ICG2022-508, updated on 06 Jun 2023
https://doi.org/10.5194/icg2022-508
10th International Conference on Geomorphology

The influence of river-hillslope interactions on fluvial hazards in the Himalaya

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The Himalayas experience frequent fluvial disasters due to precipitation-driven floods, as well as events such as glacial lake outburst floods and landslide lake outburst floods. Such floods represent a major hazard, causing loss of life and damage to property and infrastructure. In steep mountain landscapes, rivers and hillslopes are often tightly linked, and interactions between these domains can strongly influence flood impacts and dynamics. Floods can erode the base of hillslopes and terraces, driving mass wasting, while hillslopes can deliver large amounts of coarse sediment, driving aggradation and potentially creating temporary dams. Data from a 2016 glacial lake outburst flood in central Nepal demonstrate that flood-induced mass wasting can be a dominant driver of damage from such an event, with at least 85 homes and many stretches of the Araniko highway destroyed by slope failures. The hillslope impacts were not confined to the event itself, as a number of hillslopes experienced longer-term destabilization, continuing to slide for years following the flood and hampering efforts to rebuild the road. While the 2016 event represents a case of flood-driven hillslope hazards, a 2021 event on the Melamchi River in central Nepal demonstrates the amplification than can occur with more complex river-hillslope feedbacks. Here, the interaction between the river and a range of hillslope inputs, including a paleo landslide dam, recent colluvial deposits, and a flood-triggered landslide dam, led to massive aggradation throughout the Melamchi River. This aggradation substantially altered the river channel, amplifying the impacts of later floods and promoting additional mass wasting, further increasing the sediment loading of the river. This perturbation of the river-hillslope system is still ongoing, and is expected to cause continued hazard over the next monsoon seasons. These cases demonstrate the importance of considering hillslopes and river channels as an integrated system rather than as distinct domains during assessment of geomorphic hazards in steep mountain landscape such as the Himalaya.