Global Climate Forum

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GLOBAL INVESTMENT COSTS FOR COASTAL DEFENCE THROUGH THE 21ST CENTURY

Robert J. Nicholls[1], Daniel Lincke[2], Jochen Hinkel[2], Thomas van der Pol[2]

1. University of Southampton, Southampton, UK

2. Global Climate Forum, Berlin, Germany

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Plan

- Background
- Methodology
  - The DIVA model
  - Approach and cost estimates
- Illustrative results
  - Length of defences
  - Capital and maintenance costs
- Concluding thoughts

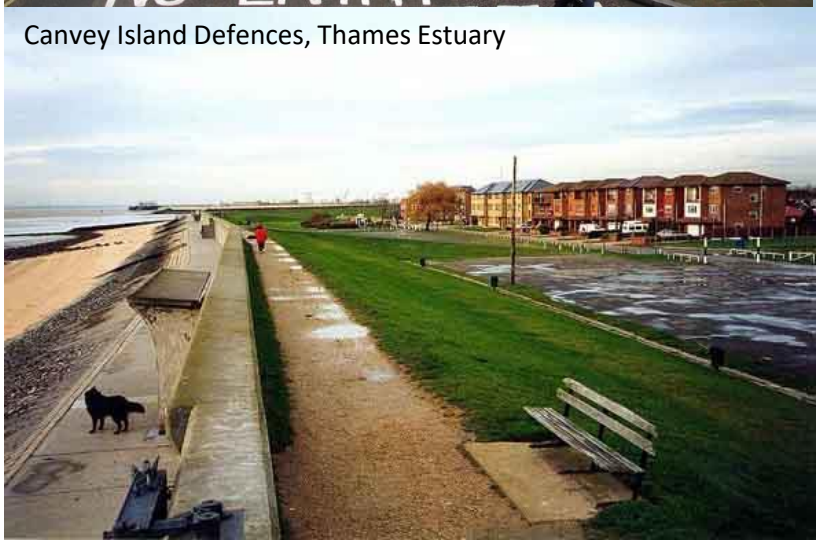
Background

- KEY QUESTION: What are plausible cost estimates for coastal defence infrastructure against coastal flooding through the 21st Century?
- Under scenarios of changing population, economy and climate-induced sea-level rise.
- Follows a pre-defined stylized protection strategy at a global scale.
- Both capital investment and maintenance costs are considered.
- Funded by World Bank.

Coastal Flood Defences in the UK

Mobile Barriers: Old Portsmouth
(source: East Solent Coastal partnership)

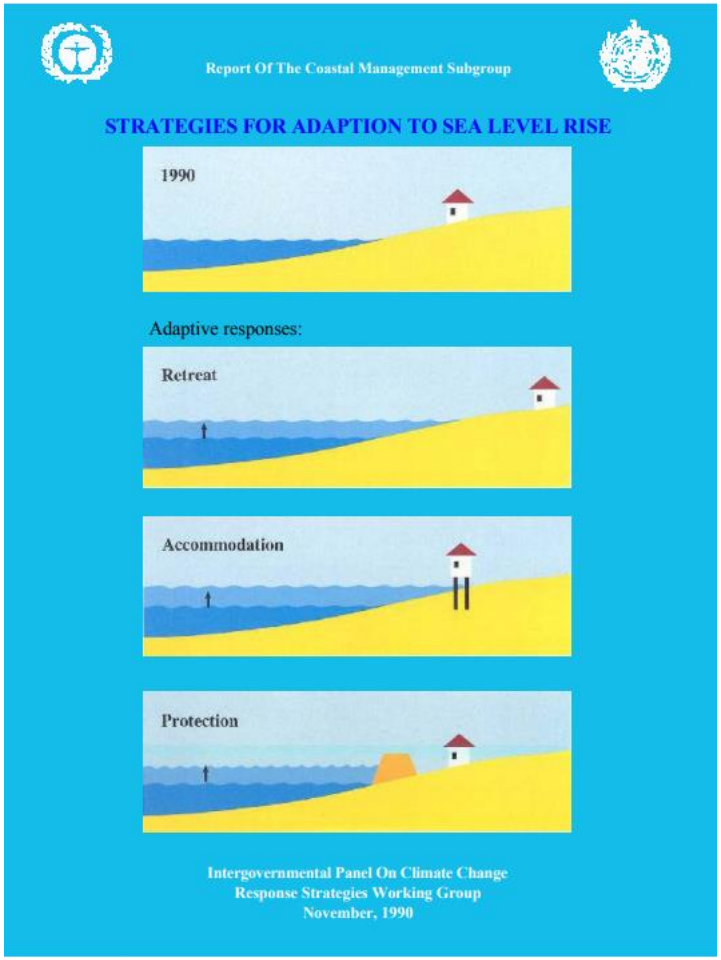

North Portsea Defences, Portsmouth


Canvey Island Defences, Thames Estuary

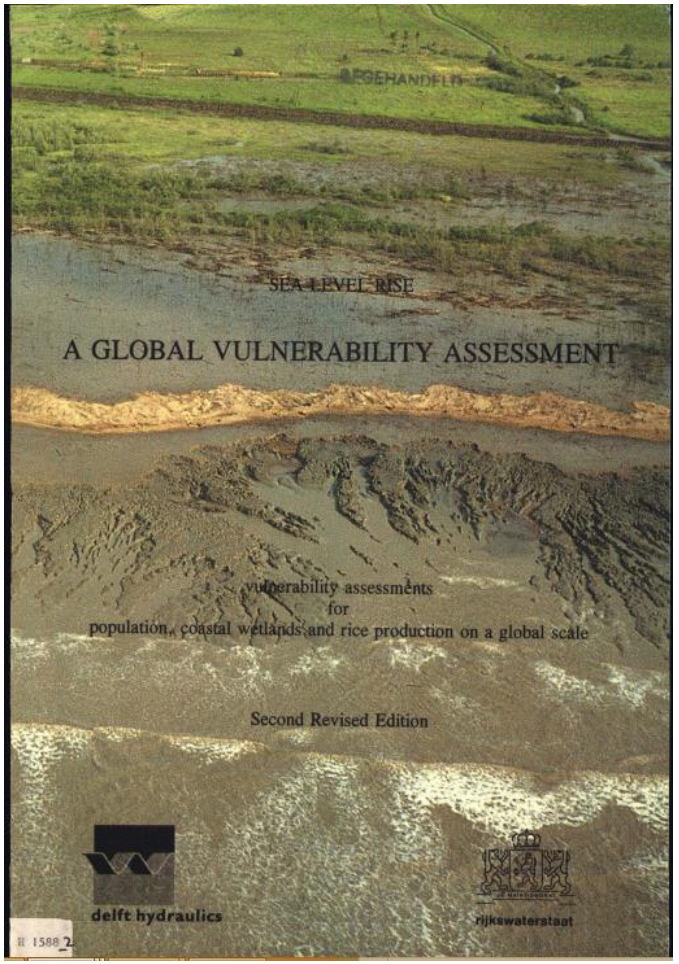

100th Closure of the Thames Barrier,
(source: Environment Agency)

