Neotropical mangroves: conservation and sustainable use in a scenario of global climate changes

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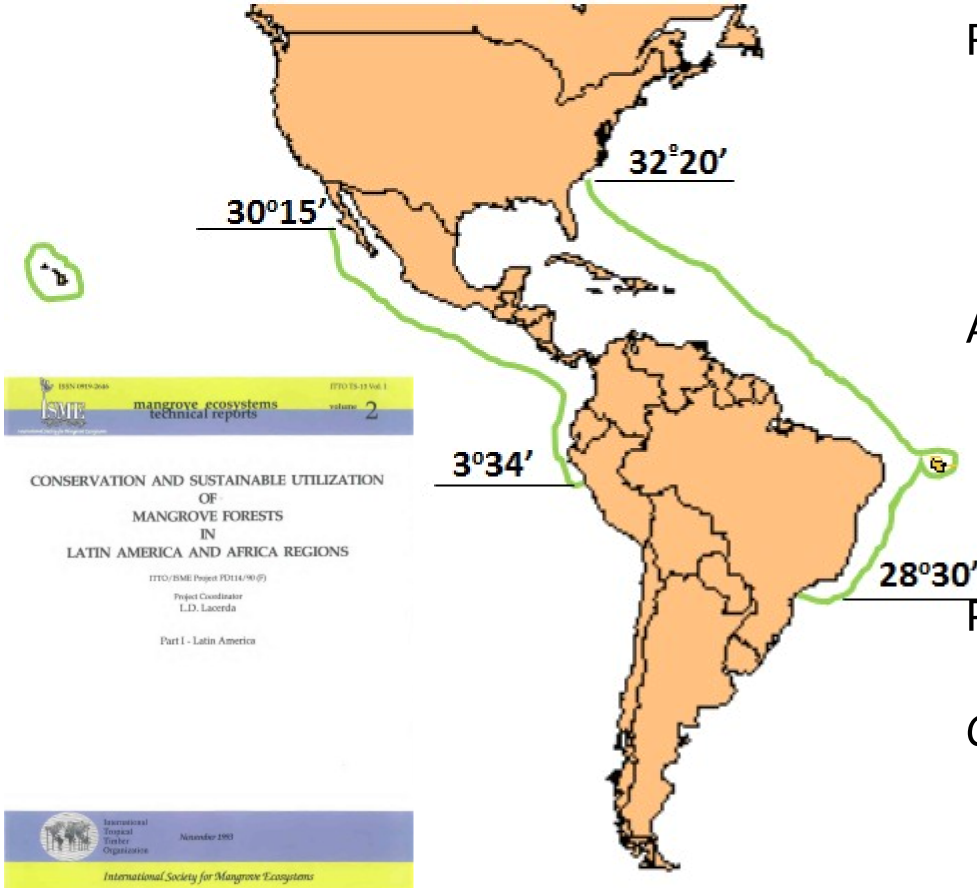
Latitudinal distribution and composition of Neotropical mangroves (Lacerda, 1993, 2002)



mangrove ecosystems technical reports volume 2

CONSERVATION AND SUSTAINABLE UTILIZATION
OF
MANGROVE FORESTS
IN
LATIN AMERICA AND AFRICA REGIONS

Project Coordinator
L.D. Lacerda

Part I - Latin America

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International Society for Mangrove Ecosystems

Rhizophoracea	1. *R. mangle*
	2. *R. harrisonii*
	3. *R. racemosa*
	4. *R. samoensis*
Avicenniaceae	5. *A. germinans*
	6. *A. schaueriana*
	7. *A. bicolor*
	8. *A. tonduzii*
Pelliciceriaceae	9. *P. rhizophorae*
Combretaceae	10. *Laguncularia racemosa*
	11. *Conocarpus erecta*

Mangrove area in Latin America and the Caribbean (~26% of the world's mangroves)

Atlantic Coast	2.14×10^6 ha
Pacific Coast	1.54×10^6 ha
Caribbean Islands	0.76×10^6 ha
Total	4.06 (3.58 – 4.54) $\times 10^6$ ha

Summary of drivers, pressures and impacts on mangroves of Latin America and the Caribbean regions acting from the 1970’s to the 1990’s *

Drivers	Major Pressures	Major Impacts	Response	Observations
Urbanization	Solid waste disposal; area conversion; wastewaters disposal	Contamination of the biota; eutrophication; mangrove eradication	Coastal Zone Management Plans; improving wastes treatment Integrating green & grey architecture, reforestation	**Major** Widespread through the region
Industrialization	Effluents disposal Oil spills	Contamination of the biota; tree and fauna mortality	Stronger regulations; improving wastes treatment; changing technologies; banning tank washing; improving preparedness	**Major** Restricted to most industrialized nations, Brazil and Colombia, in particular.
Damming	Sediment and salt balance; nutrient fluxes	Erosion of coastal forests; burying basin forests; increasing soil and pore water salinity	Watershed committees including coastal communities’ representatives.	**Major** Particularly important along semiarid regions.
Agriculture	Nutrient fluxes; chemical effluents, land reclamation	Eutrophication; contamination of the biota; deforestation	Watershed communities regulating land uses, restriction on agrochemicals use.	**Intermediate**
Forestry	Wood and wood products exploitation	Deforestation	Restraining mangrove wood use; Extractive reserves; reforestation community-based management.	**Intermediate** Particular in Central America and Venezuela
Tourism	Waste disposal; forest conversion	Localized eutrophication and deforestation.	Tourism environmental regulations; Eco-tourism.	**Intermediate** Particularly in Caribbean nations
Fisheries	Fisheries products	Overfishing and decreasing stocks	Community -based management; establishing fishing seasons (defesos)	**Minor** Particularly successful for mangrove crabs and species reproducing in mangroves.
Salt production	Conversion	Deforestation	Abandoning ponds	**Minor** In semiarid regions
Aquaculture	Conversion; Nutrient fluxes	Deforestation; eutrophication	Initial regulation laws, public awareness.	**Minor** Mostly restricted to Ecuador, the 2nd world shrimp producer in 1991; and to a lesser extent in Central America

* ITTO-ISME Project PD114/90 (F) Conservation and Sustainable Utilization of Mangrove Forests in Latin America and Africa Regions

Urbanization

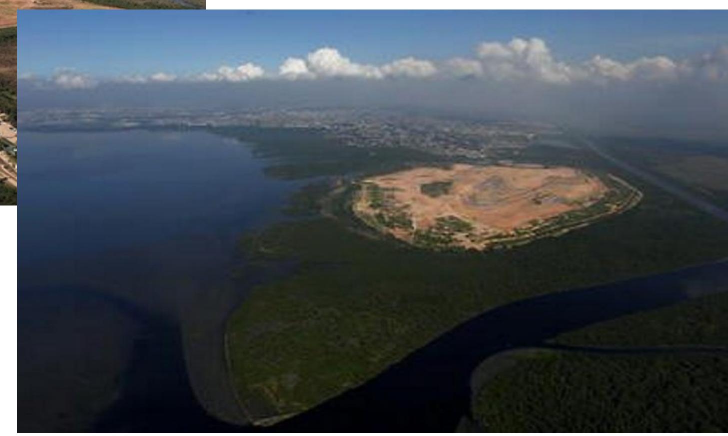
Intensive and extensive destruction of mangrove areas, solid waste disposal, contamination of biological resources.

Incorporating mangrove in urban structure (green architecture); aesthetics and protection

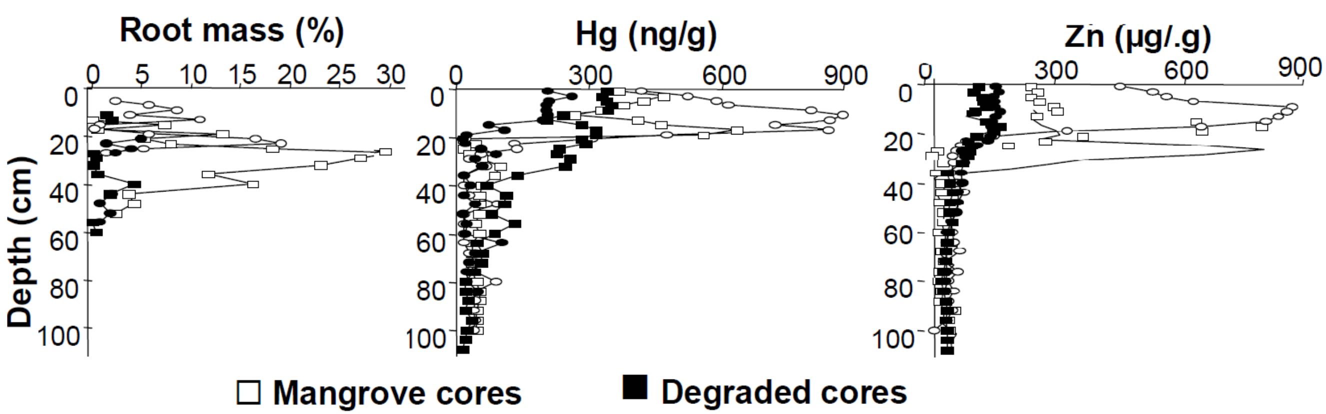
2015

Urbanization

The Jardim Gramacho Landfill in SE Brazil: about 14,000 t of solid wastes per day. The largest in South America.



