Planting mangroves for multiple benefits

On occasion of World Ocean Day, 8 June 2023

Centre on Integrated Rural Development for Asia and the Pacific, Dhaka, Bangladesh

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World Ocean Day

- **World Ocean Day (WOD)** : international day that takes place annually on 8 June.
- **Concept** was originally proposed in **1992** by Canada's International Centre for Ocean Development (ICOD) & Ocean Institute of Canada (OIC) at Earth Summit in Rio de Janerio. (UN Conference on Environment & Development; Agenda 21 in 1992).
- **Objectives** : move the ocean from sidelines to centre of intergovernmental & NGO discussions & policy & strengthen voice of ocean & coastal constituencies worldwide.
- **Globally coordinated efforts** : "The Ocean Project" & the "World Ocean Network" collaborating, dozens of events.
- **Annual themes** : **starting in 2009** : "Our Ocean, Our Responsibilities".
- **2023 : "Planet Ocean : Tides are Changing"**.

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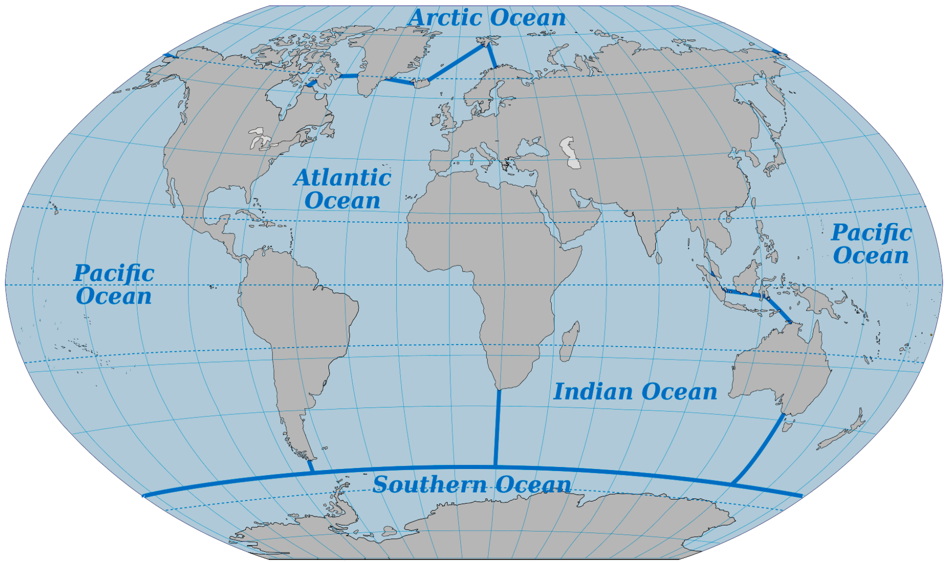
Oceans : some facts

- Cover 70% of earth's surface, contain 97% of earth's water.
- Home to 94% of all life on earth.
- <10% of world's ocean have been mapped.
- Absorb around 30% CO_2 produced by humans, buffering impacts of global warming.
- >3 billion people depend on marine & coastal biodiversity for their livelihoods. (Global population is almost 8 billion in 2023).
- Serve as world's largest source of protein, with >2.6 billion people depending on oceans as primary source of protein.
- Unfortunately, as much as 40% of world oceans heavily affected by human activities like pollution, depleted fisheries, & loss of coastal habitats.
- 37 out of 50 critical minerals found in oceans.



(Wikipedia)

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Presentation : learning journey

- Mangrove experience at early age in primary school; main road to school cut through mangrove swamps; seen usual marine life in mudflats, including aftermath of snake battle.

- During coastal work seen mangroves in Singapore, Malaysia, Indonesia, Philippines, Thailand & some islands in Indian Ocean.

- Academic interest/research started after Dec 2004 Indian Ocean tsunami impact on mangroves with fieldwork in Aceh, Andaman coast & islands of Thailand, west & south coast of Sri Lanka & east coast of India (Tamil Nadu).

- Subsequently, spent more time on mangroves in non-muddy environments, e.g. Mactan Island, Philippines & Bunaken Island, Indonesia.

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Tampines area

Mangroves have long helped define the character and culture of the Tampines area. Kampong residents used the Bakau Pasir *(Rhizophora stylosa)* and Perepat *(Sonneratia alba)* mangrove timbers to construct kelongs and boats, while the Api Api tree *(Avicennia)* lent its name to the eponymous river.

(Tampines Heritage Trail, p.14)

An illustration showing where some of kampongs in Tampines were located in the 1930s
Courtesy of National Heritage Board

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Outline

1. Mangroves
2. Adaptation and zonation
3. Benefits
4. Threats

5. Coastal protection
6. Planting and restoration
7. Modular planting

8. End note

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1. Mangroves

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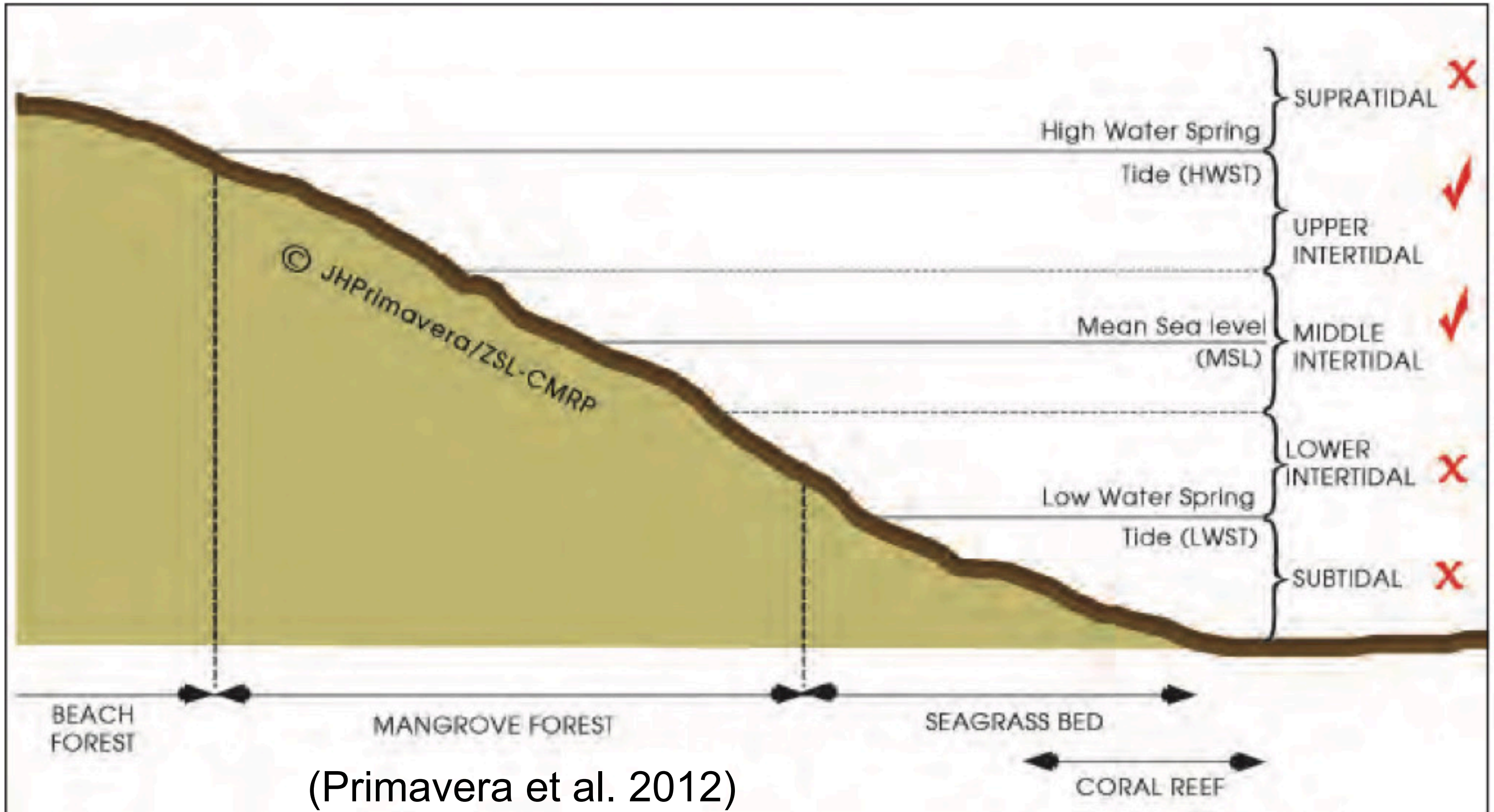
Coastal ecosystem

- **Tropical plants** straddling **interface of land & sea.**

- **Significant coastal ecosystem** : **with branches for birds, reptiles, mammals; roots when submerged as nurseries for fish & marine mammals.**

FIG. 1. Location of mangroves in relation to other coastal habitats, and tidal elevation suitable (✓) for planting (mid- to upper intertidal). Lower intertidal and subtidal sites (✗) experience high mortality.



(Primavera et al. 2012)

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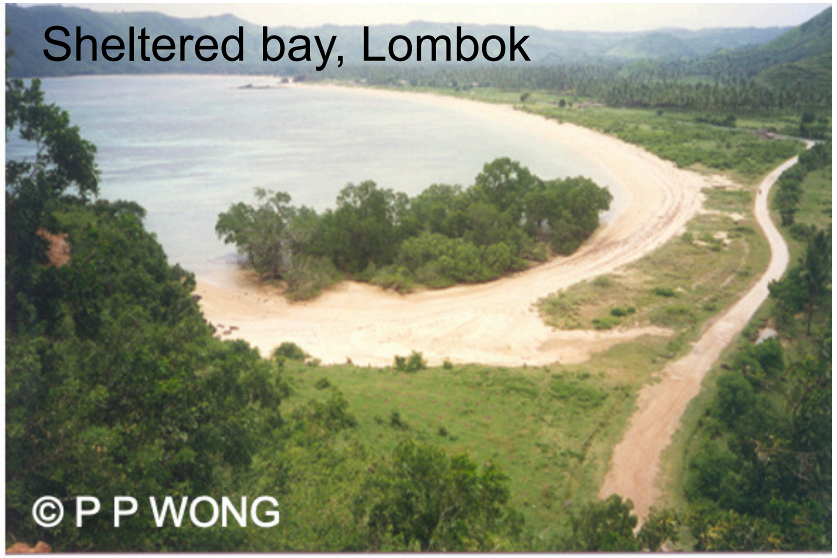
Coastal locations



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Sandy shores, Bintan Island, Indonesia

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Sandy shores, Samal Island, Philippines

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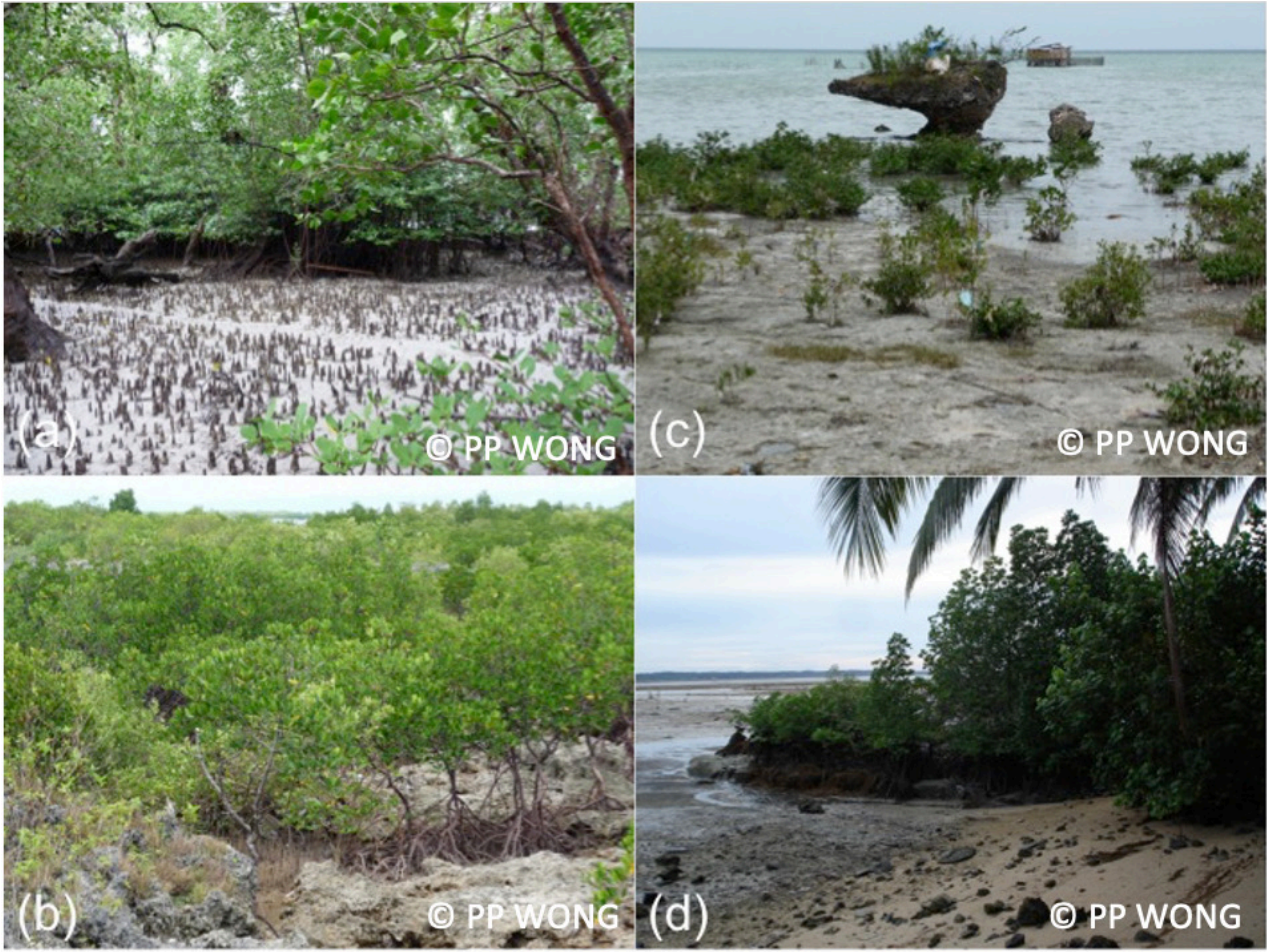
Coral flats and rocks



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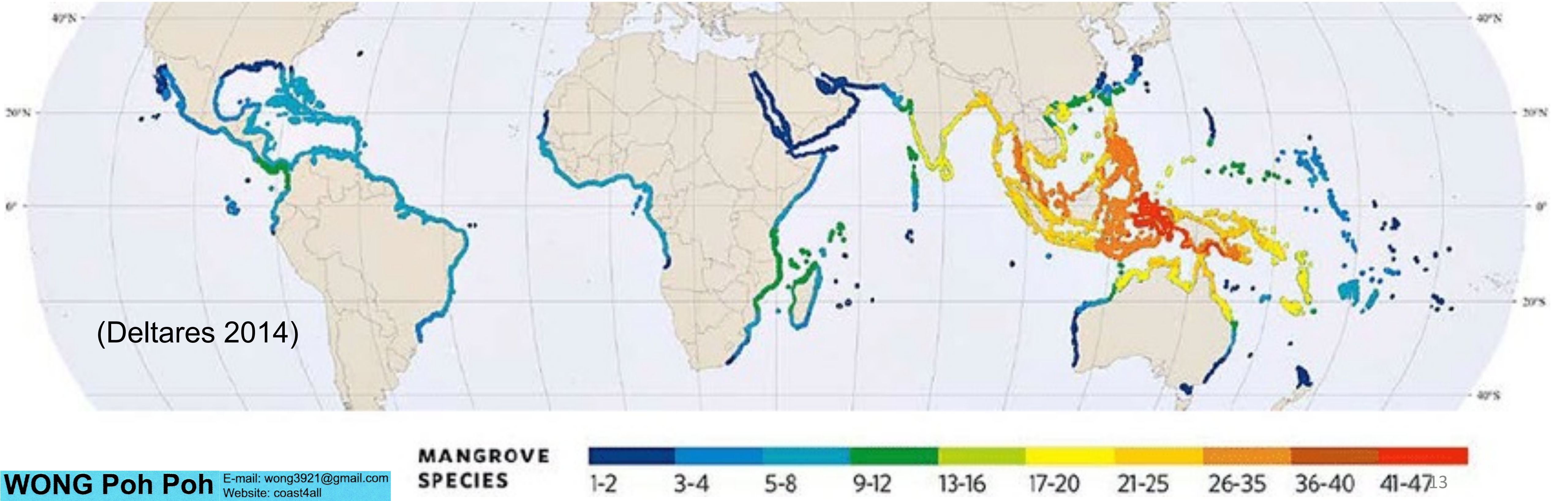
Global distribution (1)

- Grow in **sheltered tropical & subtropical coastal areas** across globe, **generally between latitudes 25°N & 25°S**.

- **Roughly 54 true species of mangrove belonging to 16 different families**. When all plants living in mangrove environment are included, >80 mangrove species.



(Deltares 2014)

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Global distribution (2)

- **Bimodal distribution.**
- **Differences in species differences between western & eastern groups.**

(Tomascik et al. 1997)

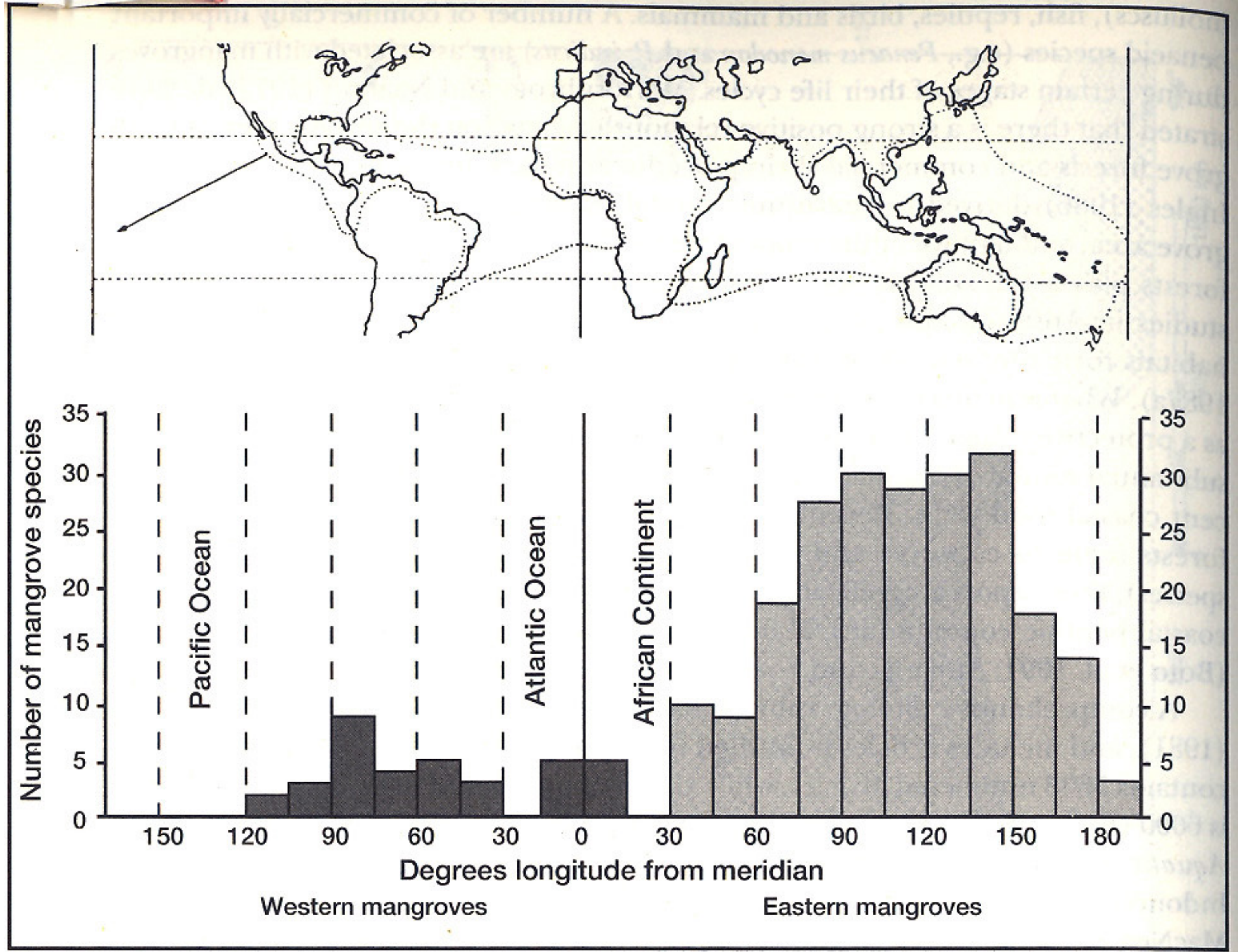

Figure 19.4. Global distribution of mangroves. Above: approximate distributional boundaries for west and east mangrove groups. Some overlap may exist in the western Pacific (*Rhizophora samoensis*) (arrow). Below: The bimodal distribution of mangroves, illustrating differences in species richness between the western and eastern groups.

