Blue Carbon

Mitigating CO_2 Emissions through Coastal and Estuarine Ecosystem Conservation & Restoration

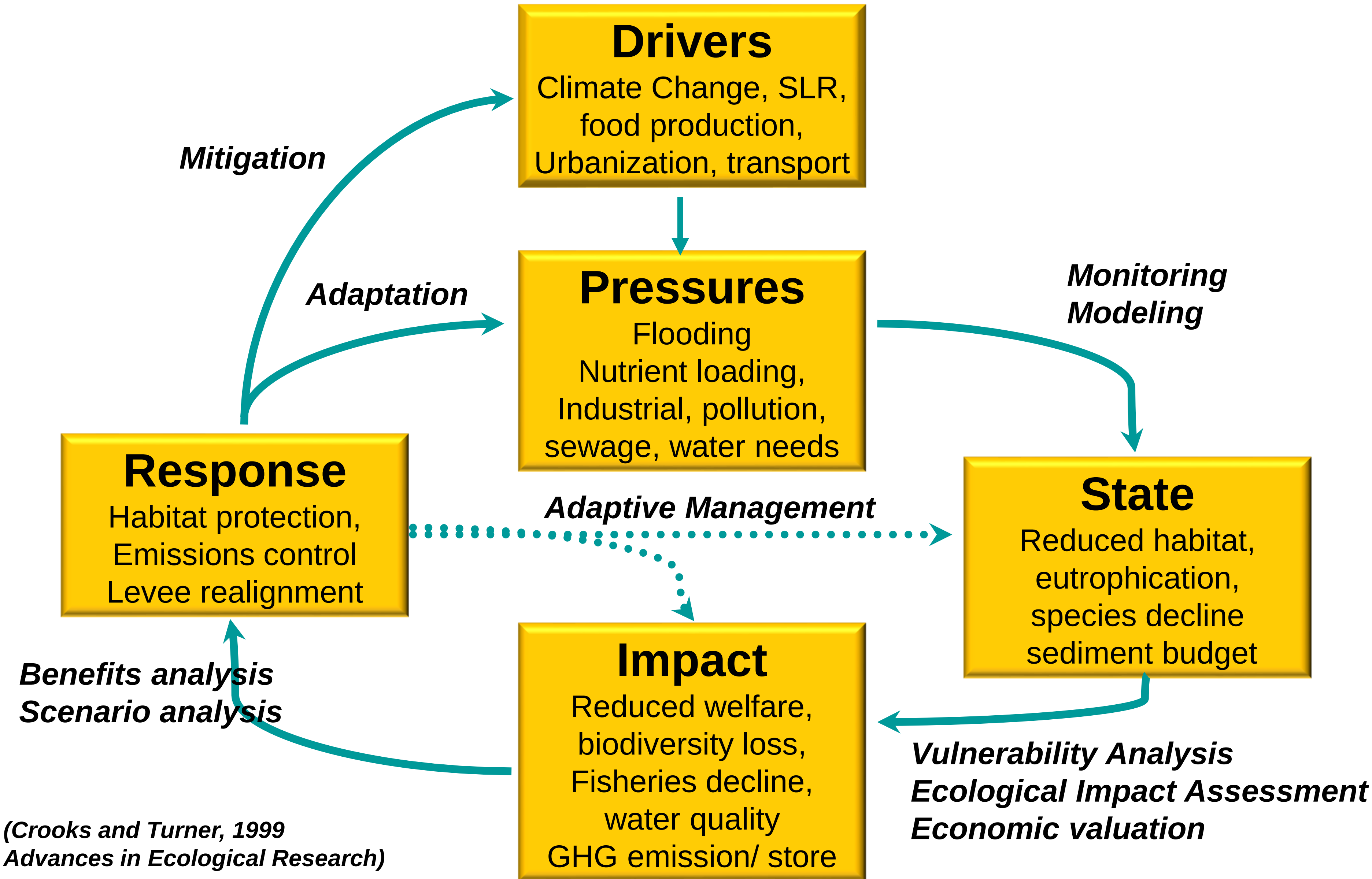
Stephen Crooks Ph.D.

Silvestrum Climate Associates

Baton Rouge
June 28h, *2016*

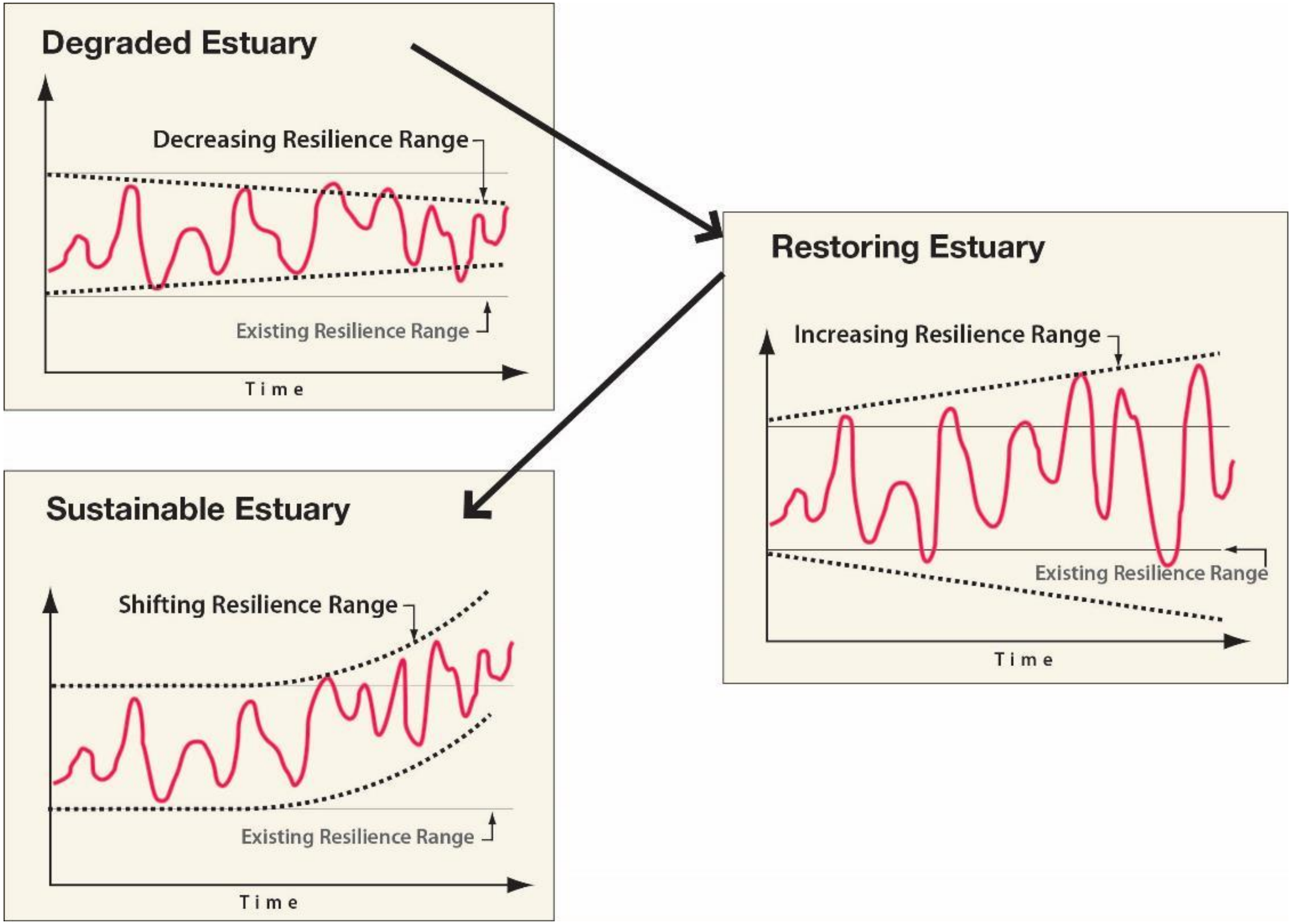
silvestrum
CLIMATE ASSOCIATES

Sustainable Management

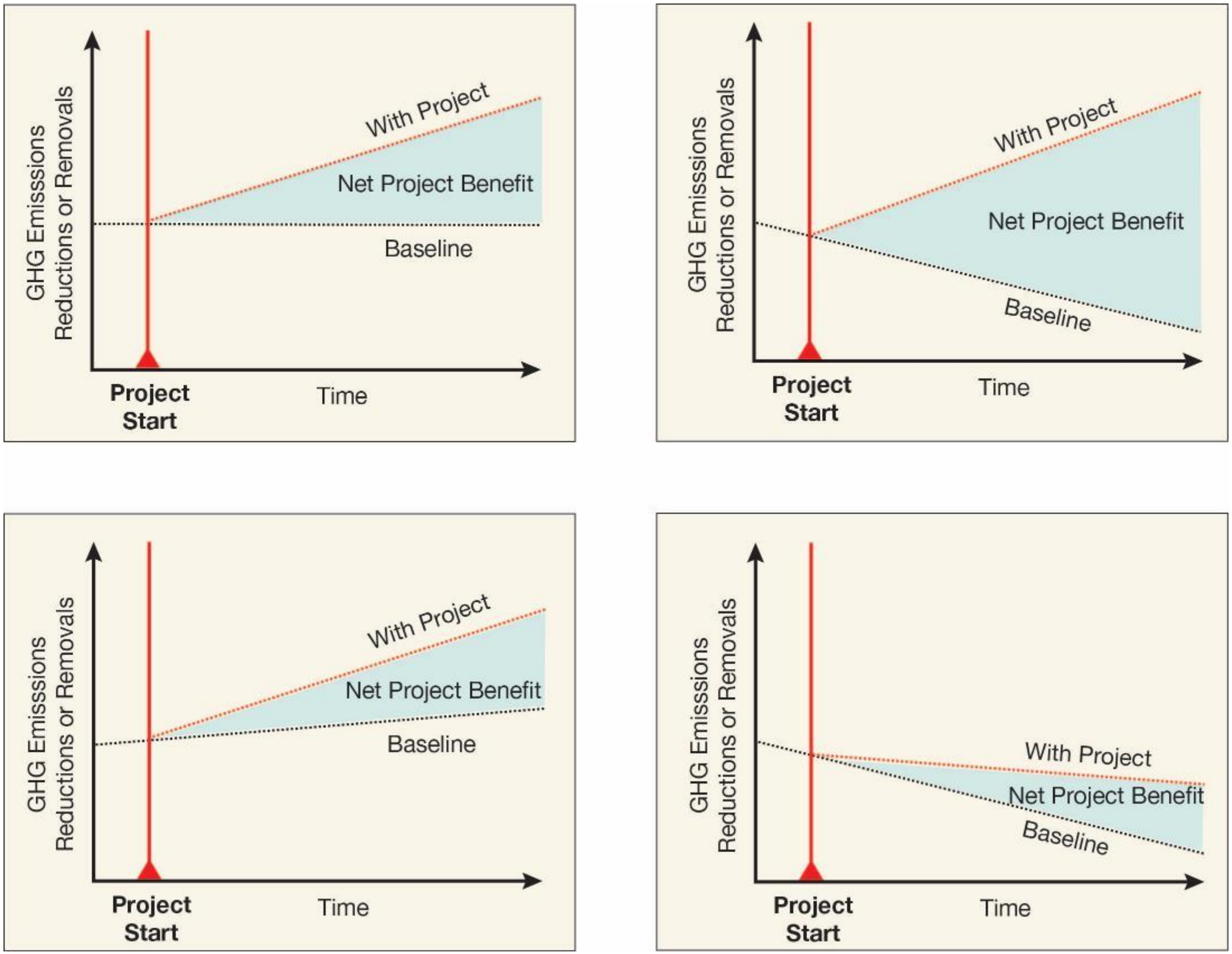


(Crooks and Turner, 1999
Advances in Ecological Research)

Goal of Ecosystem Management (Adaptation)



Goal of Carbon Management



Source: Forest Trends

Paris Agreement on Climate

- Signed by 195 nations. If fully implemented the Paris Agreement on Climate could signal the beginning of the end of the fossil fuel era. Challenges faced.

- Goals are to hold global temperatures below 2^{o}C relative to pre-levels with an ambitious target of 1.5^{o}C.

- Sea-level will continue to gradually rise under these warming scenarios though the potential of catastrophic change are reduced.

