Economic Assessment of Urban Climate Change Adaptation Measures in Ho Chi Minh City

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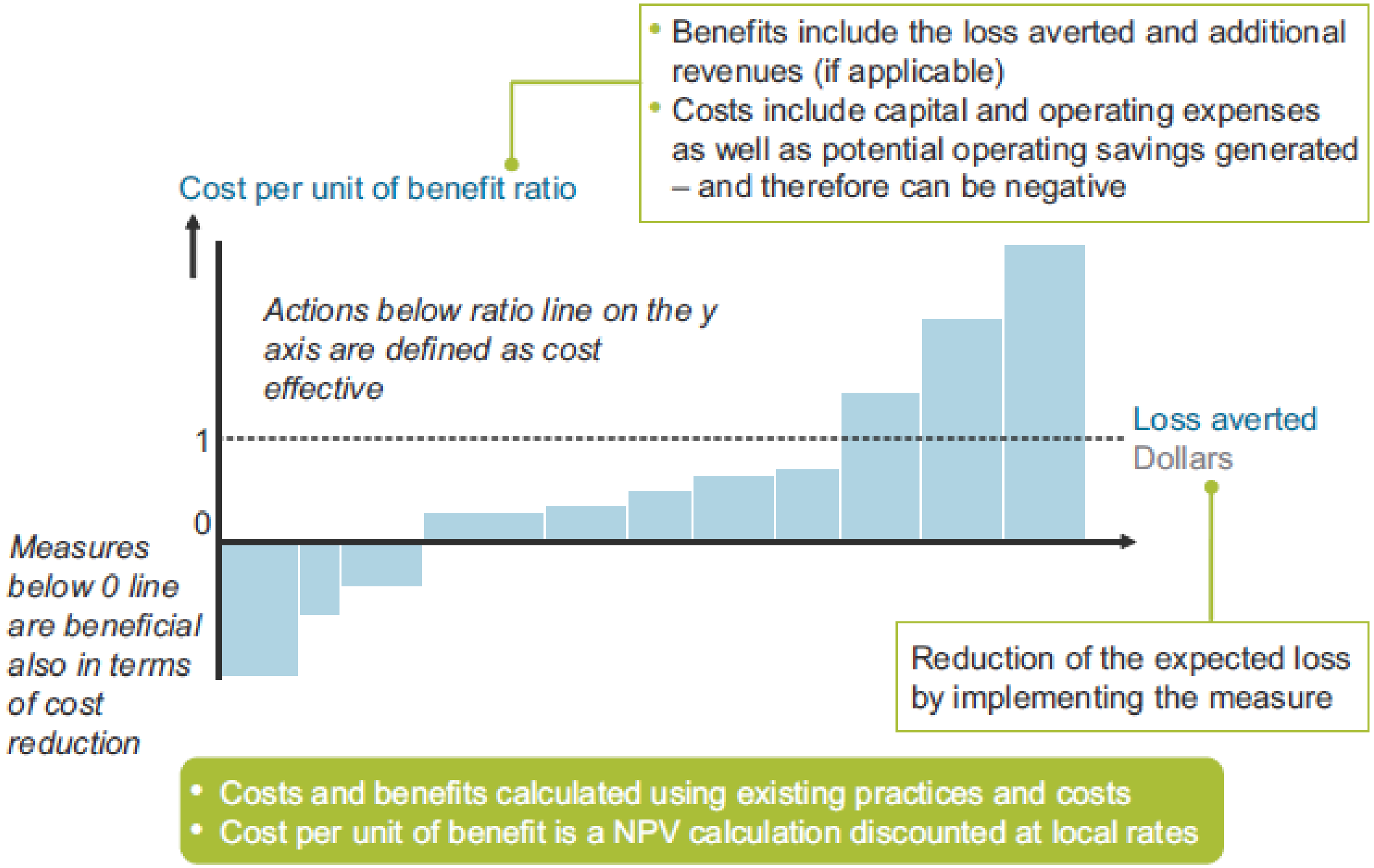
Climate change adaption in urban areas

In response to climate change both mitigation and adaptation actions are necessary at the urban level (UN-Habitat 2007).

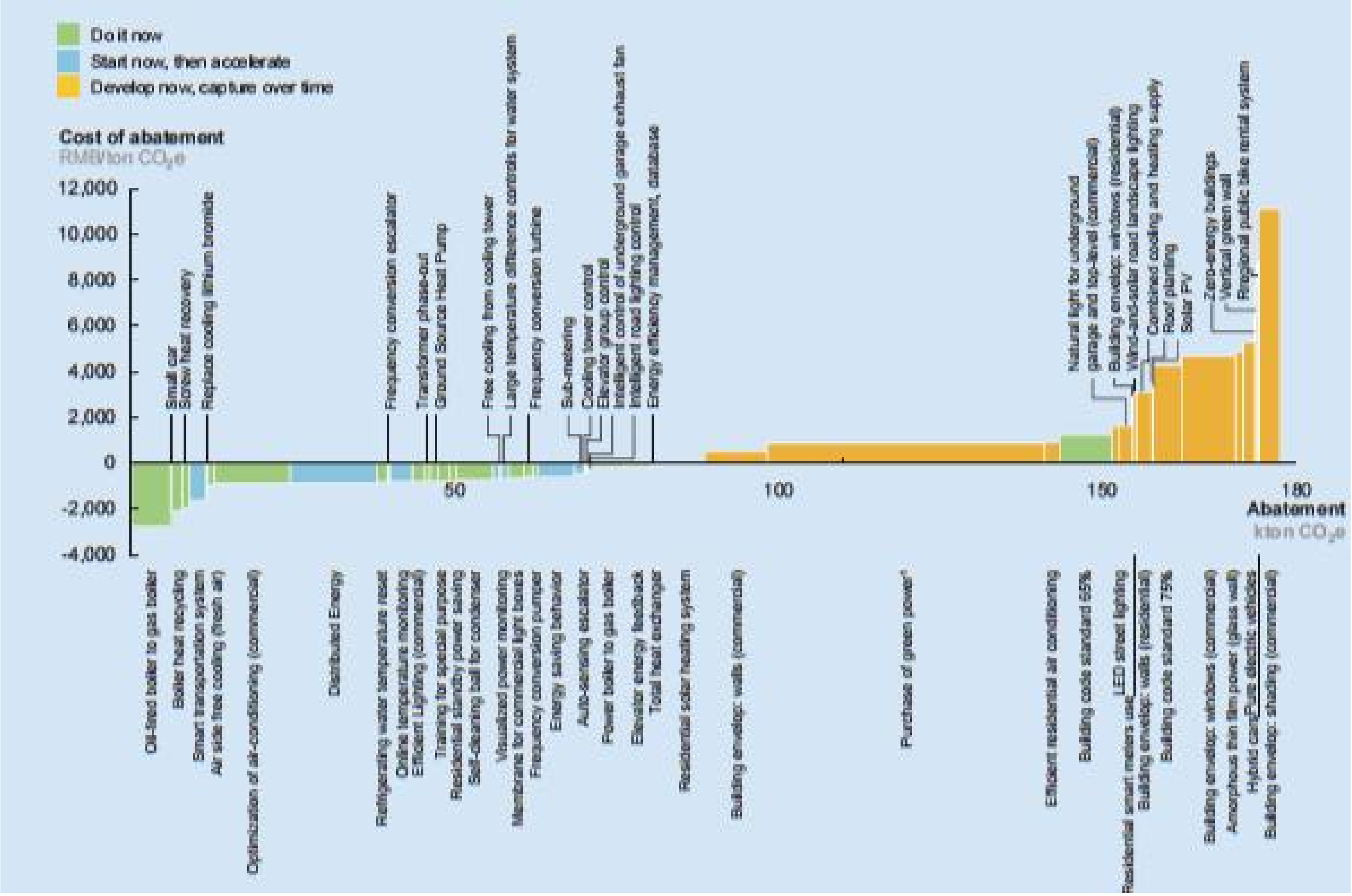
Adaptation to climate change can be defined as all actions that reduce the vulnerability of a system like an urban area, population group, or household to the adverse impacts of anticipated climate change (IPCC 2007).