Global protection costs for sea-level rise

A long history



(a) 1990



(b) 1993

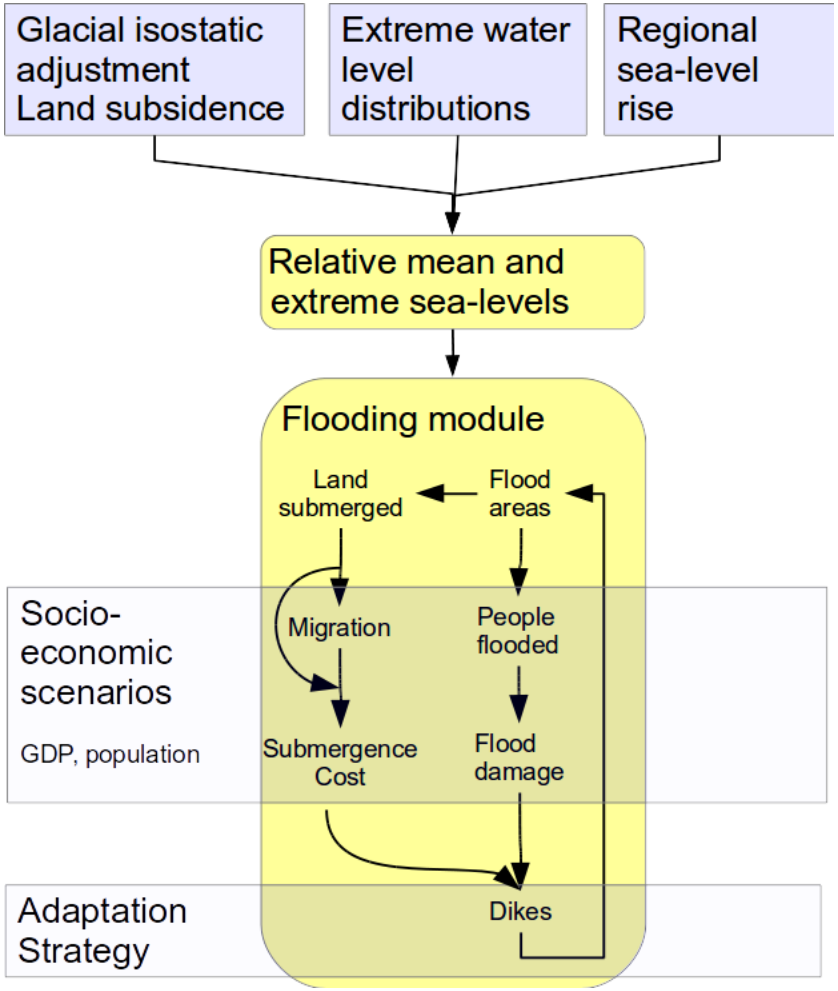
Global protection costs for sea-level rise

Study	Cost Estimate (2014 USD)	Comments
Dronkers et al., 1990	$815 billion	1-m rise, capital costs mainly reflecting flood protection and other aspects (e.g. port upgrade).
Hoozemans et al., 1993	$1,630 billion	1-m rise, as Dronkers et al. (1990) with better consideration of storm surge hazard and protection needs.
Tol, 2002	$1,524 billion	1-m rise. Optimum (benefit-cost) analysis using the FUND model. Capital costs only.
Hinkel et al. 2014	$3,000 to $6,100 billion	0.6-m to 1.23-m rise (RCP8.5 emissions). Demand for safety approach (protection scenario rather than benefit-cost approach). Costs include capital and maintenance costs of dikes built since 2005.

Methods

DIVA Flood Module (after Hinkel et al., 2014)

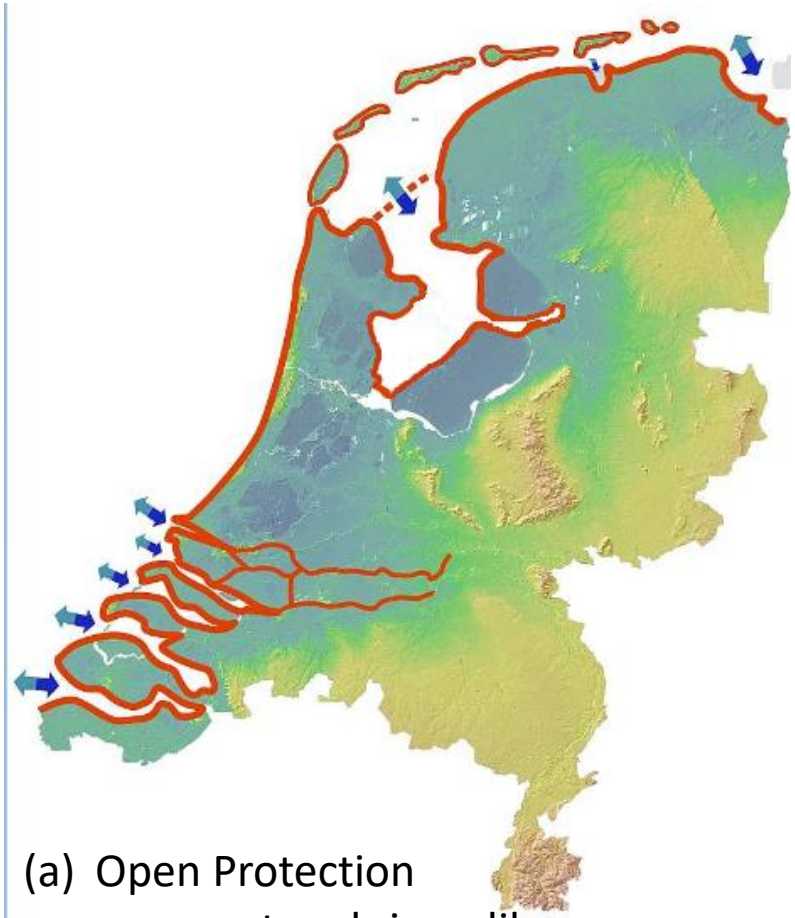
DIVA (Dynamic Interactive Vulnerability Assessment) of coastal floods, erosion and wetland change. A set of algorithms and a global database based on about 12,000 linear segments