- Elements:
  - Financing and technical support to developing countries
  - <u>Inclusion of forests and soils</u>
  - Country commitments to action.

Connecting the dots on blue carbon ecosystems…

1. *Components of an integrated multiuse landscape*
2. *Sustainable livelihoods and economies*
3. *Climate mitigation and adaptation*
4. *Natural Infrastructure and flood risk reduction*
5. *Ameliorating local ocean acidification*

Qwuloolt Wetland Restoration Project


silvestrum
CLIMATE ASSOCIATES
GREENLAND
(Kalaallit Nunaat)
DENMARK
Svalbard
Franz Josef Land
North Land
A R C T I C O C E A N
CHUKCHI SEA
EAST SIBERIAN SEA
RUSSIAN FEDERATION
KAZAKHSTAN
MONGOLIA
CHINA
INDIA
IRAN
SAUDI ARABIA
ALGERIA
SUDAN
NIGERIA
ANGOLA
NAMIBIA
SOUTH AFRICA
SOMALIA
INDONESIA
PAPUA NEW GUINEA
AUSTRALIA
UNITED STATES OF AMERICA
MEXICO
BRAZIL
CHILE
VENEZUELA
N O R T H P A C I F I C O C E A N
N O R T H A T L A N T I C O C E A N
S O U T H A T L A N T I C
I N D I A N O C E A N
S O U T H E R N O C E A N
THE WORLD
MERCATOR PROJECTION
0 km 1000 2000 3000 km
© Ezilon.com All Right Reserved.
ezilon.com

Developing the Learning Curve

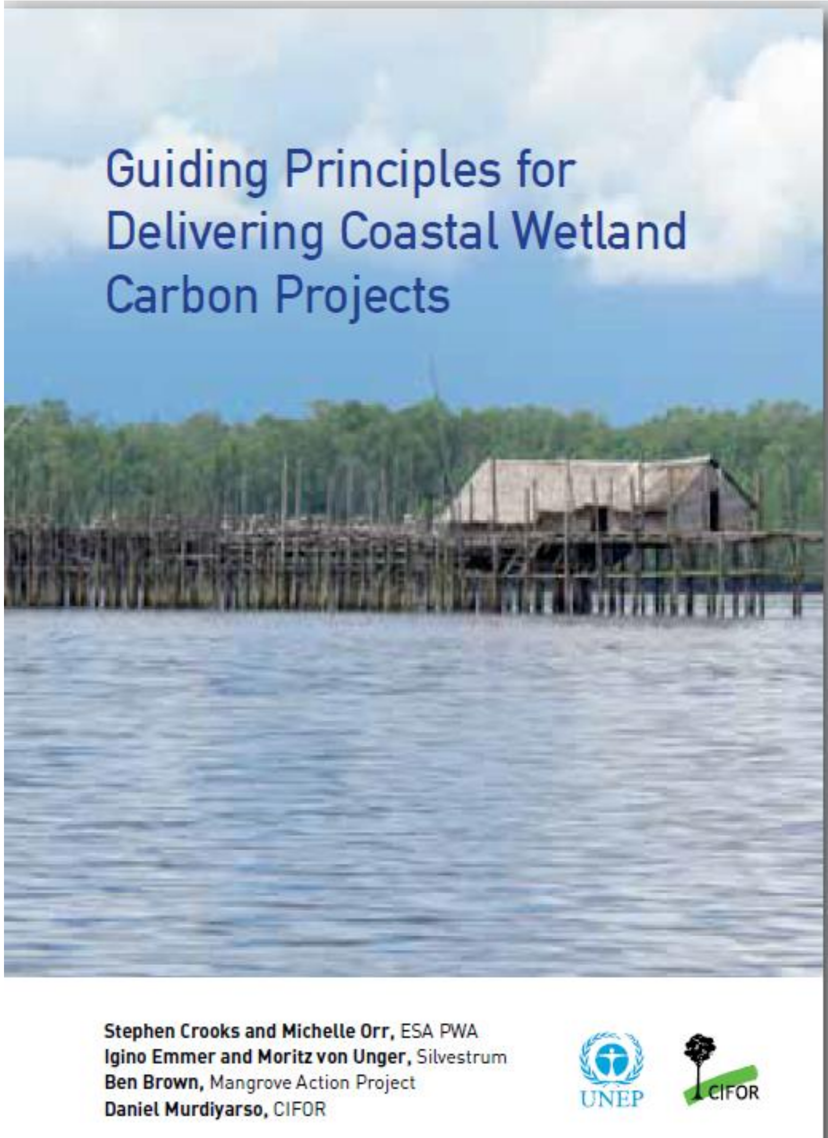
1. Recognize value of wetland management
2. Establish examples of good practice
3. Achieve multi-use functional landscape

4. Adaptation to climate change
5. Incorporate GHG fluxes and storage

Blue Carbon Interventions:

Policy adjustment
Management actions
Carbon finance projects

Available at Silvestrum.com



silvestrum
CLIMATE ASSOCIATES

Blue Carbon: The Game Plan

the BLUE CARBON initiative

- United Nations Framework Convention on Climate Change
  - Brief national climate change negotiators
  - Identify policy opportunities
  - Engage IPCC and SBSTA
  - Multi-national demonstration projects

- National Governments
  - Establish programs and science research
  - Recognize wetlands in national accounting
  - Agency awareness, action, funding
- Local Demonstration and Activities
  - Landscape level accounting
  - Establish carbon market opportunities
  - Look for synergistic conservation benefits
  - Demonstration projects and public awareness

Coastal (blue carbon) ecosystems in focus for climate change mitigation

Forest

Peatland

Mangroves

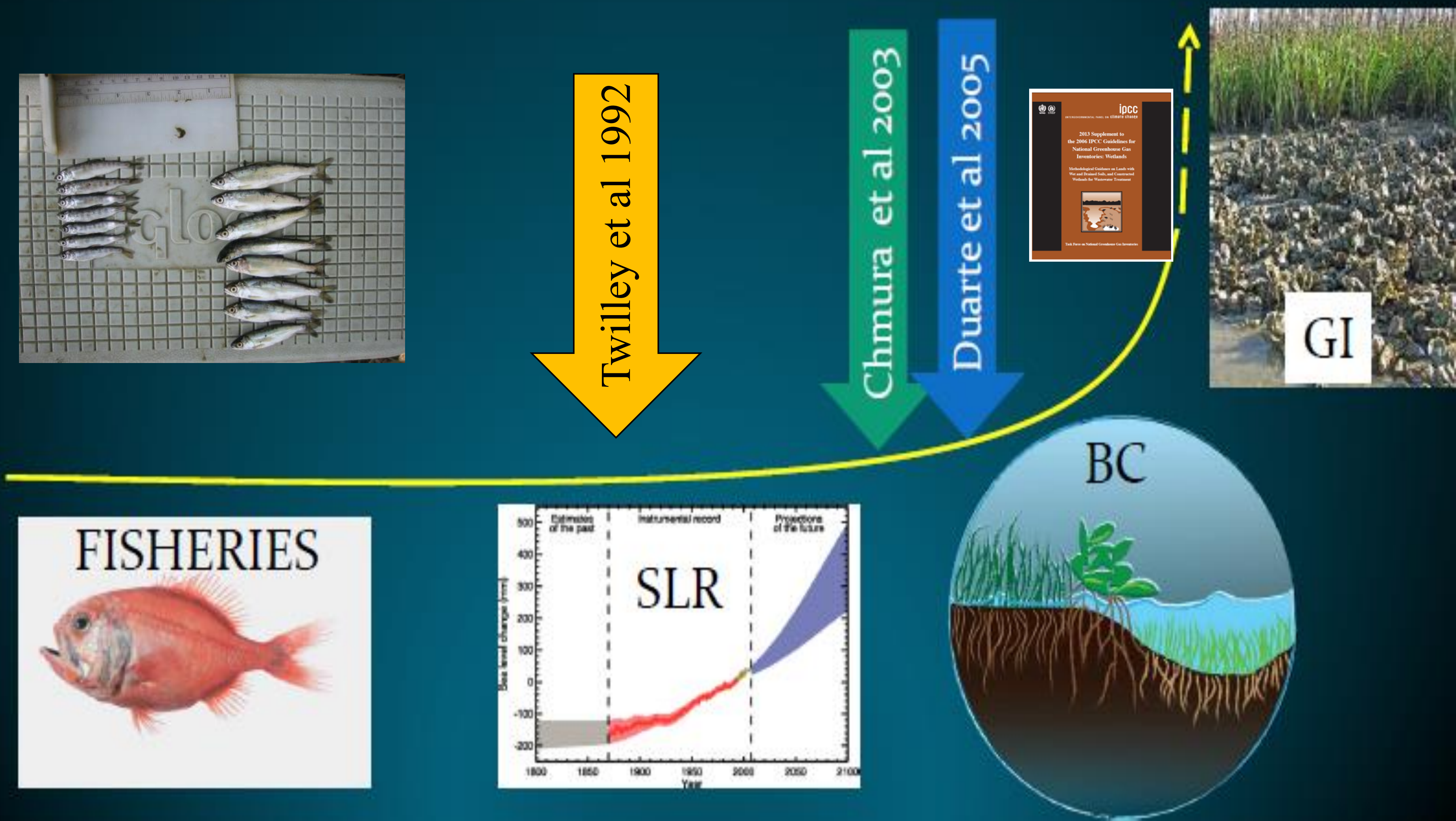
Tidal Marshes

Seagrass

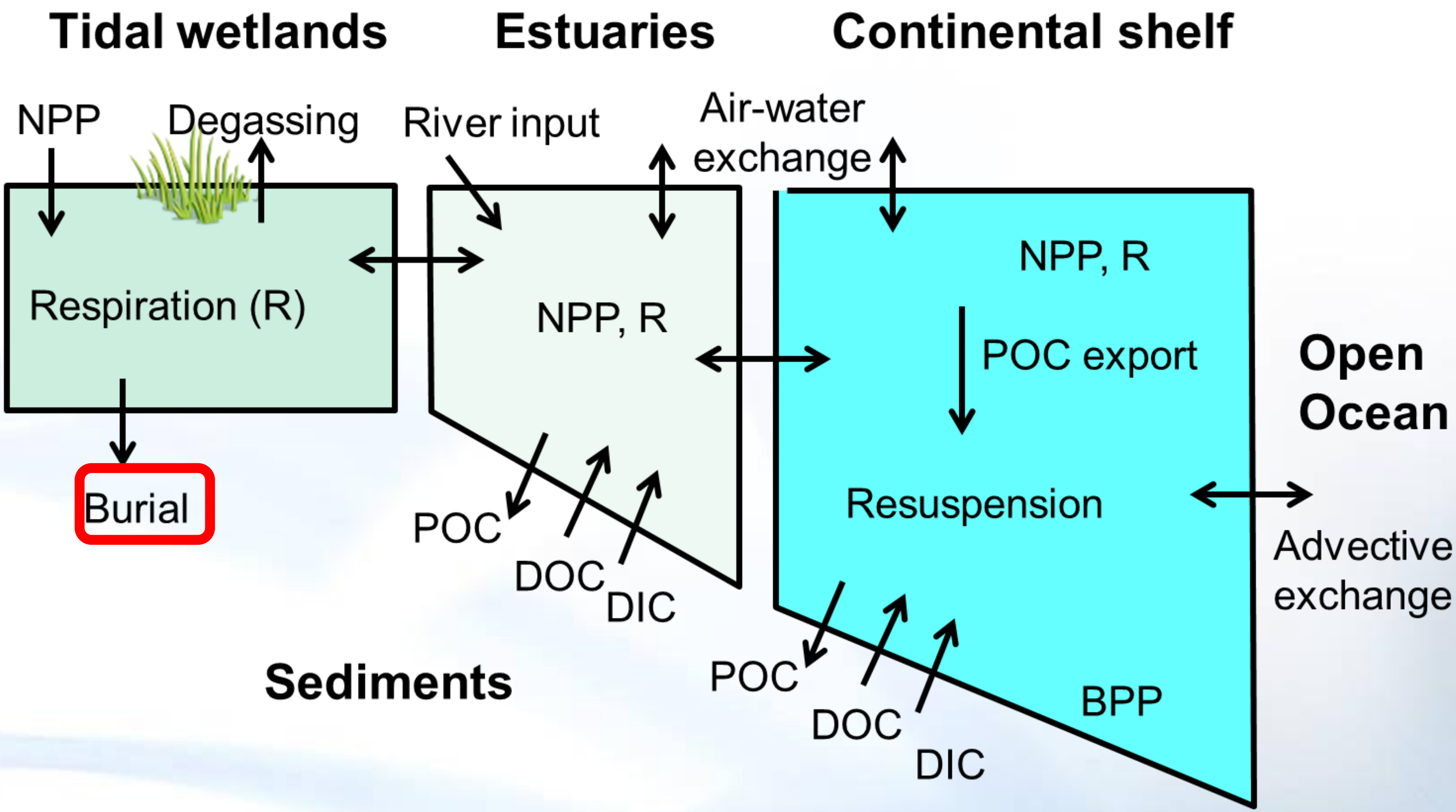
Coastal Ecosystems: Long-Term Carbon Sequestration and Storage

The state of blue carbon science:

a short review of achievements and gaps



Carbon fluxes and storage



silvestrum
CLIMATE ASSOCIATES

OPEN ACCESS Freely available online

PLOS ONE

Estimating Global "Blue Carbon" Emissions from Conversion and Degradation of Vegetated Coastal Ecosystems

Linwood Pendleton[1¶], Daniel C. Donato[2*¶], Brian C. Murray[1], Stephen Crooks[3], W. Aaron Jenkins[1], Samantha Sifleet[4], Christopher Craft[5], James W. Fourqurean[6], J. Boone Kauffman[7], Núria Marbà[8], Patrick Megonigal[9], Emily Pidgeon[10], Dorothee Herr[11], David Gordon[1], Alexis Baldera[12]

Table 1. Estimates of carbon released by land-use change in coastal ecosystems globally and associated economic impact.

