Coastal Environmental Settings as a Model to Explain Global Controls of Nutrient Storage in Mangroves

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Louisiana Sea Grant College Program

12th International Symposium on Biogeochemistry of Wetlands (2018)
Coral Springs, FL

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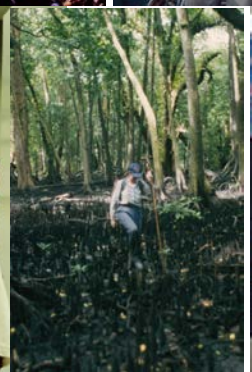
Pablo **Riul** - UFPB
Alessandra **Fonseca** - UFSC
Paulo **Pagliosa** - UFSC



Roc
(50th Anniversary)

Mexico


Africa


Micronesia

FLORIDA, USA - Scrub Mangroves

Florida Coastal Everglades LTER

Global Carbon Budget

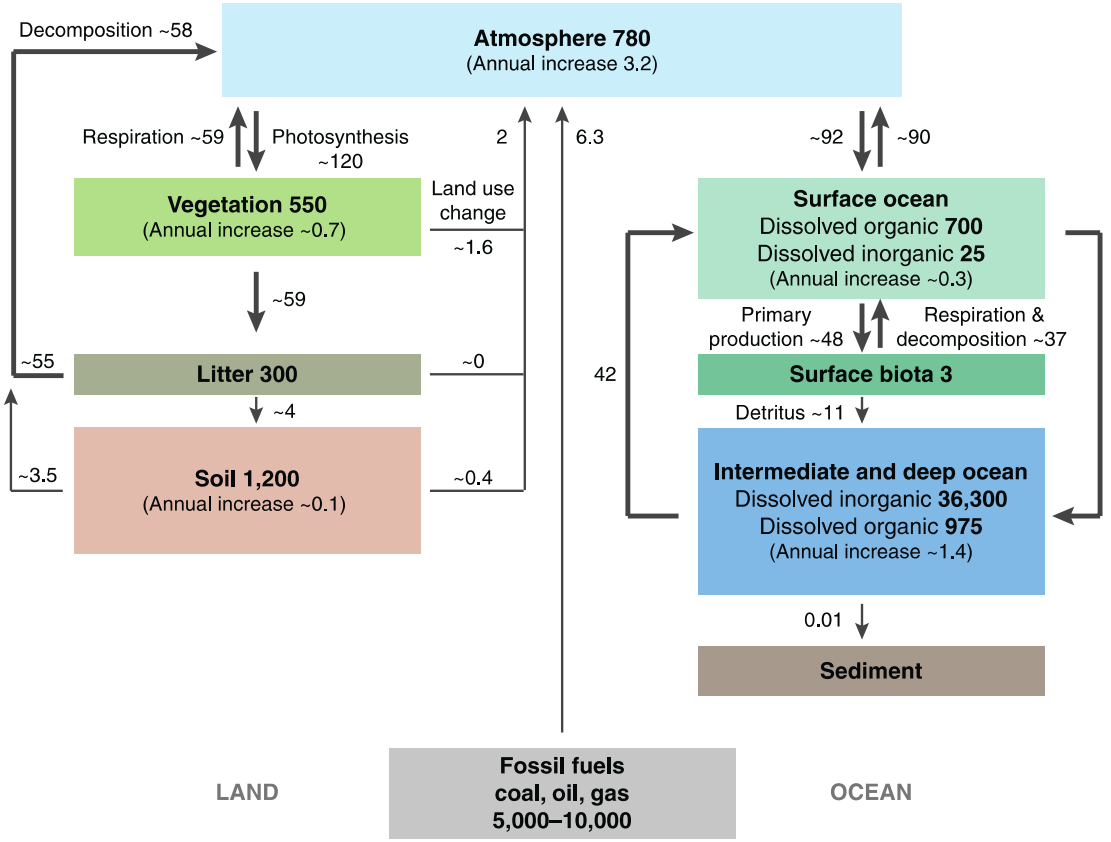


Figure 1

The global carbon cycle in the 1990s. Units are PgC or PgC year^{-1}.

Fossil Fuel 6,300 Tg C/yr

Land Use 1,000 Tg C/yr

Atmosphere CO_2

805,000Tg C + 1,166 Tg C/yr

773 Tg C/yr

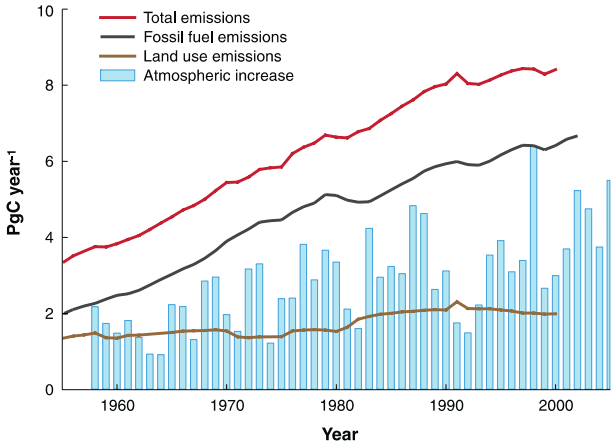
Mystery Carbon

5361 Tg C/yr

Ocean Sinks

?? Tg C/yr

Houghton, R.A., 2007. Balancing the global carbon budget. Annu. Rev. Earth Planet. Sci., *35*, pp.313-347.



Twilley, R.R., R.H. Chen, and T. Hargis. **1992**. Carbon sinks in mangroves and their implications to carbon budget of tropical coastal ecosystems. *Water, Air and Soil Pollution* 64: 265-288.

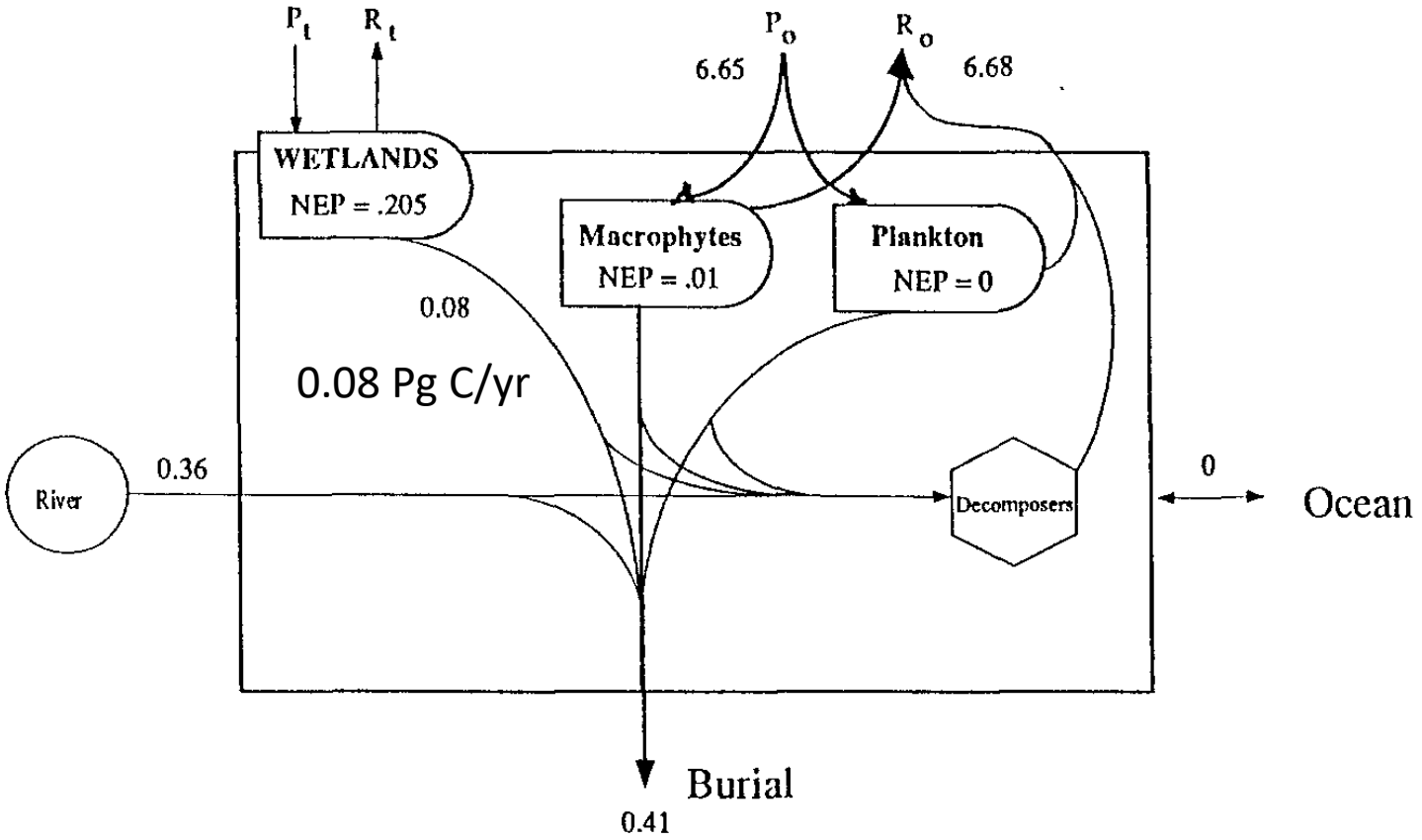


Figure 10. Mass balance of C for coastal ecosystems based on estimates of in situ net production and allochthonous inputs, minus losses associated with burial in coastal sediments. P and R represent net production and heterotrophic respiration, respectively, with exchange of CO_2 directly with atmosphere (t) or coastal waters (o).

Ecogeomorphology of Mangroves

I. The CES Framework: Coastal Environmental Settings and Ecosystem Attributes (Ecogeomorphology)

II. Testing the CES Framework: Rovai's Dissertation

III. CES Framework Methodology

IV. Results and Global Significance of CES framework

V. Some final thoughts……

VI. Questions and Discussion (preferably with adult beverages)

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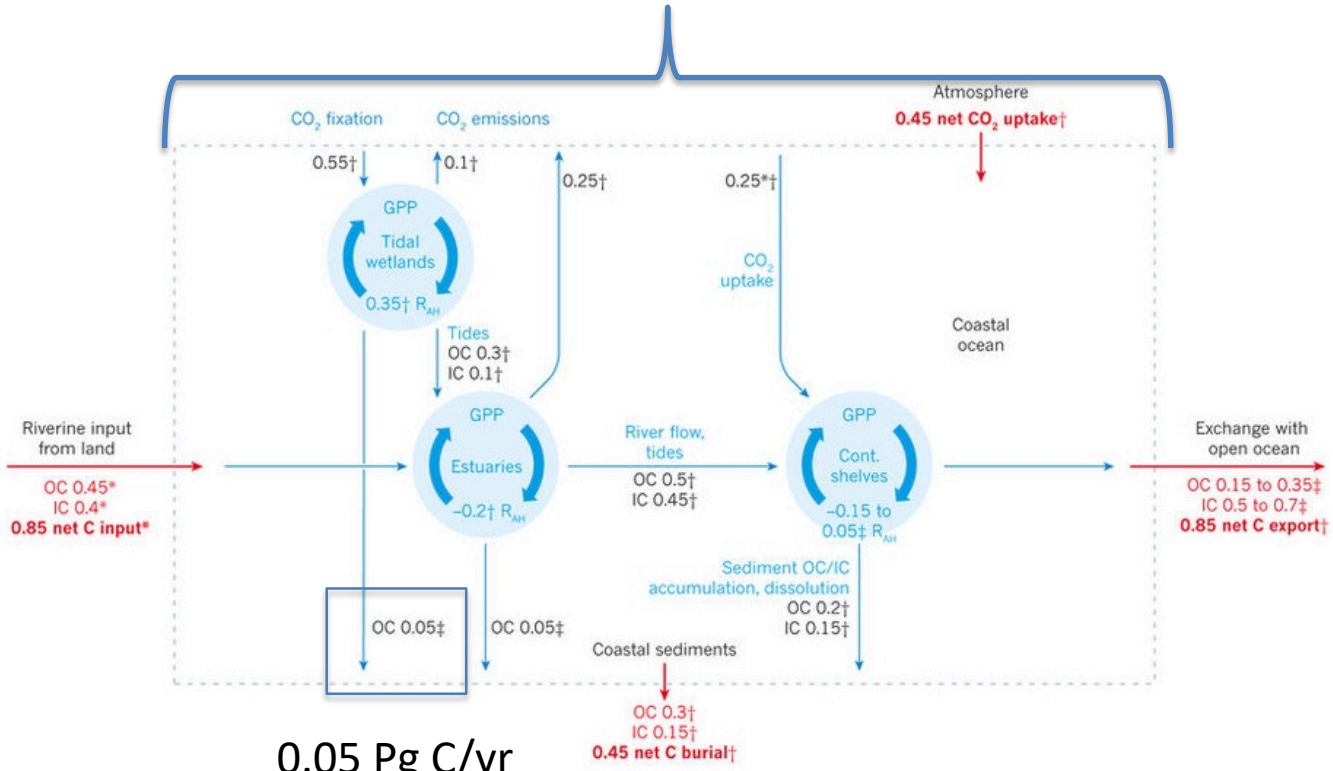
Coastal Ocean



0.05 Pg C/yr

REVIEW

doi:10.1038/nature12857

The changing carbon cycle of the coastal ocean

James E. Bauer[1], Wei-Jun Cai[2], Peter A. Raymond[3], Thomas S. Bianchi[4], Charles S. Hopkinson[5] & Pierre A. G. Regnier[6]

The carbon cycle of the coastal ocean is a dynamic component of the global carbon budget. But the diverse sources and sinks of carbon and their complex interactions in these waters remain poorly understood. Here we discuss the sources, exchanges and fates of carbon in the coastal ocean and how anthropogenic activities have altered the carbon cycle. Recent evidence suggests that the coastal ocean may have become a net sink for atmospheric carbon dioxide during post-industrial times. Continued human pressures in coastal zones will probably have an important impact on the future evolution of the coastal ocean's carbon budget.

Fluxes between adjacent subsystems and other components of coastal ocean. Carbon can flux both within (values in black) and across (values in red) the boundaries of the coastal ocean. Particulate and dissolved OC fluxes are presented as total OC values. The balance between gross primary production (GPP) and total system respiration (both autotrophic, A, and heterotrophic, H; R_{AH}) is net ecosystem production (NEP), with negative values indicating conversion of OC to IC. Units are Pg C yr^{-1} (1 Pg = 10^{15} g) rounded to ± 0.05 Pg C yr^{-1}. Within-river fluxes and transformation of carbon are excluded from this analysis.

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Land Use 1,000 Tg C/yr

Atmosphere CO_2
805,000Tg C + 1,166 Tg C/yr

773 Tg C/yr → Mystery Carbon

5361 Tg C/yr → Ocean Sinks

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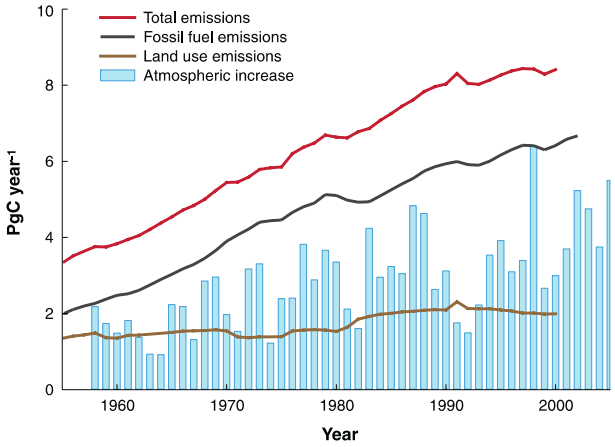


Mangrove Carbon Sequestration

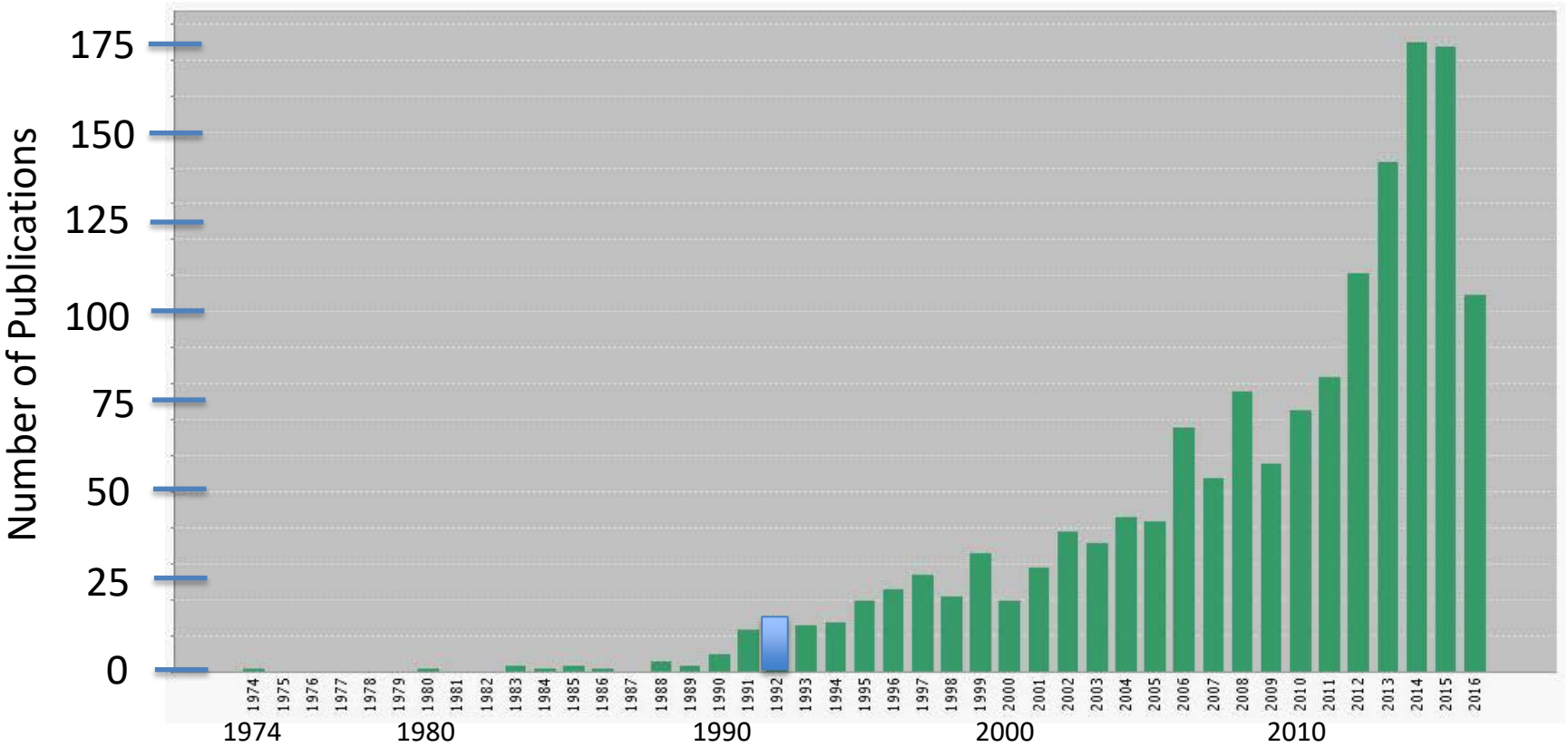
Annual C Seq Rate per unit area Per ecosystem compartment

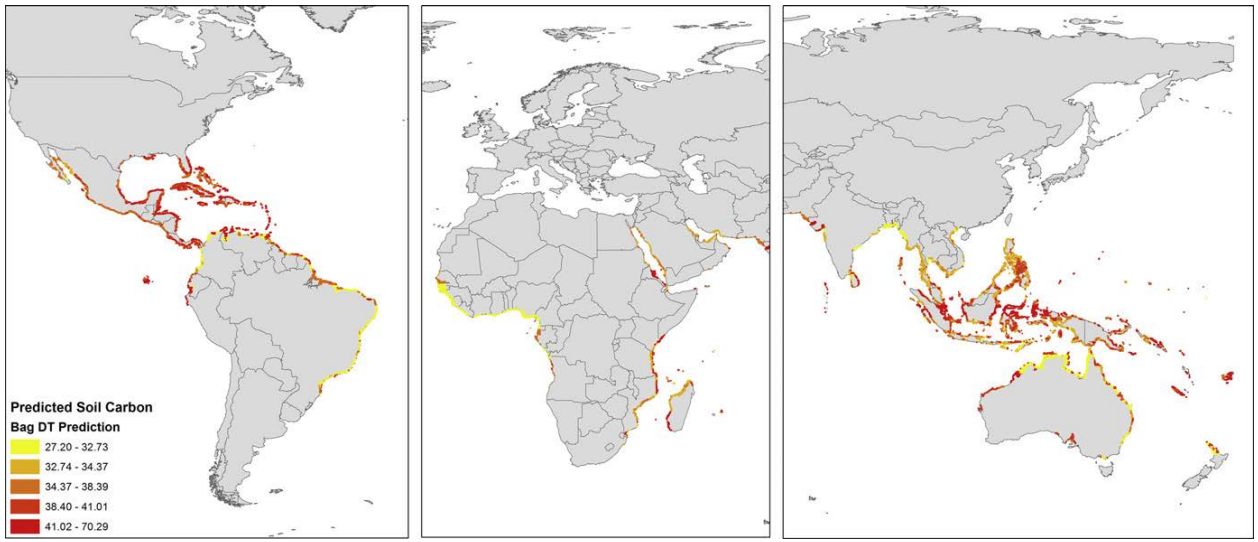
X

Mangrove Model To Extrapolate Per Area Rates to Global Rates

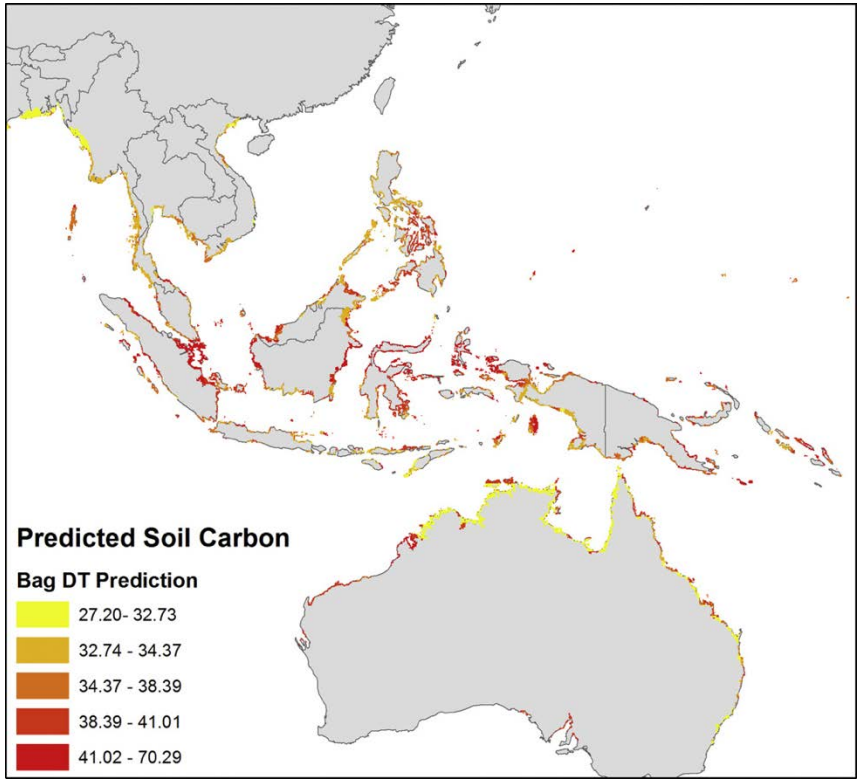
What are best integration of methods to determine global estimates of carbon sequestration?

Mangroves and Carbon





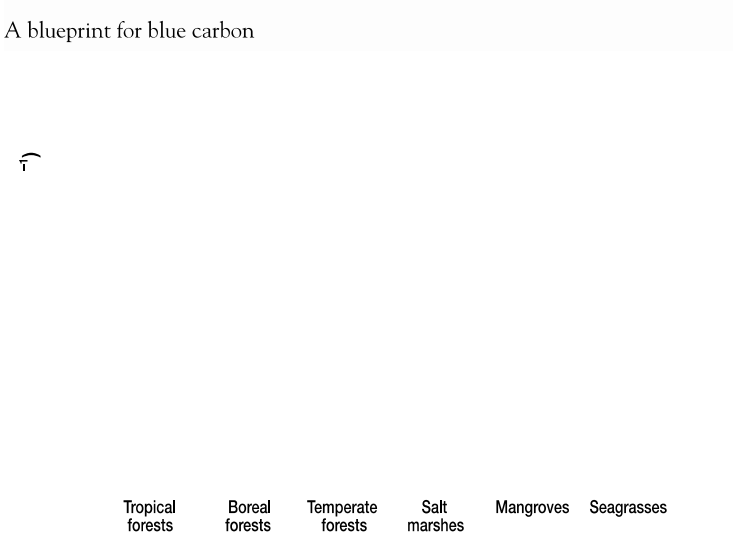
Jardine, S. L. & Siikamäki, J. V. 2014. A global predictive model of carbon in mangrove soils. Environ. Res. Lett. 9, 104013

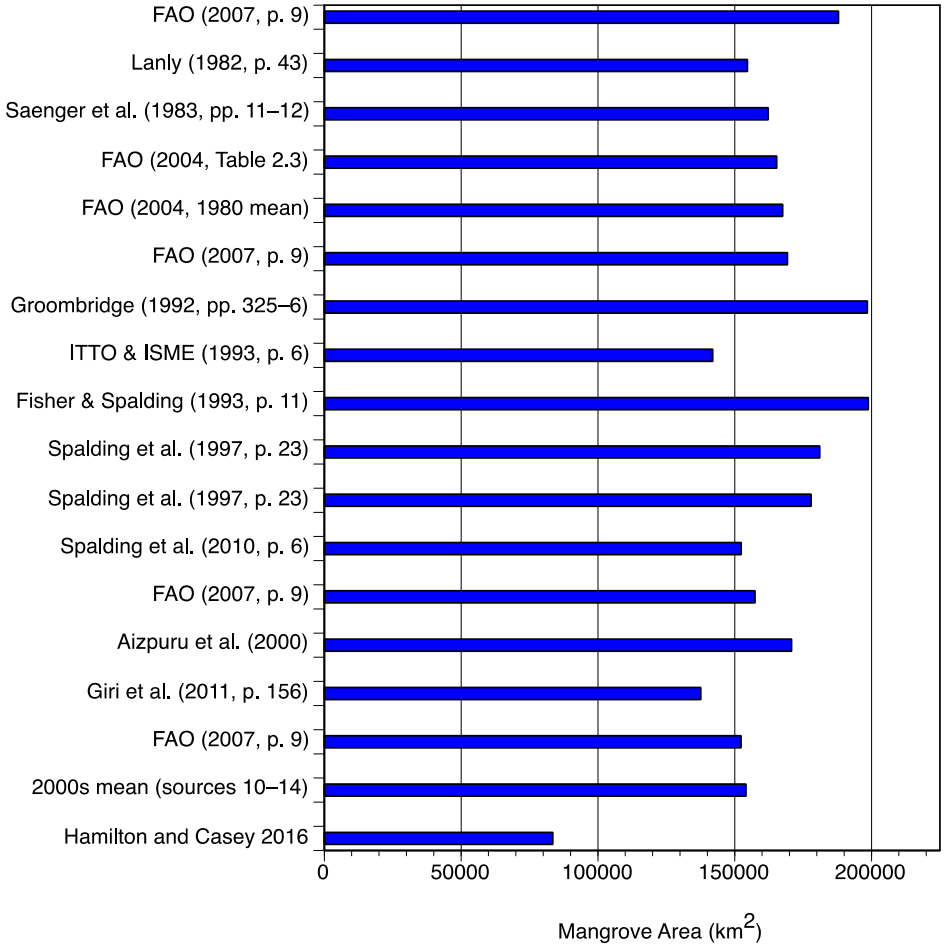


Developing global models of carbon sequestration in mangrove soils is one of the great challenges – both stocks and the annual burial rates – along with impacts from land use change.

