Chapter 1: Introduction

1.1 Introduction and literature review

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- a large Eastern Himalayan basin, form the core of this research work.

Hydrogeomorphic characterization is the quantitative description of a drainage basin which can be correlated to the hydrologic response of a basin [1]. Understanding the hydrogeomorphology of a river requires studying its dynamics through careful observation of the forms and processes that contribute to change [2]. Changes in the river's streamflow or runoff is the major contributor to hydrogeomorphic changes [3, 4]. Streamflow is in turn dependent primarily on precipitation followed by land cover change, glaciers, and snowmelt [5]. Changes in any of these factors can have manifold repercussions on the river's hydrogeomorphology. Therefore, analyzing the changes in each of these factors within the Manas-Beki catchment area is the prime objective of this study.

Quantifying the drainage basin or morphometric analysis provides valuable insights into how the basin will react or hydro-geomorphic response to variations in streamflow, making it critical information for hazard analysis, such as floods, droughts, and landslides [6, 7]. Analysis of channel planform changes including channel shifts, bar, meander, and avulsion dynamics is important for predicting river-related hazards and developing sustainable strategies for planning land use in the river corridor and restoring rivers [8].

Land use and land cover (LULC) change is a major contributor to change in a river basin's hydrological regime [9 – 13]. Land use refers to the modifications made by humans to the earth's landscape, such as agricultural activities, plantations, settlements, etc. while land cover refers to the naturally occurring features on the surface of the earth, such as vegetation, water bodies, barren land, etc. Changes in LULC significantly impact drainage basins, influencing runoff, sediment flow, and overall water availability which in turn increase the likelihood of occurrence of extreme events like floods and droughts within the basin [14, 15]. Understanding LULC changes within the river corridor is crucial for effectively managing water resources and ensuring the sustainable utilization of resources in the floodplains [16]. The difficulties in assessing change are challenged by the fact that the major river basins all have their origins in high mountain areas, and the effects of climate change in these areas and the implications for downstream water availability are complex [17]. Snow-dominated basins are highly prone to changes and the largest disturbances in the hydrological balance are observed in the snow-dominated basins [3, 5, 18].

The Himalayas have the third largest deposits of snow and ice after Antarctica and the Arctic and is rightly named the third pole [19]. Scientists have observed that more than 65% of Himalayan glaciers, which are heavily influenced by the monsoons, are retreating rapidly increasing the seasonality of runoff and altering hazards [20]. The consequences of observed changes in temperature and precipitation over the Himalayan region are most evident in the cryosphere with the retreat and disappearance of glaciers and increase in glacial lakes [21 – 25]. It is necessary to study the changes in glaciers and high-altitude lakes to understand the hydrological implications of a glaciated basin to the observed changes [26].

Three of the world's major rivers – the Indus, the Ganges, and the Brahmaputra, originate in the Himalayas. Melting glaciers in the Himalayas, resulting in an altered landscape can have a major impact on the hydrology of these rivers; increasing uncertainty in the occurrence of extreme hazards such as floods, and threatening a water system that feeds agriculture and economy in the plains below [27, 28, 29, 30]. The mean annual surface air temperature has increased by 0.1^{0}C per decade between 1901-2014 and the rate is higher (~0.2^{0}C per decade) during the second half of the 20^{th} Century, resulting in decreasing snowfall and retreating glaciers in the Himalayan region [22]. The observed changes in the Himalayan region will affect the water availability as well as have various other physical and environmental impacts such as ecosystem boundary shifts, biodiversity changes, global feedback, and livelihood changes in the downstream regions [31, 32, 33]. Though the changes are evident, the implications of change on the drainage basins are diverse and dependent on the diversity of hydroclimate across the region [34]. A knowledge gap exists in observed data for the upper reaches of the Himalayan basins limiting the analysis of change [34, 35]. The Indus, Ganges, and Brahmaputra basins are predicted to have widespread implications of climate change on the hydrological regime and water availability but the lack of sufficient baseline information especially for the Brahmaputra basin [17, 36, 37] has motivated the present study.