	Inputs			Results	
Ecosystem	Global extent (Mha)	Current conversion rate (% yr^{-1})	Near-surface carbon susceptible (top meter sediment+biomass, Mg CO_2 ha^{-1})	Carbon emissions (Pg CO_2 yr^{-1})	Economic cost (Billion US$ yr^{-1})
Tidal Marsh	2.2–40 (5.1)	1.0–2.0 (1.5)	237–949 (593)	**0.02–0.24 (0.06)**	**0.64–9.7 (2.6)**
Mangroves	13.8–15.2 (14.5)	0.7–3.0 (1.9)	373–1492 (933)	**0.09–0.45 (0.24)**	**3.6–18.5 (9.8)**
Seagrass	17.7–60 (30)	0.4–2.6 (1.5)	131–522 (326)	**0.05–0.33 (0.15)**	**1.9–13.7 (6.1)**
Total	33.7–115.2 (48.9)			**0.15–1.02 (0.45)**	**6.1–41.9 (18.5)**

Compare to national emissions from all sources

Poland

Japan

Tidal Wetland Net GHG Removal Potential

Wetland Type	Carbon Sequestration Potential (tons CO_2e/acre/year)	Methane Production Potential (tons CO_2e/acre/year)	Net balance
Salt Marsh (salinity >18ppt)	**High (0.74 – 3.71)**	**Low (< 0.2)**	**High C sequestration**
Mangrove	High (0.74 – 3.71)	Low – High	Depends on salinity
Brackish Tidal Marsh (salinity <20 ppt)	High (0.74 – 6.68)	High (0.51 – 10.12)	Approx net balance[1]
Subsidence Reversal (managed FWTM)	Very High (8 - 25)	Very High (5 - 12)	Potential very high C sequestration[2]
Freshwater Tidal Marsh	Very High (2.02+)	Very high	Approx net balance
Estuarine Forest	High (1.49 – 3.71)	Low (< 1.01)	High C sequestration

Crooks et al, 2009 Tidal Wetlands Offset Issues Paper.

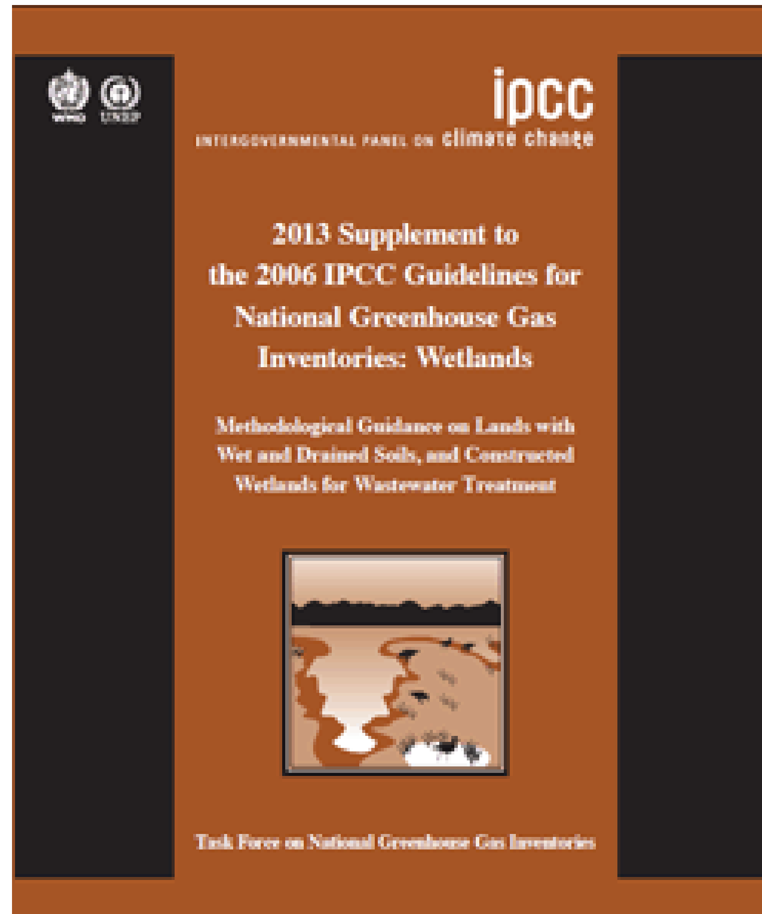
[1] Too few studies to draw firm conclusions. CH_4 emissions brackish wetlands may negate carbon sequestration within soils. Further research required.

[2] Too few studies to draw firm conclusions. CH_4 emissions from

Methodological Guidance for Coastal Wetlands in the *2013 SUPPLEMENT TO THE 2006 IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES: WETLANDS*

2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands

1. Introduction
2. Drained Inland Organic Soils
3. Rewetted Organic Soils
4. Coastal Wetlands
5. Inland Wetland Mineral Soils
6. Constructed Wetlands for Wastewater Treatment
7. Cross-cutting Issues and Reporting



Adopted by IPCC Oct 2013, Published Feb 2014
http://www.ipcc-nggip.iges.or.jp/

U.S. Coastal Wetlands:
Potential Emissions and Removal

- **Drainage and excavation**
- **Human induced subsidence of wetlands (erosion)**
  - **(e.g. Mississippi Delta)**
- **Methane emissions from tidally disconnected /impounded waters**
- **Forestry Activities on Coastal Wetlands.**
- **Restoration of coastal wetlands and seagrasses**
- **Aquaculture (operations)**

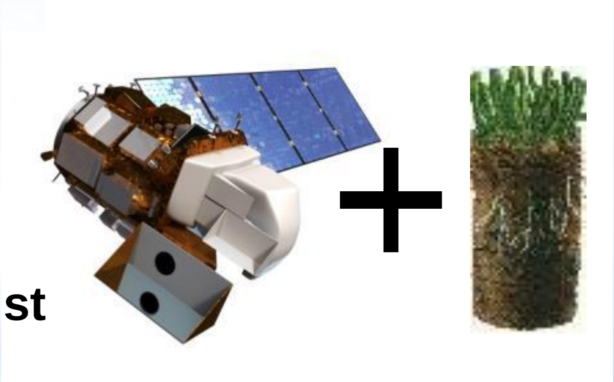
"Blue" Carbon Monitoring System

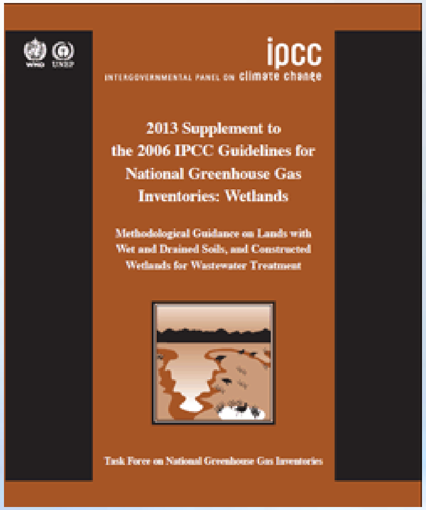
Linking soil and satellite data to reduce uncertainty in coastal wetland carbon burial:

a policy-relevant, cross-disciplinary, national-scale approach

Lisamarie Windham-Myers (18 Science PIs; October 2014-17)

Federal		Non Federal	
USGS	Brian Bergamaschi	U. South Carolina	Jim Morris
	Kristin Byrd	U. Maryland/NOAA	Ariana Sutton-Grier
	Judith Drexler	U. San Francisco	John Callaway
	Kevin Kroeger	Florida Intl. U.	Tiffany Troxler
	John Takekawa	Texas A&M U.	Rusty Feagin
	Isa Woo	Independent	Stephen Crooks
Postdoc:	Meagan Gonneea		
NOAA-NERR	Matt Ferner		
Smithsonian	Pat Megonigal		
	Don Weller		
	Lisa Schile		
Postdoc:	**James Holmquist**		
NASA-JPL	Marc Simard		




ipcc
INTERGOVERNMENTAL PANEL ON climate change

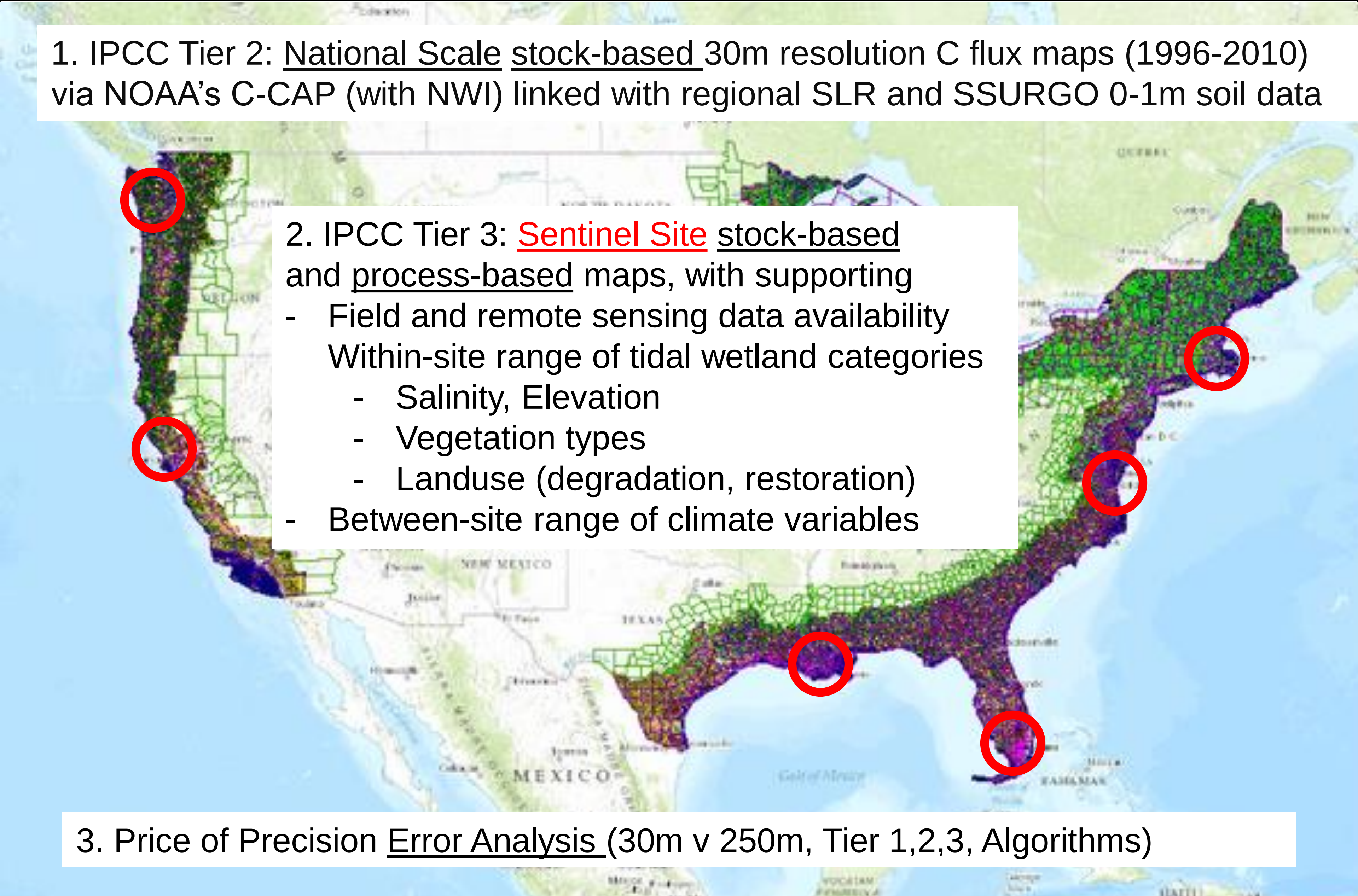
2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands

Methodological Guidance on Lands with Wet and Drained Soils, and Constructed Wetlands for Wastewater Treatment

Task Force on National Greenhouse Gas Inventories

“Blue” CMS – Product Goals

1. IPCC Tier 2: National Scale stock-based 30m resolution C flux maps (1996-2010) via NOAA’s C-CAP (with NWI) linked with regional SLR and SSURGO 0-1m soil data



2. IPCC Tier 3: Sentinel Site stock-based and process-based maps, with supporting
- Field and remote sensing data availability
  Within-site range of tidal wetland categories
  - Salinity, Elevation
  - Vegetation types
  - Landuse (degradation, restoration)
- Between-site range of climate variables

3. Price of Precision Error Analysis (30m v 250m, Tier 1,2,3, Algorithms)

silvestrum CLIMATE ASSOCIATES

Key Methodology Development Issues

Real	Demonstrate that reductions have actually occurred
Additional	Ensure reductions result from activities that would not happen in the absence of a GHG market
Permanent	Mitigate risk of reversals Verify reductions ex-post
Verified	Provide for independent verification that emission reports are free of material misstatements
Owned unambiguously	Ownership of GHG reductions must be clear
Not harmful	Avoid negative externalities
Practicality	Minimize project implementation barriers

silvestrum
CLIMATE ASSOCIATES

Lessons from Conservation and Restoration Planning

1. Have a clear and coherent planning approach
2. Plan conservation and restoration in the wider landscape context
3. Prioritize sites (not all are suitable)
4. Restore physical processes and ecosystem dynamics
5. Recognize the value of project design and engineering
6. Understand the restoration trajectory and ecological thresholds
7. Conserve and restore ecosystems sooner rather than later
8. Restoration of historic conditions is not always possible
9. Avoid transplantation of non-indigenous species
10. Be patient

silvestrum CLIMATE ASSOCIATES

Lessons learnt from carbon projects

1. Assume ownership of the project
2. Choose and demarcate the site(s) carefully
3. Choose the project standard and project delivery cycle
4. Access the market early
5. Link the project to other finance options
6. Check the costs and prepare for economies of scale

Lessons from community engagement

1. Invest in pre-project community capacity building
    - E.g. Field schools
2. Build capacity within government
    - National support
    - Subnational support
3. Meet in the middle
    - Train exensionists,
    - stakeholder communication
4. Establish livelihoods programs

Steps in Blue Carbon Project Planning

1. Define project concept and perform preliminary feasibility assessment.
2. Define target market and select a carbon standard
3. Establish effective community engagement
4. Design project activities
5. Assess permanence risk and develop mitigation strategy
6. Secure project development finance and structure agreements
7. Provide for legal due diligence and assess carbon rights
8. Provide for social and environmental impacts assessment
9. Maintain ongoing liaison with regulators.
10. Share and publish experience – build the learning curve

silvestrum
CLIMATE ASSOCIATES

Example Project Activities

- **Conservation**
  - Protection of at risk wetlands
  - Improved water management on drained wetlands
  - Sediment recharge to coastal wetlands
  - Space for migrating wetlands

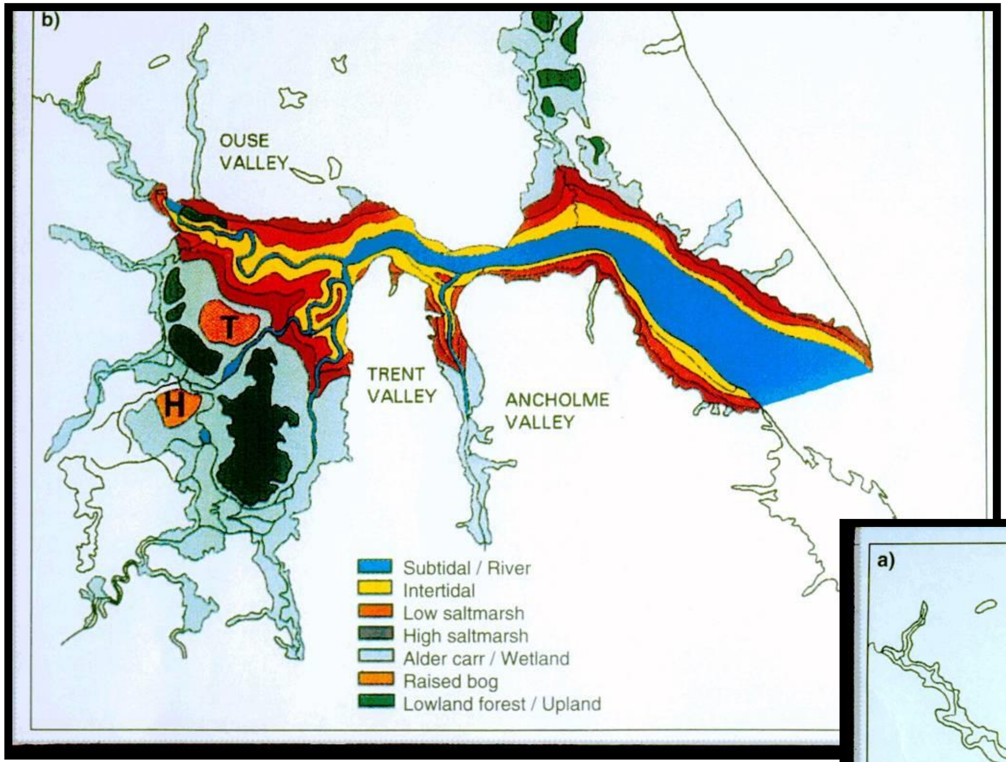
- **Restoration / creation**
  - Lowering of water levels on impounded wetlands
  - Raising soil surfaces with dredged material
  - Increasing sediment supply by removing dams
  - Restoring salinity conditions
  - Improving water quality
  - Revegetation
  - Combinations of the above

silvestrum CLIMATE ASSOCIATES

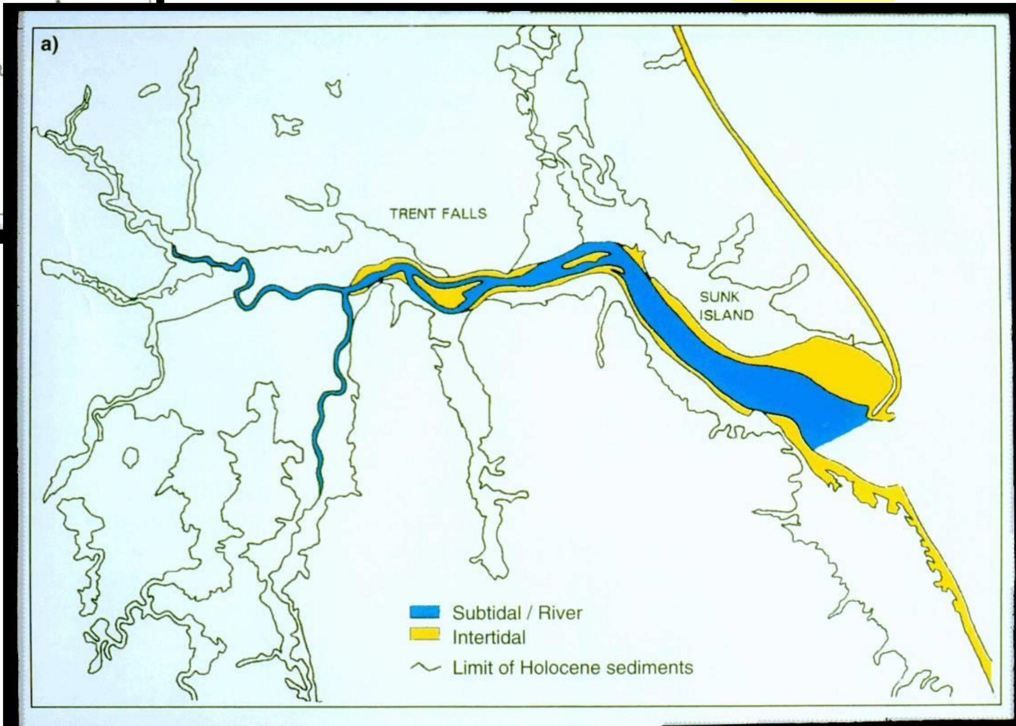
The Humber Estuary

405 km of levees
870 km^2 of drained wetlands

Historic



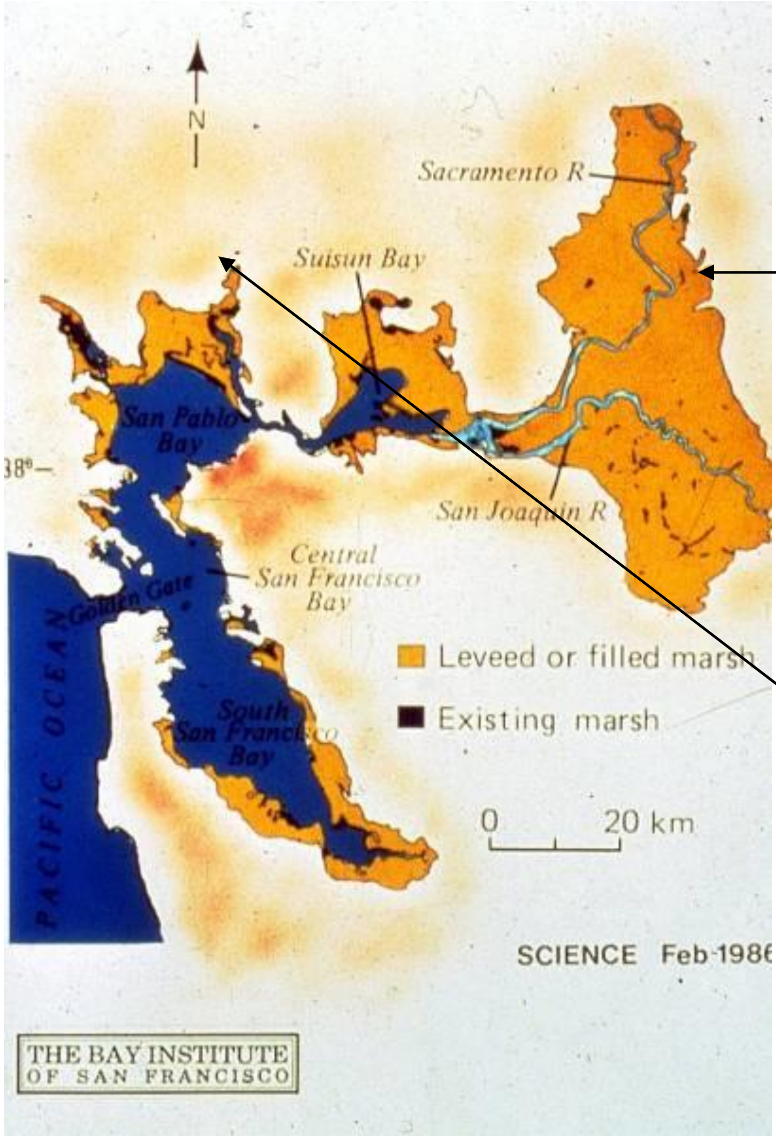
Now



Loss of biomes and carbon stocks.