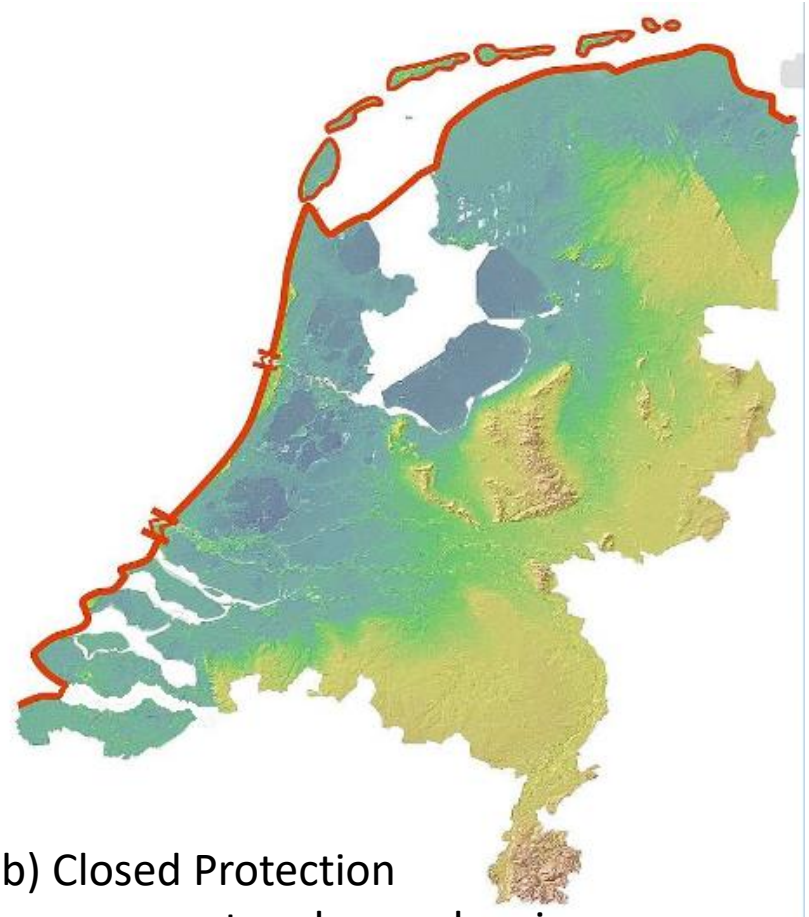
Defence technologies, approaches and adaptation strategies

Defence Technologies	(1) Sea dikes
	(2) River dikes
	(3) Surge barriers

Different protection choices



(a) Open Protection
-- open coast and river dikes



(b) Closed Protection
-- open coast and surge barriers (and closure dams)

Protection standards
(following Sadoff et al., 2015 [Securing Water, Sustaining Growth])

Wealth Class (annual income per capita) (2014 US$ GDP per capita (PPP))	Urban (>1000 people/km^2)	Rural (30 to 1000 people/km^2)	Uninhabited (<30 people/km^2)
Low income	1:10	none	none
Lower middle income	1:25	none	none
Upper middle income	1:100	1:20	none
High income	1:200	1:50	none
Special case: Netherlands	1:10,000		
Special case: 136 large coastal cities	from Hallegatte et al. (2013)		

Scenarios
SSP2 and RCP2.6/RCP8.5

Year		2015	2030	2050	2075	2100
Global population (billions)		7.4	8.4	9.4	9.7	9.2
GDP per capita (US$, global average)		14,400	20,800	30,000	46,700	72,600
Sea-level rise, (global coastal average, m)	RCP 2.6	0.03	0.08	0.14	0.21	0.28
	RCP 8.5	0.03	0.09	0.19	0.39	0.65

Note: Base year for sea-level rise is 1985 to 2005 average

Costs

- Capital costs for dikes taken from Jonkman et al (2013)

Old average costs Euro 3.47 million/km/m

New average costs Euro 4.00 to 11.04 million/km/m

- Capital costs for barriers taken from Mooyaart and Jonkman (2017)
- Maintenance costs of 1% per year of the defence stock capital investment