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2. Adaptation and zonation

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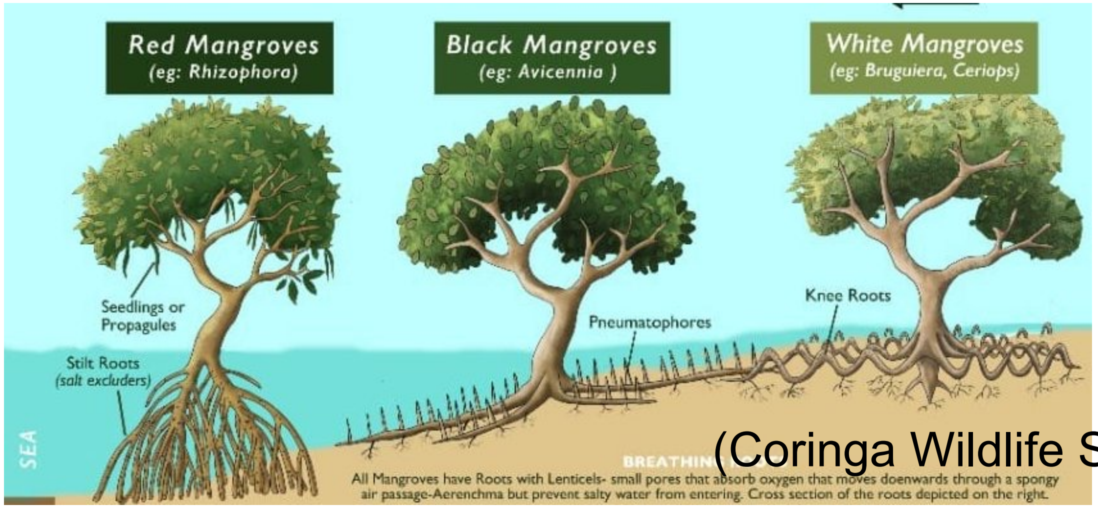
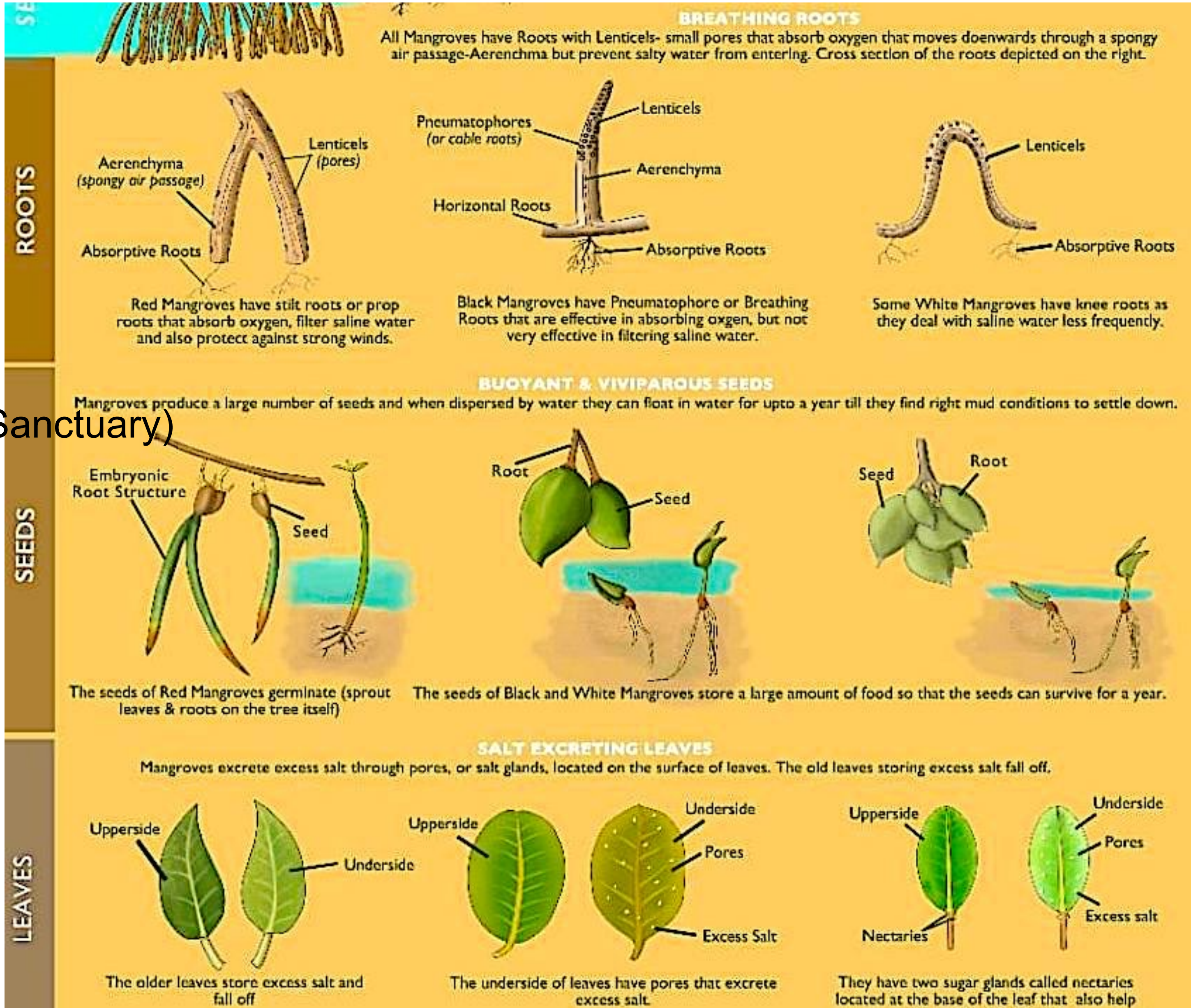
Root, seed and leaf adaptations



(Coringa Wildlife Sanctuary)

Salt crystals on *A. marina* leaf

(AskNature)



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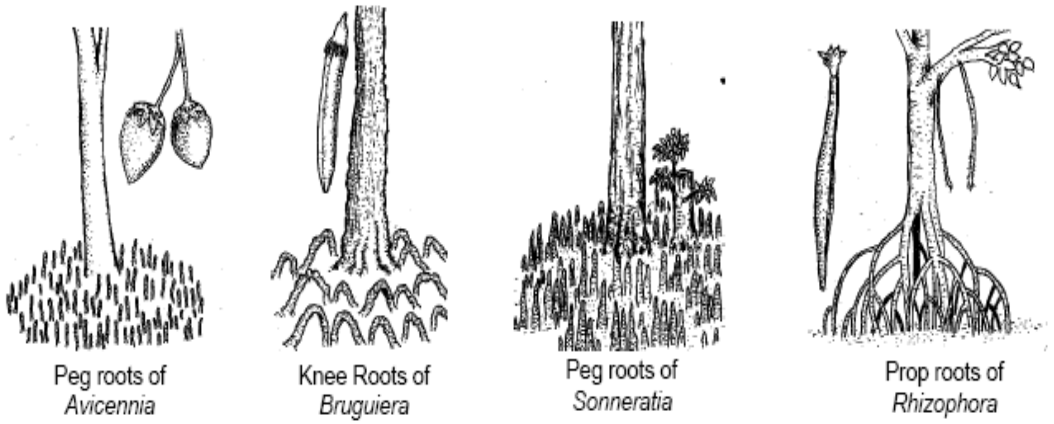
Roots adapt to changes in sea level

"Mangroves have **special root systems … and may adapt to changes in sea level by growing upward in place, or by expanding landward or seaward."** (McLeod & Salm 2006)



(Mehta 1999)

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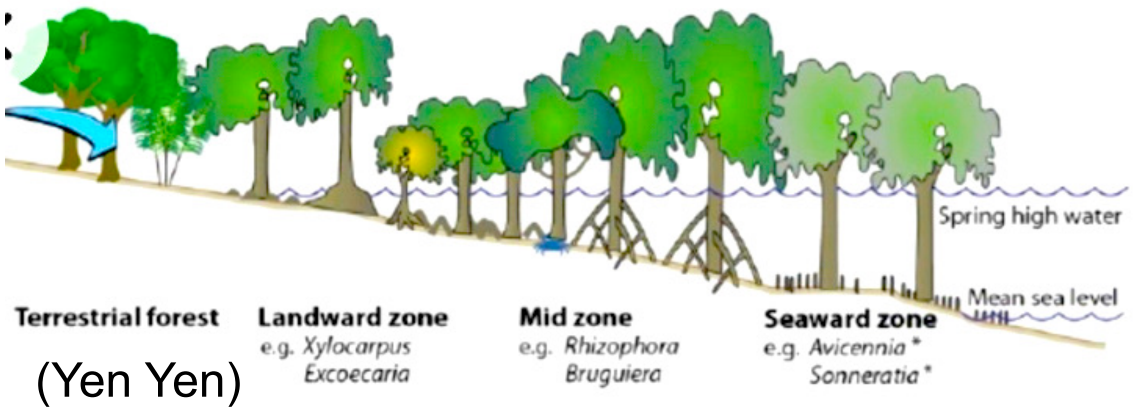
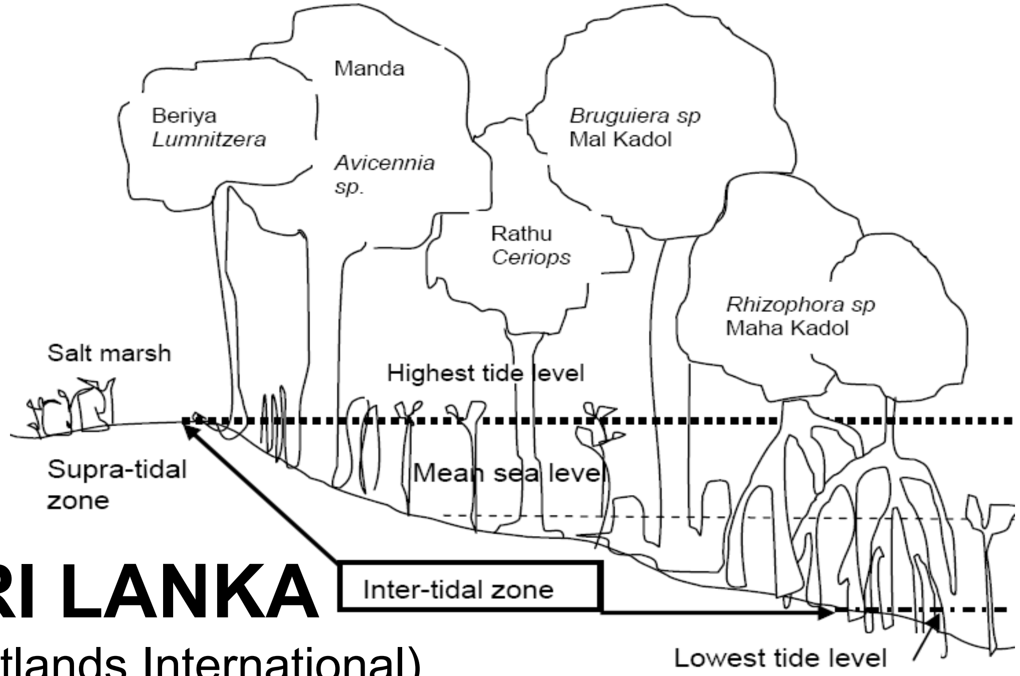
Zonation



(Yen Yen)

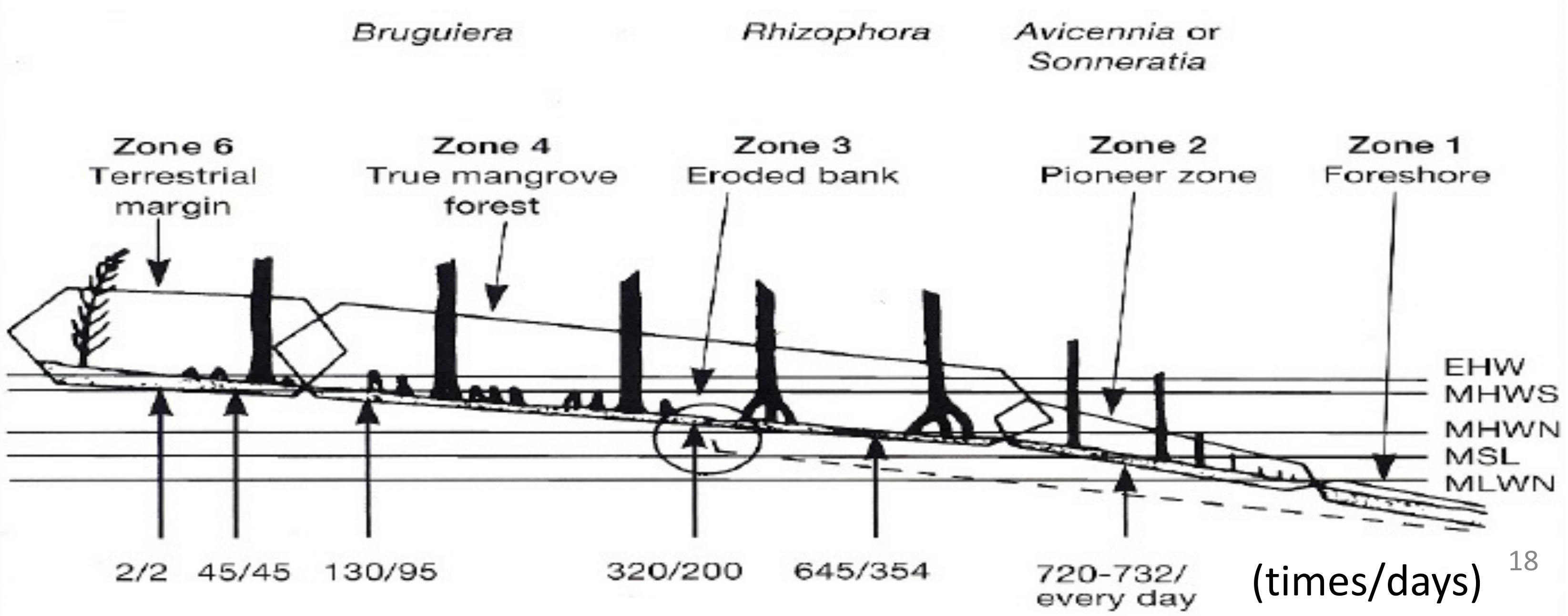


SRI LANKA

(Wetlands International)

INDONESIA

(Whitten et al. 1997)



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Inland mangroves

- **Mexico. *R. mangle*, >160 km inland on Yucatan peninsula, besides waterfall.**
- **Able to survive due to surrounding soils that leach calcium into lagoon & river waters, creating environment similar enough for trees to persist. (Top)**
- **At elevation of 6-9 m when sea level was >100,000 yr ago. (Aburto-Oropeza et al. 2021).**

- **Pakistan : *A. marina* in low-lying area of about 4.5 ha isolated from Keenjhar lake by narrow embankment as high as 4 m. Mangroves as tall as 1.5 m.**
- **Earlier, large trees as high as 10 m or more used to grow in area but were all cut by local dwellers for wood & now only their cut stumps are left over. (Bottom) (Saifullah & Rasool 2007).**

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3. Benefits

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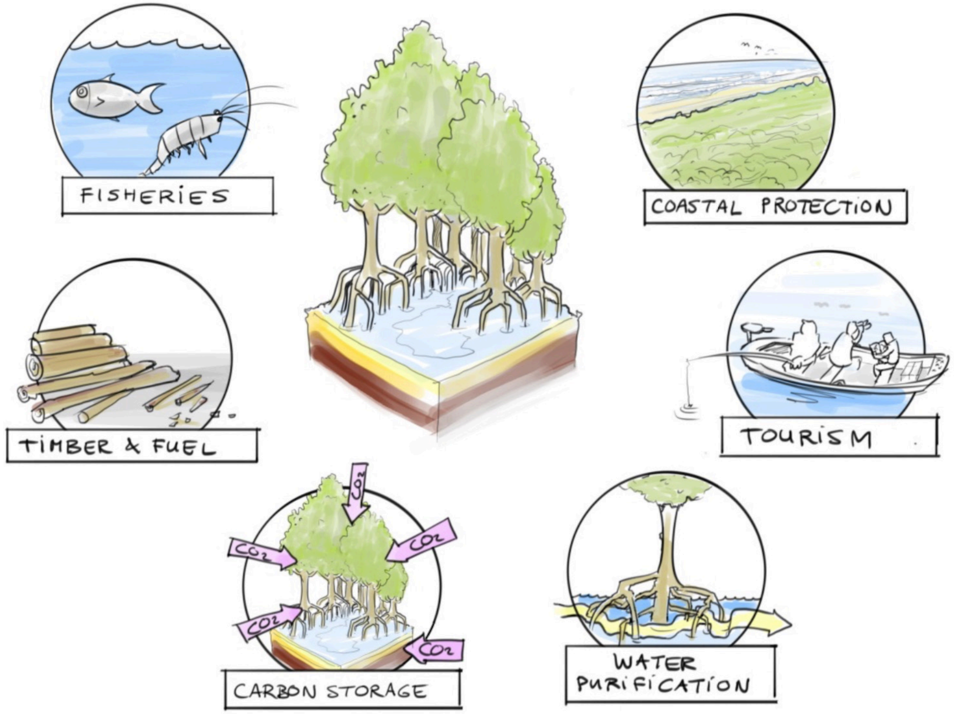
Ecosystem services



(Tonneijck et al. 2015)

