Climate Change and Anthropogenic Impacts Assessment on the Flood Hazard in the Batanghari River basin, Sumatera, Indonesia

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Date: 3rd November 2017, 13:15 – 17:30, Salak Tower Hotel
STUDY AREA

Study area consists of 14 district.

- Approximate total area is 47,479,54 km²
- Landuse type dominated by plantated area (e.g., oil palm and rubber)
- Almost every year many areas were flooded
- Biggest flood occurred in 2003
I INTRODUCTION

Local Agency for Disaster Management (BPBD) of Jambi Province
Local Agency for River Basin Management (BPDAS) of Jambi Province

FLOOD RISK AT BASIN & MICRO SCALE

OBJECTIVE: To produce the Map of Flood Hazard with High Resolution & considering CC and LUC

Requested to make Quantitative Flood Risk Map (in Damage Cost Unit) at Basin Scale and Considering More Physical Process & Climate Change Issue in Delineating the Map

Upstream
Natural Forest
Deforestation
Plantation

Downstream
Frequent flooding areas, Wetland
Peatland Area

Flood Risk at Basin & Micro Scale
I INTRODUCTION

National Disaster Management Agency (BNPB)

Existing Flood Hazard Map in the Batanghari River basin: District Scale

- Low resolution
- Created using Parametric Approach
- Qualitative information
I INTRODUCTION

Flood Disaster Risk Management

Risk Quantification & Analysis
- Hazard Assessment
- Vulnerability Assessment
- Risk Quantification

Disaster Mitigation
- Technical Measures
- Non-Technical Measures

Preparedness
- Early Warning System
- Planning Disaster Relief & Evacuation

Disaster Response
- Emergency Help - Rescue
- Humanitarian Assistance
- Reconstruction

Targeted Risk
Residual Risk

To identify priority locations;
To provide basic information for evaluation & improvement of flood disaster management

Risk Reductions (i.e., Flood Risk Control)
Batanghari River

1. Seasonal Flood
2. Flood Inundation
3. Extreme Rainfall enhances the magnitude of Flood

Effects: Community livelihood, important economic sector (agriculture), freshwater ecosystem including peat land
Flood Hazard Dimension: Flood Discharge \( (q) \), Inundation Depth \( (h) \), Inundation Area \( (A) \), Flood Duration \( (t) \)
II. METHODOLOGY

PROCESS, DATA REQUIRED & TOOLS

- Rainfall Projection (Seasonal & Extreme Conditions)
  - 41 GCM Outputs
- Land Use Projection
  - Land use/Land Cover
  - Population density
  - Infrastructure map
  - Digital Elevation Model
  - Soil types
- Flood Modeling
  - Land use & Land use Projection
  - Rainfall data
  - Water discharge
  - Stream network
  - HydroSHEDS

TOOLS
- Arc GIS version 10.2
- CLUE
- SPSS
- ERDAS
- RRI model (Fortran)
II. METHODOLOGY
Field Measurement Activity for Data Collection, Understanding the Process, Improvement of Hydrological Modeling system

Turf – tec infiltrometer

Primary Data of Soil Properties
✓ Soil Properties Analysis: permeability, texture, organic matter, bulk density, porosity
✓ Infiltration measurement
II. METHODOLOGY

Field Measurement Activity for Cross Section and River’s Bathymetric at selected sites
II. METHODOLOGY

Climate Projection Data

- SOUSEI Program (Japan): MRI-AGCM 20-km
- SimCLIM (New Zealand): 40 Ensembel GCMs

Climate Projection Data for Different RCPs (2.6 - 8.5) Scenario

Seasonal & Extreme Rainfall Analysis
II. METHODOLOGY

Land Use Change Projection

Landsat Classification

Driving factor

Land Use data series

Logistic Regression

Significant Driving Factor

CLUE

Spatial Policies
Conversion Matrix
Elasticity

Land demand

Calibration

Yes/ No?

Land Use Change Projection

Dyna-CLUE version 2

IVM Institute for Environmental Studies

The CLUE Modelling Framework

The Conversion of Land Use and its Impact
II. METHODOLOGY

Rainfall-Runoff-Inundation Model

Shallow water equations for typical 2D inundation

Mass balance equation
\[
\frac{\partial h}{\partial t} + \frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} = r
\]

Momentum equations
\[
\begin{align*}
\frac{\partial q_x}{\partial t} + \frac{\partial u q_x}{\partial x} + \frac{\partial v q_x}{\partial y} &= -gh \frac{\partial H}{\partial x} - \frac{\tau_x}{\rho_w} \\
\frac{\partial q_y}{\partial t} + \frac{\partial u q_y}{\partial x} + \frac{\partial v q_y}{\partial y} &= -gh \frac{\partial H}{\partial y} - \frac{\tau_y}{\rho_w}
\end{align*}
\]


Flood risk at District Scale

500-m grid size, 1-hr time interval
**III. RESULTS: PROGRESS**

**Extreme Rainfall Projection**
(L-Moment Method was used)

*In average, the extreme rainfall with 1-day duration and 100-year return period will increase 10%*

**Seasonal Cumulative Rainfall Projection (Rainy)**

There is a signal that the monthly rainfall amount will increase during the rainy season of the future climate condition 3-22%.

