Sediment transport in the Himalayan basin


Programme INSU "Reliefs de la Terre"
Global warming

Sea level rise

Particle flux 1.2 billion t/yr

Erosion

Transport

Deposition

Uplift

Subsidence

Northward plate motion

Bengal fan deposition
Global warming

Sea level rise

Erosion

Deposition

Transport

Particle flux 1.2 billion t/yr

Bengal fan deposition

Subsidence

≈ mm to cm/yr

Northward plate motion

≈ 2-4 mm/yr

Uplift

≈ 3-5 mm/yr
Bangladesh relies on a delicate balance between sediment deposition, subsidence, sea level rise.
1000 millions tons/yr = 50 millions trucks = 1.6 Earth-Moon distance
Only limited data exist for transport fluxes & deposition distribution

- Observation of the actual sediment transport processes
- Geochemical approach of the sediment composition
  - origin of sediments
  - flux estimates
  - erosion vs. deposition
Geochemical budget rely on REPRESENTATIVE sampling
River depth sampling

- Sampling at different depth in the river channel
- Dredging bed sediments
- ADCP acquisition
- Monsoon sampling

Ganga at Varanasi, 21 Aug 2008
Depth Profiles: Ganga at Harding bridge

- Suspended load
- Bedload

Depth (m) vs. Al/Si ratio

Quartz → Al/Si → Micas & Clays

Depth sampling + Current profiling of the Ganga at Harding bridge

\[ \phi_X = c \times v \times [X] \]

\[ \phi_X = \frac{1}{Z_{max}} \int_0^{Z_{max}} \phi_X(Z) \times dZ \]
1. What is the “real” physical rate of erosion of the Himalayan basin?

- Dissolved: $\approx 42 \times 10^6$ t/yr
- Suspended: $\approx 440 \times 10^6$ t/yr

Himalayan area: 145000 km²
1 - What is the "real" physical rate of erosion of the Himalayan basin?

Dissolved $\approx 42 \times 10^6$ t/yr

Suspended l. $\approx 440 \times 10^6$ t/yr

Bedload flux ???

Floodplain sequestration ???

Himalayan area 145000 km$^2$
Assuming that no material (soil, sediments..) is accumulated in Himalaya
Average compositions 2002-2004-2005

Suspended Load = integration of sediment concentrations, velocity, compositions

![Graph showing iron oxide to silica ratio vs. aluminum oxide to silica ratio for different river systems like Ganga, Brahmaputra, and bedload.](image-url)
Average compositions 2002-2004-2005

Suspended Load = integration of sediment concentrations, velocity, compositions
### Calculated fluxes

**Assumptions:**
- Steady state erosion (no accumulation in Himalaya)
- No uncertainty on dissolved and SL fluxes,
- Source rock $\text{Al}_2\text{O}_3/\text{SiO}_2 = 0.19$ to 0.22

<table>
<thead>
<tr>
<th>Flux Type</th>
<th>Brahmaputra (10^6 t/yr)</th>
<th>Ganga (10^6 t/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended load</td>
<td>500</td>
<td>440</td>
</tr>
<tr>
<td>Dissolved</td>
<td>43.1</td>
<td>41.9</td>
</tr>
<tr>
<td>Bedload+sequestration</td>
<td>95-750</td>
<td>165-390</td>
</tr>
<tr>
<td><strong>Total erosion</strong></td>
<td><strong>650-1250</strong></td>
<td><strong>650-870</strong></td>
</tr>
<tr>
<td>Himalayan area</td>
<td><strong>0.145</strong></td>
<td><strong>0.176</strong></td>
</tr>
<tr>
<td>Erosion rate (t/ km^2 /yr)</td>
<td><strong>4500-8620</strong></td>
<td><strong>3700-4950</strong></td>
</tr>
</tbody>
</table>
\[ \text{CO}_2 \rightarrow \text{COH}_2 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} \]

\[ 2(\text{K,Na})\text{AlSi}_3\text{O}_8 + 2\text{CO}_2 + 2\text{H}_2\text{O} \]

\[ \text{Na}^+ + \text{K}^+ + 2\text{HCO}_3^- + \text{Kaolinite} \]

\[ \approx 80 \times 10^9 \text{ mol/yr} \]
Himalayan Rivers: Ganga

\[ \frac{(Na+K)}{Si} \]

\[ \frac{Al}{Si} \]

Weathering

Himalayan Rivers: BL, SL

Ganga: BL, SL
\[ \Phi_{Na} = \Phi_{sed} \times \Delta Na \]

\[ \Phi_{sed} = 0.55 \times 10^9 \text{ t/yr} \]

\[ \Phi_{Na} = \Phi_{water} \times [Na^*] \]

\[ \Phi_{water} = 352 \times 10^9 \text{ m}^3/\text{yr} \]
\[ \Phi_{Na} = \Phi_{sed} \times \Delta Na \]
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\[ \Phi_{water} = 352 \times 10^9 \text{ m}^3/\text{yr} \]
Himalayan Rivers:

- Ganga:
  - BL
  - SL

Massive soil erosion in the western floodplain

Floodplain clays

Himalayan Rivers:  
- BL
- SL

Ganga:  
- BL
- SL

→ Massive soil erosion in the western floodplain
3 - About future evolution

- Increase of precipitation 10-20%
- Increase of seasonality
  - Higher monsoon runoff 20-30%
  - Higher sediment influx 20-50%
Conclusions

- Geochemical approaches better document fluxes of sediments:
  - scale of bedload sequestration
  - soil erosion
  - also: erosion distribution in Himalaya, impact on carbon cycle, paleo-erosion...

- However large uncertainties remain:
  - depocenter of sediments (floodplain vs. delta vs. Bengal shelf)
  - magnitude of bedload transport
  - evolution under changing global warming

- Overall lack of data
  - discharge
  - almost no survey of sediment fluxes and quality