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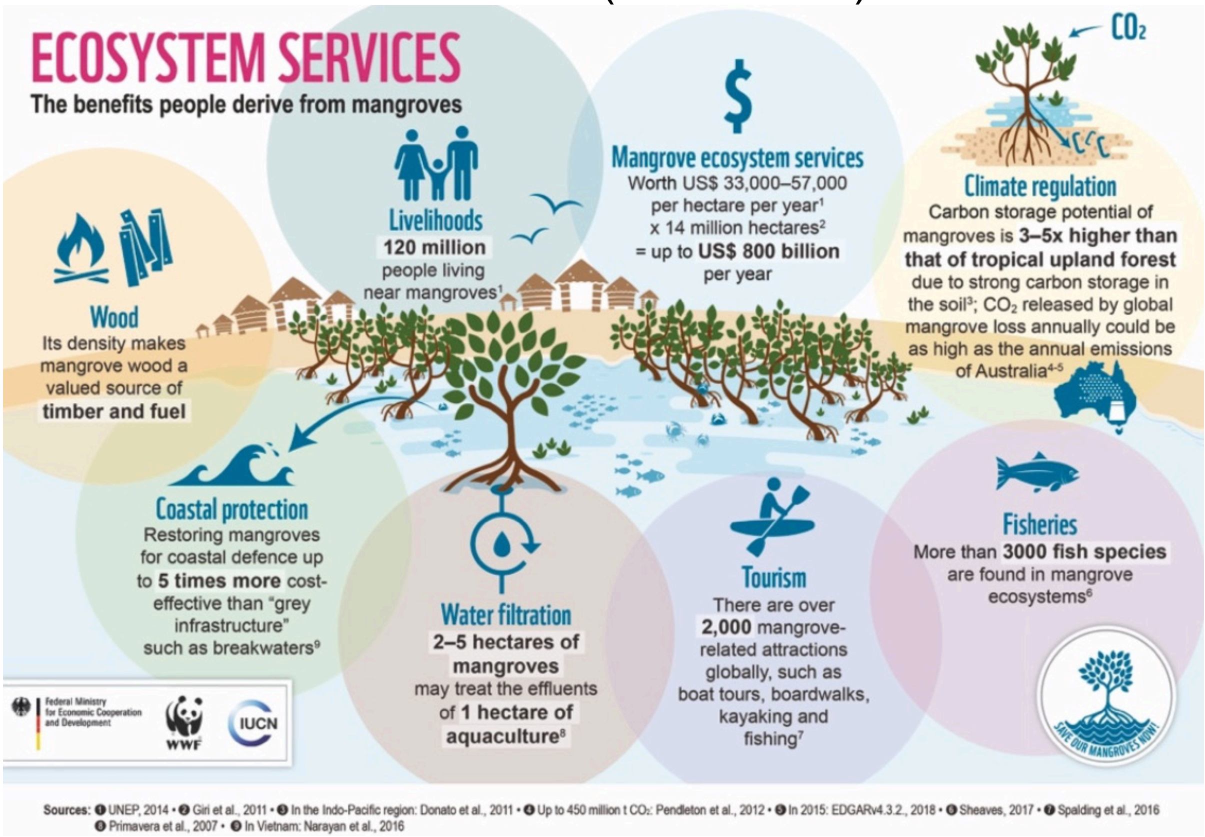
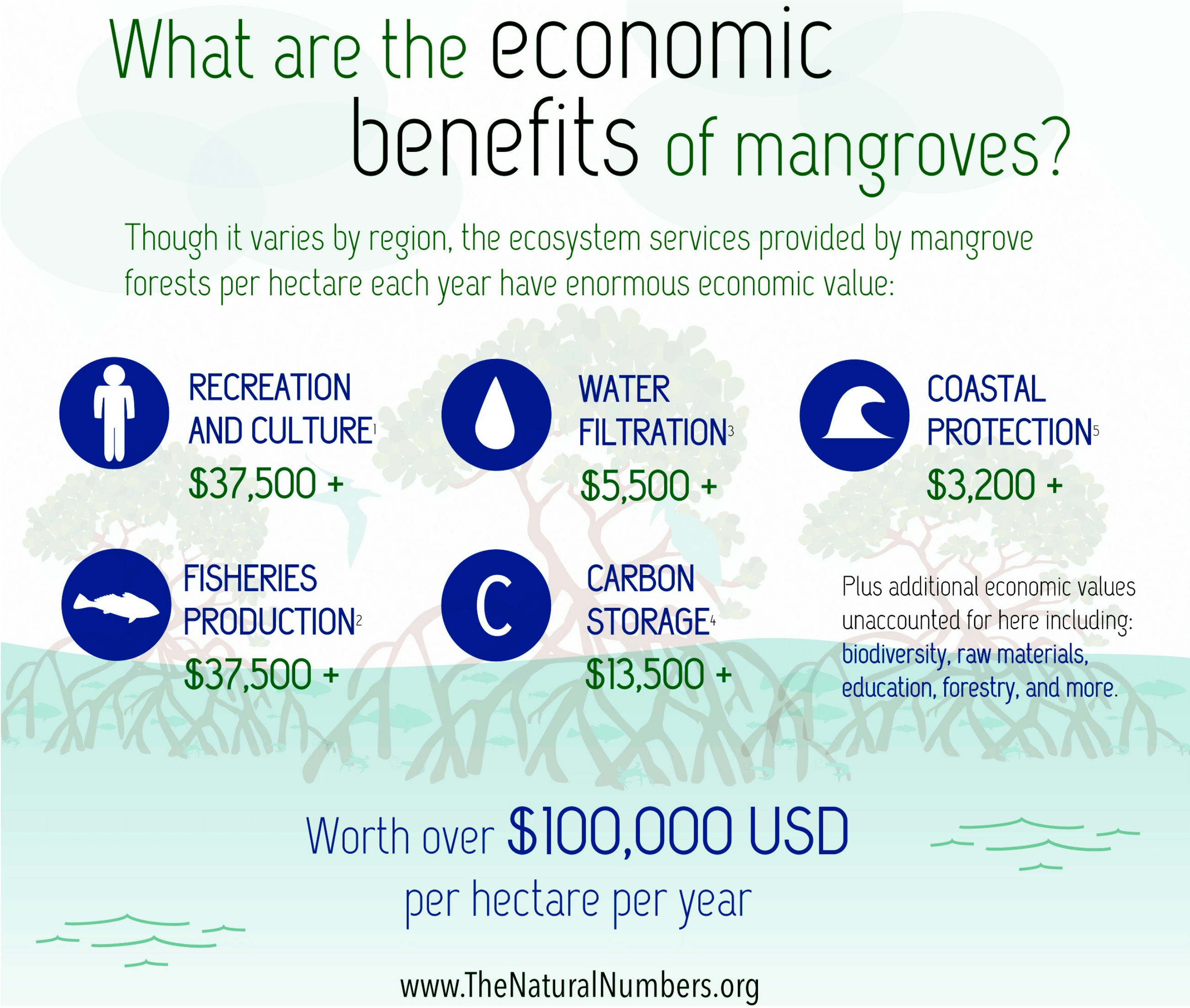
Ecosystem services : people & $

(IUCN 2019)





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Livelihoods

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Fruits for food

(MAP 2006)

Sonneratia Wajit (Sticky Mangrove Apples)................
Sonneratia Lempok (Candied Mangrove Apples).....
Sonneratia Juice (Mangrove Apple Juice)................
Sonneratia Dodol...
(Taffy made of sticky rice, coconut milk, and palm sugar)

Bolu Api-Api (Avicennia Spongecake)........................
Bolu Agar-Agar Api-Api (Avicennia Agar-agar cake)..
Onde-Onde Api-Api (Round Fried Avicennia cakes)..

Kripik Manis Buah Api-Api (Sweet Avicennia Crisps)...........
Kripik Asin Buah Api-Api (Salty Avicennia Crisps)................
Avicennia Crisps..
Kue Talam Api-Api (Avicennia Sheet Cake)........................
Kue Talam Manis Api-Api (Sweet Avicennia Sheet Cake)..

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Preperation of *Avicennia spp*. fruits for cooking

1. Use ripe Avicennia fruit. Ripe fruits are yellowish green in color. Ripe fruits are split and have seperated from the calyx. They can be collected from the ground or tree. Do not use fruit that have already developed roots.
2. Remove outer skin
3. Split into four pieces, remove the root bud/pistil
4. Boil Avicennia fruits in water and and ash, stir until ash is evenly spread.
5. Remove from heat and clean fruit until color is green.
6. Soak in clean fresh water for two days, changing water every 6 hours.

Alternatively you can peel the fruits, soak in water for 3 days, boil, and soak for another three days. During soaking the water is changed every 8 hours.

(MAP 2006)

Note: In general, Avicennia alba is used for making flour for cakes and Avicennia marina for fried crackers.

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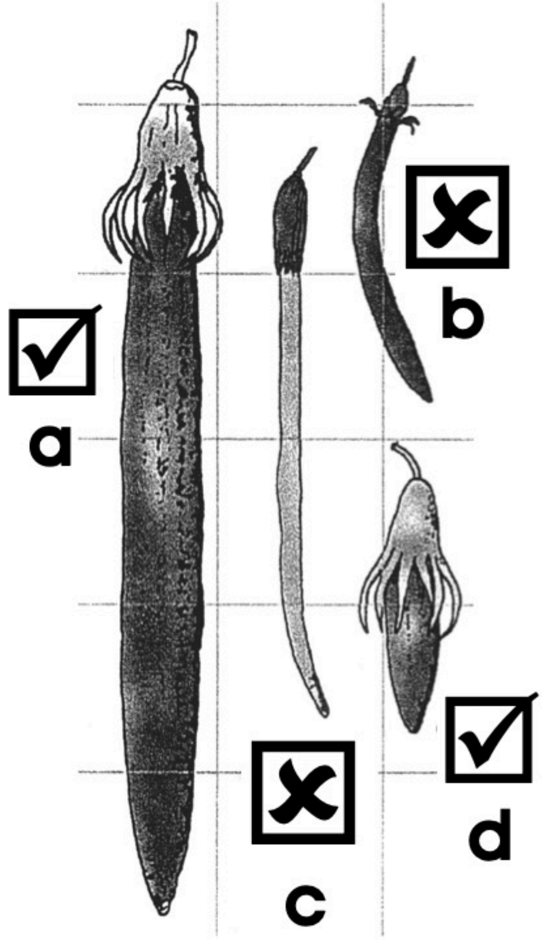
Preperation of *Bruguiera spp.* fruits for cooking

1. Pick Bruguiera fruits from trees
   Ripe fruits are greenish brown in color.
2. Remove calyx
3. Cut into inch long pieces
4. Soak fruits in clean fresh water for two days, changing water every 8 hours.
5. Boil
6. Soak in clean fresh water for two more days, changing water every 8 hours.



(MAP 2006)

a - *Bruguiera gymnorrhiza* (ok to eat)
b - *Bruguiera parviflora* (not for consumption)
c - *Bruguiera cylindrica* (not for consumption)
d - *Bruguiera sexangula* (ok to eat)

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Avicennia marina : bread

- I calculated amount of flour & bread that could be extracted from one hectare (ha) of *A. marina*.

- According to a source in S China (UNEP 2003), one ha of pure forest of *A. marina* can produce 750 kg (wet wt) of fruits per yr.

- Based on about 35% of water content in fruits (Sulistiyati et al. 2015) a ha would therefore yield 487 kg (dry wt) of fruits per yr. Based on one pound of flour for a large loaf, 487 gm (more than usual one pound or 454 gm) of dry flour would produce large loaf of bread as daily food for two persons. If available, pieces of dried fruits (bananas, pineapples), tubers (sweet potatoes, yams) could be added.

- In one year, one ha of *A. marina* can produce 487 kg of flour to make 1,000 loaves of bread sufficient to feed 2,000 persons per day or 20 persons for 100 days (>three months).

- During WWII, isolated coastal communities used *Avicennia spp* for food; also noted immediately after Dec 2004 Indian Ocean tsunami.

- *Avicennia marina* : probably most versatile mangrove species for food as it can establish on wide range of substrates, has widest geographical range & only species to survive in dry conditions & away from sea.

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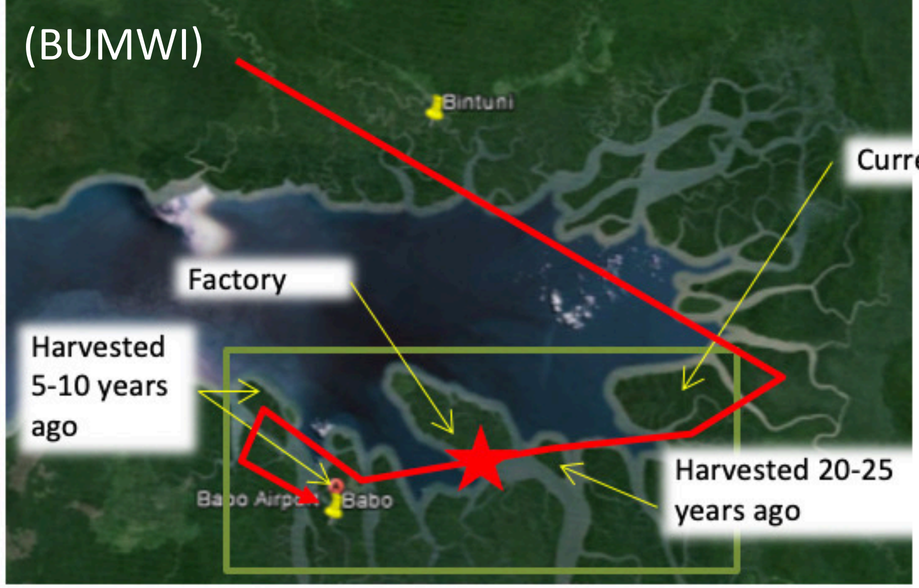
Timber for wood chips

• **PT. Bintuni Utama Murni Wood Industries** (BUMWI) established in 1988 with licence up to 2052.

• **82,120 ha concession area** covers large part of Bintuni Bay mangrove forest. **2015 : largest mangrove concession in world to obtain international forest management certification.**

• Woodchips exported to Taiwan, China & previously Japan for mixing with other species to increase pulp density & strength (Bottom).

• **Contributed significantly to local economy,** employing average of 800 workers/yr & contributed to **protection of mangrove ecosystem.**



(2013)

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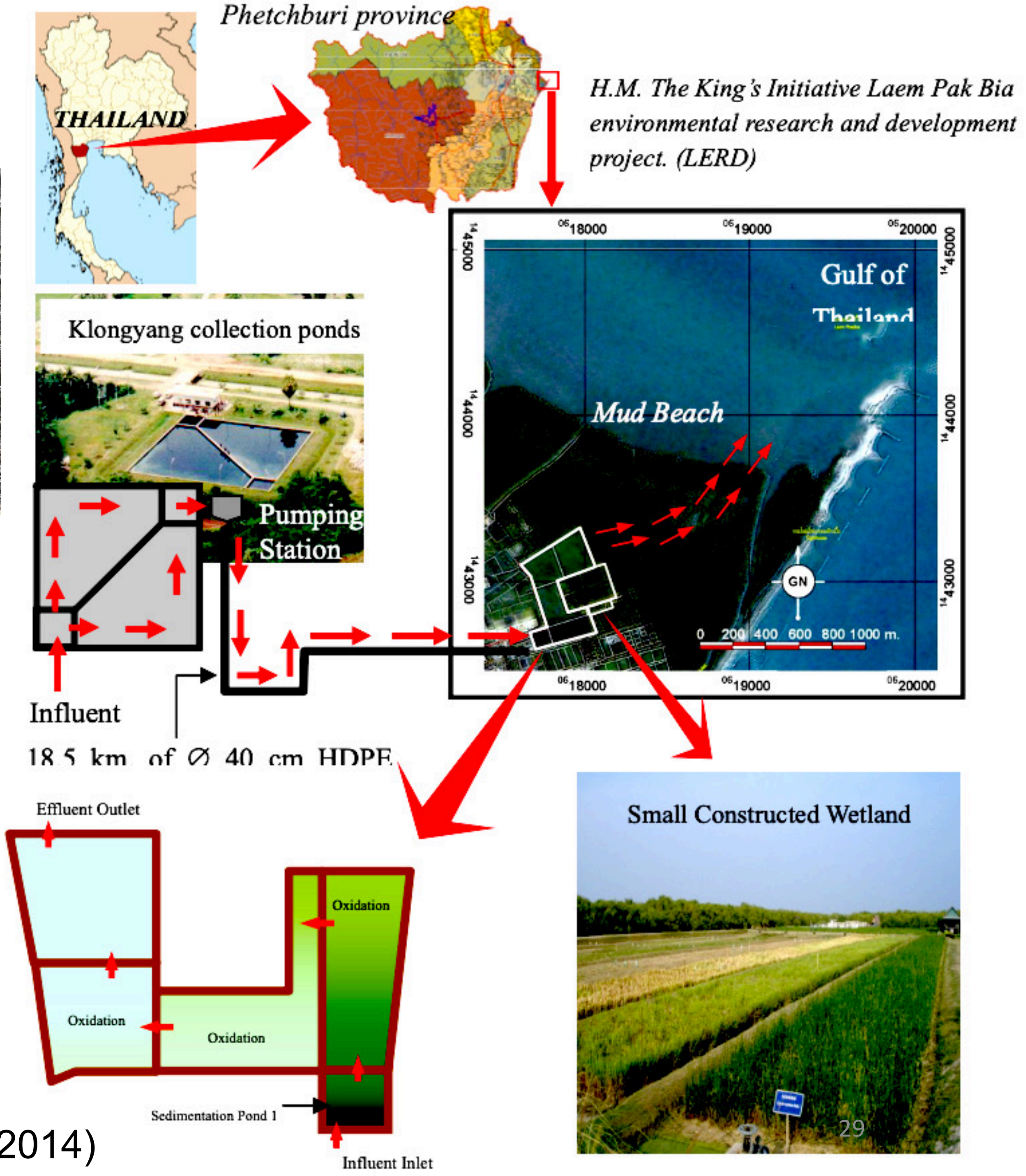
Wastewater purification



- Treat both wastewater & solid waste through environmentally & ecologically sustainable methods.

- Three methods of wastewater treatments :
1. Oxidation pond; 2. Constructed wetland;
3. Mangrove forest which filtrates wastewater from municipality of Phetchaburi.

- 300-m route through mangrove forest : mangrove crabs, mudskippers & birds.

