Estimating Probability Distribution of Benefit from Flood Control Project

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TOPICS

- Background and Objective
- Research method
- Application to the Dam construction project
- Conclusion

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BACKGROUND AND OBJECTIVE

Background

✓Increasing risk of severe flood due to climate change

- It becomes more important to evaluate and manage flood risk.
- Flood control facilities (dam, bank etc…) are constructed to mitigate flood risk.

✓Evaluation of benefit from flood control project

- In Japan, Cost-Benefit analysis is used to evaluate flood control project.
- Benefit from flood control project is evaluated by expected value of reduced damage cost.

✓Uncertainty of benefit from flood control project

- Especially in highly protected area, flooding doesn't occur frequently, and it is highly uncertain whether we can get benefit calculated from expected value.

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BACKGROUND AND OBJECTIVE

Objective

✓Define benefit from flood control project as random variable and estimate its probability distribution.

✓Reveal the uncertainty of benefit from flood control project and stochastically discuss the efficiency of flood control project from estimated probability distribution.

BACKGROUND AND OBJECTIVE

Existing Method

$$B = \sum_{t=1}^{T} b$$

b : annual expected reduced damage cost
T : Evaluation period

Evaluate by one value
*neglecting discount rate

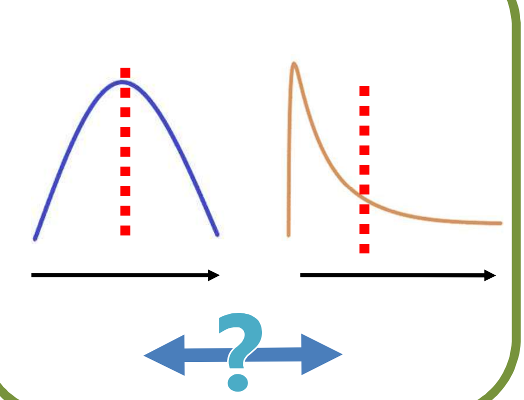
In this research

$$\Delta M_{all} = \sum_{t=1}^{T} \Delta M_t$$

ΔM_{all}: T-year cumulative reduced damage cost
ΔM_t :reduced damage cost of year t

Redefine benefit as random variable ΔM_{all}

Estimate ΔM_{all} PDF



- Expected value of PDF corresponds to the benefit value of existing method (Neglecting discount rate)
- Stochastically discuss the efficiency of flood control project.

