Coastal Adaptation Mixing Gray and Green Infrastructures to Climate Change in Vietnam

Makoto Tamura

*Institute for Global Change Adaptation Science, Ibaraki University, Japan
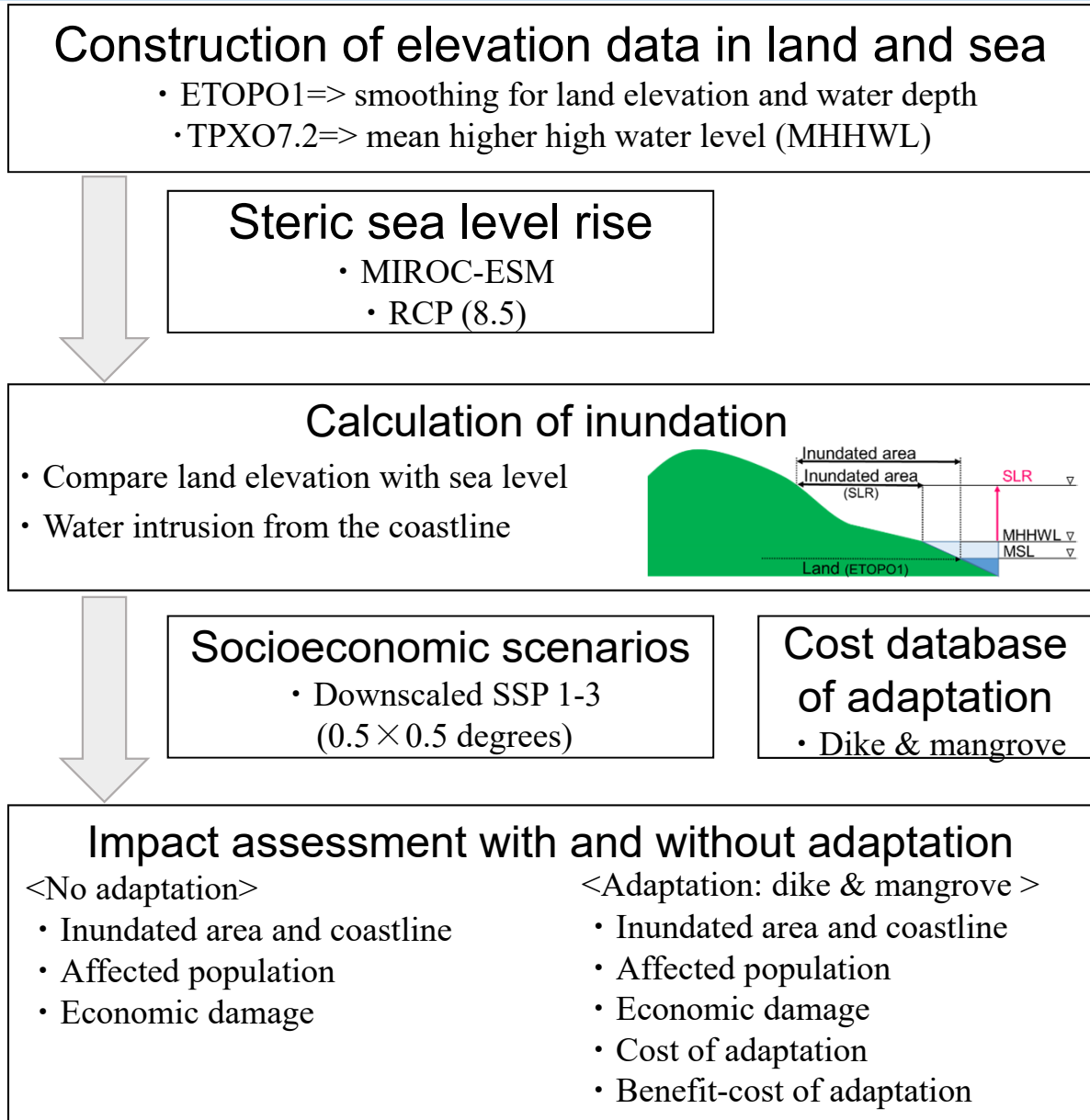
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Soc Trang, Vietnam, 2015

Tamura et al.(2018)

Method

- Impact assessment with and without adaptation
  - Dike and mangrove

Kumano et al.(2018)

Construction of elevation data in land and sea
- ETOPO1=> smoothing for land elevation and water depth
- TPXO7.2=> mean higher high water level (MHHWL)

Steric sea level rise
- MIROC-ESM
- RCP (8.5)

Calculation of inundation
- Compare land elevation with sea level
- Water intrusion from the coastline

Socioeconomic scenarios
- Downscaled SSP 1-3
  $(0.5 \times 0.5$ degrees$)$

Cost database of adaptation
- Dike & mangrove

Impact assessment with and without adaptation

<No adaptation>
- Inundated area and coastline
- Affected population
- Economic damage