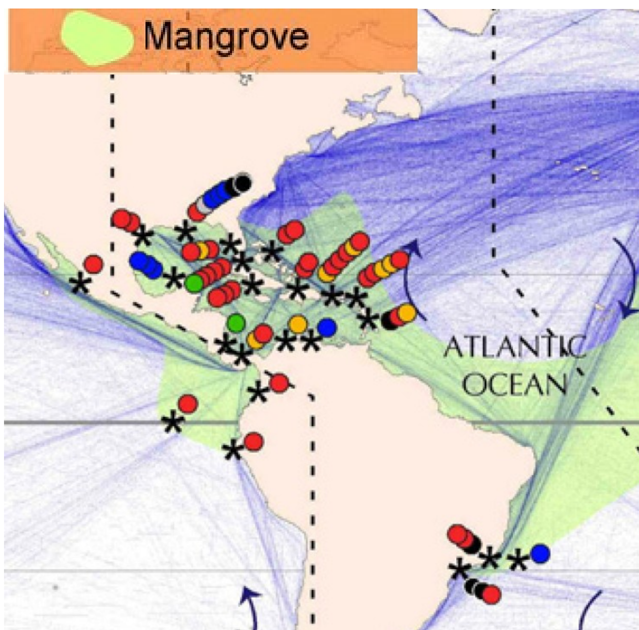
Rehabilitation and using mangrove as filters to protect adjacent coastal areas. Mangrove rhizosphere actually trap metals from ground water leaching, avoiding contamination of adjacent coastal waters



Industrialization

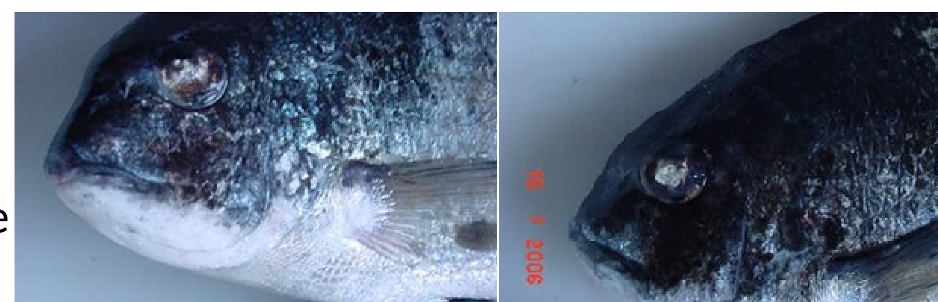
Reported oil spill incidents with actual impacts on mangrove habitats between 1970 and 1999 and between 2000 and 2016 in Latin America and the Caribbean; and global amount of oil involved, adapted from Duke (2016).

Category	1970-1999	2000-2016
Number of incidents	71 (2.4 yr^{-1})	69 (4.3 yr^{-1})
Total area of dead mangroves (ha)	100 (3.3 yr^{-1})	13 (0.8 yr^{-1})
Global amount spilled (t/spill)	30,990 – 60,187 (1,520 yr^{-1})	6,664 – 15,832 (703 yr^{-1})
Global area affected, oiled (ha)	24,419 (814 yr^{-1})	3,627 (227 yr^{-1})

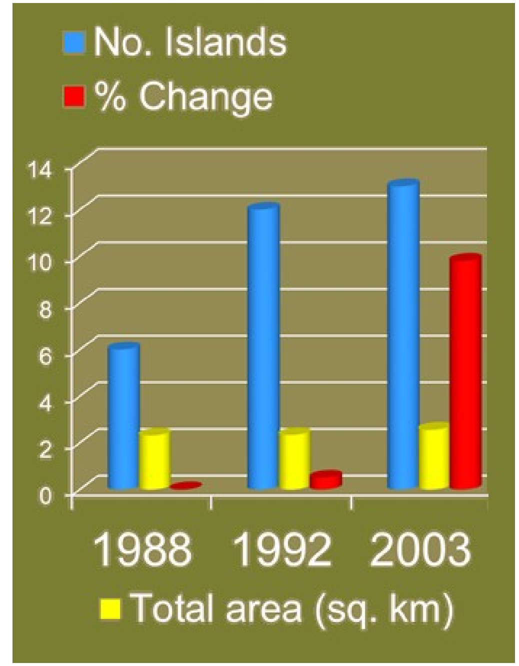


Oils spills in Latin American and Caribbean mangrove forests, showing hot spots in the Caribbean and SE Brazil. Modified from Duke (2016)

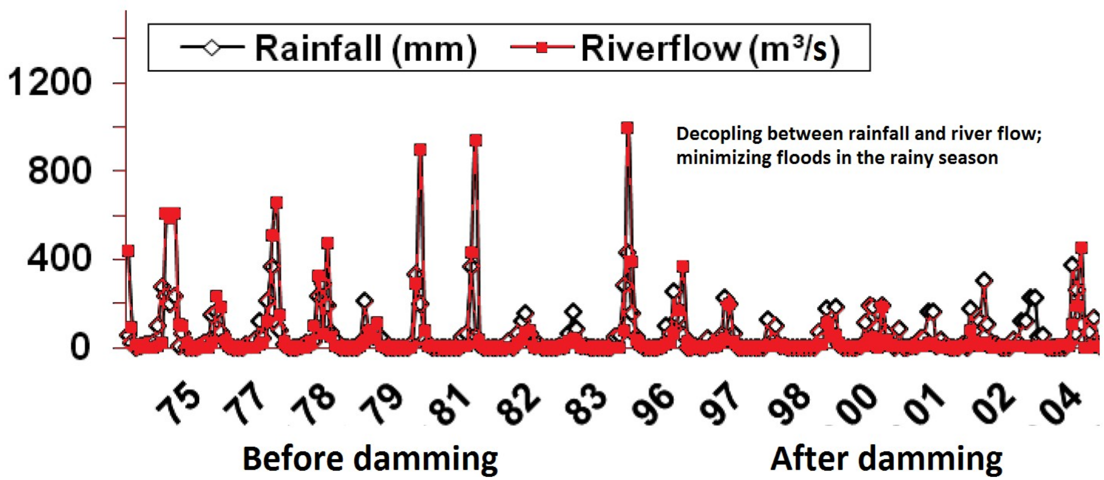
Effect on the biota



Damming

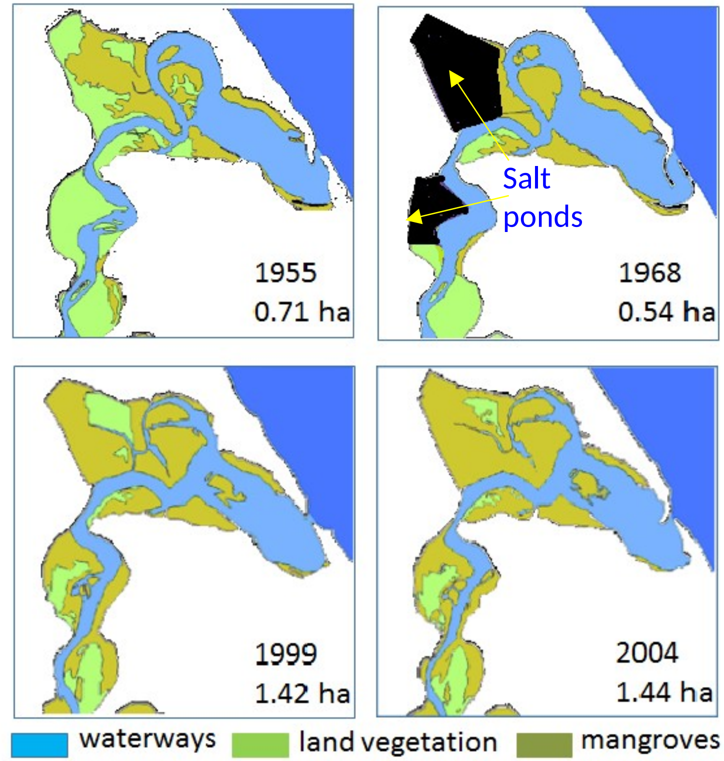


Siltation of estuaries and colonization by mangroves. Erosion of fringe mangroves due to reducing sediment supply to the coast and sea level rise in northeastern Brazil



Salt production

Salt production and mangroves. A significant area of natural mangrove rehabilitation derived from abandoned slat pods. An example is the Pacoti River Estuary, NE Brazil.



