Hydrogeomorphic and land cover dynamics of Manas-Beki river basin with special emphasis on the glacial regime

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Chapter 5: Conclusion

The current study highlights the hydrogeomorphic characteristics and land cover dynamics at the basin-site scale of Manas-Beki river with special emphasis on the glacial regime at the temporal scale of three decades from 1990 to 2020. The entire study was organized into three core parts: hydrogeomorphic characterization in terms of morphometric quantification and planform dynamics in the floodplain region, land use and land cover dynamics, and monitoring and assessment of glaciers and high-altitude lakes in the upper catchment region.

Morphometric analysis of the Manas-Beki river indicate the basin as a 10^{th} order basin, highly dissected, moderately elongated basin with a steep descent in the Himalayan region and relatively flat topography in the floodplains. The morphometric analysis of the Manas-Beki river basin suggests that the basin is susceptible to changes in streamflow, and downstream regions would be largely affected.

Analysis of channel morphology revealed remarkable changes in channel courses of the Manas-Beki river in the lower floodplain region which has impacted the land use. The river proves to be a highly active channel which is still at a youthful stage indicated by the several recent significant changes in channel courses. Channel dynamics is also directly linked to the erosion and deposition trends in the floodplain region. The major changes in the river morphology are due to the shift in the river thalweg from one anabranch to another within the span of the studied time period. The changes in the river channel are highly erratic in nature and changes might be attributed to changes in sediment and water supply coupled with the construction of man-made hindrances to the river's natural flow.

Land use and land cover dynamics in the floodplain region are driven by the channel changes, erosion, and deposition trends of the river within the river corridor. Chronic flooding near the confluence with the Brahmaputra river, resulting in prolonged waterlogging and sand casting, is also a factor influencing the land use and land cover pattern in the floodplain. The changes in the upper catchments of the river basin are primarily attributed to natural causes as human interference in these inaccessible high mountainous regions is rare.

The findings of the analysis for vegetation and snow cover area of the upper glaciated catchments from 1990 to 2020 shows immense changes in the vegetation and snow cover area which are the two major land cover categories in the high-altitude natural landscape. An

increase in vegetation area and a decline in snow cover area is observed throughout the basin. Greening is observed at higher altitudes in 2020 than observed in 1990 and snow cover is moving towards the higher altitudes. The observed changes in snow and vegetation cover area in the Manas-Beki basin are a clear indicator of basin response to climate change.

Monitoring and assessment of glaciers show extensive changes in the glacial regime from 1990 to 2020. Glacier coverage area has drastically reduced in the Manas-Beki river basin while the number of glaciers has increased due to the fragmentation of large glaciers. Several glaciers of smaller sizes at relatively lower altitudes in the basin have totally disappeared. Glacier size is a major factor for change and vulnerability to loss in glacial extent. Glaciers of medium sizes (0.5 – 1 km^2 area) are heavily affected influenced by factors including altitudinal location, orientation, and slope of the glacier. In contrast to the change in glaciers, the high-altitude lakes in the Manas-Beki river basin showed an increase in both size and number during the study period. The increase in the area of lakes at relatively lower elevations and the appearance of new lakes at higher elevations is one of the major observed changes. The highest change (area increase as well as new lakes formed) is in pro-glacial lakes followed by unconnected glacial and non-glacial lakes which is directly related to glacial retreat and snowmelt.

Climate variability in the study area is assessed with the help of ECMWF ERA5 datasets extracted for the sub-basins of the Manas-Beki river basin. A distinct increase in mean monthly air temperature is observed at each sub-basin for both monsoon as well as winter seasons. Precipitation shows variable trends in the two seasons and different sub-basins. Total precipitation is observed to be increasing in the monsoon season for the glaciated upper catchment but decreasing in the lower floodplain region. During the winter season, the trend is decreasing throughout the basin. The changes observed in river morphology and land cover in the basin during the study period can be attributed to the changes observed in the climatic variables of the basin.

The results and findings of the present study provide a cardinal resource base for the Manas-Beki river basin, one of the data scarce regions in the world, and will be vital information for the planning and development of the floodplain region as well as high-mountain region for the various stakeholders involved. The study area is a part of the larger Himalayan landscape that is a subject of interest for the research and development community owing to the vulnerability of the region to slight changes in climatic variables and with widespread potential repercussions to the other parts of the world.

Future scope

1. The upper reaches of the Manas-Beki river basin have large areas covered by permafrost. The changes in the permafrost and its relation to changes in land surface temperature and water availability in the basin can be a scope for further study.
2. Contribution of factors such as snow and glacial melt, permafrost, land use and land cover change, and evapotranspiration to the total runoff of the basin can be analyzed to understand the hydrologic response of the basin.
3. Estimation of mass balance changes in the glacial regime is a scope for further study based on the inventory of glaciers prepared in this study.
4. Changes in treeline and snowline altitude of the Manas-Beki river basin and changes to the types of vegetation in high altitudes can be of interest for further investigation.
5. Snow runoff modelling and the response of the basin to different climate change scenarios form another scope for further studies.
6. Hazard, risk, and vulnerability assessment of the basin to climate-induced hazards such as floods, landslides, and related to glacial melt such as the possibility of Glacier Lake Outburst Floods (GLOFs) can be yet another scope for further studies.