



Sea-level rise adaptation for coasts and islands

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IPCC trilogy

	<i>Protect</i> = effort to continue use of vulnerable areas	<i>Accommodate</i> = effort to continue living in vulnerable areas by adjusting living and working habits	<i>Retreat</i> = effort to abandon vulnerable areas
<i>Hard</i>	Dikes, seawalls, groins, breakwaters, salt water intrusion barriers	Building on pilings, adapting drainage, emergency flood shelters	Relocating threatened buildings
<i>Soft</i>	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

Retreat

RETREAT

- Establishing set-back zones
- Relocating threatened buildings
- Phasing out development in exposed areas
- Creating upland buffers
- Rolling easements



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Accommodate

ACCOMMODATE

- Early warning and evacuation systems
- Hazard insurance
- New agricultural practices, such as using salt-resistant crops
- New building codes
- Improved drainage
- Desalination systems



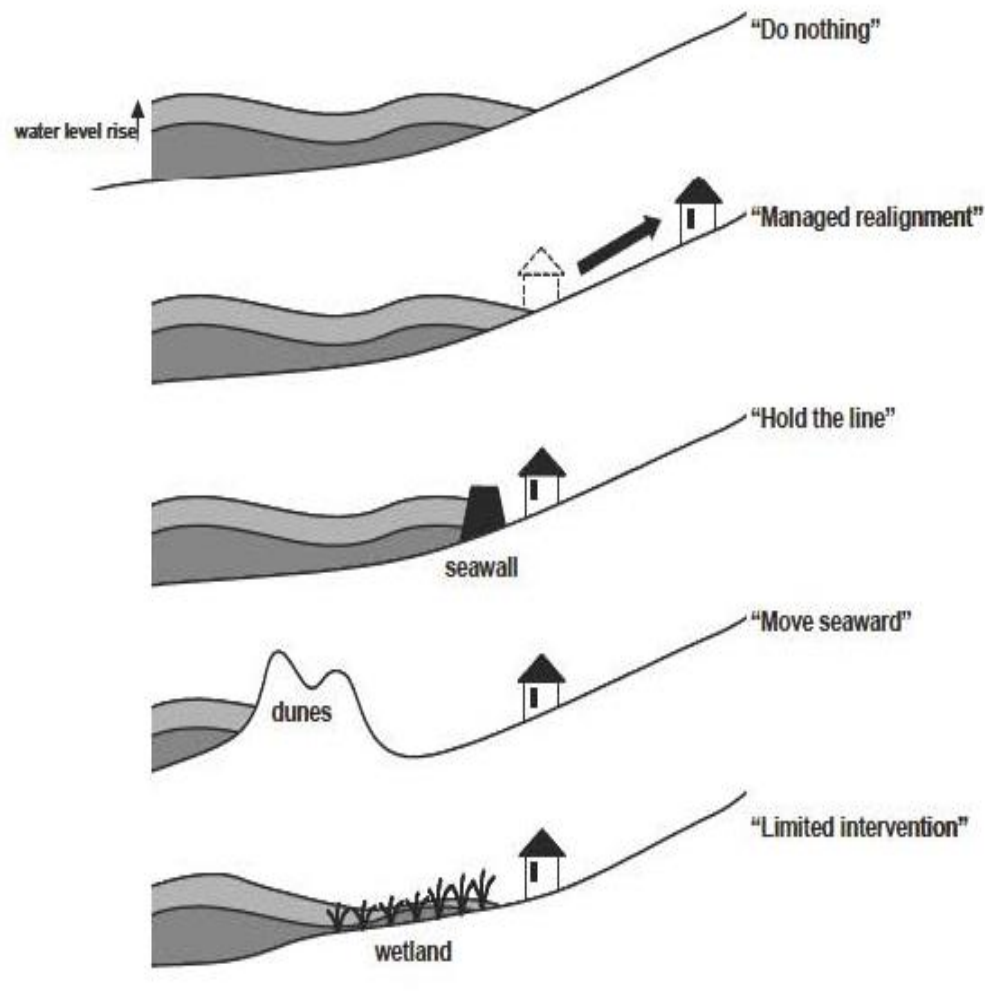
Protect

PROTECT

- *Hard Structures* - dykes, sea-walls, tidal barriers, detached breakwaters
- *Soft Structures* - dune or wetland restoration or creation, beach nourishment
- Indigenous options walls of wood, stone or coconut leaf, afforestation