Cities will have to cover approximately 80% of the yearly costs related to climate change adaptation (WB 2014).

Cost curves for mitigation and adaptions projects



Mitigation cost curve for Changning District (Shanghai)



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Diversity of adaptation projects

Flood monitoring, modelling and forecasting systems	Institutional reforms	Disaster management systems
Financial tools for risk management	Upgrading resilience of existing infrastructure	Development control and land use planning
Land elevation and flood barriers	Temporary and permanent retreat from hazardous areas	Awareness campaigns for behavioural change

Assessment of adaptation projects

NO COMMON METRIC

unlike in climate change mitigation (CO_2 equivalence) adaptation lacks an agreed metric to determine effectiveness and efficiency

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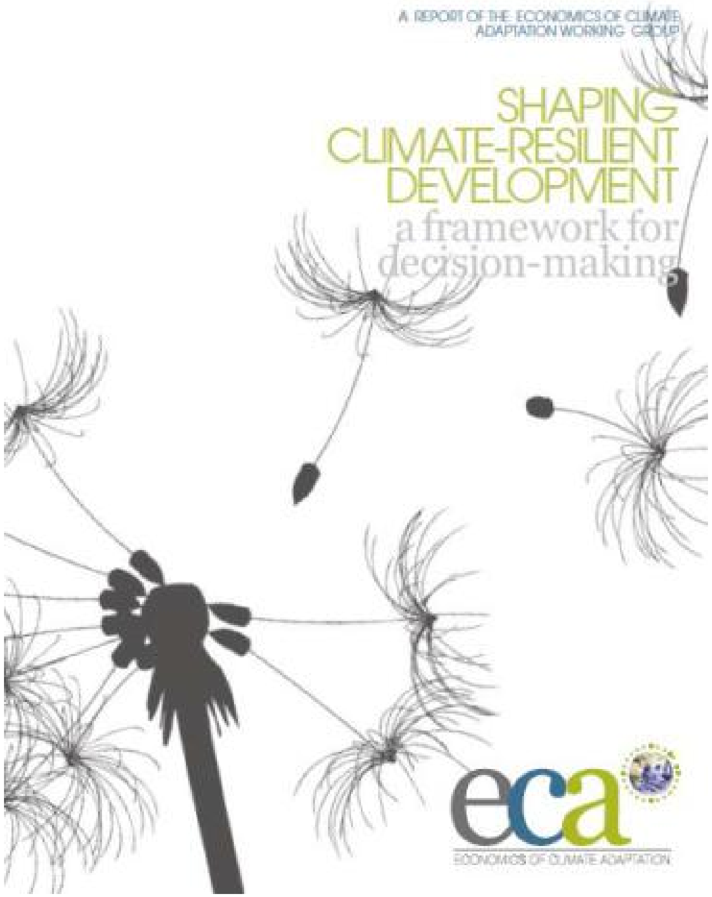
Economics of adaptation projects



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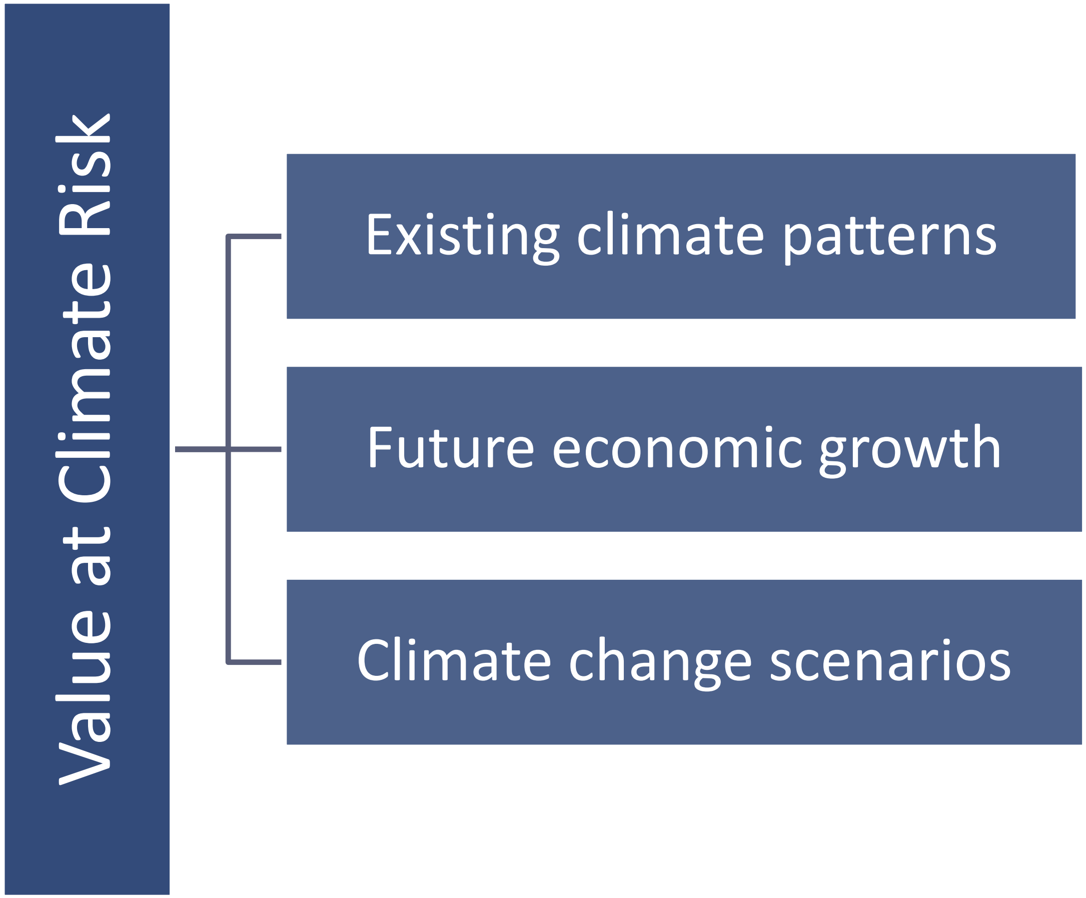
Total Climate Risk