Ongoing emissions

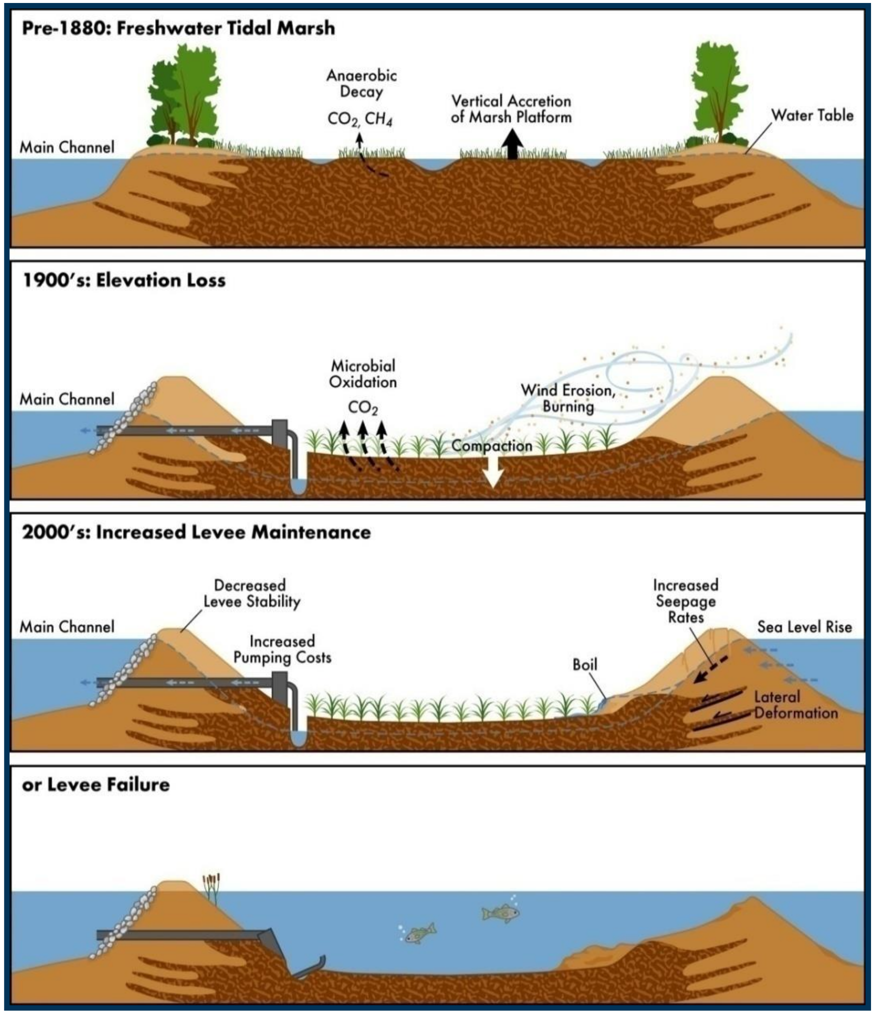
Examples from San Francisco Estuary

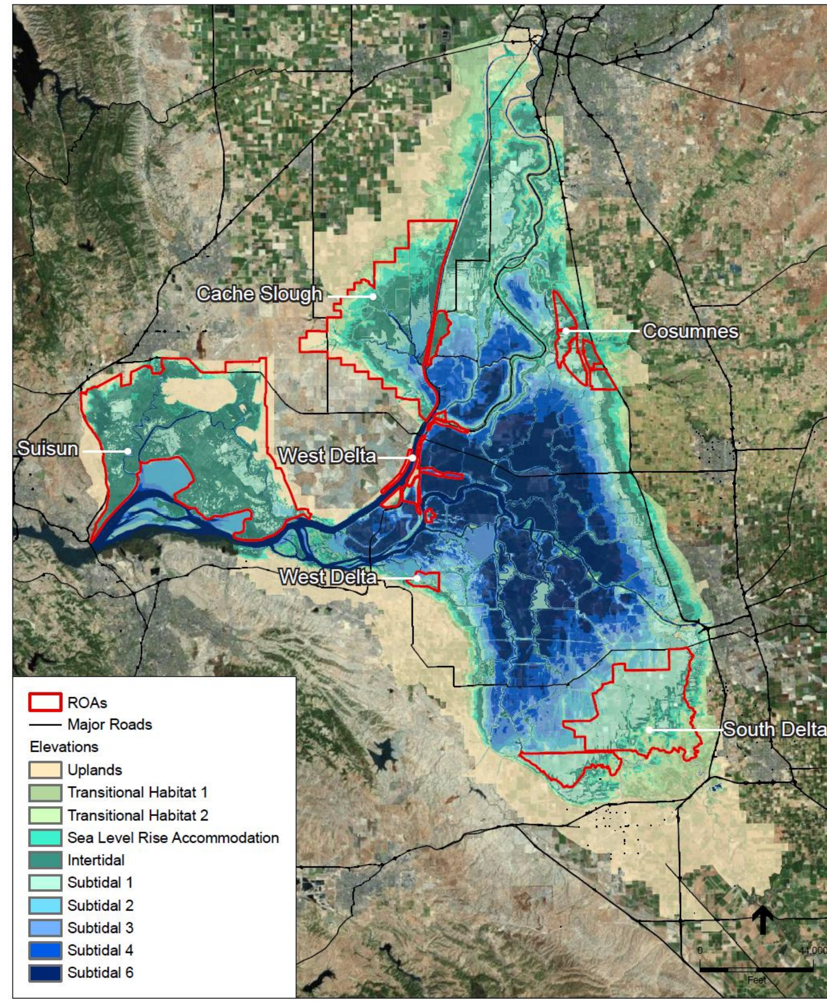


300,000 acres lost

200,000 acres lost

silvestrum
CLIMATE ASSOCIATES





SOURCE:
DWR 2007 LiDAR; ESA-PWA 2012

Bay Delta Science Conference.
Figure 1
Elevations and ROAs of Delta-Suisun Marsh Planning Area