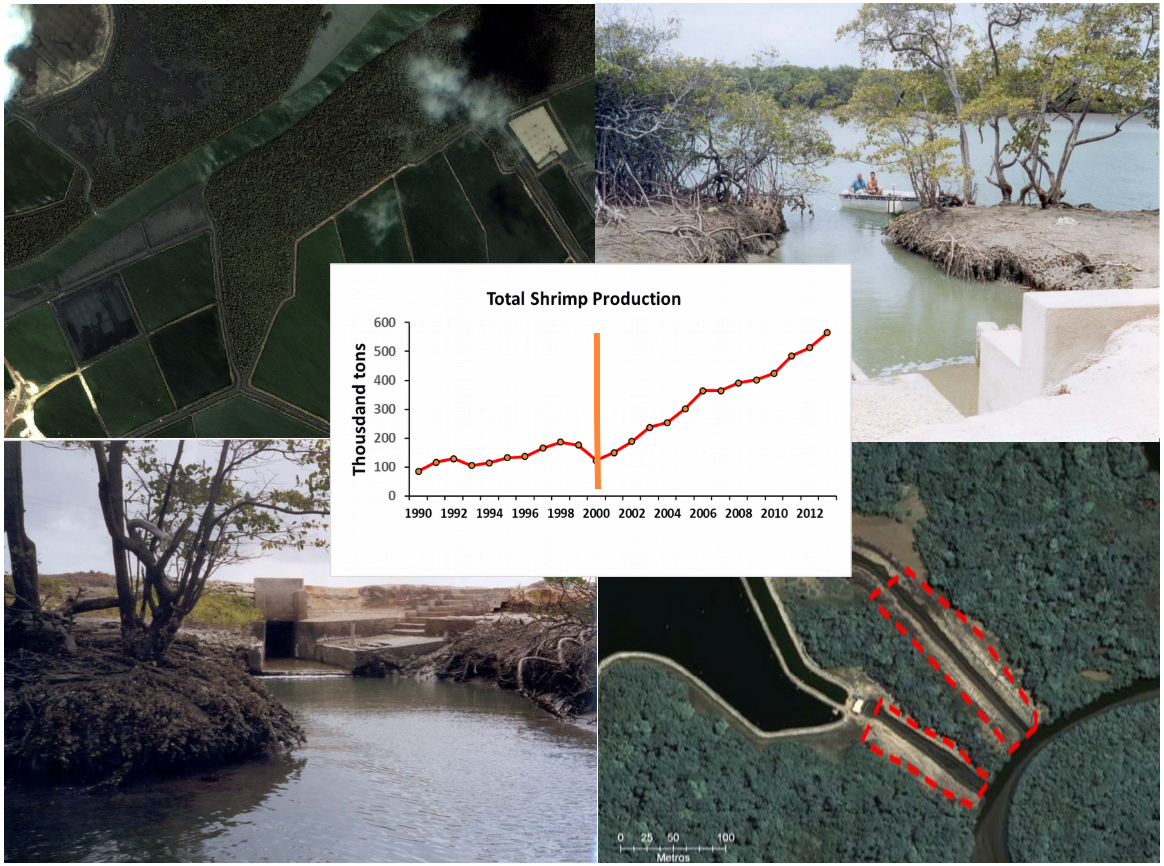
km^2

Year	1958	1968	1999	2004
Mangrove area	0.71	0.54	1.42	1.44
Salt ponds	0.00	0.69	0.00	0.00

Agriculture

Eutrophication and siltation of estuaries

Shrimp aquaculture



- Eutrophication due to excess nutrient release;
- Erosion at extrusion canals and siltation of estuaries due to large amount of suspended solids in effluents.
- Although limited in area in the 1980’s and 1990’s, emission factors from shrimp aquaculture are higher than from all other sources of nutrients and metals to LA & C estuaries. Also, effluents are released directly into the estuarine environment

Temporal trends of the 1970's-1990's drivers and impacts and response effectiveness on mangroves of Latin America and the Caribbean regions in the 21th century (Lacerda et al., 2002; Ferreira & Lacerda, 2012).

Drivers	Major Impacts	Temporal trend	Effectiveness of the response
Urbanization	Contamination of the biota	**Increasing**	Establishing Coastal Zone Management Plans (e.g. in Mexico and Brazil), but only partially able to control urban growth, in particular during economic crisis; Improving wastes treatment, but still restricted to a few metropolitan areas
	Eutrophication	**Increasing**	
	Deforestation	Stable	
Industrialization	Contamination of the biota	Decreasing	Stronger regulations applied through the region, in particular to oil and persistent pollutants; improving wastes treatment and changing technological procedures; reduced emissions from point sources. Contamination persist, but from diffuse sources.
	Tree and fauna mortality	Decreasing	
Damming	Erosion of coastal forests	**Increasing in semiarid coasts**; stable elsewhere	Coastal communities are still underrepresented in basin management committees, even when community based management is enforced, it has small impact on the decision making process.
	Burying basin forests		
	Saline intrusion		
Agriculture	Eutrophication	**Increasing**	A shift to intensive agriculture diminish the impact of responses, by increasing nutrient emissions. However, stronger legislation decreased land conversion, and agrochemicals' use.
	Contamination of the biota	Decreasing	
	Deforestation	Decreasing	
Forestry	Deforestation	Decreasing	Protection of forests and creation of extractive reserves and community -based management largely decreased deforestation
Tourism	Localized eutrophication	Decreasing	Reduction of impacts occurred throughout the region do to responses involving a better understanding of the role of preserved mangrove areas for the activity proper, such as ecotourism
	Deforestation		
Fisheries	Overfishing	Decreasing	Sustainable use of mangrove fisheries was achieved in most countries, including recovery of overexploited stocks
	Decreasing biodiversity		
Salt production	Deforestation	Decreasing	Market aspects largely reduced the activity in mangrove areas, abandoned ponds naturally regenerated
Aquaculture	Deforestation	**Increasing**	Existing regulation were not sufficiently enforced to hamper the impacts on mangroves. Recent finding on pollutants emissions from the activity increased its potential as a pollution source
	Eutrophication		
	Contamination of the biota		

Major constrains to the societal responses:

- ✓ **Lacking the inclusion of a already real climate change scenario, making some legislation towards mangrove protection, weak.**

e.g. a new forest code in Brazil, protecting forests, but excluding salt flats, which decrease mangrove resilience to rising sea level.