(Chunkao et al. 2014)

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Medicinal uses

Table 2: Medicinal uses of mangroves and halophytes

Mangrove plant names	Medicinal uses
Acanthus ilicifolius	To treat paralysis, asthma, diuretic, dyspepsia, hepatitis, leprosy, rheumatic pains. analgesic, anti-inflammatory, leishmanicidal
Aegiceras corniculatum	Cure for asthma, diabetes, rheumatism, fish poison
Avicennia marina	Cure for skin diseases
Avicennia officinalis	Aphrodisiac, diuretic, hepatitis and leprosy.
Bruguiera gymnorhiza	Eye diseases
Bruguiera parviflora	Antitumor.
Ceriops decandra	Hepatitis and ulcers
Lumnitzera racemosa	Antifertility, asthma, diabetes and snake bite
Rhizophora mangle	Angina, boils and fungal infections, antiseptic, diarrhoea, dysentery, elephantiasis, fever, malaria, leprosy, minor bruises, plaster for fractured bones and tuberculosis.
Rhizophora mucronata	Elephantiasis, febrifuge, haematoma, hepatitis and ulcers.
Salicornia brachiate	Hepatitis
Sesuvium portulacastrum	Hepatitis
Sueda maritima	Hepatitis
Sueda monoica	Hepatitis

(Vinoth et al. 2019)

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Ecotourism

- **The International Ecotourism Society : "responsible travel to natural areas that conserve the environment, sustains the well-being of the local people, and involves interpretation and education". Australian National Ecotourism : "ecologically sustainable tourism with a primary focus on experiencing natural areas that fosters environmental and cultural understanding, appreciation and conservation."**

- **Ecotourism resources : plant & animal biodiversity, local livelihoods, indigenous knowledge & culture.**

- **Benefits : benefits for local communities; environmental protection; awareness.**

- **Forms : local private, community-based, private sector, NGO, government-based.**

- **Some issues : negative environmental impacts, garbage generation, risk of turning into mass tourism, off-site negative impacts, etc.**

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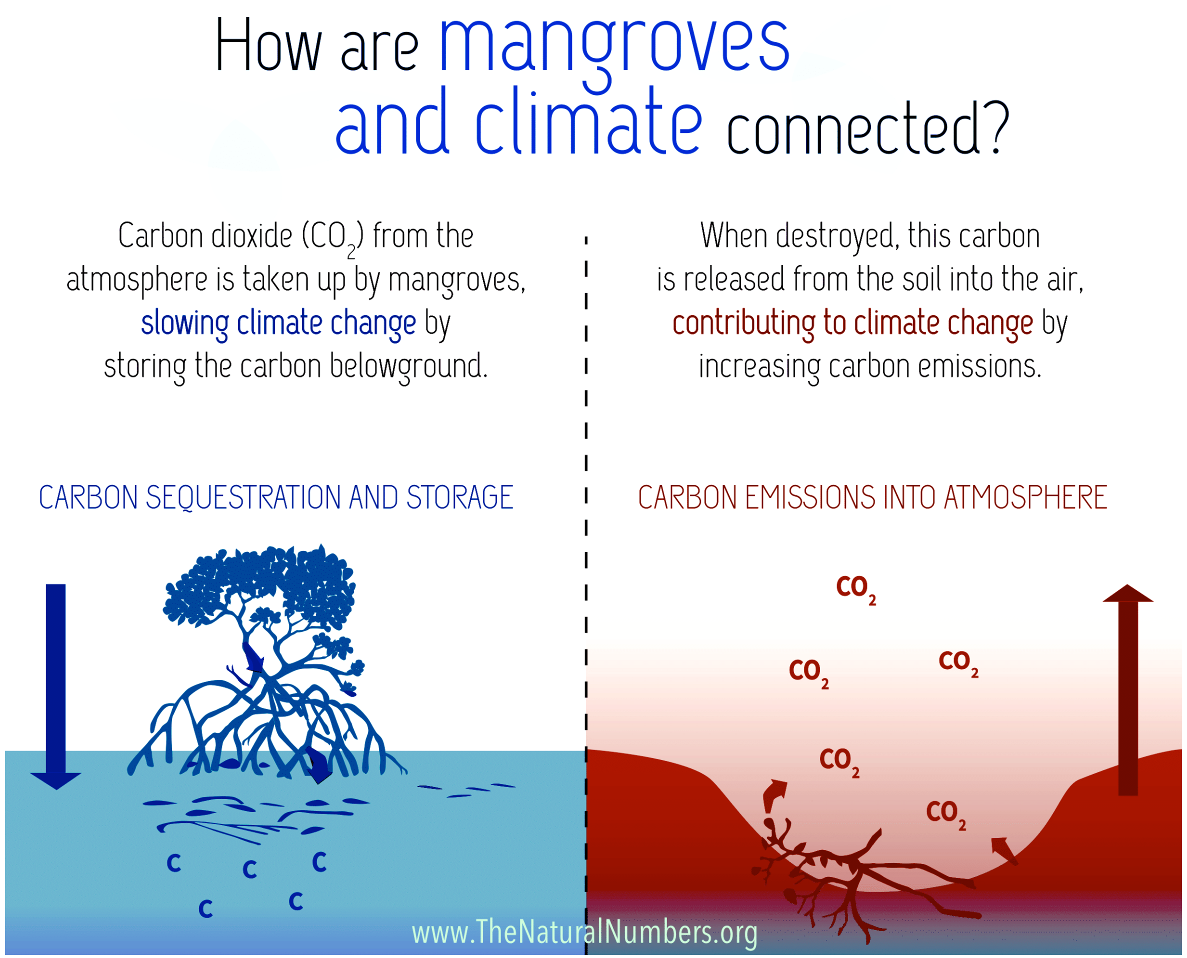
Mangroves and climate change



- ***R. mucronata***, **25 yr old (2013) : Fastest-growing species.**
- **Some erosion but not seriously.**

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Carbon sequestration

- Account for only approximately 1% (13.5 Gt year^{-1}) of carbon sequestration by world's forests; as coastal habitats they account for 14% of carbon sequestration by global ocean.

- Carbon from dead material remains trapped in sediment rather than quickly escaping into atmosphere.

- Watery carbon reservoir : "blue carbon".

Table 2. Global contribution of mangroves and other coastal habitats to carbon sequestration in the global coastal ocean.

Habitat	Area (10^{12} m^2)	Sequestration rate (gC m^{-2} year^{-1})	Global carbon sequestration (Tg year^{-1})
Mangroves	0.14 (0.5%)	174	24 (14%)
Salt marshes	0.22 (0.8%)	150	33 (20%)
Seagrasses	0.3 (1.1%)	54	16 (10%)
Estuaries	1.1 (4.0%)	45	50 (30%)
Shelves	26 (93.6%)	17	44 (26%)†
Total			167

†Assumes that depositional areas cover 10% of total shelf area [9].
Data from [41,60–62].

(Alongi 2012)

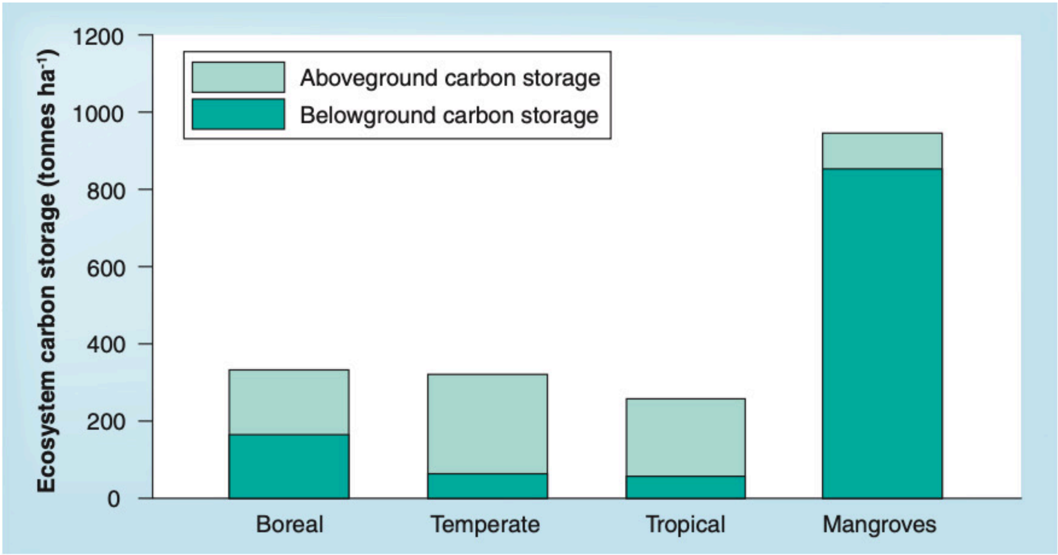

Figure 1. Differences in whole-ecosystem carbon stocks among boreal, temperate and tropical terrestrial forests, and subtropical and tropical mangrove forests.

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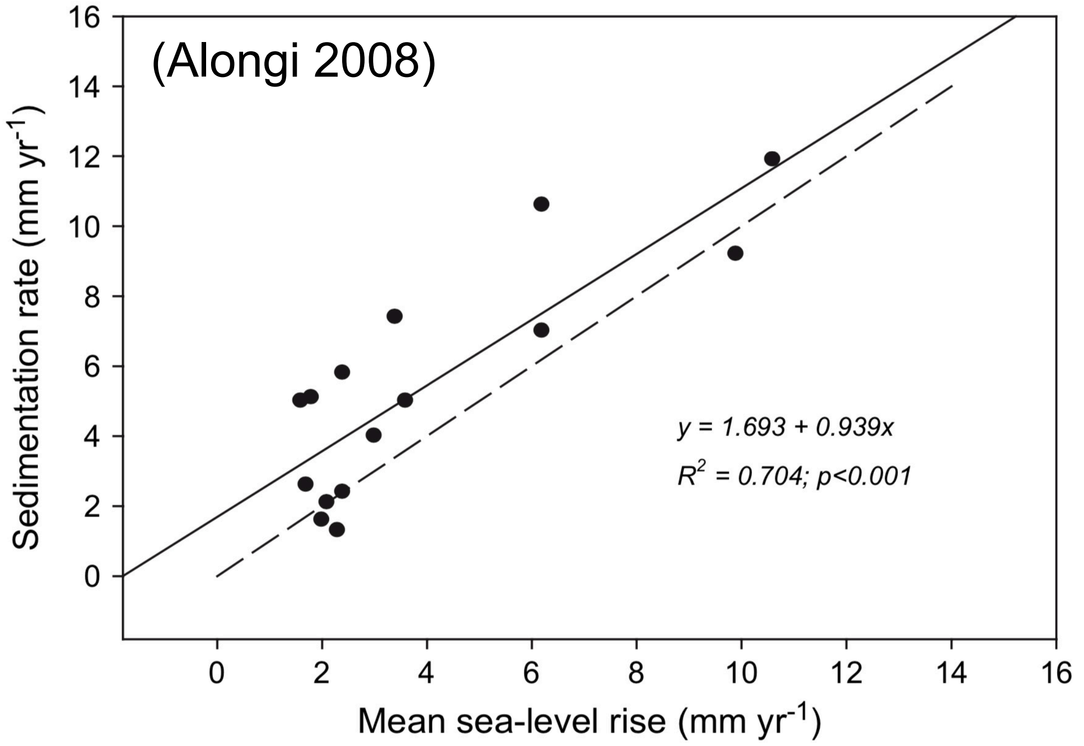
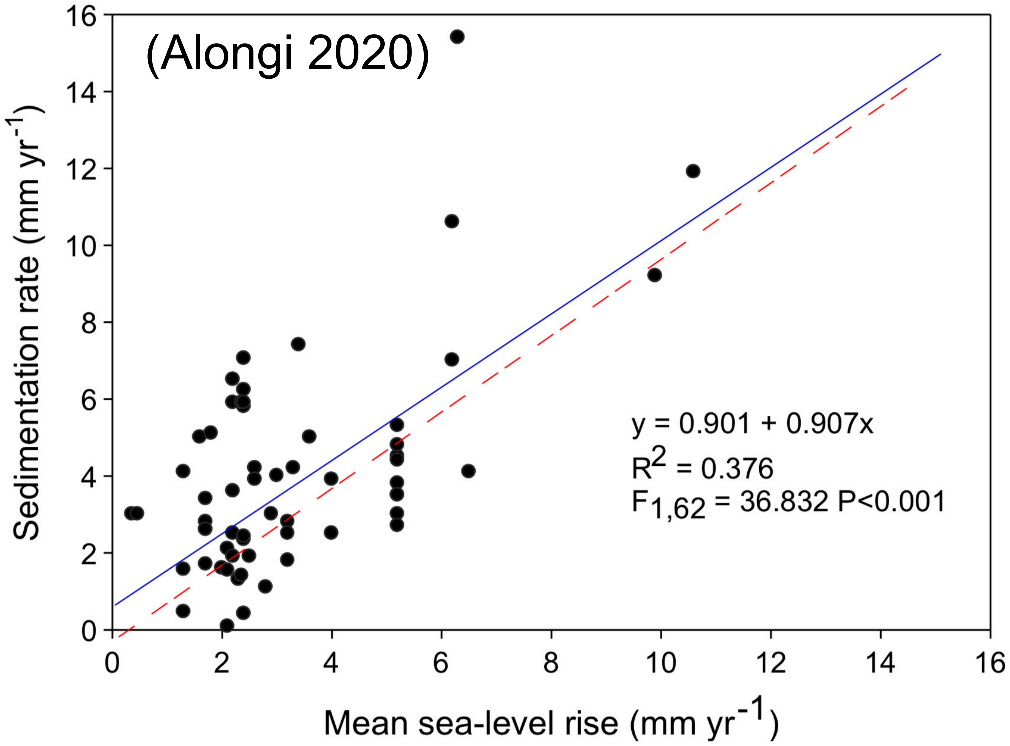
Mangroves and sea-level rise

- **Mangroves can keep up with SLR of at less 1 mm/annum & higher if conditions are suitable.**
- **“Intact and healthy mangrove systems can adapt to sea level rise; their growth can accommodate to increases of 3.8 up to 9 millimetres per year depending on local circumstances..” (Wetlands International).**





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Processes controlling sedimentation

- Sediment accretion & erosion – tides, waves, storms, etc.
- Biotic contributions – leaf litter, algal mats.
- Belowground primary production – roots, soil organic matter.
- Autocompaction.
- Fluctuations in water table & pore water – hydrology & groundwater inputs.

(Gillman et al. 2008)

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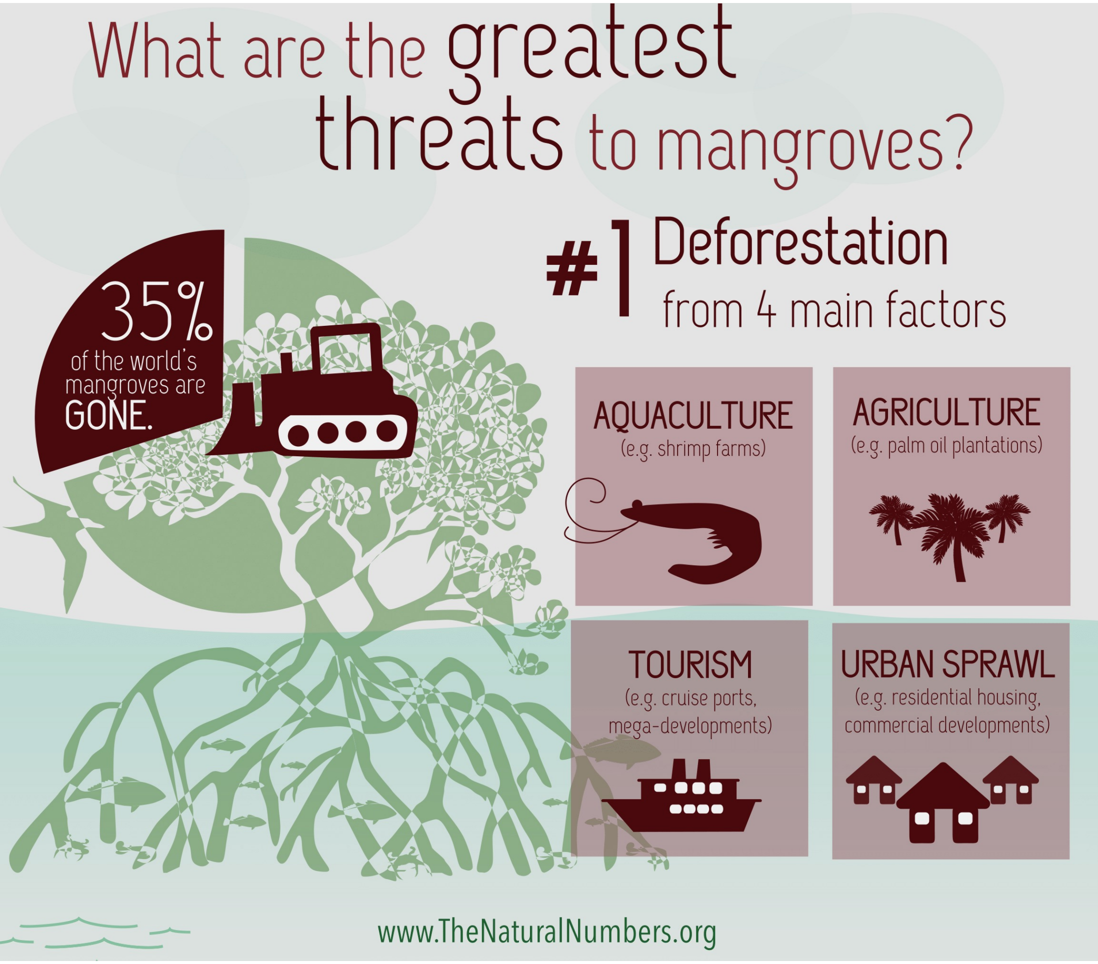
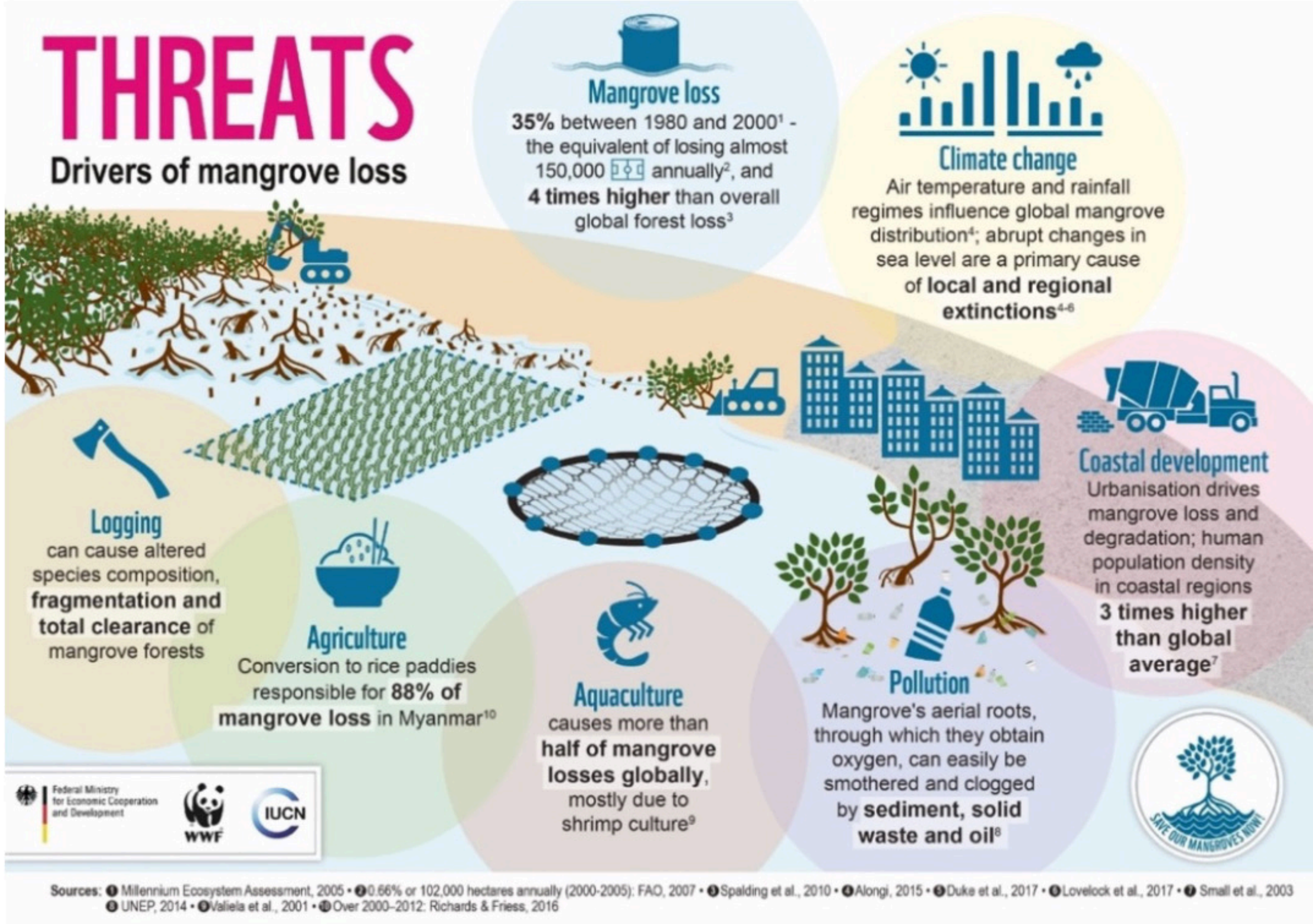
Threats ⇒ Loss