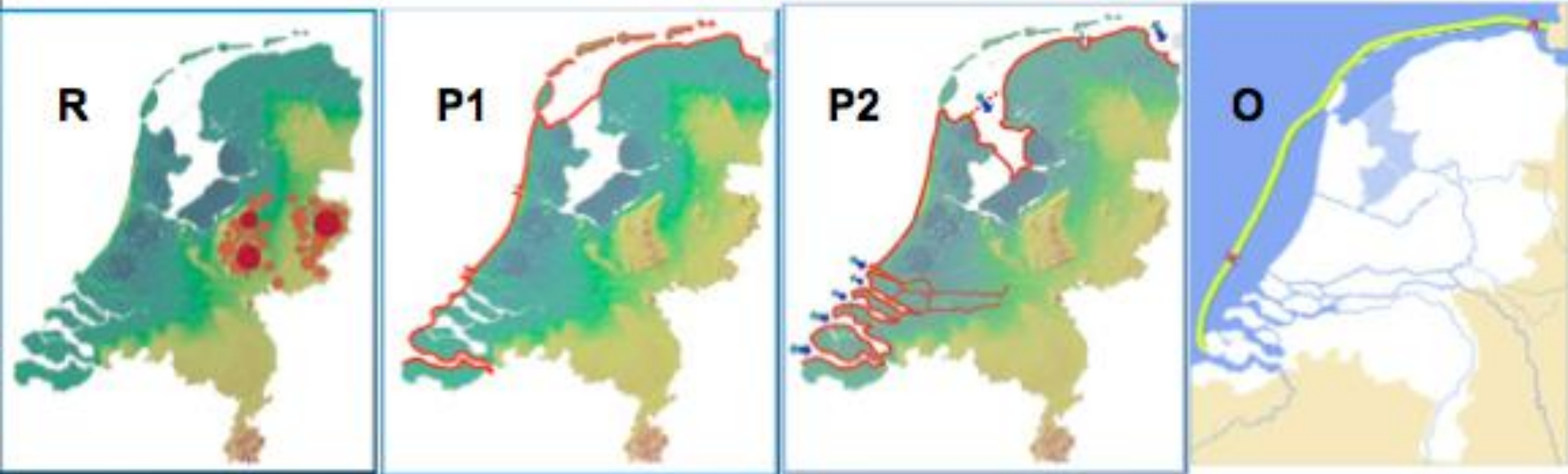
5 generic options (EU)



(EU 2004)

1. No investment in coastal protection.
2. New line of defences landward of original defences.
3. Hold existing defence line by maintaining or changing standard of protection. Include rear of existing defence.
4. Move existing defence line by constructing new defences seaward of original defence, e.g. land reclamation.
5. **Working with natural processes** to reduce risks while allowing natural coastal change; many measures.

Dutch strategy to SLR



(Vellinga 2009)

- R** Retreat to higher ground
- P1** Protection within existing boundary ('closed' version)
- P2** Protection within existing boundary ('open' version)
- O** Offensive strategy

Maldives : 'safe island'

- ★ **Maldives** : concept of '**Safe island**' to relocate people from smaller islands to larger islands.
- ★ **Enhanced** after Dec 2004 tsunami to include measures such as coastal protection, vegetation cover, higher grounds and 2-storey buildings, e.g. Gulhi Fahlu.

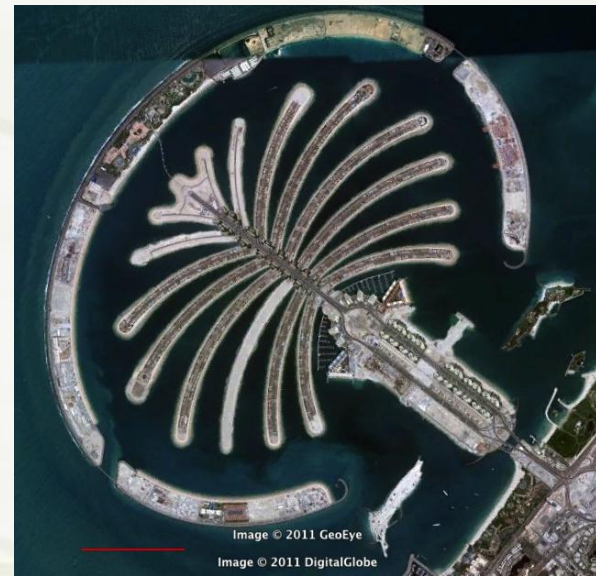


'Save some islands'