<Adaptation: dike & mangrove >
- Inundated area and coastline
- Affected population
- Economic damage
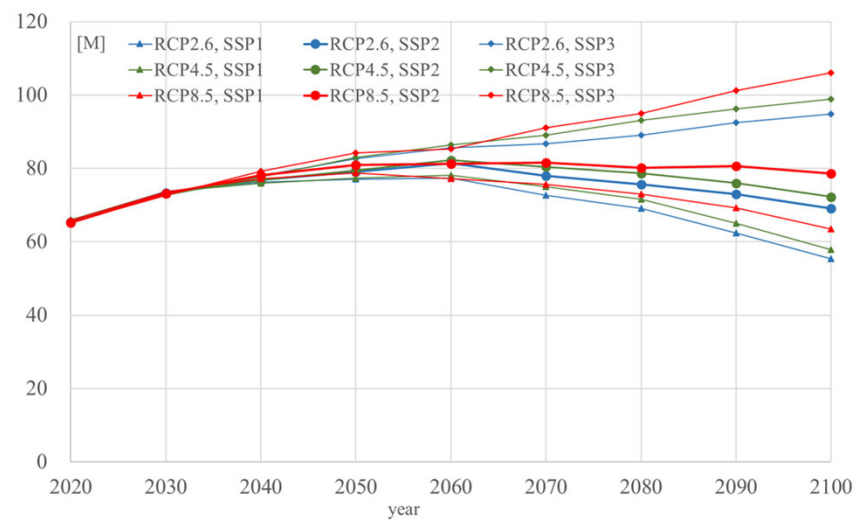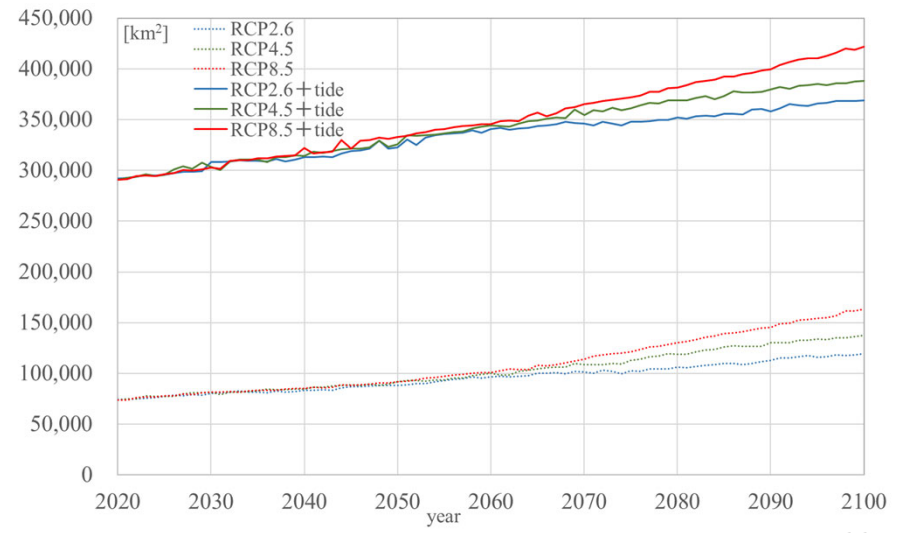- Cost of adaptation
- Benefit-cost of adaptation

Potentially inundated area（SLR&tide）

inundated area

- SLR by MIROC-ESM
- Potentially inundated areas is calculated without protection
- SSP1-3 scenarios(0.5°*0.5°)
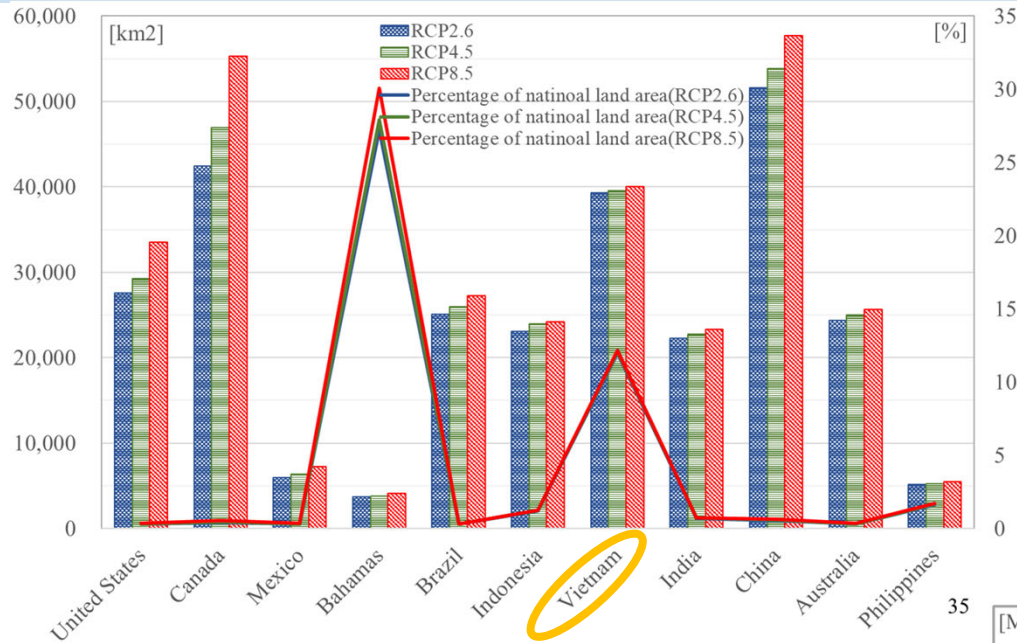 - Murakami and Yamagata(2016)

Potential inundated areas due to SLR and high tide at 2100 (MIROC-ESM, RCP8.5)

Potentially inundated areas and affected population due to SLR and high tide (MIROC-ESM)