(IUCN 2019)

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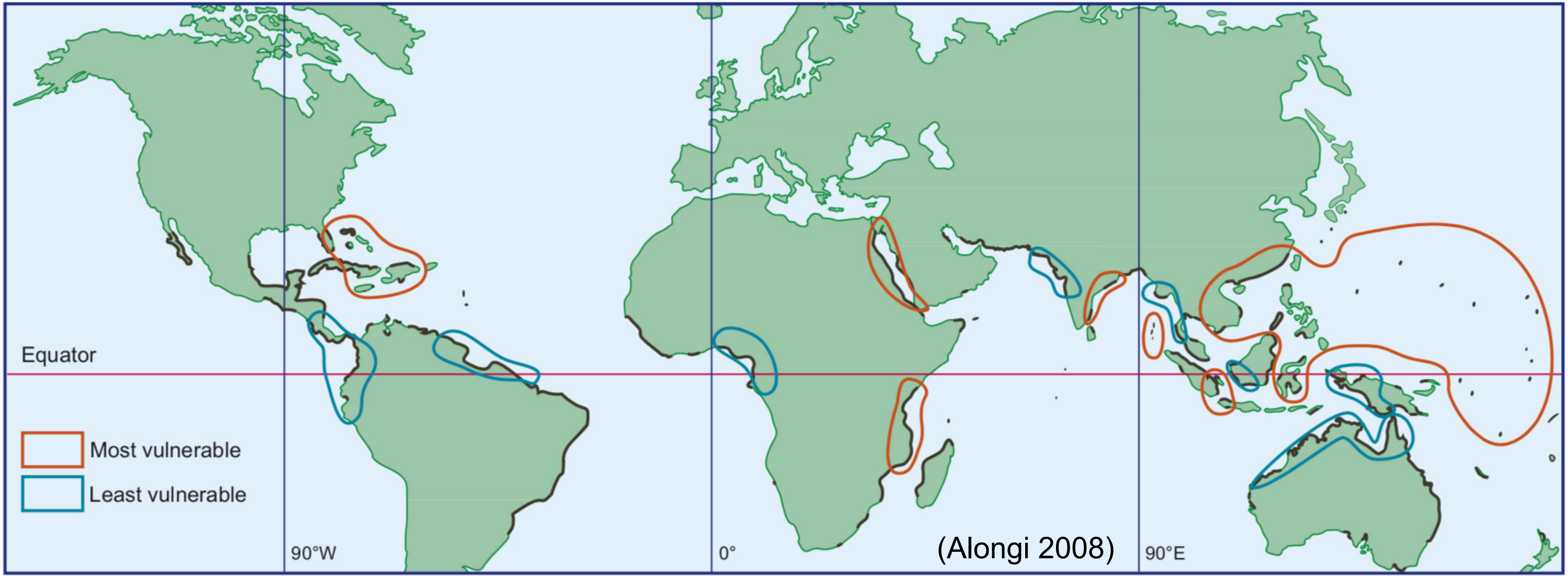
Vulnerability



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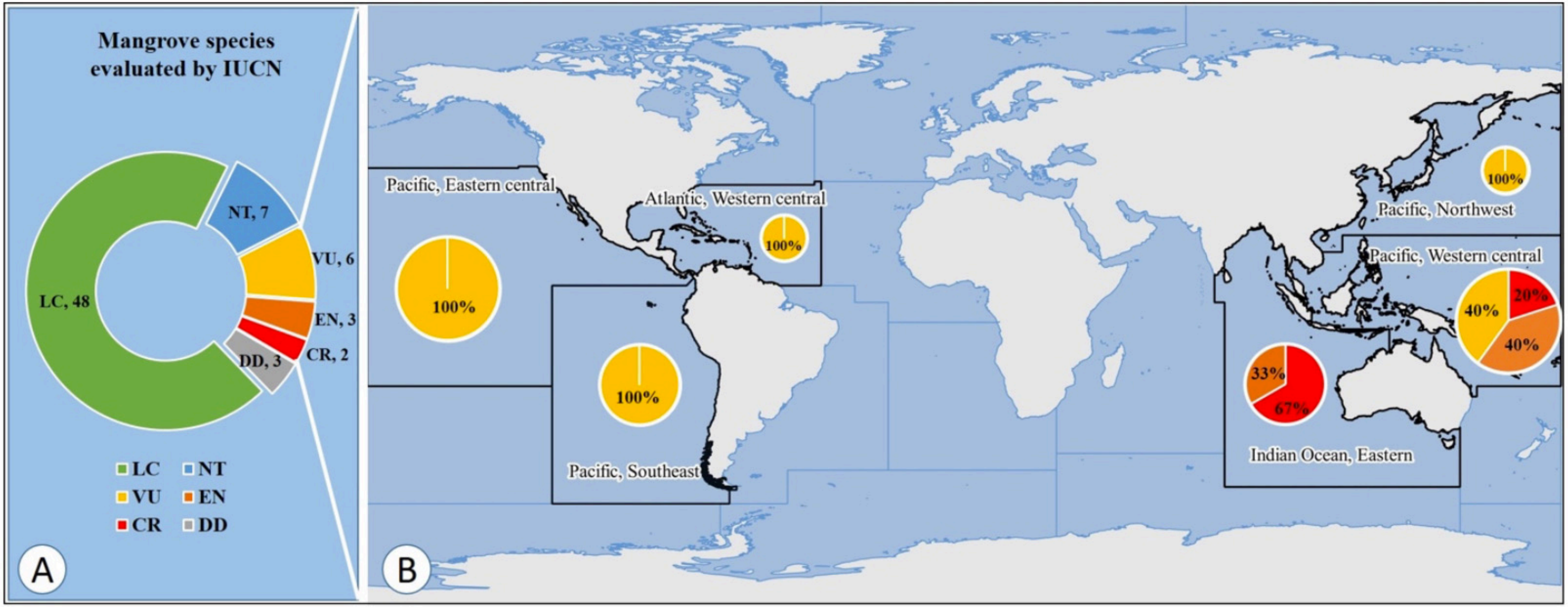
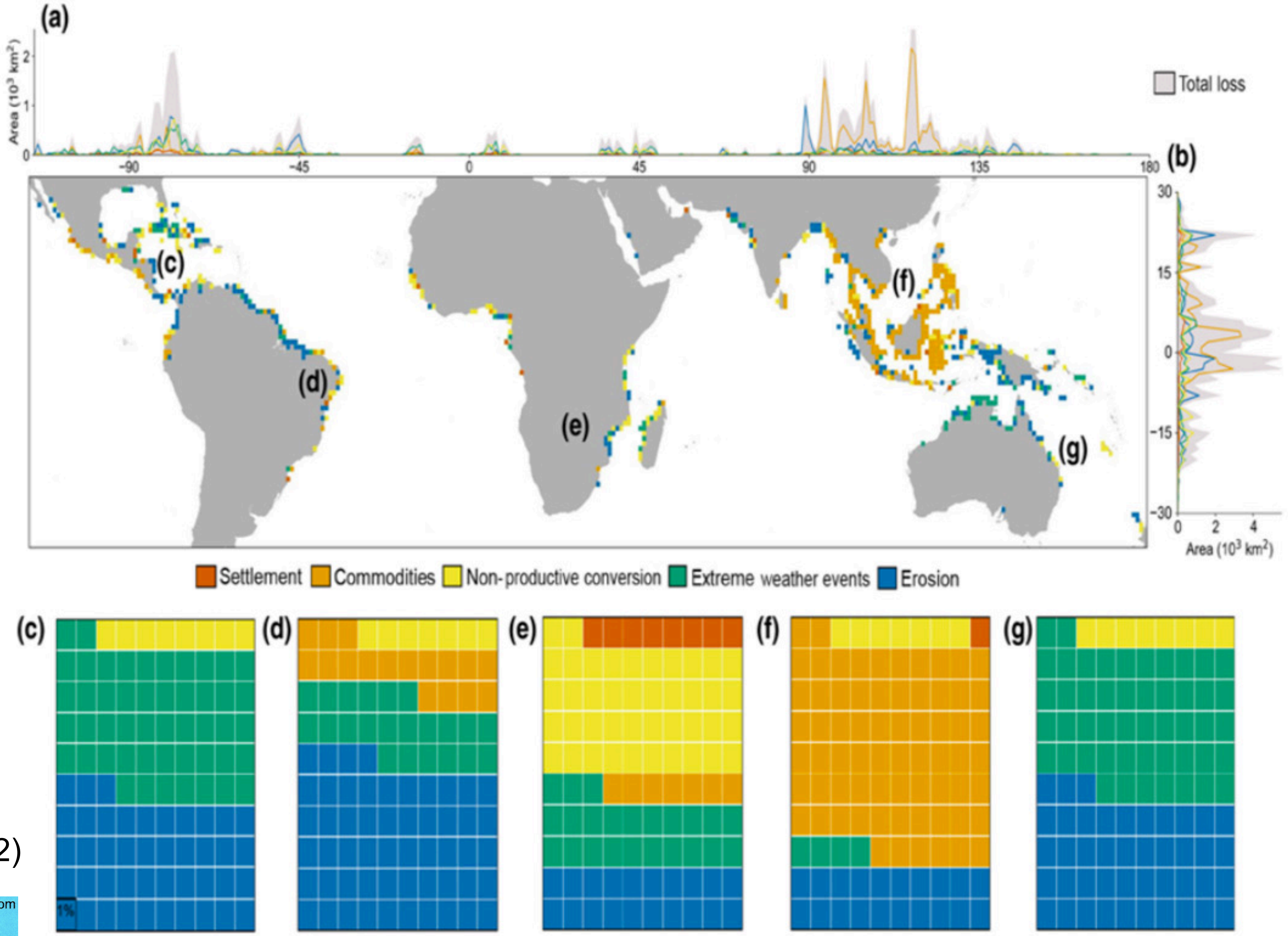
Vulnerable, Endangered & Critically Endangered



(Bhowmik et al. 2022)

Figure 1. (**A**) Status of the global mangrove species and (**B**) geographic coverage of the threatened mangrove species (LC: Least Concern; VU: Vulnerable; CR: Critically Endangered; NT: Not Threatened; EN: Endangered; DD: Data Deficient).

Mangrove loss



(Goldberg et al. 2022)

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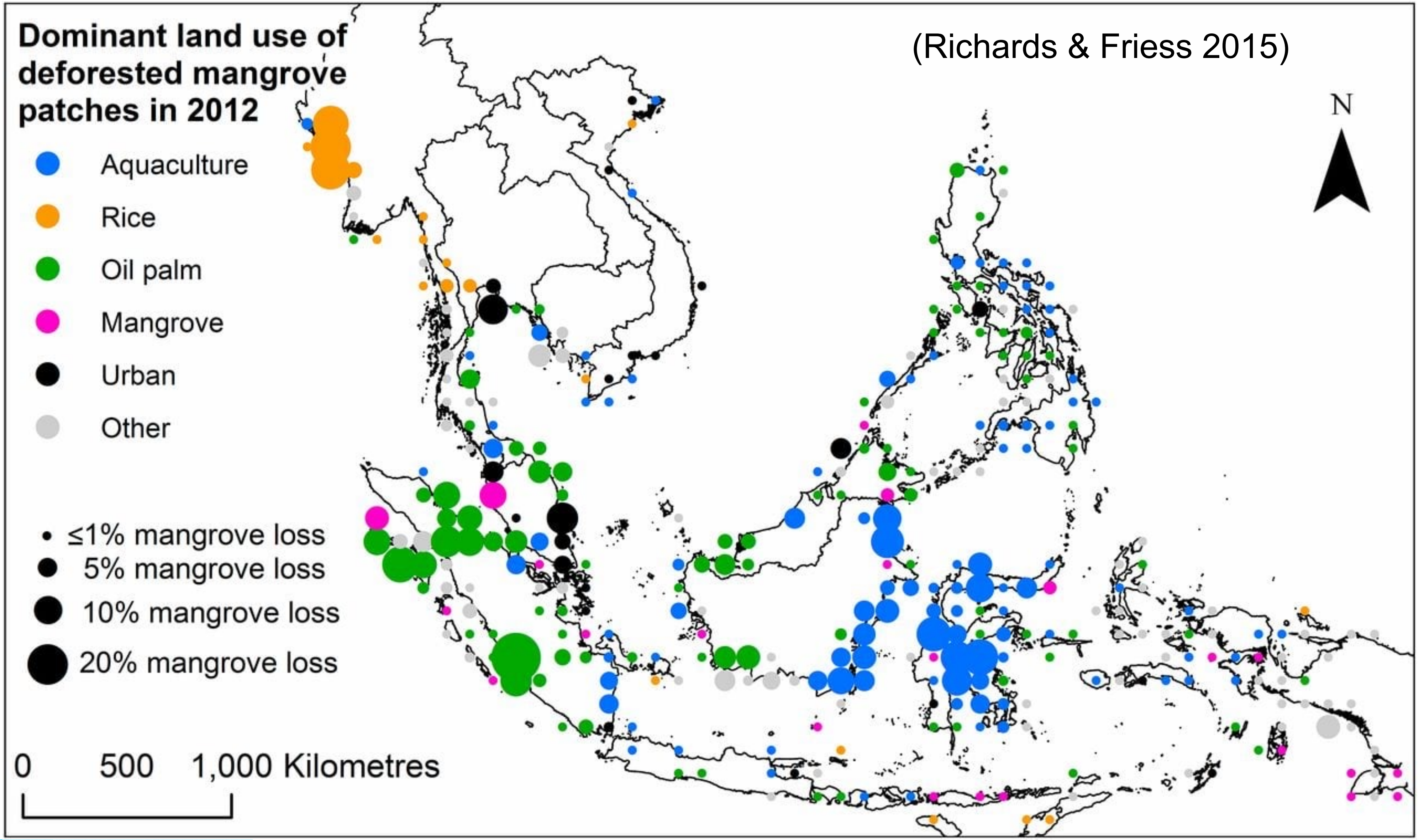
SE Asia : deforestation in 2012



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5. Coastal protection

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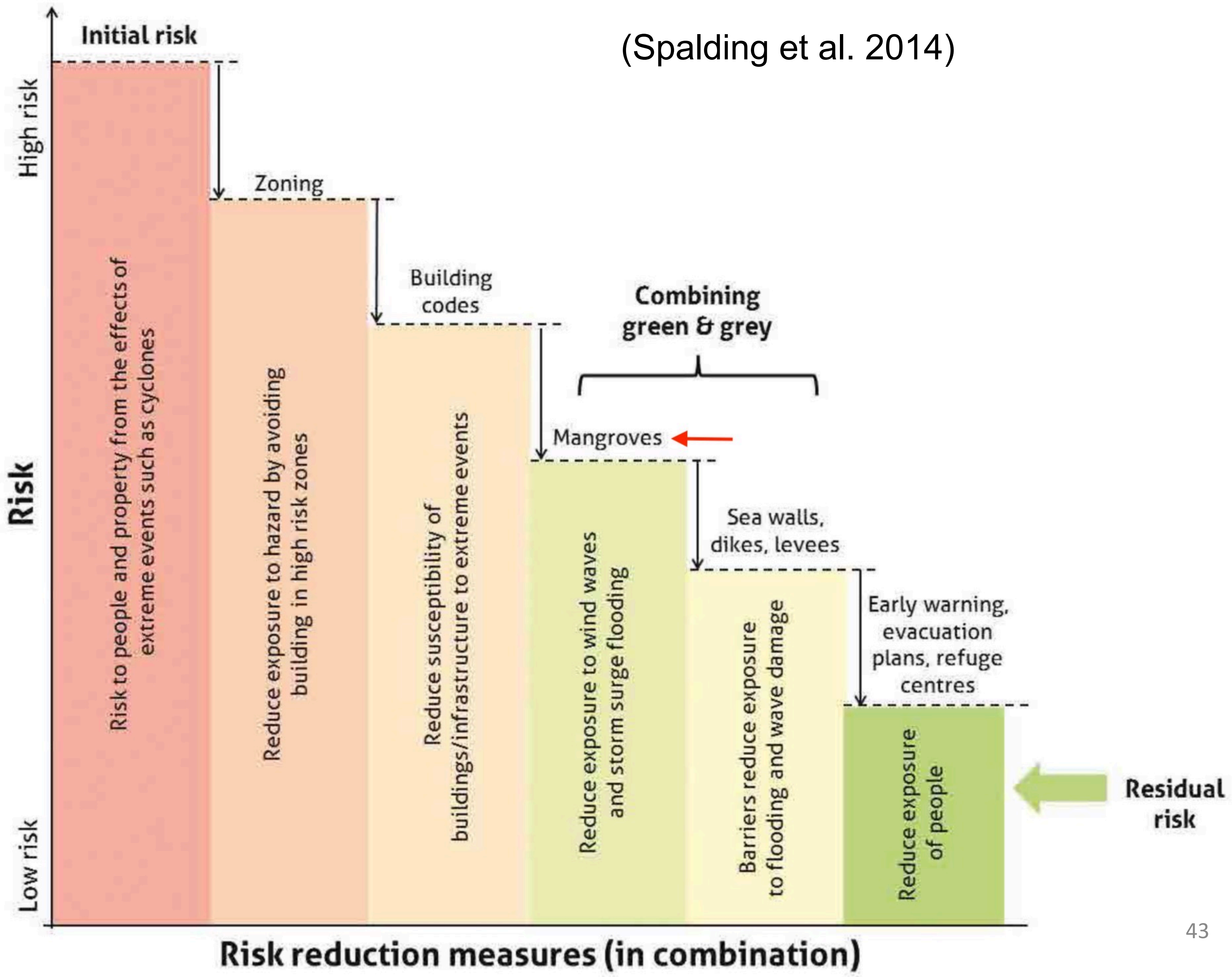
Risk reduction at coasts

Risk reduction measures diagram. Adapted from diagram presented by Ty Wamsley, US Army Corps of Engineers

(Spalding et al. 2014)



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26 Dec 2004 tsunami : mangroves

- **Anecdotal evidence of mangroves protecting villages in the rear of mangrove forests which slow down tsunami waves.**

- **Publications on protection include (Danielson et al. 2005; Dahdoub-Guebas et al. 2005; Kathiresan & Rajendran 2005; Chang et al. 2006; Tanaka et al. 2007).**

- **Publications disputing the evidence/countering argument include (Kerr et al. 2006; Kerr & Baird 2007; Bhalla 2007).**

