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Growth and evolution of Mangaldeep and Gournagar channel bars in the Hooghly River, West Bengal, India

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A B S T R A C T

Channel bars are the most common landforms of the alluvial rivers and understanding their growth and evolution is very much important. Bars play important roles for the riparian communities as they support ecologically and economically them with rich environments. Mangaldeep and Gournagar bars in the Hooghly River give appropriate environment to the riparian people by giving various opportunities for cultivation, fishing and live-stock development. In the present analysis an attempt has been made to assess the growth and development of the Mangaldeep and Gournagar chars over the last 30 years with the help of geospatial techniques. The identification and changing pattern of bars were observed through remote sensing and GIS technique. The extensions of bars along the stretch of the Hooghly River have been digitized through the ArcGIS 10.5 software. The Mangaldeep char extended gradually from 1.75 hectare in 1990 through 41.2 hectare in 2000 through 62.76 hectare in 2010 to 73.83 hectare in 2020. Whereas the extension of the Gournagar char advanced from 381 hectare in 1990 with a slight increase of 1 hectare more in 2000. On the otherhand the study revealed that in 2010 and 2020 the bar of Gournagar developed 440 hectare and 483 hectare respectively. The spatio-temporal analysis of selected channel bars and their evolution as well as the shifting will be helpful to understand the nature and characters of the river channel bars.

Keywords: Channel bar · Bar growth · River channel · Remote sensing · GIS technique

1. Introduction

Rivers are the natural courses of water flowing downstream towards the sea or lake according to ground slope. River channels are formed so naturally as well as the river valleys are formed by the active process of erosion and deposition on the concave and convex banks respectively. The erosion in the river banks leads the channel to become wider and the deposition on the accessible bank is the process of channel adjustment in the floodplains [1]. The river channels with anastomising characters may create mid-channel bars [2]. Mid-channel bars are the most common and important fluvio-geomorphic features in the alluvial rivers. Almost all the alluvial rivers in the tropical regions have numerous channel bars across the river beds [3]. Deposits of coarse sand materials form the channel bars that characterize many alluvial and bedrock channels, although finer grained sand and silt bars are also common [4]. To develop a bar in the channel a huge supply of sediment is required and these sediments are carried down from the upstream area of the channel. The bars themselves can be formed from sand, gravels or boulders.

For the development of the bars in the channels the erodible banks are required as they enhance the process of channel widening and allow the rivers for the development of channel bars (locally called char). The process of the formation of mid channel bars begin with the falls of velocity below the settling velocity of particles [5]. Several researches have been carried forward all over the world for identification of growth and development of mid channel bars [6]. The social and political aspects of charlands of the lower Damodar river and the lower Ganga River as well as most of the South Asian rivers have been studied. Bars are the areas having ungovernable and borderless states of environment and lose their usefulness due to such situation. Bars are the pieces of land having very high fertility. The fertile environment attracts the riparian communities to cultivate the land with very high production. The fertile silt and sand deposited by the recurrent flood make the land more valuable [7, 8]. In the context of social and ecological aspects of char land formation many researches have been conducted [9]. The present study is, therefore, conducted to highlight the sequential growth and development of Mangaldeep and Gournagar channel bars in the Hooghly river, West Bengal.

2. Materials and methods

2.1 Study area

The study area lies in the middle section of the Hooghly River (Fig. 1). Two important bars Mangaldeep and Gournagar are taken for the analysis. Mangaldeep bar is located in the south-western part of Ranaghat-I C. D. Block of Nadia district, West Bengal while Gournagar bar is located in the easternmost part of Balagarh C. D. Block of Hooghly district, West Bengal. Mangaldeep is located in the middle of the river course while the Gournagar char is in the right side of the river. Depositional features of the bars in the Hooghly River characterized by alluvial dominated monotonous deltaic plain. The Churni, an important tributary of the Hooghly River, joins from the left side of the river in this area. Local communities use these chars for cultivation, settlement and recently for recreational purposes *etc*. Agricultural land is the main landuse pattern of the area as the rural riparian communities are fully engaged in fisheries and agricultural

