Factors Controlling Sediment Yield in a Major South Asian Drainage Basin: The Upper Indus River Basin, Northern Pakistan

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1. Introduction

- Estimates of sediment yield are essential in water resources analysis, modelling and engineering, in investigations of continental denudation rates, and in studies of drainage basin response to changes in climate and land use
- There is a need of sediment yield models for ungauged basins, in particular in remote, alpine environments, where monitoring networks are typically sparse. This need was identified in the PUBs initiative of IAHS

2. Objective

- To develop multiple regression models for estimating sediment yield in the mountainous upper Indus River basin using high resolution, spatial data available in the public domain

3. Study Area

- The upper Indus River Basin
  - Drainage area: 181,500 km^2
  - Channel length: 1125 km
  - Mean discharge: 7500 m^3 s^{-1}
  - Mean sediment load: 200 Mt
- A large, data-sparse river basin in the Karakoram and Himalaya region
- Area of young rising mountains generating large amounts of suspended sediment

4. Data

A. Sediment yield and runoff data

- 17 active and discontinued long-term hydrological stations
- Basin areas of 598 to 166,154 km^2 and sediment yields of 333 to 3270 t km^{-2}yr^{-1}

B. Geospatial data

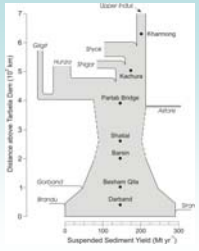
- Topography: 30 arc-second, USGS GTOPO30 DEM
- Climate: 1-km, WorldClim database
- Population density: 2.5 minute, Asian Population Database (APD)
- Land cover: 1-km, USGS Global Land Cover

5. Methods

- The DEM and gauging stations coverage were used for basin segmentation and parameterization with ArcInfo ArcGIS
- In addition to 7 runoff and sediment variables, a total of 21 other characteristics were derived from geospatial datasets for each of the 17 sub-basins

6. Results

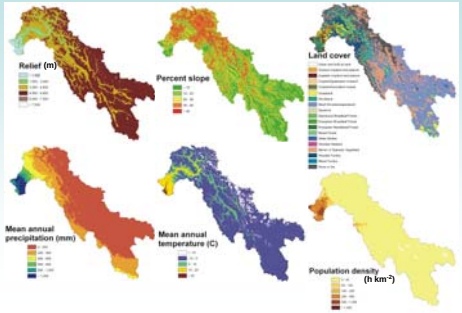
A. Sediment yield variability



- Mean annual sediment yield increases downstream along the Indus River
- The Hunza River contributes a greater proportion of sediment (22.8%) than its drainage area (8.1%) would indicate
- Decreasing sediment yield between Partab Bridge and Shatial Bridge shows deposition in the valley
- The section between Partab Bridge and Besham Qila provides a major contribution from a number of steep and relatively short and straight tributaries

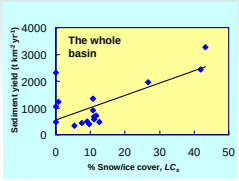
B. Physical distribution and spatial patterns of controlling variables

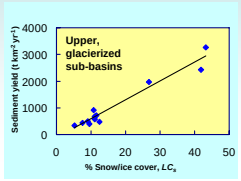
- Maps of the geospatial data portray the variability and control of major variables on sediment yield



C. Correlation between sediment yield and sub-basin variables

- Subdividing the hydrological stations into three groups: i) the main Indus River; ii) upper, glacierized sub-basins; and iii) lower, monsoon sub-basins, results in statistically significant relationships between the sediment yield and the controlling variables

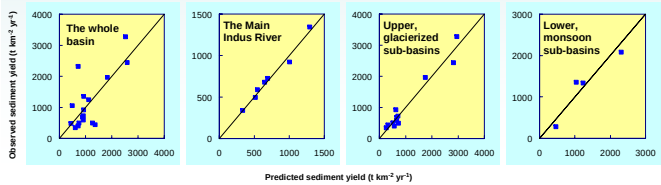




D. Modeling sediment yield variability

Regression Models	R^2	R^2_{adj}	F-ratio	p-value	ME
The whole basin SY_{sp} = 556.4 + 45.7 LC_s	47.1%	43.5%	13.3	0.002	0.471
The Main Indus River SY_{sp} = - 4255.1 + 443.7 R_r + 9.2 P	95.0%	92.6%	38.3	0.002	0.950
Upper, glacierized sub-basins SY_{sp} = - 126.7 + 71.1 LC_s	95.1%	94.6%	193.0	0.000	0.950
Lower, monsoon sub-basins SY_{sp} = - 5613.6 + 66124.4 Q_{pk} + 3.91 P	89.8%	69.5%	4.4	0.319	0.889

SY_{sp} = specific sediment yield (t km^{-2}yr^{-1}); LC_s = percent snow/ice cover (%); ; P = mean annual precipitation (mm yr^{-1}); R_r = relief ratio; Q_{pk} = discharge peakedness (mean annual discharge/maximum annual discharge)



7. Conclusions

- Percent snow/ice cover (LC_s) emerges as the single major land cover control for sediment yield in the high mountainous upper Indus River basin
- Regression models using percent snow/ice cover (LC_s) as single independent variable explain 47% of the variance in sediment yield for the whole Indus basin, and 95% of the variance for the upper, glacierized sub-basins
- Along the main Indus River, relief ratio (R_r) and mean annual precipitation (P) explain 95% of the variance in sediment yield

8. Selected References

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