- **Watershed for conservation of global mangroves.**

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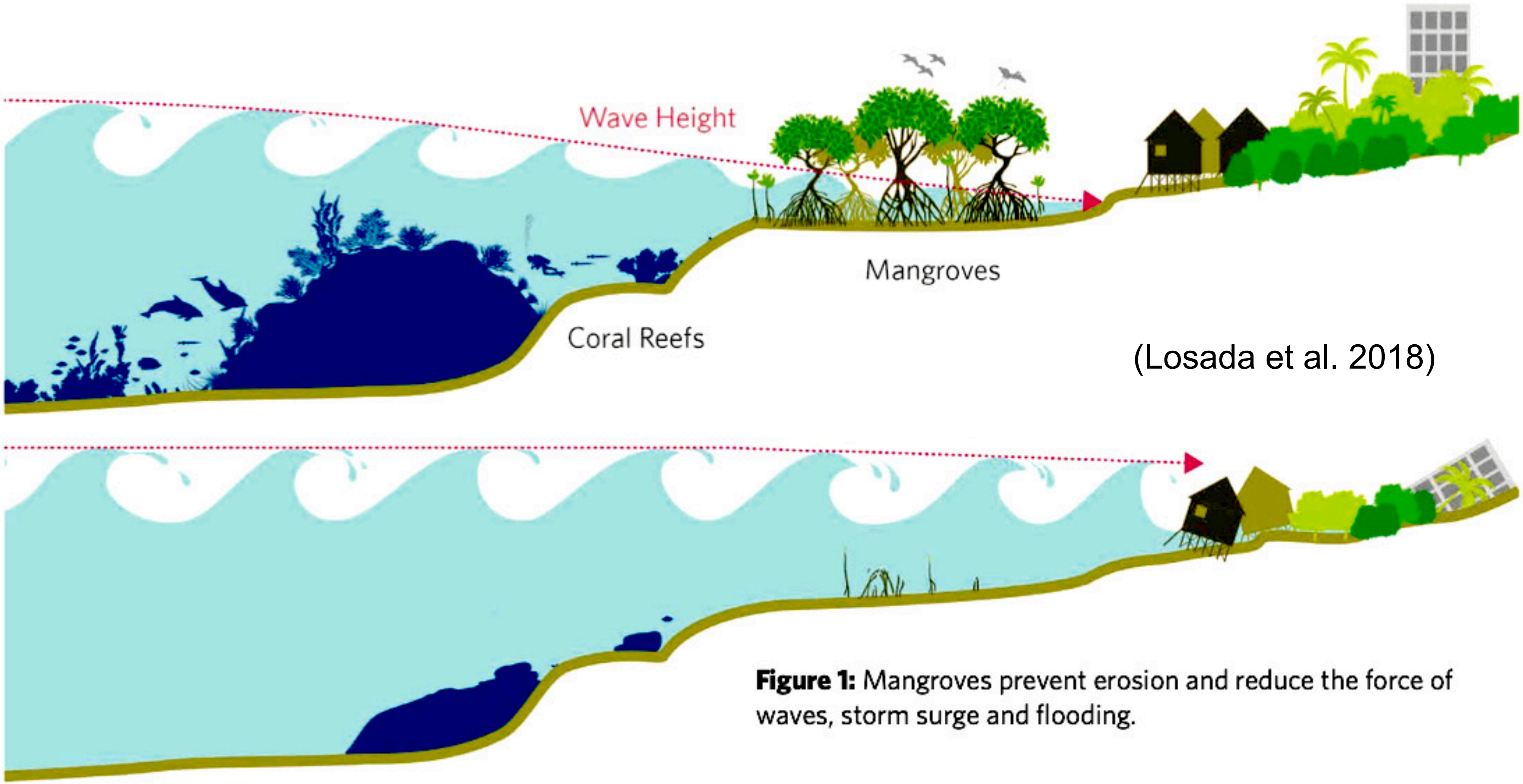
Mangroves reduce wave height



(Losada et al. 2018)

Figure 1: Mangroves prevent erosion and reduce the force of waves, storm surge and flooding.

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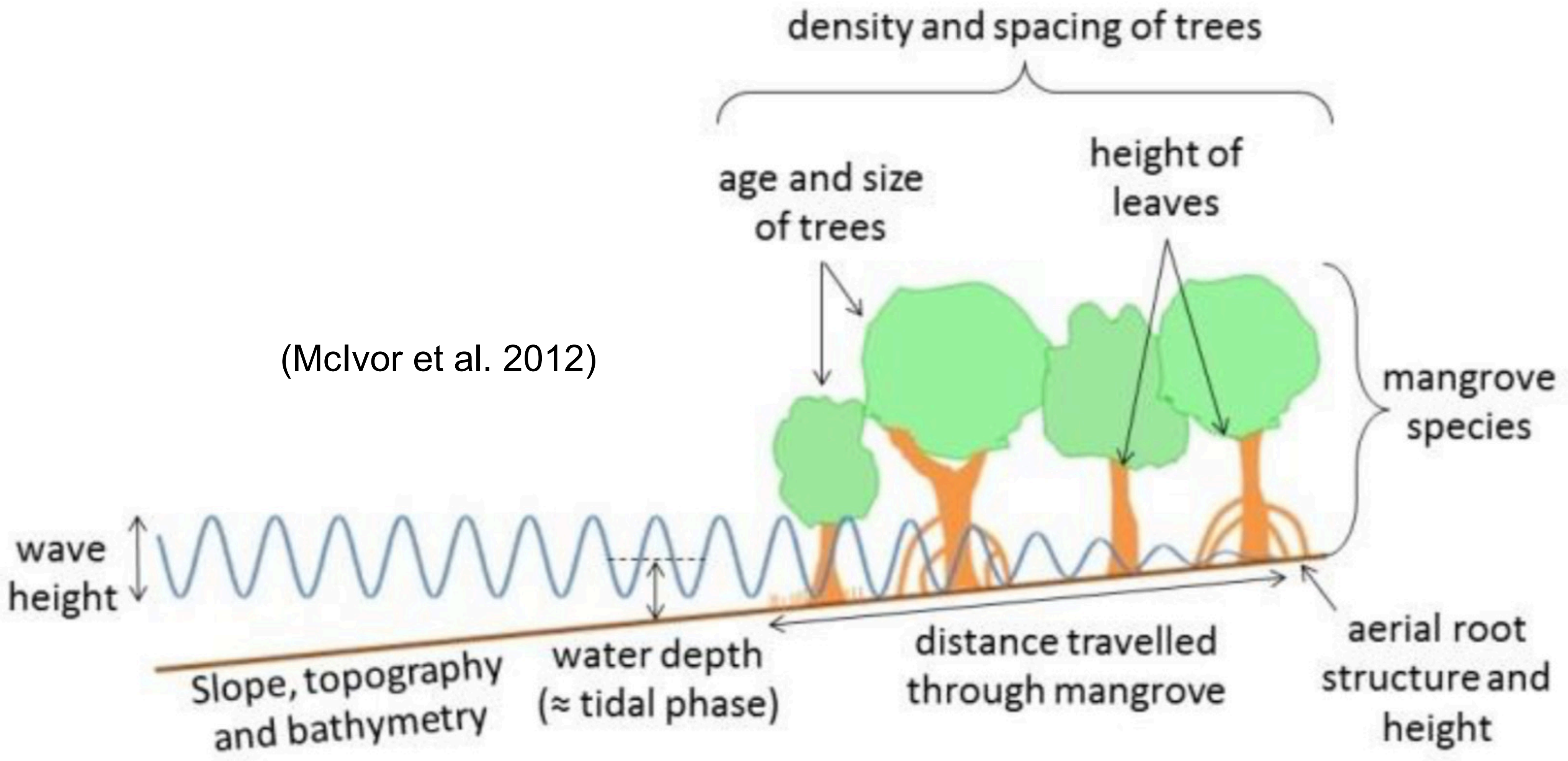
Mangroves : factors in wave height reduction

(McIvor et al. 2012)



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Mangroves as wave buffer (1)

- Publications on experiments & field studies done on effectiveness of mangroves (Mazda et al. 2007).

- All evidence suggests that mangroves can reduce height of wind & swell waves over relatively short distances: wave height can be reduced by 13 - 66% over 100 m of mangroves (McIvor et al. 2012).

- Review by Cochard et al. (2008) & other studies show that mangrove forests can be a significant buffer to waves up to 4 m.

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Mangroves as wave buffer (2)

Ecosystem type	Dominant ecosystem processes	Dominant buffer composition	Approximate wave buffer effectiveness range				Expected tsunami energy exposure
			Normal waves	Storm waves	< 4 m high tsunami	> 8 m high tsunami	
(a) Coral reefs	Biotic	Physical	▼~**▼**[1]	X~▼[1]	▴~▼[6]	▴~▾[6]	Small~High
(b) Seagrass beds	Biotic/ physcial	Biotic/physical	▾~**▼**[2]	X~▼[2]	▾~**▼**[7]	X~▾[7]	Medium~High
(c) Mangrove forests	Biotic/ physical	Biotic	▼~**▼**[3]	▾~**▼**[3,5]	▾~**▼**[8]	▴~▼[8]	Medium~High
(d) Beaches and dunes	Physical	Physical	**▼**[4]	▾~▼[4,5]	▾~▼[9]	X~▾[9]	Medium
(e) Beach forest	Biotic	Biotic	–	▾~**▼**[5]	▾~▼[10]	X~▾[10]	Medium~High
(f) Other dense forests	Biotic	Biotic	–	▾~**▼**[5]	▾~**▼**[10]	X~▼[10]	Small~Medium

Legend:

▲	Hazard amplification	▾ ▴	Slight effect (not evident, but measurable)	▮	Small
▼	Hazard mitigation	▼	Moderate effect (evident, ~20–50% energy reduction)	▮	Medium
X	No effect	→ **▼**	Considerable effect (~50–100% energy reduction)	▮	High

(Cochard et al. 2008)

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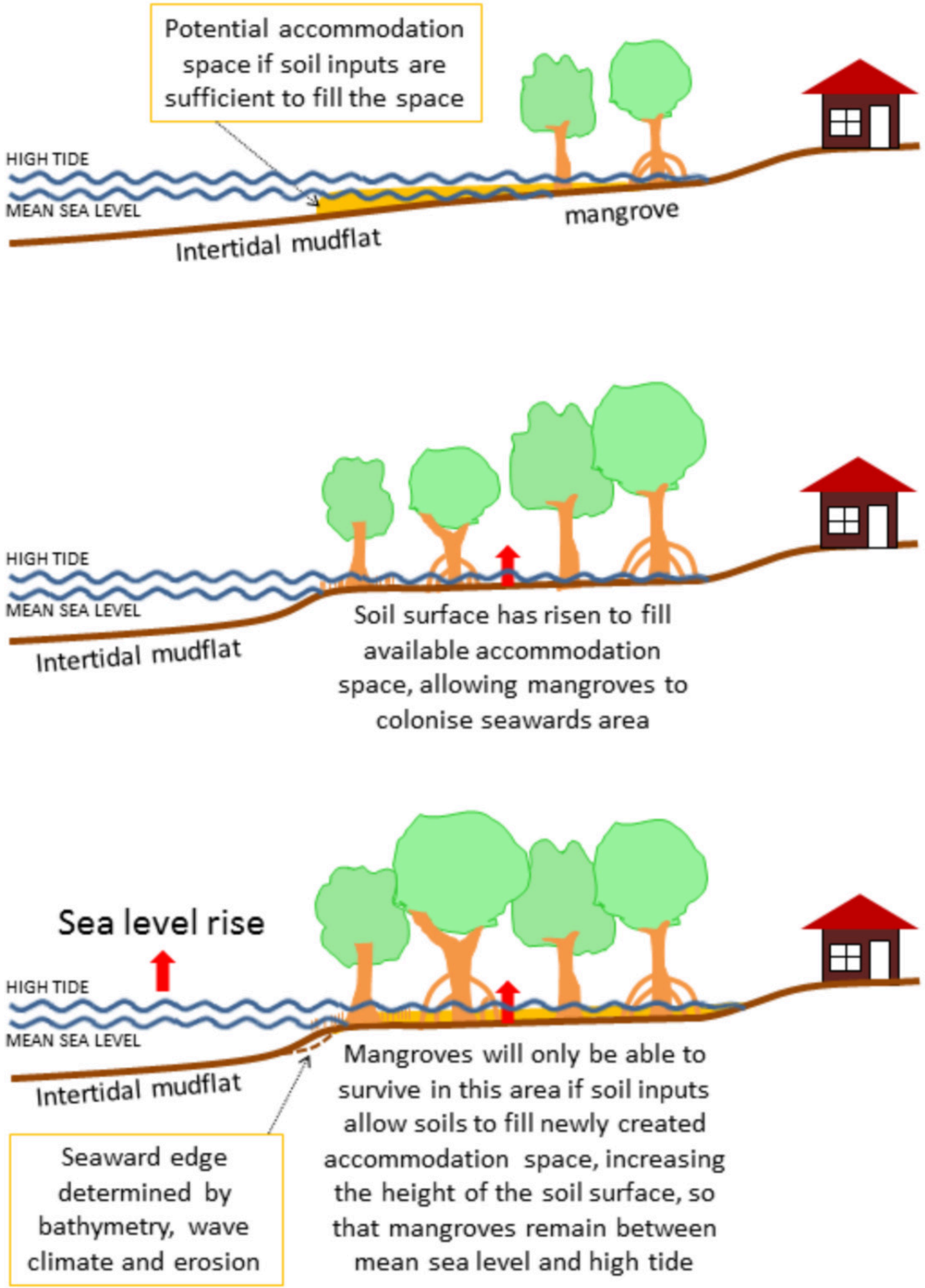
Mangroves for coastal protection : need for soil inputs



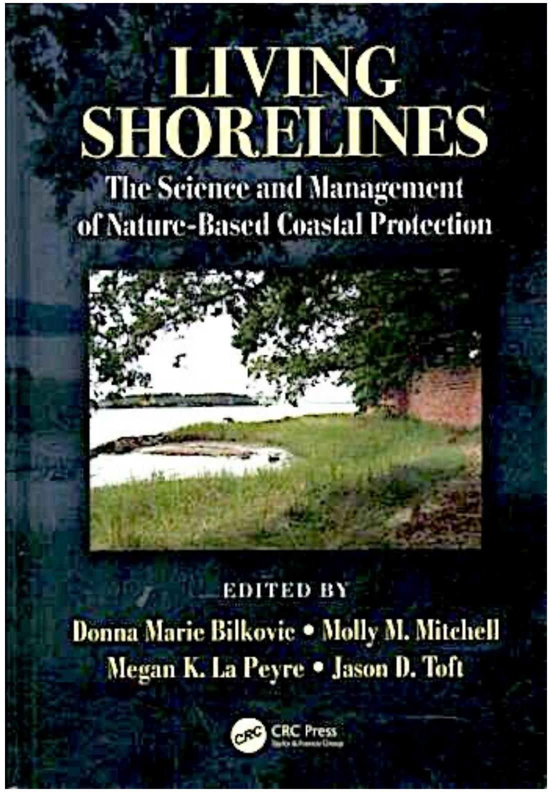
(McIvor et al. 2013)

EbA and NbS

- "**Natural ecosystems** such as coastal forests, coral reefs, **mangrove belts**, beach ridges, sand dunes or forested slopes **are effective barriers against many types of natural disasters**. Such reinforcements can be a cost-effective insurance against storm surges, tsunami and sea-level rise for coastal communities that cannot afford expensive infrastructural protection." (*Planet Prepare* 2008: 63)

Living shorelines

- **Delfland Sand Engine : mega-nourishment of 21.5 million m^3 of sand in single location at +5 msl.**



The Delfland Sand Engine after realisation (2011)

The Delfland Sand Engine in 2015

(Ecoshape)

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System Approach to Geomorphic Engineering (1)

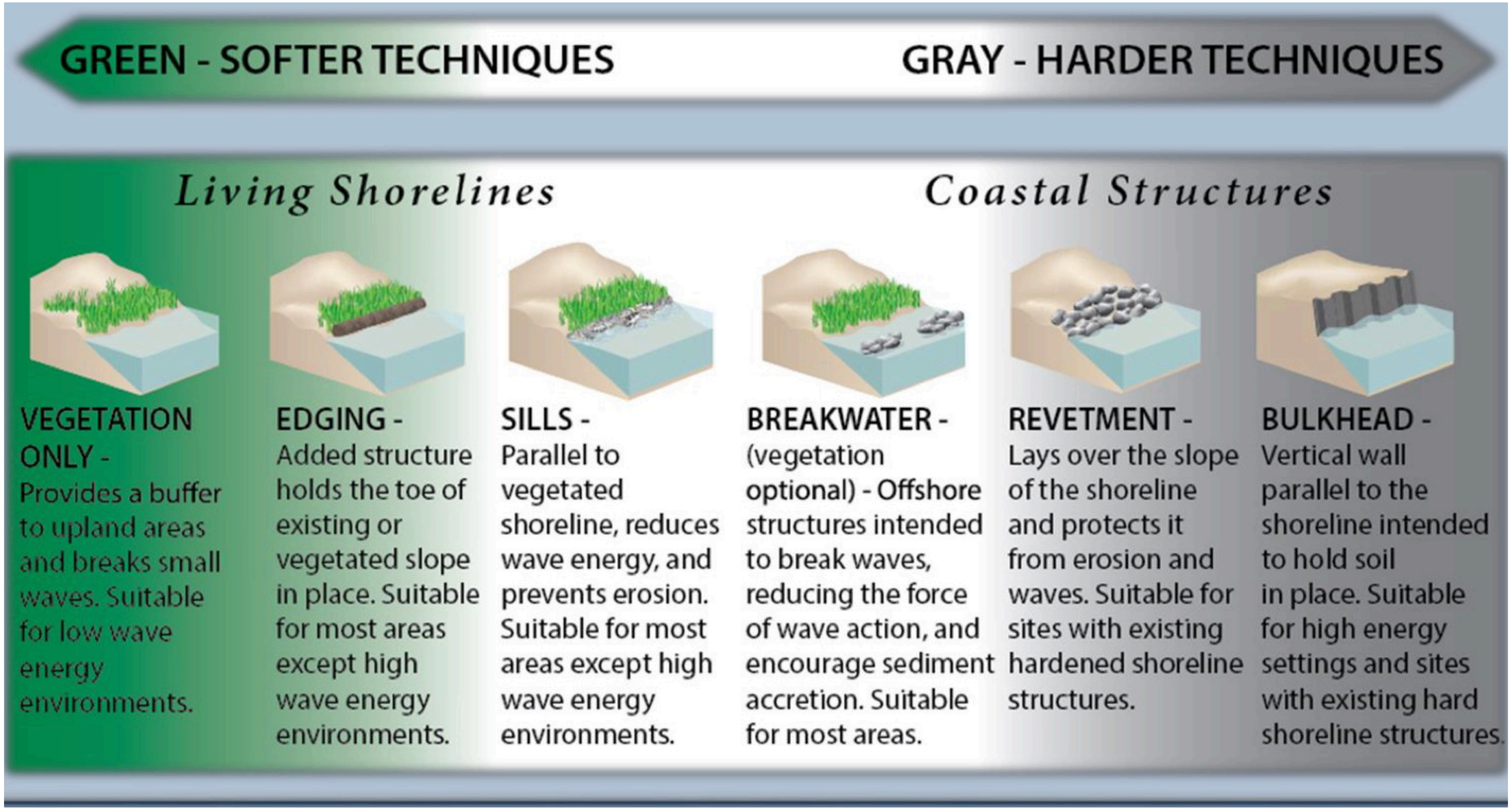

Figure 1: A continuum of green (soft) to gray (hard) shoreline stabilization techniques. Source: This continuum is based on the more detailed continuum in the Systems Approach to Geomorphic Engineering (SAGE) Natural and Structural Measures for Shoreline Stabilization brochure (SAGE 2015).