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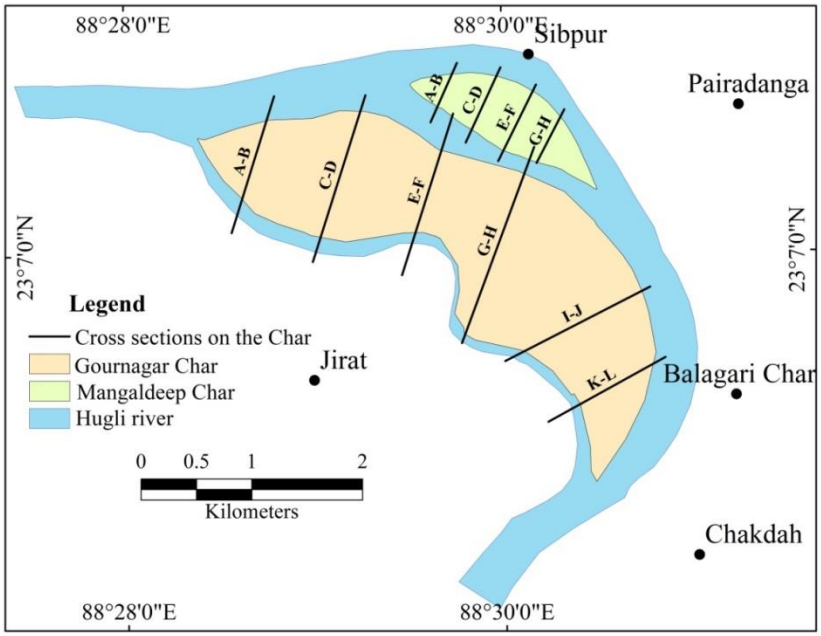

Fig. 1. Location map of the study area

activities. The Churni, an important tributary of the Hooghly River, joins from the left side of the river in this area. Local communities use these chars for cultivation, settlement and recently for recreational purposes *etc*. Agricultural land is the main land use pattern of the area as the rural riparian communities are fully engaged in fishery and agricultural activities.

2.2 Remote sensing and GIS techniques

The entire work has been based on satellite imageries of different time periods. The Google earth images from 1990 to 2020 have also been considered for the analysis. Landsat imageries (1990, 2000, 2010 and 2020) have been used to assess the changing nature of chars. For the identification of the changing pattern of chars remote sensing and GIS techniques has been adopted. The river course and the extension of bars have been digitized in the ArcGIS 10.5 software. Shape files have been created with the help of Landsat imageries of the study periods. All the spatial datasets were projected into WGS-84 UTM 45 degree north datum. The areal extension of chars or the growth and evolution of the chars have been measured and mapped with the help of remote sensing and GIS techniques. All the digitized shape files of Mangaldeep and Gournagar char were overlaid and the areal extensions of the chars have been measured. In the present day concern, monitoring of the river channel dynamics using remote sensing and GIS techniques is widely used method. Significantly immense progress has been made lacustrine and riverine environment.

For measuring the changing nature of the char lands four cross sections for the Mangaldeep char and six cross sections for the Gournagar char were drawn. Cross section wise shifting of char edges was measured with the help of line tool from measure tool in the ArcGIS 10.5 software.

3. Results and discussion

3.1 Formation of Channel bars

Channel bars are the raised part of sediment which has been continuously deposited through the flow of the stream. The formation of chars in the middle or in the side of the river has different development process. The formation process of these chars in the meandering and braided channel is also different from each other. The chars found in the upstream consist of coarser materials when in the downstream chars the materials are very fine. There are many studies related to morphologic changes and the channel bar development was carried out using the filed data and/ laboratory analysis [10-16].

In the present study area the meandering of the Hooghly River formed two important chars, one is Mangaldeep char and the other is Gournagar char. The coarseness of the materials of the chars is the same as the bed materials of the reach of the river. In the floodplains in case of point bars the finer materials deposit in the lee side [17]. When the bar elevation reaches close to average flood levels, a layer of silt and clay is deposited over the sand layer, facilitating the development of vegetated islands named as chars [18-21].

3.2 Growth and evolution of Mangaldeep and Gournagar bars

Mangaldeep char is an example of longitudinal bar which is developed along the direction of the flow of the river. On the other hand Gournagar char was attached with

right bank of the river in the meander bend just like a point bar. The sequential growth, evolution and development of Mangaldeep and Gournagar bars have been shown in figure 2. It is found from the figure 2 that both chars have

