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Flow partitioning between branches of the Karnali river in Nepal

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Introduction

The dynamics of the bifurcating Karnali river in the western plains of Nepal and India is governed by the geomorphological processes in an alluvial fan. The dynamic branches showcase a notable degree of braiding, dominant channel switching and unequal discharge partitioning. Since recent switching of the dominant channel of Karnali system occurred after an intense monsoon in 2009, the

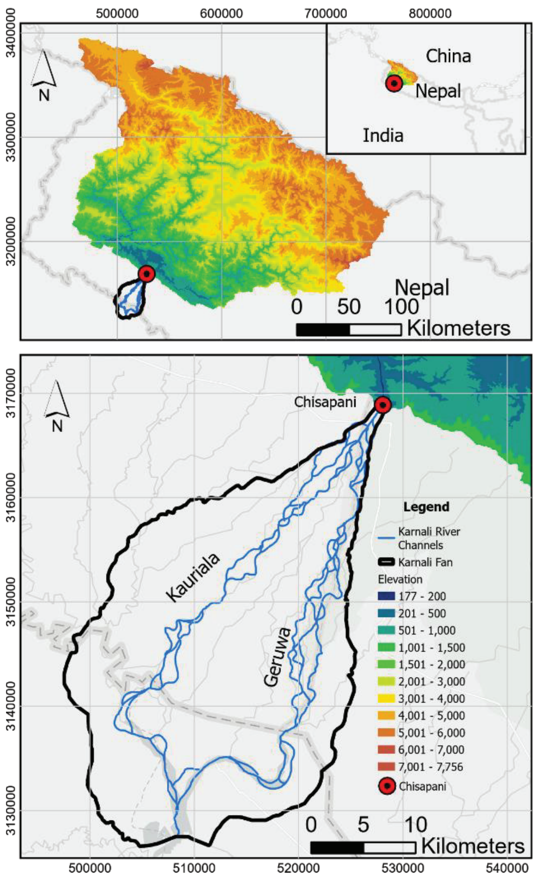

Figure 1: Karnali Discharges from mountain catchment (Top) at Chisapani and bifurcates into two branches Kauriala and Geruwa and gives rise to the Karnali Fan (Bottom)

eastern Geruwa branch of the system, which used to be dominant channel passing through the Bardiya National Park, is now receiving a lower share of discharge. This situation exacerbates in the low flow periods when there is very small flow in the Geruwa branch. This decreasing discharge has been associated with depleting diversity of wildlife habitat in Bardiya National Park (Bijlmakers et al., 2023). For sustainable habitat management in the Bardiya National Park, there is a necessity to study the dynamic Karnali river and its two branches, the eastern Geruwa branch and the western Kauriala branch. Activities such as sediment mining, construction of irrigation and hydropower and inter-basin water transfer projects will potentially influence the system dynamics. Our objective is to understand the switching behaviour of the Karnali system to the natural dynamics such as bend sorting (Baar et al., 2020; Parker & Andrews, 1985) of sediments at the location where water from the main Karnali enters the Geruwa branch, and offer understanding of system response to human interventions especially with regards to the distribution of discharge between the Geruwa and Kauriala branches. We combine the technique of field observations and numerical modelling to study the system.

Methods

The initial screening of the system is done via available historical maps and optical satellite images. This sediment distribution serves for setting up our numerical model. The cross sections are used for model setup and also to understand the slope of different sections of the Karnali system. The numerical models, still in the phase of development, can be expected to provide an insight into the dynamics and the associated causes of water distribution between the Geruwa and Kauriala branches of the Karnali system and possible closure of the Geruwa branch. We set up a one dimensional hydrodynamic model to study the discharge partitioning in the two branches, the eastern Geruwa branch and the western Kauriala branch, of the Karnali system. We utilize the information from the field work and satellite images to setup and validate the model.
For the bifurcation area, we develop a two dimensional hydro-morphodynamic model in order to understand the effect of bend sorting on the closure of Geruwa channel.

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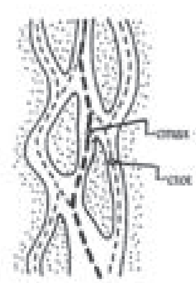
Remote sensing

Maps since 1817 are used to identify the bimodality (two branch) of the system. Satellite images between 1972 and 2022 from different Landsat and Sentinel missions are observed and analysed. For estimating the distribution of the water in the two branches, the area covered by water in each branches is taken as reference and the percentage distribution of area is used as the first estimate of percentage distribution of water in each branch. The braiding index (BI) at different sections of each branch is calculated as:



$$BI = \frac{L_{ctot}}{L_{cmax}}$$

Sediment analysis

We perform sediment analysis by photo-sieving (Ibbeken & Schleyer, 1986). We take photographs of the sediment across river cross-sections in different locations along streamwise direction and use them in computer aided tool BASEGRAIN (Detert & Weitbrecht, 2013) to determine the grainsize distribution.

Channel Geometry

We measure channel geometry as function of depth and width. We use Real Time Kinematic positioning to determine the elevation of the river bed, water level and high flow levels as well as to obtain the cross section of the river. We use single beam sonar for determining the depth of water where it is deep and use the RTK water level with depth obtained from the sonar to determine the cross sections of the river.

Results

Analysis of historical maps and satellite images show that Karnali has been a bifurcating river system at least since 1817. The discharge partitioning from the satellite images show increasing discharge in Kauriala branch after 2009. More than 50% of discharge during the low flow conditions flow in Kauriala branch. The BI of Kauriala has increased by a range of 1.0 to 1.5 near the bifurcation areas whereas decreased by 0.9 to 1.2 in the areas downstream of the bifurcation. The BI of Geruwa has decreased by 1.8 to 3.0 in different sections. The field observation shows abundance of large size sediments in Geruwa. The average slope of the Kauriala branch is 1.6×10^{-3} and that of Geruwa branch is 1.5×10^{-3}.

Conclusion

The Karnali is a river flowing in two branches since at least past two centuries which occasionally switches the dominant channel. It is still a matter of investigation if this type of switching occurred in the past or will happen in the future especially with recent and planned anthropogenic interventions in the future. The Kauriala branch is prone to lose its braiding pattern given its confinement with the dikes as observed in the field and from the timeseries of satellite observations. The elevation of the inlet, which is the outer side of the bend, to Geruwa is higher and that may be attributed to the deposition of larger sediments in the outward bend due to bend sorting of the sediments. The higher slope of the Kauriala and increasing bed level of the Geruwa at its inlet will increase the flow in Kauriala and decrease it in Geruwa. The issue of lowering wildlife habitat heterogeneity may exacerbate given the decreasing BI and flow in Geruwa.

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