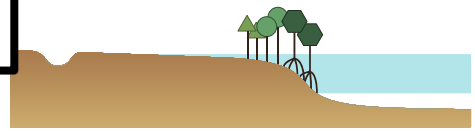
LSU

Carbon inventories depends on carbon density per unit area (Mg/ha) times the mangrove area





Mcleod, E., G. L. Chmura, S. Bouillon, R. Salm, M. Björk, C. M. Duarte, C. E. Lovelock, W. H. Schlesinger & B. R. Silliman, 2011. A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. Frontiers in Ecology and the Environment 9: 552-560



Atmosphere CO_2

Mangrove C Sequestration in wood growth $\Delta C_{org}/dt$

Atmosphere CO_2

Mangrove C Sequestration in soil dev $\Delta C_{org}/dt$

Woodroffe, C, K. Rogers, K.L. McKee, C.E. Lovelock, I.A. Mendelssohn, and N. Saintilan, 2016. Mangrove Sedimentation and Response to Relative Sea-Level Rise. Annu. Rev. Mar. Sci. 8:243–66

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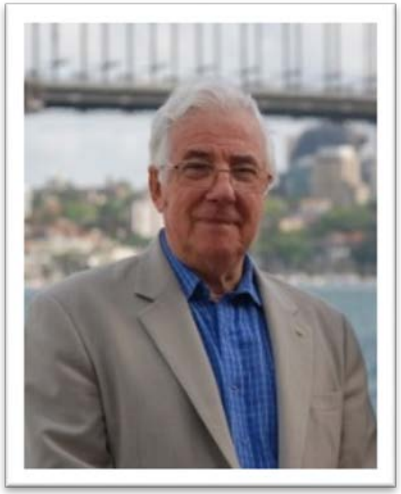


Bruce G. THOM

Journal of Ecology, Vol. 55, No. 2 (Jul., 1967), pp. 301-343

MANGROVE ECOLOGY AND DELTAIC GEOMORPHOLOGY: TABASCO, MEXICO

By BRUCE G. THOM

Journal of Ecology, Vol. 63, No. 1 (Mar., 1975), pp. 203-232

MANGROVE ECOLOGY AND DELTAIC-ESTUARINE GEOMORPHOLOGY: CAMBRIDGE GULF–ORD RIVER, WESTERN AUSTRALIA

By BRUCE G. THOM*, L. D. WRIGHT†‡ and J. M. COLEMAN†

Proceedings of the Australian National Mangrove Workshop
Australian Institute of Marine Science
Cape Ferguson
18-20 April 1979

MANGROVE ECOSYSTEMS IN AUSTRALIA

Structure, function and management

Mangrove Ecology – A Geomorphological Perspective

B.G. Thom

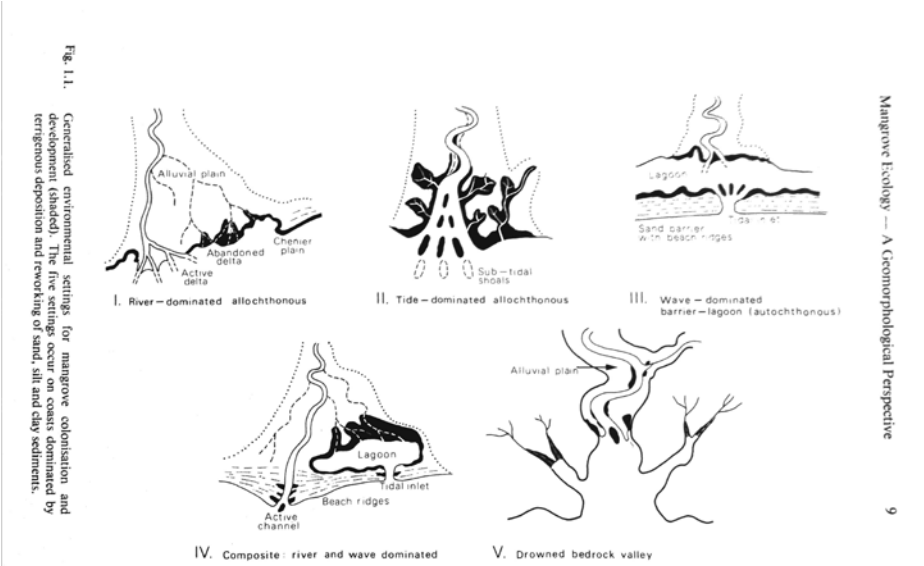


Fig. 1.1. Generalised environmental settings for mangrove colonisation and development (shaded). The five settings occur on coasts dominated by terrigenous deposition and reworking of sand, silt and clay sediments.

Table 1.1 Geomorphic and ecologic responses to varying combinations of environmental process variables. Some attempt is made to quantify these variables for large river and open-ocean wave energy conditions (H = high; M = moderate; L = low).

SETTING	Tide	Rainfall	PROCESSES River discharge	Turbidity	Wave power	GEOMORPHIC RESPONSE Landform diversity	Shoreline stability	ECOLOGIC RESPONSE Zonation diversity	Community stability	EXAMPLE
	L	H	H	H	L	H	L	H	L	Mississippi
I	M	H	H	H	L	H	L	H	L	Orinoco
II	H	H	H	H	L	M	M	M	M	Ganges
	H	L	M	H	L	L	L	L	H	Ord
III	M	M	L	L	H	L	H	L	H	El Salvador
	M	L	L	L	H	L	M	L	M	Senegal
IV	L	H	H	H	M	H	L	H	L	Grijalva
	M	H	H	H	M	M	M	M	L	Burdekin
V	M	M	M	M	H	L	H	L	H	Broken Bay

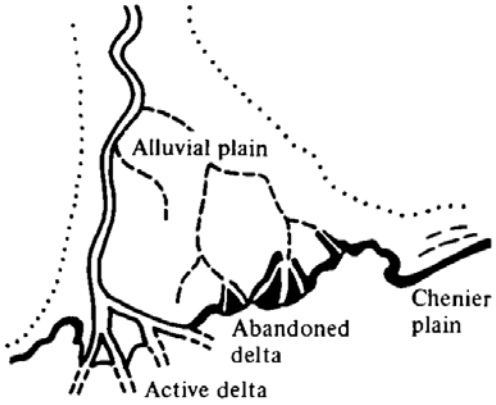
Tide: H > 4m; M 2-4m; L < 2m

Rainfall: H > 1500mm; M 700-1500mm; L < 700mm

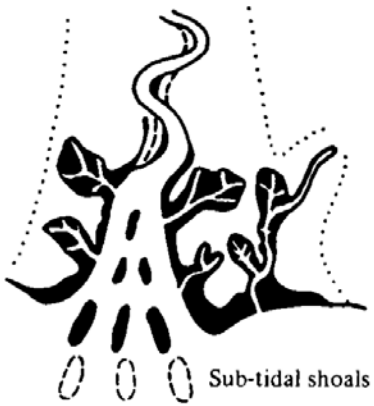
River discharge in m³/sec: H > 10000; M 3000 to 10000; L < 3000

Wave power in $X10^7$ ergs/sec: H < 100; M 10-100; L > 10

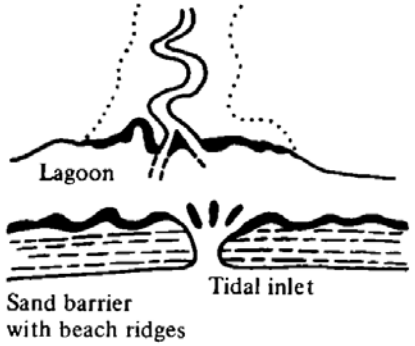
THOM'S Environmental Settings For Mangroves



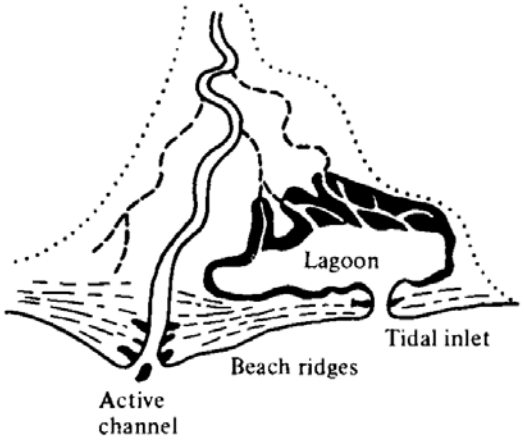
1. River-dominated allochthonous



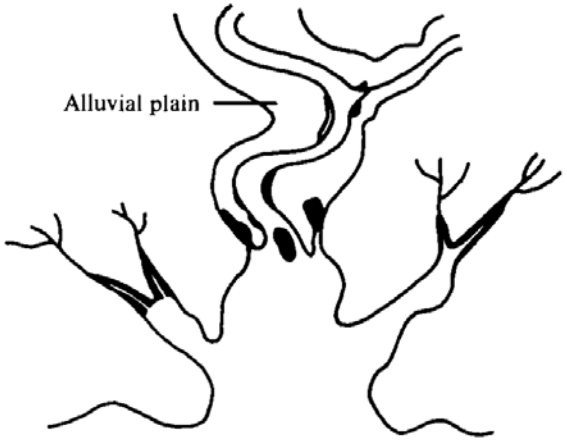
2. Tide-dominated allochthonous



3. Wave-dominated barrier lagoon (autochthonous)



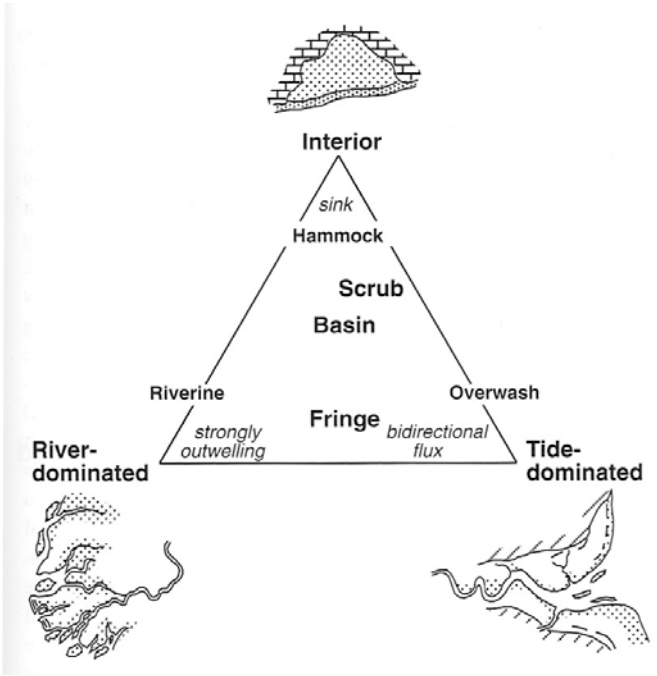
4. Composite—river and wave dominated



5. Drowned bedrock valley

Thom (1982)

Colin D. WOODROFFE



Pacific Science (1987), vol. 41, nos. 1–4

Pacific Island Mangroves: Distribution and Environmental Settings

COLIN D. WOODROFFE

Coastal and Estuarine Studies Tropical Mangrove Ecosystems Vol. 41

Mangrove Sediments and Geomorphology

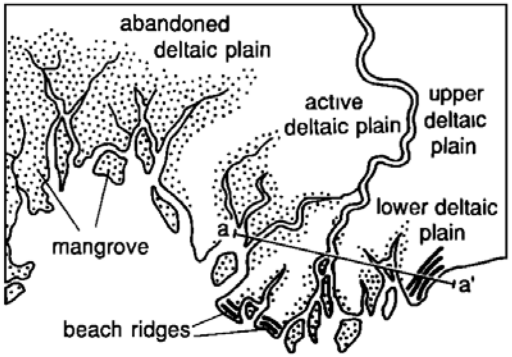
Colin Woodroffe

Mangrove Sedimentation and Response to Relative Sea-Level Rise

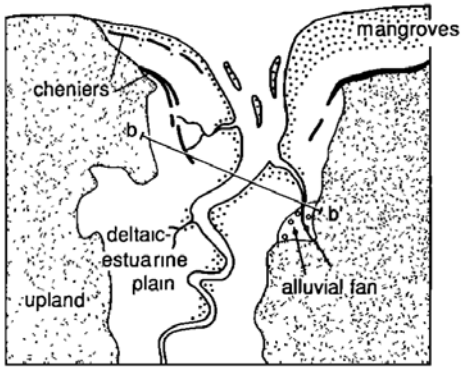
C.D. Woodroffe,[1] K. Rogers,[1] K.L. McKee,[2]
C.E. Lovelock,[3] I.A. Mendelssohn,[4] and N. Saintilan[5]

WOODROFFE'S Environmental Settings For Mangroves

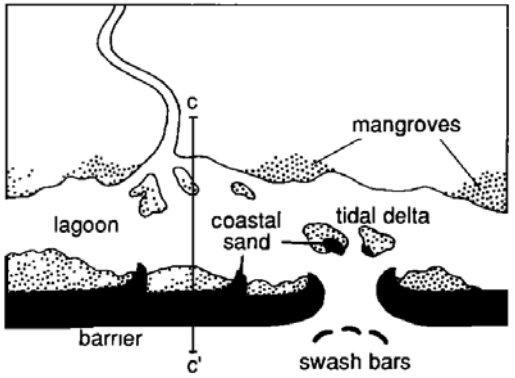
A. River dominated



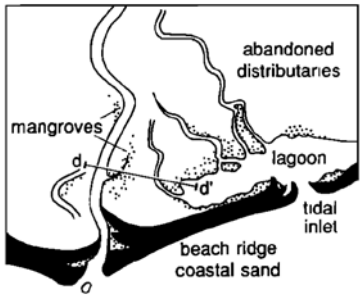
B. Tide dominated



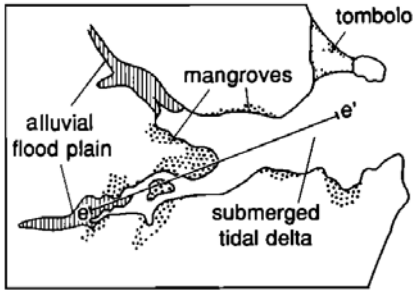
C. Wave dominated



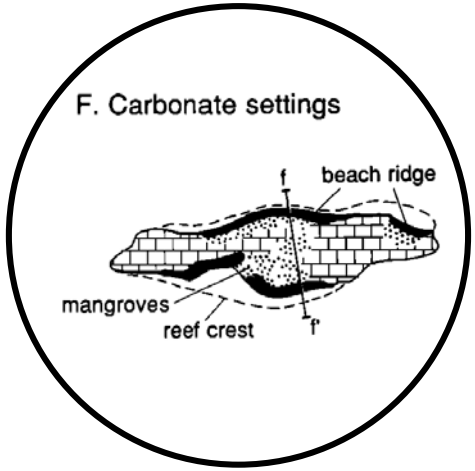
D. Composite river and wave dominated



E. Drowned bedrock valley



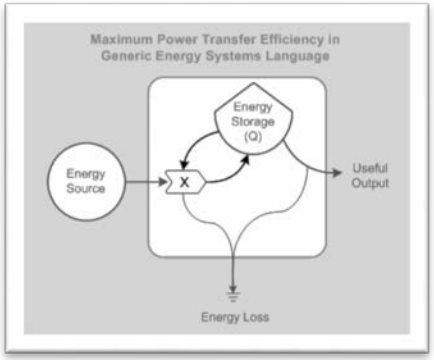
F. Carbonate settings

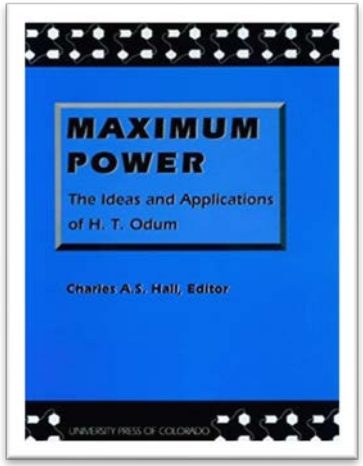


Woodroffe (1992)

PROPERTIES OF MANGROVE ECOSYSTEMS RELATED TO THE ENERGY SIGNATURE OF COASTAL ENVIRONMENTS

Robert R. Twilley 1995





65th Birthday Party for HT Odum, UNC Chapel Hill NC, 1989

LSU

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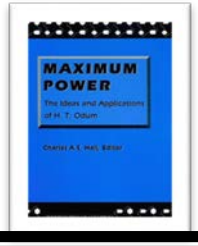
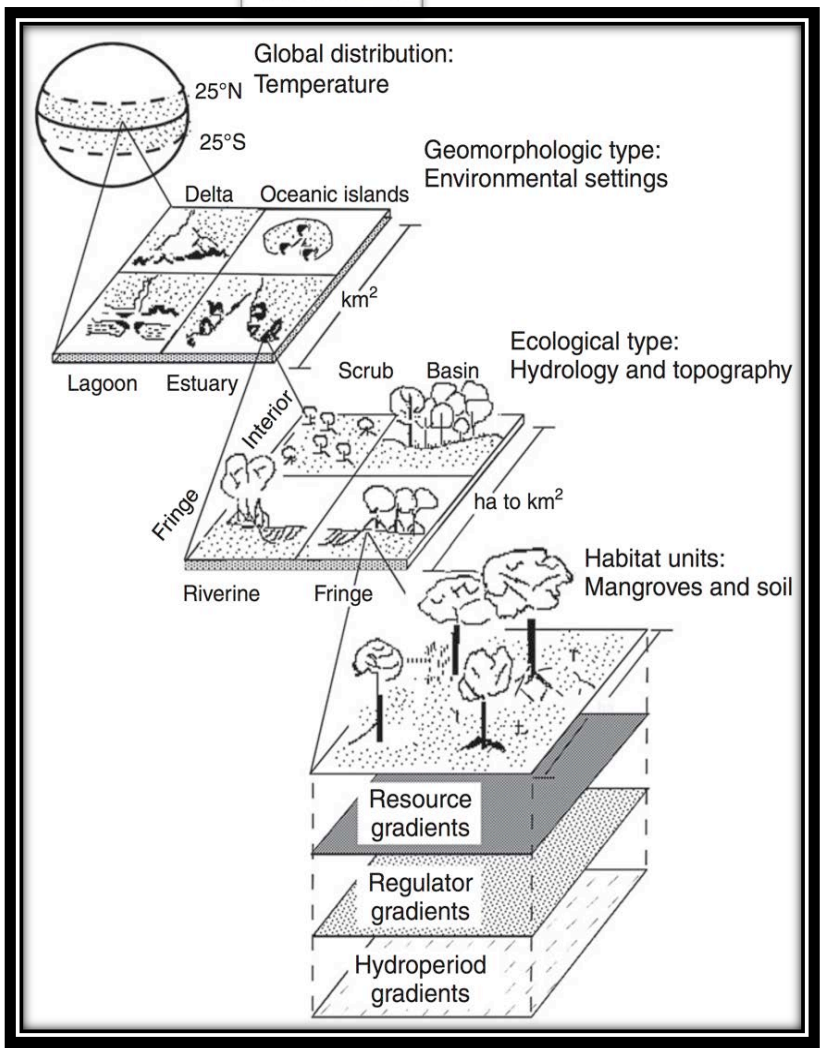
Robert R. Twilley



Twilley et al. (1995)



The Ecogeomorphology of Mangroves

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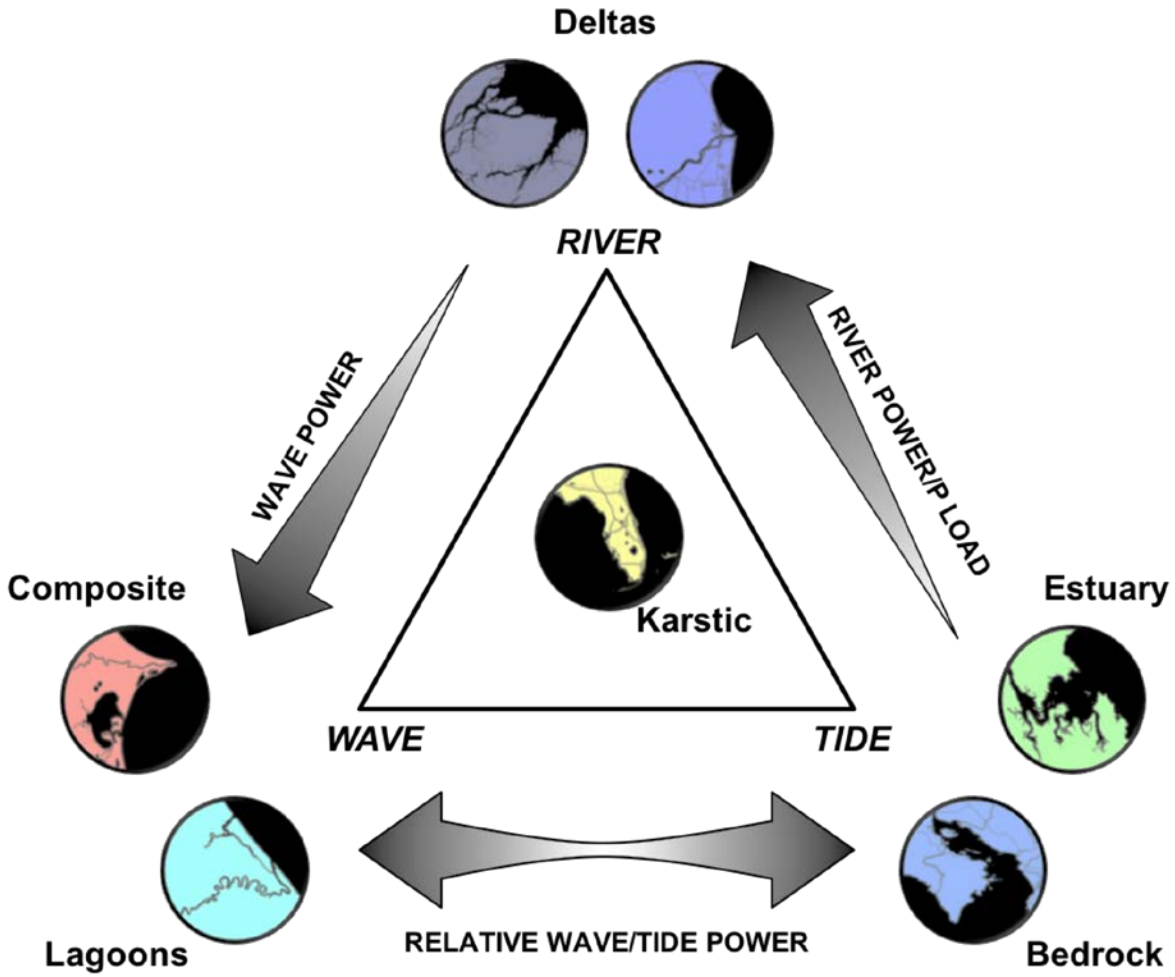
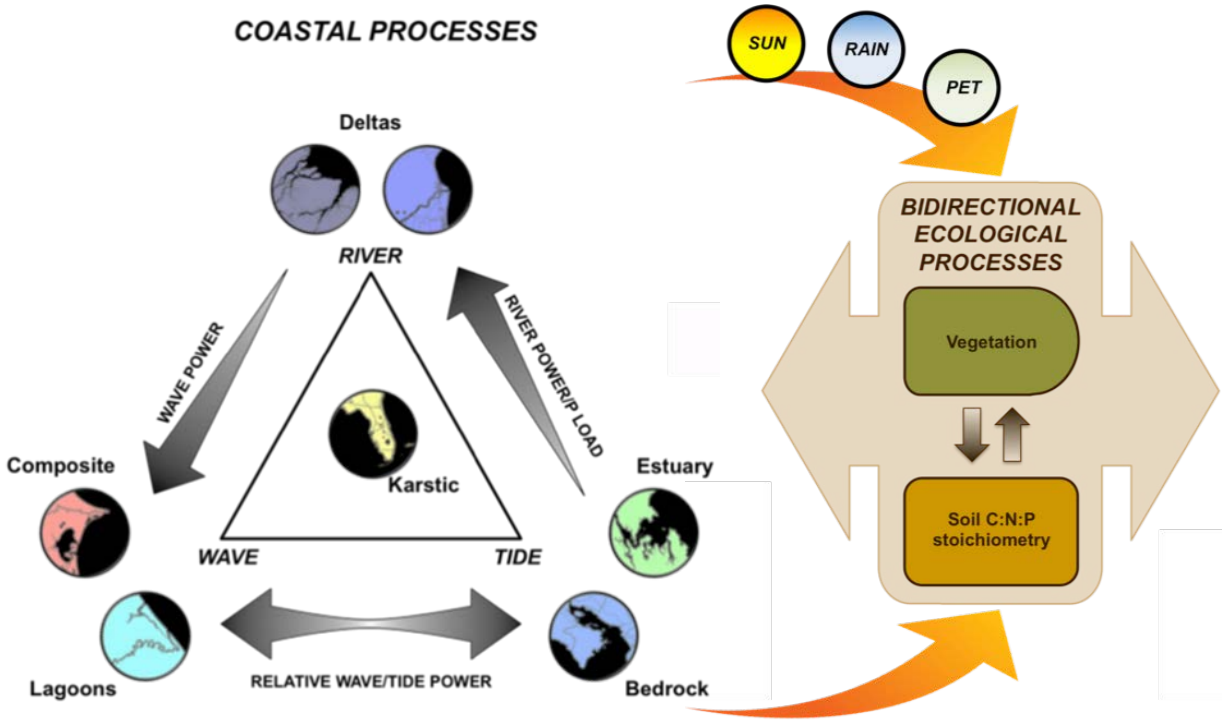
THOM'S + WOODROFFE'S Environmental Settings For Mangroves



After Boyd et al. (1992), Dürr et al. (2011), Thom (1982), Twilley (1995), Woodroffe et al. (1992)



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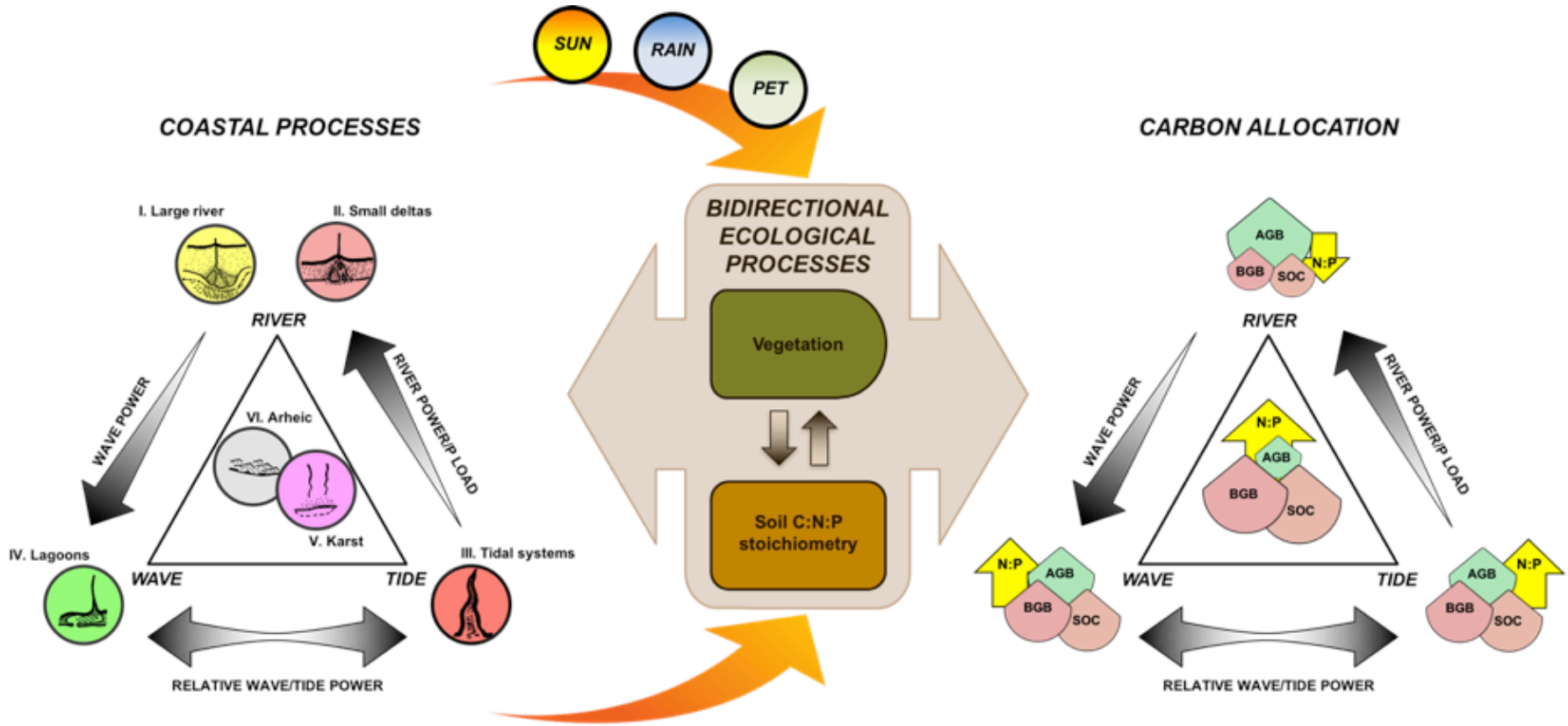
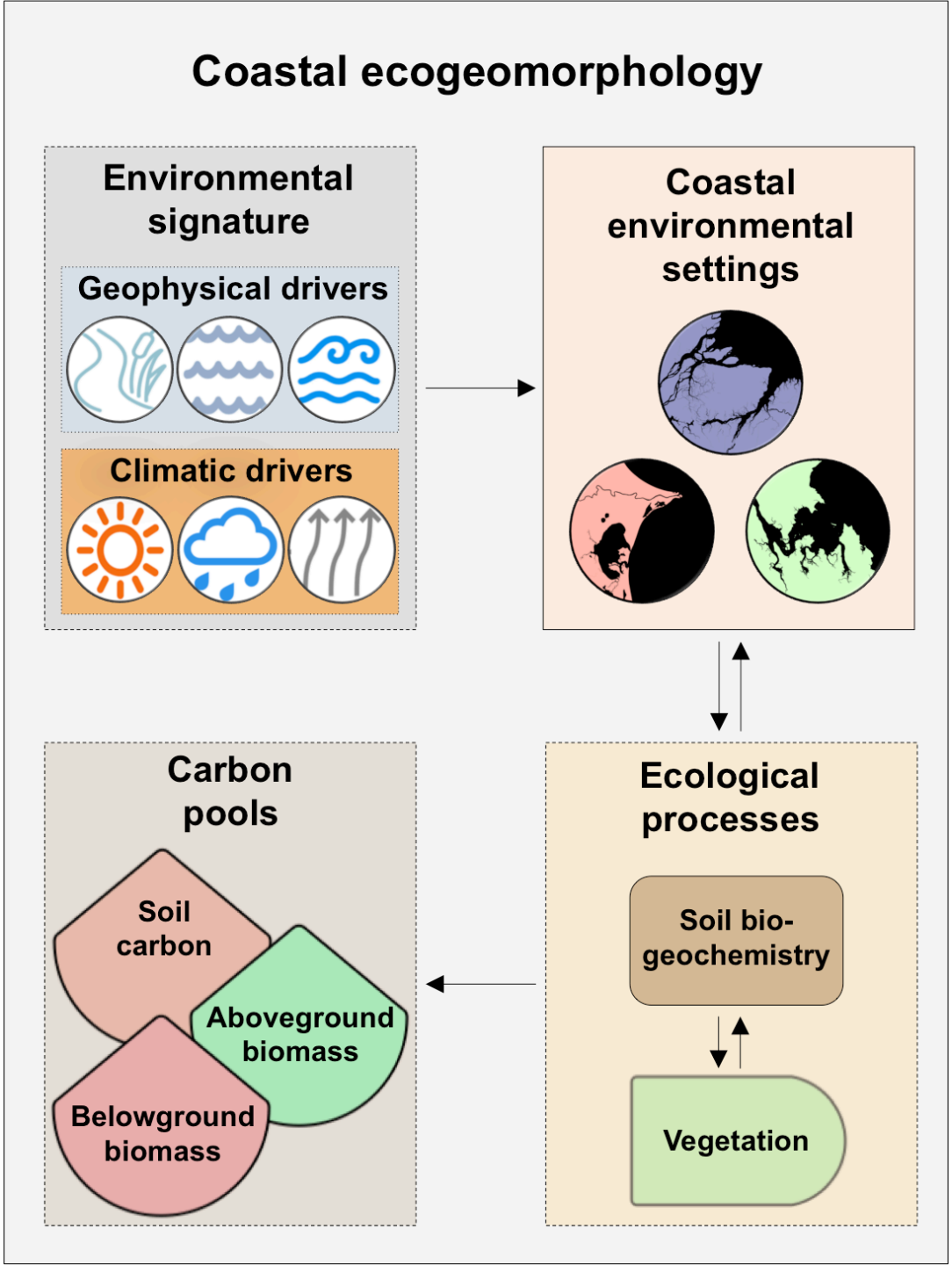

SUN
RAIN
PET
COASTAL PROCESSES
I. Large river
II. Small deltas
RIVER
WAVE POWER
RIVER POWER/P LOAD
VI. Arheic
V. Karst
IV. Lagoons
III. Tidal systems
WAVE
TIDE
RELATIVE WAVE/TIDE POWER
BIDIRECTIONAL ECOLOGICAL PROCESSES
Vegetation
Soil C:N:P stoichiometry
CARBON ALLOCATION
AGB
BGB
SOC
N:P
RIVER
WAVE POWER
RIVER POWER/P LOAD
WAVE
TIDE
RELATIVE WAVE/TIDE POWER



Coastal ecogeomorphology conceptual framework. a, The relative contribution of geophysical (e.g. river discharge, tidal amplitude, wave energy) and climatic (temperature, precipitation, evapotranspiration) drivers shape (**b**) distinct coastal environmental settings (e.g. deltas, estuaries, lagoon, karstic). **c,** Bidirectional influences of biota and landscapes on each other constrain (**d**) carbon partitioning among ecosystem compartments (soil, above- and belowground biomass).