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Typology of risks

Cost Types	Tangible Costs	Intangible Costs
Direct Costs	Damage to residential buildings and assets	Loss of human life
	Damage to commercial buildings and assets	Loss of ecosystem services
	Damage to industrial buildings and assets	
	Damage to public infrastructure (transport, energy, water supply and sanitation)	
	Damage to public and private vehicles	
Indirect Costs	Population loss of income	Long term health costs
	Commercial units loss of income	Decrease in level of well being
	Industrial units loss of income	
	Public utilities loss of income	
	Additional public health costs	

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Economic assessment of adaptation in HCMC

Climate change vulnerability in HCMC

Key economic and financial centre with current population estimated at 7–9 million.

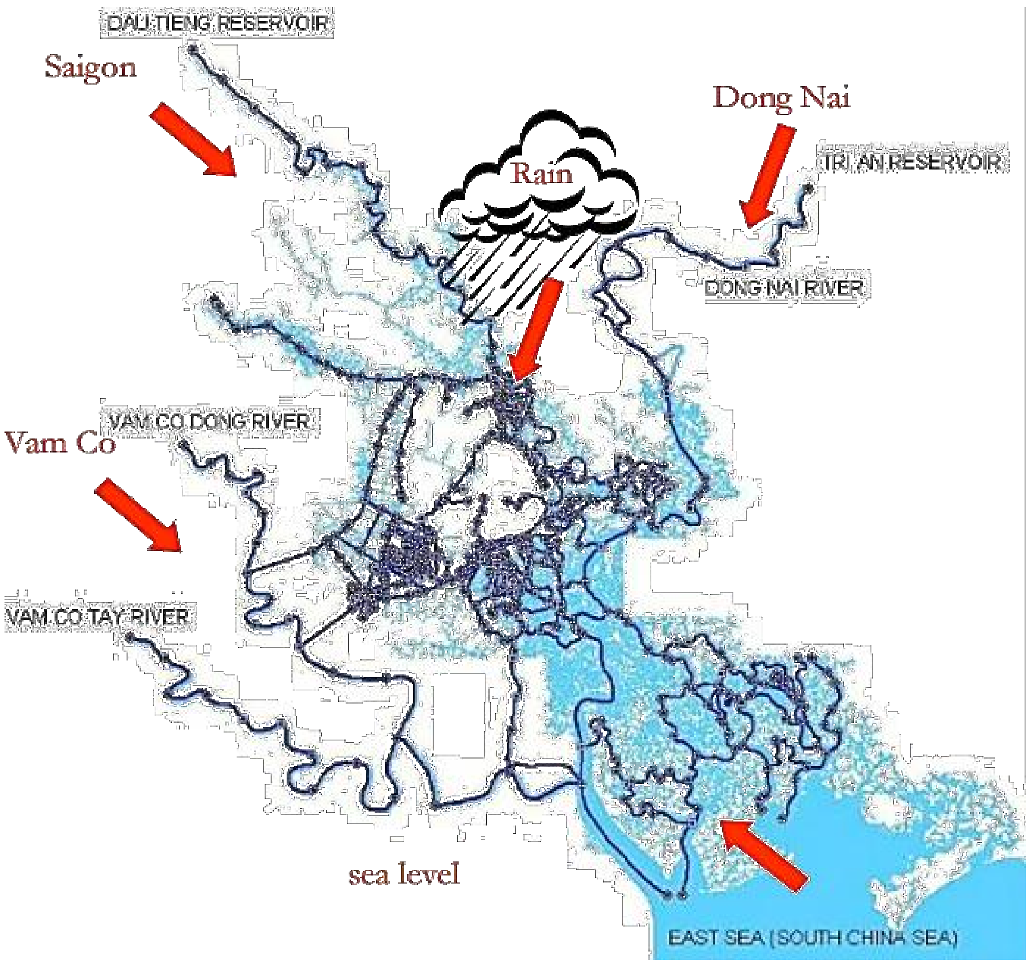
One of the most exposed urban areas in the world to climate change dynamics.

Regular and extreme flooding as 40–45 percent of land cover has elevation between 0 and 1 m.

Tides, storm surges, heavy rains in city or in the upper watershed and typhoons.

By 2100 1/5 of the total urban area is at risk of being under water.

