Costs and Benefits of Adaptation for River Flooding in Jakarta

Pini Wijayanti

Supervisors: Prof. Ekko van Ierland
Prof. Petra Hellegers
Dr. Xueqin Zhu

WAGENINGEN UNIVERSITY
WAGENINGEN UR

DeltaAlliance

Knowledge for Climate

Overview of Presentation

- Background
- Framework
- Economic modelling for selection of flood adaptation measures in Jakarta
- River flood damage estimation in Jakarta
- Conclusions

Overview of Presentation

- **Background**
- Framework
- Economic modelling for selection of flood adaptation measures in Jakarta
- River flood damage estimation in Jakarta
- Conclusions

Background

- The central government and local authority have a limited budget to conduct all flood adaptation measures.
- Economic consideration is needed
- The decision makers should consider the costs and the benefits of such measures.

> - The costs include investment costs, and operational and maintenance costs required during the lifetime of the measure.
> - The benefits refer to the expected flood damages reduction due to implementation of such a measure.

Background

- The optimal level needs to be identified

Such a "level" indicates the level where the costs still can be provided by the government and the resulting expected damage is acceptable by the society.

Research objective

- To develop an **economic model**, which assists us to select optimal flood adaptation measures
  - ➢ By considering spatial aspects and temporal aspects

Overview of Presentation

- Background
- **Framework**
- Economic modelling for selection of flood adaptation measures in Jakarta
- River flood damage estimation in Jakarta
- Conclusions

Framework

- The objective function is to minimize the total costs, *TC*, of implementing the flood measures.

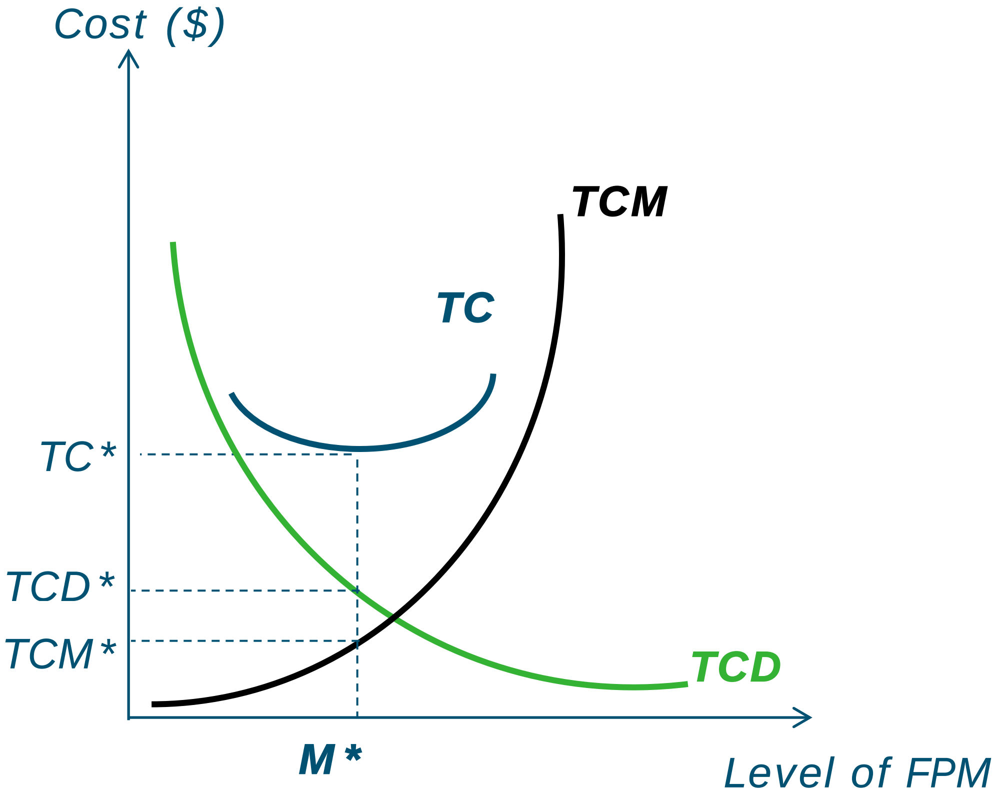
$$\min_{M} TC = TCM + TCD$$

  - *TCM*: total measure costs.
  - *TCD* : total damage costs.
  - Control variable: *M*, level of measure.
  - Subject to several constraints, e.g. budget constraint and the hydrological system.

