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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Tamura et al. (2018)
Method

- Impact assessment with and without adaptation
  - Dike and mangrove

**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 × 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

Kumano et al. (2018)
Potentially inundated area (SLR&tide)

- SLR by MIROC-ESM
- Potentially inundated areas 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)

- 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)

Potentially inundated areas

Modified from Yotsukuri et al. (2017)
Cost of coastal adaptation

- Design standards and cost database of adaptations from world projects

**Dike/sea walls**

**Beach nourishment**

**Mangroves**

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

<table>
<thead>
<tr>
<th>Dike</th>
<th>Durability is 30 years</th>
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</thead>
<tbody>
<tr>
<td>Mangrove</td>
<td>Forest grows for 30 years</td>
</tr>
<tr>
<td></td>
<td>Forest life is 50 years</td>
</tr>
<tr>
<td></td>
<td>2% decrease in area per year</td>
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</tbody>
</table>

Construction Costs

\[
\Delta A_{C,t} = \sum \Delta L_{j,t} \cdot UC_{j,t} + \sum MC_{j,t}
\]

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

\(\Delta L_{j,t}(\text{km})\): Length of the inundated coastline (km)

\(MC_{j,t}(\text{US$})\): Maintenance Cost

\(d(\text{year})\): Durability (30 years)
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:
    \[ s_t = e^{-\alpha t} \]
    \( Y^s_t = s_t \cdot Y_t \)
    \( \alpha \): lifetime parameter (0.1)

- Plant every 5 years to compensate the decreased amount
- Initial and maintenance costs

  \[ M_t = \left( Y_t - \sum Y^s_t \right) Y_{t-n} + 0.1 Y_{t-n} \]

  \[ AC_{\text{mangrove}} = M_t \cdot c_{\text{mangrove}} \]
Impacts of SLR

Potentially inundated area in 2100 and mangrove distribution (MIROC-ESM, RCP8.5, TroCEP) Kumano et al. (2018)
Economic damage and adaptation cost in Vietnam (MIROC-ESM)

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

Kumano et al. (2018)
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)
Multiple Protection

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

Yasuhara et al. (2016)
Optimal climate change adaptation strategies using green & gray infrastructures

● From scientific assessments to policies

Research image
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
References