- ✦ Proposed strategy of **'Save some than not to have any'** using available technology in large-scale island reclamation (Wong 2011).
- ✦ Suction-dredgers to remove material from dispensable islands and their nearshore zone to increase height of other islands.



(Nakheel)



(Google Earth)

EBA (ecosystem-based adaptation)

- ★ **Emerging approach** using biodiversity and ecosystem services (supporting, provisioning, regulating, cultural) as part of overall strategy to adapt to adverse effects of climate change.
- ★ **Part of broader portfolio** of adaptation measures – can be applied at different geographical scales and within various time frames.
- ★ **Is cost-effective** to protect communities from climate change and extreme weather events.



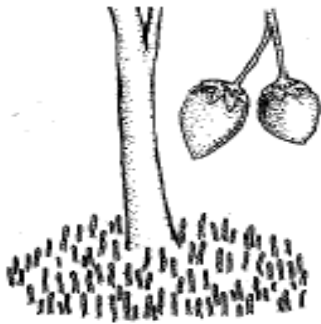
EBA – for coasts and islands

“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)

Mangroves

- ★ Have **special root systems** and may adapt to changes in sea level by growing upward in place, or by expanding landward or seaward.

(Bunaken 1999)



Peg roots of *Avicennia*



Knee Roots of *Bruguiera*



Peg roots of *Sonneratia*



Prop roots of *Rhizophora*



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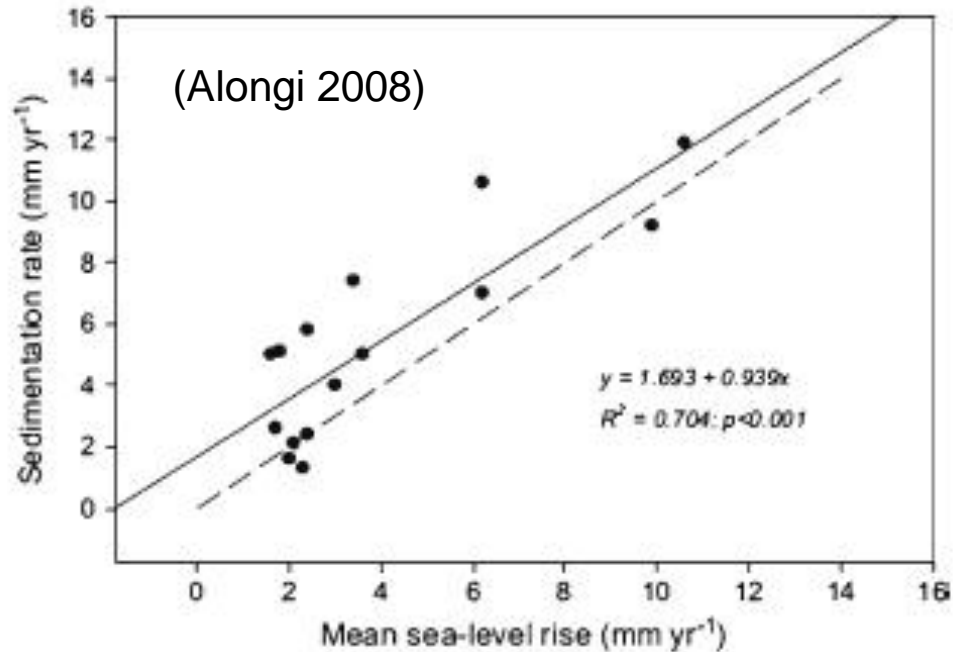
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Mangroves

- ★ Have special root systems that grow upwards and **keep up with SLR.**
- ★ Considerable **buffer to waves up to 4 m high.**



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	
(c) Mangrove forests	Biotic/physical	Biotic	▼~▼ ¹	▼~▼ ^{1, H}	▼~▼ ^H	▲~▼ ^H	■~■

