Sediment budgeting as a tool for sustainable sediment mining: Case study from a bedrock river in Peninsular India

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A multiscalar hydrogeomorphic approach for suspended sediment dynamics and budgeting, with reference to sediment mining

1 River processes using sediment budgeting

- River processes are controlled by balance between sediment supply and channel transport capacity.
- Sediment budgeting involves accounting of sources and behavior of sediment as it travels from its point of origin to exit from a drainage basin. [1]
- The approach has been applied globally for applications ranging from geomorphic process understanding and stream management. [1-5]
- This study: merges hydrology based stream power distribution and sediment budget to understand channel dynamics with reference to sediment mining

2 A multidisciplinary approach to sustainable sediment mining

- Assessment of spatiotemporal variability of aggradation and degradation processes through cross scalar stream power and sediment yield relationship.
- SWAT (Soil and Water Assessment Tool) [6] based watershed modelling to account for smaller tribuary processes.
- Development of process based understanding of channel morphology by integrating sediment budgeting and planform morphology.
- Evaluation of geomorphic threshold to explain spatiotemporal variability in morphological changes using the Maximum Flow Efficiency (MFE) principle. [7]

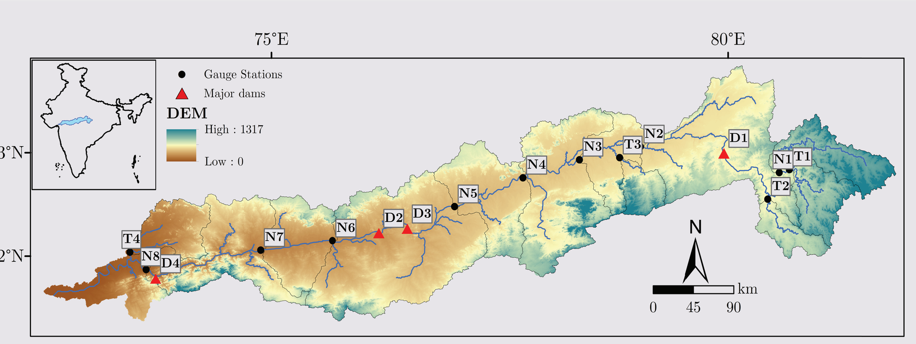


Figure 1
Topographic map of the study area and its geographical location. Gauge stations and major dams in the basin are also shown.

3 Narmada River basin and Methodology used

- Monsoon dominated, 1300 km long, $1*10^5$ km^2 area. Discharge and suspended sediment concentration data for 12 stations in the basin (8 along main channel + 4 on tributaries).
- Semi distributed hydrologic model: SWAT to account for smaller tributaries. Parameterization and uncertainty analysis using SWAT-CUP
- Sediment mass balance = u/s – d/s sediment load, at long term and monthly timescales