Though several pieces of research related to change analysis have been undertaken in the Himalayas, the Eastern Himalayas have been neglected until recently. The Brahmaputra River, with a total drainage area of approximately 530000 km^2, originates in the Eastern Himalayas, and is a major transboundary river with its basin encompassing 4 countries - China, Bhutan, India, and Bangladesh before flowing into the Bay of Bengal [38]. About 60% of the catchment has an elevation above 2000 m where cryospheric processes are supposedly an important factor for streamflow and the impact of climate change is estimated to be particularly strongly influenced by snow and ice melt [39]. The implications of changes in the high mountain regions will be demonstrated in the downstream regions where more intense and frequent flooding is expected to occur in the future [40]. The entire basin is predicted to be warmer by approximately 4.3^{0}C by the end of the 21st Century, with 16.3% increase in mean precipitation, 16.2% increase in surface runoff, and 16.4% increase in evapotranspiration based on the outputs of a macro-scale hydrologic model [41]. Seasonal variabilities in response to climate change and changes in land use and land cover are estimated to increase with flooding incidents during the months of August-October whereas indications of drought-like conditions are projected to increase during the months of May-July [42].

The present study focuses on the Manas-Beki river basin, one of the largest sub-basins of the Brahmaputra river system with its origin in the Eastern Himalayas and basin encompassing the countries of China, Bhutan, and India. The impact of climate change on the cryosphere in the upper basin area within the countries of China and Bhutan such as changes in snow cover, glaciers, and glacial lakes has been studied to some extent but these are limited to specific smaller catchments within the Manas-Beki basin and a comprehensive transboundary study on the basin as a whole is lacking [43-48]. An analysis of the changes in mean annual air temperature and precipitation in the Bhutan Himalayas from limited observation data revealed a temperature increase of approximately 0.68^{0}C per decade [49]. Though the effects of climate change are evident in the entire Himalayan region, the impacts on the hydrological regime of the Manas-Beki river and the downstream changes need to be studied more elaborately. This study aims to characterize the hydro-geomorphic aspects of the Manas-Beki river basin with special reference to morphology, land cover dynamics, and changes in the glacial regime

1.2 Objectives

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.

1.3 Study area

The present study focuses on the Manas-Beki river basin, which is one of the largest river constituent basins of the Brahmaputra River system contributing to around 5.48% of the total discharge of the Brahmaputra, and is the largest river system of Bhutan [50]. The Manas-Beki river, as known in its downstream reach where it meets the Brahmaputra at the Barpeta district of Assam, is a major Eastern Himalayan north bank transboundary tributary of the Brahmaputra originating in Tibet, and flowing through Bhutan and India. The geographic location of the basin extends from roughly $26^0$10′N to $26^0$50′N latitudes and 90^0E to 91^0E longitudes. With a total drainage area of approximately 32,000 km^2, the Manas-Beki river basin comprises of four glaciated sub-basins, viz. the Mangde, Chamkhar, Kuri, and Dangme, and one downstream floodplain catchment, Manas-Beki.

The river originates as the Kuri Chu from a glacier on the northern slope of Mount Kula Kangri (28°15' N, 90°35' E) in Tibet. The eastern tributary of Dangme merges into Kuri Chu in Bhutan to form the Manas river which is joined by western tributaries of Chamkar and Mangde at Mathanguri, a border location between Bhutan and India (Fig 1.1). The river flows for around 90 km through Tibet and 140 km through Bhutan before bifurcating into the Manas and Beki rivers when it enters India at Mathanguri [50]. The two rivers, Manas and Beki join further south in Assam just before the railway and National Highway crossing near Barpeta Road.

The streams contributing to the Manas-Beki river system originate in the Tibetan Plateau region, the Bhutan Himalayas, and a minor contribution from streams originating in the Arunachal Himalayas and hills south of the Himalayan Main Boundary Thrust (MBT). (Fig 1.1). Throughout its course through Tibet and Bhutan, the river traverses high mountainous and hilly terrain with high gradient. From Mathanguri as it enters India, the river transitions into a relatively flat floodplain region south of the MBT. The sudden changes in flow energy results in the river transitioning to a multi-thread pattern and bifurcating into Manas and Beki sub-sections before merging again further south and finally draining into the Brahmaputra river near Baghbar hills in Barpeta, Assam. The river has much historical evidence of channel shift and confluence migrations and is highly dynamic in nature, characteristic of the north bank tributaries of the Brahmaputra [51].

The elevations of the entire basin range between 30 to >7500 m a.m.s.l. The part within the Tibetan Plateau is a barren permafrost region and south of it is the perennially snow-covered region falling within north Bhutan and Arunachal Pradesh. The climate of the basin is highly diverse, with cold and dry alpine conditions in the north, hot and humid subtropical conditions in the south, and experiences heavy rainfall [52]. The entire region north of the MBT below the snow line altitude is hilly with dense forests up to the floodplain region in Assam. The river basin has two major reserve forest areas, namely the Royal Manas National Park in Bhutan and Manas National Park in India. The lower Brahmaputra plains in Assam are very fertile, highly populated lands, but are extremely prone to flooding as well as rapid shifts in river courses resulting in an exceedingly dynamic landscape dotted with numerous riverine features [52, 53, 54]. Figure 1.1 shows the location of the study area with the elevation profile of the basin derived from satellite-based DEM.