- ✓ **Community-based management unable to cope with large capital investments.**

e.g. Harbor development and shrimp farming

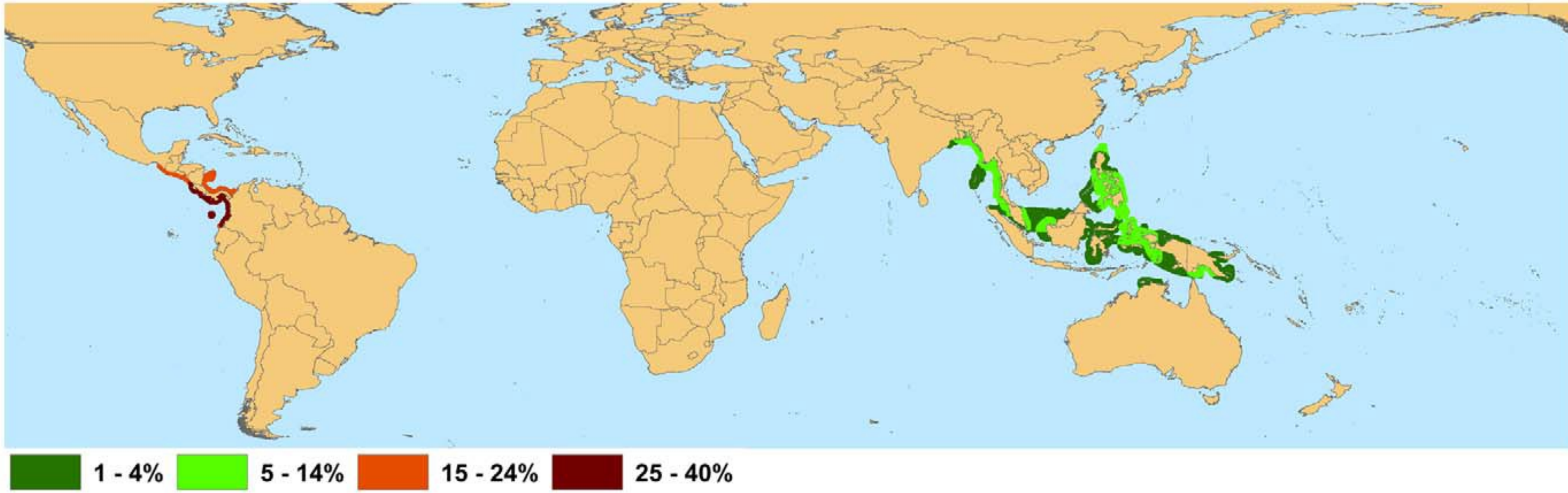
- ✓ **Extractive reserves seldom with economic planning to augment product value or finding new markets.**

e.g. organic honey production, most traditional fisheries

- ✓ **Global climate change and increasing water demand along watersheds results in expanding river damming with environmental impact assessment derived for upstream systems and not including the coastal zones and their mangroves.**

e.g. Most LA&C coasts under semiarid climate

Neotropical mangroves in the 21st Century



Globally, in 2010, the highest proportion of threatened mangrove species is found along the **Atlantic and Pacific coasts of Central America**. Four of the 10 (40%) mangrove species present along the Pacific coasts of Costa Rica, Panama and Colombia are listed in one of the three threatened categories, and a fifth species *Rhizophora samoensis* is listed as **Near Threatened**. Three of these species, *Avicennia bicolor*, *Mora oleifera* and *Tabebuia palustris* all listed as **Vulnerable**, are rare or uncommon species only known from the Pacific coast of Central America
(Polidoro et al., 2010).

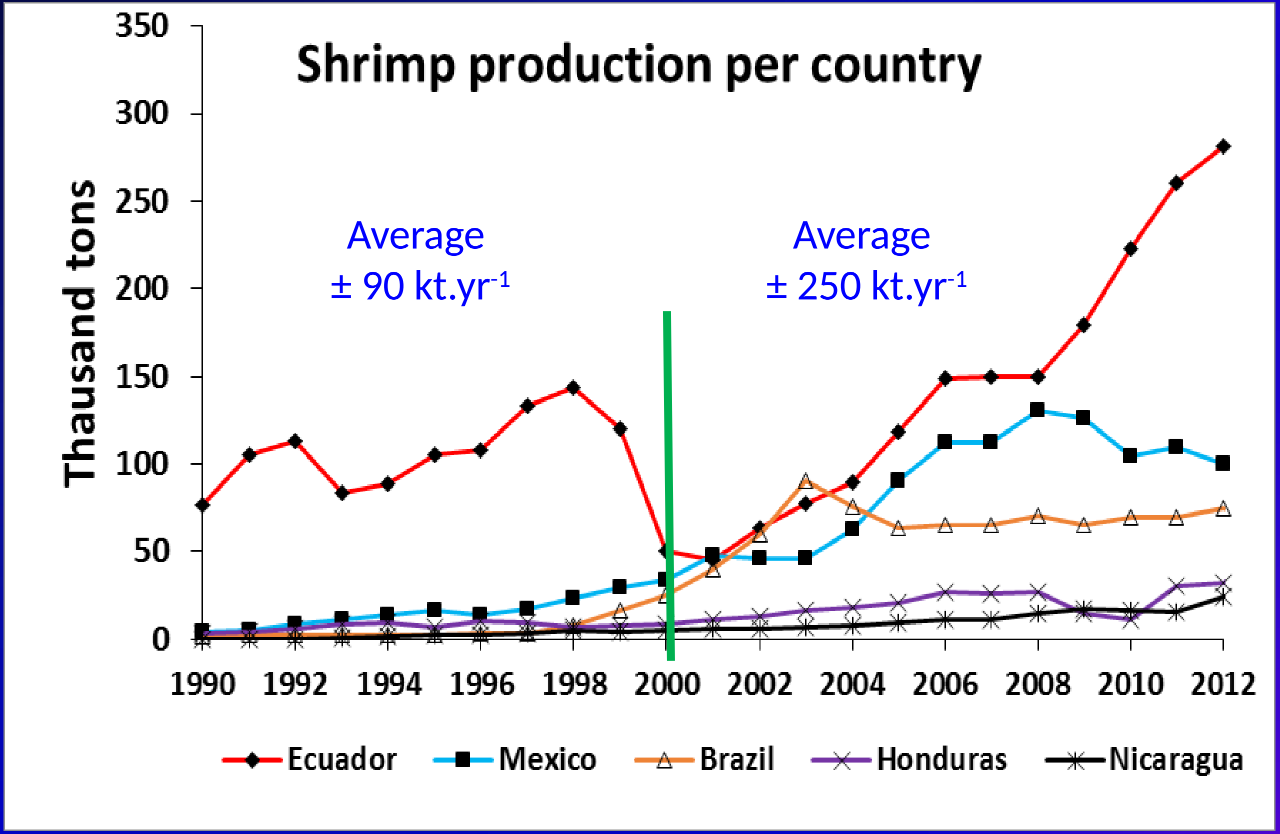
Preliminary* summary of drivers, pressures and impacts on mangroves of Latin America and the Caribbean regions acting in the 21th century*

Drivers	Major Pressures	Major Impacts	Response constrains	Observations/Trends
Aquaculture	Conversion; Nutrient emissions Sediment emissions Heavy metal emissions	Deforestation; eutrophication; Pollution siltation	Initial regulation laws did not take into consideration climate change. Public awareness insufficient or poorly distributed. Community-based management weak relative to capital pressures	**Major/Increasing** Widespread through LA&C continental margins; increasing up to 40% per year. Legally releasing new areas for pond construction; highest emission factors for nutrients and metals
Damming	Sediment and salt balance; nutrient fluxes	Erosion of coastal forests; burying basin forests; increasing soil and pore water salinity	Watershed committees including coastal communities' representatives fail to consider downstream, coastal impacts.	**Major/Increasing** Particularly important along semiarid regions.
Climate change	Sediment and salt balance; Remobilization of pollutants Frequency of extreme events	Erosion of coastal forests; burying basin forests; increasing soil and pore water salinity Contamination of biological resources Mangrove migration	No specific societal response so ever. Adaptation depends on local environmental setting and permitted adjacent human activities. Conservation laws do not include climate change as a variable.	**Major/Increasing** Atmospheric CO_2 increased from 390 ppm, in 1995, to 407 ppm in 2017. Notwithstanding the Kyoto protocol, emissions are on the rising. Unknown resistance / resilience threshold for mangroves
Replanting and Rehabilitation (+)	Augmenting mangrove area;	Augmenting carbon sequestrations, natural resources availability, natural protection reduces erosion	Community-based; small relevance to government; lack of monitoring; environmental conditions resulted from the past activity	**Major/Increasing** Rehabilitation policy not regulated at country level. Natural regeneration treated unattained. Planting on seagrass beds
Urbanization	Solid waste disposal; area conversion; wastewaters disposal	Contamination of the biota; eutrophication; mangrove eradication	Economic crisis and impoverishment of the population	**Intermediate/Stable** Widespread through the region, changing with economic growth and crisis
Agriculture	Nutrient fluxes; chemical effluents, land reclamation	Eutrophication; contamination of the biota; deforestation	Watershed committees failed to advance on the coastal zone., illegal commercialization of agrotoxics	**Intermediate/Stable** Major impacts are from intensive irrigated agriculture

** Fisheries, tourism, salt production and industrialization, are, today, considered of minor significance (??) and either decreasing or stable in importance (??), although, very site-specific. Urgent regional assessment needed, extension and gravity vary enormously locally.*

Aquaculture

Shrimp aquaculture in Latin America and the Caribbean (FAO, 2015)



Expanding shrimp aquaculture in northeastern Brazil, the Jaguaribe Estuary.