ESA PWA

Emissions from One Drained Wetland: Sacramento-San Joaquin Delta

Area under agriculture	**180,000 ha**
Rate of subsidence (in)	1 inch

2-3 million tCO_2/yr released from Delta

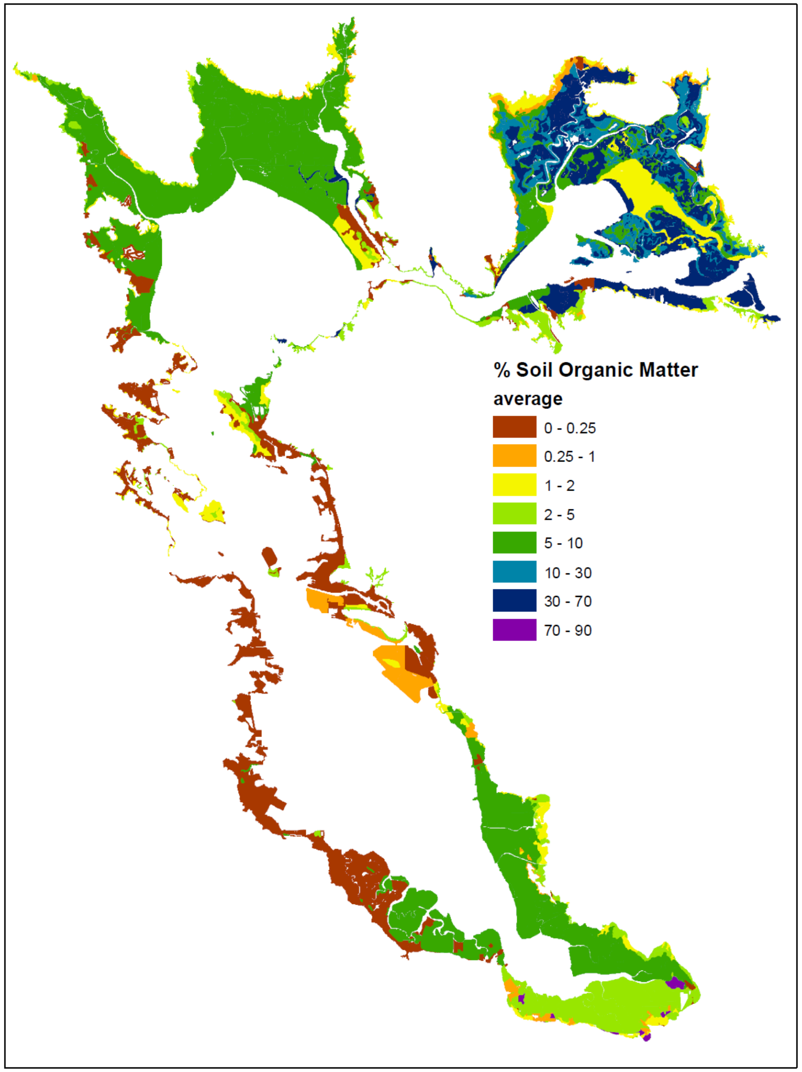
1 $GtCO_2$ release in c.150 years

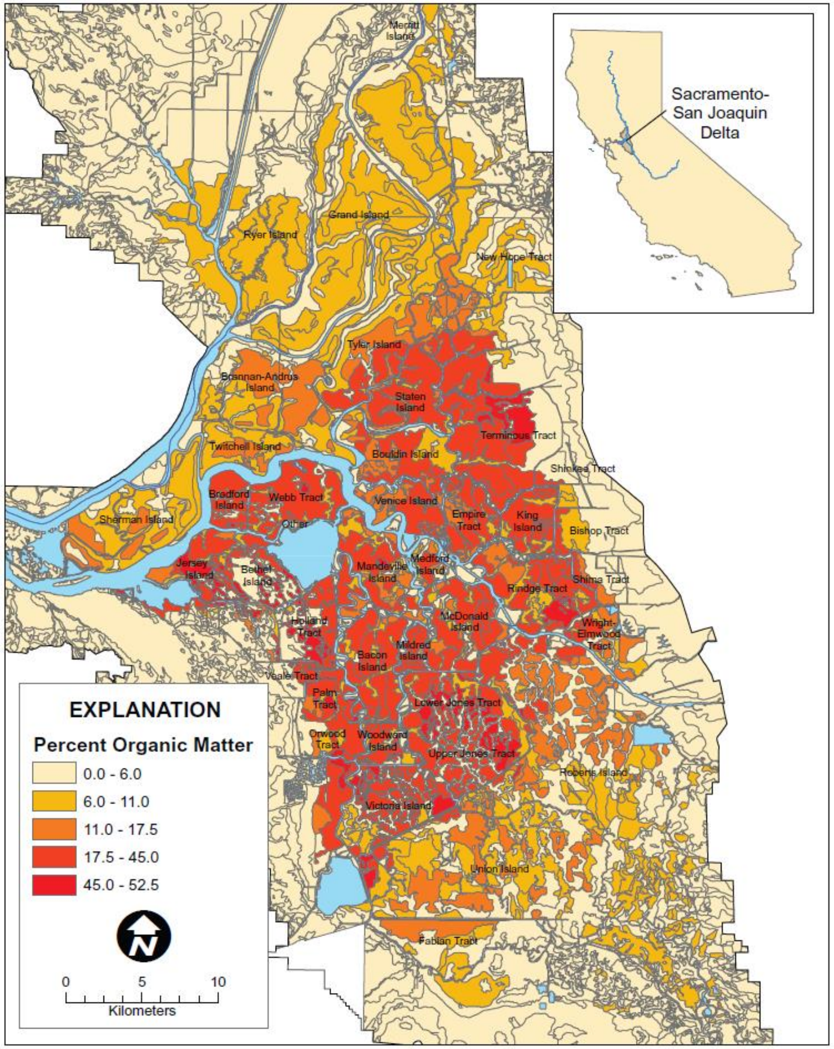
4000 years of carbon emitted

Equiv. carbon held in 25% of California's forests

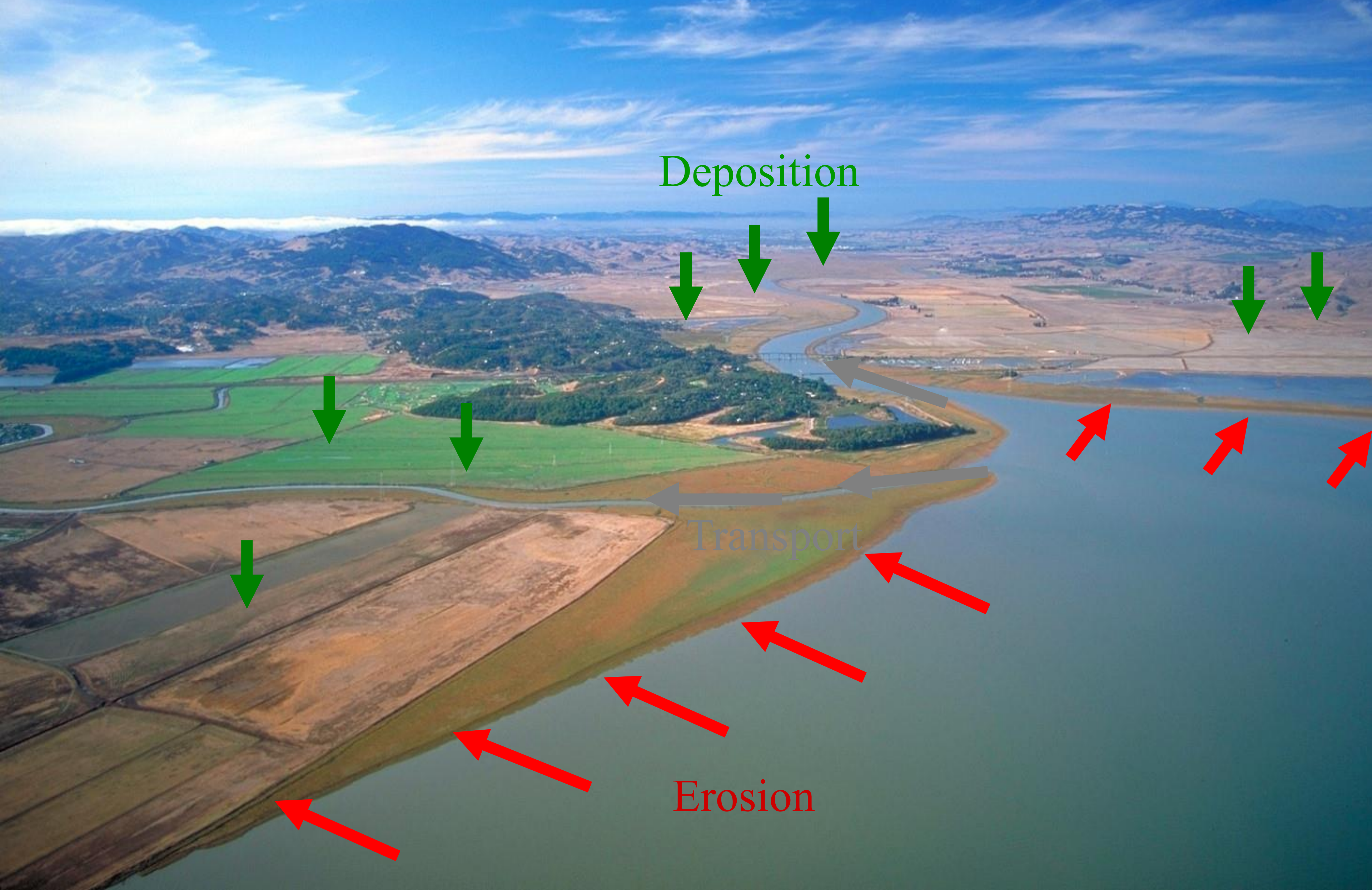
Accommodation space: 3 billion m^3

Baseline emissions



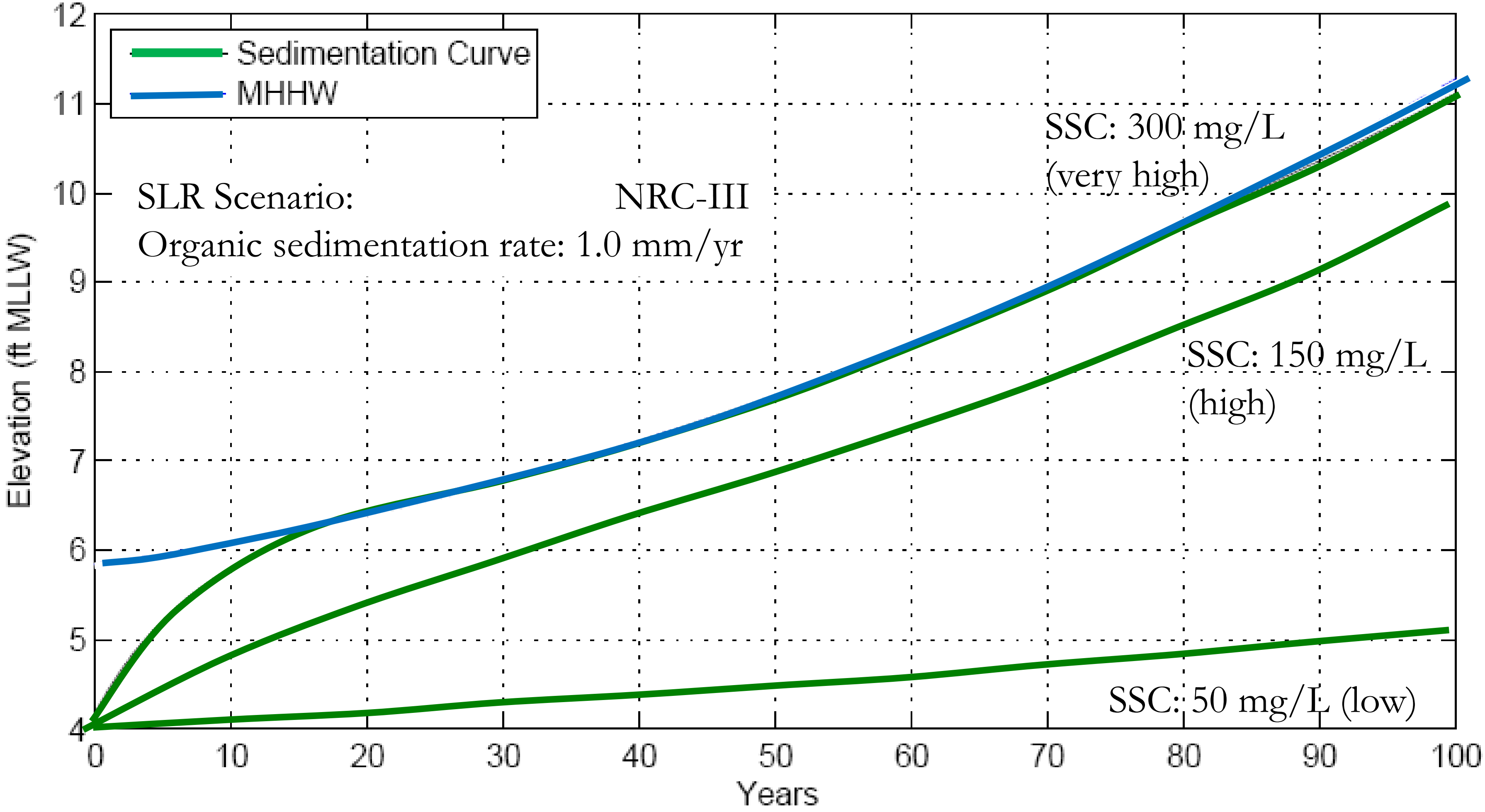


Factor in Sea Level Rise into Project



ESA PWA

Resilience to Sea Level Rise



Modeled with Marsh98

ESA PWA

COASTAL BLUE CARBON OPPORTUNITY ASSESSMENT
FOR THE SNOHOMISH ESTUARY
THE CLIMATE BENEFITS OF ESTUARY RESTORATION

- 4749 ha of drained wetlands
- 29% of wetland loss in Puget Sound
- 1353 ha of restoration planned.

RESTORE AMERICA'S ESTUARIES ESA WESTERN WASHINGTON UNIVERSITY EARTH CORPS

WILDLIFE FOREVER FUND BOEING NOAA

ESA PWA

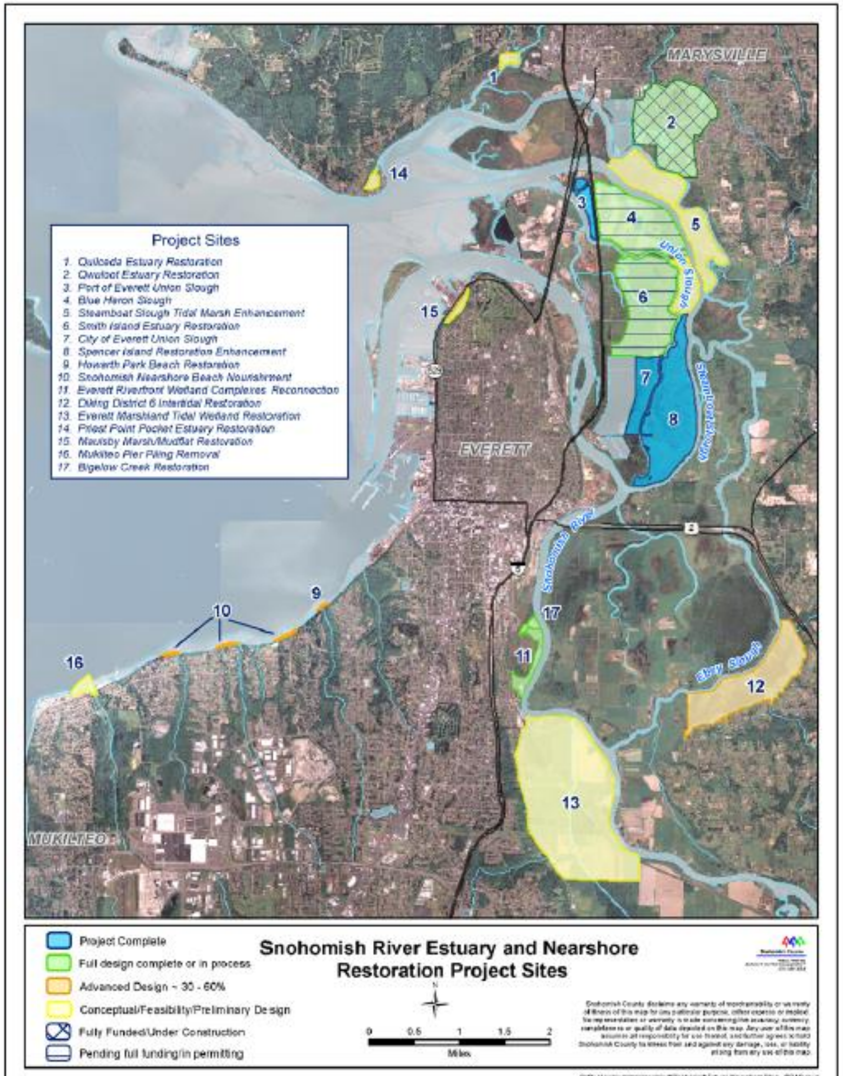


Figure 2 Snohomish Estuary nearshore restoration sites (Snohomish County, 2013).