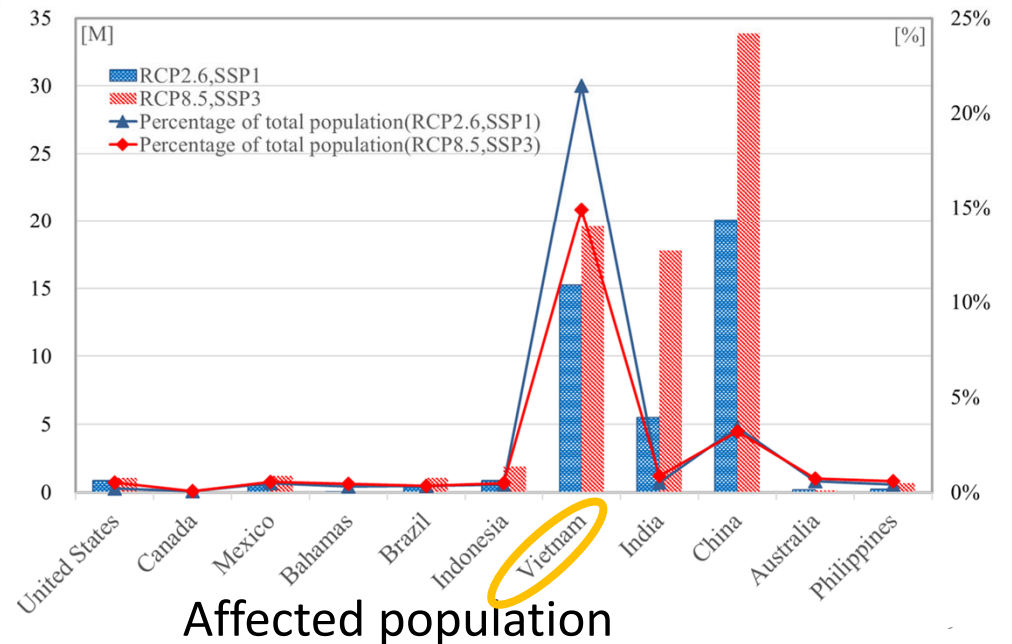Modified from Yotsukuri et al.(2017)

Coastal inundation due to SLR in some countries （MIROC-ESM）

Potentially inundated areas

- Inundated rate= potential inundated area/Land area
- MIROC-ESM, RCP/SSP
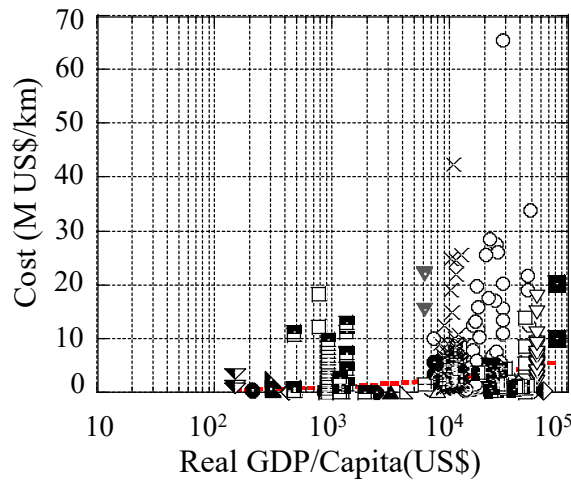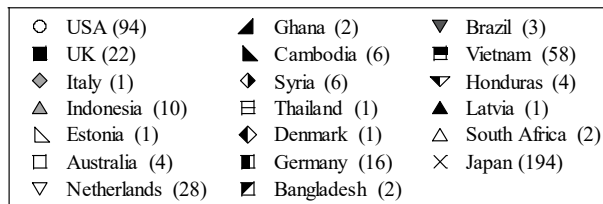- Top 10 inundated countries are almost the same regardless of GCMs (Tsuchida et al. 2018)
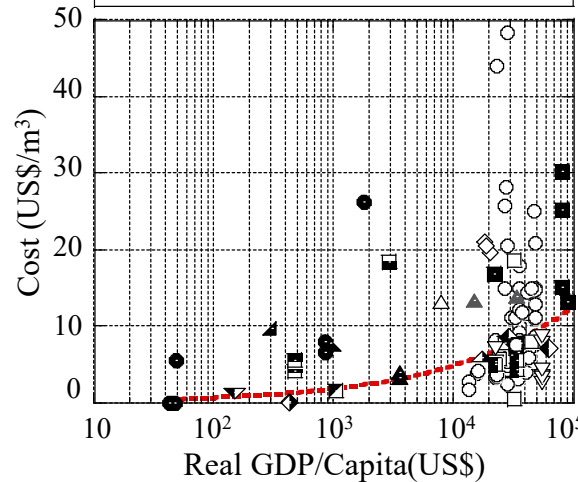

Affected population

Modified from Yotsukuri et al.(2017)