Hydrological system in HCMC



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District 7 HCMC

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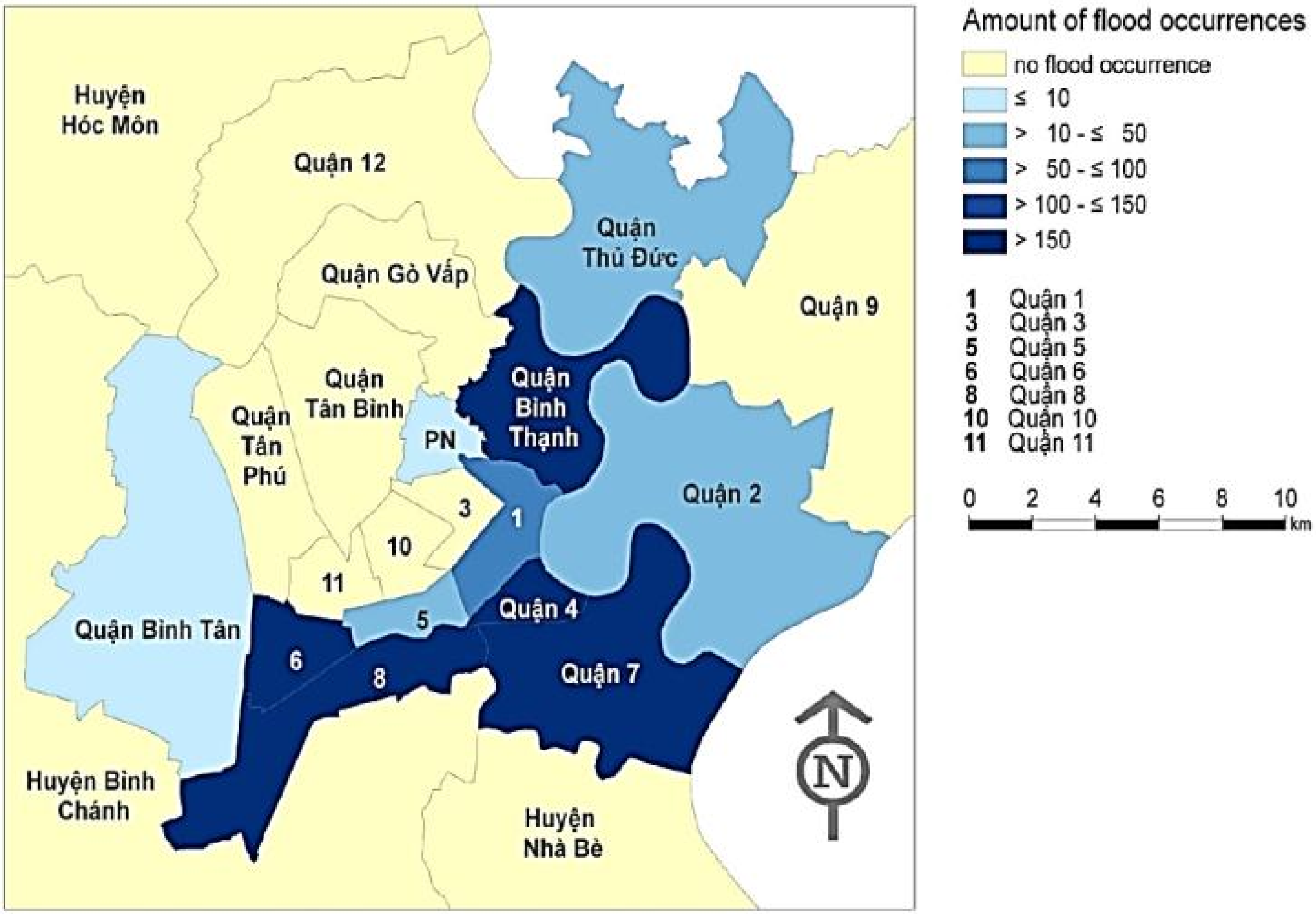
Flood occurrences in HCMC



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Methodological steps

1. Modelling urban area development
2. Flood modelling under different climate scenarios
3. Estimation of Value at Climate Risk
4. Identification and assessment of adaption measures
5. Development of adaptation cost curve

Modelling urban area development

Zones	Completion level (%)	Land use changes by 2025
Tan Thuan Export Processing Zone	100%	The construction currently covers 81.7% of the total area (HEPZA 2016). It is expected that the construction phase will be completed by 2025. The port areas of Ben Nghe and Tan Thuan will be transformed into mixed-use developments. It is assumed that the development will follow the master plan of Tan Thuan Export Processing Zone (see Annex 1a).
Phu My Hung Urban	100%	The expansion and development of the Phu My Hung Urban area is expected to be completed by 2025 (see Annex 1b).
Settlements 1 and 2	100%	By 2025, the total surface area of Settlements 1 and 2 will remain unchanged and will be characterised by higher density.
Zone 5	50%	Currently covered by green areas, Zone 5 is expected to become a regional park with 82.1 hectares of green areas and 35.7 hectares of residential and commercial buildings by 2035. These developments will be 50% completed by 2025 (Annex 1c).

Modelling urban area development

Class		Area (ha)		Changes (±ha)	Building density
		2010	2025		
1	Cemetery	89.4	1.0	+ 145.3	40%
	Education		146.1		
	Military		8.7		
	Religious		1.5		
	Public		77.4		
2	Agriculture	294.4	0	-294.4	0%
3	Mixed-used	0	190.4	+190.4	40%
4	Residential	1267.3	1139.1	-128.2	60%
5	Green	8.6	404.5	+395.9	0%
6	Roads	404.4	466.5	+62.1	100%
7	Industrial	483.4	278.7	-204.7	40%
	Commercial	111	38.1	-71.9	
8	Rivers and canals	889.4	778.2	-111.2	0%
	Total	3530.0	3530.0		

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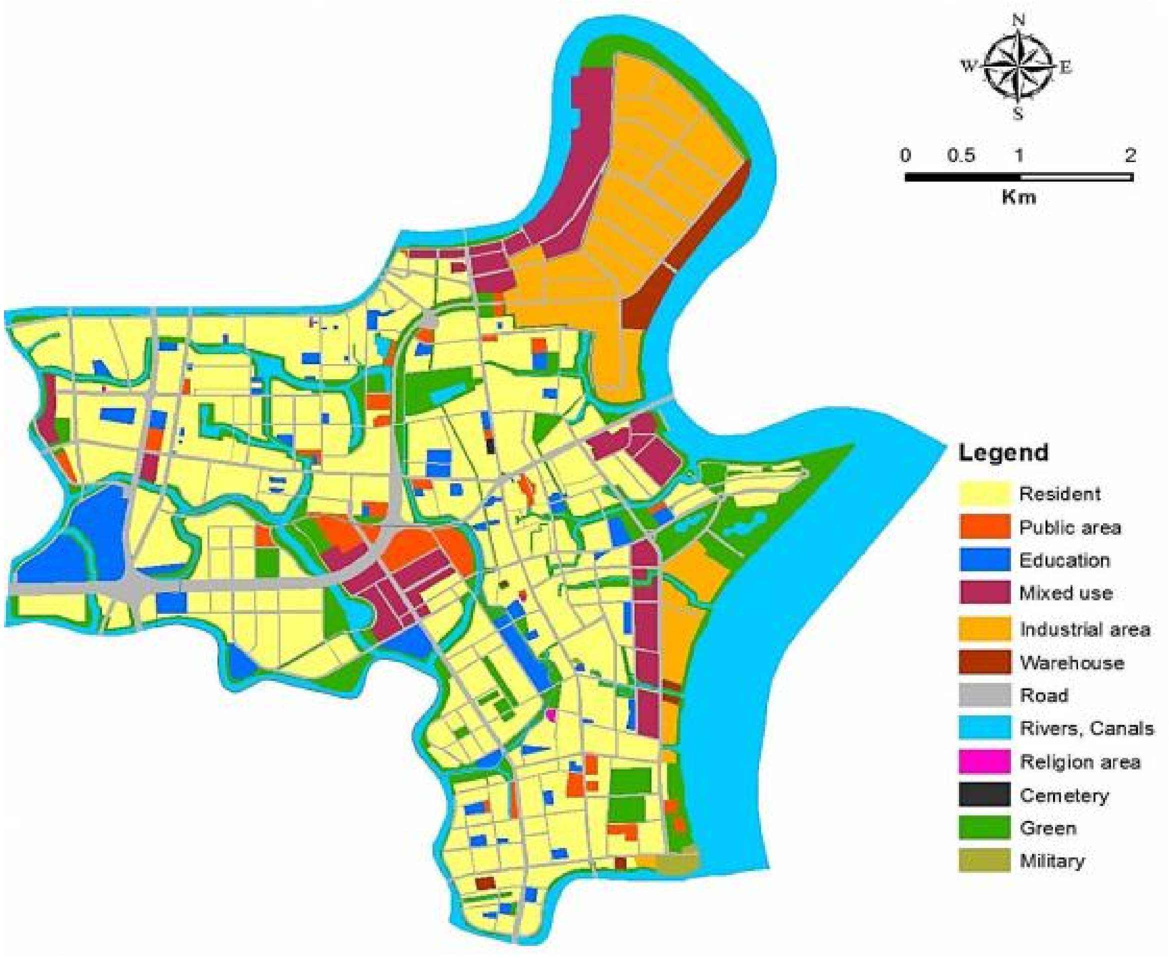
Modelling urban area development