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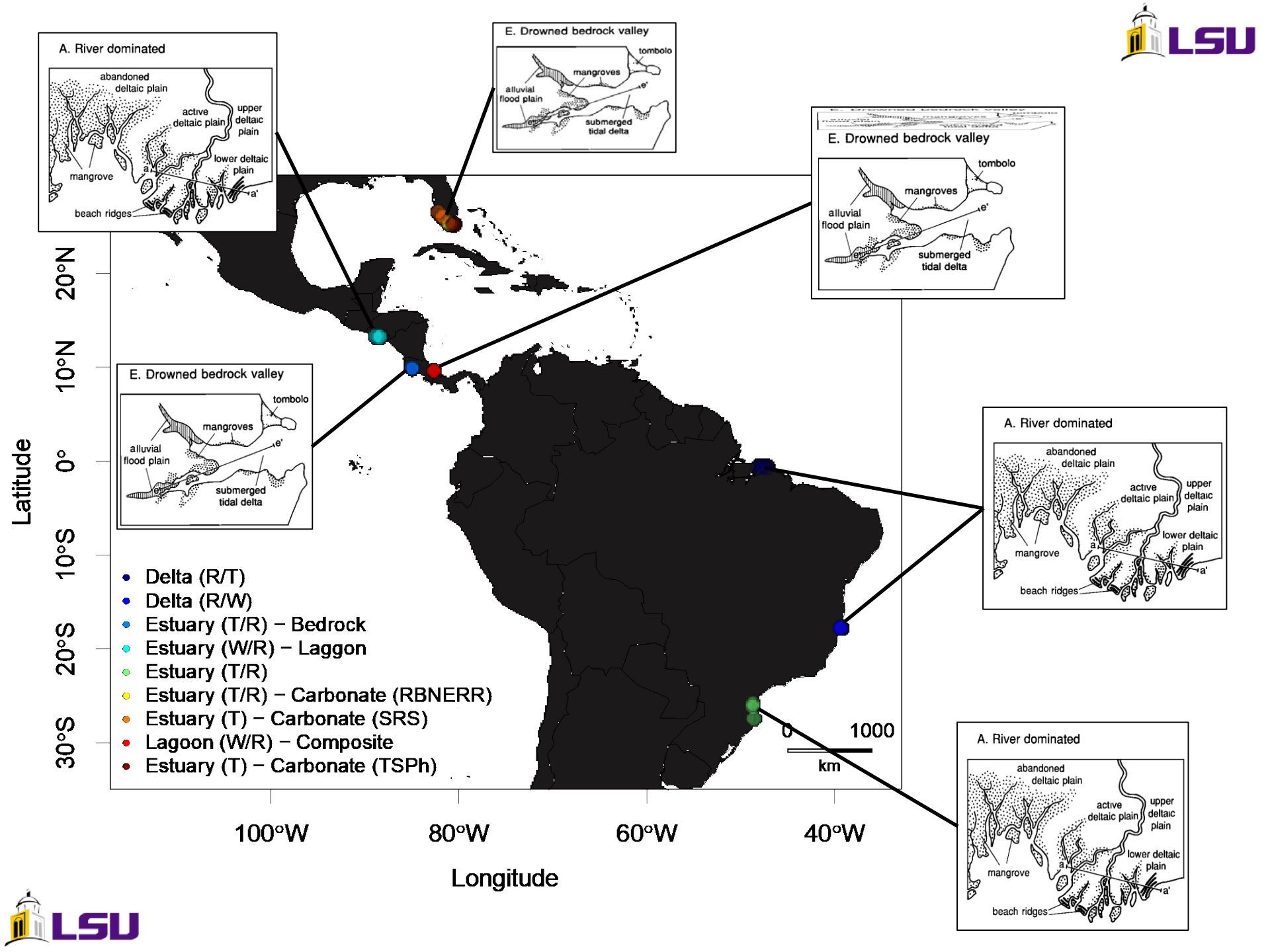
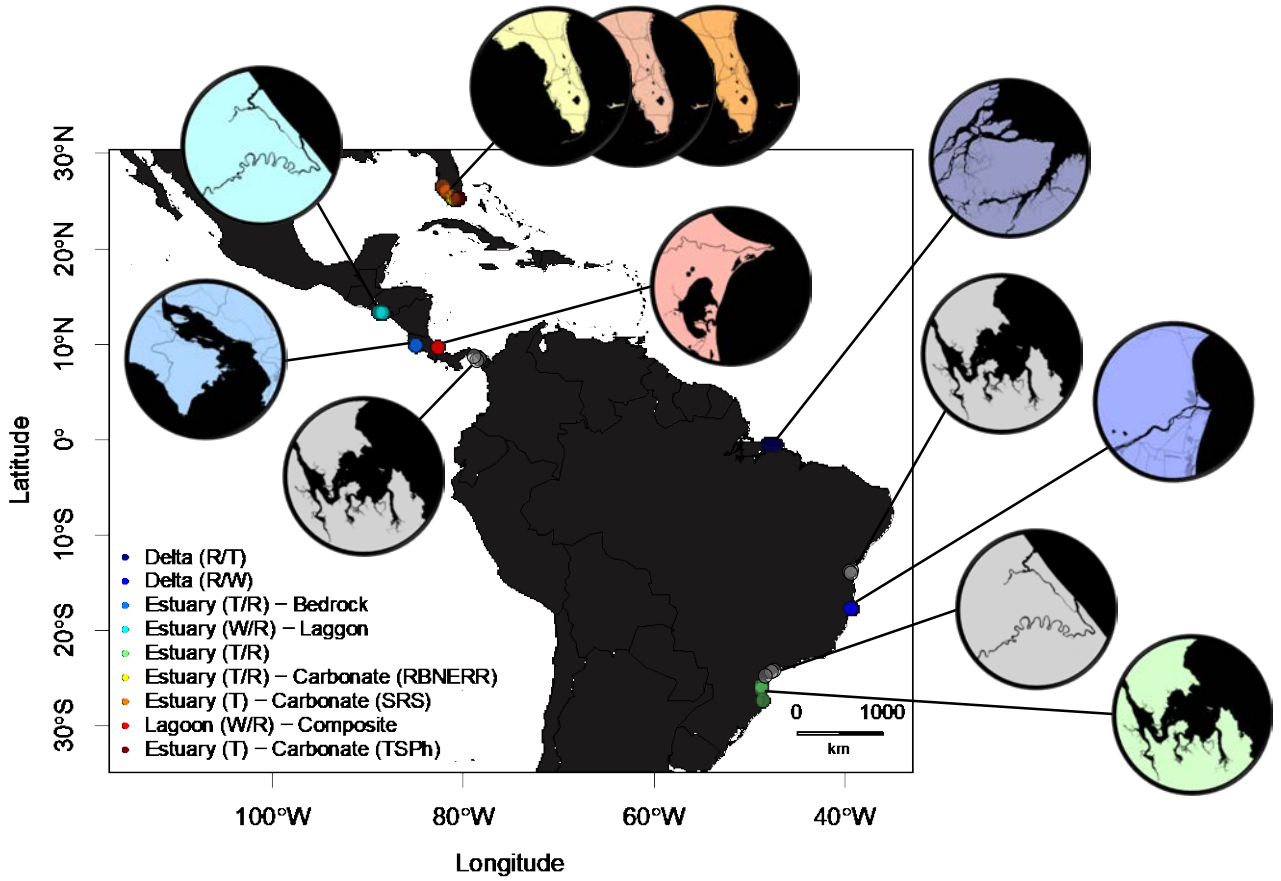
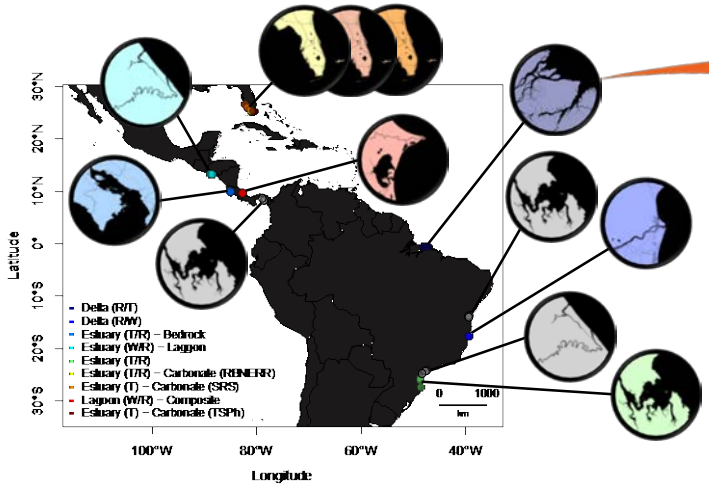

A. River dominated
abandoned deltaic plain
active deltaic plain
upper deltaic plain
lower deltaic plain
mangrove
beach ridges
a
a'
E. Drowned bedrock valley
tombolo
mangroves
alluvial flood plain
e
e'
submerged tidal delta
Latitude
20°N
10°N
0°
10°S
20°S
30°S
Longitude
100°W
80°W
60°W
40°W
Delta (R/T)
Delta (R/W)
Estuary (T/R) – Bedrock
Estuary (W/R) – Laggon
Estuary (T/R)
Estuary (T/R) – Carbonate (RBNERR)
Estuary (T) – Carbonate (SRS)
Lagoon (W/R) – Composite
Estuary (T) – Carbonate (TSPh)
0
1000
km

RIVER NO RIVER

Delta Lagoon - Estuary Karstic





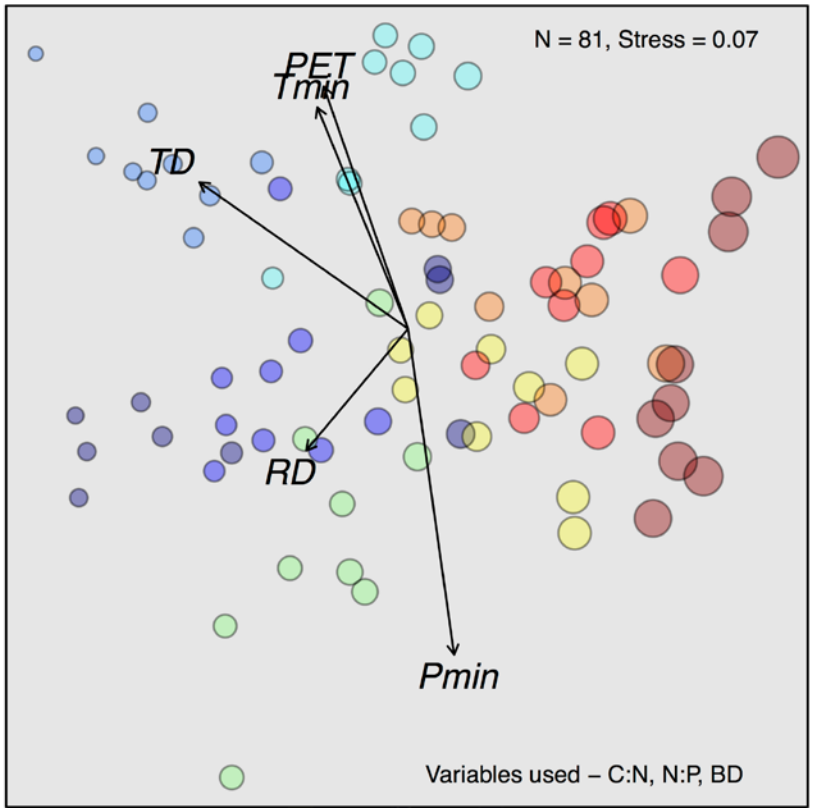
Each CES Type

- Site #1
  - Core #1
    - Depth (0-100cm)
  - Core #2
  - Core #3
- Site #2
- Site #3

RIVER **NO RIVER**

Delta Lagoon - Estuary Karstic

a



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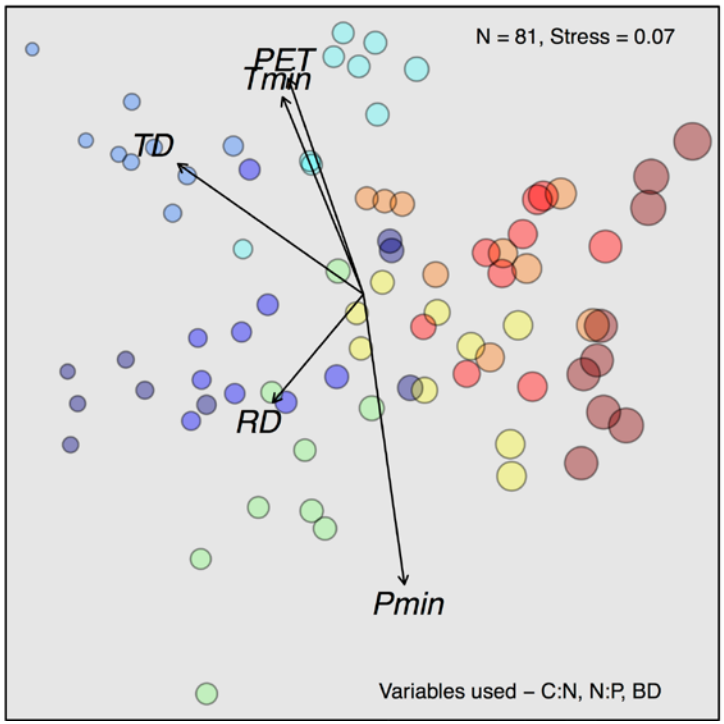
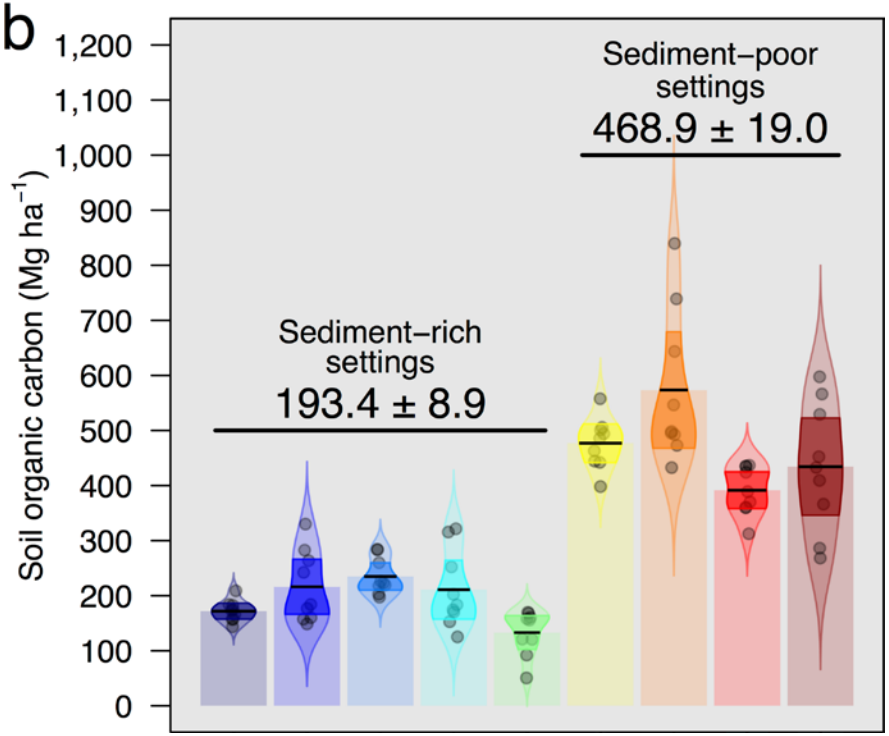
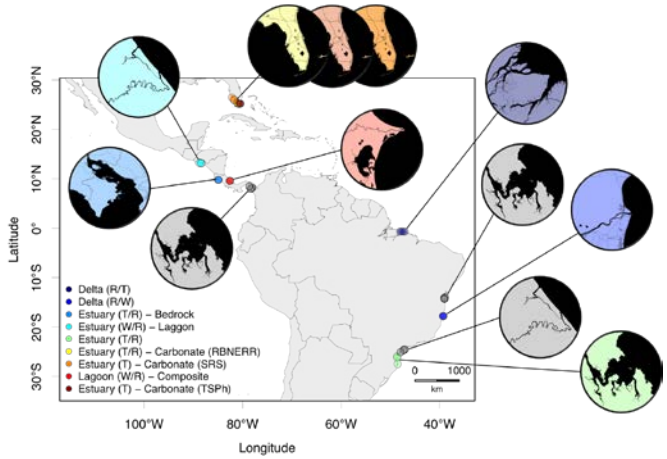
Delta Lagoon - Estuary Karstic

a

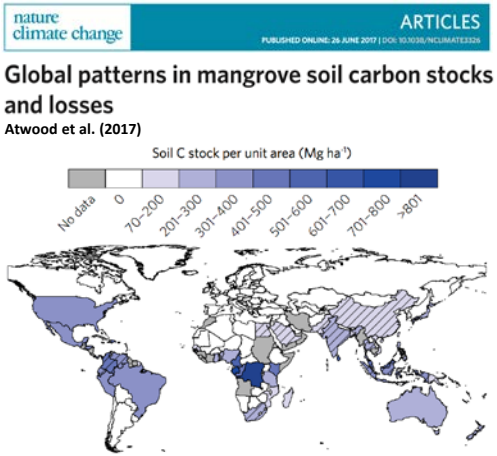


b



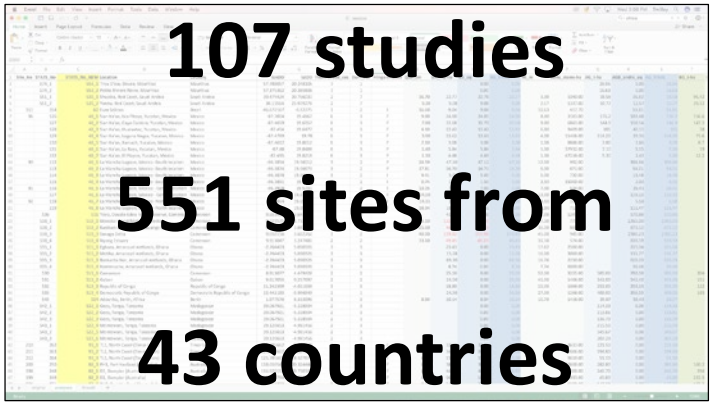

Latitude
30°N
20°N
10°N
0°
10°S
20°S
30°S
100°W
80°W
60°W
40°W
Longitude
Delta (R/T)
Delta (R/W)
Estuary (T/R) – Bedrock
Estuary (W/R) – Laggon
Estuary (T/R)
Estuary (T/R) – Carbonate (RBNERR)
Estuary (T) – Carbonate (SRS)
Lagoon (W/R) – Composite
Estuary (T) – Carbonate (TSPh)
0
1000
km

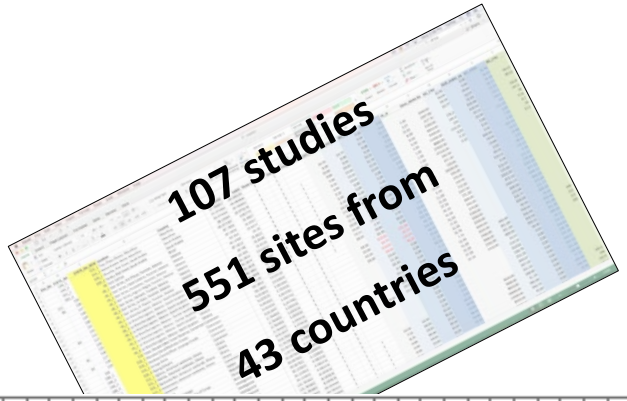
+

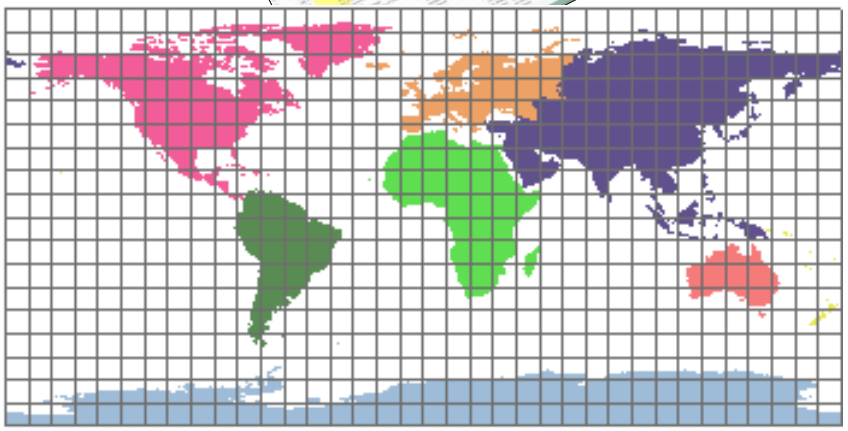

nature climate change
ARTICLES
Global patterns in mangrove soil carbon stocks and losses
Atwood et al. (2017)
Soil C stock per unit area (Mg ha⁻¹)
No data
0
70–200
201–300
301–400
401–500
501–600
601–700
701–800
>801


Depth <0.3m
C from LOI

=


107 studies
551 sites from
43 countries





142 cells

(0.25 degrees)

~

Tide

River

Temp.

Precip.

PET

Environmental signature

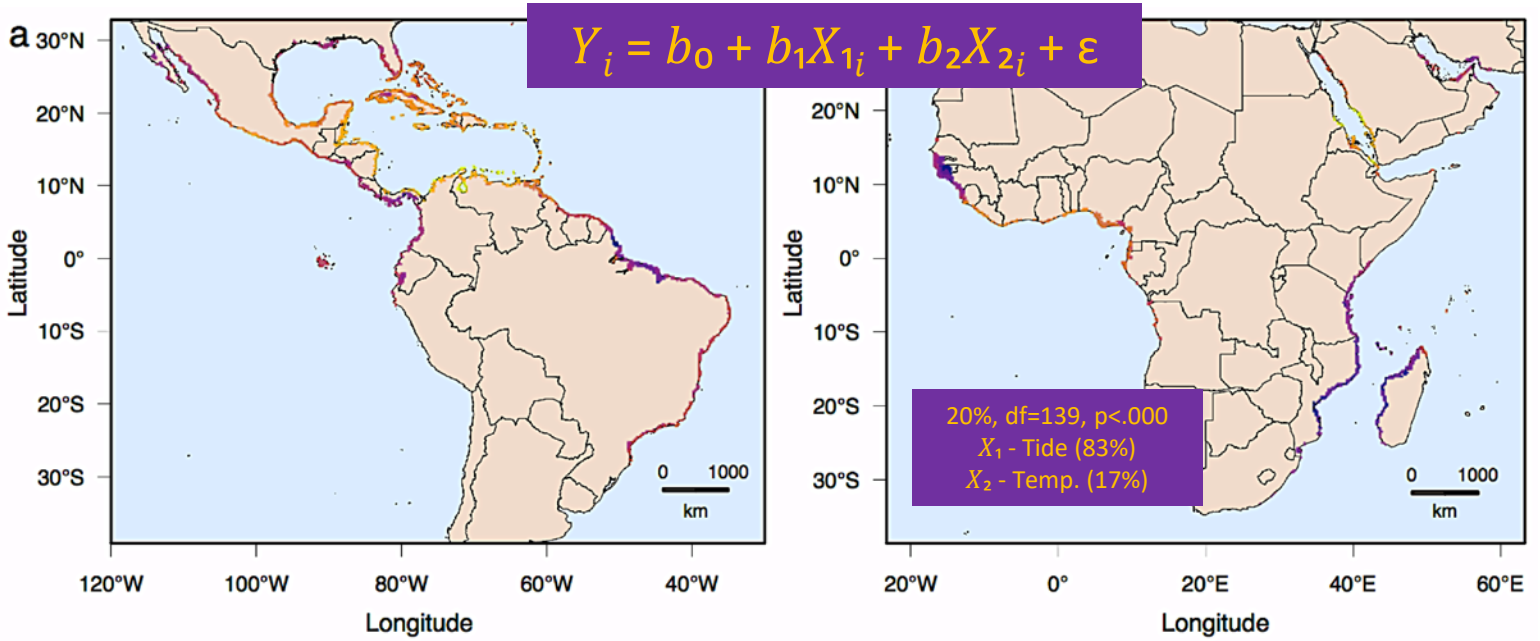
Geophysical drivers

Climatic drivers

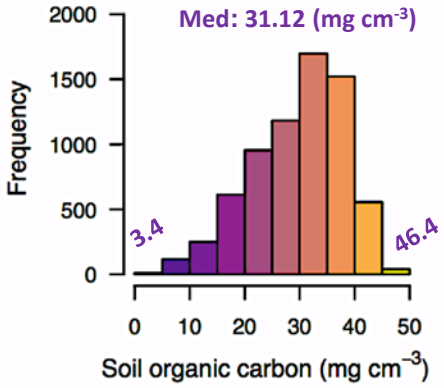
From Carrère et al. (2012), Fekete et al (2002), Hijmans et al. (2005), Mu et al. (2011)

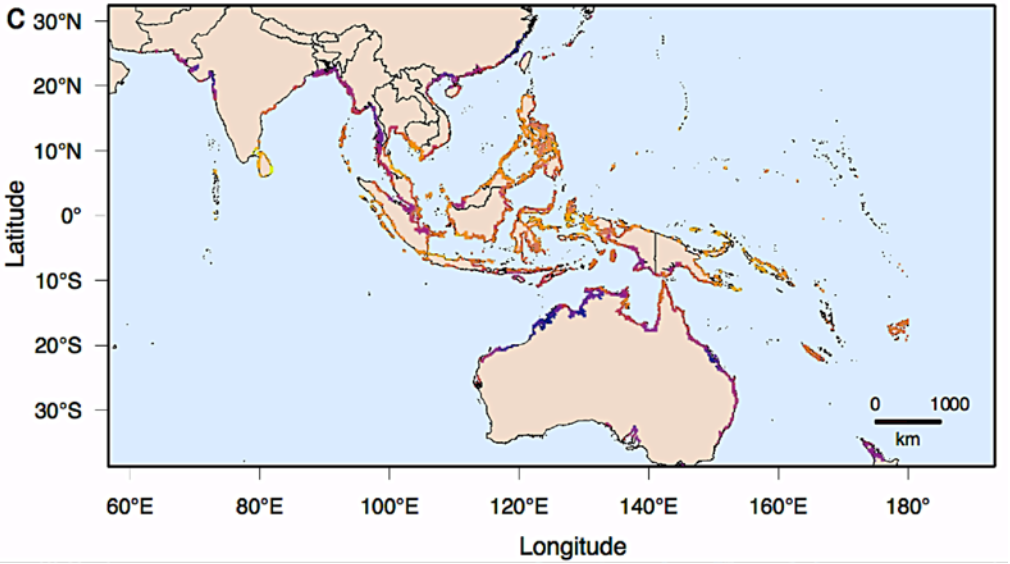
LSU

$$Y_i = b_0 + b_1 X_{1i} + b_2 X_{2i} + \varepsilon$$

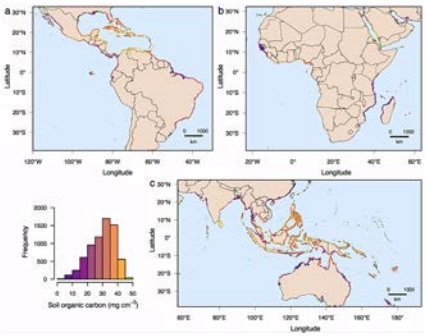


20%, df=139, p<.000
X_1 - Tide (83%)
X_2 - Temp. (17%)