TOPICS

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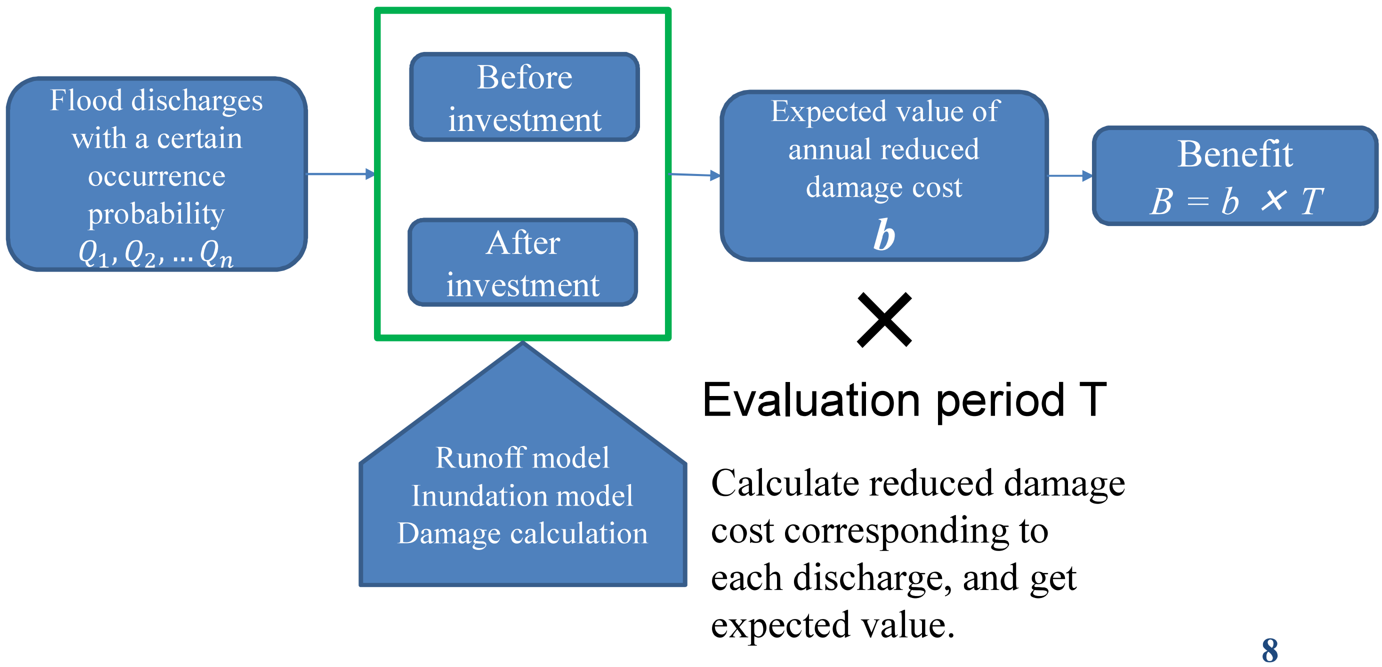
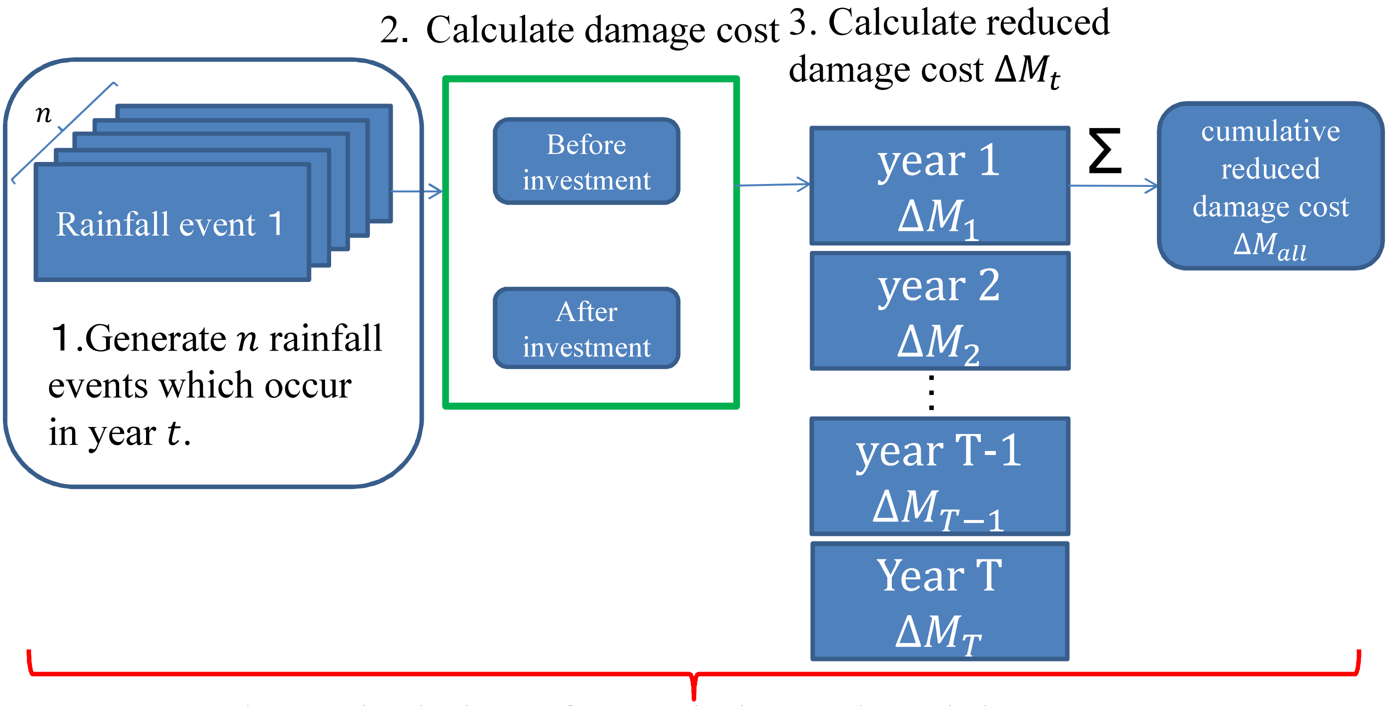
METHOD