1993

320 ha

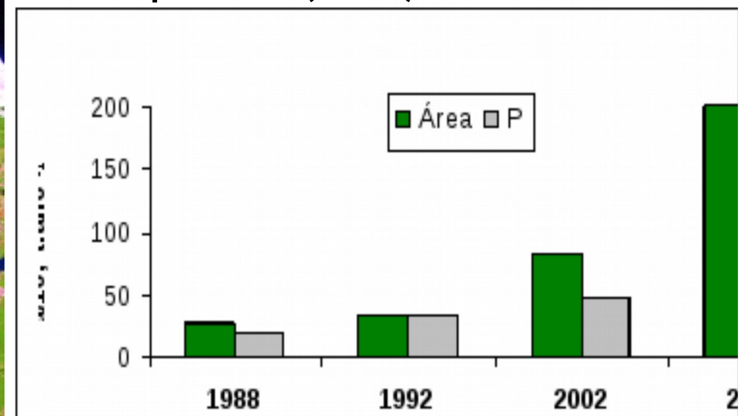
1999

940 ha

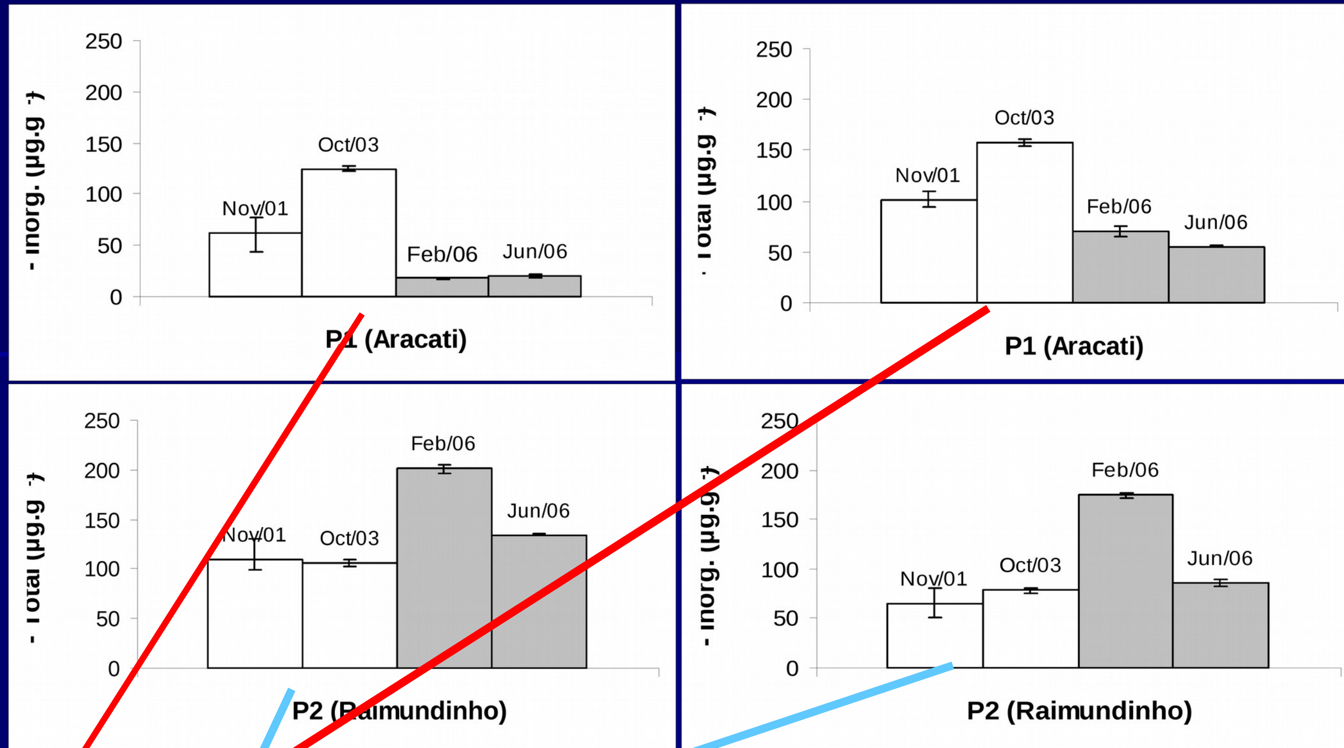
2010

1,680 ha

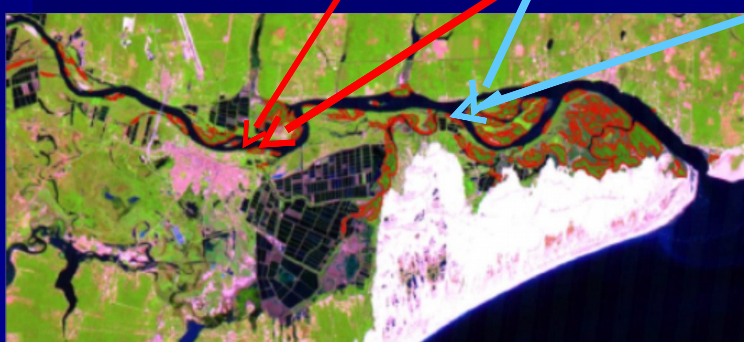
Pond area and phosphorus emission to the Jaguaribe Estuary (upper) and fast eutrophication (lower)



Shifting eutrophication sources



(c.f. Marins *et al*., 2008)



P1- downstream urban areas
P2- downstream shrimp farms

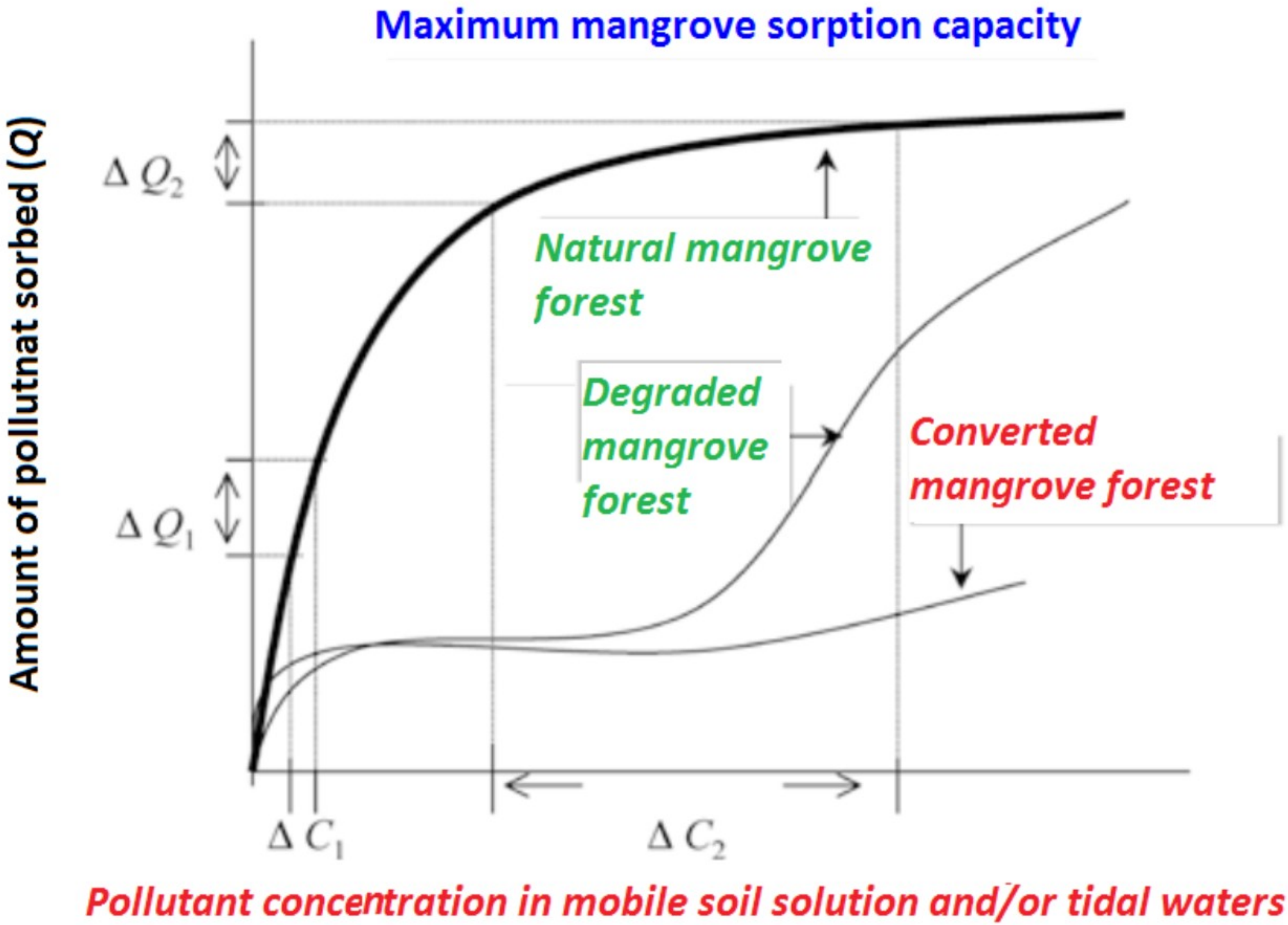
Year	Waste waters	Shrimp farming
2001	42.5	21.9
2008	45.6	60.9

