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Gautam, Kshitiz; Roebroeck, Mathieu E.; Bogaard, Thomas A.; Blom, Astrid

Publication date
2023

Document Version
Final published version

Citation (APA)
Gautam, K., Roebroeck, M. E., Bogaard, T. A., & Blom, A. (2023). *To what extent is morphodynamics of Terai Arc Landscape rivers altered by human actions?*. 86-87. Abstract from NCR Days 2023, Nijmegen, Netherlands.

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Book of Abstracts
NCR DAYS 2023
12-13 April | Radboud University

Netherlands Centre for River studies NCR

Wilco C.E.P. Verberk
Frank P.L. Collas
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Marie-Charlott Petersdorf (eds.)

NCR Publication: 51-2023

NCR DAYS 2023

Towards 2048: The next 25 years of river studies

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Organising partner:

Radboud University

Conference venue

Lindenberg Cultuurhuis
Ridderstraat 23
6511 TM Nijmegen
The Netherlands

telephone: +31 24 327 39 11
e-mail: info@delindenberg.com
www: https://www.delindenberg.com

Contact NCR

dr. ir. K.D. Berends (Programme Secretary)
Netherlands Centre for River Studies
c/o Deltares
Boussinesqweg 1, 2629 HV Delft
P.O. Box 177, 2600 MH Delft
The Netherlands

telephone: +31 6 21 28 74 61
e-mail: secretary@ncr-web.org
www: http://www.ncr-web.org

Cite as: Wilco Verberk, Frank Collas, Gertjan Geerling, & Marie-Charlott Petersdorf (eds.) (2023), *Towards 2048: The next 25 years of river studies: NCR DAYS 2023 Proceedings*. Netherlands Centre for River Studies publication 51-2023

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To what extent is morphodynamics of Terai Arc Landscape rivers altered by human actions?

Kshitiz Gautam[a], Mathieu E. Roebroeck[a], Thomas A. Bogaard[a], Astrid Blom[a]

Highlights

- Analysis of extreme flows and images of the Karnali and the Koshi rivers
- Increased sedimentation affected by channelization and dam construction
- River morphodynamics affected by combination of natural and anthropogenic activities

Overview

Most of the Himalayan rivers emerge out of the mountains into the flat lands of Nepal, India and Bhutan. This landscape is called Terai Arc Landscape (TAL), where these rivers release a large quantity of sediment forming fertile alluvial fans. The rivers in TAL are crucial for both the environmental conservation and continuity of socio-economy in countries such as Nepal. However, the increased demands for the socio-economic activities have highly influenced the TAL rivers. Increased anthropogenic interventions such as hydropower and irrigation projects, flood protection structures, and sediment mining alter the flow, sediment transport and hence the morphology of the TAL rivers. This research makes an attempt to identify the impacts of such anthropogenic activities on the hydro-morphodynamics of the TAL rivers. Here we discuss the morphodynamics of the Karnali and the Koshi rivers in Nepal.

The yearly maximum discharge in the Koshi River and yearly minimum discharge in the Karnali River show a decreasing trend. Meanwhile, the trend of the minimum discharge in the Koshi River and the maximum discharge in the Karnali River do not show significant change (Figure 1).

Analysis of remote sensing data and historical maps for both rivers within the stretch of TAL show that they have changed their flow course multiple times. Often, the course switches between former channels (Chakraborty et al., 2010; Dingle et al., 2020). Records and image analysis show that these avulsions are usually abrupt and occur during high flood. Channelization has affected the morphodynamic processes in both rivers. The western branch of the Karnali River (the Kauriala), channelized on both banks, has low braiding index than its eastern branch (the Gerua) which is embanked only on right bank. The embankments and barrage construction in the Koshi River has increased the river sedimentation by more than double in about 54 years (Sinha et al., 2019).

Rivers in TAL are naturally dynamic braided systems. The changing hydrological conditions and the human interventions have restricted this dynamic behaviour. As an example, channelization and controlled flow have reduced the channel-floodplain connectivity. They have also altered morphodynamic processes such as channel shifting and flow partitioning as observed in the Koshi River. There may have been a paradigm shift from natural to human induced morphodynamic processes. Identifying, distinguishing and studying the extent of impact caused by these processes, be it natural or anthropogenic, has become of utmost importance to help in maintaining the river functions in TAL and this needs extensive exploration and research.

Affiliations

[a] *Faculty of Civil Engineering and Geosciences, Delft University of Technology, The Netherlands*

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Hydrological Analysis

Hydrological analysis (Figure 1A) shows decreasing trend in maximum discharge of the Koshi River at Chatara. Hydropower development may be one of the factors influencing this decline. The extent of hydropower and associated river dams in the Koshi river basin has increased since the past two decades. This development has played role in attenuation of the flood peaks and hence altered the natural discharge as well as sediment transport in the Koshi River. The future of the Karnali River, which thus far is one of the least altered rivers by anthropogenic intervention in TAL, may resemble the current state of the Koshi River, as multiple hydropower projects are in construction or planned. The declining trend in minimum discharge of Karnali (Figure 1B) may be due to changing precipitation dynamics, land use change or increased consumptive use of water in the catchment and this needs further research.