Cost of coastal adaptation

- Design standards and cost database of adaptations from world projects

Unit cost of coastal adaptations (Kumano et al. 2018)
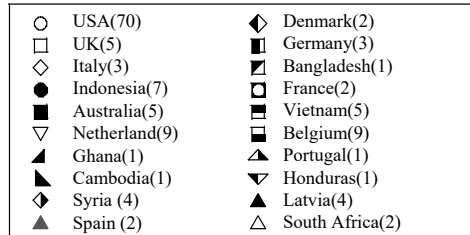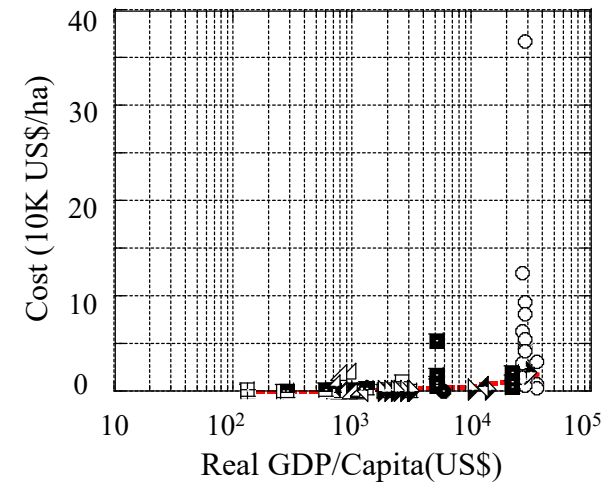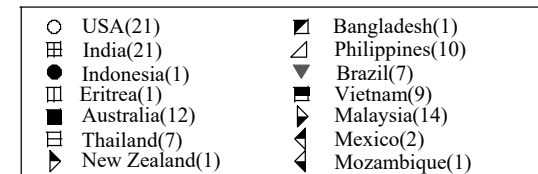
Assessment of adaptations

Case 1: Dike protection only
Case 2: Combination of dikes and mangroves

- Case 1: Dikes will be constructed along the entire inundated coastline in response to SLR.

- Case 2: Mangroves will be planted periodically in inundated coastal areas where mangrove forests already exist. Dikes will be only constructed along inundated coastline where there is no mangrove forests.

Assumptions

Dike	Durability is 30 years
Mangrove	Forest grows for 30 years
	Forest life is 50 years
	2% decrease in area per year

250m

1km

Around 250m of mangroves along the coast are assumed to have a protection effect equivalent to the same length of dike.
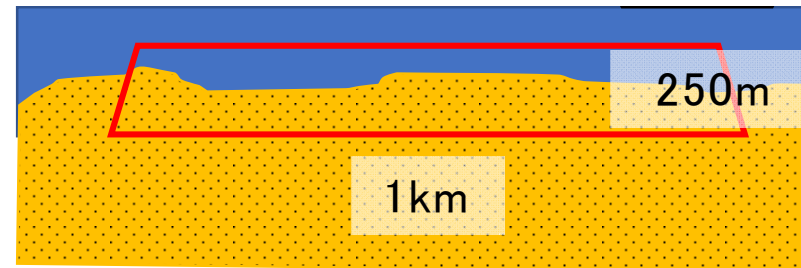
Construction Costs

$$\Delta AC_t = \sum \Delta L_{j,t} \cdot UC_{j,t} + \sum MC_{j,t}$$

$$MC_{j,t} = \frac{1}{d} \left(\Delta L_{j,t} \cdot UC_{j,t} \right)$$

$\Delta L_{j,t}$(km): Length of the inundated coastline (km)
$MC_{j,t}$(US$): Maintenance Cost
$d(year)$: $Durability$(30 years)
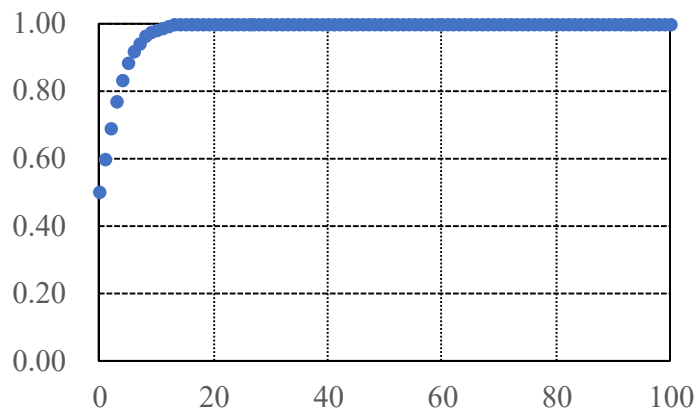
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Mangrove protection

- Growth scenarios of planting mangrove

  - Growth rate: sigmoid type

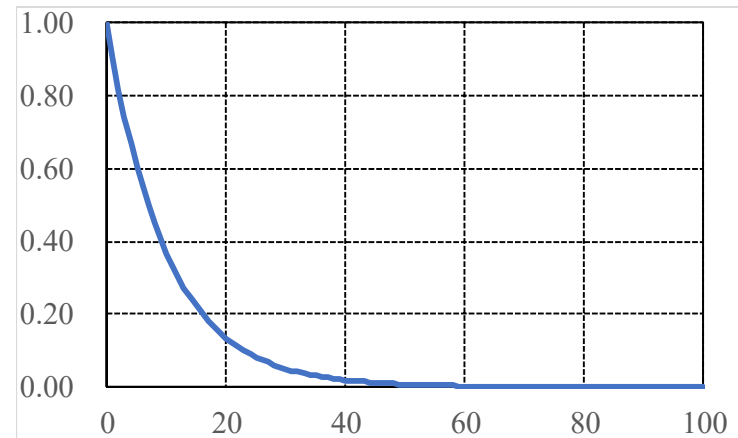 $$Y_t = \frac{BA}{1+e^{-at}}$$

    BA : area of mangrove

    a : growth parameter(0.4)

  - Survival rate :

    $$s_t = e^{-\alpha t} \qquad Y_t^s = s_t \cdot Y_t$$

    α : lifetime parameter(0.1)

- Plant every 5 years to compensate the decreased amount

  - Initial and maintenance costs

    Amount of planting $\quad M_t = \left(Y_t - \sum Y_t^s \right) Y_{t-n} + 0.1 Y_{t-n}$