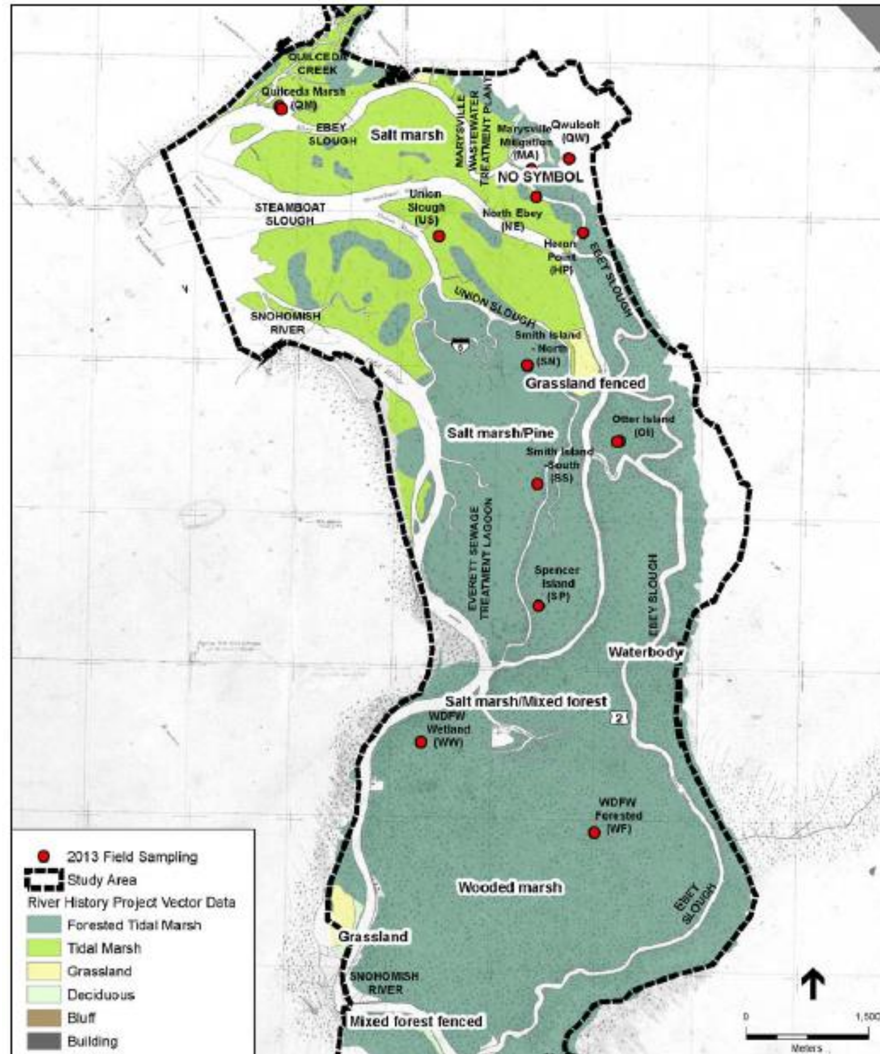


Figure 8 Historic habitats of the Lower Snohomish Estuary based on River History Project (Geomorphological Research Group, Quaternary Research Center, 2005) and Haas and Collins (2001) and 2013 soil core and vegetation plot locations.

Snohomish

Planning for Sea Level Rise

- Define future high water
  - 1 m
  - Location of future habitat/
  - Areas of future flood risk

- Basis for discussion
  - How to adapt to SLR
  - Land use decisions
    - Farming
    - Development
    - Conservation
    - Carbon management

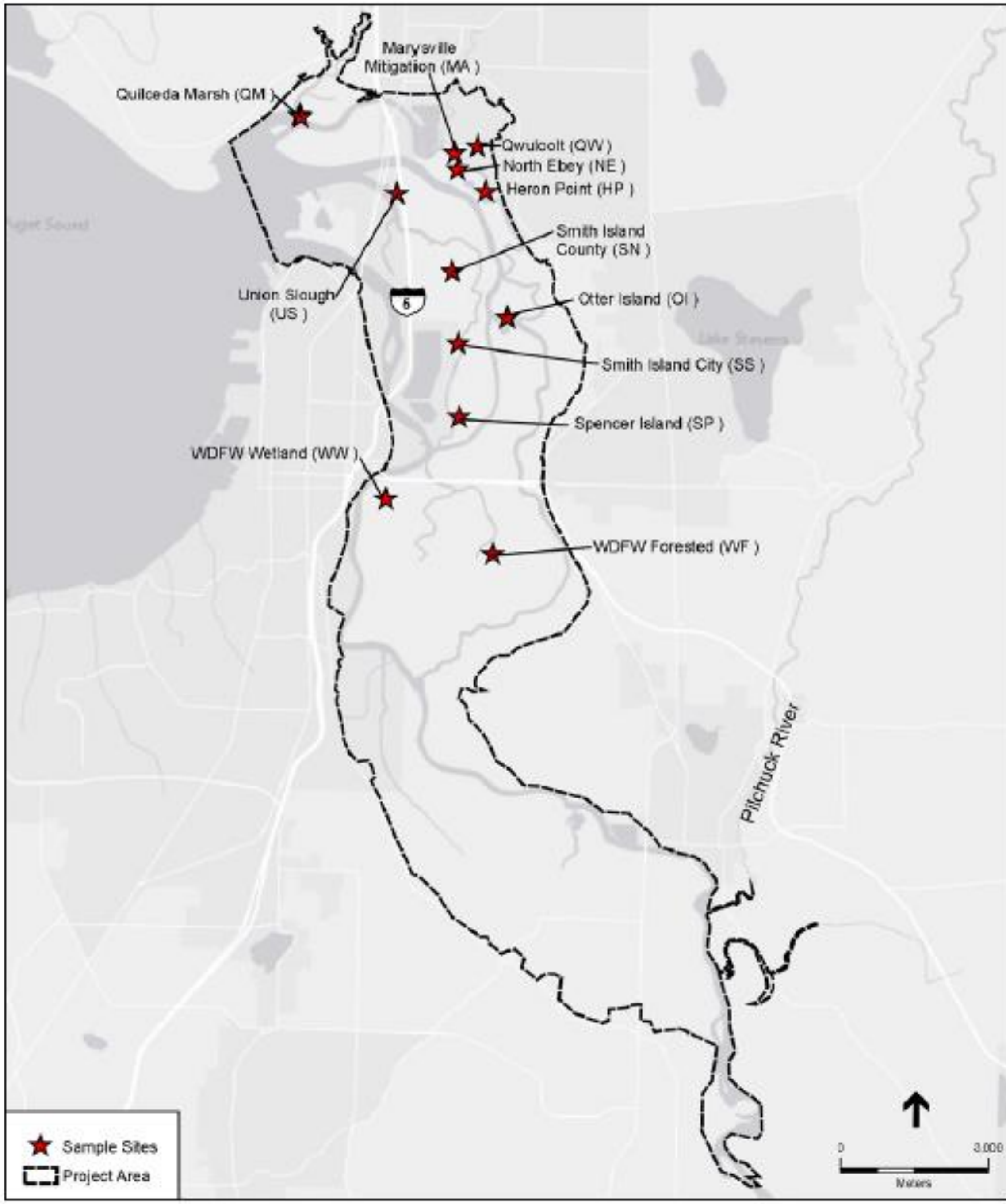
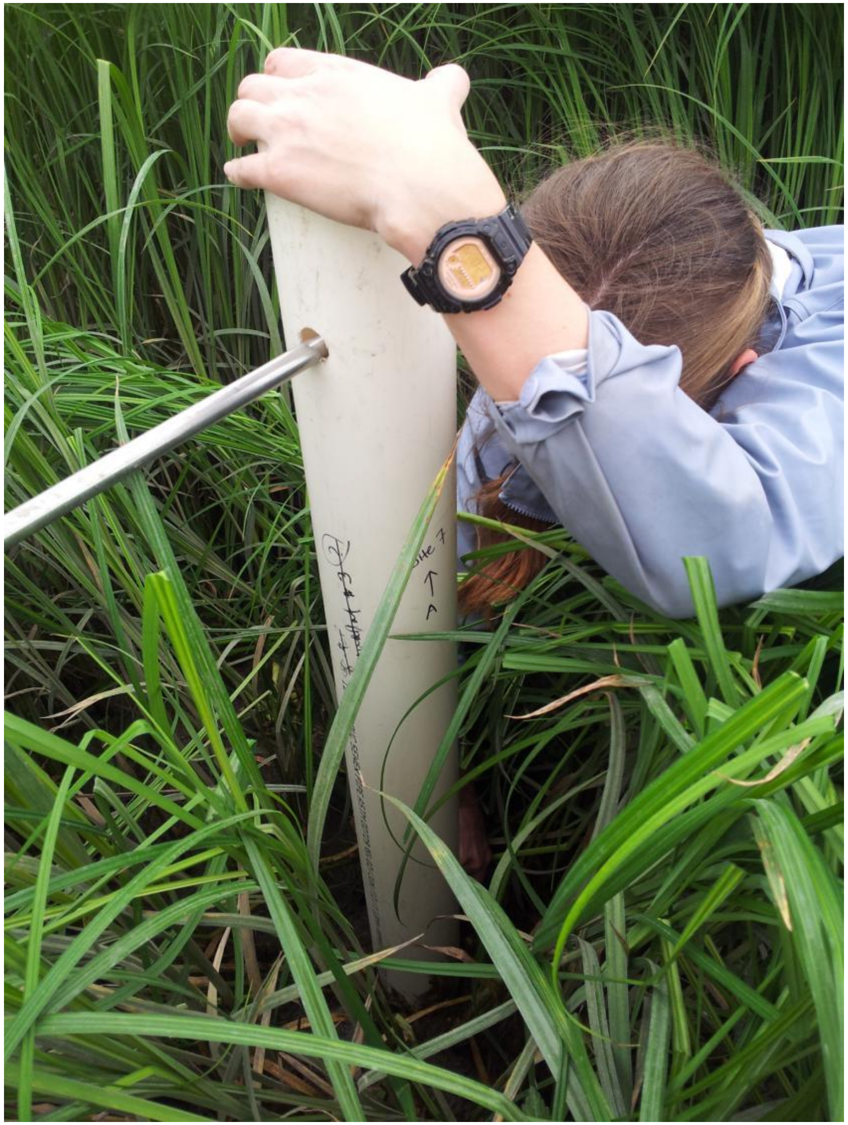


Figure 6 Study Area (dashed black line) and 2013 field sampling sites (red star).



Field and Laboratory Analysis

Soil carbon stock quantification:

- 3 Natural sites
- 5 Restoring sites
- 4 Restoration potential sites

Accretion rates:

- 5 sites

Restoration and carbon sequestration potential

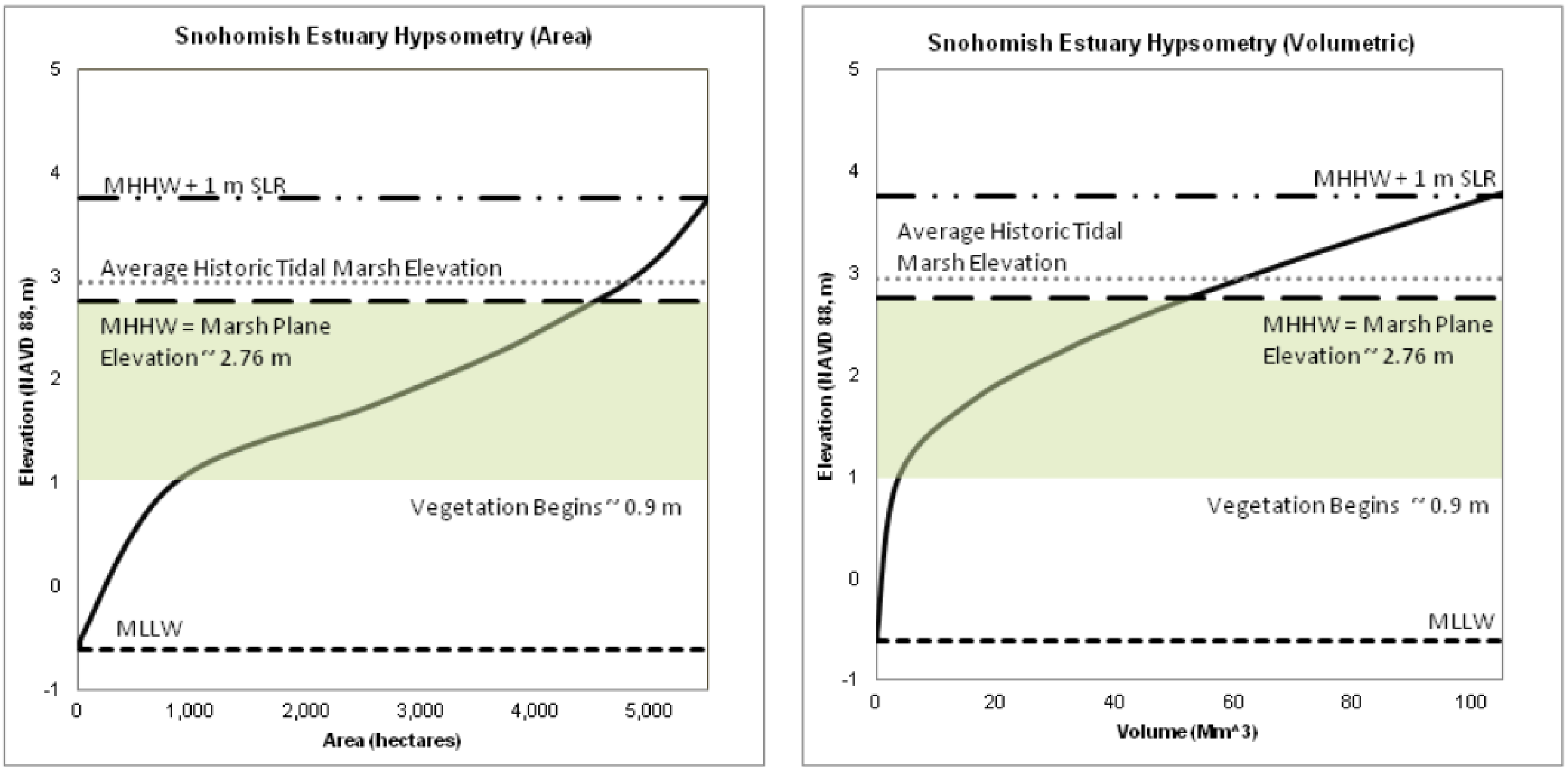


Figure 18 Hypsometric analysis of entire project area (ha).