4 Results: Sediment sources and sinks: Process controls

Basin scale sediment supply

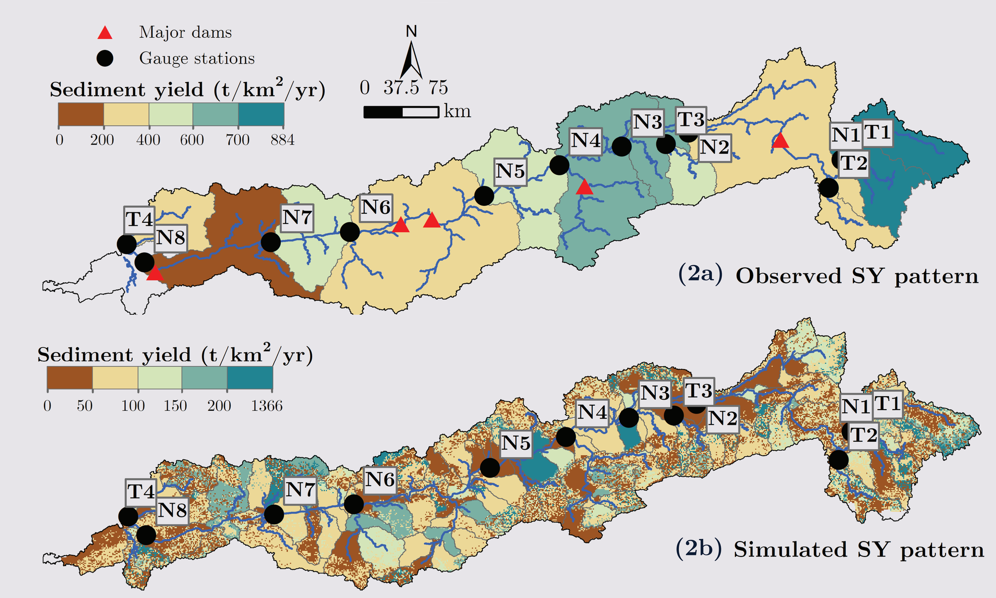
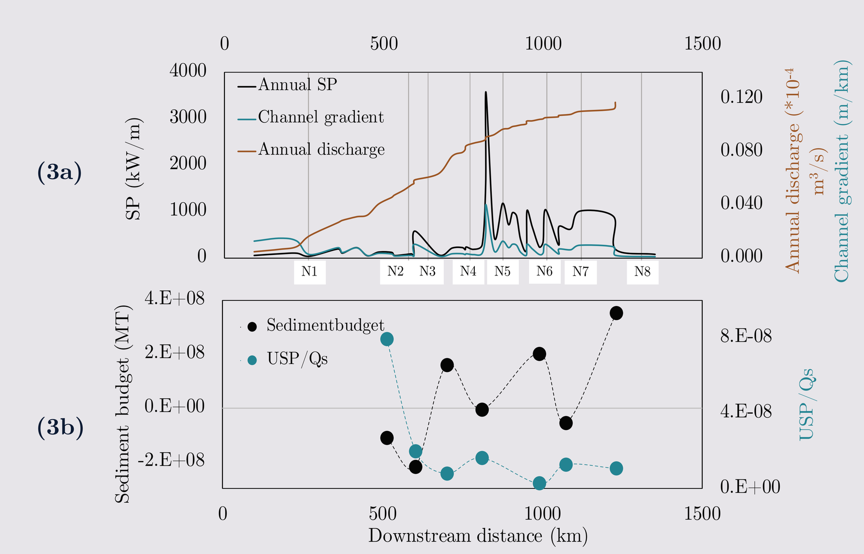


Figure 2
Sediment yield distribution based on (a) observed data from 12 gauge stations (b) SWAT, calibrated at N6 site. Figure indicates the suitability and advantage associated with hydrological modelling using SWAT in informing river management deci-

Reach scale sediment budget



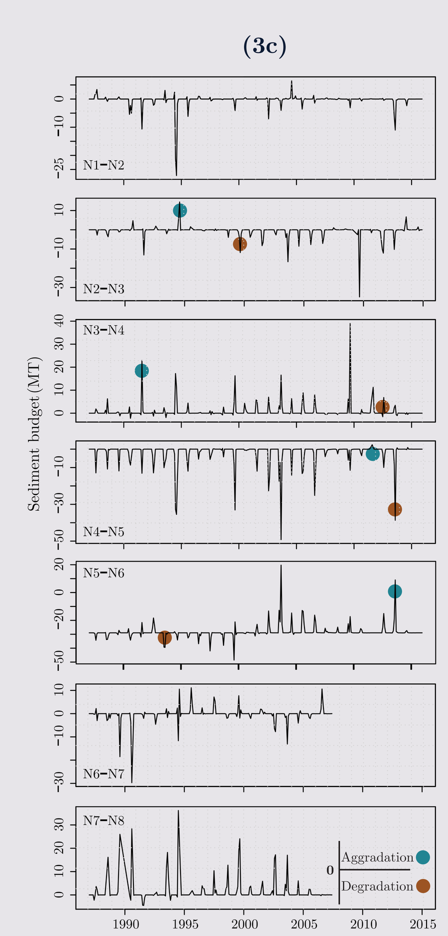


Figure 3
(a) Stream power distribution obtained from SWAT indicates that downstream reaches possess the highest energy. (b) The spatial variability of sediment budget can be explained with the ratio of sediment supply and stream power. (c) Temporal variability of sediment budget: even long term erosion dominated reaches may experience periods of deposition, and vice versa.