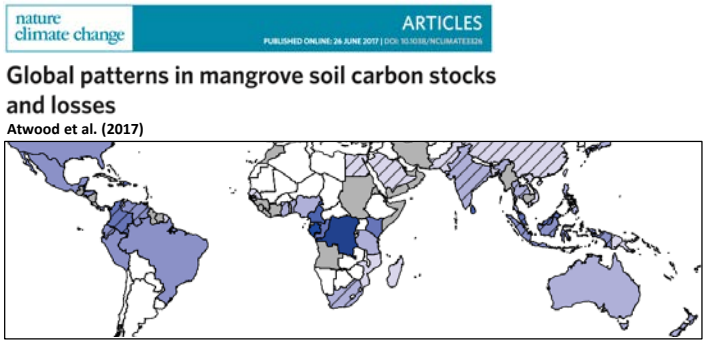


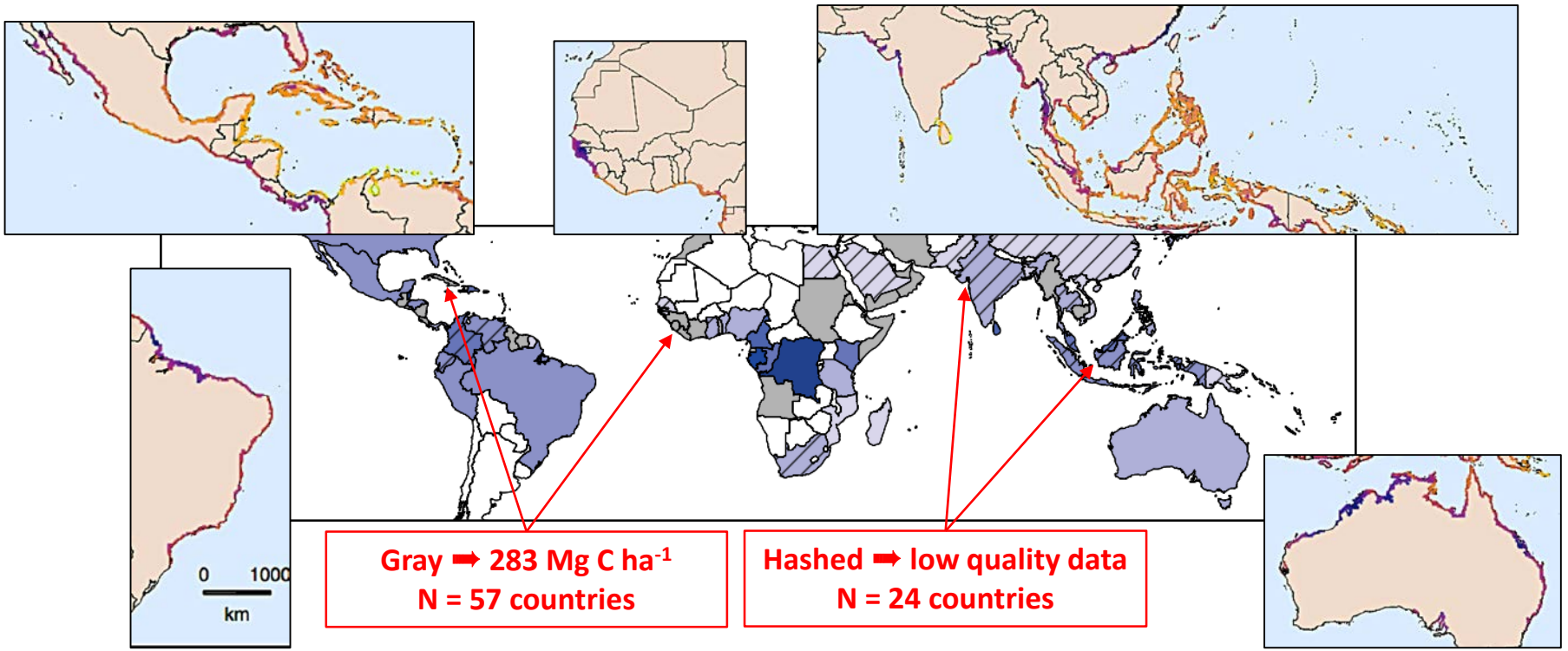


This study



vs.





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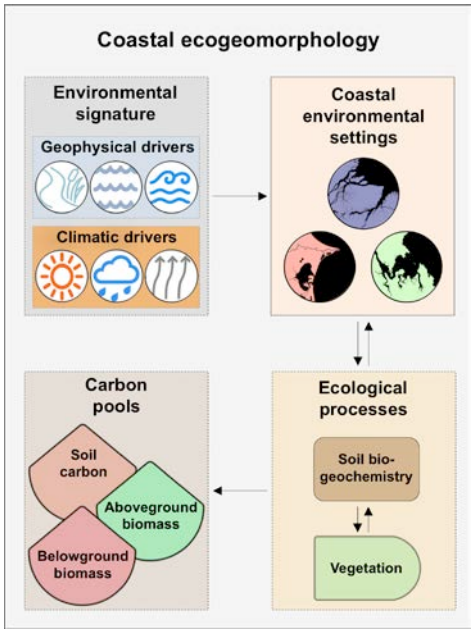

Estuaries and Coasts (2011) 34:441–458
DOI 10.1007/s12237-011-9381-y

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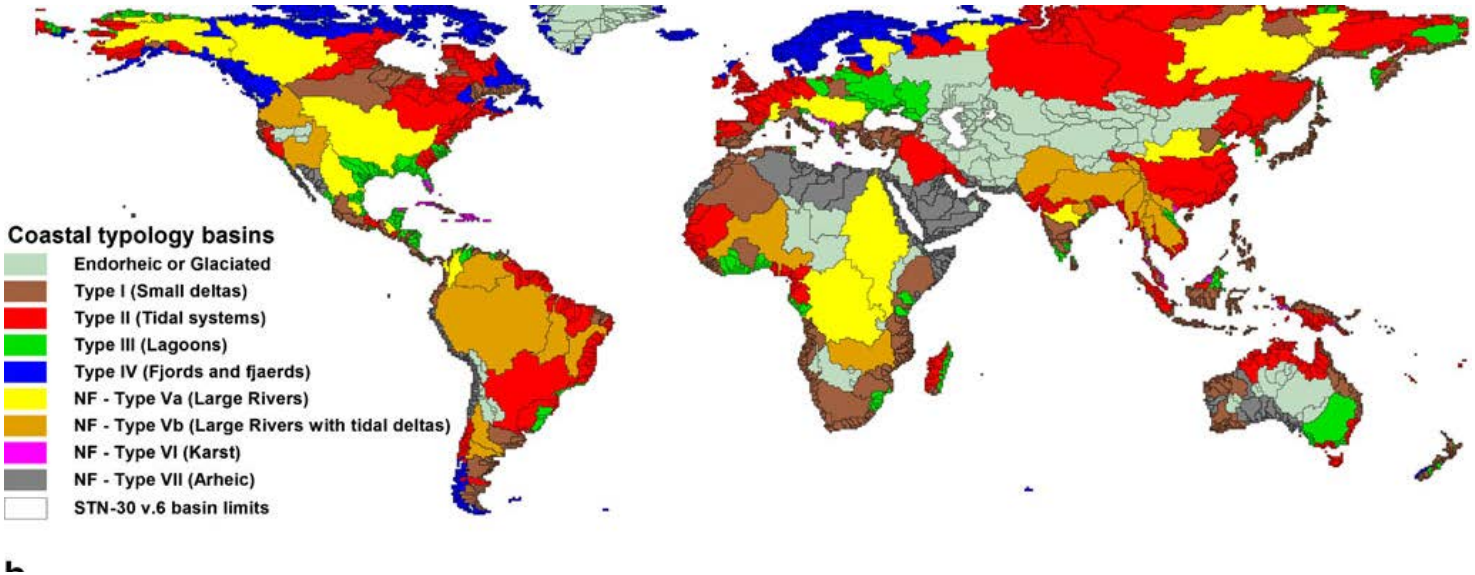
Hans H. Dürr · Goulven G. Laruelle · Cheryl M. van Kempen · Caroline P. Slomp · Michel Meybeck · Hans Middelkoop



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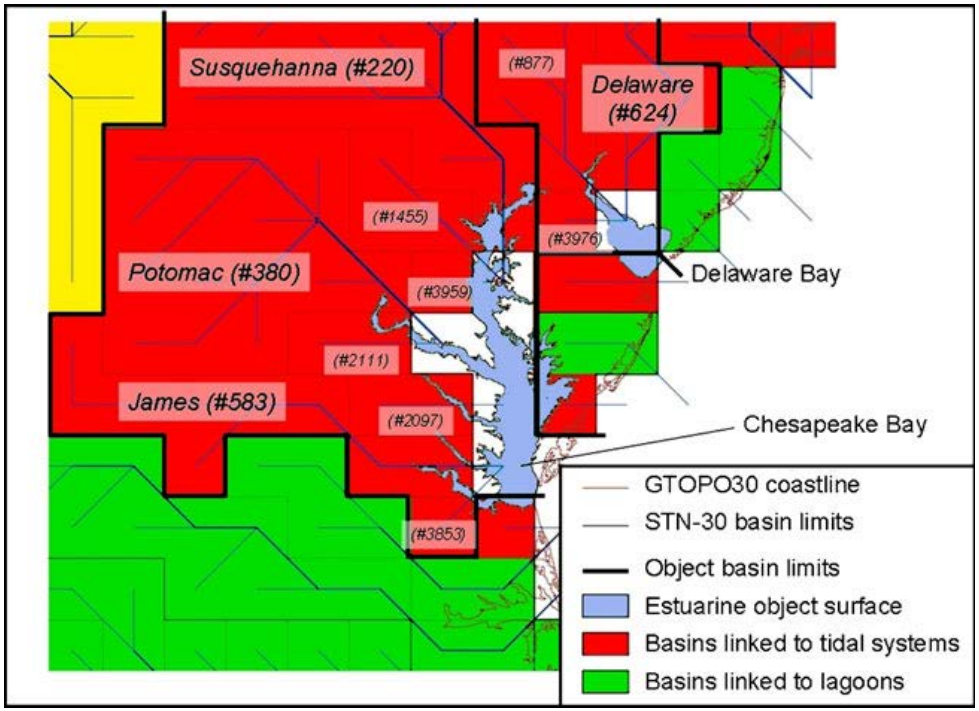


I. Large rivers

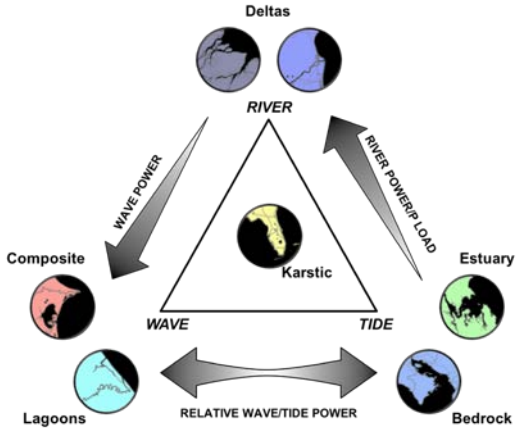
II. Small deltas

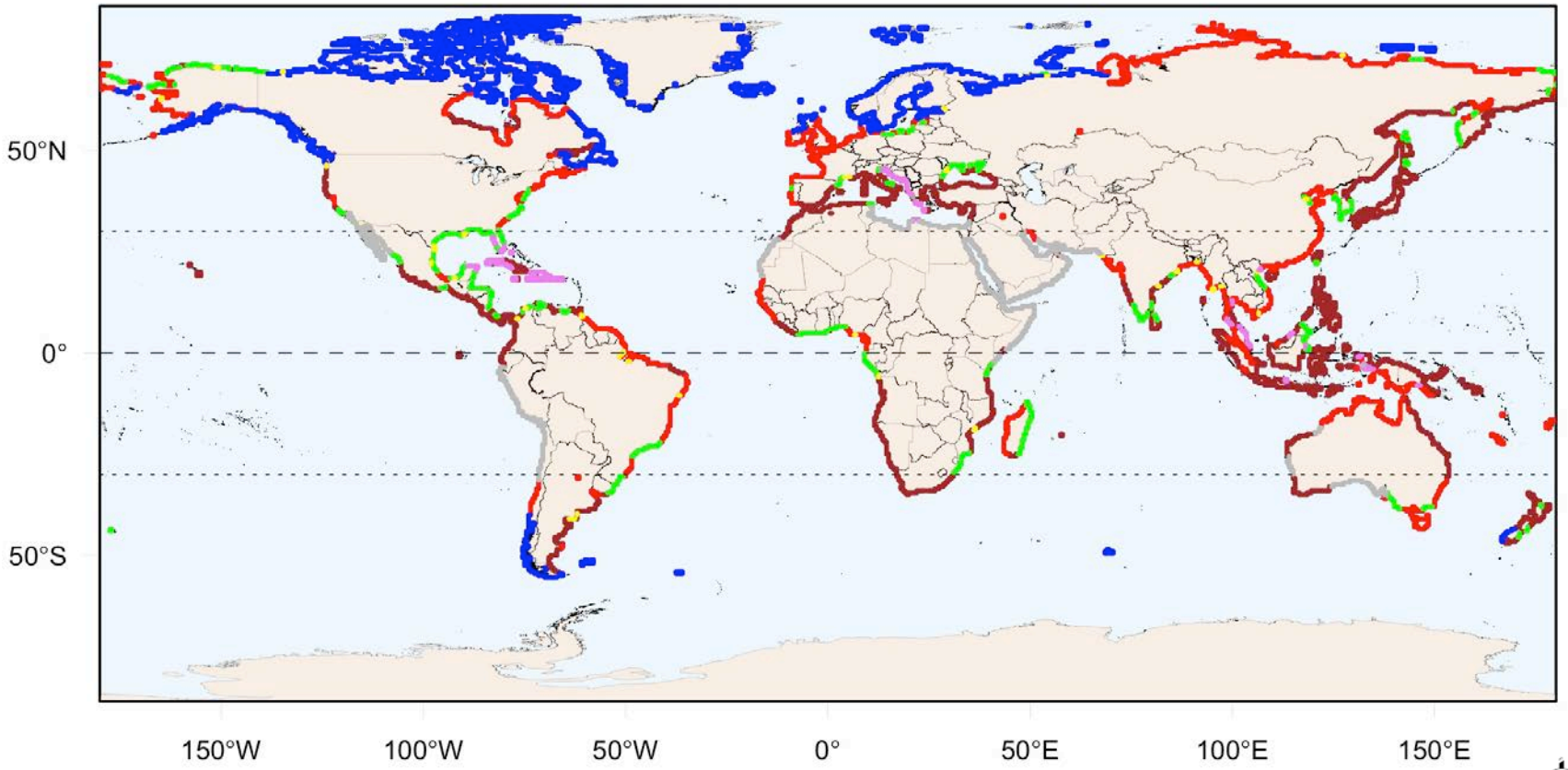
III. Tidal Systems

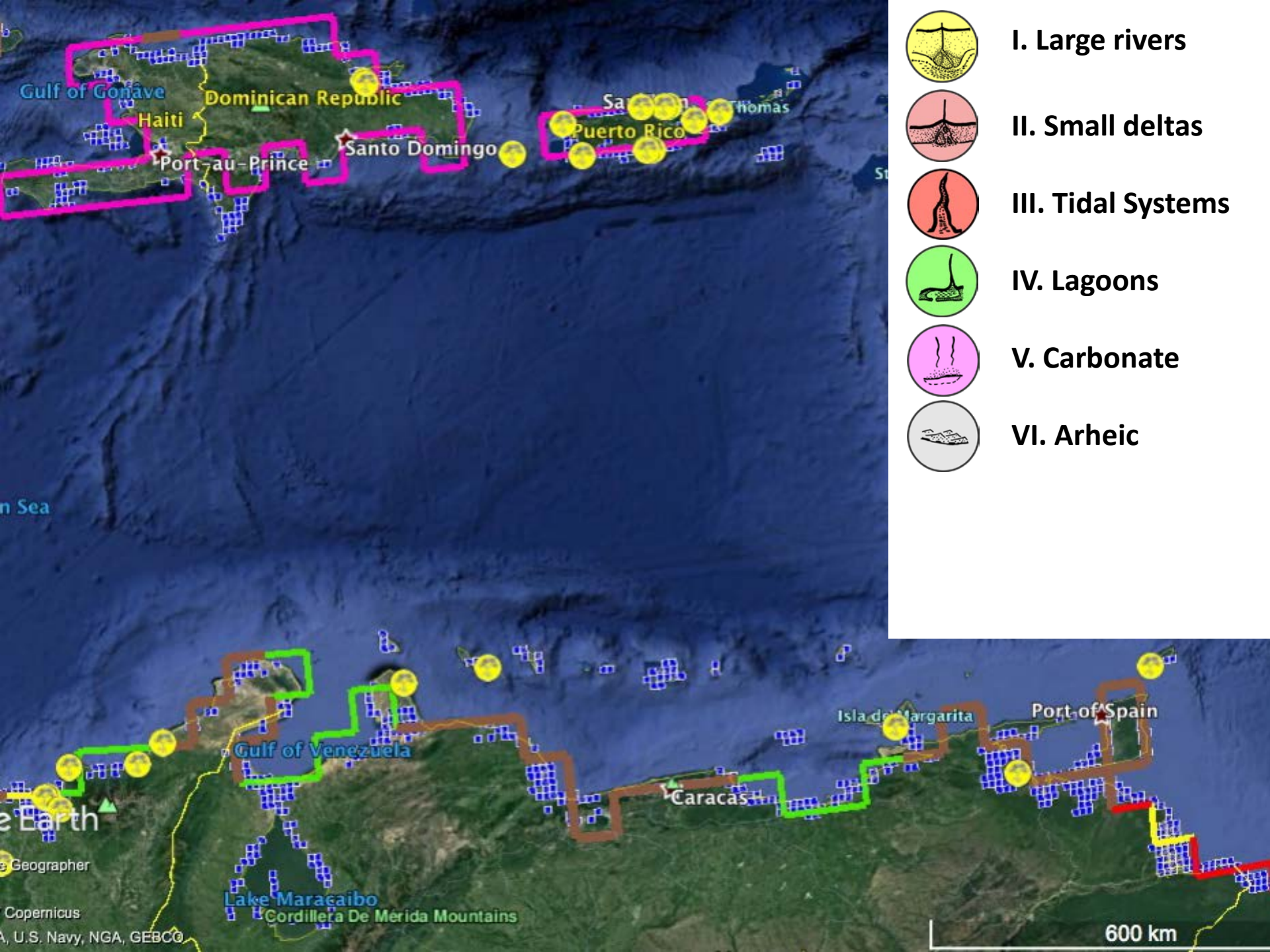
IV. Lagoons

V. Carbonate

VI. Arheic






Gulf of Gonâve
Haiti
Dominican Republic
Port-au-Prince
Santo Domingo
Puerto Rico
Gulf of Venezuela
Caracas
Isla de Margarita
Port of Spain
Lake Maracaibo
Cordillera De Mérida Mountains
600 km
I. Large rivers
II. Small deltas
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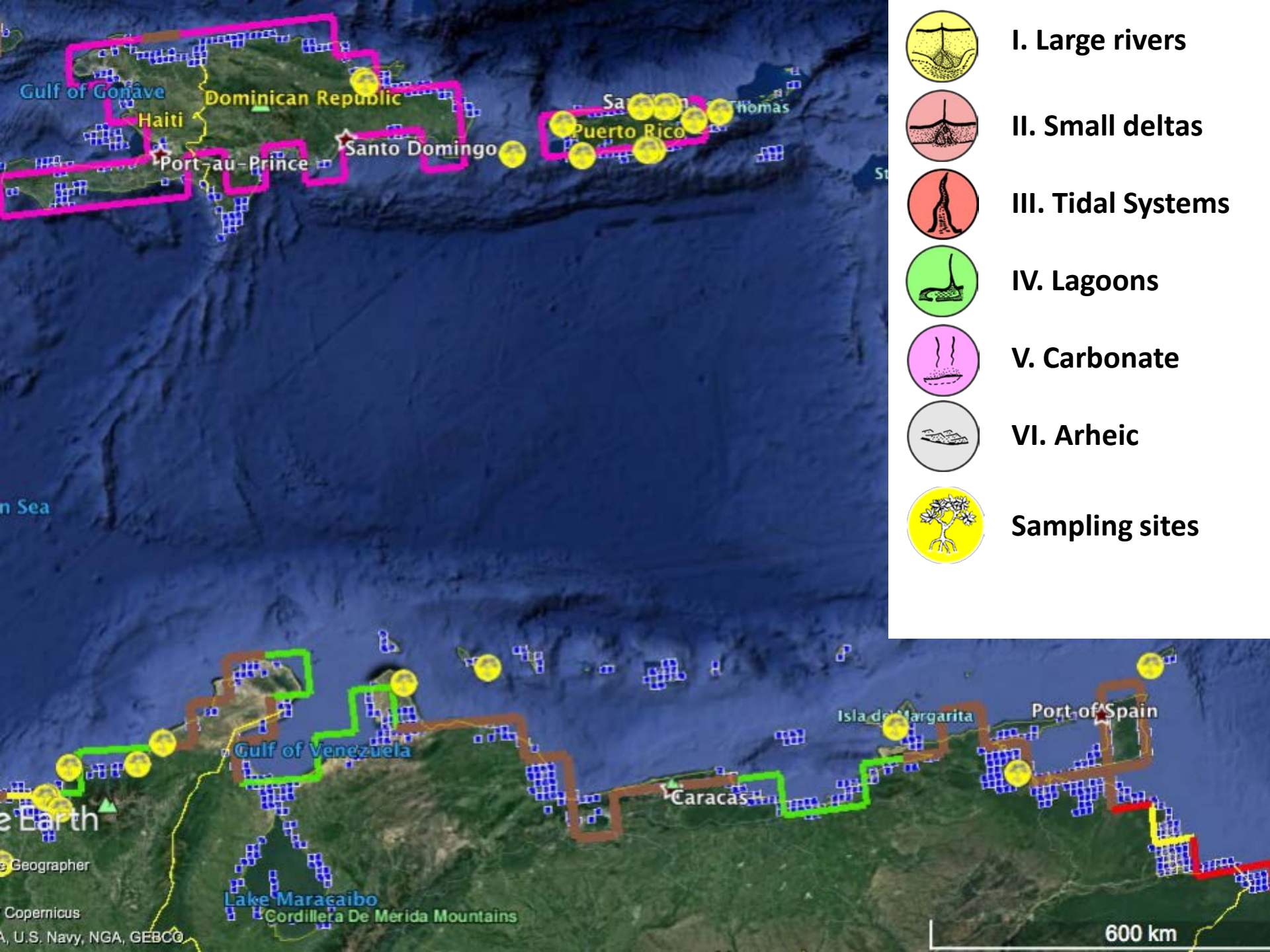
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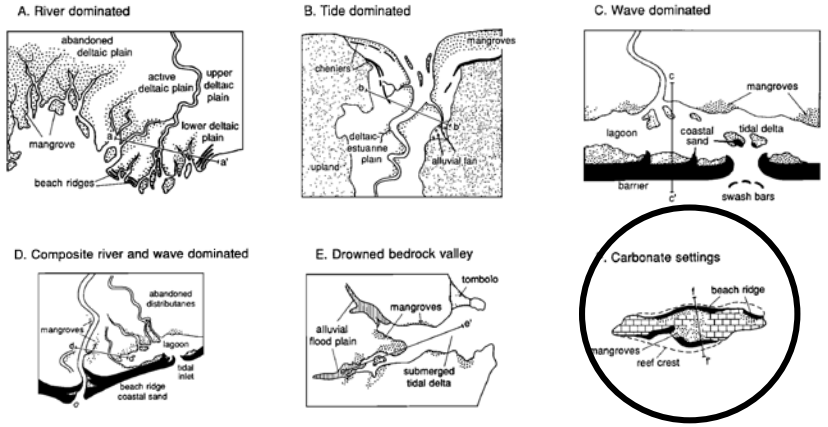
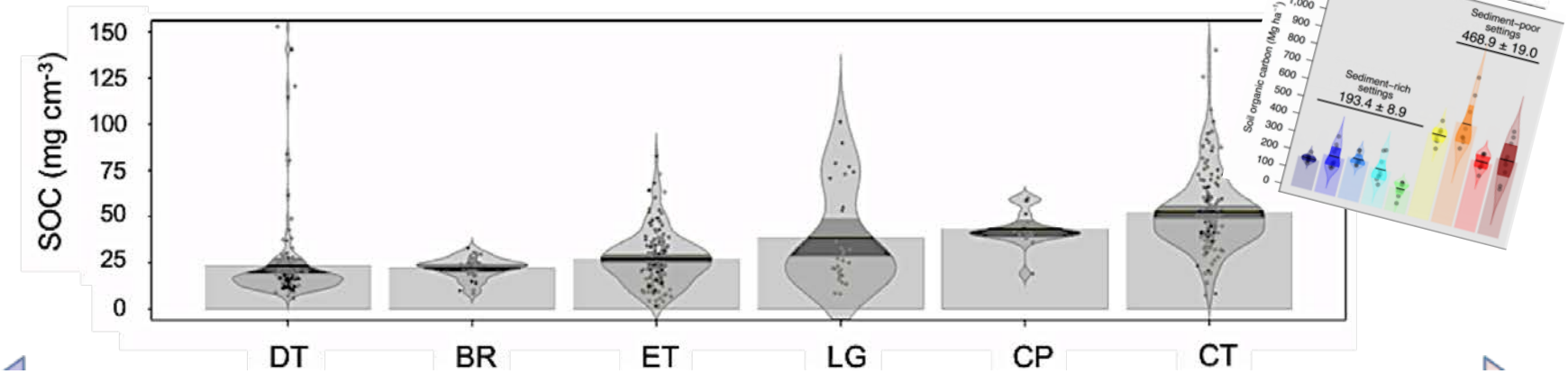
Sampling sites





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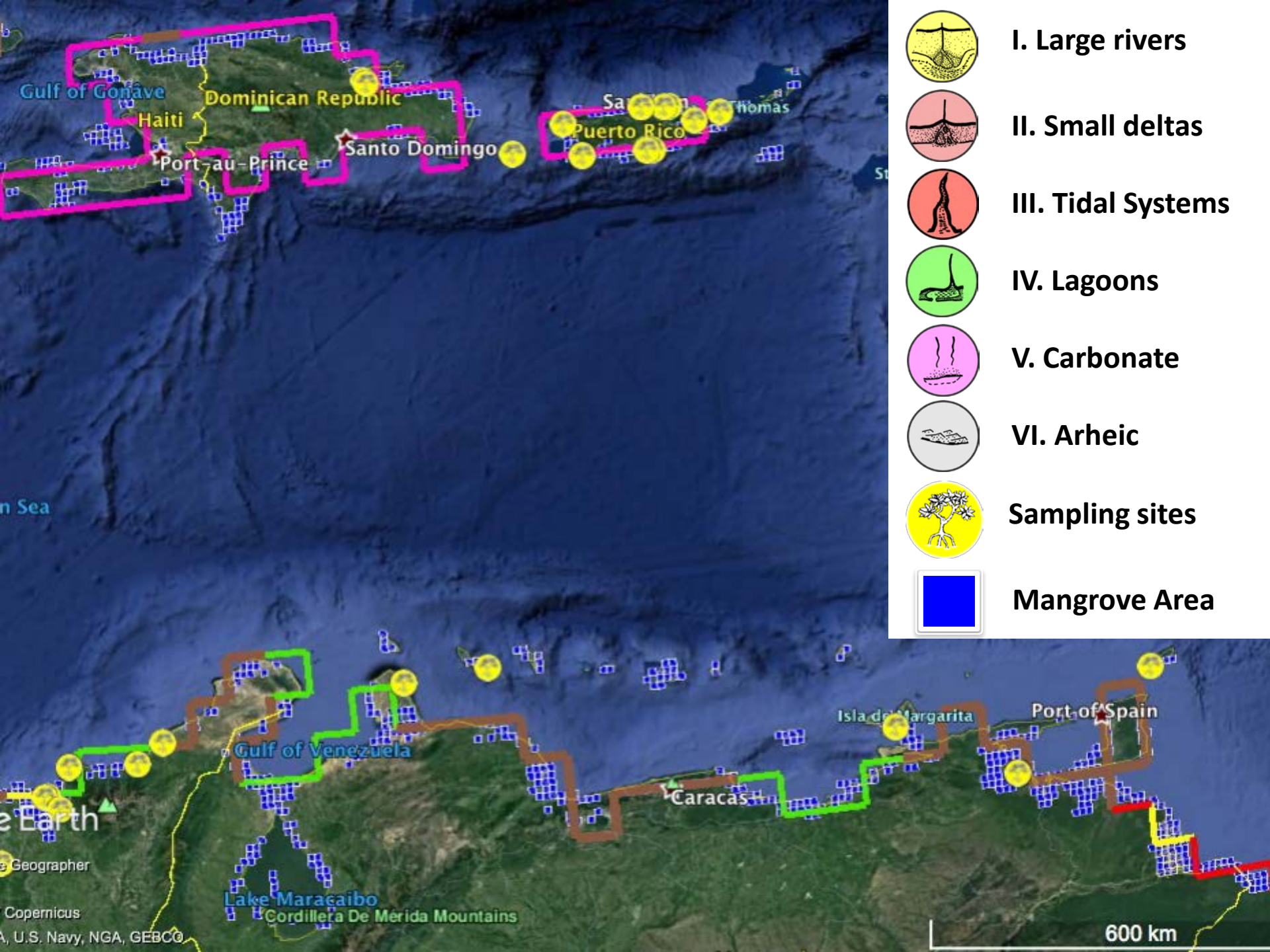
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Mangrove Area