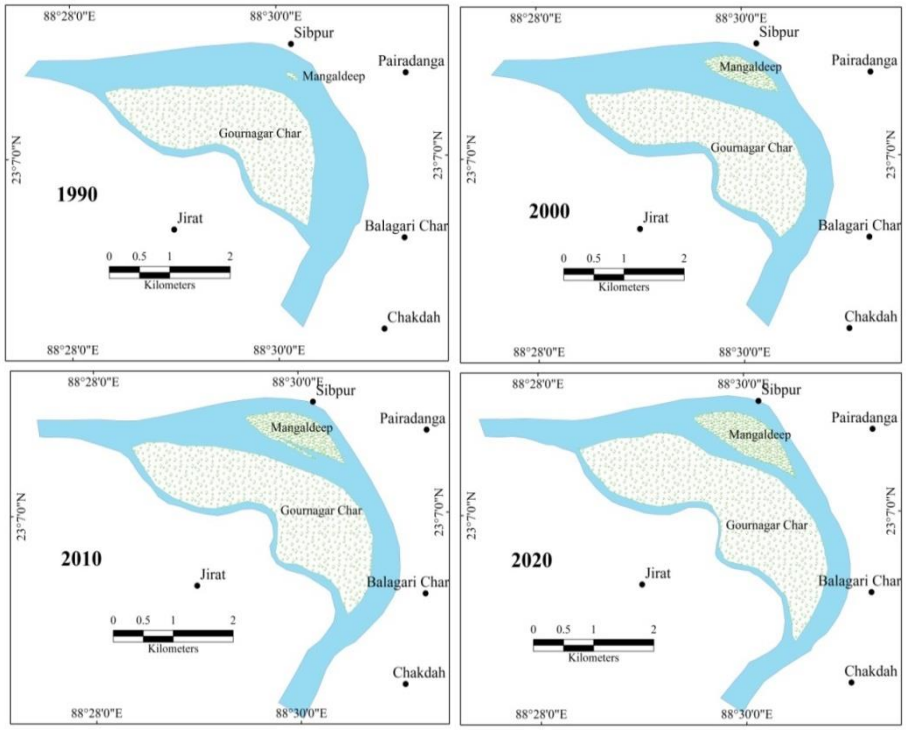

Fig. 2. Growth and evolution of Mangaldeep and Gournagar channel bars

been expanding. The areal extent of the Mangaldeep char was 1.75 hectare in 1990 and in 2000 it became 41.12 hectare which indicates a huge increase of the char in this period. In 2010 the area of the char became 62.76 hectare and in 2020 it became 73.83 hectare indicating gradual increase towards outside (Fig. 3). The Gournagar char also shows the similar trend though the rate of increase was less in comparison to Mangaldeep channel bar. The study reveals that bars are developing with the time. In 1990 the area of the Gournagar char was 381 hectare and in 2000 it became 382 hectare indicating a slight increase. The increment was observed through the remote sensing and GIS technique. But in 2010 and 2020 the area of Gournagar char was 440 hectare and 483 hectare respectively (Fig. 3).

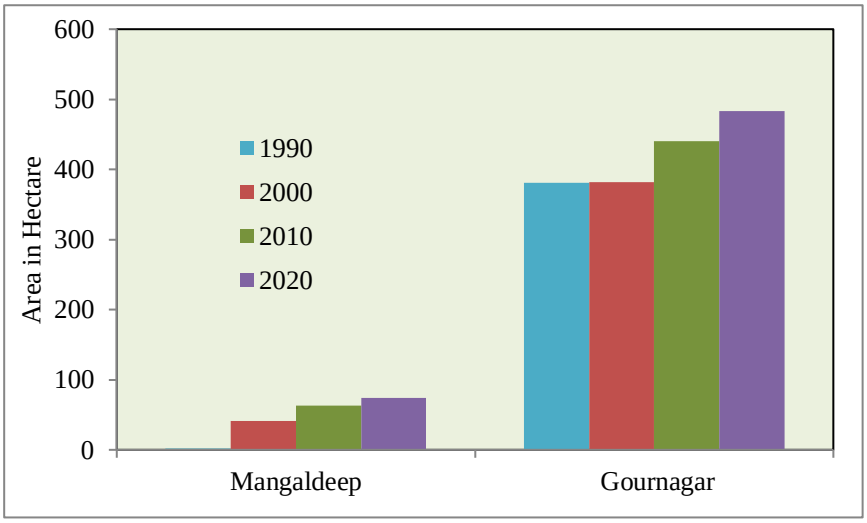

Fig. 3. Areal extension of Mangaldeep and Gournagar bars

3.3 Shifting of the eastern and western boundary of Mangaldeep and Gournagar bars

Cross section wise changing location of the boundary of the bar has been measured. In figure 4 and 5 the shifting of eastern and western edge of the Mangaldeep and Gournagar bars has been shown. The positive values represent the outgrowth of the chars which indicates the extension of the bar. Negative values represent the reduction of the char land. In 2000-2010 both the east and west sides were extended along the outside increasing the char areas while in 2010-2020 period the eastern side was shifted inwards but the western side was shifted more than 100 meters towards the right bank of the river (Fig. 4).