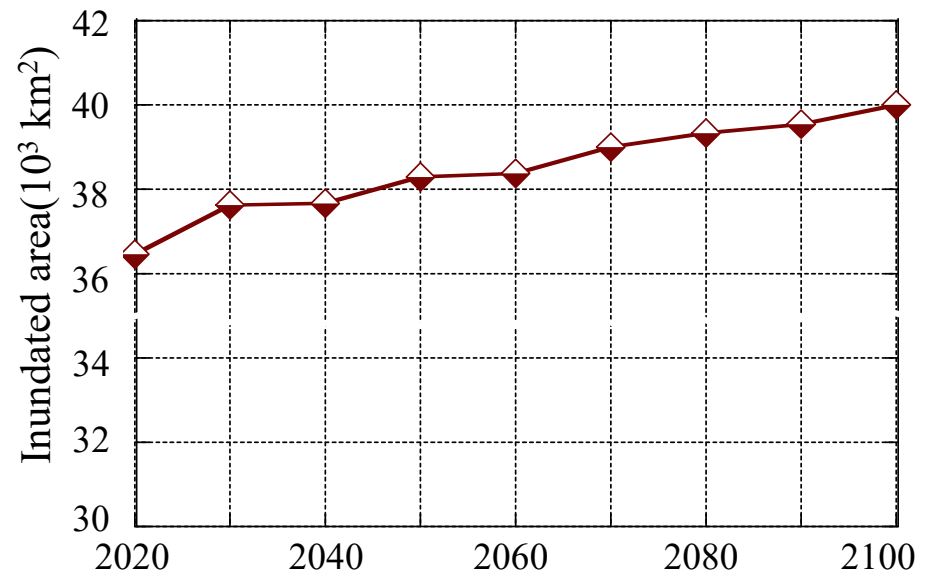   Cost of planting $\quad AC_{mangrove} = M_t \cdot c_{mangrove}$
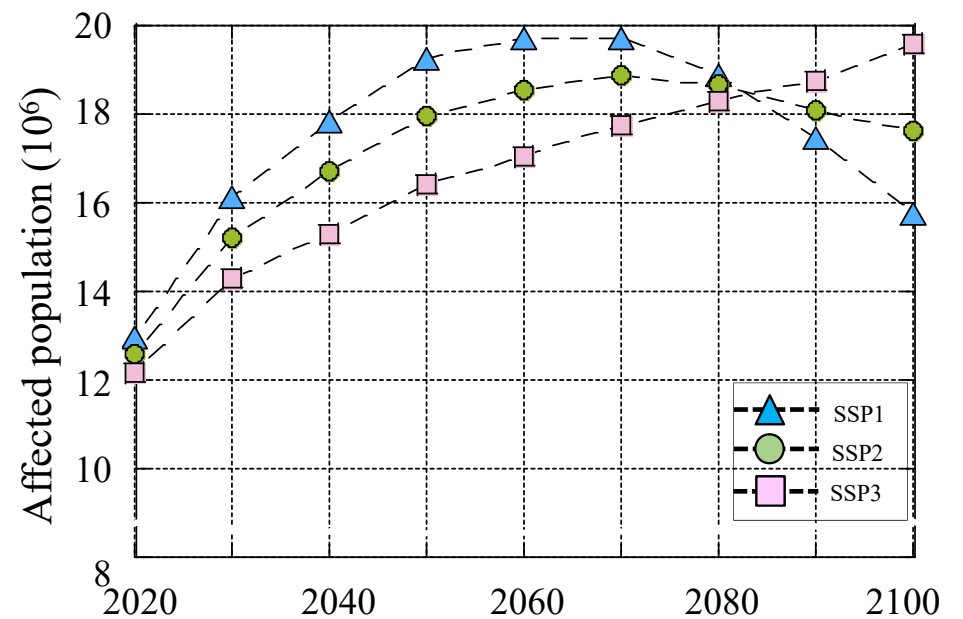
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Impacts of SLR

Potentially inundated area in 2100 and mangrove distribution
(MIROC-ESM, RCP8.5, TroCEP)

Legend:
- Land
- Mangrove
- Mangrove outside of land
- Ocean
- Inundated area

Inundated area(10^3 km^2) vs year (2020–2100)

Potentially inundated area under RCP8.5

Affected population (10^6) vs year (2020–2100)

- SSP1
- SSP2
- SSP3

Affected population under RCP8.5

Kumano et al.(2018)   11

Economic damage and adaptation cost in Vietnam (MIROC-ESM)