▪How to calculate benefit B by the existing method
Calculate B by using expected value of annual reduced damage cost.
Efficiency of the flood control project is evaluated by one value, B.



METHOD

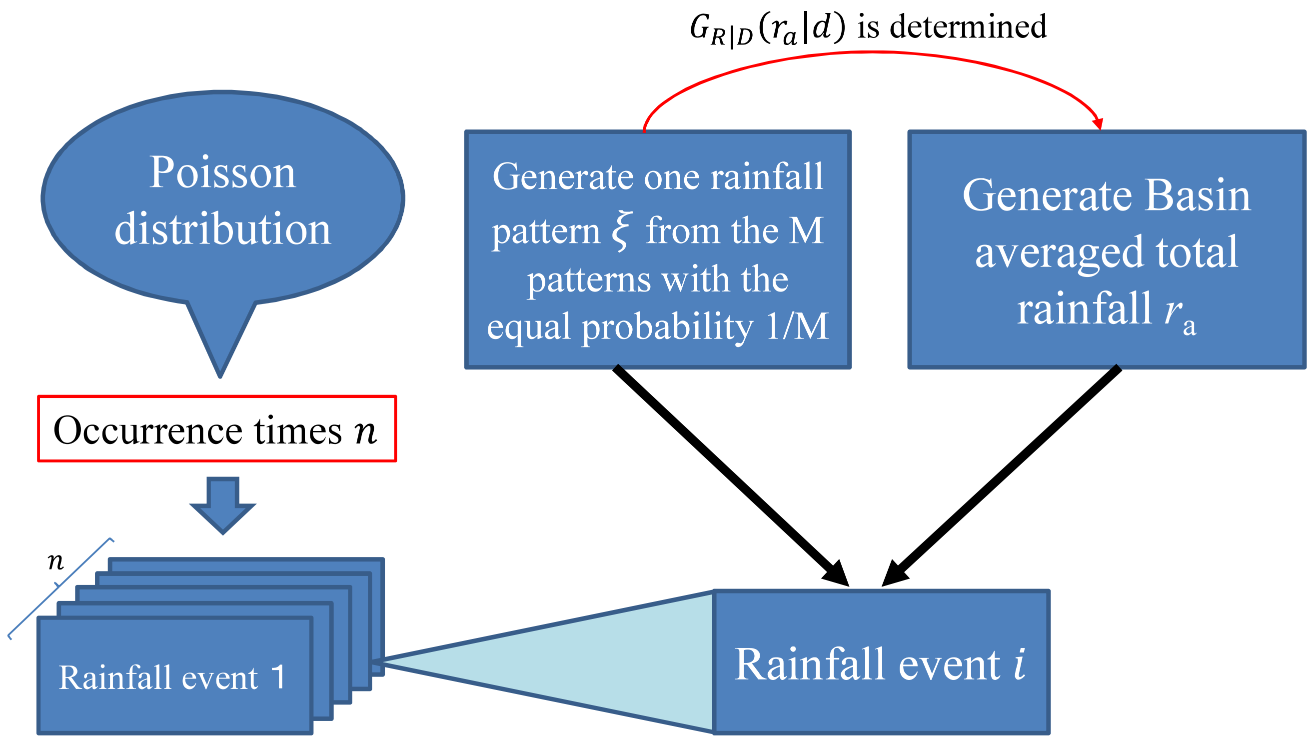
Numerically estimate PDF of cumulative reduced damage cost, ΔM_{all}.



