/ha)
- Cost of mangrove restoration in the Everglades from average abatement cost ($45.8/tC)

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Limitations

- Wide range of C values
  - Variation in C stock across landscape – spatial gradient in biomass distribution
  - Need for more long-term sampling points across the Everglades
  - Ecosystem service maps
- No single economic value of C
  - Must be used in appropriate context
- C storage and sequestration only one of the many services that mangroves

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