Economic damage due to SLR and tides (RCP8.5)
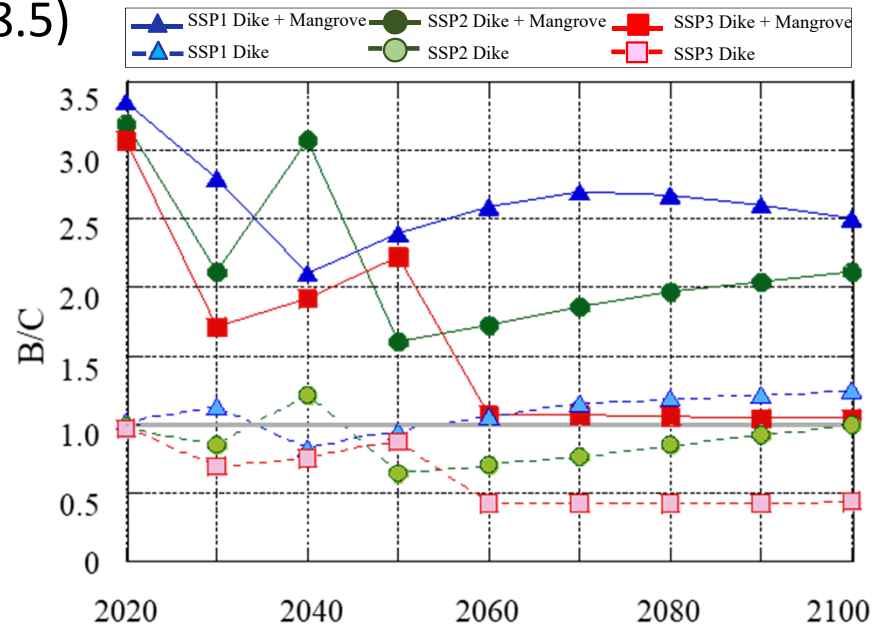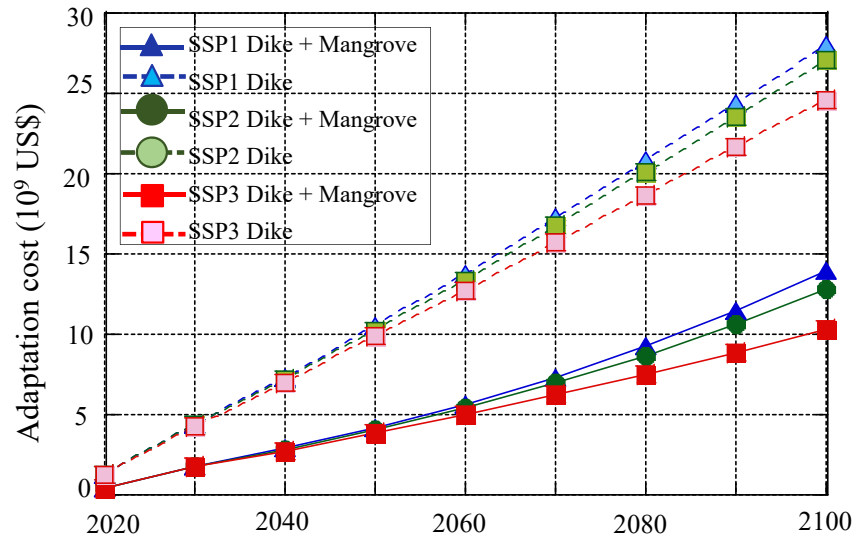
Cost of adaptation (RCP8.5)

- Economic damage > cost of adaptation
  - Cost of only dike > cost of mixing dike & mangrove

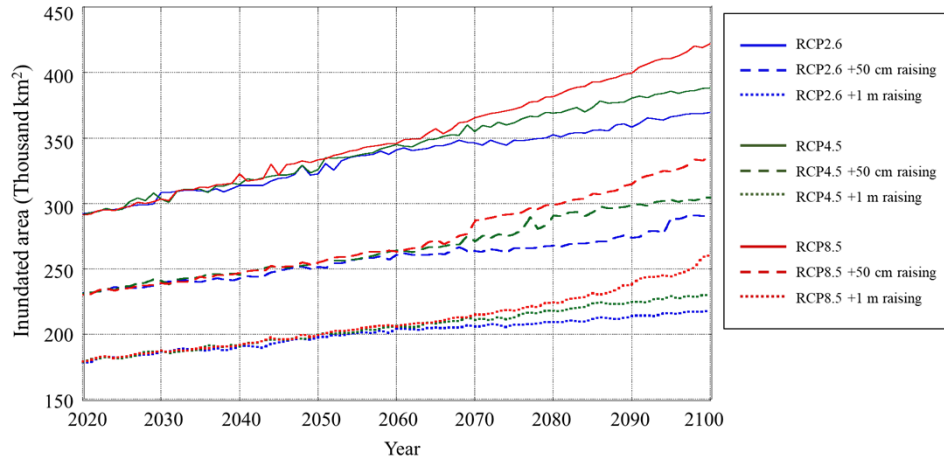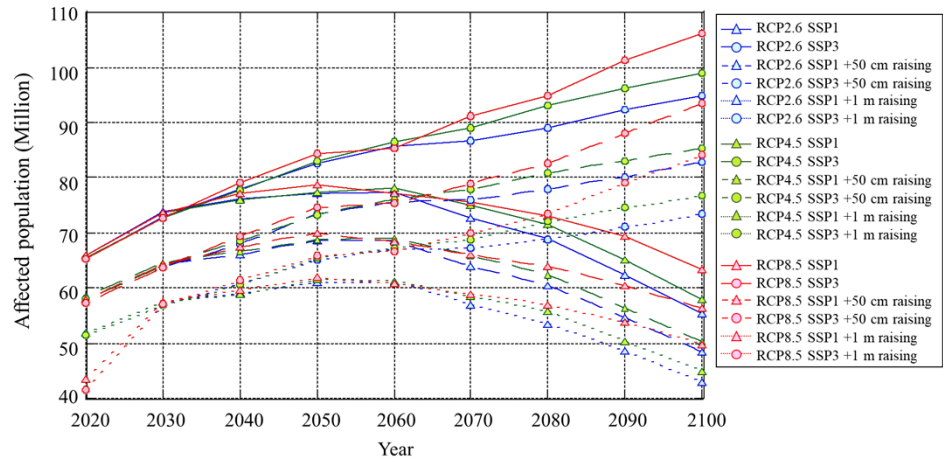Kumano et al.(2018)