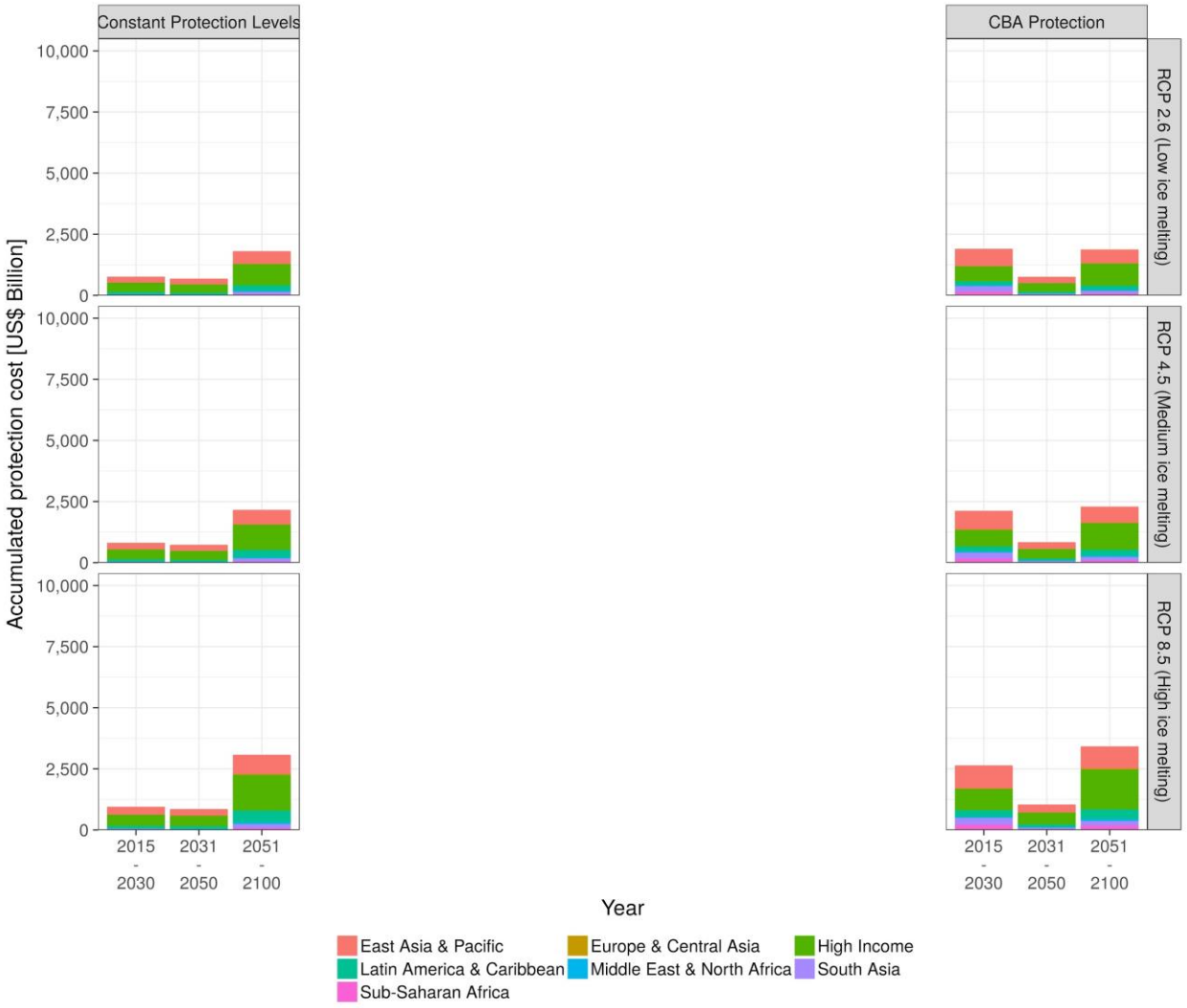
Results

All for dike and barrier protection

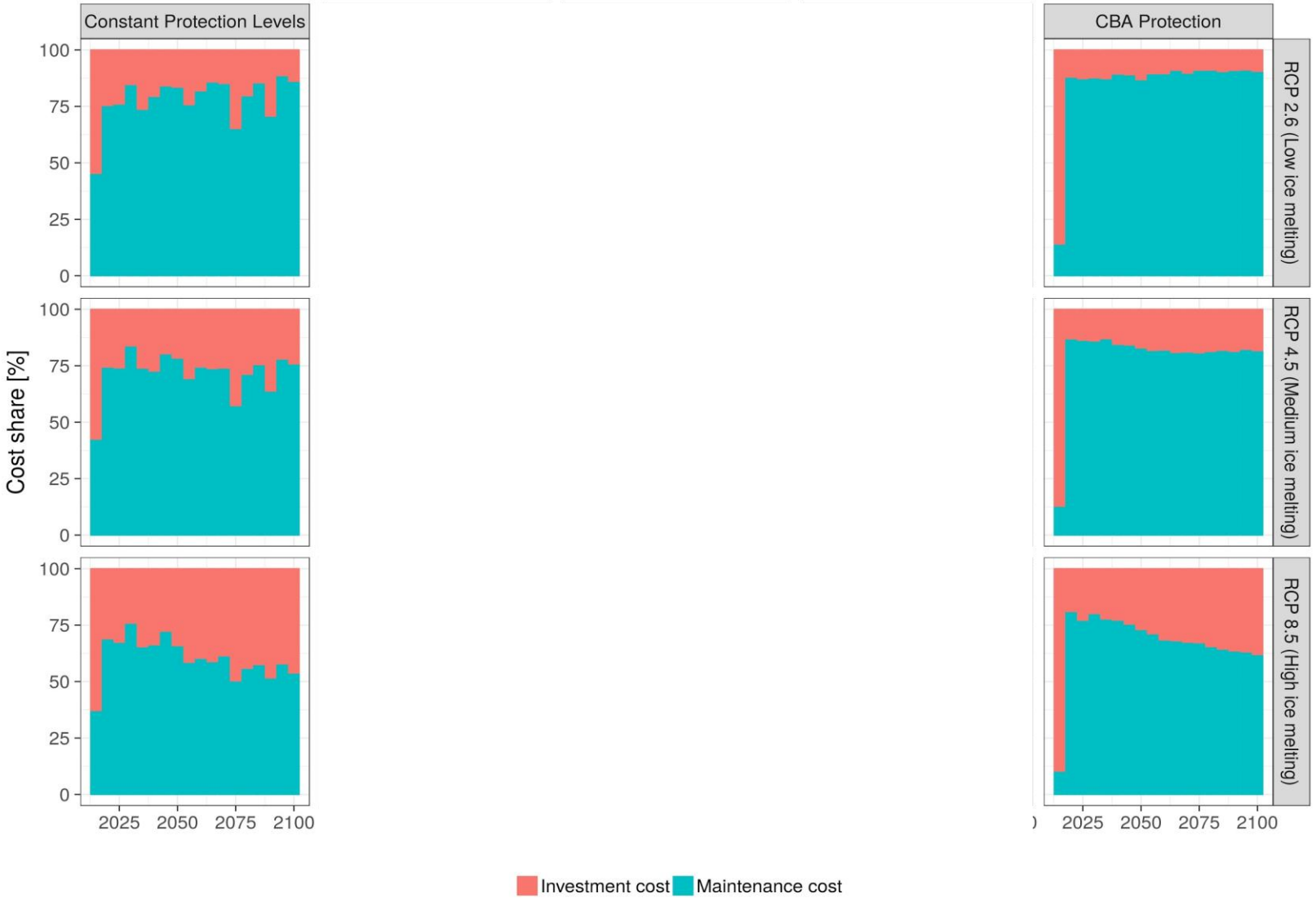
Protection costs, 2015-2030, 2031-2050, 2051-2100