Repeating calculation of cumulative reduced damage cost N times, and estimate PDF numerically

METHOD

Generation of annual rainfall events



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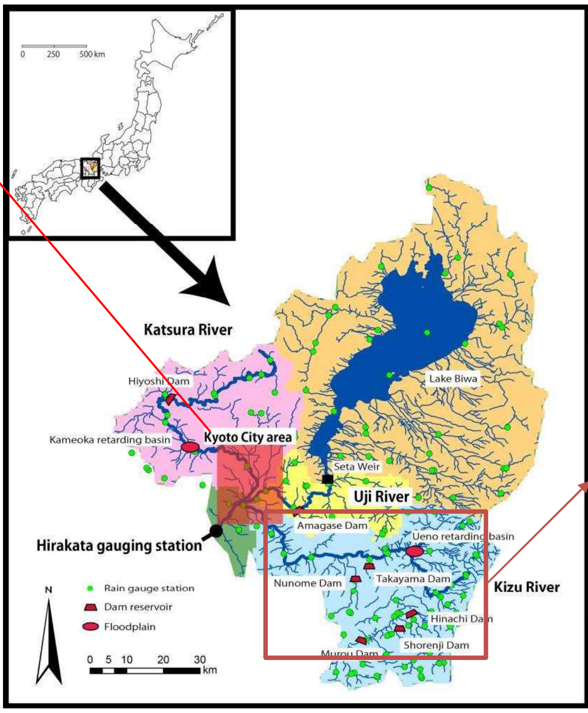
APPLICATION TO THE DAM CONSTRUCTION PROJECT

Calculate the reduced damage cost in the area of the three tributaries' conjunction.



Set several flood control projects about the existing dam reservoirs in upper stream of the river basin

- basin: Yodo basin
- Calculation times N:100,000
- Evaluation period T : 50 years
- Rainfall-runoff/inundation models constructed by the existing research are used.

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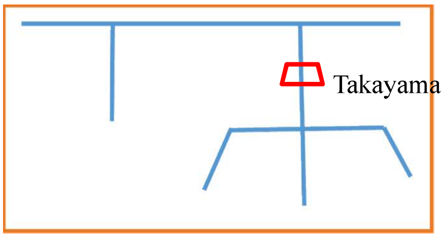
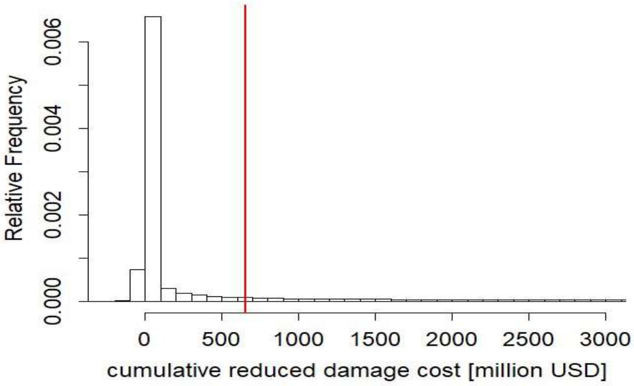
APPLICATION TO THE DAM CONSTRUCTION PROJECT

Project A : Constructing Takayama dam



Histgram of ΔM_{all} (red line : expected value)



