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Morphodynamic similarities between rivers in the Terai Arc Landscape

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1. Introduction

Rivers flowing from the highlands to the lowlands, characterize the Terai Arc Landscape (TAL) in Nepal and India, but also the neighbouring region in Bhutan. The sudden change in slope results in deposition of nutrient-rich sediment, which forms large alluvial or fluvial fans that enhance biodiversity and economic activities in the region. Our objective is to identify similarities and differences in hydro-morphodynamics between the TAL rivers, with a focus on the Karnali and Koshi systems in Nepal. It is expected that such insight in river dynamics will aid the sustainability and management of the TAL rivers. To this end, we investigate and compare discharge characteristics, historical flow paths, and morphodynamic characteristics such as channel shifting, braiding, and flow partitioning to identify and understand the fan scale dynamics of the two systems. Hereto we used optical remote sensing images and river discharge time series from Chisapani (Karnali) and Chatara (Koshi) gauging stations. In addition, we conducted a field campaign in November 2022.

2. Results

The Koshi River has formed an alluvial fan of more than 10,000 km^2 (Chakraborty et al., 2010) whereas the Karnali fan area equals about 800 km^2 (Rakhal et al., 2021). The mean annual peak flows of the Koshi and Karnali are similar and, respectively 7800 m^3/s and 9700 m^3/s. Also the average annual minimum flow rate is similar, 280 m^3/s for Koshi and 240m^3/s for Karnali.

The yearly minimum discharge of the Karnali River where it leaves the highlands shows a decreasing trend over the period 1962-2015 but the Koshi River (over the period 1977-2015) does not. For the same periods, the maximum discharge of the Koshi River shows a declining trend, whereas the Karnali River does not. The declining trend of the Koshi can be attributed to regulation of flow in the river caused by rapid development of hydropower projects in the Koshi basin over the past two decades.

In the lowlands both rivers are braided systems. The Koshi River displays a single braiding channel whereas the Karnali River has two braiding branches, the Gerua branch (east) and the Kauriala branch (west). The braiding index of the Gerua is higher than the Kauriala, which can be attributed to the channelization of the Kauriala branch through embankments. We observe similar channelization in the Koshi system where channel migration is restricted within the embankments and is often manipulated by dredging and operation of the gates of the Koshi Barrage.

A large scale shift of the Koshi River occurred in 2008 (annual peak discharge of 6010 m^3/s), as it breached the embankment and changed its course and rejuvenated older channels east to its current flow path. In the Karnali River, the major part of the flow switched from Gerua to Kauriala in 2009 (annual peak discharge of 17000 m^3/s). Both changes occurred during a major flood event.

Remote sensing images since 1972 indicate a larger river surface area in the Gerua branch than the Kauriala branch. After the flood of 2009, however, the flow area of the Kauriala branch increased and that in Gerua decreased. Since 2012 the Kauriala river surface area has been larger than the Gerua. Relating this river surface area to the magnitude of the water discharge implies that the major share of the water discharge is now carried by the Kauriala branch.

3. Conclusions

The Koshi and Karnali systems have developed alluvial fans of significantly different scales despite their relatively similar flow rates. The temporal trends of water discharge extremes differ: the annual minimum of the Karnali is declining and so is the annual maximum of the Koshi. Both rivers are dominated by channel switching marked by major flood events. The Koshi River generally shows a complete channel shift, whereas the Karnali River usually maintains flow in each of its two branches. Both systems are braided but embankments tend to reduce dynamics and braiding index.

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