Framework

- **TCM**: construction costs and operational costs required by the flood measure during its lifetime
- **TCD**: the expected value of flood losses in a specific area.

The higher the level of M, the lower will be the damage



Overview of Presentation

- Background
- Framework
- **Economic modelling for selection of flood adaptation measures in Jakarta**
- River flood damage estimation in Jakarta
- Conclusions

Selecting the optimal level of flood measure in one area

The objective function:

$$\min_{M_i} TC = TCM + TCD \qquad (1)$$

Subject to the following constraints i.e.:

$$TCM \leq Budget \qquad (2)$$

$$TCM = summation\ of\ all\ measure\ costs = \sum_{i=1}^{N} \alpha_i (M_i)^2 \qquad (3)$$

$$TCD = current\ damage\ minus\ sum\ of\ reduced\ damage = D_0 - \sum_{i=1}^{N} \beta_i M_i \qquad (4)$$

A simple illustrative example:

The Jakarta government is planning to implement three flood measures i.e. dike, river normalisation, and polder. The maximum budget to implement those measures is $ 600 million.

What are the optimal levels of those measures?

Applying the optimization model in this example, the optimal level for the design level of dike, normalisation, and polder areas, are found to be 4.2 m, 3.0 km, and 7.5 ha, respectively. Those levels will require TC of about $562.5 million.