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2016) **25,** 729–738

RESEARCH PAPER

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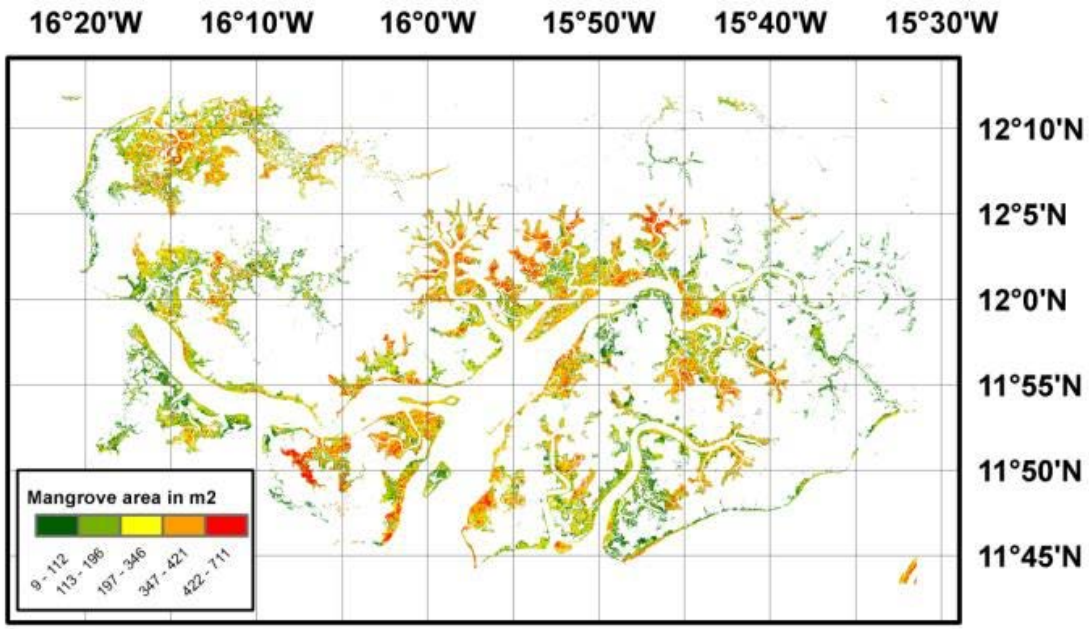
Stuart E. Hamilton[1]* and Daniel Casey[2]



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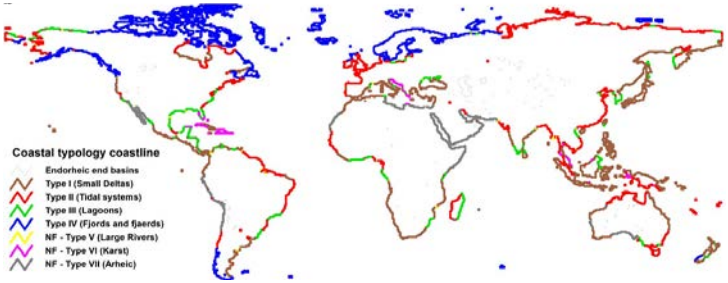

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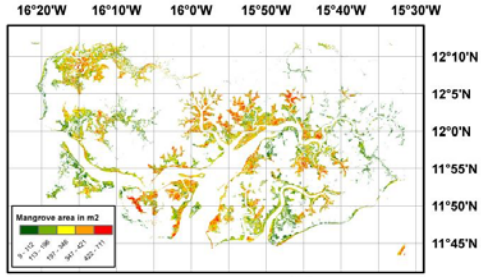

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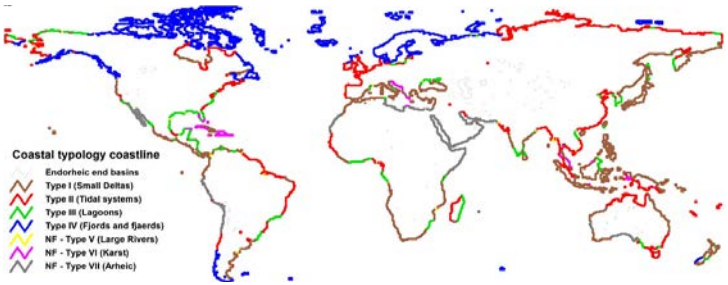

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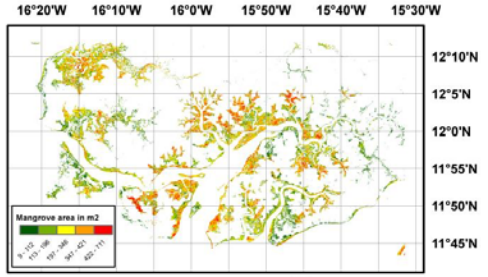
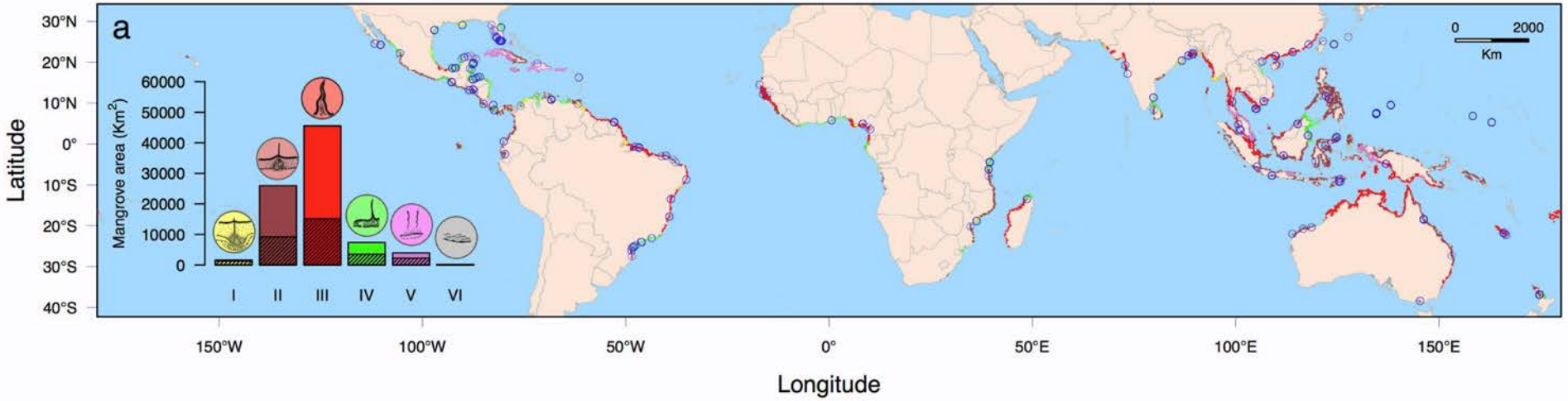


Large river · Small deltas · Tidal systems · Lagoons · Carbonate · Arheic



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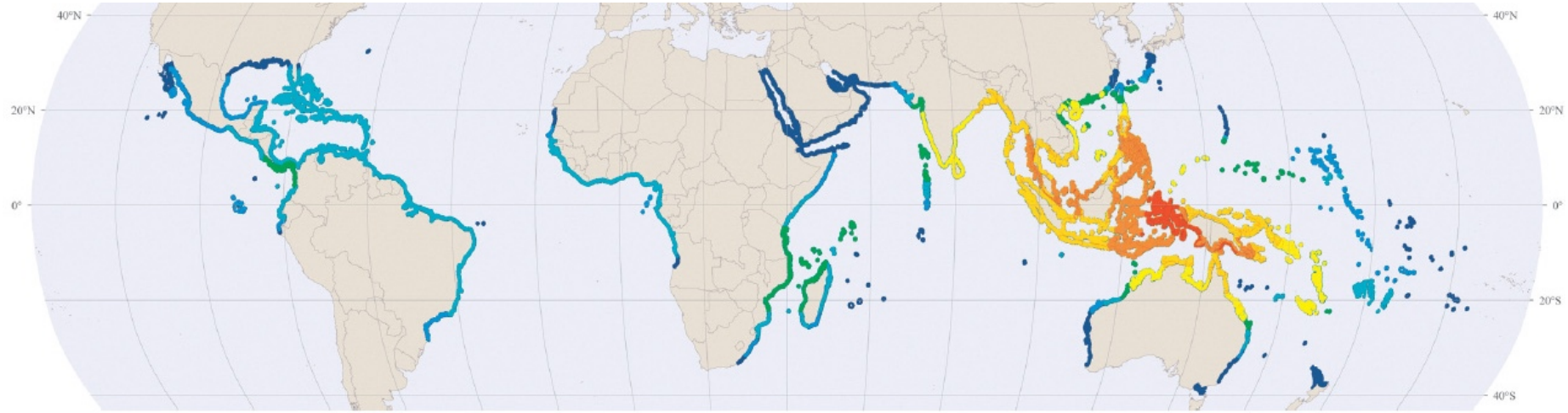
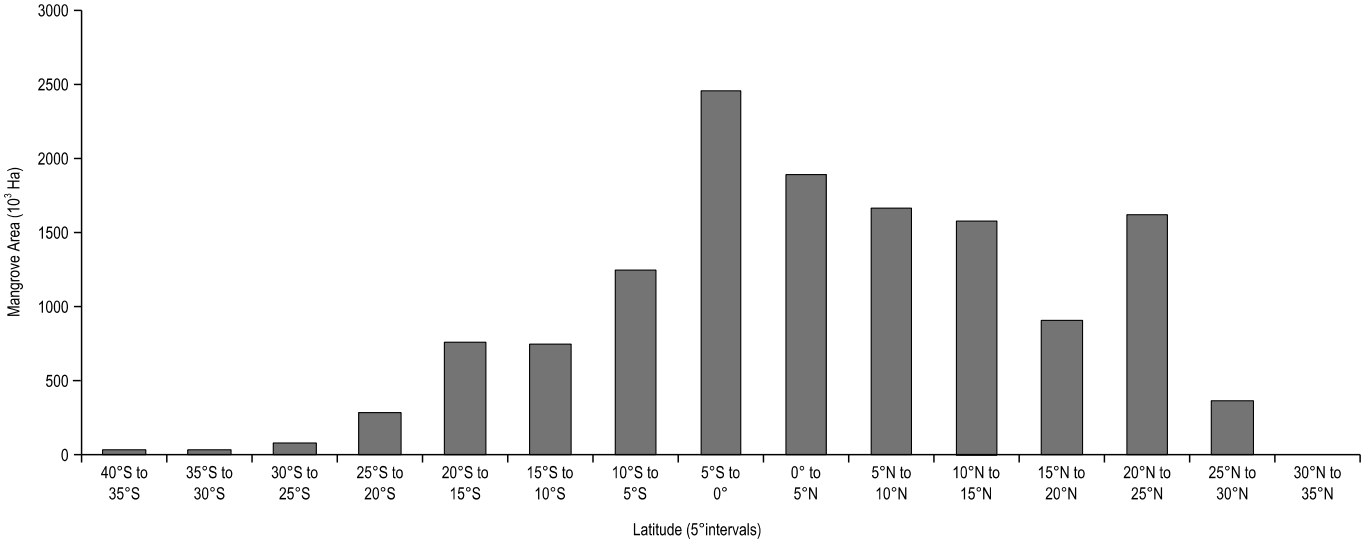


C. Giri *et al*.



world.

Giri, C., E. Ochieng, L.L. Tieszen, Z. Zhu, A. Singh, T. Loveland, J. Masek, and N. Duke. 2011. Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography* 20: 154-159

Atlantic/Eastern Pacific (AEP) Indo/West Pacific (IWP)

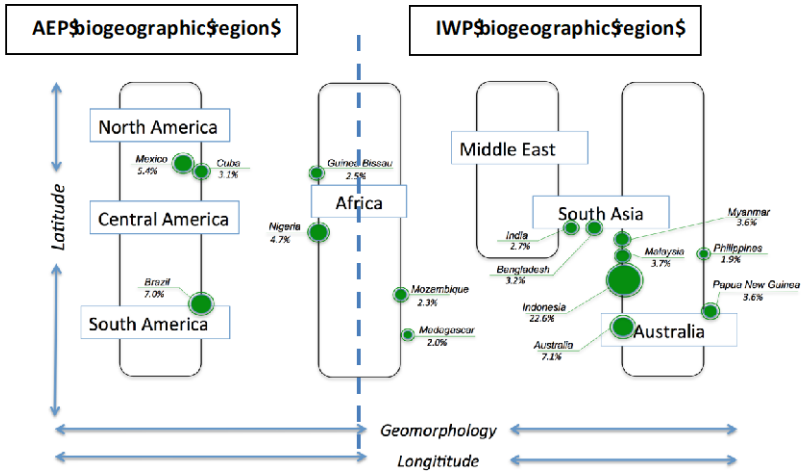
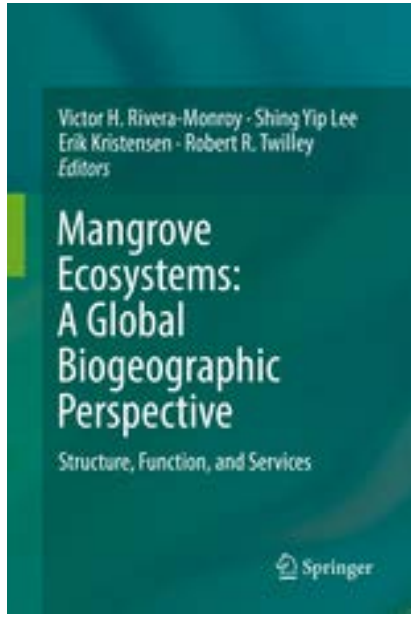


Figure 1. The biogeographic and regional dimensions scales considered in the comparative analysis of ecological and socioeconomic mangrove processes discussed in this book. The circles represent the 15 countries contributing 75.3% of the total global mangrove area in 2000 (Data from Giri *et al.*, 2011).



RIVER **NO RIVER**

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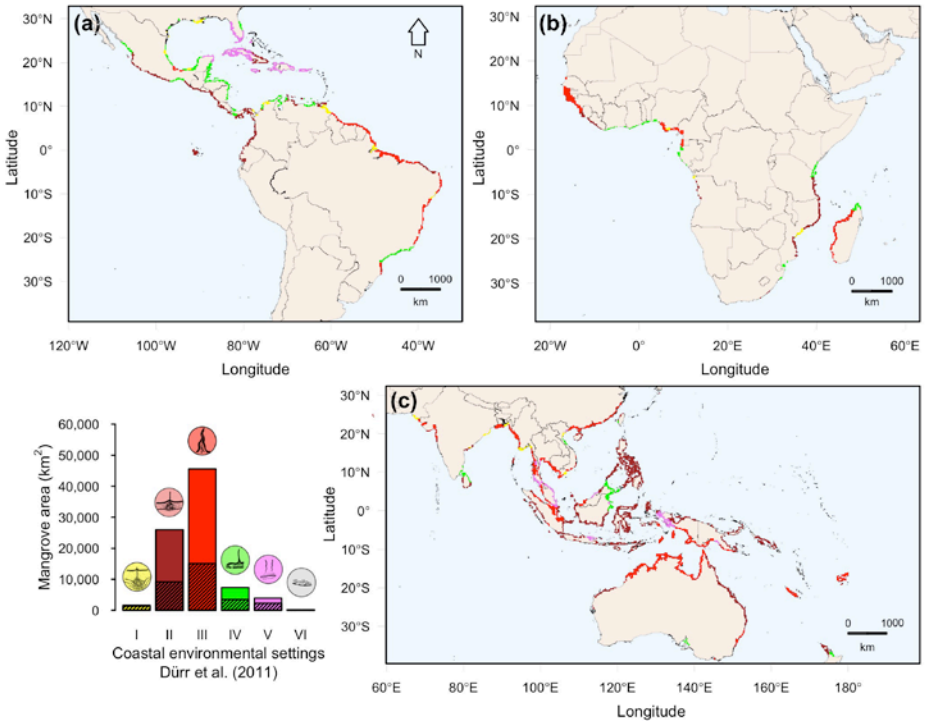

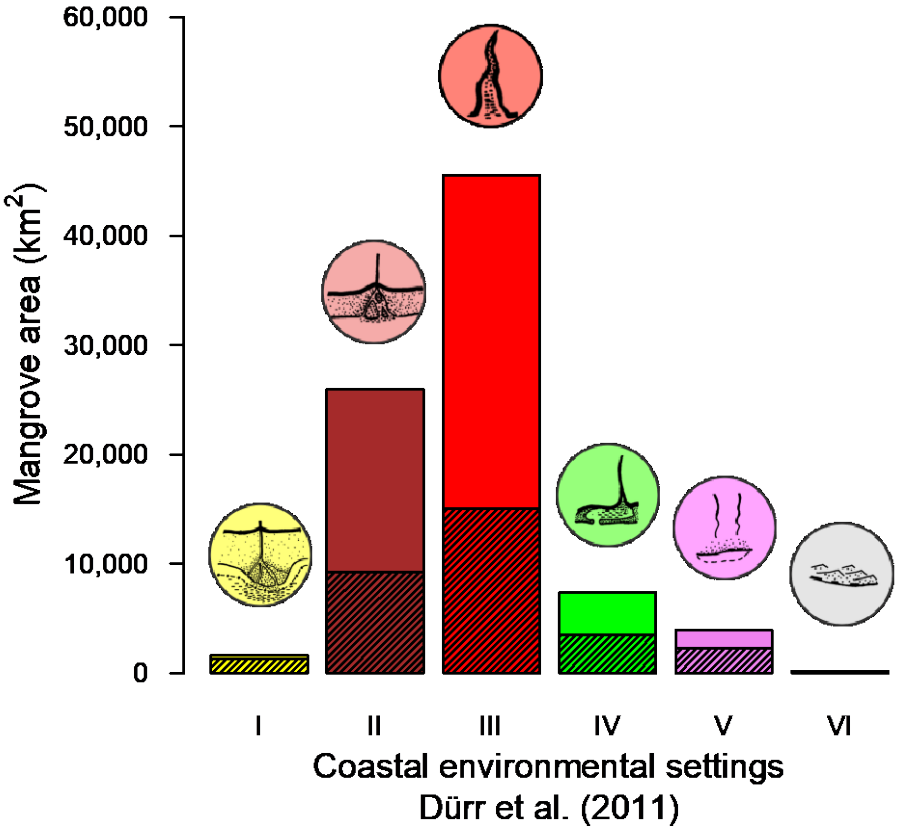

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II. Small deltas

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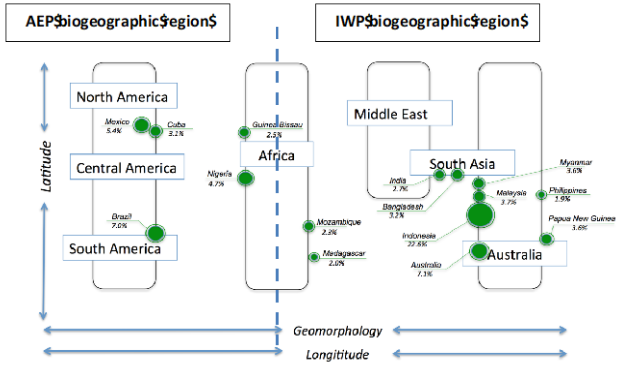

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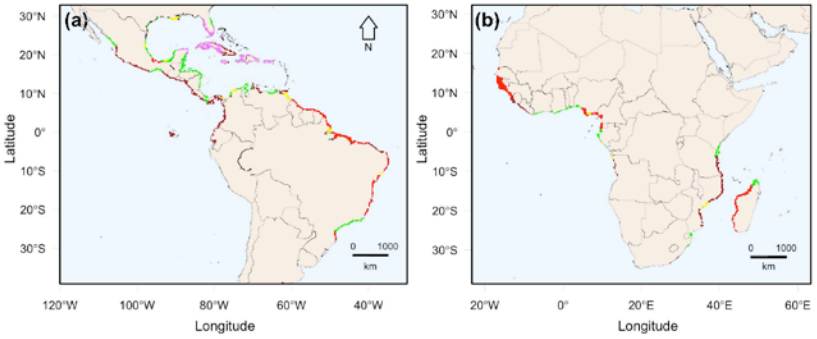
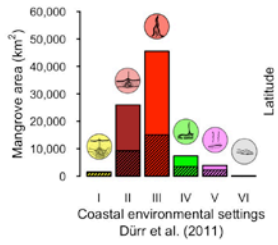
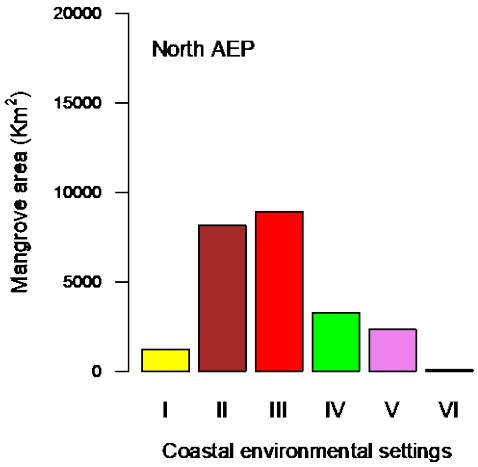
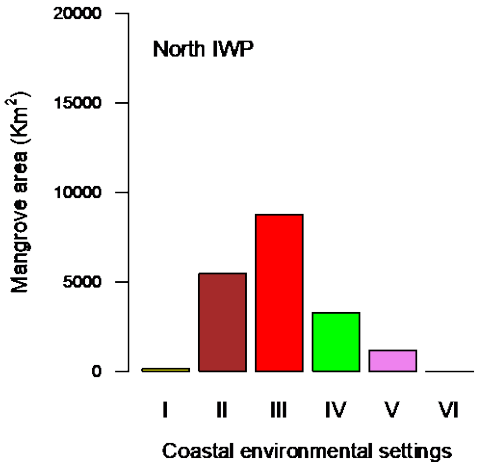
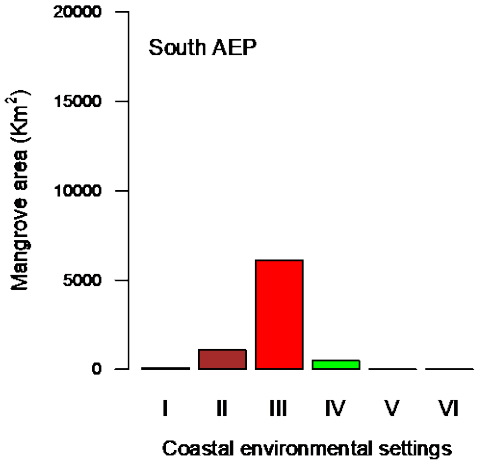
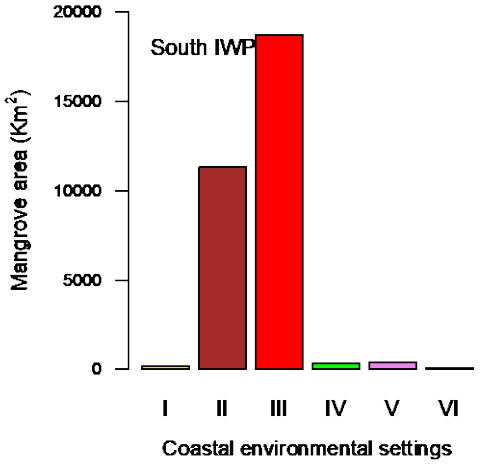




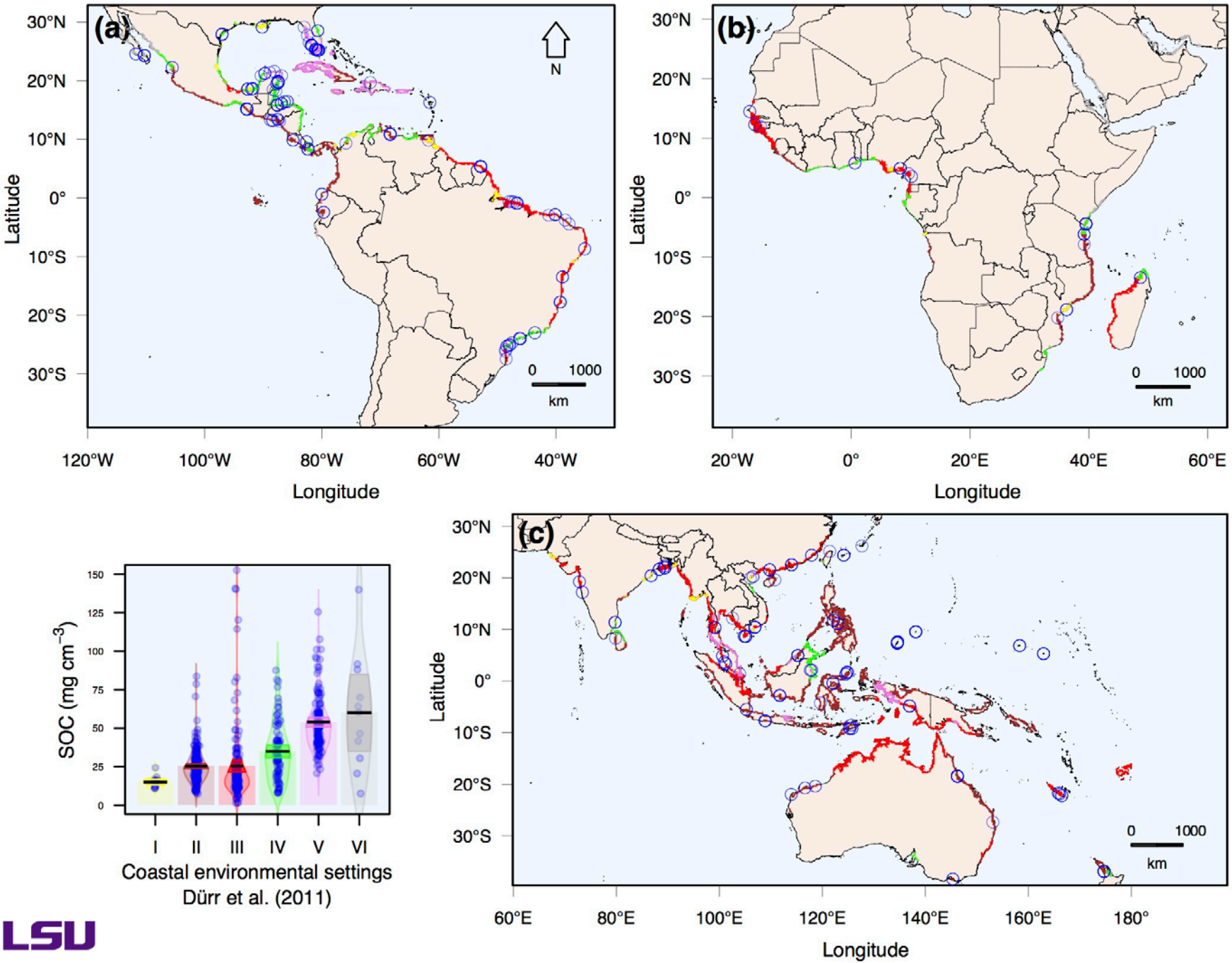








LSU


(a)
(b)
(c)
N
0 1000
km
Latitude
Longitude
30°N
20°N
10°N
0°
10°S
20°S
30°S
120°W
100°W
80°W
60°W
40°W
20°W
0°
20°E
40°E
60°E
80°E
100°E
120°E
140°E
160°E
180°
SOC (mg cm^{-3})
150
125
100
75
50
25
0
I
II
III
IV
V
VI
Coastal environmental settings
Dürr et al. (2011)