RCP8.5 sea-level rise scenario

Sums maintenance and capital costs



Capital versus maintenance costs



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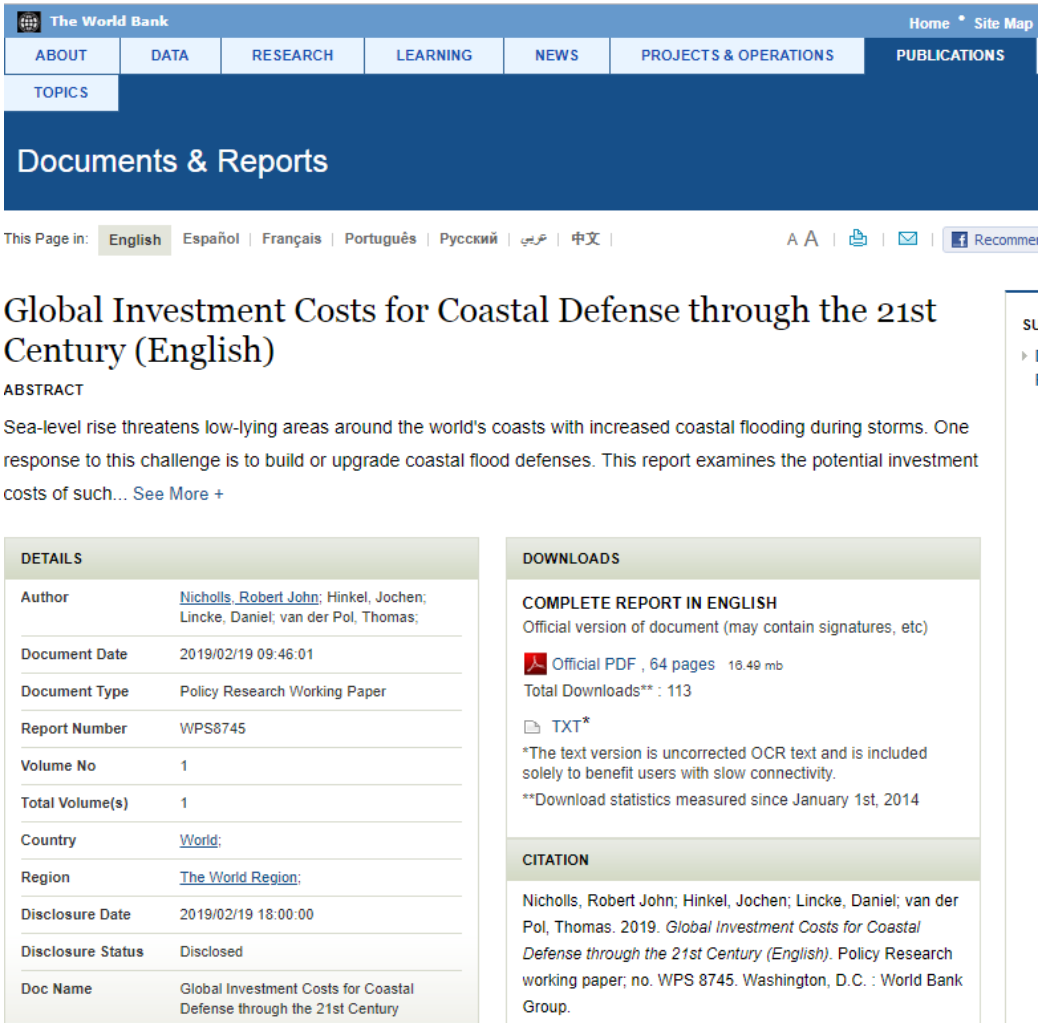
Summary of Costs

Total undiscounted protection costs 2015 to 2100 (US dollars 10^3 billion). Main uncertainty is unit cost.

Scenario		Constant Protection	Cost-Benefit Analysis
RCP8.5	SSP2	4.6 - 13.2	6.8 - 16.0
	SSP3	4.4 - 12.5	6.2 - 13.6
	SSP5	4.9 - 14.0	7.9 - 18.2
RCP4.5	SSP2	3.5 - 10.0	5.0 - 11.4
	SSP3	3.3 - 9.4	4.4 - 10.0
	SSP5	3.7 - 10.5	5.7 - 13.2
RCP2.6	SSP2	3.1 - 8.8	4.3 - 9.8
	SSP3	2.9 - 8.3	3.8 - 8.8
	SSP5	3.3 - 9.3	5.8 - 11.5

Report available at: http://documents.worldbank.org/curated/en/433981550240622188/Global-Investment-Costs-for-Coastal-Defense-through-the-21st-Century



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Global Investment Costs for Coastal Defense through the 21st Century (English)

ABSTRACT

Sea-level rise threatens low-lying areas around the world's coasts with increased coastal flooding during storms. One response to this challenge is to build or upgrade coastal flood defenses. This report examines the potential investment costs of such... See More +

DETAILS

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Concluding Thoughts (1)

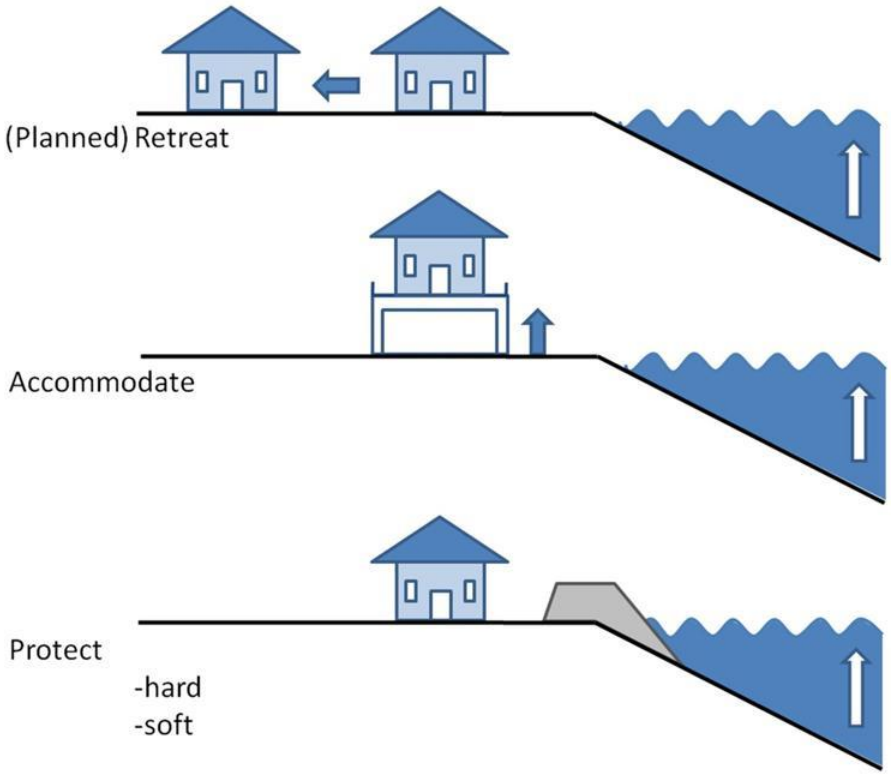
- The total accumulated defence costs from 2015 to 2100 are up to US$11.5 trillion and US$18.2 trillion for the RCP2.6 and RCP8.5 scenarios, respectively (Cost-benefit analysis).
- These are higher than earlier estimates, mainly reflecting: (1) higher range of unit defence costs; and (2) consideration of maintenance of the existing dike stock (in 2015).
- Maintenance costs are larger than capital costs.
- Cost-benefit analysis raises costs by more than 20% over the century compared to Constant Protection (more defence can be economically justified