Emission factors for Nitrogen, Phosphorus, Cooper, Zinc and Mercury from anthropogenic and natural sources, compared to shrimp farming.

Shrimp aquaculture

Sources	Emission factors N e P ($t/km^2/ano$); Cu, Hg e Zn ($kg/km^2/ano$)		Substances present in effluent		
Natural sources	N = 0.05 – 0.9 P = 0.01 – 0.06	Cu = 2.0 – 2.6 Zn = 5.0 – 6.5 Hg = <0.001	Mostly associated with particulate matter		Receiving body
Agriculture	N = 0.05 – 2,65 P = 0.12 – 0.56	Cu = 0.7 – 13.5 Zn = 0.04 – 0.13 Hg = 0.02	Nitrate, Ammonia Phosphate	Cu^{2+}, Zn^{2+}, Part. Cu and Zn	Soil
Husbandry	N = 0.09 – 1.31 P = 0.09 – 1.73	Cu = 0.3 – 1.0 Zn = 0.4 – 7.3 Hg = <0.001	Ammonia Phosphate	Part. Cu and Zn	Soil
Urban waste waters and runoff	N = 0.03 – 0.55 P = 0.01 – 0.14	Cu = 0.1 – 15.3 Zn = 0.01 – 47.2 Hg = < 0.001	Nitrate, Ammonia Phosphate, P-particulate	Cu^{2+}, Zn^{2+}, Hg^{2+}, Part. Cu and Zn	Soil, water ways and estuaries
Urban solid wastes disposal	N = 0.001 – 0.2 P < 0.0001	Cu = 0,001 – 0,03 Zn = 0,001 – 0,07 Hg = 0.04	Forms of N and P unknown	Cu^{2+}, Zn^{2+}, Hg^{2+}, Part. Cu and Zn	Soil
Shrimp aquaculture*	N = 1.25 – 4.09, P = 0.13 – 0.32 Cu = 38.6 – 59.8, Hg = 0.03 – 0.04 Zn = 508		PON (70%); NO_3^-, Ammonia, NO_2^-, POP, Phosphate	Part. Cu, Zn and Hg	Water ways and estuaries

* (Lacerda et al., 2006; 2008; 2011; León-Canhedo et al., 2017)



Modidified from Lacerda (2003)

Some technical people suggest mangroves as filters for aquaculture effluents, however, most mangroves are far from pristine. e.g. Phosphorus balance in two mangrove forests in NE Brazil, receiving effluents from shrimp aquaculture

2,020 ha of ponds

69 t/year

Retention of 44% of the total tidal input

9 ha of ponds

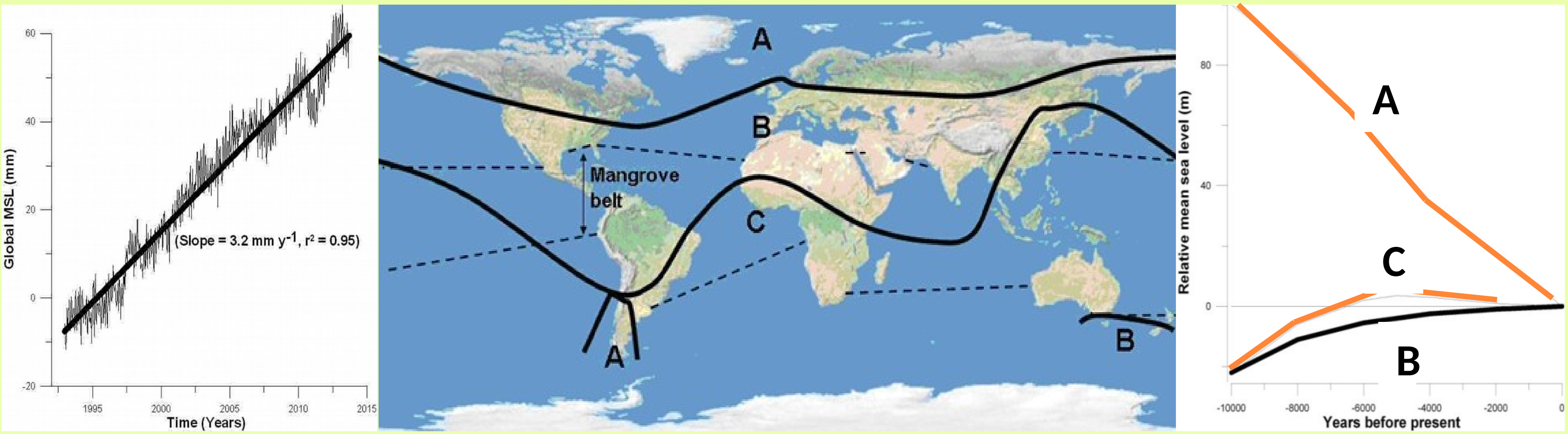
0.1 t/year

Retention of 96% of the total tidal input

Export through tides

Climate change

Mangrove and sea level rise (adapted from Jennerjahn (2017)

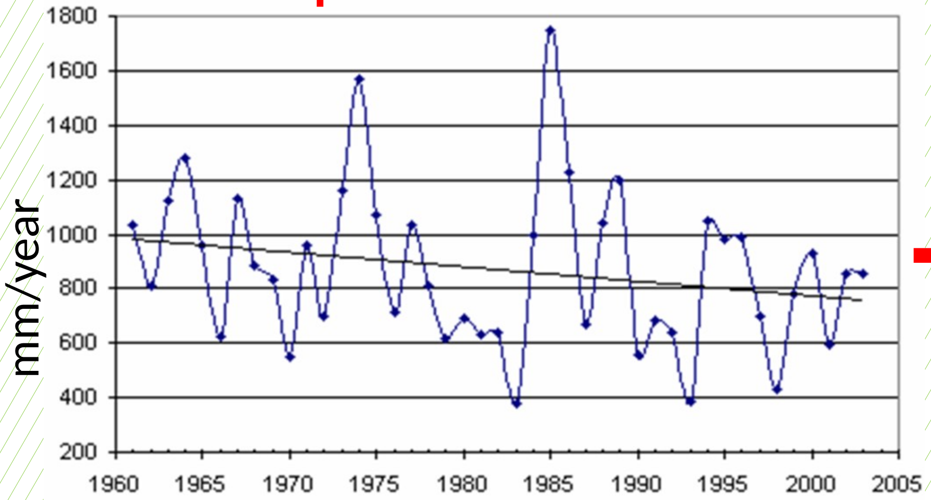


	RCP2.6 ΔT (°C)	RCP4.5 ΔT (°C)	RCP6.0 ΔT (°C)	RCP8.5 ΔT (°C)
Global	1.0±0.4	1.8±0.5	2.2±0.5	3.7±0.7
Land	1.2±0.6	2.4±0.6	3.0±0.7	4.8±0.9
Tropics	0.9±0.3	1.6±0.4	2.0±0.4	3.3±0.6
Ocean	0.8±0.4	1.5±0.4	1.9±0.4	3.1±0.6

Surface air temperature increase between the period 1986-2005 and the period 2081-2100 according to the four IPCC scenarios.