Site	Site Name	Sediment accretion rate (cm yr^{-1})	Carbon accumulation rate (g C m^{-2} yr^{-1})	Mineral accumulation rate (g m^{-2} yr^{-1})
QM	Quilceda Marsh	0.43	110.2	2134
HP	Heron Point	0.18	58.0	484
OI	Otter Island	0.58	173.1	2543
NE	North Ebey	1.61	352.1	7585
SP	Spencer Island	0.35	91.4	2148

Table 11. Rates of sediment accretion, carbon accumulation, and mineral accumulation for five sites. Accretion rates were determined from the distribution of excess ^{210}Pb activity with depth using one core from each site. Carbon and mineral accumulation rates were calculated from the accretion rates

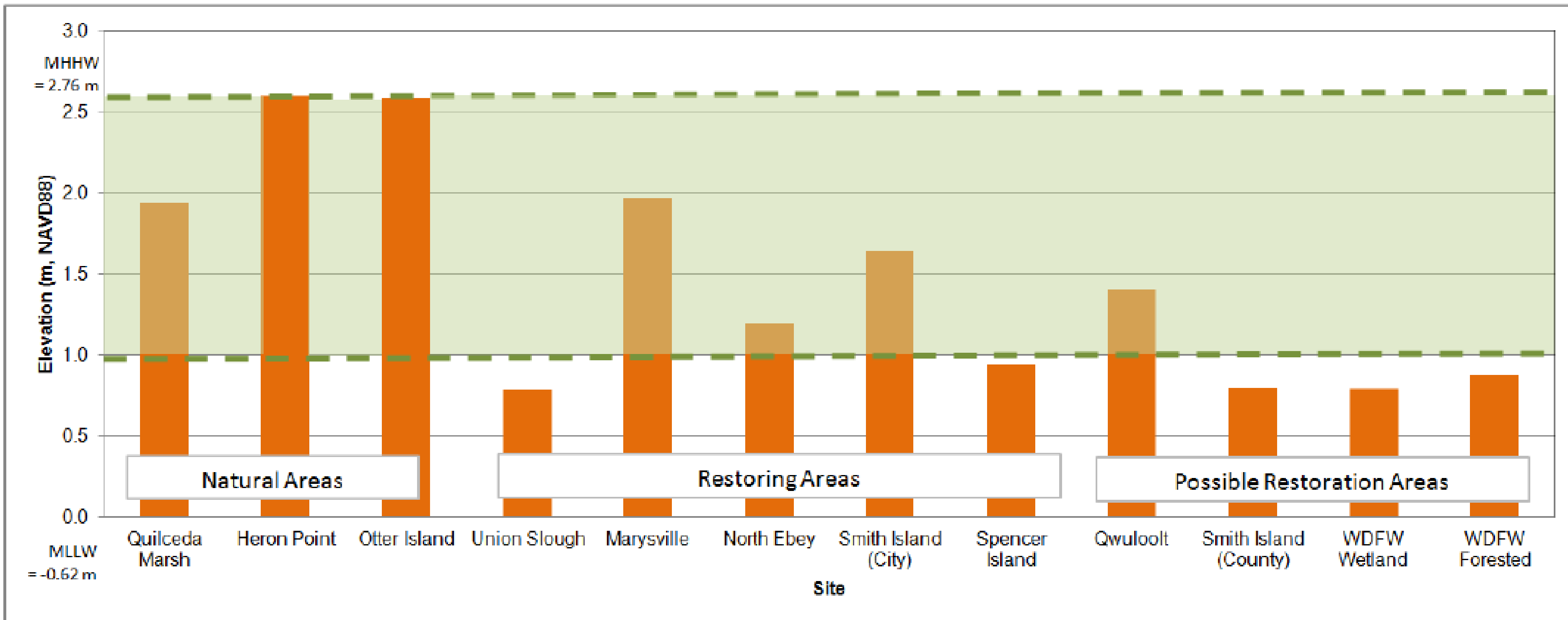
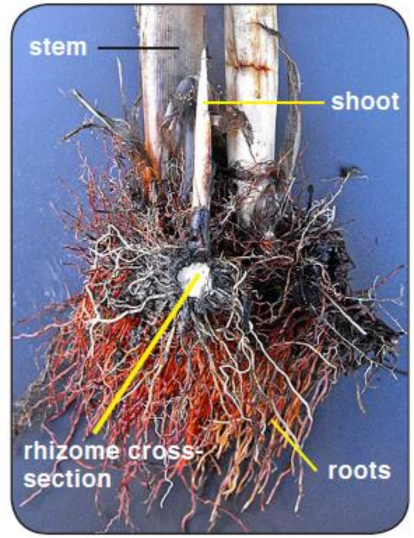
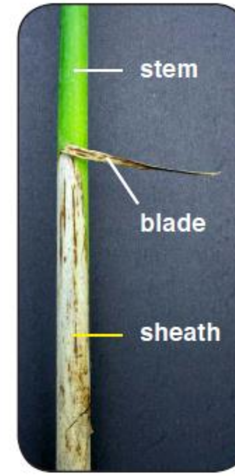


Figure 19 Existing and approximate targeted restoration elevations by site as of 2013. Units are in meters (m), NAVD88.

Great Bulrush stems, roots and new shoots in autumn

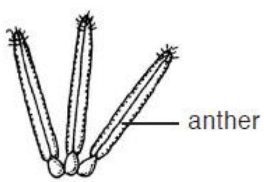


Cross-section of rhizome 7 mm thick with roots and new white shoot 5 cm tall

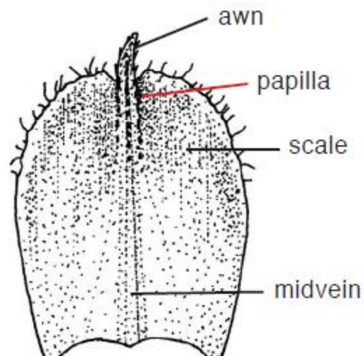


Lower stem 12 mm wide with leaf blade shorter than sheath

Inflorescence with green rays, peduncles and brown spikelets c. 8 mm long with exserted styles



Young stamens x10; each c. 2 mm long



Fertile scale x15; dorsal side

ESA PWA

Key Results – Existing Projects

1. *Planned* restoration of 1,353 ha would yield 1,176,000 tons CO_2 sequestration at current sea level

2. Planned restoration would yield additional 1,377,000 tons CO_2 sequestration to future sea level

3. Total CO_2 sequestration of 2,553,000 tons

4. This is equivalent to the emissions from 500,000 cars in one year, or 5,000 cars/year for 100 years

Snohomish Estuary Opportunities and Constraints

- Opportunities
  - High restoration potential (topo, sediment, vegetation)
  - Whole landscale restoration opportunities
  - High resilient to sea level rise (veg, floodplain, sediment)
  - Grouping project instances under single large project.
  - Community aware (local, state, federal)
  - Regional replication

- Constraints
  - Quantification of methane in baseline and project.

silvestrum
CLIMATE ASSOCIATES

Concluding thoughts

- Base carbon projects on good practice for restoration and conservation
- Embed mitigation planning in a climate adaptation context
- Look to account across whole landscape to improve system wide resilience.
- Account for all greenhouse gases
- Include coastal forest and seasonal floodplains in GHG management
- Areas with high sediment availability will be the most resilient to sea level rise
- Methane reductions by reconnecting impaired drainage areas offer zero permanence risk.

Steve Crooks
415 272 3916
Steve.crooks@silvestrum.com

silvestrum
CLIMATE ASSOCIATES

Extent of Coastal Lands

Coastal Land Cover (Ha)

		California				Conterminous US	
COASTAL LAND COVER BY CATEGORY -ALL SOILS							
CCAP Class	Total Area	Organic Soil	Mineral Soil		Total Area	Organic Soil	Mineral Soil
High Intensity Developed	2,573	66	2,507		16,470	3,727	12,742
Medium Intensity Developed	8,281	316	7,965		36,306	7,935	28,371
Low Intensity Developed	6,761	568	6,193		73,550	21,530	52,019
Developed Open Space	2,579	271	2,308		24,979	4,475	20,504
Cultivated	101,433	50,269	51,164		205,335	90,776	114,559
Pasture/Hay	15,469	8,072	7,397		61,802	23,791	38,011
Grassland	25,948	11,142	14,807		47,405	14,119	33,286
Deciduous Forest	27	-	27		5,939	766	5,173
Evergreen Forest	227	18	208		34,965	3,998	30,967
Mixed Forest	63	4	59		4,497	594	3,902
Scrub/Shrub	656	80	576		18,504	3,379	15,124
Palustrine Forested Wetland	703	195	508		873,340	563,487	309,853
Palustrine Scrub/Shrub Wetland	2,190	652	1,538		134,371	64,914	69,457
Palustrine Emergent Wetland	12,589	2,491	10,098		599,595	356,053	243,543
Estuarine Forested Wetland	130	5	124		197,728	50,891	146,837
Estuarine Scrub/Shrub Wetland	2,535	462	2,073		99,800	15,018	84,782
Estuarine Emergent Wetland	42,246	13,815	28,431		1,891,096	998,315	892,781
Unconsolidated Shore	4,710	94	4,615		344,502	13,439	331,063
Bare Land	1,541	161	1,380		40,337	5,040	35,297
Palustrine Aquatic Bed	-	-	-		19,440	8,894	10,546
Estuarine Aquatic Bed	7,228	-	7,228		180,106	15,431	164,675
Total	237,888	88,681	149,207		4,910,066	2,266,572	2,643,494

silvestrum
CLIMATE ASSOCIATES

		California	
COASTAL LAND COVER BY CATEGORY -ALL SOILS			
CCAP Class	Total Area	Organic Soil	Mineral Soil
High Intensity Developed	2,573	66	2,507
Medium Intensity Developed	8,281	316	7,965
Low Intensity Developed	6,761	568	6,193
Developed Open Space	2,579	271	2,308
Cultivated	101,433	50,269	51,164
Pasture/Hay	15,469	8,072	7,397
Grassland	25,948	11,142	14,807
Deciduous Forest	27	-	27
Evergreen Forest	227	18	208
Mixed Forest	63	4	59
Scrub/Shrub	656	80	576
Palustrine Forested Wetland	703	195	508
Palustrine Scrub/Shrub Wetland	2,190	652	1,538
Palustrine Emergent Wetland	12,589	2,491	10,098
Estuarine Forested Wetland	130	5	124
Estuarine Scrub/Shrub Wetland	2,535	462	2,073
Estuarine Emergent Wetland	42,246	13,815	28,431
Unconsolidated Shore	4,710	94	4,615
Bare Land	1,541	161	1,380
Palustrine Aquatic Bed	-	-	-
Estuarine Aquatic Bed	7,228	-	7,228
Total	237,888	88,681	149,207

Does not include upland transition areas

silvestrum CLIMATE ASSOCIATES

Emission / removals from California's coastal lands

Ecosystem	Area (Ha)	Emission tC / Ha/ yr	Total tC / yr	Total tCO2 / yr
Impaired Drainage	10,000	1.11	11,100	40,703
Salt marsh restoration	40,000	-0.91	-36,400	-133,479
Drained organic soil	69,483	7.9	584,916	2,146,641
seagrass	?	-0.43	?	?
Natural saltmarsh	42,246	-0.91	-38,444	-140.974

Notes: Negative value reflects sequestration.
Emissions factors derived from IPCC default values