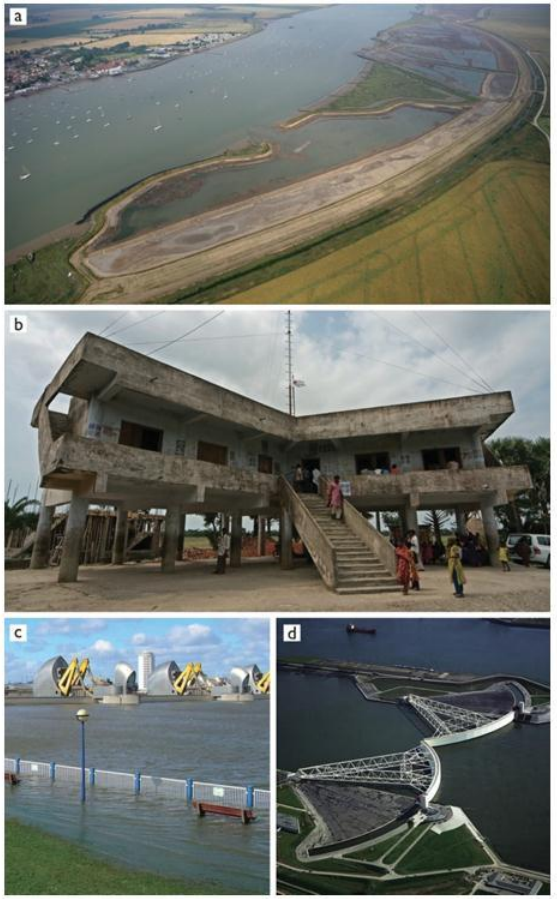
Concluding Thoughts (2)

- There are more defence options than dikes and barriers – what is presented is stylised (and there are other adaptation options).
- There are downsides to a defence (or protect) strategy. The world's developed coast will have growing (and deeper) flood plains and potential damage and threat to life if defences fail.
- Hence, residual risk must be considered and managed which implies ongoing investment in flood simulation, forecasting and warning.
- Delivering maintenance implies significant efforts to enhance flood management and governance institutions.
- Sea-level rise continues after 2100 (there is a long-term commitment to sea-level rise and adaptation to sea-level rise).
- The interplay between sea-level rise and adaptation remains the major uncertainty for the future of the coast.
- The role of nature-based approaches?