Relationship between sediment budget and channel morphology

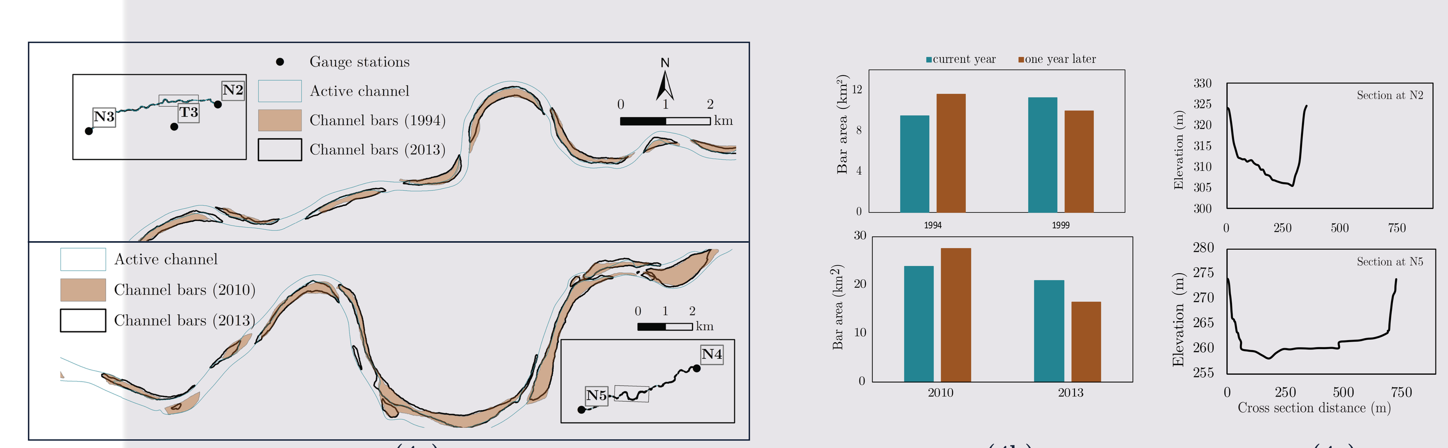


Figure 4
Reach wise morphological mapping of the Narmada River basin. (a) shows the reach scale morphological features and their temporal variability across the study period. (b) shows the quantitate change in the bar area for the chosen events. (c) represents the cross-section of the downstream station.

5 Discussion: Fluvial process dynamics in Narmada River

- Sediment budget:
  - Erosion sites
    - Basin scale: subbasins draining to stations N1, T1, N3-N4
    - Channel scale: reaches N1-N2, N2-N3 and N6-N7
  - Deposition sites: reaches N3-N4, N4-N5 and N7-N8
- Threshold:
  - Spatial variability: explained by ratio of sediment yield and unit stream power. Aggrading reaches- USP/Qs > 1
  - Temporal variability: explained by sediment concentration. A threshold of 1.5 g/l was determined for aggradation processes in dominantly degrading reaches.
- Suggestions for sediment mining:
  - Midstream reaches which were dominantly aggrading shall be focused.
  - Rate of bar skimming not exceeding 0.25 m/yr in midstream reaches.
  - Temporal variability of sediment supply shall be monitored.

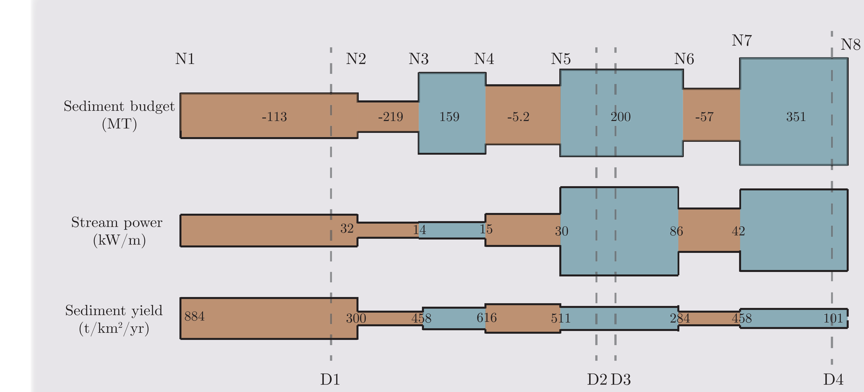


Figure 5
Process controls on sediment budget: The coupled interaction of reach-scale stream power, upstream sediment yield and dams explains the variability of sediment yield.

6 Conclusions

- Based on the SY distributions, the upstream and midstream reaches (N1, N3, N4) were the hotspots of sediment erosion.
- Based on the sediment budgeting approach, midstream and downstream reaches were deposition dominated with up to 350 MT of sediment surplus, explained by variability of sediment yield and stream power.
- Even within the deposition dominated reaches, morphological mapping revealed that bar dynamics may be different from reach scale dynamics, which is also controlled by the channel cross section.

7 References

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