Selecting the optimal level and combination of FPMs in multiple areas

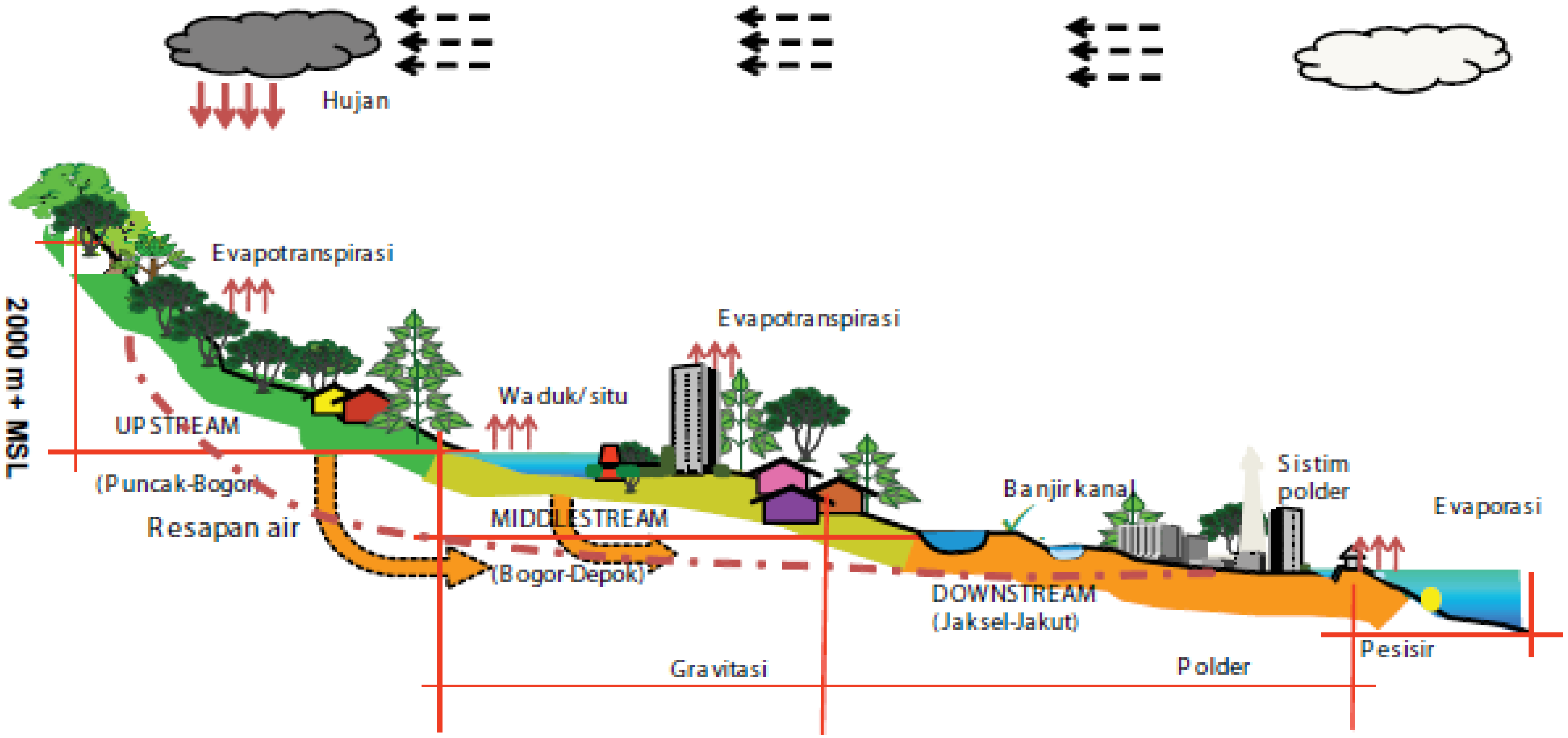


Figure 1. An illustration of the *Ciliwung* watershed from upstream to downstream (Mirah Sakethi, 2010)

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Another example:

There are three flooded areas, i.e.: upstream, middle stream and downstream. The central government is planning to implement three measures in each area with maximum budget $2 billion. We assumed the types of flood measures in each are similar i.e. dike, normalisation, and polder.

What are the optimal levels of those measures?

- The model considers the "dual effect", e.g. dike heightening in middle stream decreases the frequency of inundation in that area; but it might increase the flooding downstream

Overview of Presentation

- Background
- Framework
- Economic modelling for selection of flood adaptation measures in Jakarta
- **River flood damage estimation in Jakarta**
- Conclusions

River flood damage estimation in Jakarta: Background

- Estimation of flood damages enables us to estimate the benefits of implementing flood measures.

River flood damage estimation in Jakarta: Methodology

1) **Survey:**

- Interviews 300 households and 150 businesses units
- Based on the January 2013 flood event (30-years FRP)
- Pesanggrahan River
- Actual flood damage model
  - Flood characteristics
  - Socio-economics characteristics

2) **Expert assessment in a GIS analysis.**

- the *damage scanner* model, based on Budiyono et al (2014)

River flood damage estimation in Jakarta: Results

Table 1. The average actual flood damage per household for the 17-19 January 2013 flood event

Damage	Value (US$)	Percentage (%)
1. Direct		
1.a. Structural damage	43	14
1.b. Content damage (inside and outside)	193	60
2. Indirect		
2.a Clean-up cost	25	8
2.b. Loss of income	30	9
2.c. Evacuation and temporary house	12	4
2.d. Cost of illnesses	15	5
Total	**318**	100

River flood damage estimation in Jakarta: Results

Table 2. The average actual flood damage per business for the 17-19 January 2013 flood event

Damage	Value (US$)	Percentage
1. Direct		
1.a. Structural damage	58	7
1.b. Content damage	158	18
2. Indirect		
2.a. Turnover loss	540	61
2.b. Temporary quarters	6	1
2.c . Labour cost	39	4
2.d Clean-up cost	81	9
Total	**882**	100