(NOAA 2015)

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System Approach to Geomorphic Engineering (2)

(NOAA-SAGE)

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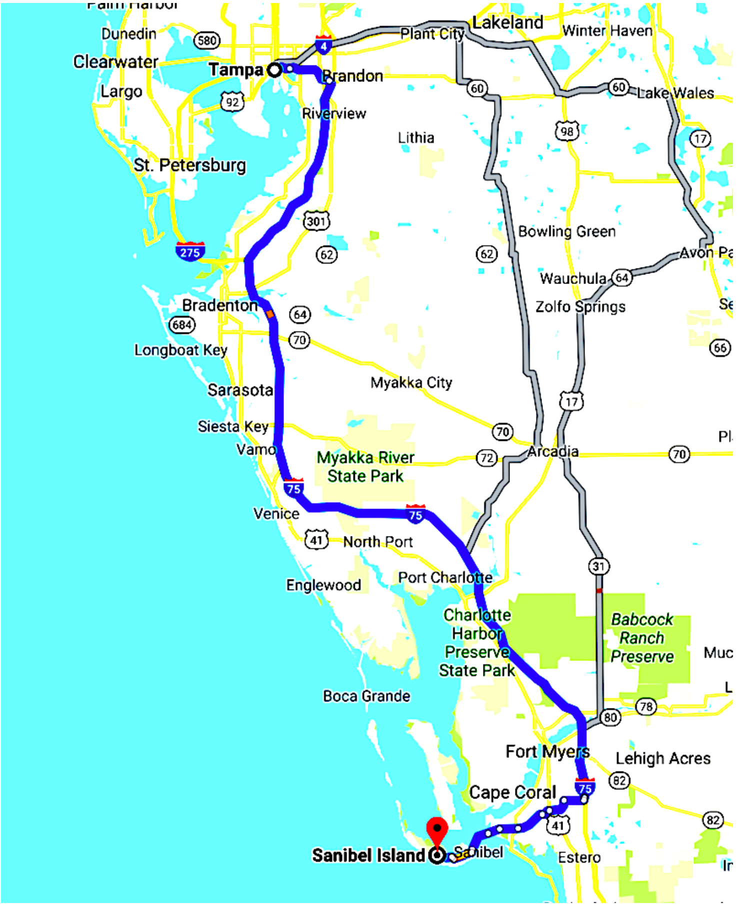
Living shoreline, Sanibel, Florida



(Sanibel & Captiva News 28.5.2022)

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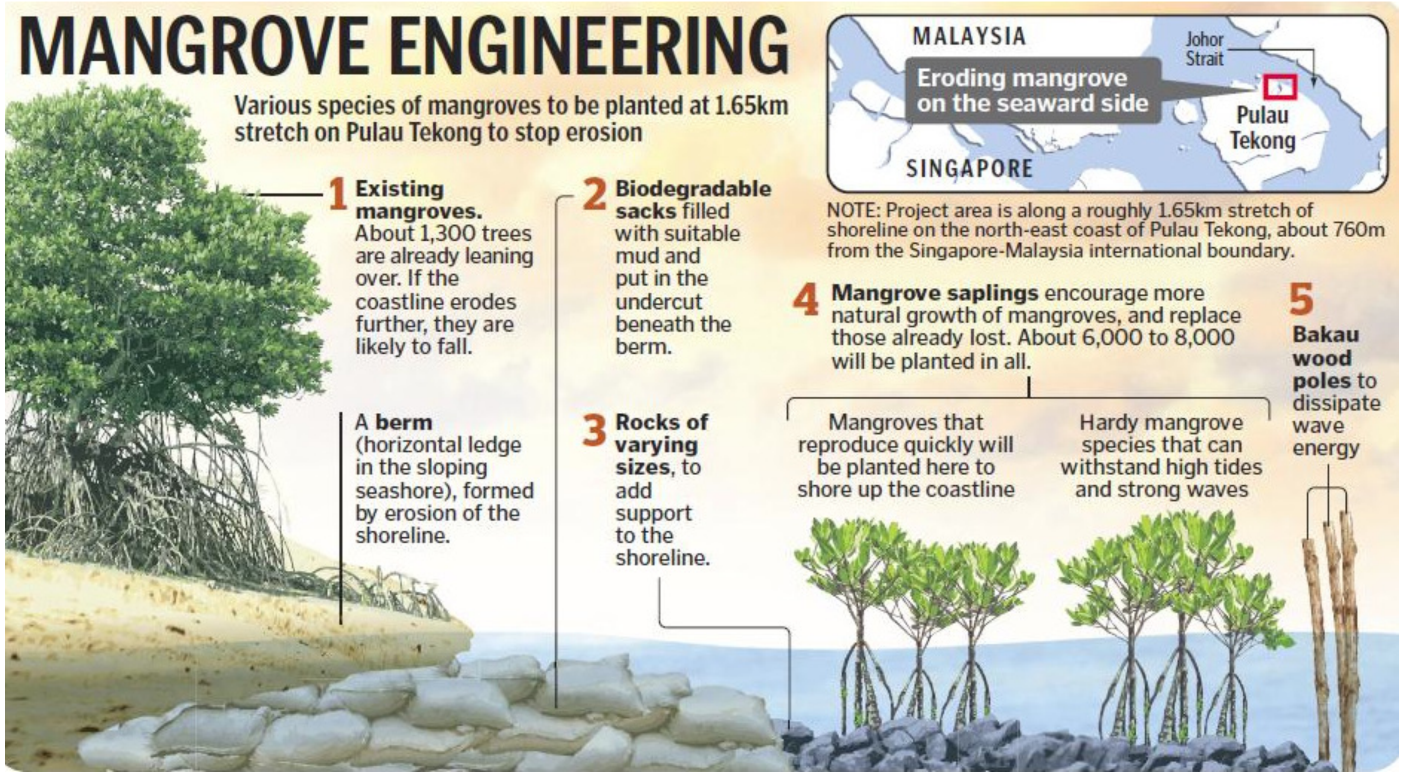
Mangrove engineering, Singapore



(Straits Times 12.5.2010)

(National Parks)

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6. Planting and restoration

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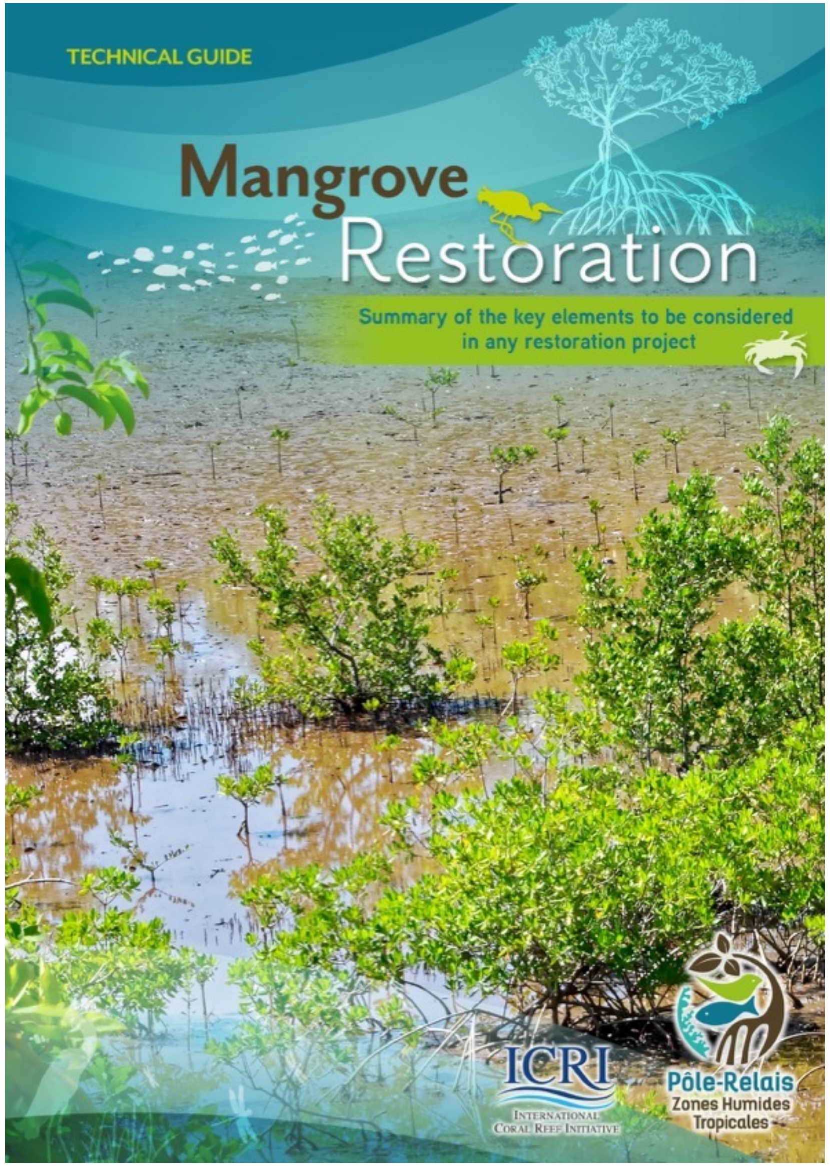

Pôle-Relais Zones Humides Tropicales 2018. *Mangrove Restoration*. Technical Guide.

Primavera, JH et al. 2012. *Manual on Community-based Mangrove Rehabilitation*

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Planting : success and failure

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Restoration : factors

- **Reforestation : generic term for replanting trees in a specific area with various goals.**
- **Forest restoration : involves all activities, including reforestation, helping forests return to healthy state.**

Factors affecting mangrove restoration success	▪ Soil stability and flooding pattern ▪ Elevation of the site ▪ Soil/ water salinity and freshwater input to the site ▪ Tidal and wave energy associated with the site ▪ Availability of propagules/ seed material ▪ Spacing and thinning of plants ▪ Presence of weeds ▪ Success of nursery techniques ▪ Monitoring the progress ▪ Incidence of propagule predation ▪ Cost of restoration ▪ Cooperation of the local inhabitants

(Wetlands International)

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Planting pitfalls

- **Wrong site** : Popular choice of **mudflats** because of few competing claims to land. But too saturated with water for roots to source enough oxygen.
- **Wrong species**. ***Rhizophora*** with their **propagules** on exposed coasts & mudflats failed. ***A. marina*** & ***S. alba*** are better choice.
- **Unavailable best sites**, e.g. former mangrove areas converted to fish & shrimp ponds, are **not readily available** : not easy to identify or owners do not want to give them up.
- **Lack of monitoring** after planting.
- **Solution** : put needs of local communities first; find ways to make conservation pay off for them.

If restoration efforts plant mangrove species in the wrong places, they will fail. These *Rhizophora* seedlings are planted on a poorly drained area and are likely to die in the salty, waterlogged soils. Experts say the more salt-tolerant mangrove *Avicennia marina* would make a better choice.

(Knowable Magazine 22.7.2021)

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Replanting : concession in Papua

***B. gymnorrhiza* & *R. mucronata*; fastest-growing species, *R. mucronata*.**

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Restoration : post-tsunami May 2005, Aceh

- **(L) Luepueng, west coast** : **Mangrove restoration.**

- **(R) East of Lam Bada Lhok, north coast** : **Mangrove restoration include *Rhizophora stylosa, R. apiculata, Ceriops* sp; 267,000 saplings planned in 50-ha site.**

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Restoration : Ko Samui (Thailand), Jakarta

- (L) Bang Keow, Ko Samui : Line of bamboo poles as wave shelter to protect & enclose earlier planting which has failed. Replanting is sponsored; mangroves behind barrier.

- (C) Taman Wisata, Jakarta. Only conservation programme in Jakarta & created by Sri Lela Muniwati with initial 100 ha of cut mangrove land. About 50 ha have been planted by volunteers & much donation is required. Boardwalk to the sea. Main replanting area. (R) Planting module.

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Ecological mangrove restoration

• **If coastal habitats are degraded, mangroves may need a little help from workers to restore right conditions : approach called "ecological mangrove restoration".**

• **On rapidly eroding coast in Java in Indonesia, Wetlands International workers built semi-permeable dams to stop sediment from washing away, allowing seafloor to rise just enough for mangroves to grow back.**

• **In Guinea Bissau, workers broke dikes around abandoned rice fields to restore tidal flow. Soon, *Avicennia* & *Rhizophora* propagules from nearby forests washed into sites & started growing more successful & suitable than planting.**

(Knowable Magazine 22.7.2021)

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7. Modular planting

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Mangroves – coastal protection measure for tsunamis and sea-level rise

Coastal zone management in relation to extreme events

University of Twente, 19 June 2009

Poh Poh Wong
National University of Singapore
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I have argued that atoll nations should think of sacrificing some islands now in order to raise the level of others – a strategy of "better to save some than not to have any" (*Wiley Interdisciplinary Reviews: Climate Change*, DOI: 10.1002/wcc.84).

A new method of large-scale modular planting of mangroves, complemented by the addition of sediments, is another option that should be considered. Mangroves can grow on non-muddy substrates, including sand, gravels, coral flats, rock surfaces and even on the boulders of some sea defences.

Singapore

***New Scientist*, 6 Nov 2010**

Proposed large-scale modular planting

- Large-scale planting using modular system to meet needs of various coastal locations.

- Modular system of planting & deployment is comparable to LEGO® set on a large scale.

- Faster deployment using wooden sledges. Modules anchored by wooden sticks/pegs if necessary.

- Suitable for wide range of coastal types & not confined to muddy tidal flats.

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Modules

• Ideally of space-fitting shapes (triangles, squares, rectangles, hexagons) containing sediments with mangroves grown to various heights or maturity.

• Made of mixture of compressed sediments that become self-destructive & formed part of sediments supporting mangroves. Alternatively of local materials.

• Nutrients & sediments added to growing mangroves in field.

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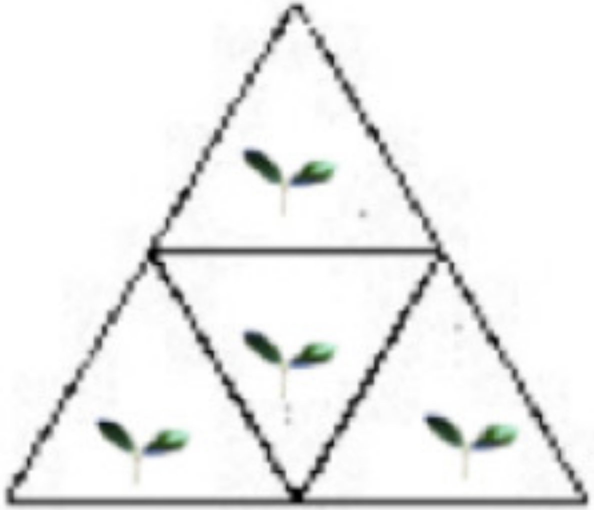
Layout examples



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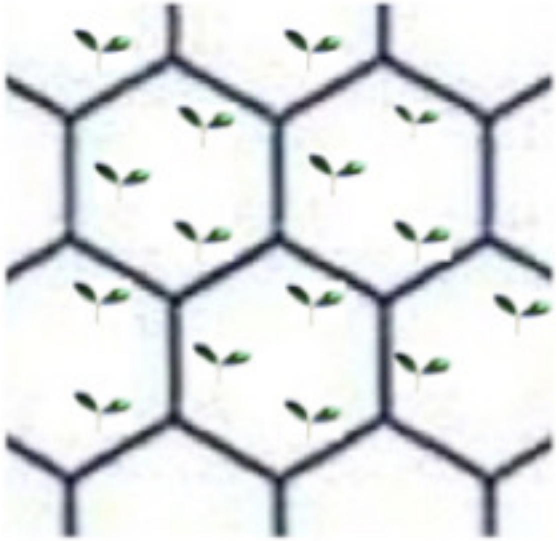

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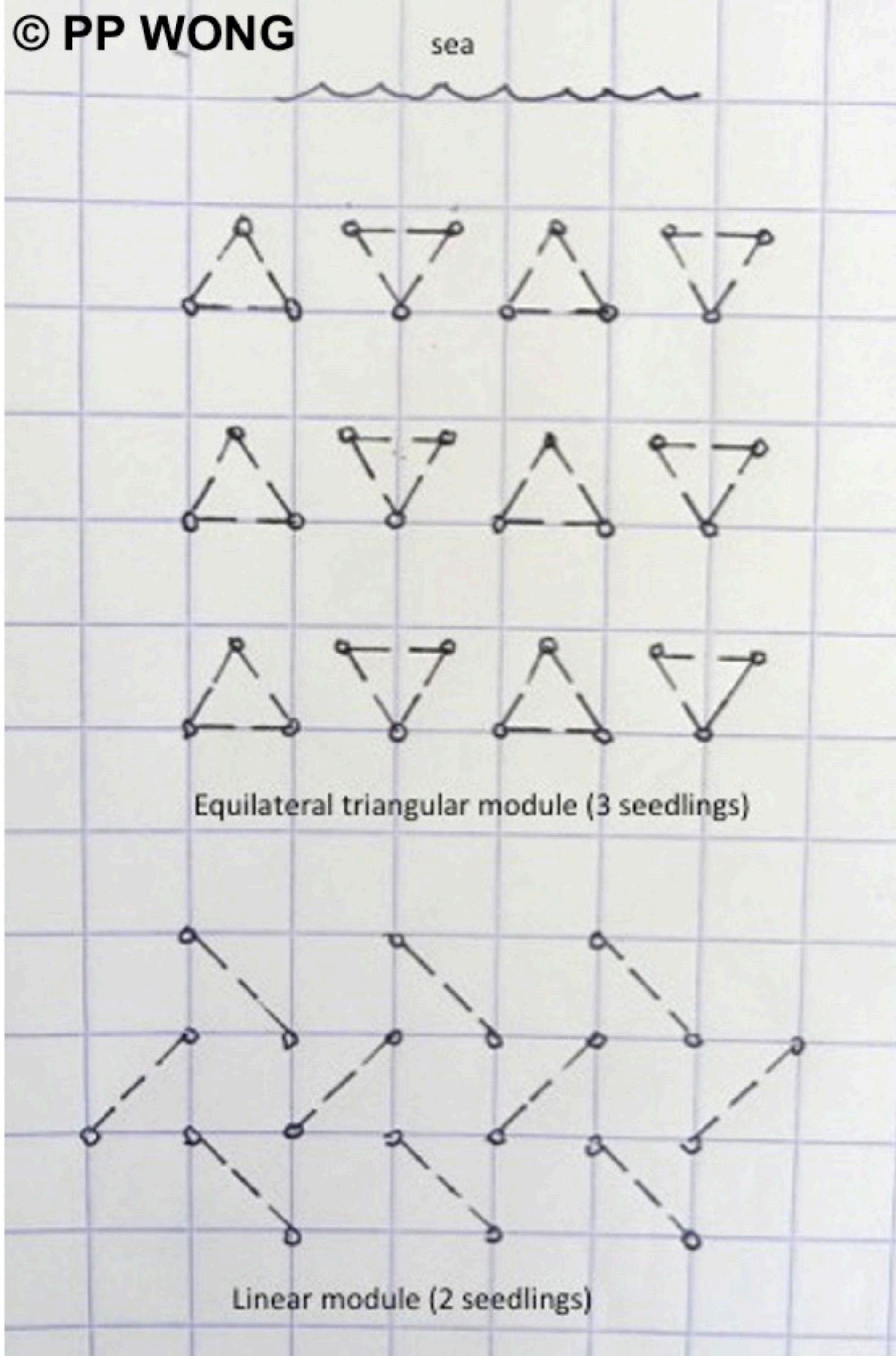
(IOC 2011)



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Modular planting = Development

- Modular planting moves to higher level of development for villages, as suitable materials have to be sourced, adapted & manufactured.

