Contributions of Historical Extreme Typhoon Events to Sediment Yield from Lin-Pien Watershed

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Paper #11082
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- Introduction
- Material and Methods
- Results and Discussion
- Conclusion
Due to the climate change, extreme climatic events occur more frequently around the globe; especially in the last decade.

Taiwan was unable to be excluded from this global phenomenon. **Weak geologic formation**, position in Pacific Fire Ring, abundant precipitation received from **summer typhoon** makes Taiwan be prone to natural disasters.
The objective of this study is to investigate how climate change affects the occurrence and magnitude of extreme typhoon events as well as the sediment yield from 314,695 km² Lin-Pien watershed.
Introduction

2009/08/09

Morako
**Material and Methods (1/5)**

**Location and Geologic Formation**

- **Area**: 314,695 km$^2$

**Material and Methods**

- **Avg. annual precipitation**
  - 3632.5 mm
  - Record length: 38yr

- **Avg. annual precipitation**
  - 4220.7 mm
  - Record length: 55yr

- **Avg. annual precipitation**
  - 2451.7 mm
  - Record length: 45yr
Location and Geologic Formation

Legend:
- Llin-Pien Watershed
- Miocene, Lushan Formation (Argillite, Slate, Phyllite)
- Eocene, Hsitsun Formation, Hsinlcao (Phyllite, Slate, with Sandstone interbeds)
- Pleistocene, Terrace Deposits (Gravel, Sand, Clay)
- Recent, Alluvium

Argillite, slate, and phyllite
More than 50%

A thrust fault
used to be active dated back 10 to 500 thousand years ago
Data Sources

Suspended sediment concentration, 10-yr precipitation records from three gauging stations, and flow discharge records gathered by Water Resources Agency at the outlet of the watershed was used to facilitate the analysis.
Antecedent Precipitation Index (API)

- Continuous rain without breaks
  \[ API = I_t \times K^t \]
  - \( I_t \) is the total precipitation for \( t \) days
  - \( K \) is the recession coefficient (\( k=0.9 \))
  - The first day \( t=0 \)

- Rain ceases at \((t-1)\) day
  \[ API = K \times API_{t-1} \]
  - \( API \) for \((t-1)\) day
  - \( I_0 \) is the total precipitation on day zero (mm)

- Rain ceases at \((t-1)\) day but resumes at day zero
  \[ API = I_0 + K \times API_{t-1} \]
Data Sources

- Typhoon events affecting Taiwan
  - from 2004 to 2009

- Suspended sediment
  - sampled using DH-48 and DH-58 samplers

- Precipitation
  - Thiessen polygon method was used to estimate the average precipitation of the study watershed
Methods of Data Analysis

Anomaly method was used to analyze the trend of storm characteristics. Average annual precipitation from n-year records was first obtained.

Variation of annual precipitation; defined as the difference between annual and average annual precipitation; was calculated for the entire n-year records.
Variations of Annual Precipitation

Variation of annual rainfall (mm)

Hsin-Laii
Nan-Ho
Tai-Wu(1)

Year

2004 2005 2006 2007 2008 2009

$P_y - P_{\text{Record}} = \text{Variation of annual rainfall}$
Variations of Annual Rainy Day

$D_y - D_{(2004-09)} = \text{Variation of annual rainy day}$

![Graph showing variations of annual rainy days across years 2004 to 2009 for different locations such as Hsin-Laii, Nan-Ho, and Tai-Wu(1).]
### Top Ten Typhoon Events (2004~2009)

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Typhoon</th>
<th>Year of occurrence</th>
<th>Effective date</th>
<th>Total event precipitation Pe (mm)</th>
<th>Annual precipitation Py (mm)</th>
<th>Pe/Py (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Morakot</td>
<td>2009</td>
<td>08/05~10</td>
<td>2117.2</td>
<td>3777.7</td>
<td>56.05</td>
</tr>
<tr>
<td>2</td>
<td>Haitang</td>
<td>2005</td>
<td>07/16~20</td>
<td>1602.5</td>
<td>4997.5</td>
<td>32.06</td>
</tr>
<tr>
<td>3</td>
<td>Bilis</td>
<td>2006</td>
<td>07/12~15</td>
<td>857.9</td>
<td>3524.3</td>
<td>24.34</td>
</tr>
<tr>
<td>4</td>
<td>Mindulle</td>
<td>2004</td>
<td>06/28~07/03</td>
<td>695.0</td>
<td>2914.4</td>
<td>23.85</td>
</tr>
<tr>
<td>5</td>
<td>Fung Wong</td>
<td>2008</td>
<td>07/26~29</td>
<td>670.4</td>
<td>4448.8</td>
<td>15.07</td>
</tr>
<tr>
<td>6</td>
<td>Kalmaegi</td>
<td>2008</td>
<td>07/16~18</td>
<td>669.0</td>
<td>4448.8</td>
<td>15.04</td>
</tr>
<tr>
<td>7</td>
<td>Kaemi</td>
<td>2006</td>
<td>07/23~26</td>
<td>435.3</td>
<td>3524.3</td>
<td>12.35</td>
</tr>
<tr>
<td>8</td>
<td>Jangmi</td>
<td>2008</td>
<td>09/26~29</td>
<td>465.8</td>
<td>4448.8</td>
<td>10.47</td>
</tr>
<tr>
<td>9</td>
<td>Sepat</td>
<td>2007</td>
<td>08/16~19</td>
<td>475.7</td>
<td>4610.2</td>
<td>10.32</td>
</tr>
<tr>
<td>10</td>
<td>Krosa</td>
<td>2007</td>
<td>10/04~07</td>
<td>449.4</td>
<td>4610.2</td>
<td>9.75</td>
</tr>
</tbody>
</table>
Top Ten Typhoon Events (2004~2009)