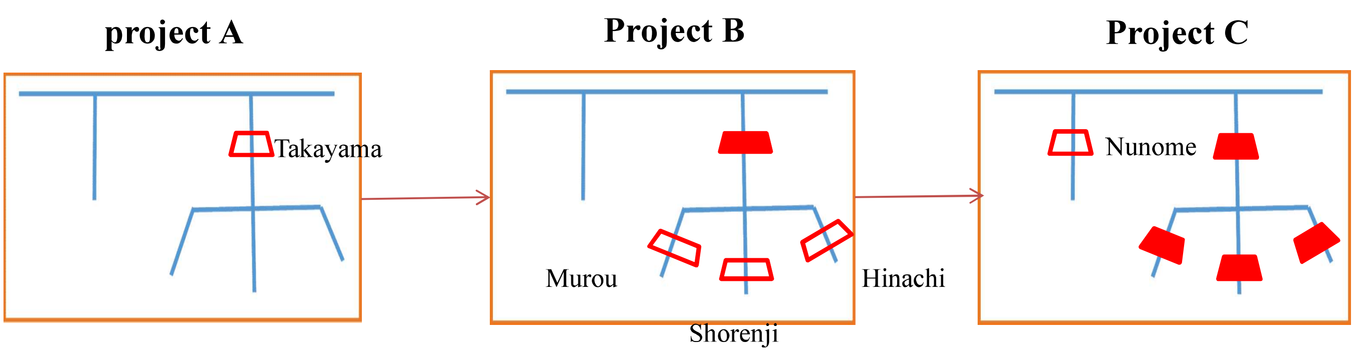
Expected value B	655
$\Pr[\Delta M_{all} \geq B]$	0.18
$\Pr[\Delta M_{all} > 0]$	0.55

- ΔM_{all} distribution is unsymmetrical, has a long tail.

➢ it is highly uncertain whether we can get benefit calculated from expected value

➢ the expected value made it difficult to grasp the whole characteristic of the benefit of the project

APPLICATION TO THE DAM CONSTRUCTION PROJECT



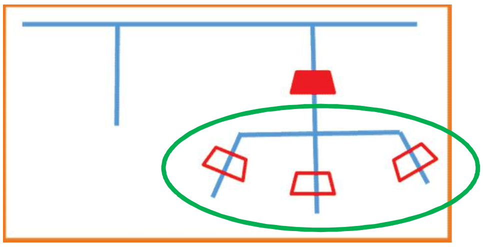
To examine the impact of the location of dams on the estimated probability distribution, we split the construction project of the four dams into projects B, and project C

APPLICATION TO THE DAM CONSTRUCTION PROJECT

	Project A	Project B	Project C
$\Pr[\Delta M_{all} \geq B]$	0.18	0.10	0.23
$\Pr[\Delta M_{all} > 0]$	0.55	0.30	0.74

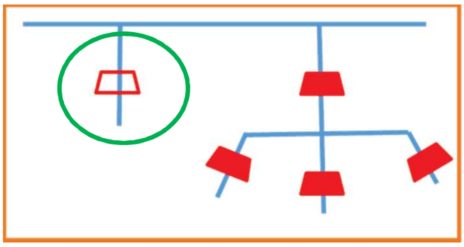
Project A & Project B : the probability that the dam effect comes out decreases
Project B & Project C : the probability that the dam effect comes out increases

Project B



Constructing dams on the same tributaries

Project C



Another tributary's discharge can be reduced

APPLICATION TO THE DAM CONSTRUCTION PROJECT

	Project B	Project C
Expected value (B)	197 ≒	157
$\Pr[\Delta M_{all} \geq B]$	0.10	0.23
$\Pr[\Delta M_{all} > 0]$	0.30	0.74

Expected value is not so changed, but the probability that the dam effect comes out is doubled.

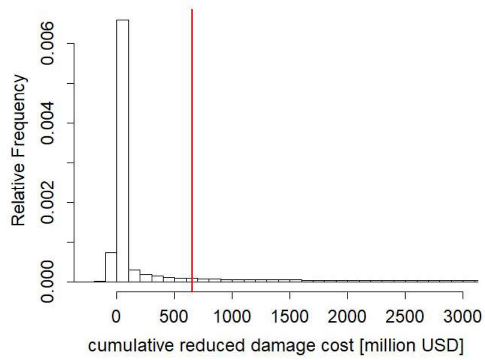
→Indicating the importance of using some statistics beside expected value when evaluating flood control project.