I. Large rivers

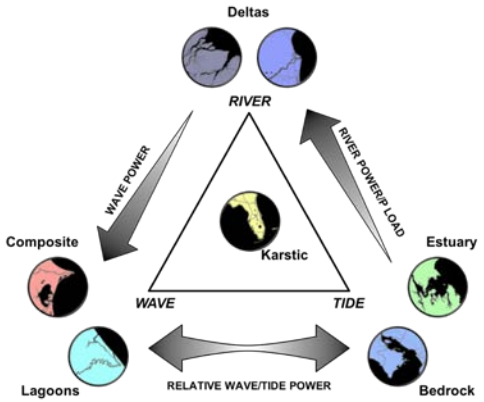
II. Small deltas

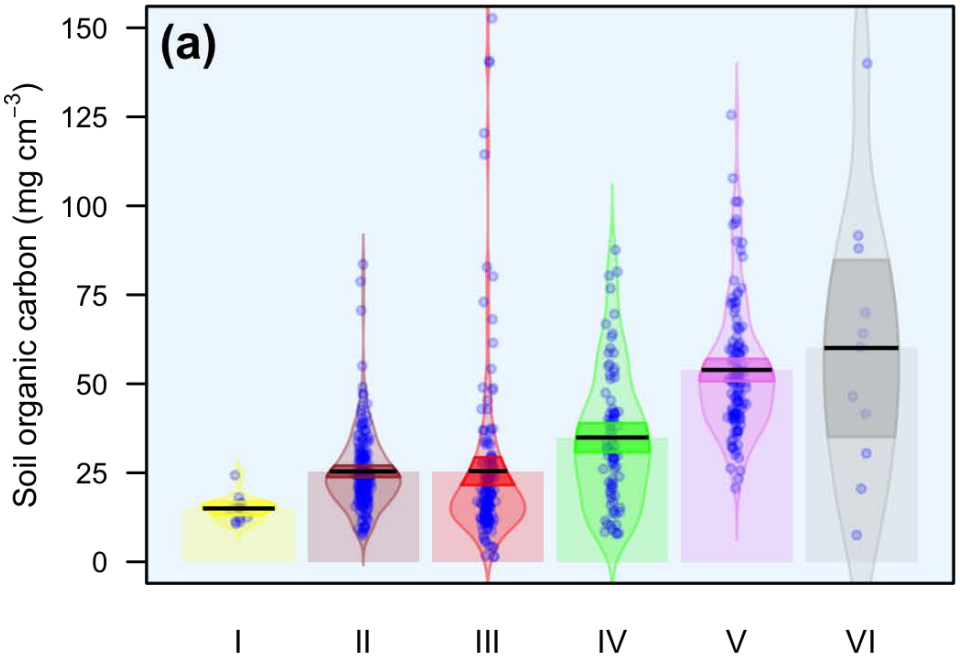
III. Tidal Systems

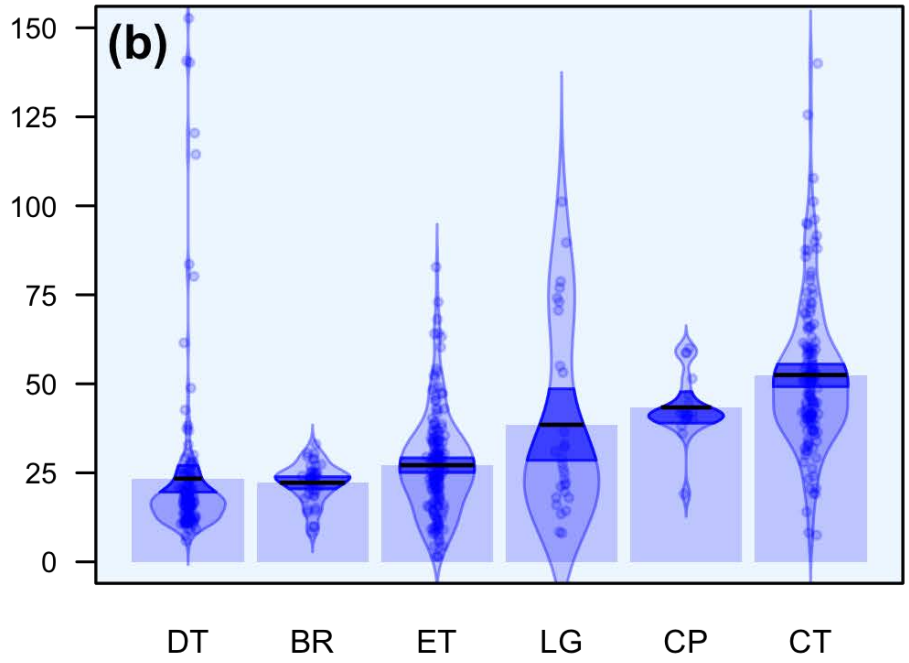
IV. Lagoons

V. Carbonate

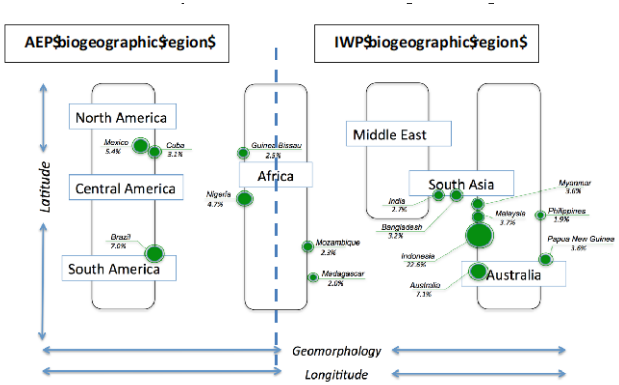
VI. Arheic







LSU



I. Large rivers

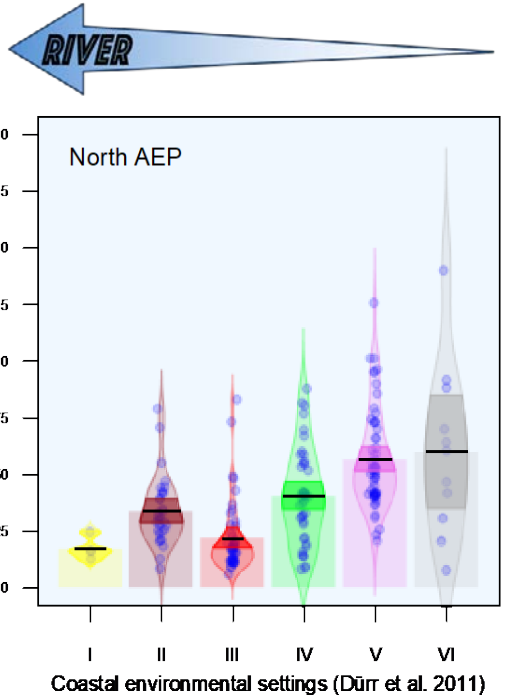
II. Small deltas

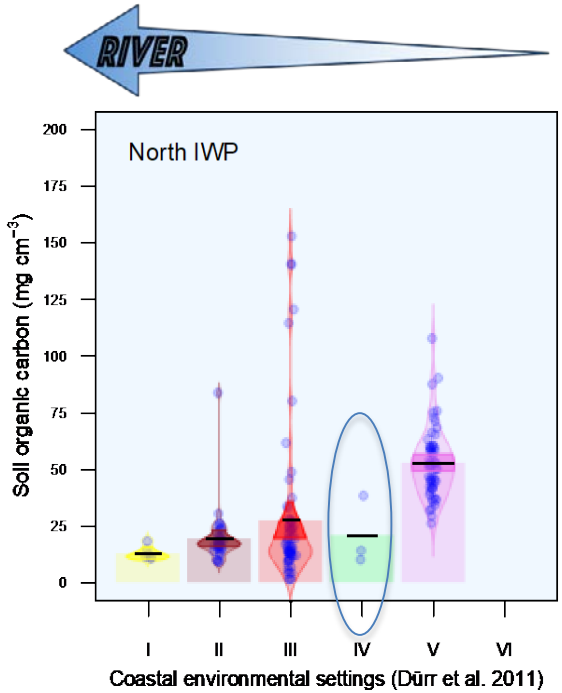
III. Tidal Systems

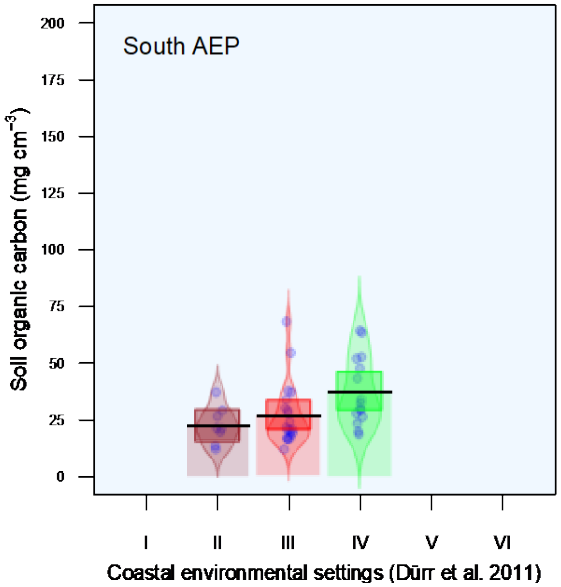
IV. Lagoons

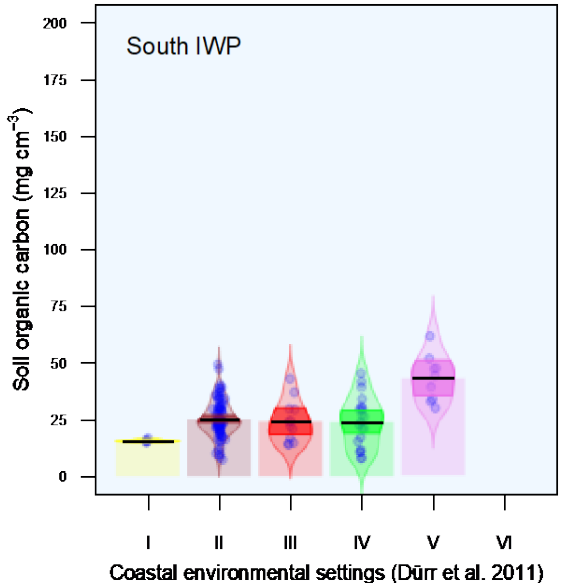
V. Carbonate

VI. Arheic









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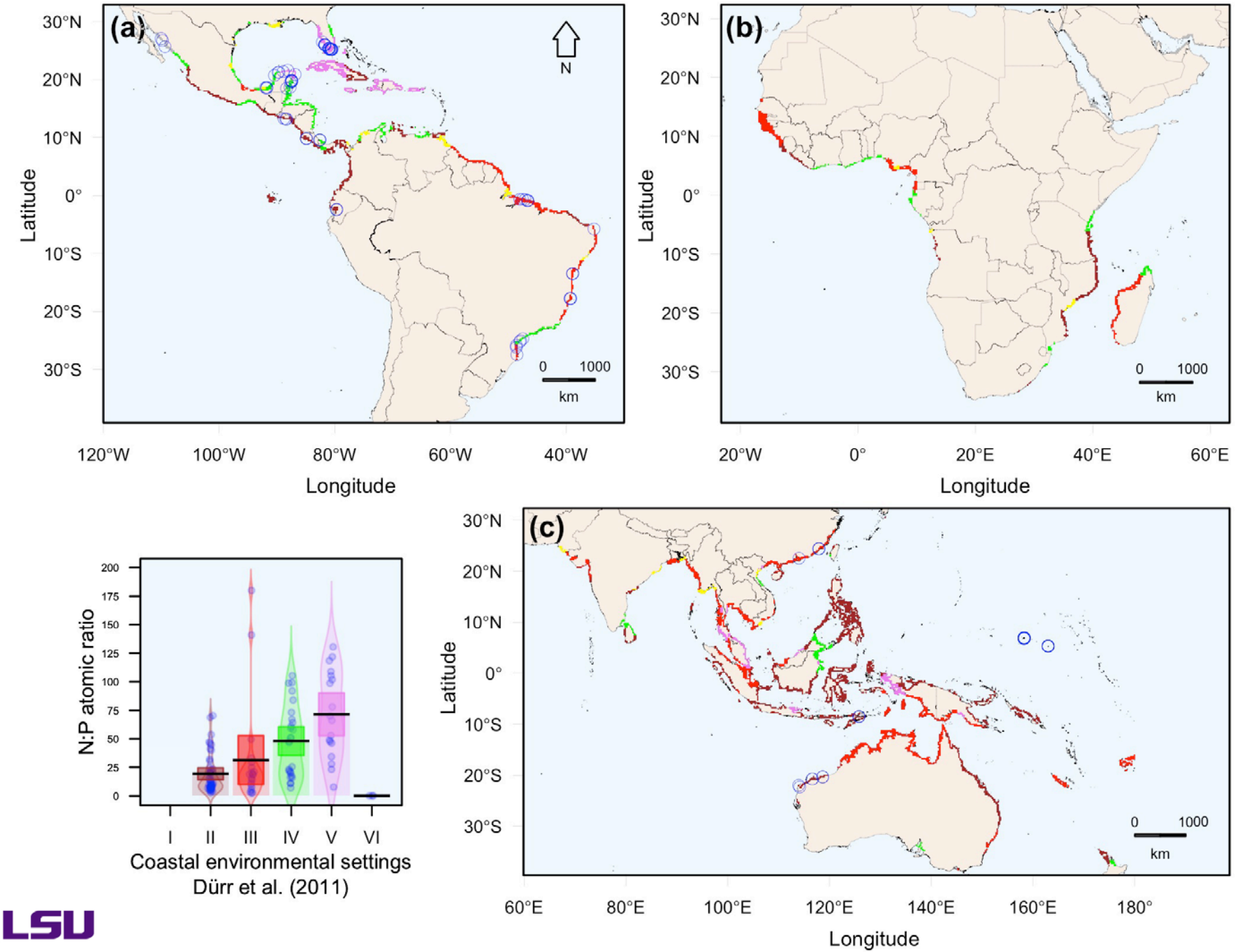
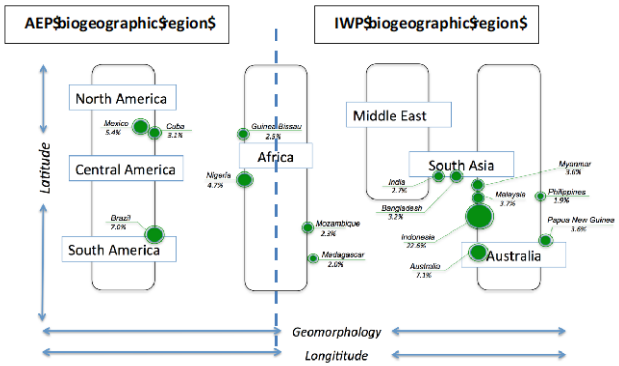

(a)
(b)
(c)
N
0 1000
km
Latitude
Longitude
30°N
20°N
10°N
0°
10°S
20°S
30°S
120°W
100°W
80°W
60°W
40°W
20°W
0°
20°E
40°E
60°E
80°E
100°E
120°E
140°E
160°E
180°
N:P atomic ratio
0
25
50
75
100
125
150
175
200
I
II
III
IV
V
VI
Coastal environmental settings
Dürr et al. (2011)



I. Large rivers

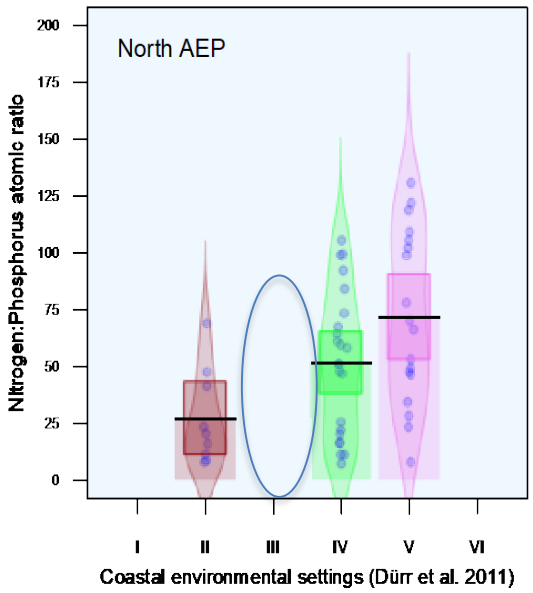
II. Small deltas

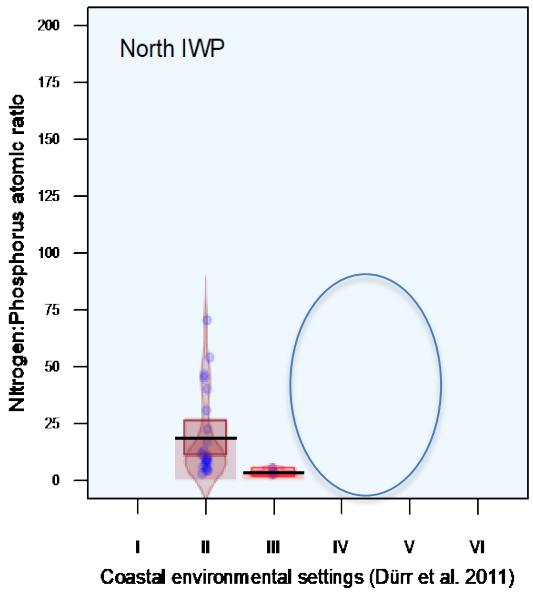
III. Tidal Systems

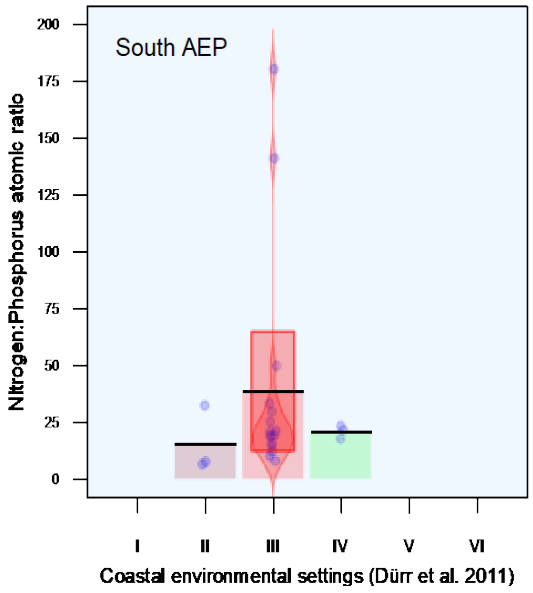
IV. Lagoons

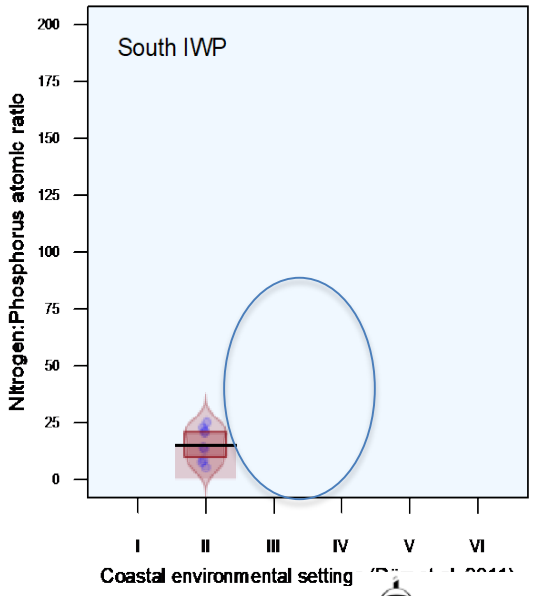
V. Carbonate

VI. Arheic









Ecogeomorphology of Mangroves

I. The CES Framework: Coastal Environmental Settings and Ecosystem Attributes (Ecogeomorphology)

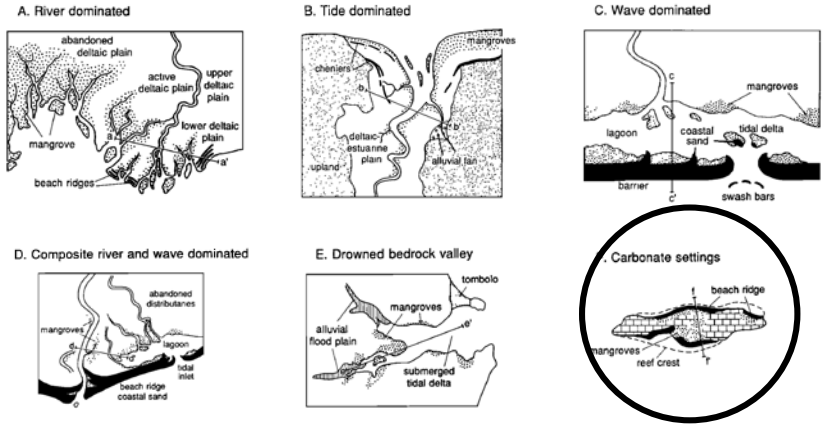
II. Testing the CES Framework: Rovai's Dissertation

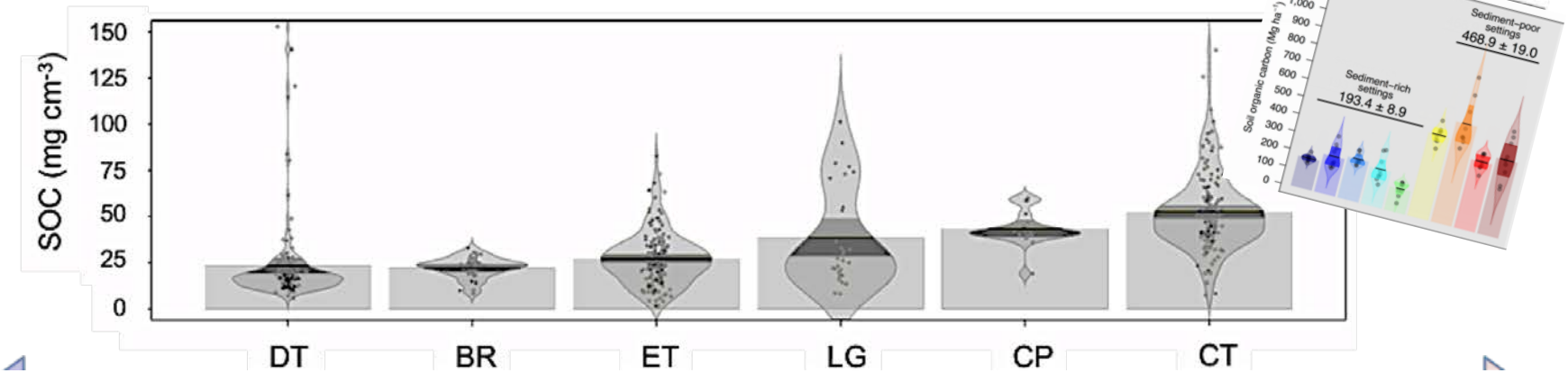
III. CES Framework Methodology

IV. Results and **Global Significance** of CES framework

V. Some final thoughts……

VI. Questions and Discussion (preferably with adult beverages)





RIVER ***NO RIVER***

Delta Lagoon - Estuary Karstic

I. Large rivers

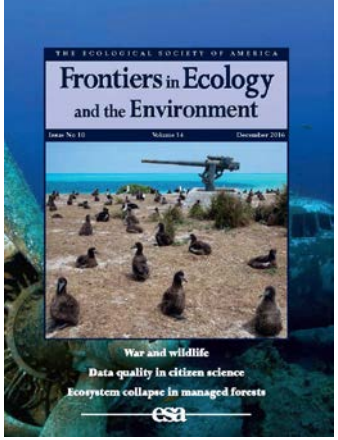
II. Small deltas

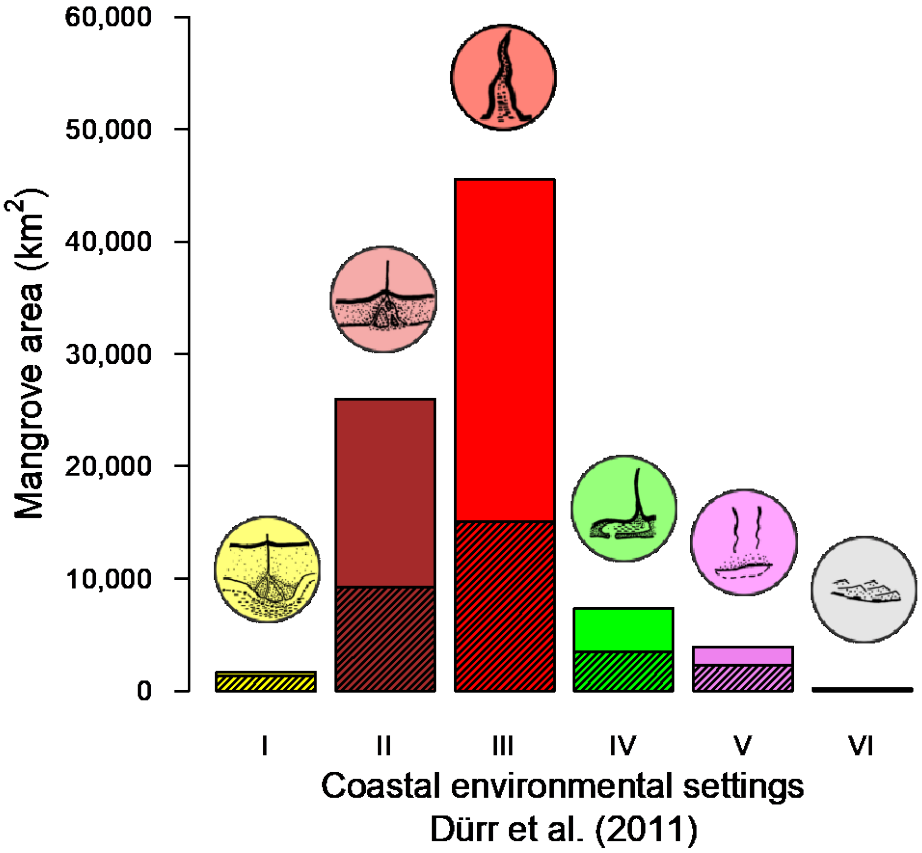
III. Tidal Systems

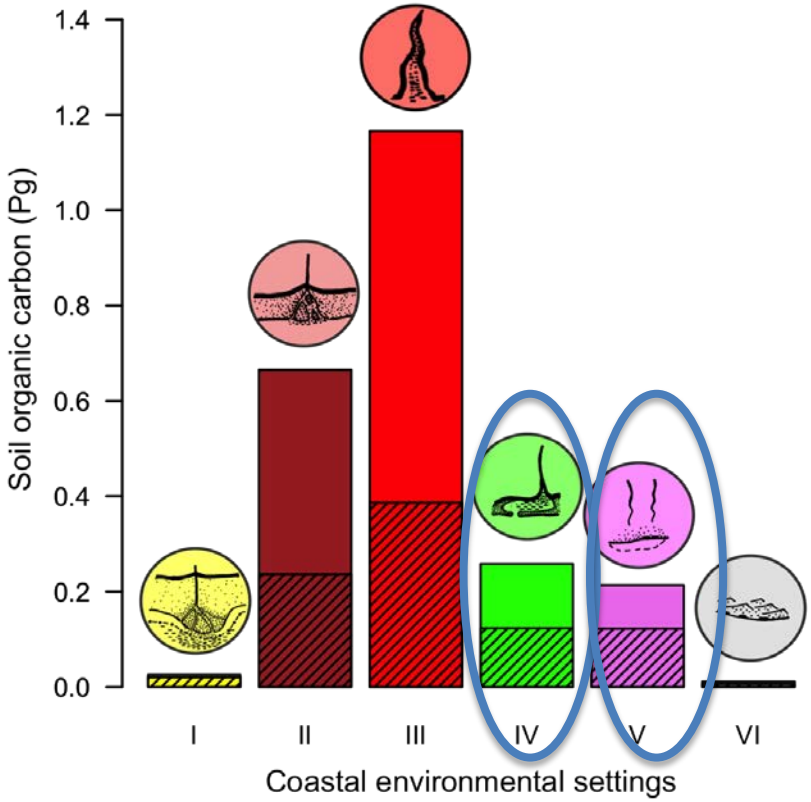
IV. Lagoons

V. Carbonate

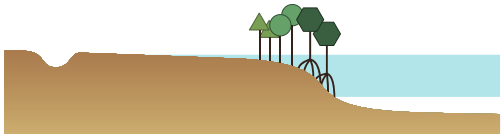
VI. Arheic







LSU



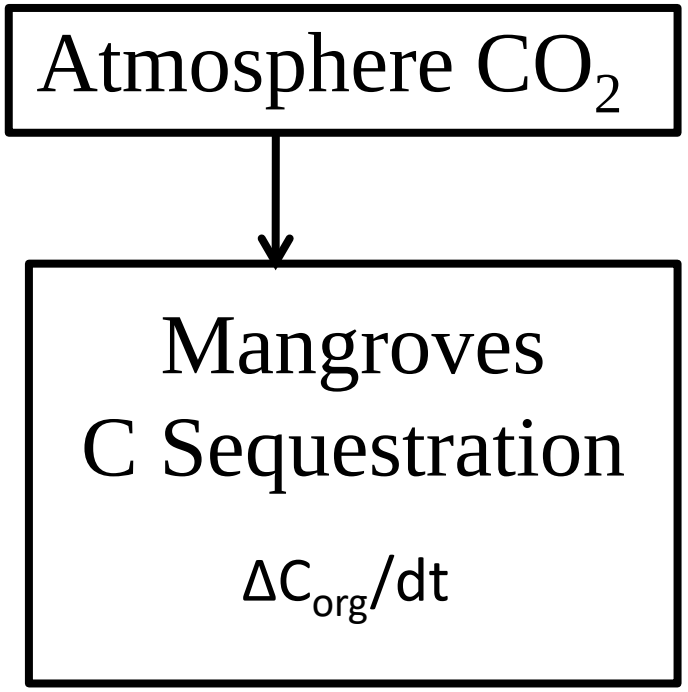
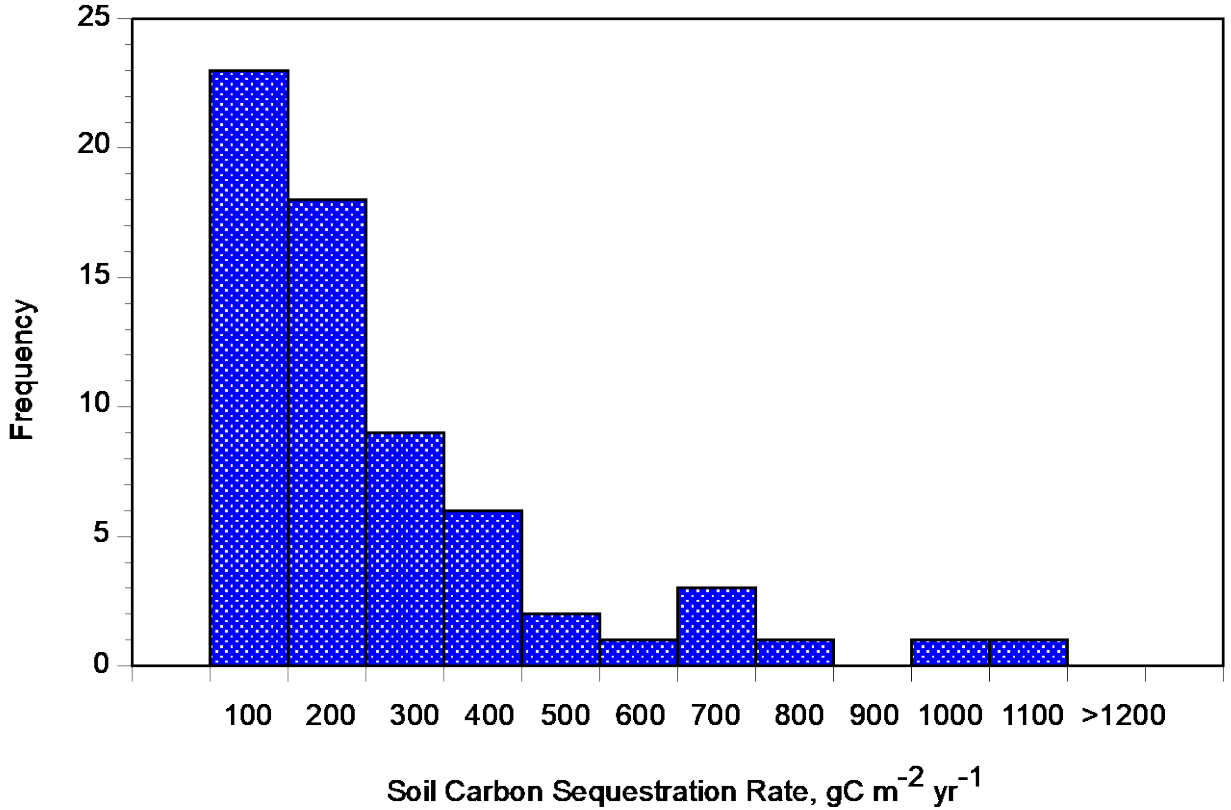


Table 1 Published ranges of surface elevation change, vertical accretion, and subsurface adjustment for different mangrove hydrogeomorphic settings determined using surface elevation table–marker horizon (SET-MH) methods (for a full list of references, see Krauss et al. 2014)

Hydrogeomorphic setting	Surface elevation change (mm year^{-1})	Vertical accretion (mm year^{-1})	Subsurface change (mm year^{-1})
Fringe	−1.3 to +5.9	+1.6 to +8.6	−9.7 to +2.4
Riverine	+0.9 to +6.2	+6.5 to +13.0	−11.2 to −0.2
Basin/interior	−3.7 to +3.9	+0.7 to +20.8	−19.9 to +2.8
Scrub	−1.1	−2.0	−3.1
Overwash	−0.6 to −2.5	+4.4 to +6.3	−3.8

Woodroffe, C, K. Rogers, K.L. McKee, C.E. Lovelock, I.A. Mendelssohn, and N. Saintilan, 2016. Mangrove Sedimentation and Response to Relative Sea-Level Rise. Annu. Rev. Mar. Sci. 8:243–66



Rates can range from 4 to 1000 gC m^{-2} yr^{-1}

The largest proportion of observations, 41 of the 65 sites, occur from 4 to 200 gC m^{-2} yr^{-1},

Average = 225 gC m^{-2} yr^{-1} for all sites.