A positive feed back occurs between damming and climate change, particularly under dry climates.

Precipitation anomalies



Evolution Trend (1961 – 2008) in annual precipitation over Ceará. (5,3 $mm.yr^{-1}$ reduction)

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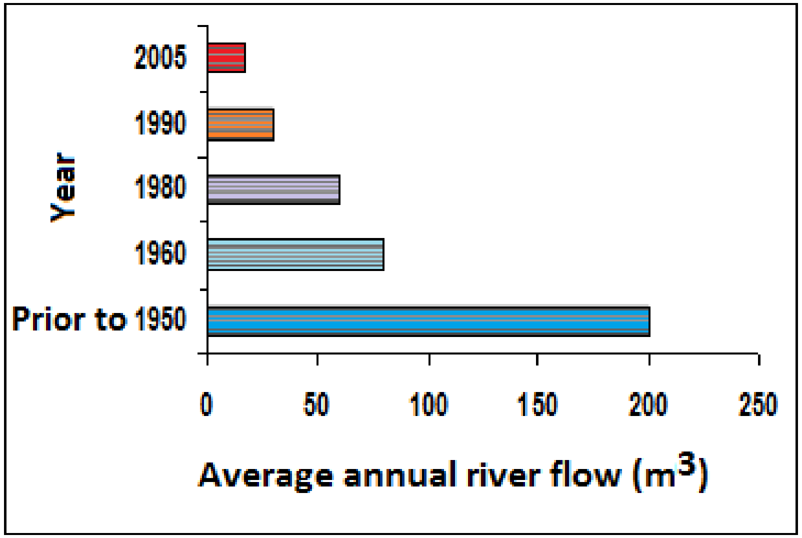
Fluvial flux decrease



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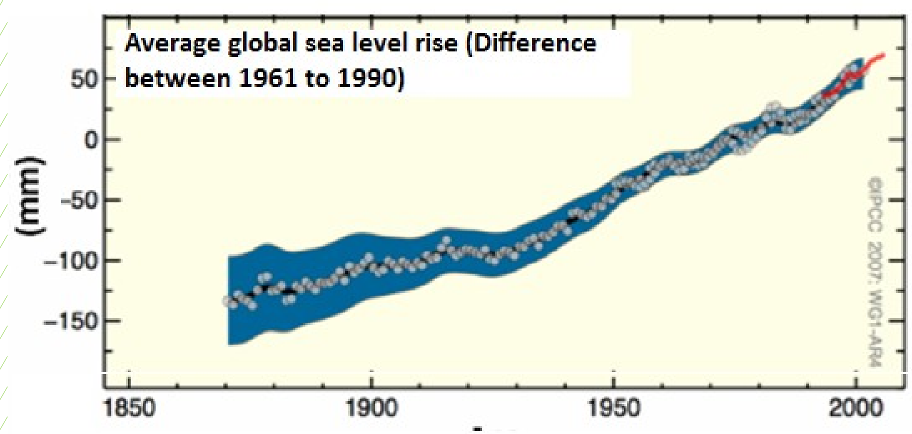
Sea level rise



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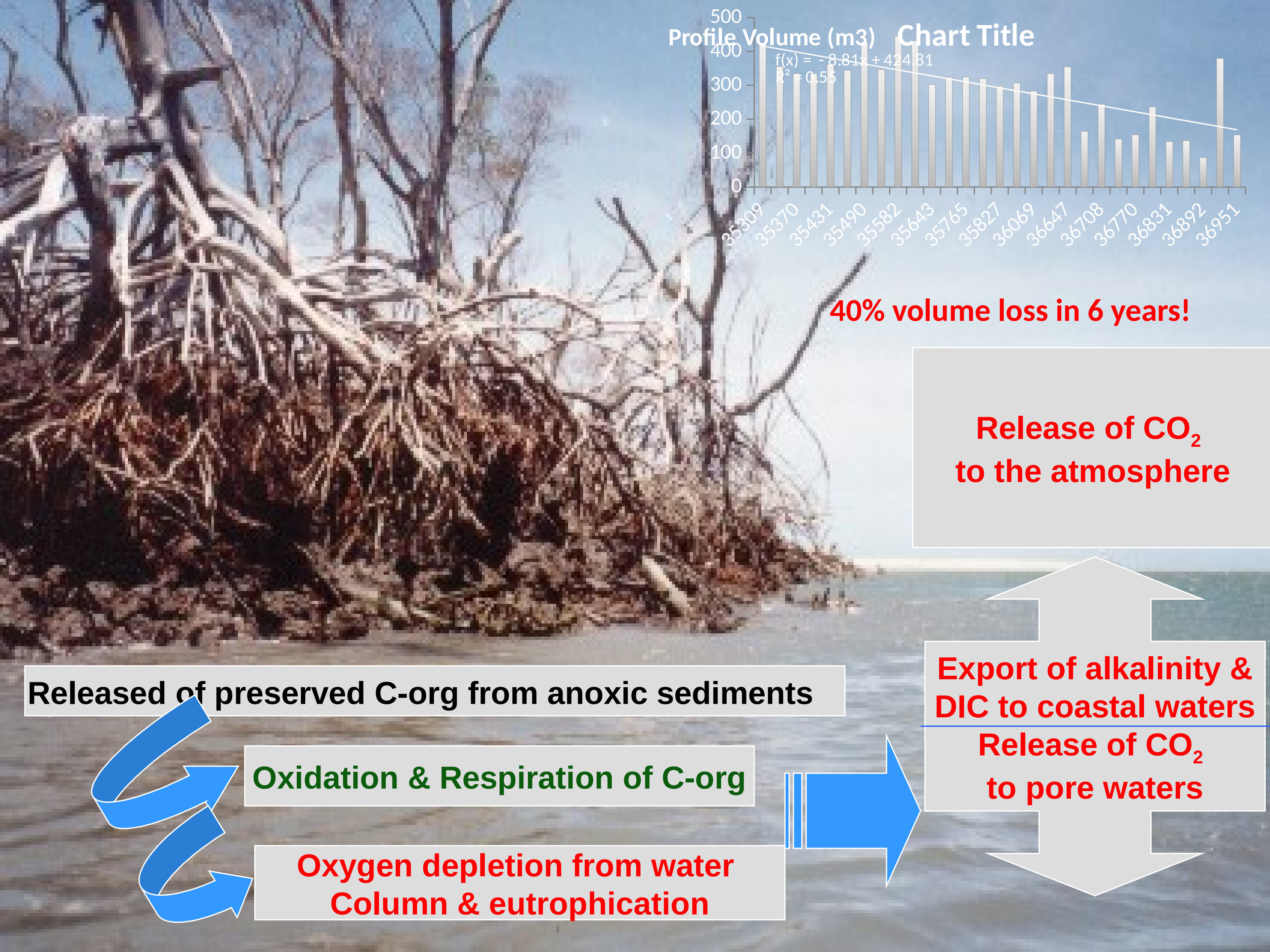
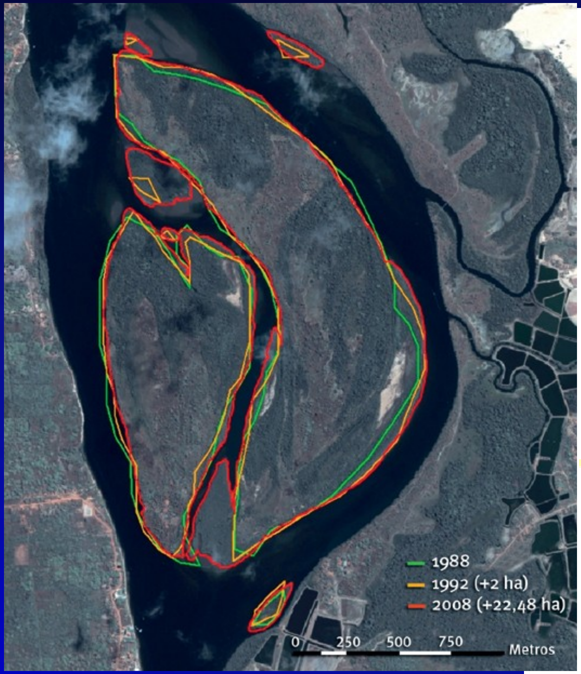
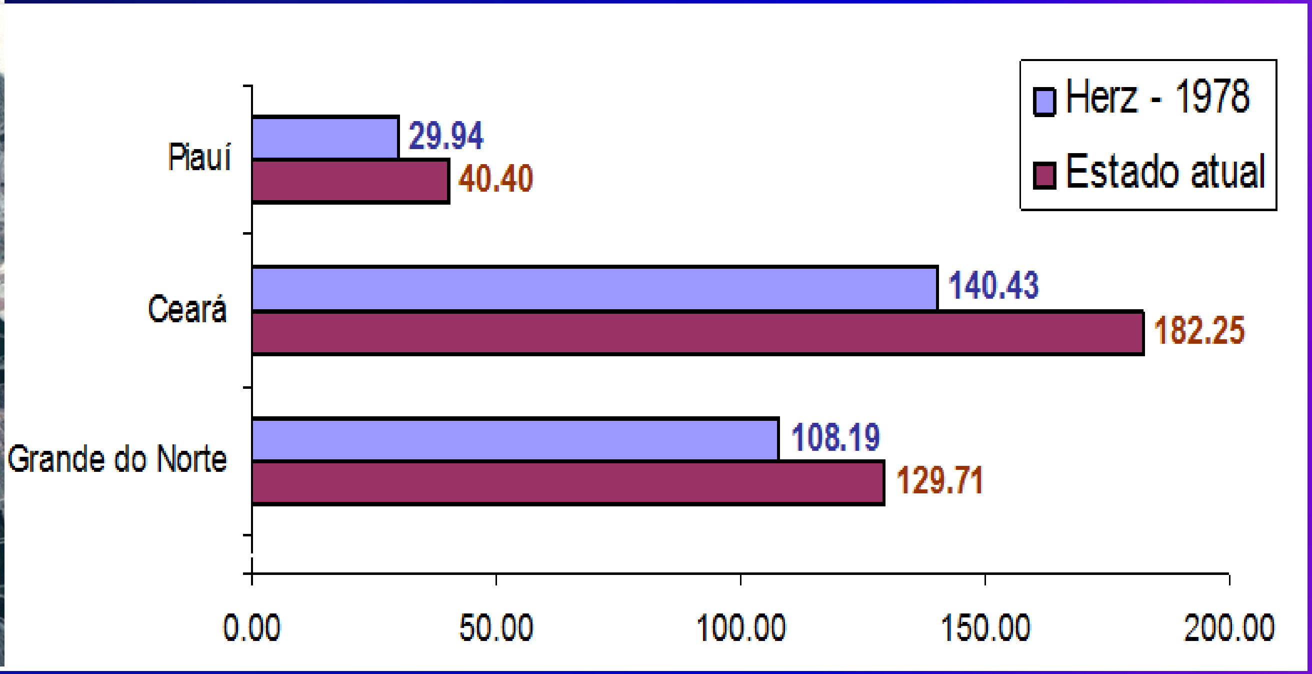