Planned Adaptation to SLR

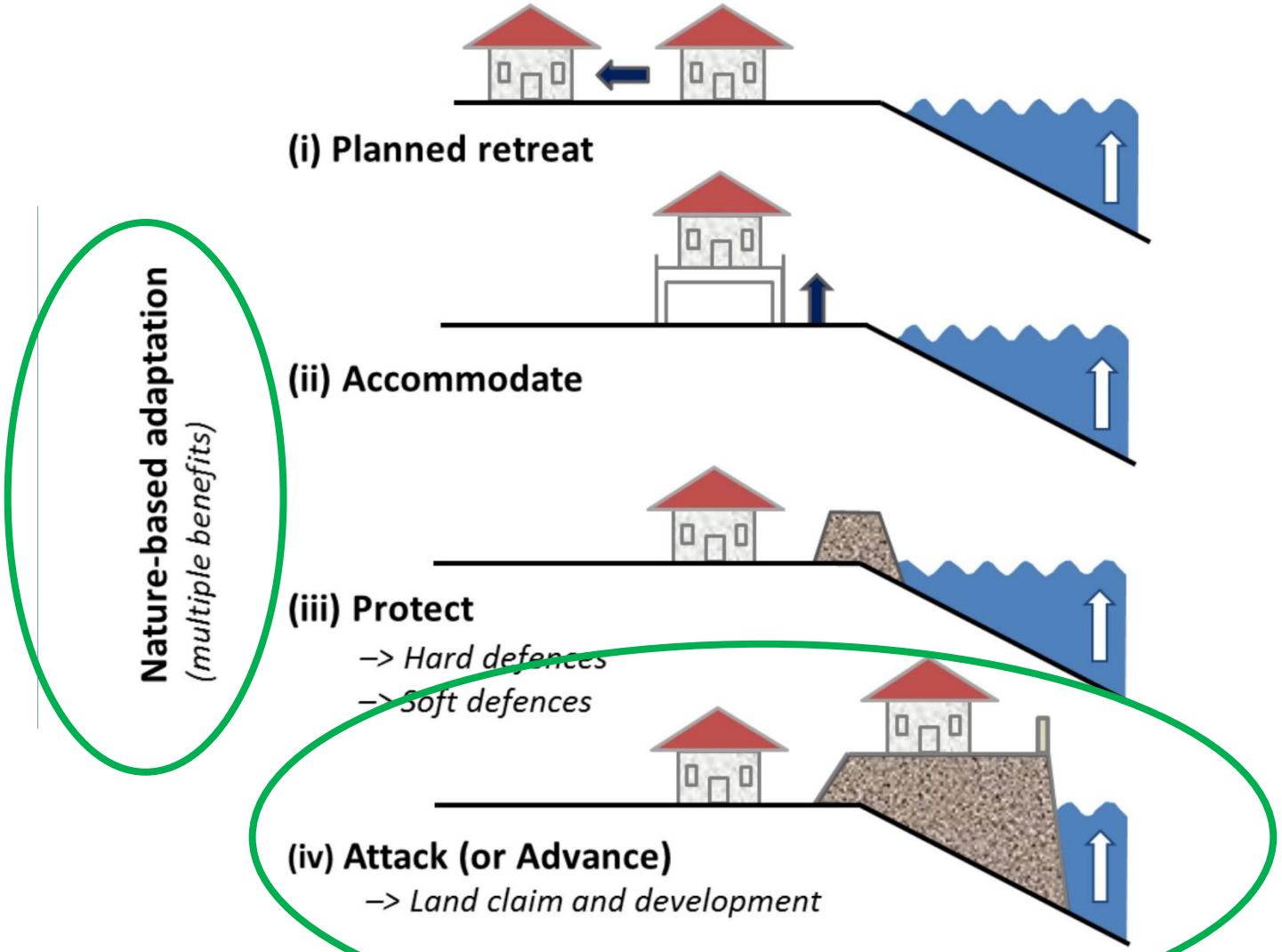
The IPCC Approach





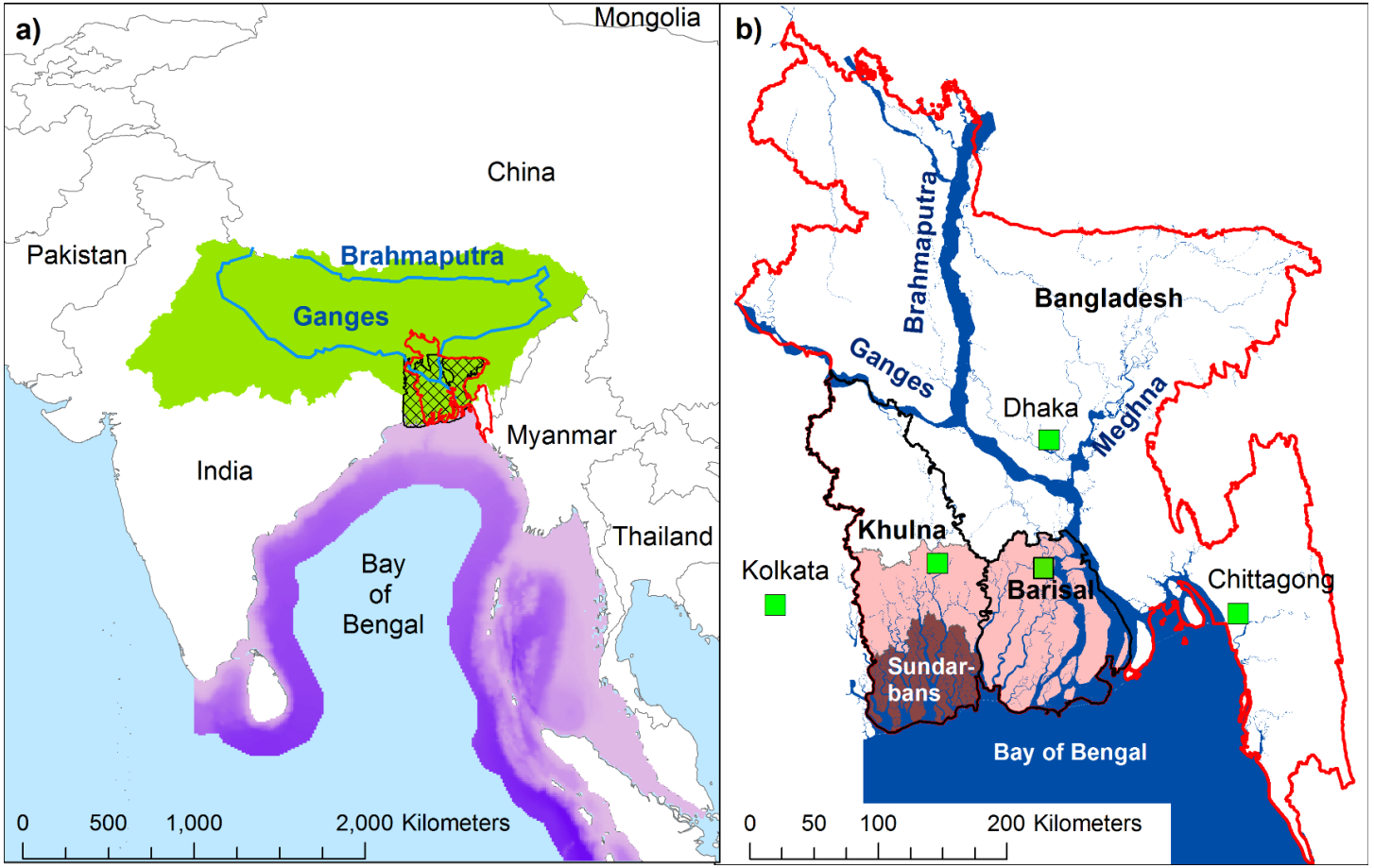
Source: Nicholls (2010) Book on "Understanding Sea-Level Rise and Variability"