Atmosphere CO_2

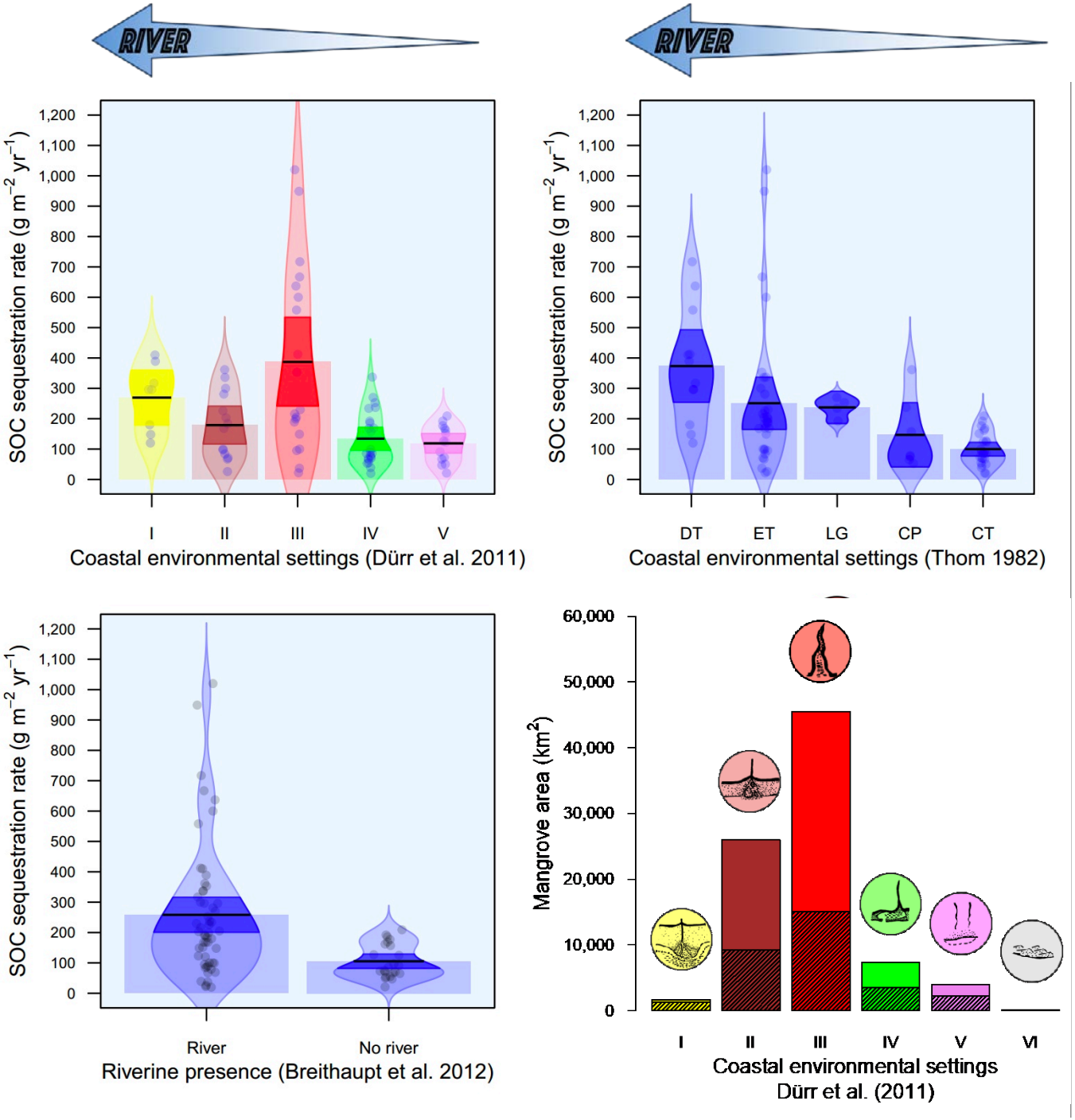
C Sequestration

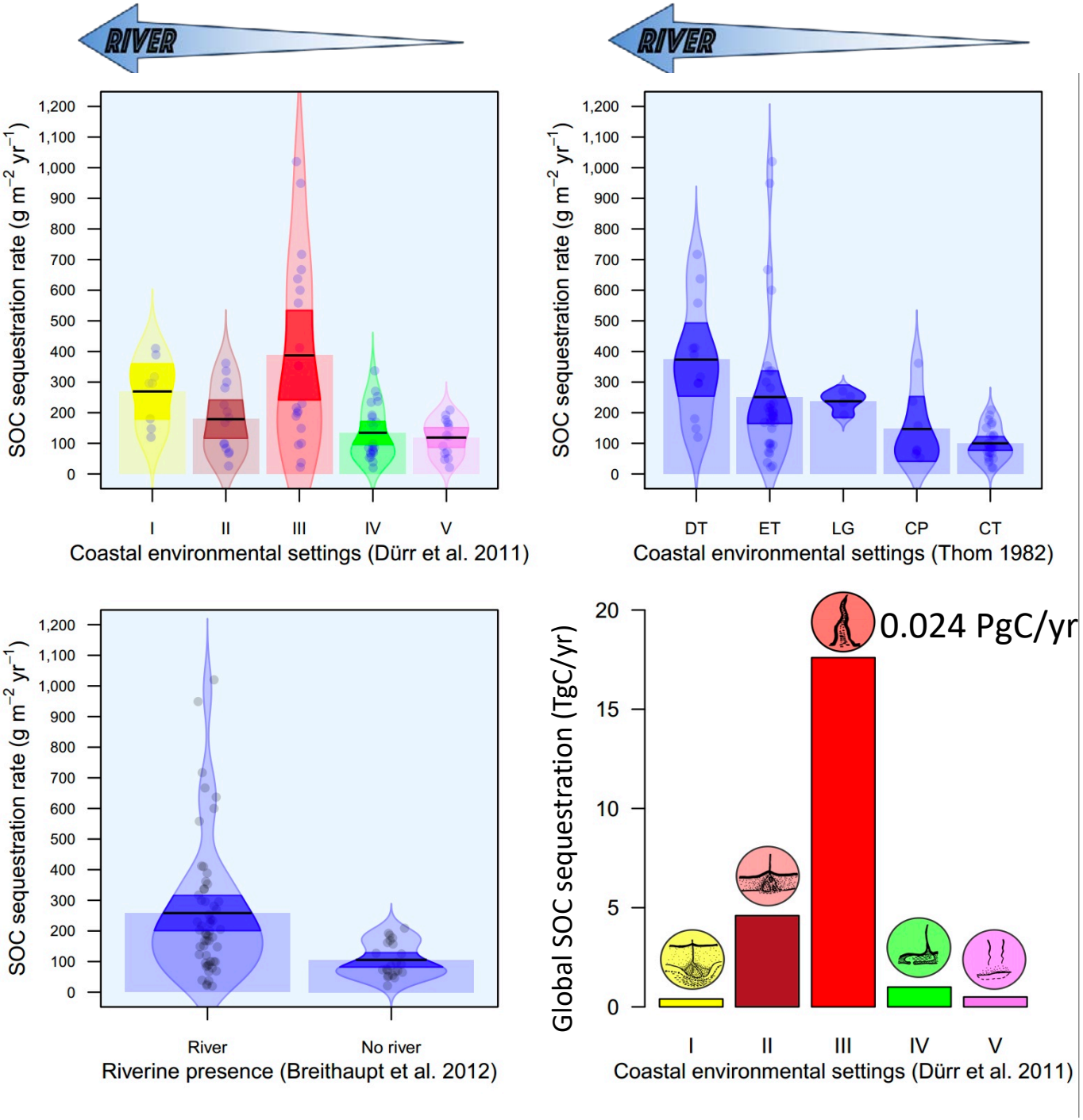
Soil C Burial

$\Delta C_{org}/dt$

225 g C m^{-2} yr^{-1}

Breithaupt, J. L., J. M. Smoak, T. J. Smith, C. J. Sanders, and A. Hoare (2012), Organic carbon burial rates in mangrove sediments: Strengthening the global budget, Global Biogeochem. Cycles, 26, GB3011, doi:10.1029/2012GB004375


RIVER
RIVER
SOC sequestration rate (g m^{-2} yr^{-1})
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
I
II
III
IV
V
Coastal environmental settings (Dürr et al. 2011)
DT
ET
LG
CP
CT
Coastal environmental settings (Thom 1982)
River
No river
Riverine presence (Breithaupt et al. 2012)
Mangrove area (km^2)
60,000
50,000
40,000
30,000
20,000
10,000
0
VI
Coastal environmental settings
Dürr et al. (2011)


RIVER
RIVER
SOC sequestration rate (g m^{-2} yr^{-1})
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
I
II
III
IV
V
Coastal environmental settings (Dürr et al. 2011)
DT
ET
LG
CP
CT
Coastal environmental settings (Thom 1982)
River
No river
Riverine presence (Breithaupt et al. 2012)
Global SOC sequestration (TgC/yr)
20
15
10
5
0
0.024 PgC/yr
Coastal environmental settings (Dürr et al. 2011)

Ecogeomorphology of Mangroves

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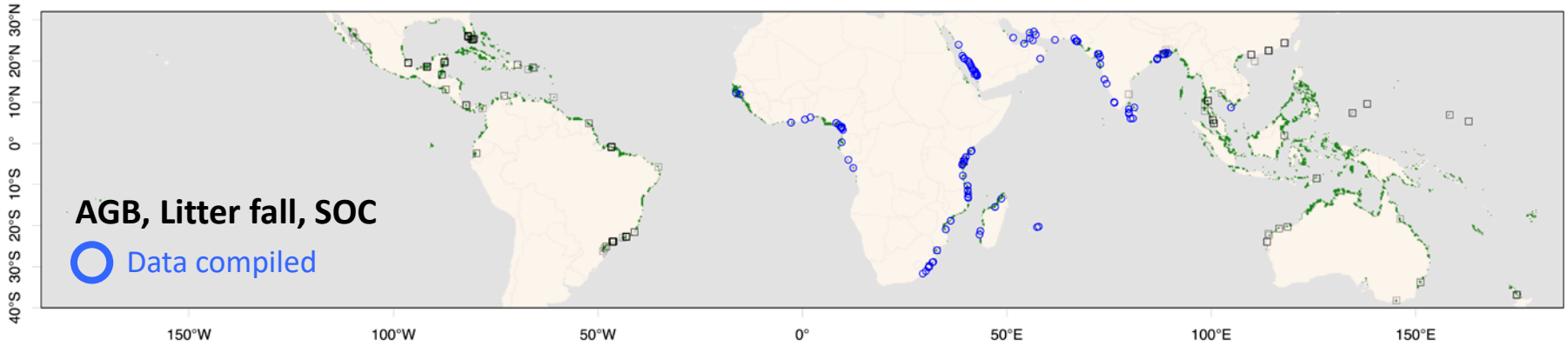
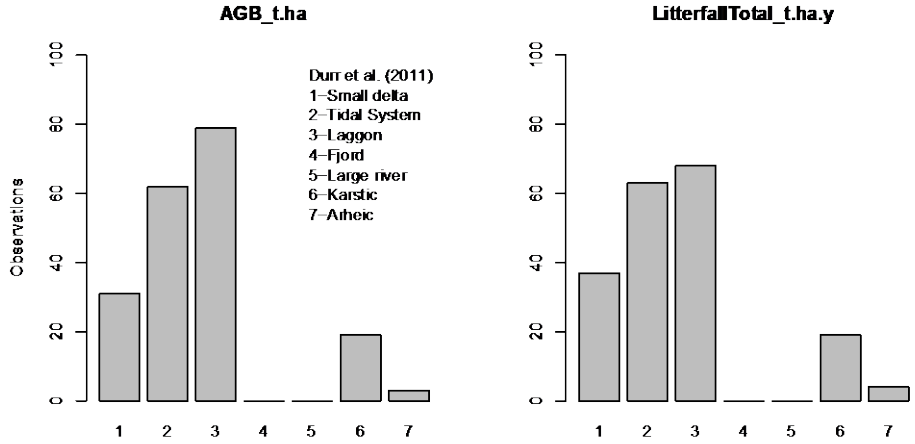
III. CES Framework Methodology

IV. Results and Global Significance of CES framework

V. Some final thoughts……

VI. Questions and Discussion (preferably with adult beverages)





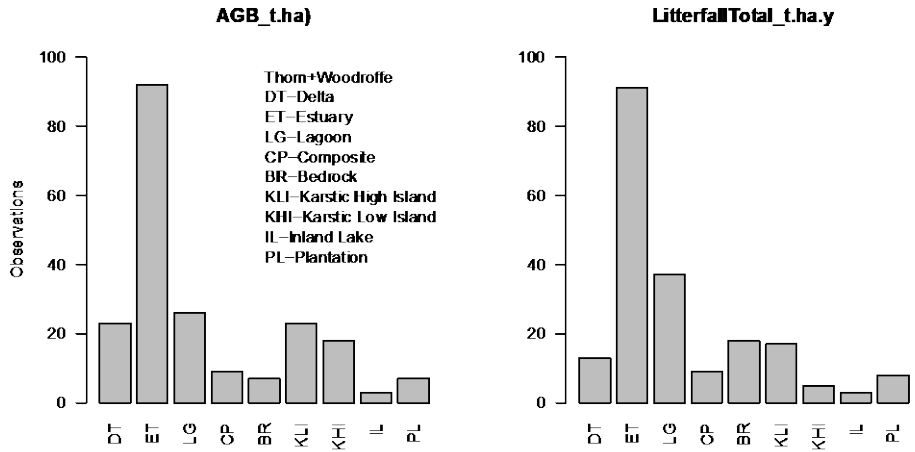
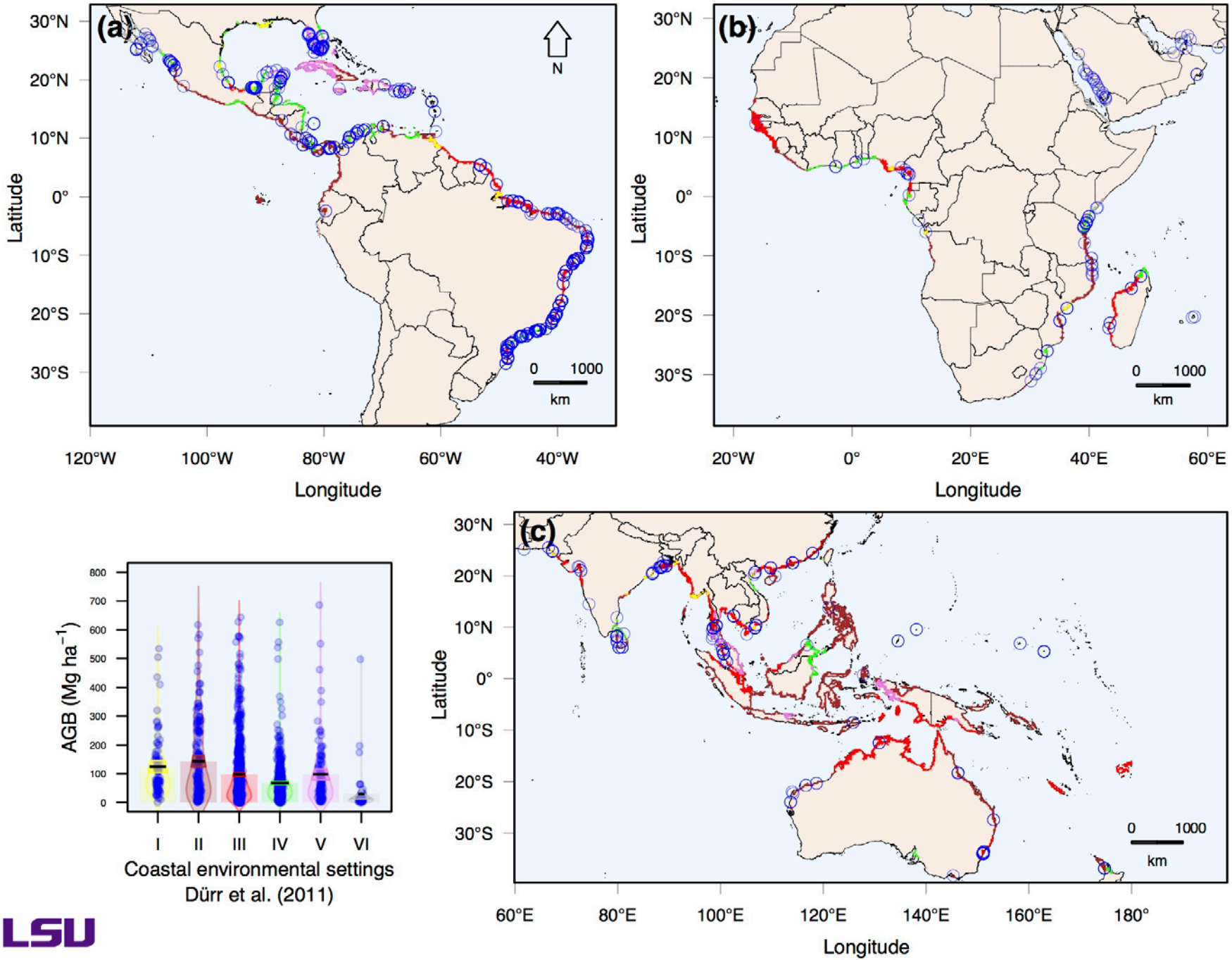
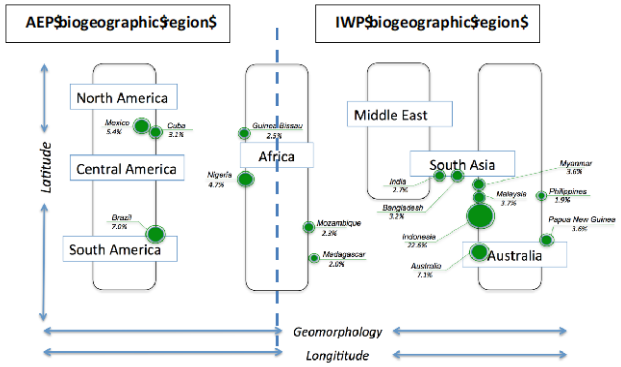


Figure XX. Bar graphs show the number of sites classified after Dürr (2011) and Thom (1982) classifications


(a)
(b)
(c)
N
0 1000
km
Latitude
Longitude
30°N
20°N
10°N
0°
10°S
20°S
30°S
120°W
100°W
80°W
60°W
40°W
20°W
0°
20°E
40°E
60°E
80°E
100°E
120°E
140°E
160°E
180°
AGB (Mg ha^{-1})
800
700
600
500
400
300
200
100
0
I
II
III
IV
V
VI
Coastal environmental settings
Dürr et al. (2011)



I. Large rivers

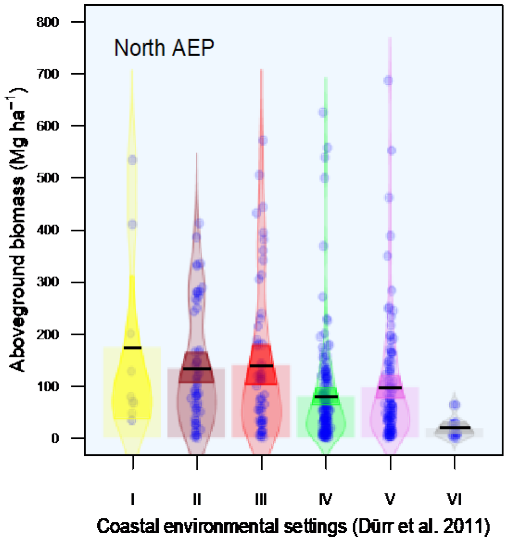
II. Small deltas

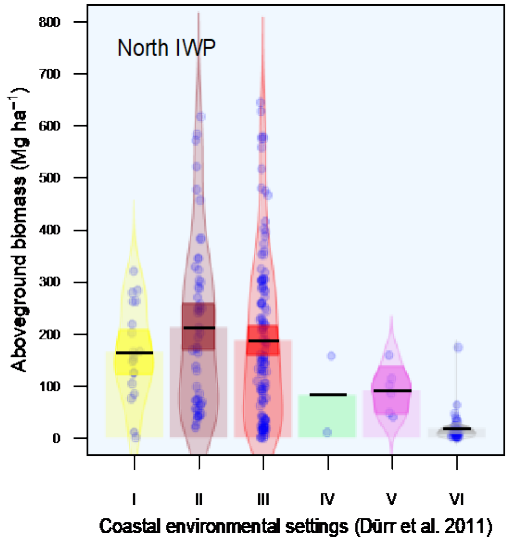
III. Tidal Systems

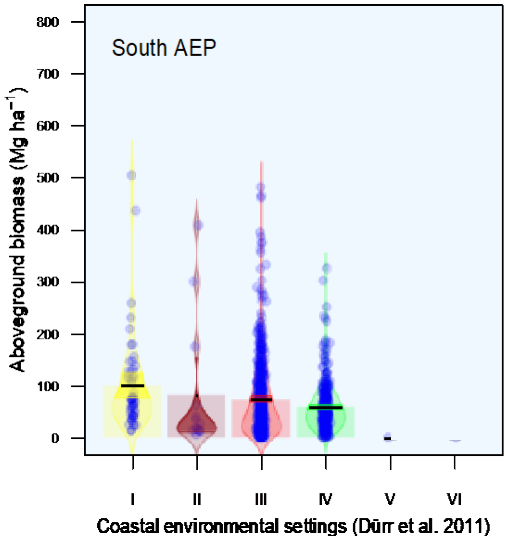
IV. Lagoons

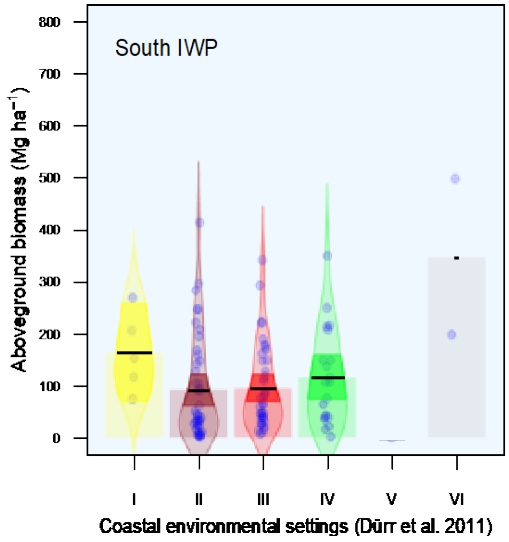
V. Carbonate

VI. Arheic

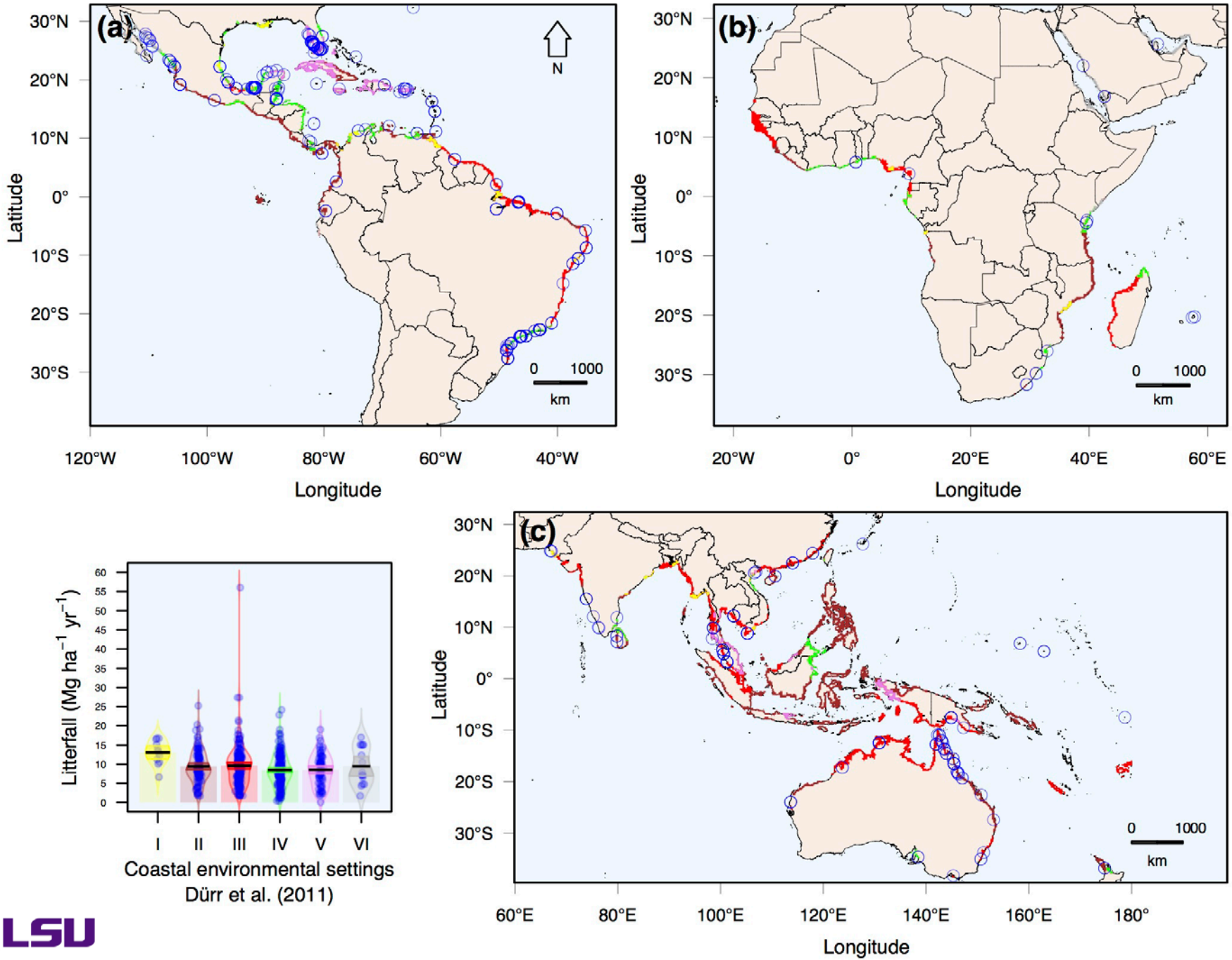


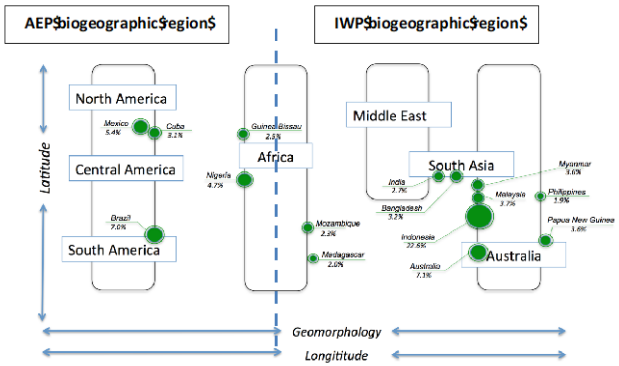






LSU


(a)
(b)
(c)
N
0 1000
km
Latitude
Longitude
30°N
20°N
10°N
0°
10°S
20°S
30°S
120°W
100°W
80°W
60°W
40°W
20°W
0°
20°E
40°E
60°E
80°E
100°E
120°E
140°E
160°E
180°
Litterfall (Mg ha^{-1} yr^{-1})
I
II
III
IV
V
VI
Coastal environmental settings
Dürr et al. (2011)



