Abstract

Hydrogeomorphic characterization, monitoring, and assessment of changes in channel planform, land use/ land cover, glaciers, and high-altitude lakes at the basin-site scale of the Manas-Beki river basin, form the core of this research work. Manas-Beki is a transboundary eastern Himalayan river, and one of the largest tributaries of the Brahmaputra river system originating in Tibet with glaciers as its major source of streamflow.

The analysis of hydrogeomorphic and land cover dynamics with special emphasis on the glacial regime of the basin has been carried out using geospatial analytical tools at the basin-site scale for three decades, 1990 to 2020. The study is organized into five chapters. A brief outline of each chapter is presented in the succeeding subsections.

Chapter 1: Introduction

This chapter outlines the research gap and significance of the research work along with an account of the relevant literature consulted for the understanding of the wide scope of the research area. Specific objectives with their broad methodological approach and an outline of the study area are also presented in this chapter.

The specific research objectives undertaken for this thesis are:

i. **Hydrogeomorphic characterization and dynamics of Manas-Beki river basin:** The scope includes the morphometric characterization of the entire basin; change analysis in different channel and planform parameters in the floodplain region from 1990 to 2020.

ii. **Land use and land cover dynamics of Manas-Beki river basin**: The analyses include the changes in six major land use and land cover categories observed in the floodplain region and changes in vegetation and snow cover analysis in the hilly and mountainous upper catchment region as these are the major land cover categories in this region, and the contribution of other land cover categories is negligible.

iii. **Monitoring and assessment of glaciers and high-altitude lakes of Manas-Beki river basin**: The scope includes monitoring the glaciers and high-altitude lakes in the catchment for the period 1990 to 2020, and available gridded climate data analysis to correlate the findings of monitoring and assessment of glaciers and high-altitude lakes.

Chapter 2: Hydrogeomorphic characterization and dynamics of Manas-Beki river basin

The hydrogeomorphic response of a drainage basin is correlated to the basin characteristics also termed morphometry. Morphometry is the quantitative characterization of a drainage basin and is the baseline information for river dynamics studies to understand how the basin will respond to any changes in processes affecting it. Morphometric analysis was carried out using Remote Sensing (RS) and Geographical Information Systems (GIS) tools. The Digital Elevation Model (DEM) was used for drainage delineation in hilly terrain whereas high-resolution satellite data was used to delineate drainage in the relatively flat floodplain region. Topographical maps of the study area were used to cross-check, and limited field visits were carried out to validate the delineated drainage at areas of confusion. Morphometric analysis includes studying three aspects of the basin: linear, areas, and relief aspects. Specific widely accepted methodologies were employed to calculate the morphometric parameters. A total of 13 parameters were calculated including stream order, stream length, mean stream length, stream length ratio, bifurcation ratio, Rho co-efficient, drainage density, stream frequency, drainage texture, form factor, elongation ratio, circulatory ratio, and relief ratio. To achieve the morphometric characterization, initial estimations of basin form including drainage basin area, perimeter, length, and hypsometry were calculated.

To assess channel and planform changes the entire channel length traversing through the floodplains of the lower Brahmaputra plains in Assam was divided into reaches and cross-sections at every 5 km channel length. Sinuosity, braiding, channel migration, erosion, and deposition were calculated at each equidistant section of the river and the entire floodplain section for every 10-year period from 1990-2000, 2000-2010, and 2010-2020 with the earlier year as the reference. The overall change in all parameters was also estimated for the entire period with 1990 as the base year.

Morphometric characterization of the drainage basin characterizes the basin as a highly dissected, slightly circular basin with a steep descent in the upper catchment and flat topography in the floodplains. The relatively low drainage density and flat slope of the floodplains make them exceedingly susceptible to changes in streamflow resulting in widespread flooding. The most significant changes in the Manas-Beki river system are in the floodplains and delineation of river thalweg and bank lines indicate immense changes in the channel. Anabranching is a common phenomenon and thalweg shift is prominent between anabranches over the years. The overall sinuosity of the river in the flood plain area is decreasing from 1990 to 2020. A slight decrease in the sinuosity indicates a gradual straightening over the years but the values remain less than 1.5 representing an immature river with high erosion potential. Channel dynamics, erosion, and deposition trends in specific reaches indicate the influence of road and railway crossing and associated restricting constructions in this high-energy river system.

Chapter 3: Land use and land cover dynamics of Manas-Beki river basin

Causes and consequences of LULC change has been widely studied by researchers because of its linkage to an array of biophysical processes and phenomena including climate change. To analyze the changes in land use and land cover (LULC), secondary geospatial dataset for LULC available for Assam was combined with LULC classification for upper catchment areas in Arunachal Pradesh, Bhutan, and China. A suitable classification scheme including 9 classes was selected for manual delimitation from satellite images including agriculture, grassland, open forests, dense forests, scrublands, snow- and ice-covered areas, barren lands, waterbodies, and streams/riverbeds. After LULC classification, two areas of change were identified for change analysis from 1990 to 2020: the floodplain region adjacent to the channel and the upper catchment comprising of four glaciated sub-basins.

The floodplain area was demarcated by merging the flow paths of the river from 1990 to 2020 and selecting an area of 5 km on both sides of the farthest bank lines. Hybrid classification (unsupervised classification followed by supervised classification) was carried out on Landsat images of 1990, 2000, 2010, and 2020 and 6 major classes in the flood plains were identified, viz. water, vegetation, grassland, agriculture, sand, and built-up area. Accuracy assessment was also carried out using 120 random points (20 representing each class) with field validation for 2020. Temporal changes for only two significant classes in the upper catchment area: snow and vegetation, which covers more than 95% area were analyzed. Normalized Difference Vegetation Index (NDVI) from satellite data of different years (1990-2020) was used for vegetation cover changes while NDVI coupled with Normalised Difference Snow Index (NDSI), band ratio, and elevation from DEM were used for detecting snow cover changes.

Agriculture shows a slightly decreasing trend and built-up areas show a rapid increase in the floodplain region adjacent to the channel while all other classes show random changes over the years. A significant overall decrease in the snow- and ice-covered areas and an increase in the vegetated areas is observed in the upper catchment area.

Chapter 4: Monitoring and assessment of glaciers and high-altitude lakes of Manas-Beki river basin

Glaciers and high-altitude lakes are susceptible to even slight variations in climate and are global indicators of climate change. However, studies on changes in glaciers and associated lakes in high-altitude regions are scarce in the Eastern Himalayan region, especially for Bhutan and Arunachal Pradesh. Any changes in the cryosphere will largely affect the hydrological regime of the river and affect water availability in the basin making it an important parameter for change analysis. Glaciers and lakes were identified in high-resolution Sentinel-2 images for 2020. Available glacier and lake databases for the study area were also used as a reference. Glacier and lake distribution in different altitudes and aspects were observed. Spatio-temporal changes in the glaciers and lakes from 1990 to 2020 were estimated from Landsat satellite data and trends of change in different sub-basins with elevations and aspects were analyzed. Major climatic drivers of change (temperature and precipitation) were analyzed from reanalysis data.

The glacier coverage area in the basin has drastically reduced from 1990 to 2020 whereas the lake area and number have increased. Analysis of climatic reanalysis data shows an increase in mean monthly temperature during the period in the study area supporting the changes observed in glaciers and lakes.

Chapter 5: Conclusion

This chapter provides a summary of the entire work carried out with relevant results of the specific objectives exploring their linkages in the fluvial environment. Limitations and scope for further research are also discussed in this section.

Keywords: Hydrogeomorphology, planform changes, LULC changes, Glacier change, High-altitude lakes.