Planned Adaptation to SLR

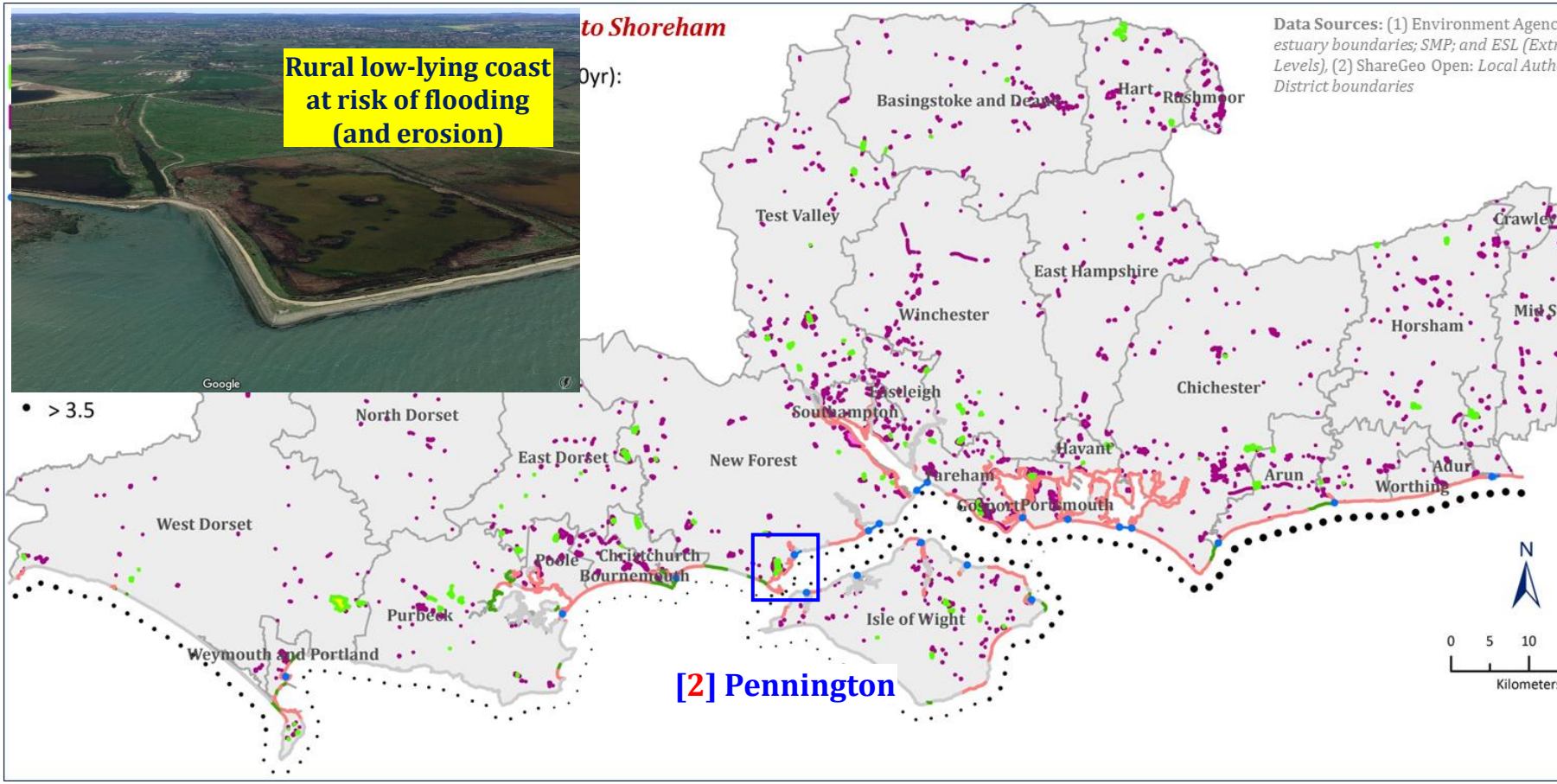


Source: adapted from Nicholls, 2018 in Alverson and Zommers (eds.), Resilience: the Science of Adaptation to Climate Change, Elsevier

The Sundarbans



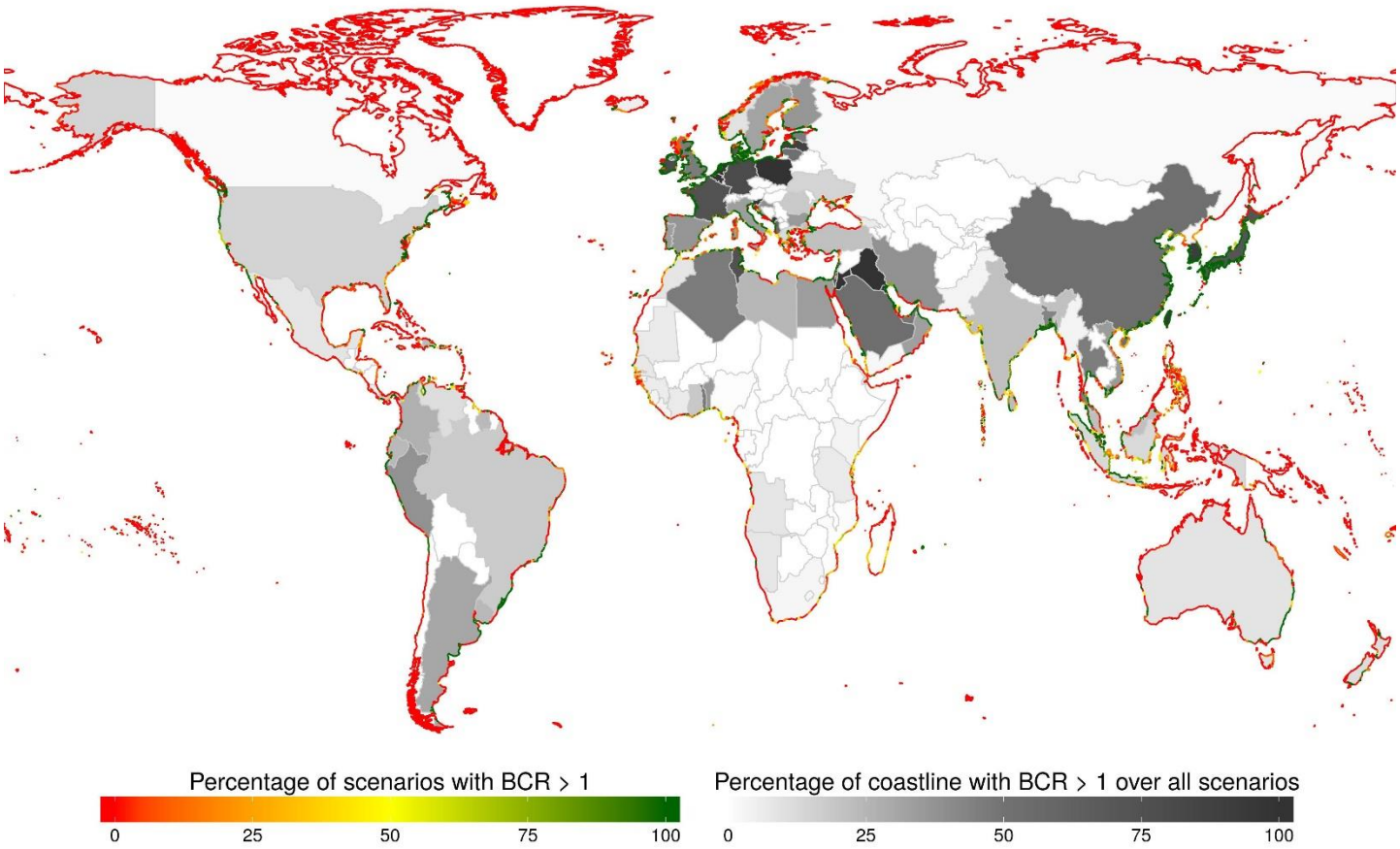
Pennington Marshes



Pennington Marshes

Economic robustness of coastal protection

SLR scenarios from 0.3 m to 2.0 m, the five SSPs and 10 discount rates of up to 6%.
Source: Lincke and Hinkel (2018) Global Environmental Change



92,500 km is always protected (13%): 90% of global coastal floodplain population
451,000 km is never protected (65%): 0.2% of coastal floodplain population
22% world's coast and 9.8% of coastal flood plain population – result is scenario dependent

Next Steps

- Integration “attack” and “nature-based” approaches into broad-scale assessment.

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