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Climate scenarios and flooding

- **Total area of District 7 divided into grid cells of 10m by 10m and hydraulic model TELEMAC2D used to estimate future flood frequencies and depths in 2025.**
- **Five flood drivers (i.e. rainfall, downstream water level, upstream flow, flood measures and elevation) to estimate potential inundation.**
- **Two scenarios obtained by combining different estimates of the five flood drivers (i.e. moderate and extreme).**
- **For each scenario four inundation maps are created corresponding to four flood frequencies (1:1; 1:10; 1:100; 1:1000).**

Climate scenarios and flooding

Drivers	Current baseline (2015)	Future estimations (2025)	
		Moderate scenario	Extreme scenario
Rainfall	116.5mm/3h	+2 %	+4 %
Downstream water level	Water level at Vam Kenh station 1.52 m, 1.73 m, 1.83 m, 1.92 m corresponding to 4 frequencies periods (1/1, 1/10, 1/100, 1/1000)	+10 cm	+ 20 cm
Upstream flow	Dau Tieng Saigon river 513m3/s Phuc Hoa, Tri An and Dong Nai rivers 4590 m3/s	No change	No change
Flood measures	Implementation ongoing	Efficiency 100 %	Efficiency 50 %
Elevation	See DOST (2012)	Local change elevation	Local change elevation

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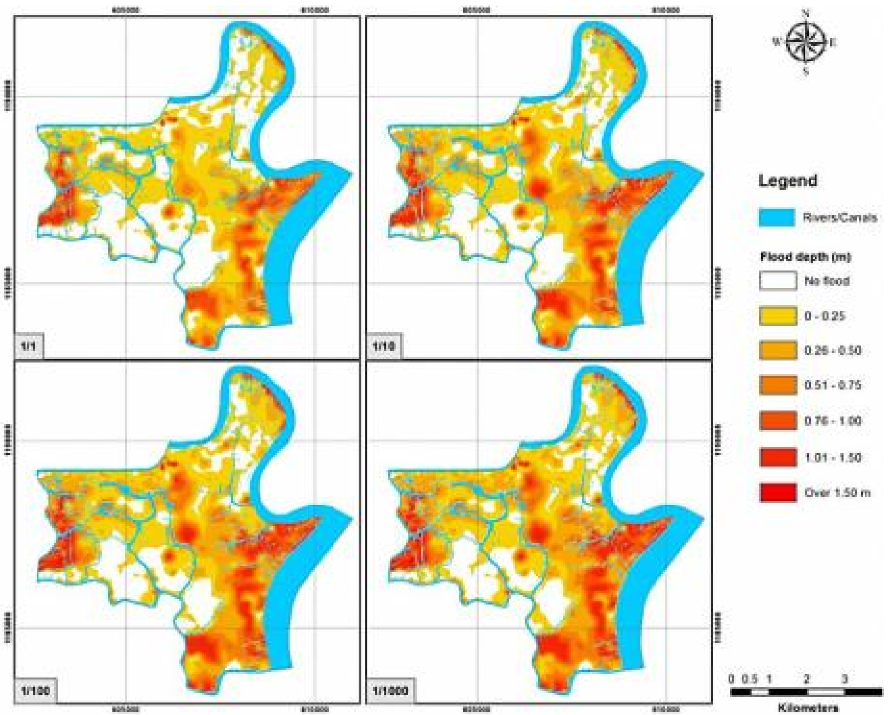
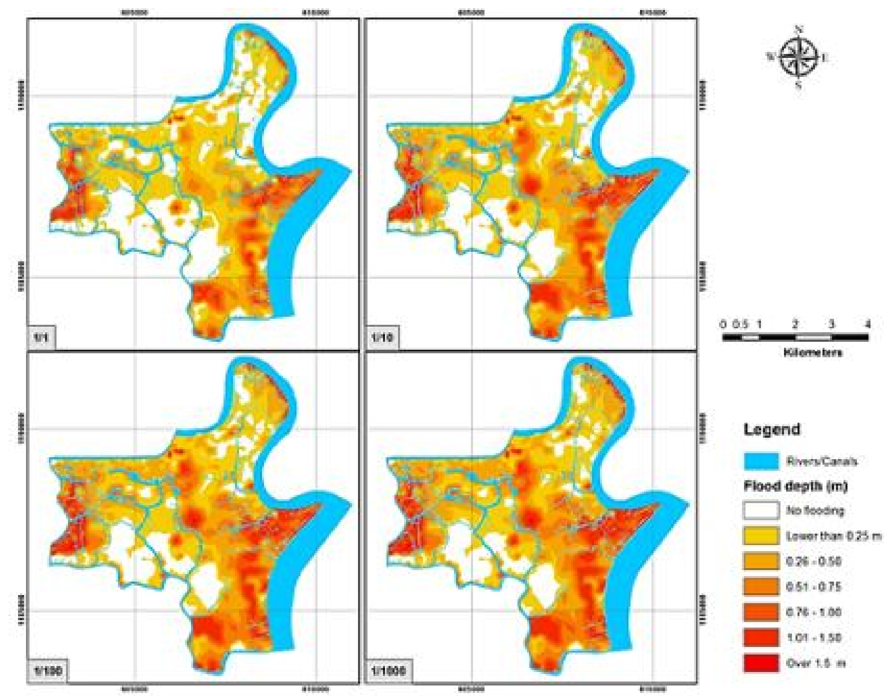
Climate scenarios and flooding





Estimation of Value at Climate Risk

Estimation of the Value at Climate Risk at each flood frequency under both the moderate and extreme scenarios:

$$D = \sum_{j=1}^{n} \sum_{k=1}^{m} c_{jk} \times S_{jk} \times d_{max_j}$$

D = total damage (VND) at one frequency

c = damage factor (%)

S = inundated area (m^2)

d_{max} = maximum damage per area (VND/m^2)

j = land use class

n = number of land use classes

k = inundation depth (m)

m = level of inundation depth (m)