WAGENINGEN UNIVERSITY
WAGENINGEN UR

River flood damage estimation in Jakarta: Results

- Depth, duration, income, and total area have a positive and statistically significant impact on the flood damage
- Distance from the river does not significantly influence the damage
- The highest losses per building occurs for the middle income class in the residential sector, and for the small-medium scale business in the business sector

River flood damage estimation in Jakarta: Results

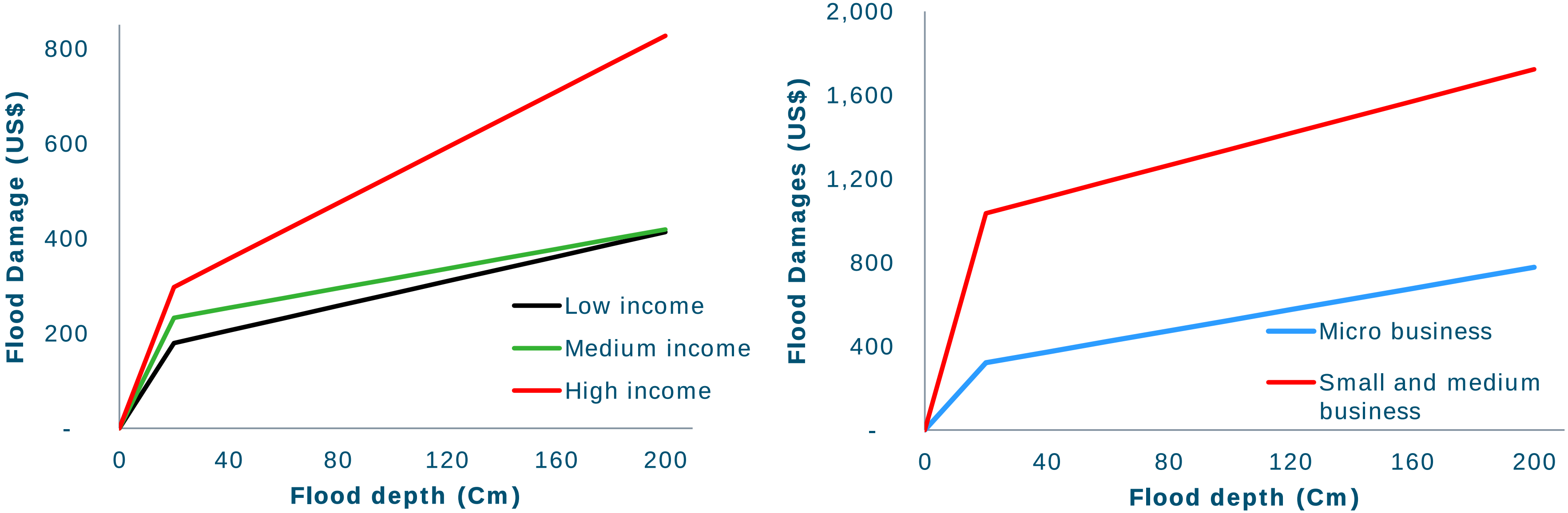


Figure 2. Stage damage curves for residential sector based on income level (left) and business sector based on business turnover (right)

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Results: comparison of damages in six villages (*kelurahan*) (shown as blue and green areas)