- Small machine shops to produce modules in larger numbers & in standardized format, thus pushing development to a higher level. More skills as modules are deployed to coasts.

- When mangroves are fully grown, forests themselves could open opportunities for villages to another level of development, e.g. ecotourism development.

- Timeline from mangrove seedlings to their maturity along coasts generates increasing levels of development/opportunities for villages & at same time brings many benefits.

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Short-term and long-term benefits

- Provides employment; utilizes existing skills of coastal communities in mangrove planting.
- Restores degraded coasts caused by shrimp farming & other activities.
- Improves biodiversity; mangroves are nurseries for fish.
- Low cost protection measure compared to seawalls & dikes.
- Offers coastal protection from erosion, storm surges & buffer to tsunami waves.
- Adaptation to sea-level rise.
- Important carbon sink.
- Supplementary/emergency food supply.
- 'No regrets' measure; beneficial irrespective of future outcome of climate change.

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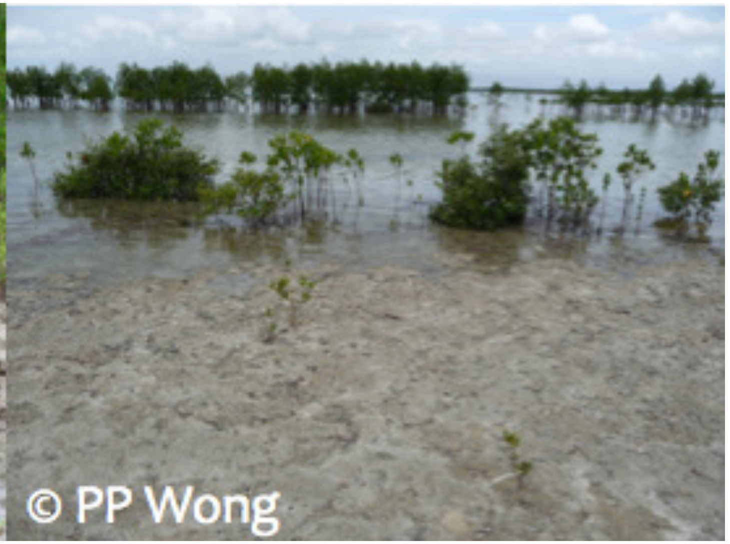
Avicennia marina : ideal

- **Widest latitudinal range**, ability to adapt to wide range of physical conditions; only mangrove to survive in arid areas.
- **Present on both seaward & landward margin of mangrove belt ('disjunct' zonation).**
- **'Opportunistic' colonization due to ecological characteristics.**
- **Grows on mud, sand, gravels, rubble, rock surfaces.**
- **Most tolerant to sea-level rise.**



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PROPOSED MODULAR MANGROVE PLANTING

Poh Poh Wong, Visiting Associate Professor, School of Social Sciences, University of Adelaide

The rivers from the Himalayas have caused erosion and deposition on the floodplains of Bangladesh (Fig. 1). In some cases, deposition has been encouraged by channelling sediments to fill up 'beels' (local depressions) and raising the ground level suitable for cultivation (Fig. 2). This method is seen as a suitable measure to protect the eroding coast from a rising sea level (Fig. 3).

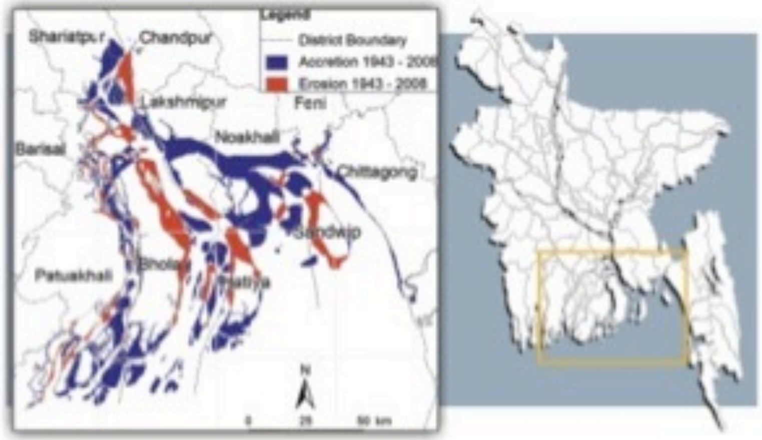

Fig. 1 (Daily Star, 27.4.2010)

Fig. 2 (NYT, 20.3.2009)

Fig. 3 (Practical Action 2009)

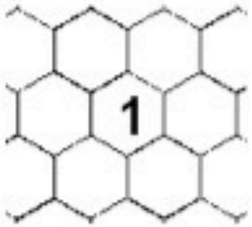

Fig. 4

Fig. 5 (Xin Yong Yuan)

It is proposed that large-scale modular planting of mangroves (Fig. 4) can be combined with sedimentation to create more land and adapt to sea-level rise. Mangroves can be grown to various heights in modules deployed into areas or coasts requiring protection from erosion. The modules can be made of local materials that will self-destruct and form part of the substrates (Fig. 5). Sediments are added to the mangroves as they grow. *Avicennia marina* is the best species for planting as it can establish itself on various substrates and tolerate a wide range of environmental conditions (Fig. 6, 7, 8).

Fig. 6 (PP Wong)

Fig. 7 (PP Wong)

Fig. 8 (PP Wong)

Knowledge on planting mangroves and local materials for the modules are readily available within Bangladesh. Mangroves also serve as an important carbon sink and planting them is a 'no regrets' measure and conforms to the 'precautionary principle'.

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WINNER

Judges' Choice Award

Poh Poh Wong

FOR THE PROPOSAL

FUTURE MANGROVES

IN THE 2014 ADAPTATION TO CLIMATE CHANGE CONTEST

Professor Thomas W. Malone
Director, MIT Center for Collective Intelligence
Patrick J. McGovern Professor of Management
Sloan School of Management
Massachusetts Institute of Technology

MIT Climate CoLab

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(Revised copy of proposal available from author)

8. End note

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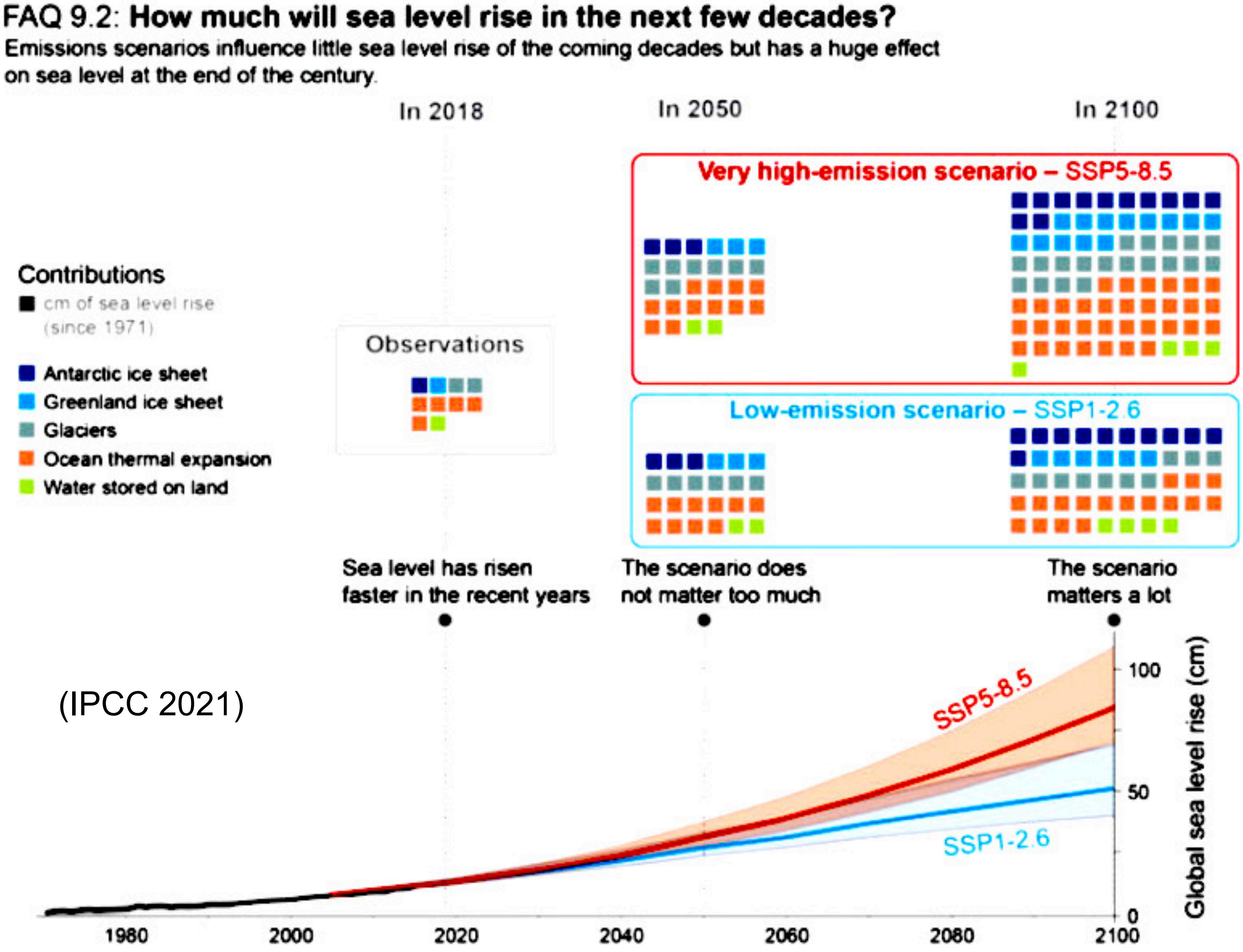
Sea-level rise…



(IPCC 2021)

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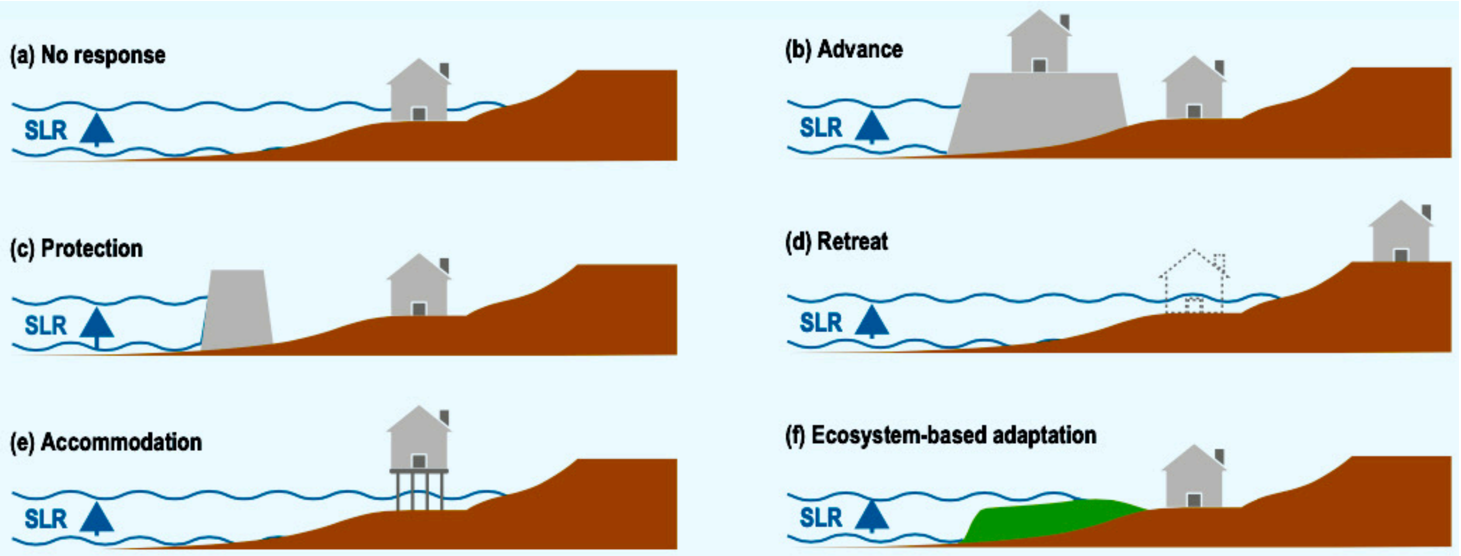
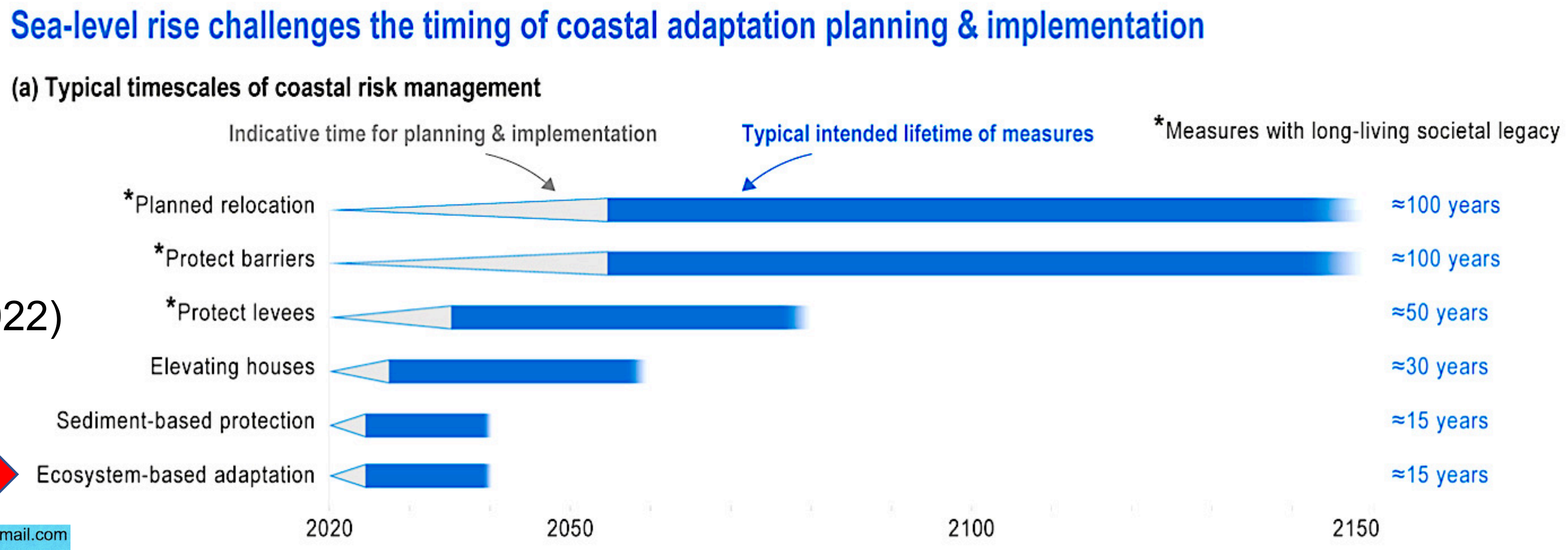
…and adaptation

	Protect = effort to continue use of vulnerable areas	*Accommodate* = effort to continue living in vulnerable areas by adjusting living and working habits	*Retreat* = effort to abandon vulnerable areas
Hard	Dikes, seawalls, groins, breakwaters, salt water intrusion barriers	Building on pilings, adapting drainage, emergency flood shelters	Relocating threatened buildings
Soft	Sand nourishments, dune building, wetland restoration or creation	New building codes, growing flood or salt tolerant crops, early warning and evacuation systems, risk-based hazard insurance	Land use restriction, set-back zones

(Policy Research Corporation)



(IPCC 2019)



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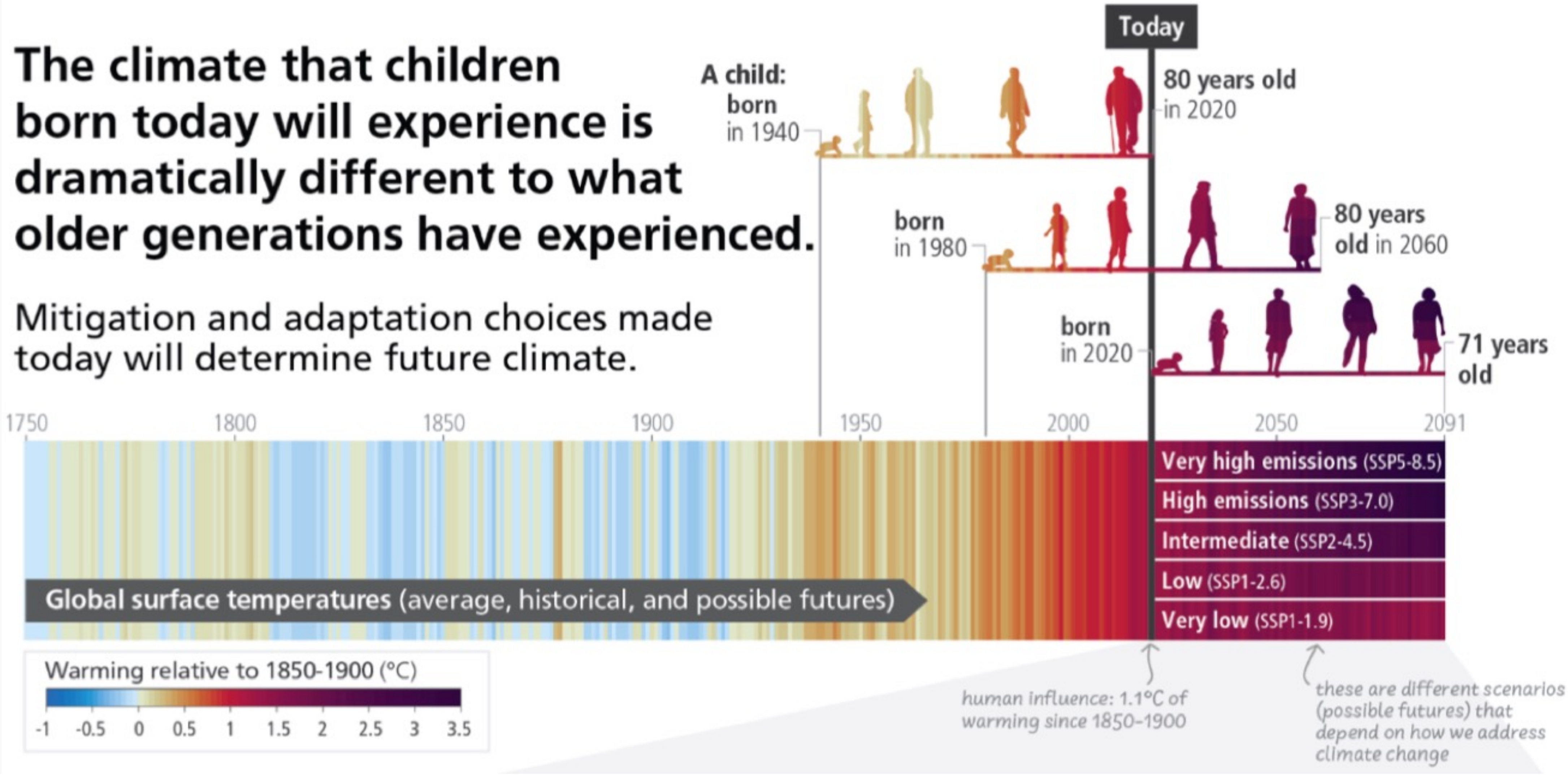
OUR future climate



(IPCC 2022)

Where there's a will there's a way

Thank you

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