- MORAKOT
- HAITANG
- BILIS
- MINDULLE
- FUNG-WONG
- KALMAEGI
- KAEMI
- JANGMI
- SEPAT
- KROSA

Ranked by Pe/Py
# Devastating Typhoon Event - Morakot

<table>
<thead>
<tr>
<th>Year</th>
<th>Typhoon</th>
<th>Effective date</th>
<th>Total precipitation (mm)</th>
<th>API 7-day before typhoon (mm)</th>
<th>Flow discharge at sampling (cms)</th>
<th>Sediment load at sampling (ton/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Morakot</td>
<td>08/05~10</td>
<td>2117.2</td>
<td>7.29</td>
<td>948.05</td>
<td>2977313.6</td>
</tr>
</tbody>
</table>

- **Rainfall (mm)**
- **Discharge (cms)**

![Graph showing rainfall and discharge over time](image)
Total Precipitation, API, and Flow Discharge

1. Flow Discharge (cms) vs. Total Precipitation of the Event (mm)
2. Flow Discharge (cms) vs. API 7-day before Event (mm)
Total Precipitation, API, and Suspended Load

- **Suspended Load (ton/day)**
  - **Morakot**
  - **Kalmaegi**
  - **Hagupit**

- **Total Precipitation (mm)**
  - API 7 days before event (mm)
  - Morakot
  - Kalmaegi
  - Hagupit
Flow Discharge and Sediment

### Characteristics of events greater than 8-yr mean

<table>
<thead>
<tr>
<th>Year</th>
<th>Discharge (tons/day)</th>
<th>Sediment load (tons/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>59.96</td>
<td>22941.81</td>
</tr>
<tr>
<td>2001</td>
<td>59.96</td>
<td>22941.81</td>
</tr>
<tr>
<td>2004</td>
<td>162.92</td>
<td>204697.90</td>
</tr>
<tr>
<td>2005</td>
<td>222.88</td>
<td>227639.71</td>
</tr>
<tr>
<td>2007</td>
<td>385.80</td>
<td>432337.61</td>
</tr>
<tr>
<td>2008</td>
<td>548.71</td>
<td>637035.52</td>
</tr>
<tr>
<td>2009</td>
<td>711.63</td>
<td>841733.42</td>
</tr>
<tr>
<td>2009</td>
<td>874.55</td>
<td>1046431.32</td>
</tr>
</tbody>
</table>

#### Mean $\mu$ $\sigma$ $x + \sigma$ $x + 2\sigma$ $x + 3\sigma$ $x + 4\sigma$ $x + 5\sigma$

- **Morakot (2009/8/9)**
- **Lekima (2001/9/28)**

#### Number of events

- 2000: 2
- 2001: 3
- 2002: 2
- 2004: 2
- 2005: 2
- 2006: 2
- 2008: 4
- 2009: 4

- **Sediment content**
- **Discharge**
CONCLUSIONS

- The scatter plot of sediment load and flow discharge collected between 2001 and 2009 shows that greater portion of data points fall in the sector with sediment load one standard deviation heavier than the 8-yr mean.

- Data collected in 2009 constitute the majority in the sector with sediment load measured 5 standard deviation higher than the 8-yr mean.

- All evidence supports the negative impact of less frequent yet high precipitation typhoon events exerts on watershed sediment yield.
Rise in annual precipitation from 2004 to 2009 along with a negligible increase in annual rainy day emerges the intensification of rainfall intensity, greater soil loss, and higher sediment yield.

API calculated 7-day before the typhoon event fails to reflect the flow discharge and sediment load sampled during or immediately after the storm event.

Total precipitation seems to correlate better to both flow discharge and sediment concentration.
Anomaly method shows that apparent increase in annual precipitation with negligible increase in annual rainy day, which implies the increase of average daily rainfall intensity. Hence, the study watershed has been constantly facing the risk of high intensity rainfall in recent years.