In average, the extreme rainfall with 1-day duration and 100-year return period will increase 10%.
Land use in 1990, 1997, 2005 and 2015 (left to right)
By 2040, the projected forest area will be reduced by **53%** from the actual year of 1990. While the area of agriculture increases up to **129%** in the year 2040.
III. RESULTS: PROGRESS

Reconstruction of Historical Flood Event on Nov-Dec 2003. It was for Producing a Flood Hazard Map derived from the Past Worst Flood Event Condition

Cumulative Rainfall during the Period of Nov - Dec 2003 (mm)

1. GSMaP Reanalysis Data
2. Gauging Stations Data
III. RESULTS: PROGRESS

Flood Model Performance in Simulating Hazard Dimension

Batanghari Flood, Nov - Desember 2003 (50-Year Return Period)

Observed Water Level Data at Jambi City Station

Simulation Result
### III. RESULTS: PROGRESS

**Flood Model Performance in Simulating Hazard Dimension**

**Batanghari Flood, Nov - Desember 2003 (50-Year Return Period)**

**Model Output Vs. Observed Data**

<table>
<thead>
<tr>
<th>Date</th>
<th>Observasi</th>
<th>Sim.GSMaP</th>
<th>Sim. Stasiun Hujan</th>
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<tr>
<td>1-Nov-03</td>
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<td>4-Nov-03</td>
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<td>28-Nov-03</td>
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<td>1-Dec-03</td>
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<td>31-Dec-03</td>
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</tbody>
</table>

**Information:**

\[
RE = \left( \frac{h_{\text{max, sim}} - h_{\text{max, obs}}}{h_{\text{max, obs}}} \right) \times 100\% 
\]

- **RE** = Relative Error (%)
- \( h_{\text{max, sim}} \) = Simulated Max. Water Level during Peak of Flood
- \( h_{\text{max, obs}} \) = Simulated Max. Water Level during Peak of Flood
- Sim. Stasiun Hujan = Gauging Station
- Sim.GSMaP = GSMaP Reanalysis
III. RESULTS: PROGRESS

Spatial Flood Risk (Flood Hazard) for Present Climate Condition & 50-year Return Period in the Batanghari River basin:

- Kota Jambi
- Muara Tembessi
- Tebo
- Sarolangun
- Muara Bungo
- Sungai Penuh-Kerinci
- Merangin
- Sarolangun
- Muaro Jambi
- Dharmasraya
- Solok
- Kota Jambi

Dynamic Changes of the Area and Flood Depth

Simulated Flood Water Propagation during the Flood Event on November - December 2003:
Spatial Flood Hazard Information for the Present Climate Condition in the Batanghari River basin

Flood Depth (mm)

Lokasi Banjir Investigated Flood 2003 Location
III. RESULTS: PROGRESS

Flood Hazard Mapping

Dissemination & Discussion with stakeholders and local people
III. RESULTS: PROGRESS

Projection of Climate and Landuse Changes Impact on the Future Flood Hazard

**Extreme Rainfall:**

<table>
<thead>
<tr>
<th>Return Period (Year) for 1-day duration</th>
<th>Present Climate (mm)</th>
<th>Future Climate (mm)</th>
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<tbody>
<tr>
<td>2</td>
<td>32</td>
<td>45</td>
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<tr>
<td>5</td>
<td>45</td>
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<td>10</td>
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<td>100</td>
<td>105</td>
<td>189</td>
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<tr>
<td>200</td>
<td>125</td>
<td>235</td>
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</table>

**Scenario Inundated area (km²) & Maximum depth (m):**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Inundated area (km²)</th>
<th>Maximum depth (m)</th>
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</thead>
<tbody>
<tr>
<td>I</td>
<td>1168</td>
<td>4.7</td>
</tr>
<tr>
<td>II</td>
<td>1391</td>
<td>4.7</td>
</tr>
<tr>
<td>III</td>
<td>2018</td>
<td>6.9</td>
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<tr>
<td>IV</td>
<td>2181</td>
<td>7.4</td>
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</table>
IV. FURTHER WORKS

Baseline & Projected Extreme Rainfall & Landuse

Downstream Area of Batanghari

Landuse Maps

Flood Hazard Spatial Information

Flood Hazard Dimension for Each Landuse

Risk Maps (unit in damage costs)

Damage Curve

Flood Hazard Spatial Information

Baseline & Projected Extreme Rainfall & Landuse

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Flood Hazard Dimension for Each Landuse

Risk Maps (unit in damage costs)

Damage Curve
Spatial quantification of flood hydrodynamic & hazard for the local scale (hot spot areas), such as Jambi City Area:

1. Detail flood hazard and risk
2. Flood mitigation
3. Aquatic ecosystem restoration

IV. FURTHER WORKS
V. SUMMARY

1. Quantitative flood hazard assessment with considering climate change and anthropogenic factors, have been made and applied in the Batanghari River basin;

2. Physically-based distributed hydrological modeling system, called as rainfall-runoff-inundation model, was used as the main method in quantifying flood hazard dimensions ($q, h, A, t$);

3. The greatest land conversion in Batanghari river basin was forest area into agriculture area. Forest area is predicted to decline continously until the next 30 years. While agricultural always expand along with the increasing of population;

4. Based on the simulation, in 2040 inundation area will be wider than area in 2015. Which means that there will be a potential changes on flood hazard dimension in response to climate and landuse changes in the future.
Thank You

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(INDOONESIAN INSTITUTE OF SCIENCES)