Profile Volume (m3)
Chart Title
500
400
300
200
100
0
f(x) = - 8.81x + 424.81
R² = 0.55
35309
35370
35431
35490
35582
35643
35765
35827
36069
36647
36708
36770
36831
36892
36951
40% volume loss in 6 years!
Release of CO_2 to the atmosphere
Export of alkalinity & DIC to coastal waters
Release of CO_2 to pore waters
Released of preserved C-org from anoxic sediments
Oxidation & Respiration of C-org
Oxygen depletion from water Column & eutrophication

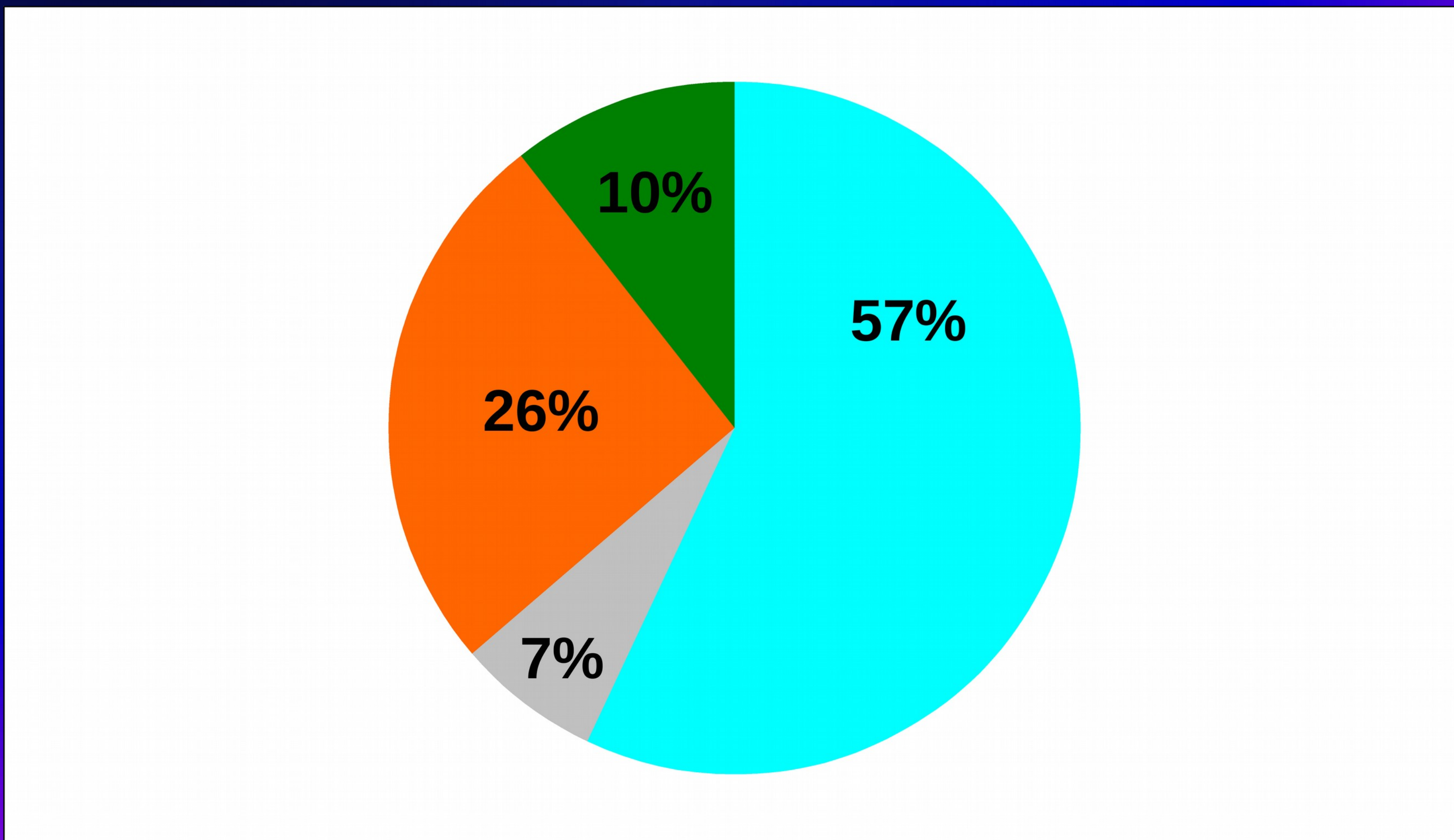
Changes in mangrove extension in 27 estuaries along the semiarid coast of Brazil (Maia et al., 2006), Mangrove Atlas of NE Brazil. www.insitutomilenioestuarios.com.br





Parameter	km^2	%	
Total mangrove area in 1978	278		
Total mangrove area in 2004	352		
Increase (uncertainty)	74	21%	(± 8%)

Origins of alterations identified in 41 estuaries of the semiarid littoral of northeast Brazil. Comparing radar data from 1980 to Landsat, SPOT & Quickbird data from 1999 to 2013



Some conclusions and gaps

- **Drivers of impacts on mangroves have changed drastically, this has reduced the effectiveness of some important societal responses towards conservation and sustainable management .**

- **It is clear that rehabilitation strategies and conservation and management legislation and practices of existing forests shall take into consideration not only local anthropogenic drivers but the climate change scenario. However…**

- **How global climate change interacts with local anthropogenic drivers?**

- **Does and how typology influences the impacts onto and the response of mangrove forests to climate change?**

- **How major anthropogenic drivers presently affecting mangroves may maximize or minimize impacts from climate change?**

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