B/C of adaptation (RCP8.5)

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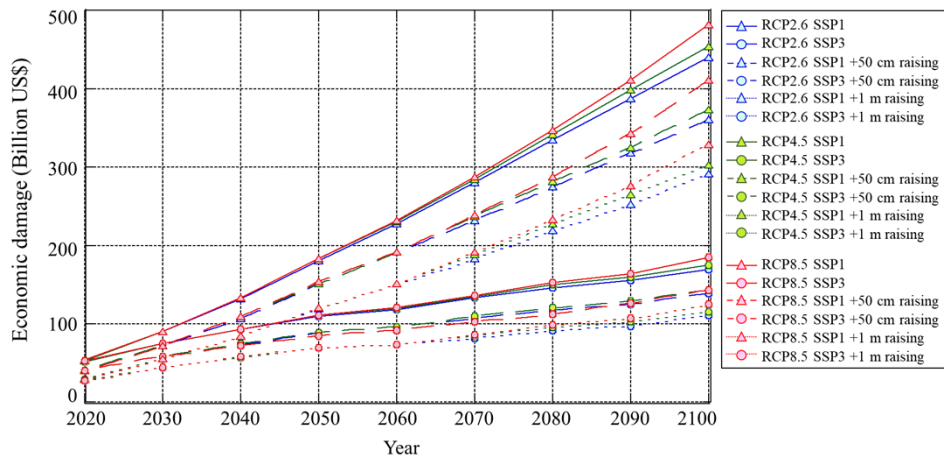# Economic damage and adaptation cost in the world (MIROC-ESM)

● Adaptation => raising dikes (new dikes or upgraded dikes)
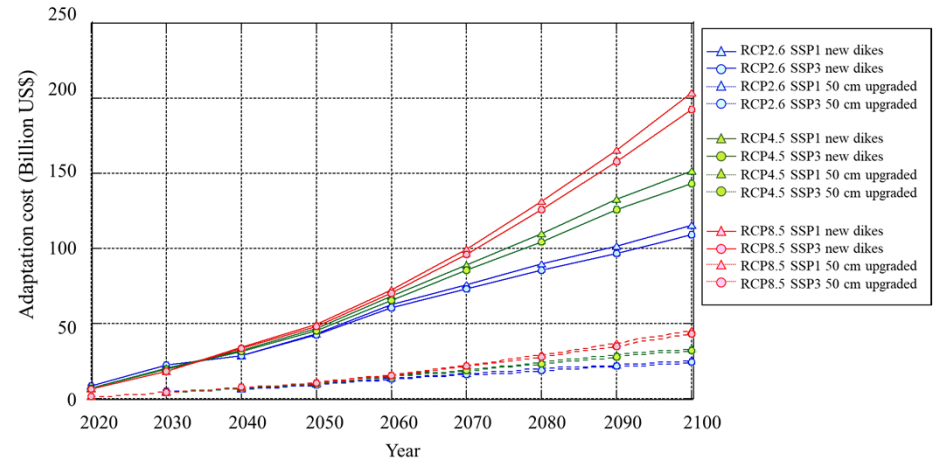

Inundated area w & w/o adaptation

Affected population w & w/o adaptation

Economic damage w & w/o adaptation
(three-function estimate)

Cost of adaptation

Tamura et al.(2019)

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Multiple Protection

- Mixed techniques which are suitable for local situation
- Multiple protection, harmonized with ecosystem and livelihoods
  - Artificial beach nourishment
  - Mangrove
  - Gabion

Artificial Beach Nourishment

Breaking wave

Reinforced Levee

Wave eater
(e.g., Distorted Ripple Mat)
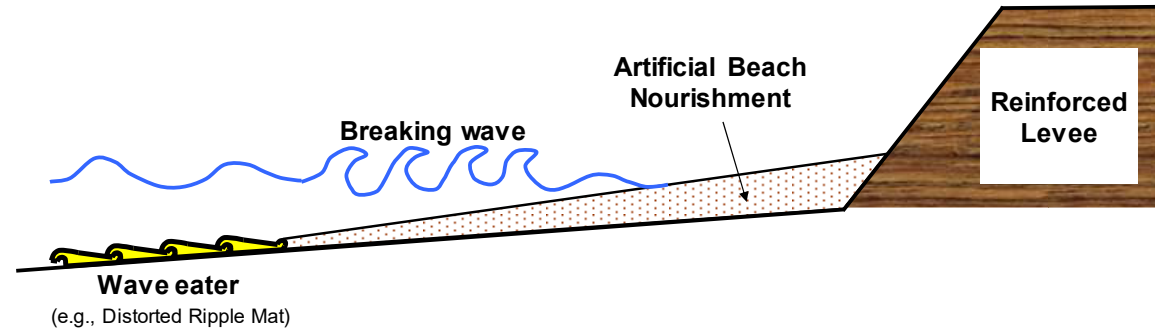
(a) Combination with artificial beach nourishment