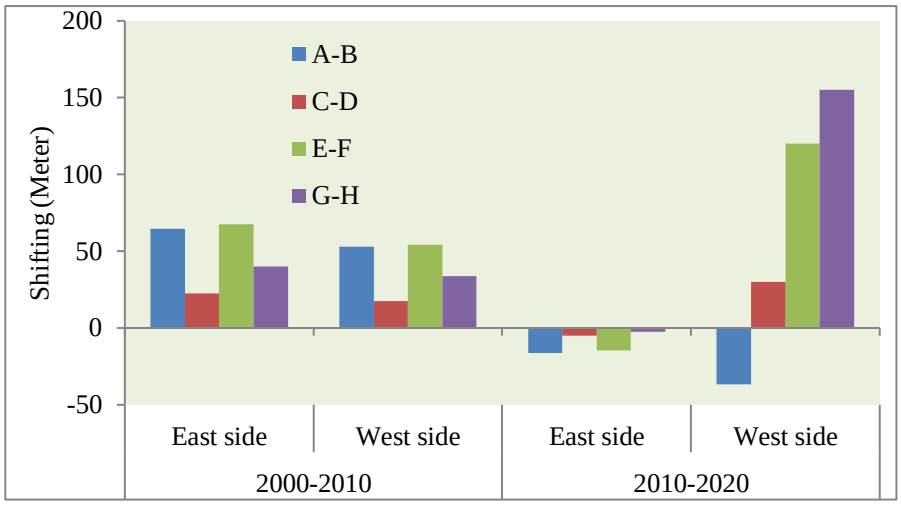

Fig. 4. Shifting of the eastern and western boundary of Mangaldeep bar

The Mangaldeep channel bar develops shifting nature towards the western bank by depositing materials in the western edge of the char over the last decades. The Gournagar channel bar on the other hand shows the discontinuous shifting pattern to eastern and western edges of the channel bar (Fig. 5).

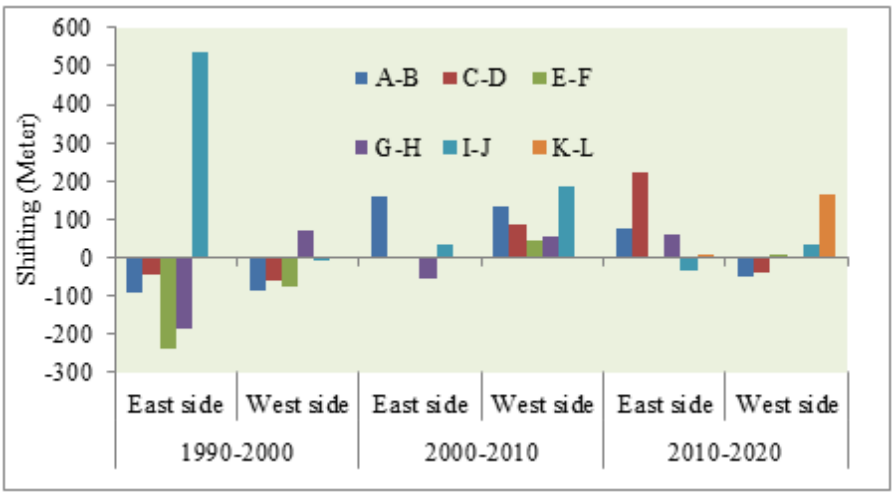

Fig. 5. Shifting of the eastern and western boundary of Gournagar bar

In the first observation period the eastern side of the bar was shifted around 500 meters and the shifting was detected towards the east along the cross section I-J (southern section) but the eastern and western, both edges of the chars along other cross sections were shifted inwards indicating narrowing of the bar land. In the second observation period the eastern edge did not shift remarkably but western edge was shifted towards the west along all the cross sections indicating widening of the char. In the last observation period remarkable changes was occurred in the cross section C-D as the eastern edge was shifted along outside (200 meter) and the western edge was shifted around 200 meter at cross section K-L towards the west indicating widening of the bar in the northern and southern section.

4. Conclusion

The study explored the growth and evolution of Mangaldeep and Gournagar bars over the last 30 years

with the help of remote sensing and GIS techniques. The area of the bars has been increasing and the trend of the movement along outside. In the last decade the area of the Mangaldeep char has increased towards the west and in case of the Gournagar bar the area has increased towards the southern section of the bar. River bank erosion and deposition of sand may change the course and the depositing materials over the decades develop bar elevation and bar edge also. The study revealed that the Mangaldeep channel bar has been shifting towards the western bank by depositing materials in the western edge of the char over the last decades. In case of the Gournagar bar, the shifting of eastern and western edges of the chars has shown a discontinuous pattern. The spatio-temporal analysis of selected bar land evolution as well as the shifting of the bars will be helpful for understanding the nature and character of the bars and the study will be supportive for further analysis in this regard.

Conflict of interest

The author declares that there is no conflict of interest in this manuscript.

Data availability

The author confirms that all data collected or analyzed during this study are included in this published article.

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