I. Large rivers

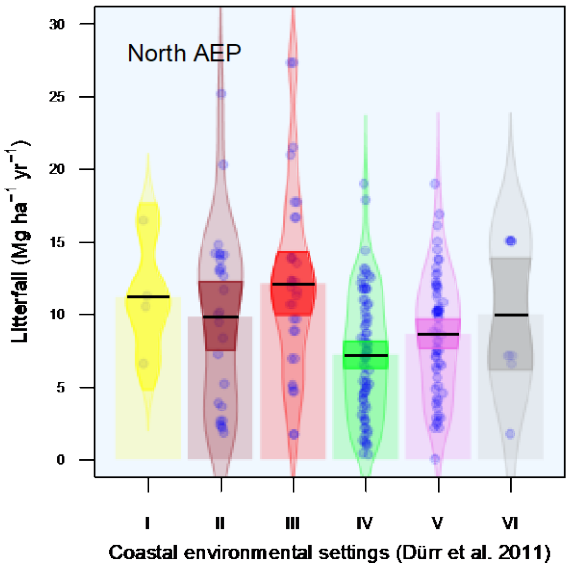
II. Small deltas

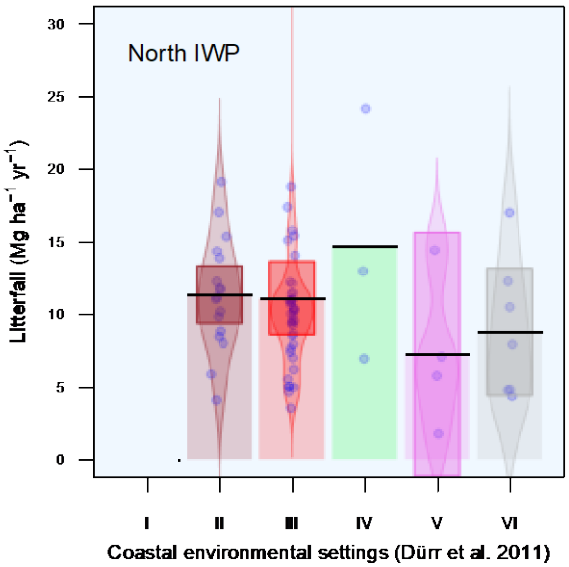
III. Tidal Systems

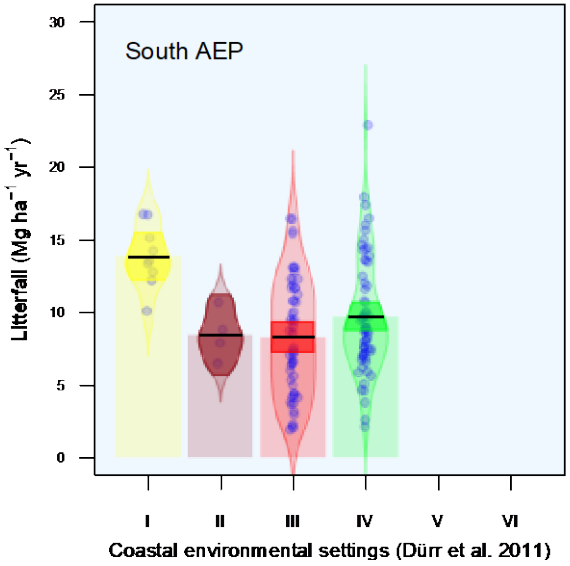
IV. Lagoons

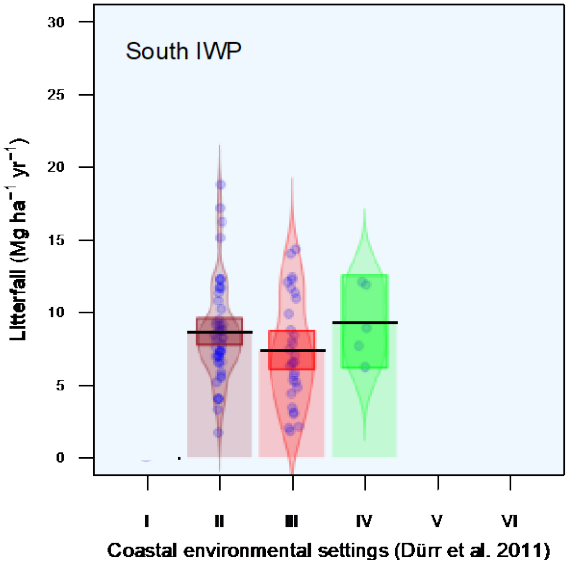
V. Carbonate

VI. Arheic









LSU

Ecogeomorphology of Mangroves

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V. Some final, final thoughts…..

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Ecogeomorphology of mangroves vs marshes?

I. Large rivers

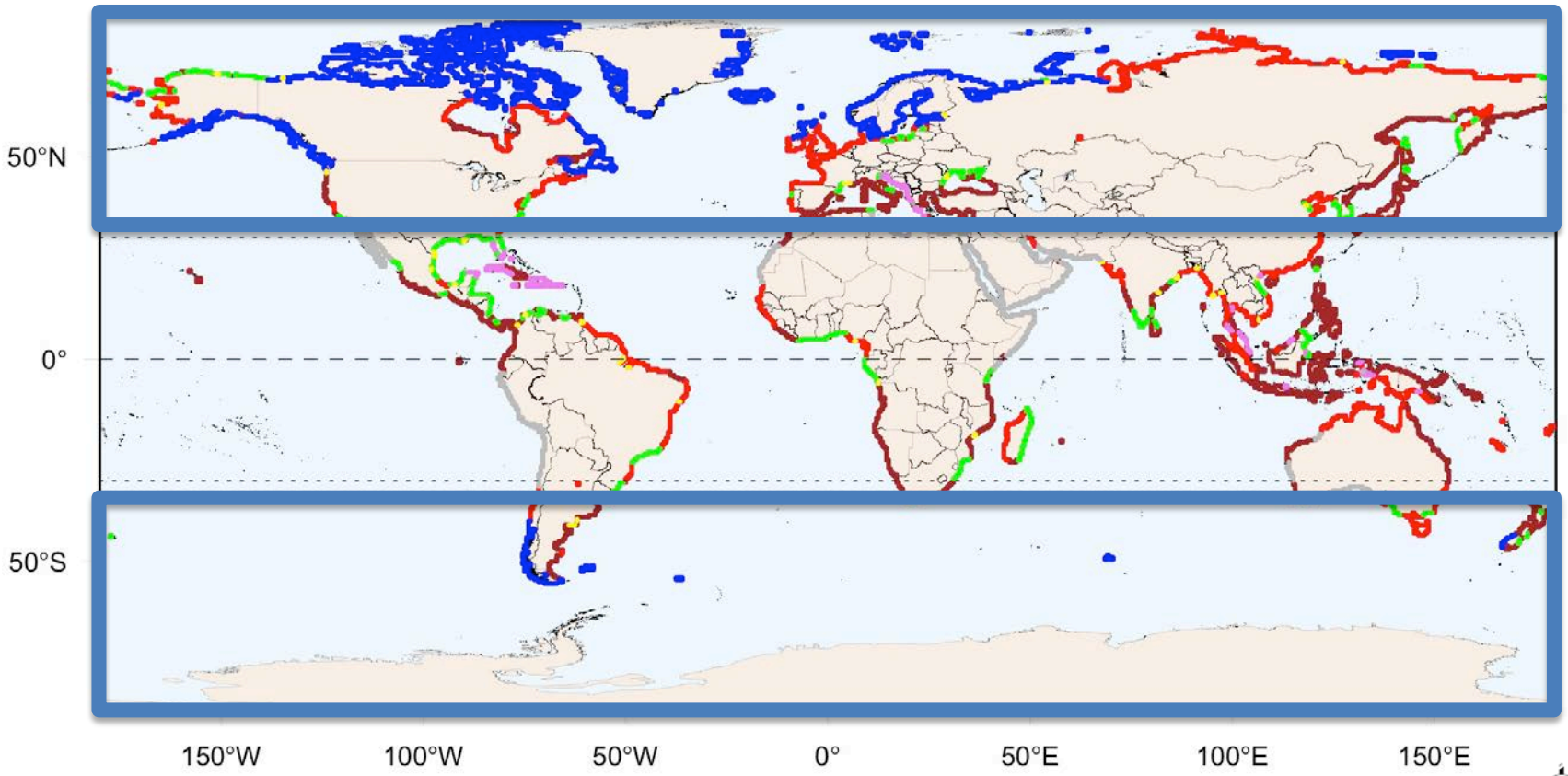
II. Small deltas

III. Tidal Systems

IV. Lagoons

V. Carbonate

VI. Arheic



Analysis of relative contribution of transported detritus from wetlands to the in situ productivity of phytoplankton. This is critical concept to evaluating the importance of subsystems to food webs of estuaries.

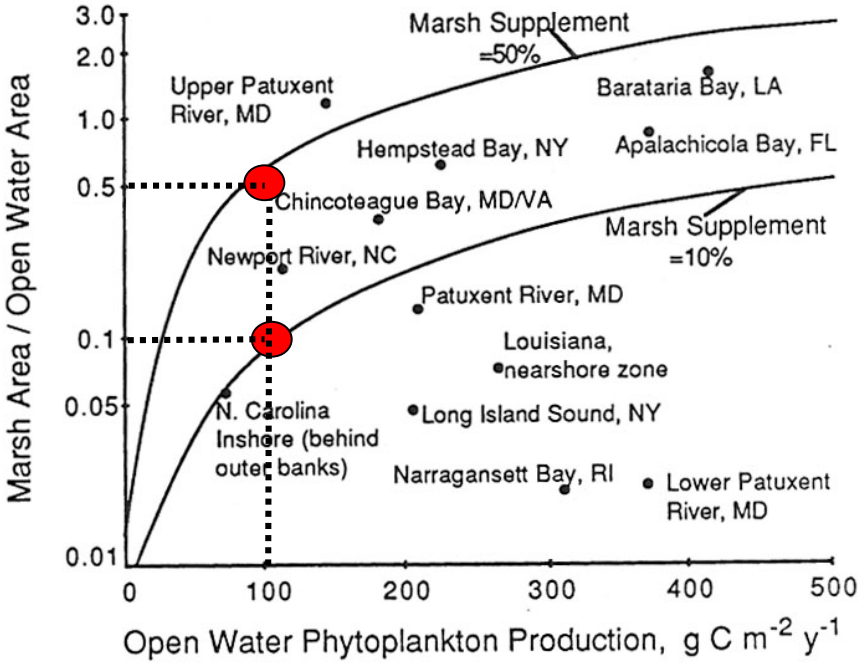
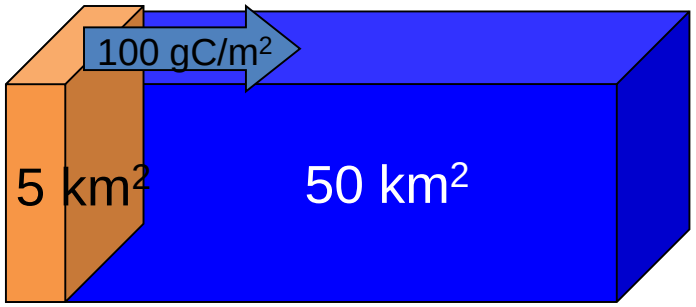
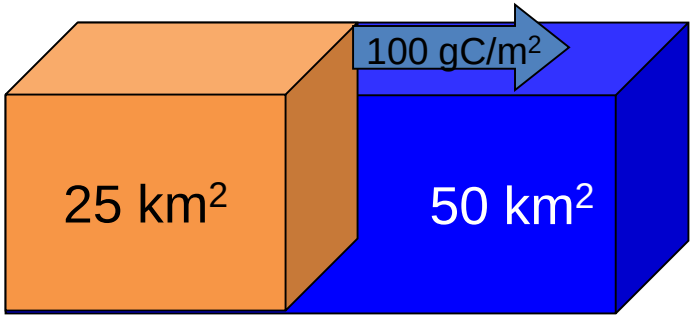
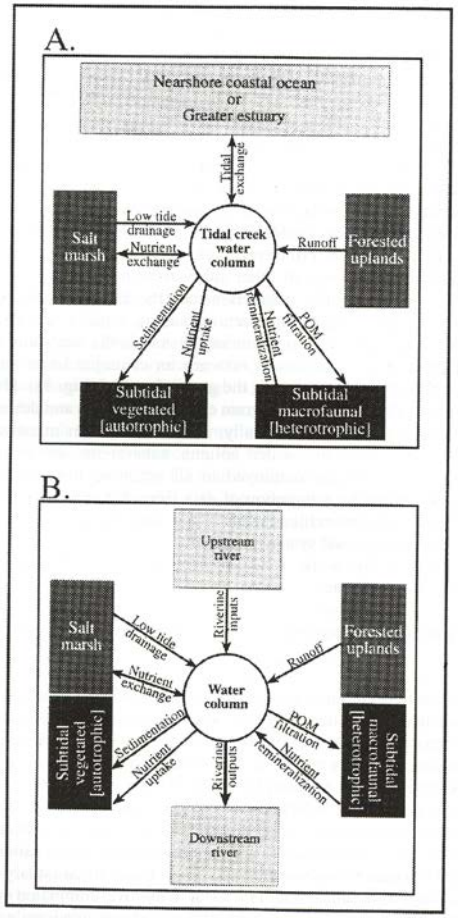


Figure 7.14 The ratio of vegetated marsh area to open water area in various estuarine ecosystems compared to annual phytoplankton production in the open water. The lines are drawn to show where organic carbon exports from the marshes would provide a supplement for the open waters equal to 10 and 50% of phytoplankton production, assuming an export of 100 g/C m² yr (from Nixon 1980).







The types of primary producers that dominate estuarine 'landscape' is related to the resources, regulators, and hydrology (light, nutrients, salinity, physical constraints) of the coastal setting. The subsystem area times the per unit production will determine net system productivity.

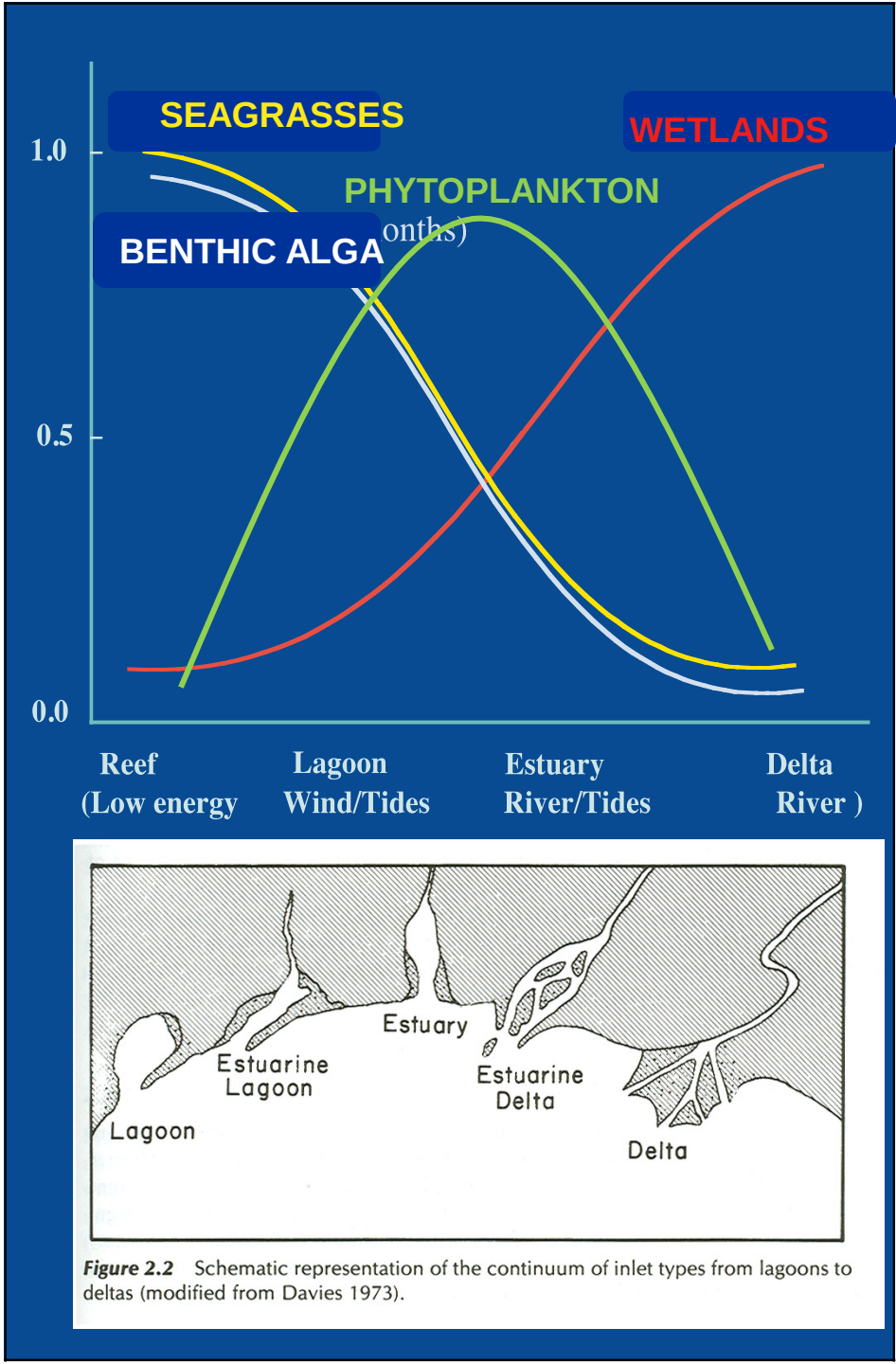
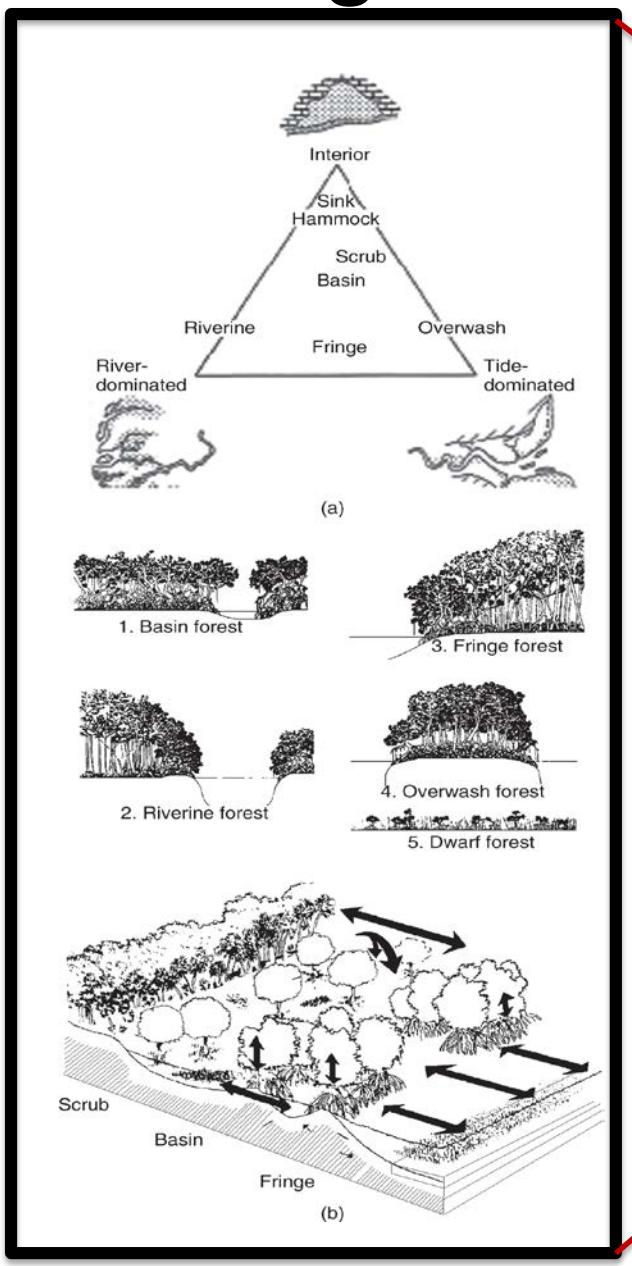
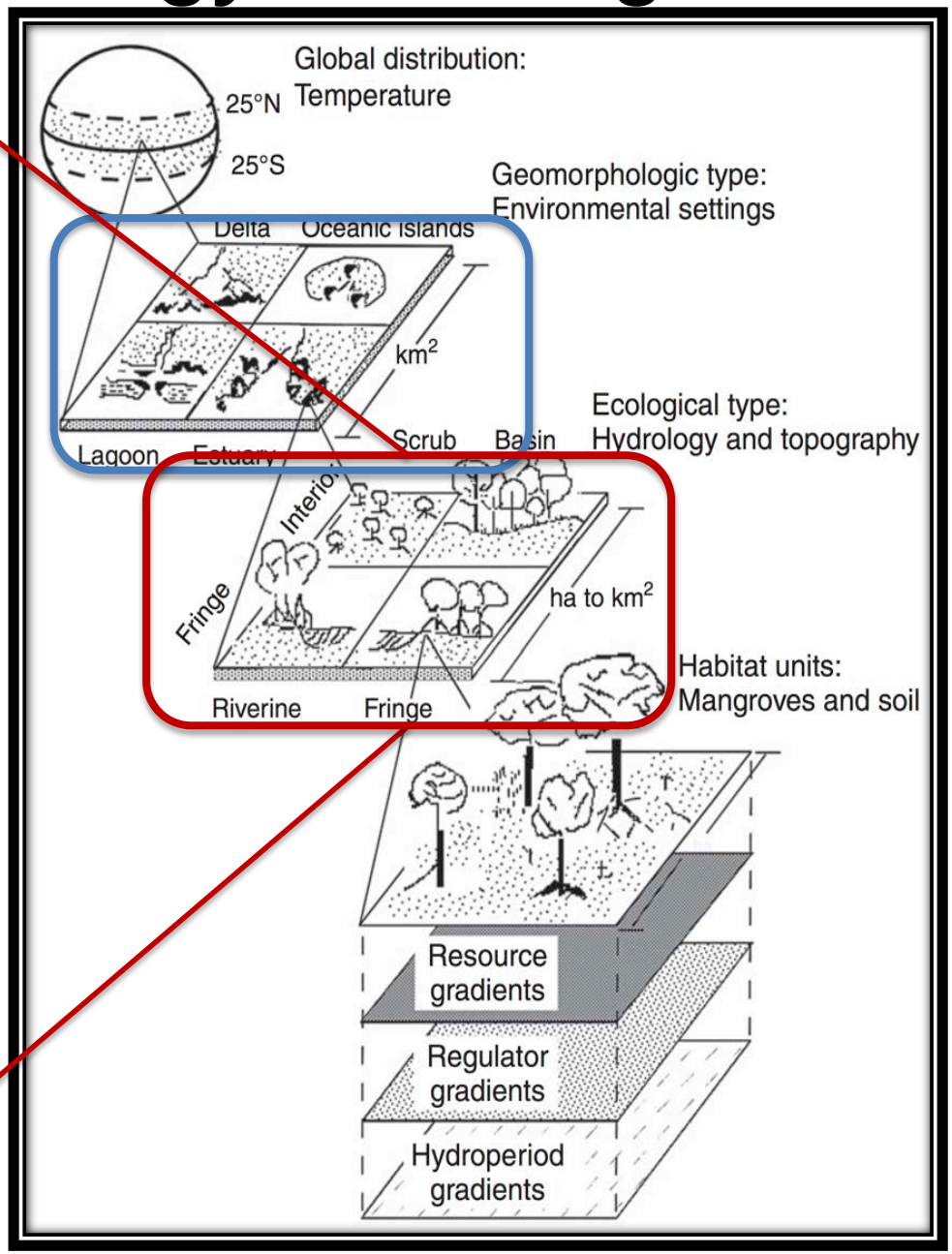


Figure 2.2 Schematic representation of the continuum of inlet types from lagoons to deltas (modified from Davies 1973).

The Ecogeomorphology of Mangroves





Twilley, R.R., R.H. Chen, and T. Hargis. **1992**. Carbon sinks in mangroves and their implications to carbon budget of tropical coastal ecosystems. *Water, Air and Soil Pollution* 64: 265-288.

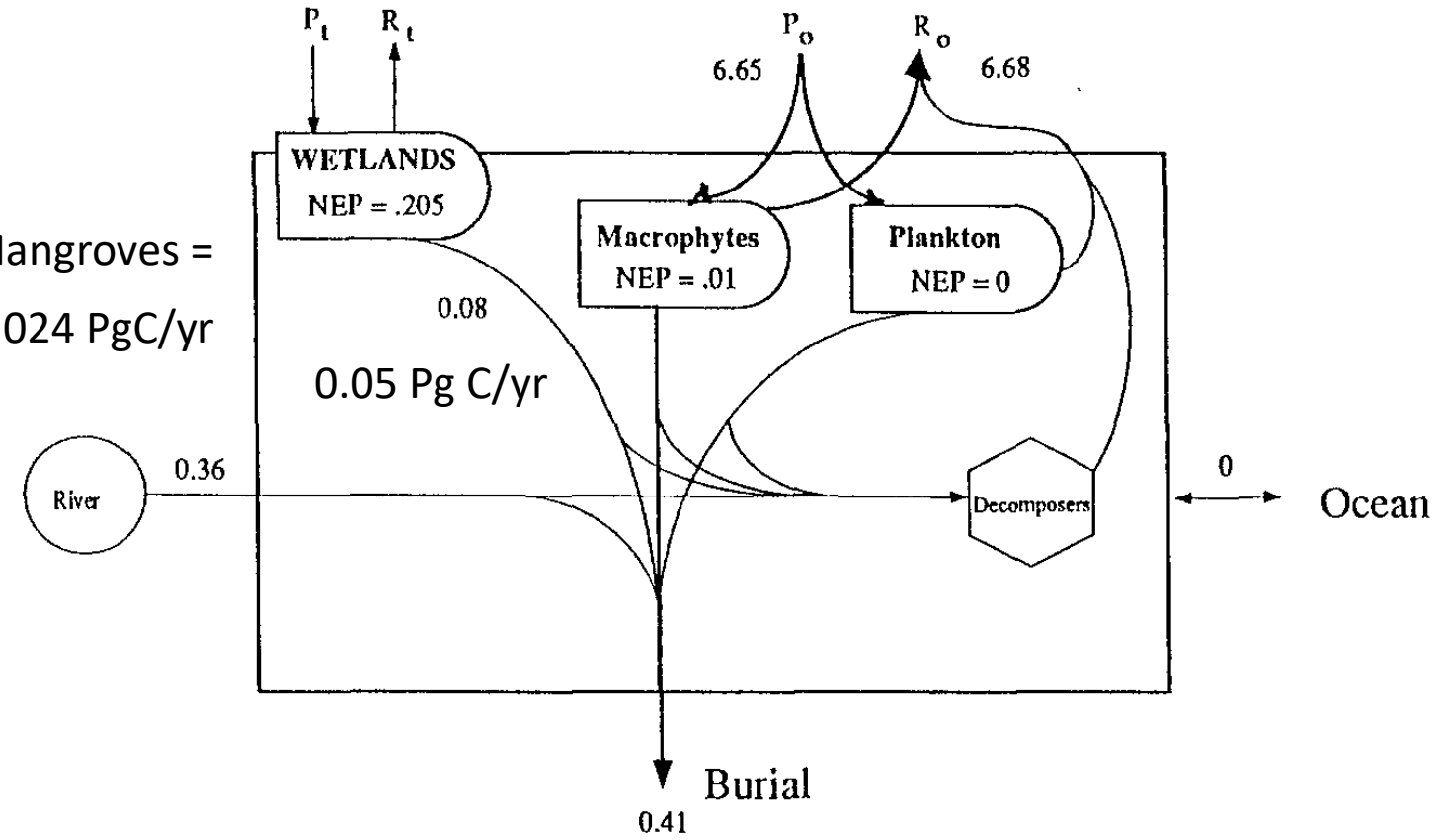


Figure 10. Mass balance of C for coastal ecosystems based on estimates of in situ net production and allochthonous inputs, minus losses associated with burial in coastal sediments. P and R represent net production and heterotrophic respiration, respectively, with exchange of CO_2 directly with atmosphere (t) or coastal waters (o).

Ecogeomorphology of Mangroves

I. The CES Framework: Coastal Environmental Settings and Ecosystem Attributes (Ecogeomorphology)

II. Testing the CES Framework: Rovai's Dissertation

III. CES Framework Methodology

IV. Results and Global Significance of CES framework

V. Some final thoughts……

VI. Questions and Discussion (preferably with adult beverages)

Questions/Comments

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