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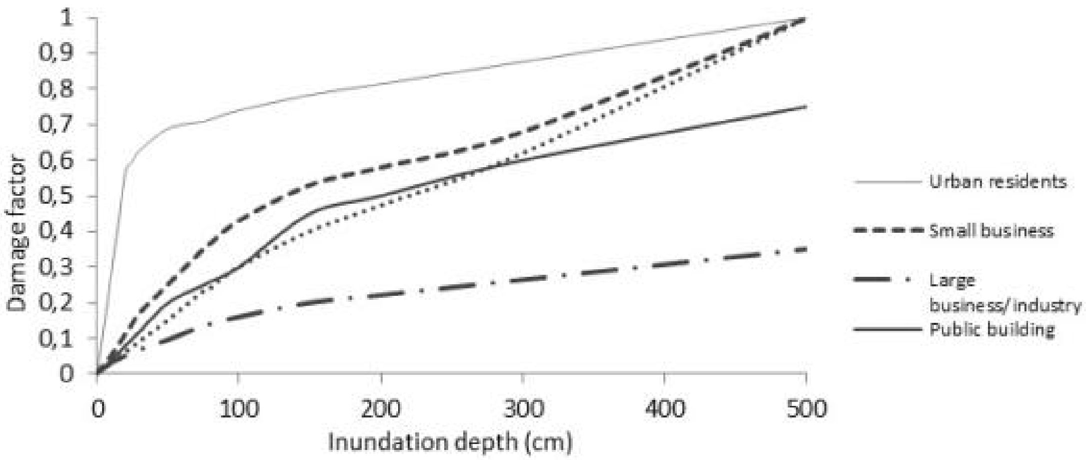
Estimation of Value at Climate Risk



Land use class	Maximum damage d_{max} (VND per m²)	Damage factor c (%) per inundation depth (cm)												
		10	15	20	25	30	50	75	80	100	150	200	300	500
Residential	603,000	0.27	0.40	0.54	0.57	0.59	0.66	0.68	0.69	0.72	0.76	0.80	0.87	1.00
Furniture	126,000	0.29	0.43	0.57	0.60	0.63	0.69	0.71	0.72	0.74	0.78	0.81	0.88	1.00
Small business	772,000	0.05	0.08	0.11	0.14	0.17	0.25	0.35	0.37	0.43	0.53	0.58	0.68	1.00
Large businesses	772,000	0.03	0.04	0.05	0.06	0.07	0.10	0.14	0.14	0.16	0.20	0.22	0.27	0.35
Roads	8,000	0.03	0.05	0.06	0.08	0.09	0.15	0.23	0.24	0.30	0.40	0.47	0.62	1.00
Public buildings	556,000	0.04	0.06	0.08	0.10	0.12	0.20	0.25	0.26	0.30	0.45	0.50	0.60	0.75

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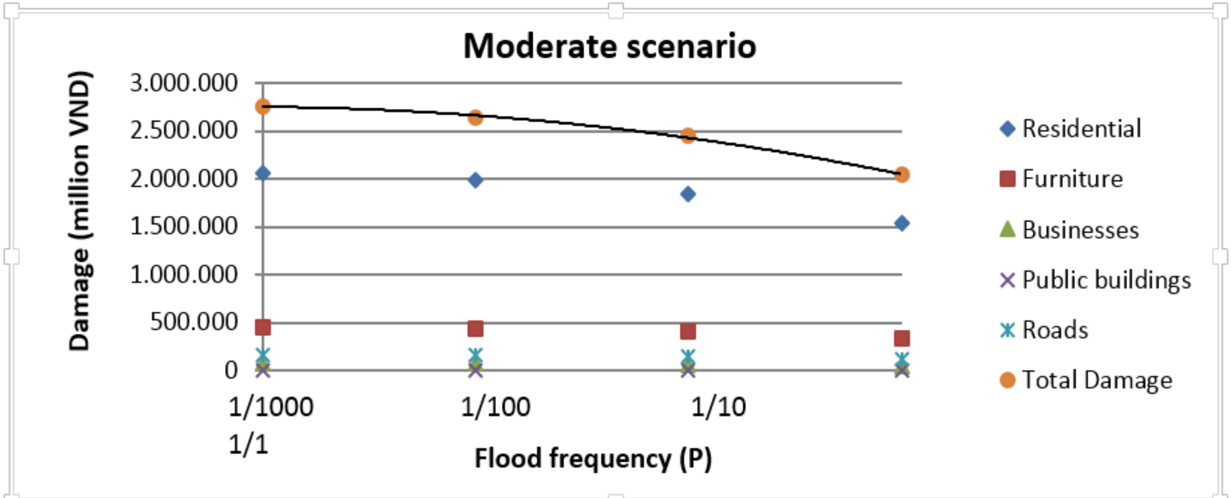
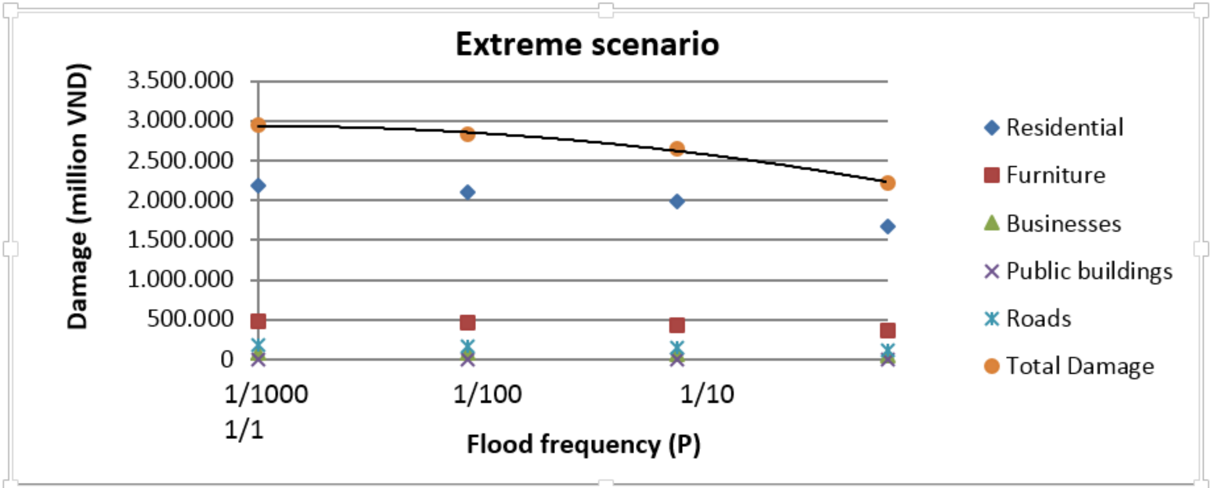
Estimation of Value at Climate Risk

