Economic Damage of Flood caused by Extreme Rainfall in Japan

So KAZAMA

Dept of Civil Engineering
Tohoku University
Introduction

Extreme rainfall increase (IPCC, 2007)
Heavy rainfall produces frequent flooding.

Rainfall with 100yrs return period increase 20% from now in 2100. (JMA RCM results)

It is necessary to evaluate economic damage in 2100 for the adaptation.
Objectives
Calculation of economic damage by flooding after climate change in a whole Japan using extreme rainfall data.

Quantifying the adaptation cost using the increase of damage cost from current flood control.
# Content

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#2 Dataset

#3 Inundation simulation

#4 Damage cost evaluation

#5-1 Potential damage

#5-2 Extreme rainfall cases

#5-3 Estimation of adaptation cost under GW

#5-4 Verification

#6 Conclusions

- Distribution of Return Period
  - 5, 10, 30, 50, 100 yrs

- 2D Non-uniform flow

- Manual of cost investigation for flood control for each land use

- Downpour of 2006 in Japan
Dataset

1) Elevation  

2) Landuse  

3) Extr. Rain

LU code:  

1) Pad  
2) Crop  
3) Fore  
4) Bare  
5) Build  
6) Road  
7) Others  
8) Water  
9) Coast  
10) Ocean  
11) Golf
Inundation model

Ignoring flood control facilities and structures.
Applying the model in a whole Japan

2D Non-uniform model $\iff$ Precise expression

<table>
<thead>
<tr>
<th>Landuse</th>
<th>Manning roughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pad.Crop.Forest</td>
<td>0.060</td>
</tr>
<tr>
<td>Roads</td>
<td>0.047</td>
</tr>
<tr>
<td>Others</td>
<td>0.050</td>
</tr>
<tr>
<td>Buildings</td>
<td>0.050</td>
</tr>
<tr>
<td>Water bodies</td>
<td>0.020</td>
</tr>
</tbody>
</table>

Momentum eq. $\downarrow$

discharge $\iff$ Conserv. eq.

Water depth
Model Verification

- Flood simulation

<table>
<thead>
<tr>
<th>Landuse</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agri. &amp; Forest</td>
<td>0.060</td>
</tr>
<tr>
<td>Traffic area</td>
<td>0.047</td>
</tr>
<tr>
<td>Others</td>
<td>0.050</td>
</tr>
<tr>
<td>Urbaned</td>
<td>0.050</td>
</tr>
<tr>
<td>Waterbody &amp; Beach</td>
<td>0.020</td>
</tr>
</tbody>
</table>

WD: 0.0m, 0.5m, 1.0m, 1.5m, 2.0m, 2.5m
Results (case: 100yrs RTN)

Max. Water depth

Elevation

#3 INUNDATION
Results (case: 100yrs RTN)

Max. Water depth

Extreme rainfall

#3 INUNDATION
Estimation of damage cost

1) Paddy field
   D.C. = \text{rice production/area} \times \text{rice price} \times \text{inundated area} 
   \times \text{damage rate to water depth}

2) Crops field
   D.C. = \text{crops production/area} \times \text{average crops price} \times \text{inundated area} 
   \times \text{damage rate to water depth}

3) Buildings (4) Golf links
   D.C. of houses = \text{damaged floor area to water depth} \times \text{price/m}^2 
   \times \text{damage rate to water depth}
   D.C. of house articles = \text{house number to water depth} 
   \times \text{house article value/house} \times \text{damage rate to water depth}
   D.C. of asset of office = \text{worker number} \times 
   (\text{amortized asset value/person} \times \text{coefficient to water depth} + 
   \text{stock asset value/person} \times \text{damage rate to water depth})

5) Public facilities
   D.C. = \text{general damaged asset value} \times 1.694
Example of paddy case

(Statistics of Agriculture, Japan)

D.C. = Annual rice production/area

× price of rice/ton

× inundated area

× damage rate to water depth
Example of paddy case

(Statistics of Agriculture, Japan)

D.C. = Annual rice production/area
× price of rice/ton
× inundated area
× damage rate to water depth
Example of paddy case

D.C. (JPY) = 489 (kg/100a) × 285 (th.JPY/t) × inundated area (km²) × Damage rate

<table>
<thead>
<tr>
<th>Inundation period (day)</th>
<th>Damage rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1~2</td>
<td>20</td>
</tr>
<tr>
<td>3~4</td>
<td>40</td>
</tr>
<tr>
<td>5~6</td>
<td>60</td>
</tr>
<tr>
<td>more than 7</td>
<td>80</td>
</tr>
</tbody>
</table>

Inundation depth (m) | less than 0.5 | 0.5~0.99 | more than 1.0

damage rate of paddy fields by inundation depth
D.C. for RTN period

<table>
<thead>
<tr>
<th></th>
<th>AGRI.</th>
<th>BUILDINGS</th>
<th>PUBLIC FAS</th>
<th>TOTAL DC</th>
<th>Increase rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>100year</td>
<td>7,867</td>
<td>414,672</td>
<td>702,455</td>
<td>1,124,994</td>
<td>2.91</td>
</tr>
<tr>
<td>50year</td>
<td>6,032</td>
<td>335,149</td>
<td>567,742</td>
<td>908,923</td>
<td>2.35</td>
</tr>
<tr>
<td>30year</td>
<td>4,820</td>
<td>283,883</td>
<td>480,897</td>
<td>769,600</td>
<td>1.99</td>
</tr>
<tr>
<td>10year</td>
<td>2,039</td>
<td>202,746</td>
<td>343,452</td>
<td>548,238</td>
<td>1.42</td>
</tr>
<tr>
<td>5year</td>
<td>734</td>
<td>143,392</td>
<td>242,907</td>
<td>387,033</td>
<td>1.00</td>
</tr>
</tbody>
</table>

- **#5-1 EXTR RAIN**

- EXT rainfall of RTN 5 yrs makes 400 billion USD damage.
- Comparing with 5yrs, 1.4 times in 10yrs, 2.0 times in 30yrs, 2.4 times in 50yrs, 3.0 times in 100yrs in potential damages.
The increase rate of agricultural damages is larger. It is 3.0 times in 10yrs, 7 times in 30yrs, 8 times in 50yrs, 11 times in 50yrs, and 11 times in 100yrs.