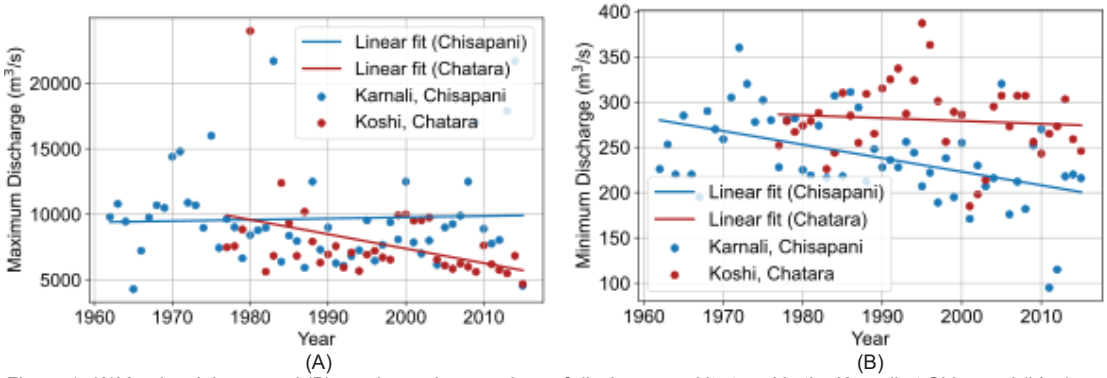

Figure 1: (A) Yearly minimum and (B) yearly maximum values of discharge and its trend in the Karnali at Chisapani (blue) and the Koshi at Chatara (red).

Channel Migration

We use difference of Normalized Difference Water Index (NDWI) in Google Earth Engine (GEE) to identify the change of river course over time. Figure 2A shows the switching of channel in Karnali River in 2009. The river changed its major flow path from the eastern branch (red colour indicates the areas where the river used to flow before the 2009 avulsion) to the western branch (blue color indicates the flow path after channel switching). The avulsion took place at the apex of the island, Rajapur and the two branches join back at Kailashpuri. These avulsions can be characterised as nodal (occurring around same area) and partial (take away a part of discharge) (Slingerland & Smith, 2004). This avulsion has significantly reduced the flow in the eastern braided branch (Gerua) which flows through the Bardiya National Park. Subsequently, the main river course has followed a narrower and mostly single threaded western channel (Kauriala). The embankments on both banks of the western branch has channelized it. Similar is the case of the Koshi river. Figure 2B shows the NDWI difference image of the Koshi River from Chatara to Mahisi. The Koshi River is confined by embankments on both banks and flows through the Koshi Tappu Wildlife Reserve and is regulated by the Koshi Barrage. The operation of the barrage gate determines the flow path of the river in the downstream channel. In 2008, an eastern embankment breach resulted in an avulsion which rejuvenated a paleo channel. This led to casualties and significant damage.

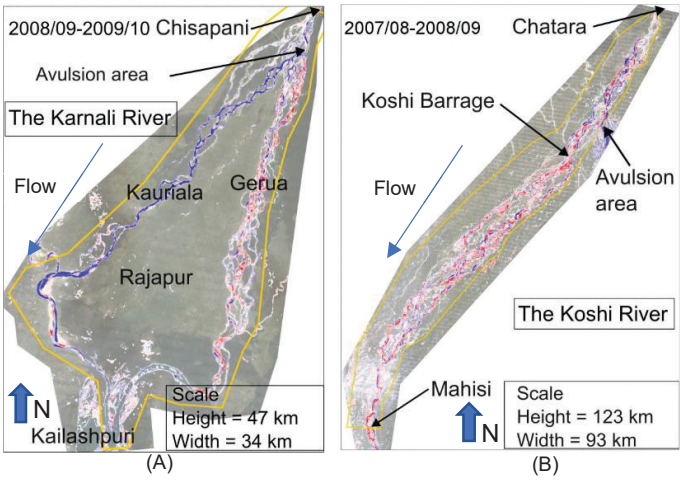

Figure 2: NDWI difference image showing channelization and channel switching of (A) the Karnali river in 2009 and (B) the Koshi river in 2008. The red areas show the old flow path and the blue are the flow path after channel switching.

Acknowledgement

This research is a part of “Save the tiger! Save the Grassland! Save the Water!” project funded by Dutch Research Council (NWO) with co-financing partners VanderSat (currently Planet), Rotterdam Zoo, Himalayan Tiger Foundation and Practical Action.