Land use class	D (p) - million VND			
	1/1	1/10	1/100	1/1000
Residential	1,543,391	1,846,350	1,981,536	2,066,463
Furniture	339,929	405,177	434,069	452,154
Businesses	43,746	59,679	68,826	76,547
Public buildings	2,937	3,915	4,436	4,818
Roads	112,890	139,083	153,033	163,314
Total Damage	**2,042,893**	**2,454,205**	**2,641,901**	**2,763,296**



Estimation of Value at Climate Risk

Land use class	D (p) – million VND			
	1/1	1/10	1/100	1/1000
Residential	1,676,154	1,986,231	2,108,864	2,192,115
Furniture	368,680	435,081	461,200	478,947
Businesses	50,835	69,075	80,294	88,560
Public buildings	3,315	4,450	5,009	5,421
Roads	122,488	153,523	168,224	178,750
Total Damage	**2,221,471**	**2,648,359**	**2,823,590**	**2,943,794**



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Estimation of Value at Climate Risk

The total damage (D) calculated in VND at each frequency used to create an annual probability-damage curve which allows to calculate the Expected Annual Damage (EAD) by aggregating damage estimates for different probabilities and taking the integral under the probability-damage curve.

$$EAD = \int_{p_1}^{p_2} D(p)dp$$

D(p) = expected damage for a given probability p

p_1 = probability of an extreme flood event

p_2 = probability of a moderate flood event that causes insignificant damages

Estimation of Value at Climate Risk

Value at Climate Risk (moderate scenario): 2,144,315 million VND

Value at Climate Risk (extreme scenario): 2,322,990 million VND

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Adaptation measures

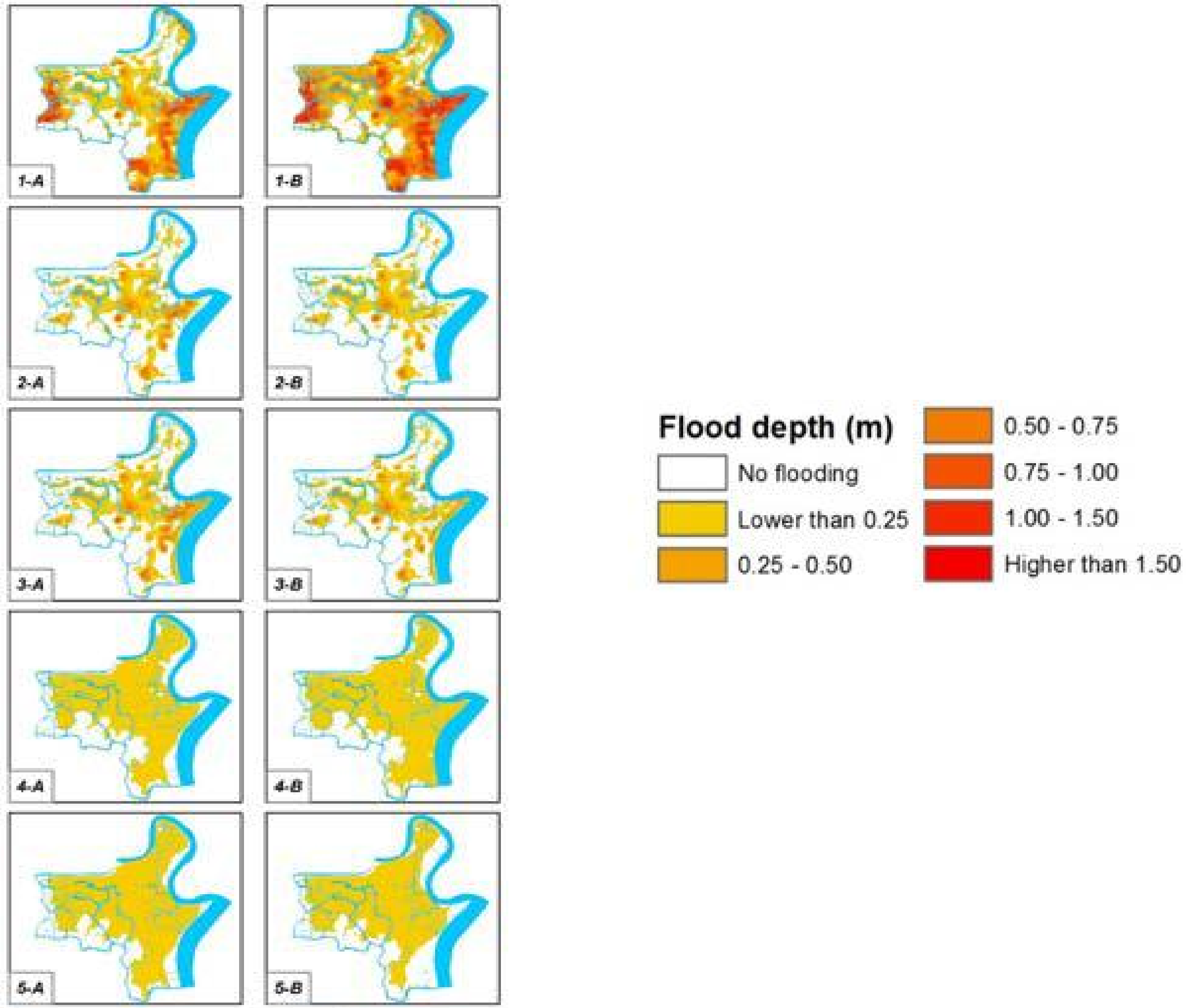
Land elevation

- Sub-option 1 (lower protection against flooding): H = 2.0 m a.s.l. and landfill volume = 12,194,866 m3 (based on GIS estimation)
- Sub-option 2 (higher protection against flooding): H = 2.2 m a.s.l. and landfill volume = 16,473,183m3 (based on GIS estimation)

Ring dike

- Sub-option 1 (lower protection against flooding): high dike of 2.3 m a.s.l. to protect District 7 from floods by the Nha Be River on the east side and the Sai Gon River on the south-east side and low dike of 2.1 m a.s.l. for inner water bodies
- Sub-option 2 (higher protection against flooding): high dike of 2.7 m a.s.l. to protect District 7 from floods by the Nha Be River on the east side and the Sai Gon River on the south-east side and low dike of 2.5 m a.s.l. for inner water bodies

Adaptation measures



Adaptation measures

Moderate scenario			
Adaptation options	**Flood frequencies**	**Total damage (million VND)**	**EAD (million VND)**
Land elevation 2.2 m a.s.l.	1/1	1,336,338	1,313,310
	1/10	1,297,035	
	1/100	1,269,524	
	1/1000	1,287,904	
Land elevation 2.0 m a.s.l.	1/1	1,393,600	1,370,545
	1/10	1,354,657	
	1/100	1,326,883	
	1/1000	1,307,074	
Ring dike 2.7 m a.s.l. and 2.5 m a.s.l	1/1	1,157,319	1,126,694
	1/10	1,104,386	
	1/100	1,082,919	
	1/1000	1,022,580	
Ring dike 2.3 m a.s.l. and 2.1 m a.s.l	1/1	1,226,690	1,186,815
	1/10	1,155,955	
	1/100	1,140,086	
	1/1000	1,122,111	