APPLICATION TO THE DAM CONSTRUCTION PROJECT

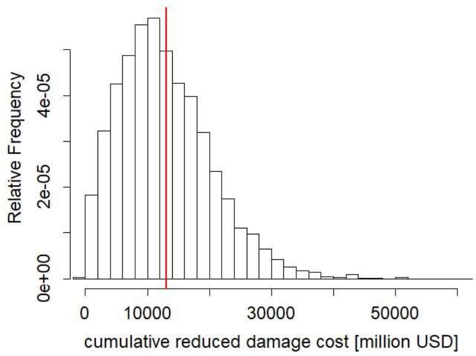
- Set longer evaluation period (T = 1,000 year) and estimate the distribution
- Distribution becomes symmetrical, the probability that ΔM_{all} exceeds expected value increases

→The actual evaluation period was not long enough to represent the expected value as the benefit due to low frequency of flooding.

Histgram of ΔM_{all} (50 years)



Histgram of ΔM_{all}(1000 years)



	Project A (50 years)		Project A (1,000 years)
skewness	38.3	>	8.38
$\Pr[\Delta M_{all} \geq B]$	0.18	<	0.43

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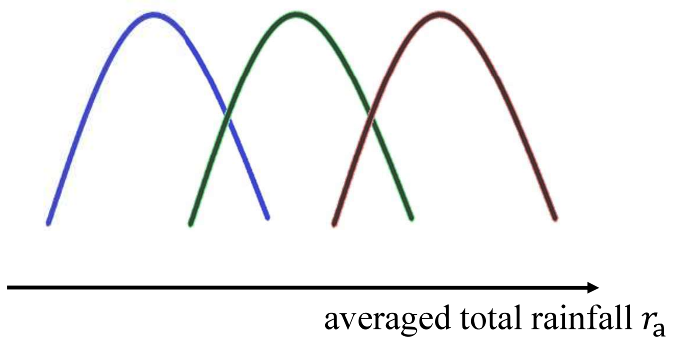
CONCLUSION

Develop method of estimating ΔM_{all} distribution.
It enables us to stochastically discuss the efficiency of flood control project. In my case study, following findings are obtained.

- ✓ ΔM_{all} distribution was unsymmetrical, has a long tail.
- ✓ Depending on the projects, some statistics (e.g. $\Pr[\Delta M_{all} \geq B]$) are totally different while expected value is almost the same.
- ✓ The actual evaluation period was not long enough to represent the expected value as the benefit due to low frequency of flooding.

FURTHER APPLICATION

- In this research, rainfall generation was done using the same rainfall distribution every year.
- If you can predict the change of rainfall distribution caused by climate change, you can reflect the impact of climate change on the evaluation process by changing the rainfall distribution for rainfall generation in each stage.



THANK YOU FOR LISTENING !

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METHOD

Three assumptions about rainfall are set to generate rainfall event
1. Rainfall pattern 2. Basin averaged total rainfall
3. Annual number of occurrences of rainfall events

1. When rainfall occurs, possible rainfall pattern is limited to the N patterns. Pattern ξ_i $(i = 1,2,\ldots,N)$ occurs with the same probability p. Denote rainfall duration time of pattern ξ_i as d_i.
2. Basin averaged total rainfall r_a follows the conditional cumulative distribution function (CDF) $G_{R_a|D}(r_a|d_i)$ given d_i.

→One rainfall event (rainfall intensity at a location (x, y) and time t) is determined by $r(x, y, t) = r_a \xi(x, y, t)$

3. Annual number of occurrences of rainfall events follows the Poisson distribution with occurrence ratio of μ_a.

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