The damage cost is small but the sensitivity for GW is higher.
Ext rain and damage cost

(Base year: RTN 5 yrs)

<table>
<thead>
<tr>
<th>Year Extremal Precipitation</th>
<th>Precipitation Increase Rate</th>
<th>Damages Increase Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1.94</td>
<td>2.91</td>
</tr>
<tr>
<td>50</td>
<td>1.70</td>
<td>2.35</td>
</tr>
<tr>
<td>30</td>
<td>1.53</td>
<td>1.99</td>
</tr>
<tr>
<td>10</td>
<td>1.20</td>
<td>1.42</td>
</tr>
<tr>
<td>5</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Considering adaptation cost for Global warming basing on flood control estimation

Countermeasure cost, which is equaled to benefit of asset value, is adapted to global warming.
Countermeasure costs for increase of rainfall

Global warming
(Ext rain increase)

present

Adaptation

Necessity areas of new adaptation.

Past infrastructures

RTN 100yrs

RTN 50yrs

Adaptation cost

The difference between current and new necessity infrastructures is adaptation cost for global warming.
#5-3 ADAPTATION COST

## Estimation of adaptation cost

( unit: million USD )

<table>
<thead>
<tr>
<th>RTN period</th>
<th>Agri.</th>
<th>Buildings</th>
<th>Public sp.</th>
<th>total damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-50year</td>
<td>1,834</td>
<td>79,524</td>
<td>134,713</td>
<td>216,071</td>
</tr>
</tbody>
</table>

Supposed that there are no damage until 50yrs ext rainfall.

To 100yrs extreme rainfall, expected value of necessity adaptation cost is **220 billion USD**.
Estimation of adaptation cost

Annual expected damage

= Annual adaptation cost (B/C=1.0)

<table>
<thead>
<tr>
<th>RTN Period</th>
<th>Annual extreme P.</th>
<th>Damage Cost</th>
<th>Interval Av. Damage</th>
<th>Interval probability</th>
<th>Av. Annual expected damage cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.20</td>
<td>380</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.10</td>
<td>550</td>
<td>470</td>
<td>0.1</td>
<td>47</td>
</tr>
<tr>
<td>30</td>
<td>0.03</td>
<td>770</td>
<td>660</td>
<td>0.067</td>
<td>44</td>
</tr>
<tr>
<td>50</td>
<td>0.02</td>
<td>910</td>
<td>840</td>
<td>0.013</td>
<td>11</td>
</tr>
<tr>
<td>100</td>
<td>0.01</td>
<td>1,120</td>
<td>1,020</td>
<td>0.010</td>
<td>10</td>
</tr>
</tbody>
</table>

This amount is similar to annual expense of flood control in Japan.
Urban Areas have huge damage.
Rural areas have less damages.

100 million JPY/km²
= 1 million USD/km²

Kazama et al., 2009.
Sustainability Science
Verification

- Case: Niigata & Fukushima downpour in 2004
- Date: 12 to 13 in July, 2004
- Study area: Sanjyo district in the Shinano River basin
- Rainfall: 421mm at Tochio town
Rainfall gouge stations

Name (daily rainfall, RTN period)

- Tochio (421mm, 530)
- Niitsu (101mm, 10)
- Maki (109mm, 15)
- Sanjyo (208mm, 155)
- Teradomari (194mm, 175)
- Ngaoka (225mm, 175)
- Oguni (127mm, 20)
- Koide (136mm, 25)
- Tokamachi (88mm, 2)
- Tsunami (121mm, 25)

Ave. Return period: 113 yrs

Rainfall gouge stations

#5-4 VERIFICATION
Comparison of damage costs between actual record and calculation using extreme rainfall increase (Unit: 100 million JPY)

<table>
<thead>
<tr>
<th>Damage record (flood statistics 2004)</th>
<th>2,395</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTN period</td>
<td></td>
</tr>
<tr>
<td>100 yrs</td>
<td></td>
</tr>
<tr>
<td>100–50 yrs</td>
<td></td>
</tr>
<tr>
<td>Damage cost</td>
<td></td>
</tr>
<tr>
<td>15,283</td>
<td>13,346</td>
</tr>
<tr>
<td>Almost same value</td>
<td></td>
</tr>
<tr>
<td>1,937</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

• We see the linear relationship between the increases rate of extreme rainfall and flood damage cost.

• The expected countermeasure cost of return period 100 to RTN period 50 years is 22 billion JPY supposed that current infrastructure prevents from flood with 50 yrs.

• The estimation of the cost can help the decision making of adaptation.
Conclusions

• Discussion on concrete adaptation is necessary.
• **Cost** is one of the restriction factors for adaptation.
• Adaptation should be considered in view of the regional culture and tradition with cost.