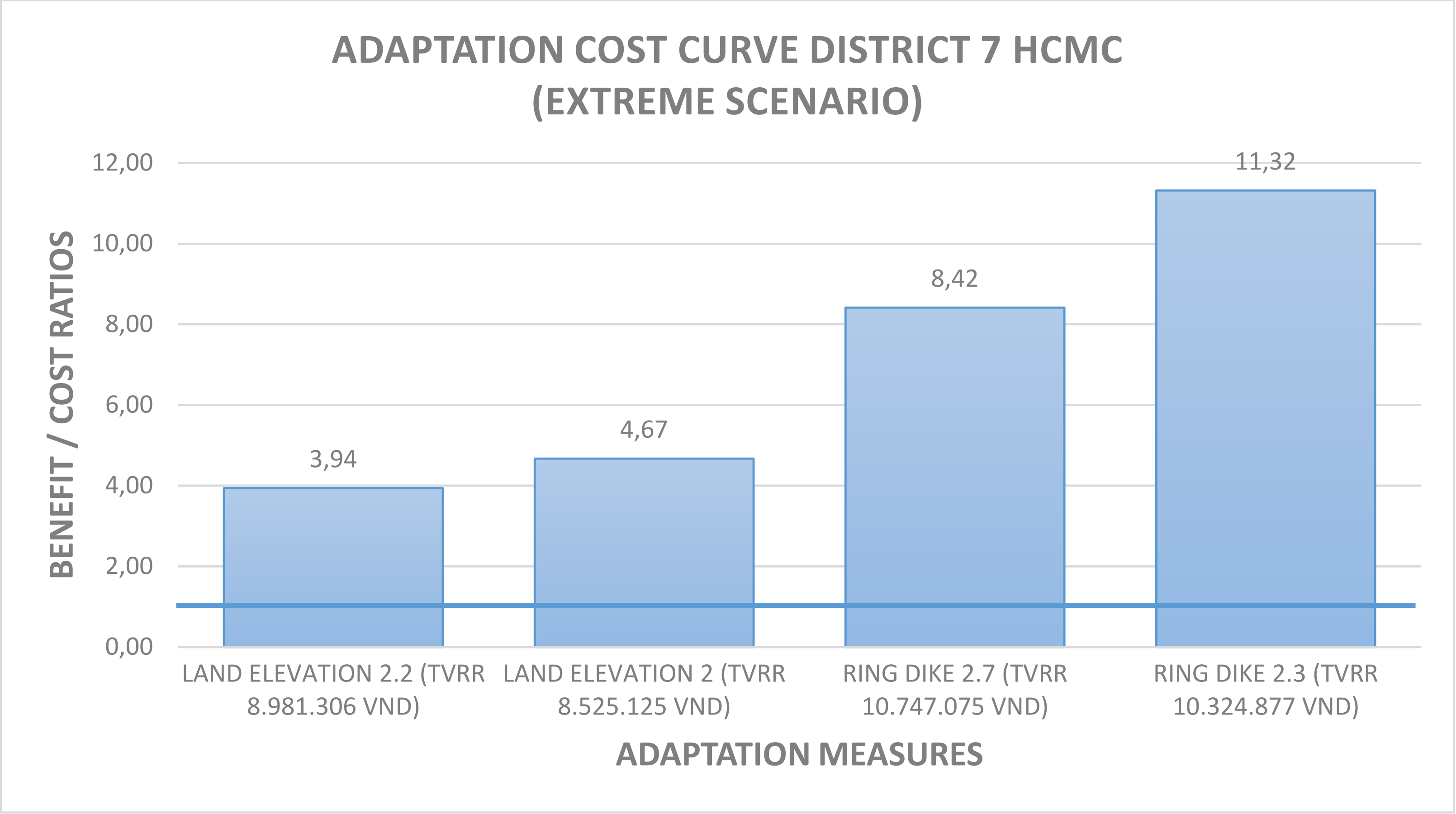
Extreme scenario			
Adaptation options	**Flood frequencies**	**Total damage (million VND)**	**EAD (million VND)**
Land elevation 2.2 m a.s.l.	1/1	1,344,837	1,318,427
	1/10	1,291,436	
	1/100	1,340,529	
	1/1000	1,387,907	
Land elevation 2.0 m a.s.l.	1/1	1,401,186	1,369,451
	1/10	1,346,770	
	1/100	1,317,231	
	1/1000	1,284,137	
Ring dike 2.7 m a.s.l. and 2.5 m a.s.l	1/1	1,130,152	1,120,925
	1/10	1,121,426	
	1/100	1,040,651	
	1/1000	1,043,369	
Ring dike 2.3 m a.s.l. and 2.1 m a.s.l	1/1	1,192,741	1,168,148
	1/10	1,150,445	
	1/100	1,128,447	
	1/1000	1,106,551	

Adaptation cost curve

$$\text{NPV} = \sum_{t=1}^{T} \frac{(B_t - C_t)}{(1+r)^t}$$

- **Adaptation measures have a life cycle of 20 years**
- **Discount rate is 5% as prescribed by the National Bank of Vietnam**
- **Land elevation and the ring dike have a construction period of 3 years (year 1 = 40% of construction costs, year 2 = 30% of construction costs, year 3 = 30% of construction costs)**
- **The value of EAD reduction is set constant during the period 2025 - 2035 at the 2025 reference value whereas in 2019 it is set at 70% of the 2025 reference value, in 2020 it is set at 75% of the 2025 reference value, in 2021 it is set at 80% of the 2025 reference value, in 2022 it is set at 85% of the 2025 reference value, in 2023 it is set at 90% of the 2025 reference value, and in 2024 it is set at 95% of the 2025 reference value**

Adaptation cost curve



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Limitations

- 10-year time frame
- Downscaling climate and flood models
- High degree of uncertainty in flood damage simulations both in terms of data limitations and model assumptions
- Underestimation of Value at Climate Risk
- Spillover effects

?

Estimation of Value at Climate Risk

$$EAD = \int_{p_1}^{p_2} D(p)dp$$

$$D(p) = a - b \times ln(p)$$

$$EAD = \int_{p_1}^{p_2} [a - b \times \ln(p)]dp = (a + b)(p_2 - p_1) - bp_2\, ln(p_2) + bp_1 ln(p_1)$$

Value at Climate Risk (moderate scenario): 2,144,315 million VND

Value at Climate Risk (extreme scenario): 2,322,990 million VND

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