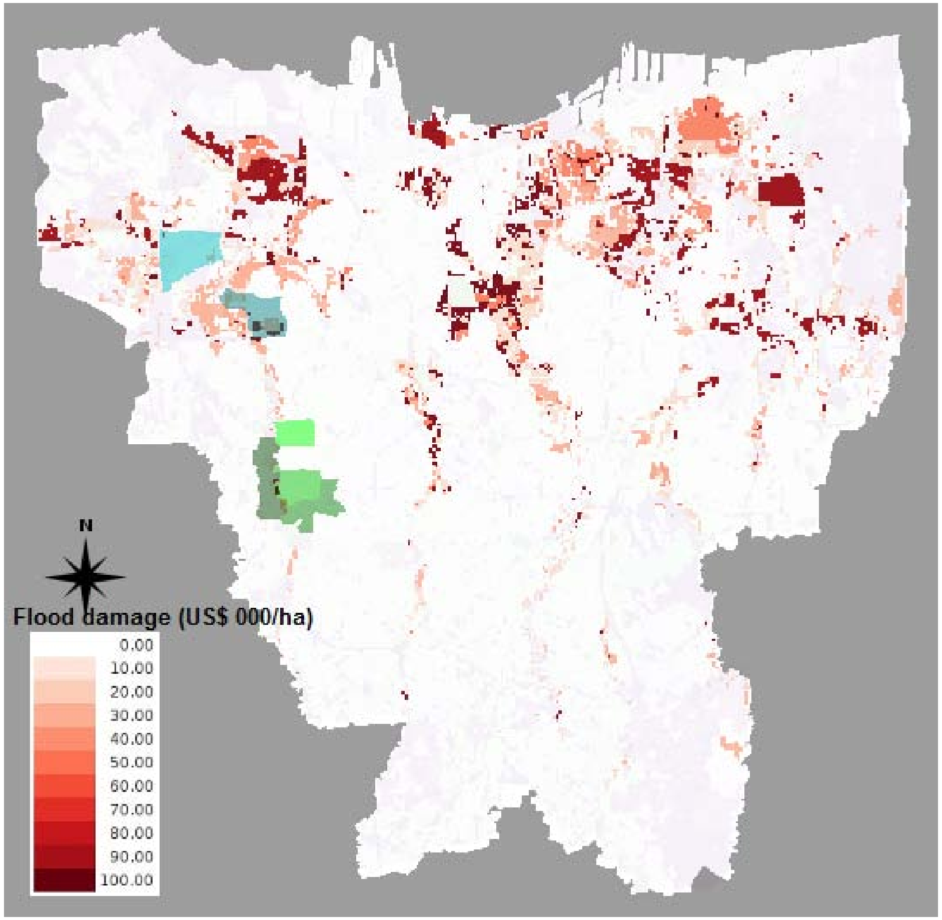


Figure 3. Jakarta flood damage map under a 50 year flood return period

River flood damage estimation in Jakarta: Results

Table 3. Estimated flood damage for the 17-19 January 2013 flood event in the survey area, based on survey and expert/GIS approaches

Sector	Flood damages (US$)	
	Survey	Expert/GIS
Residential	525,120	1,318,235
Business	682,929	9,248,201

- The damage estimation based on regression analysis is lower than when using the expert/GIS analysis.
- The differences can be attributed to various factors e.g.
  - the survey in residential area was conducted in low and medium income areas, whereas expert/GIS also includes high income;
  - the survey in business area was conducted in micro, small and medium business, whereas expert/GIS also includes large business.

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Overview of Presentation

- Background
- Framework
- Economic modelling for selection of flood adaptation measures in Jakarta
- River flood damage estimation in Jakarta
- **Conclusions**

Conclusions

1. Measures to reduce the damages should be based on profound cost benefit analysis (CBA) of alternatives.
2. Risk of flooding cannot be reduced to zero. It is important to determine the "optimal level" of the risk of flooding on the basis of CBA.
3. On the basis of damage estimates, analysis can be made of the most efficient measures to reduce these damages.
4. This requires better information on the cost structure of the various measures and the hydrological impacts.
5. To have a good result, further studies are needed to integrate the economic and the hydrological analysis.

Thank you

- ***pini.wijayanti@wur.nl***

WAGENINGEN UNIVERSITY
WAGENINGEN UR

DeltAlliance

Knowledge for Climate