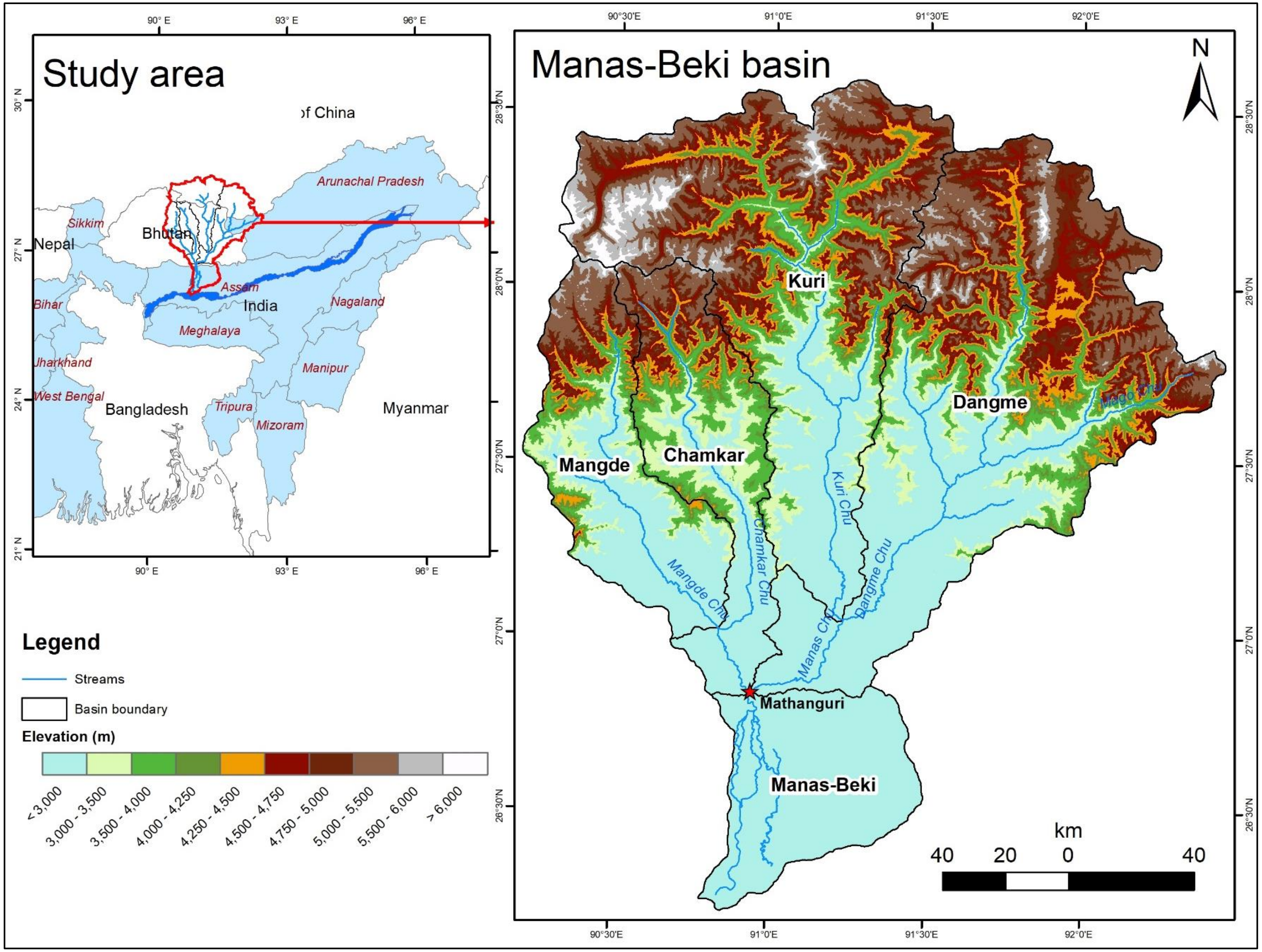

Figure 1.1 Location of the Study Area- Manas-Beki river basin

1.4 References:

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