Mangrove

Breaking wave

Reinforced Levee

Wave eater
(e.g., Distorted Ripple Mat)
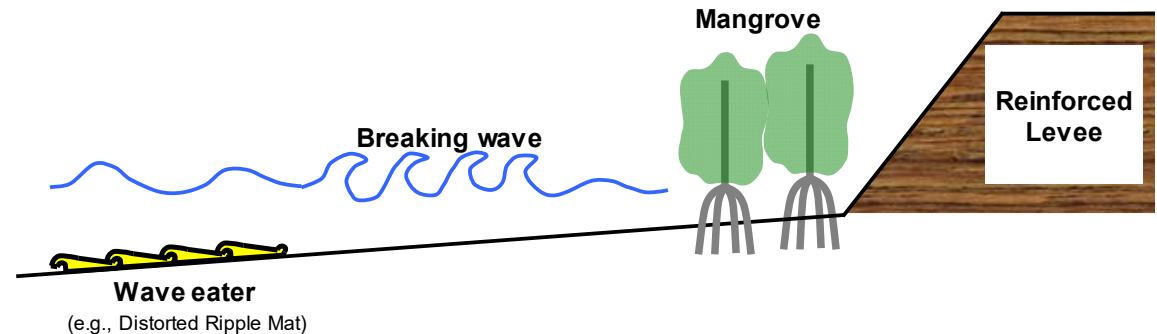
(b) Combination with mangrove plantation

Breaking wave

Gabion

Reinforced Levee

Wave eater
(e.g., Distorted Ripple Mat)
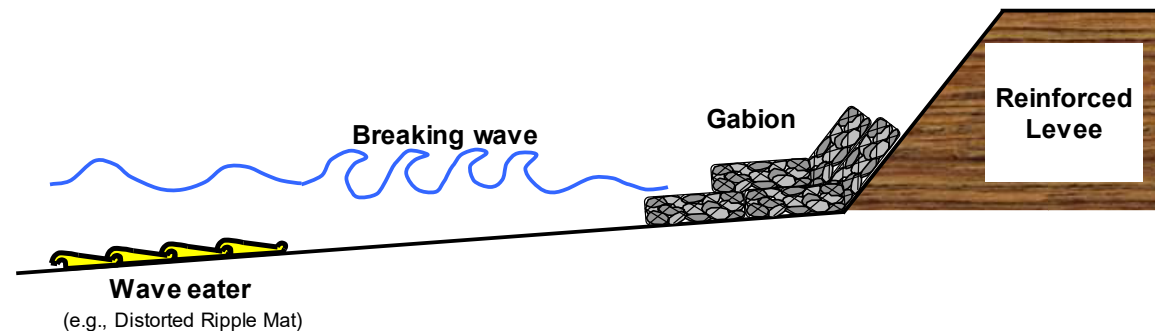
(c) Combination with gabion

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Yasuhara et al.(2016)

Optimal climate change adaptation strategies using green & gray infrastructures

- **From scientific assessments to policies**

Research image

Adaptation strategies using green & gray infrastructures in the coastal regions

① Climate impacts — SLR, erosion, agriculture; Typhoon, flood, erosion; SLR, erosion, agriculture

② Vulnerability assessment — Potentially inundated areas in 2100/RCP8.5(MIROC-ESM) and mangrove forests. Legend: Land, Coast with mangroves, Sea with mangroves, Sea, Inundated area

③ Adaptation data — ③-1 Extraction of coastal dikes; ③-2 Spatiotemporal analysis on mangroves
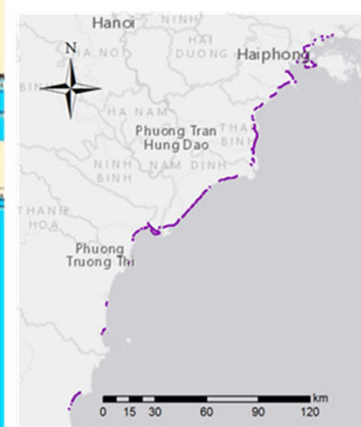
④ Adaptation technologies — Numerical analysis; Multiple protection (Breaking wave, Mangrove, Reinforced Levee, Wave eater)
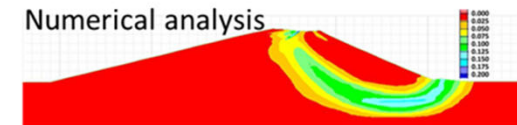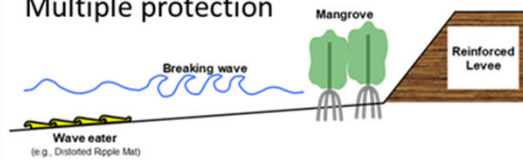
⑤ Zoning — 1. Nature rehabilitation zones 2. Social activities zones 3. Reform purposes zones

⑥ Assessment of adaptations — Safety, Productivity, Ecology, Longevity, Economy (A, B)
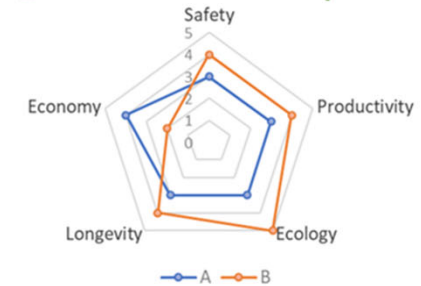
Concluding remarks

- Global impact assessment of SLR based on RCP/SSP
- Coastal vulnerability in the Mekong Delta and Red River Delta
- Impact and cost analyses of coastal protection using both gray and green infrastructures against SLR
  - Only dikes vs. mixing dikes and mangroves
    - Economic damage > cost of adaptation
  - Multiple protection, harmonized with ecosystem and livelihoods
- Resilient adaptation strategies that are suitable in local situation
  - Scientific assessment and collaboration with local stakeholders

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