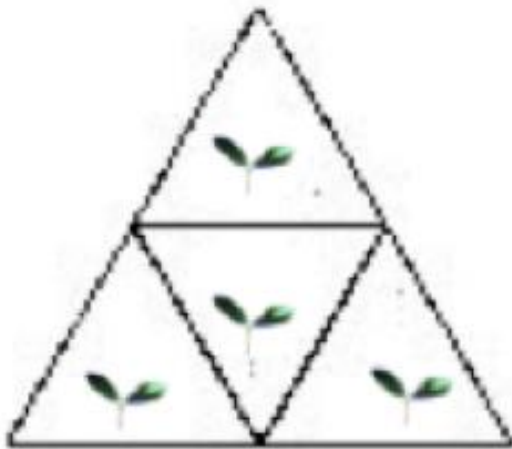
Legend:

▲	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

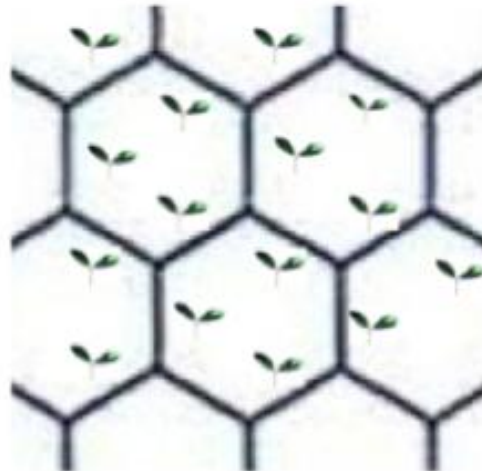
(Cochard et al 2010)

Large-scale modular planting

- ★ Large-scale planting using modular system to meet requirements of various coastal locations. **Modular system of planting and deployment** is comparable to LEGO® set on large scale.
- ★ Ideally space-fitting shapes containing sediments with mangroves grown to various heights. Modules made of local materials or mixture of compressed sediments that become self-destructive and formed part of substrates. Nutrients and sediments added to growing mangroves in field (Wong 2011).
- ★ Suitable **for variety of coasts** and not confined to muddy coasts.



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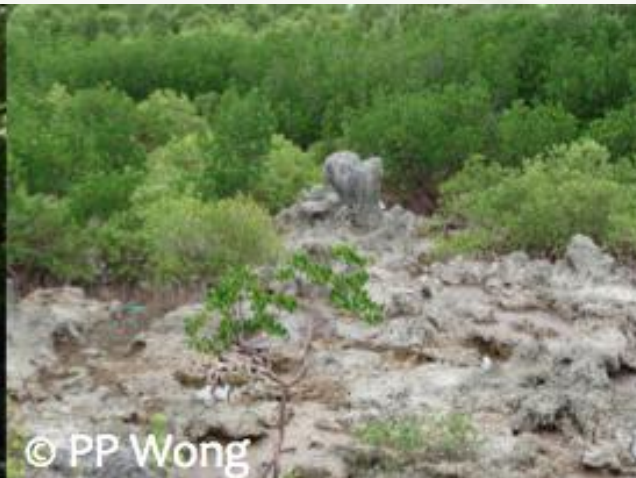
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(IOC 2011)

Avicennia marina

- ✦ Wildest 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.
- ✦ 'Opportunistic' colonization due to ecological characteristics.
- ✦ Grows **on mud, sand, gravels, rocks, rock surfaces.**



Mangrove planting - benefits

- ✦ Provides employment; utilizes existing skills of coastal communities in mangrove planting.
- ✦ Restores degraded coasts caused by shrimp farming and other activities.
- ✦ Improves biodiversity; nurseries for fish.
- ✦ Provides **food** and medicine.
- ✦ Low-cost compared to hard measures.
- ✦ Coastal protection from erosion, storm surges, buffer to tsunami waves; integrated CCA and DRR.
- ✦ ‘No regrets’ measure; beneficial irrespective of future outcome of climate change.



Concluding remarks



- ✦ John Connor in “Terminator 3 : The Rise of the Machines” on Judgment Day. “We should have realized our destiny was never to stop *climate change*. It was merely **to survive it. Together. ...The battle has just begun.**”



Thank you

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