Chapter-1

Introduction

Chapter 1

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1.1 Introduction

Rivers are the channel in which the surface water flows under the influence of gravity. These rivers systems are considered as an open system in which matter and energy are exchanged with the outer environs. The rivers are classified Based on the nature of the materials through which it flows, are classified into three types (a) Bedrock, (b) Semi-controlled and (c) Alluvial [1].

The bedrock channel is fixed in the floodplain, and it is stable over a long period of time. There can be a lateral shifting of the channel if bedrock is weak, but in most cases, these channels are highly stable. This phenomenon occurs in the regions which have hard lithology. The semi-controlled channels refer to the rivers that are controlled locally by less resistant bedrock or low resistant alluvium. The channel pattern may change where the channel encounters more resistant materials, and the channel either can be very stable at that particular locality or can shift away from the bedrock controls. Alluvial rivers are those rivers whose banks and beds are composed of sediments transported by the river. Therefore, the alluvial channel is susceptible to planform changes due to the presence of low resistance alluvium as the alluvium is eroded, transported, and deposited as the sediment load with the discharge changes.

Channel planform can be defined as the planimetric geometry of an alluvial river as display in the maps or satellite image. These streams are usually divided into three main categories, e.g. straight, meandering, and braided. A further classification of river planform as a combination of straight, sinuous and braided planform are done at three different scales or structural levels (low water channel, flood channel and valley bottom) [2]. In a low water channel, islands and bars are formed within the river which split the river into multiple channels at three scales, e.g. riffle-pool sequences, alternate bars and medial bars which are controlled by incised channel. The flooded channel is classified as straight, meandering and braided which is controlled by the confined channel. At the valley bottom structural level, the planform is classified as single-thread, macro-meander and anabranching with limiting condition of the broad flood plain.

Meandering planform is the most common pattern of alluvial rivers. The geomorphic features such as oxbow lakes, avulsions and, cut-offs often formed due to the horizontally shifting of the river across the floodplain. However, channel migration can occur steadily, as a stream erodes one bank and deposits sediment along with the other, or it may happen during a massive flood event as an abrupt shifting of the channel take place to a new location. Channel planform dynamics has been studied for its geomorphological and engineering importance using empirical and theoretical models for better river management activities. It is one of the major problems of alluvial streams around the globe, which causes natural hazards like horizontal channel shifting, bank erosion, flooding, and damage to hydraulic structures, transport network, agricultural land and settlement along the river. A proper understanding of the historical planform change and to predict future course through time is significant for water resources scientists, managers and policymakers for river management activities in the floodplain [3, 4].

Therefore, a strong necessity is now being realized to model the channel planform dynamics in present hydrological conditions.

Modelling is the simple abstraction of the river system that represent the salient properties and processes which affect river morphology and dynamics [5]. Morphological models provide the controlled environment in which channel planform dynamics can be modelled for future analysis. Over the past decade, Geoinformatics based modelling of the fluvial environment has substantially increased. In which remote sensing (RS), geographic information systems (GIS), global positional system (GPS) and digital elevation models (DEMs) have become universally acceptable techniques in fluvial morphological studies [6]. Geoinformatics is now globally used for fluvial geomorphological studies along with the spatial database for land use/ land cover mapping, hydrological analysis of river basins and the impact of climatic change in river studies. Further, GIS becomes an essential component in the modelling of the fluvial environment in which prediction can be made using spatial data of the river. There are two primary approaches available for modelling of fluvial erosion in GIS environment are (i) the extrapolation of river planform based on statistical models, and (ii) the physical-based models. Physically-based modelling requires the simulation of the processes, e.g. hydrodynamics, sediment transport, bed morphodynamics, and bank erosion rate of the rives [7]. Such physically- based predictive model is highly accurate in the prediction of river morphology. These models can be utilised for the prediction of channel planform dynamics in highly meandering rivers like Ramganga.

1.2 Background and motivation

The world's largest rivers are found in the tropical region of the world. These rivers generally have large catchments area with very high discharge due to complex climate. In this region, Himalayan rivers are also susceptible to flood every year due to high discharge during the monsoon season. These rivers are a vital support for a large population and are an essential source of water for irrigation, domestic and industrial supply. Such rivers have significant seasonal variations in flow and sediment load and are adjusted to an array of discharges. The discharge pattern of the Himalayan rivers is controlled by monsoonal rainfall and snowmelt from the Himalayan glaciers. Due to this, these rives show high discharge variability during the summer monsoon and low discharge in the remaining months. Rivers in the Ganga-Brahmaputra plain exhibit a 40-50 times higher discharge during the monsoon months (June – September) compared to the non-monsoon months [8]. Rivers of this region is highly dynamic with extreme variability of discharge and sediment load, which results in a dynamic morphology of the river in this region.

Earth scientists are well aware of the dynamic characteristics of the Himalayan region, mainly Indo – Gangetic – Brahmaputra (IGB) plains for a long time. The rivers of IGB plain respond to huge variations in discharge and sediment load by changing their morphology. Such morphology can be found in the form of fluvial morphological features like ox-bow lakes, meander scars and abandoned channels throughout the IGB plains [9]. Several Geomorphologists have noticed that the channel planform dynamics is the main problem in Himalayan rivers, which always shifted channel in their lower reaches [9–12]. Lower reaches of the rivers frequently alter its course due to different tectonic tilting, hydrological variability and sedimentological readjustments [13–16]. The Ganga river is one of the largest river in the Himalayan river system. Ganga and its tributary also show the dynamics character in lower reaches. The Ramganga river is a first major tributary of the Ganga river basin [18]. A population of around 18.6 million are settled in the basin, which is mainly dependent on agricultural activities.

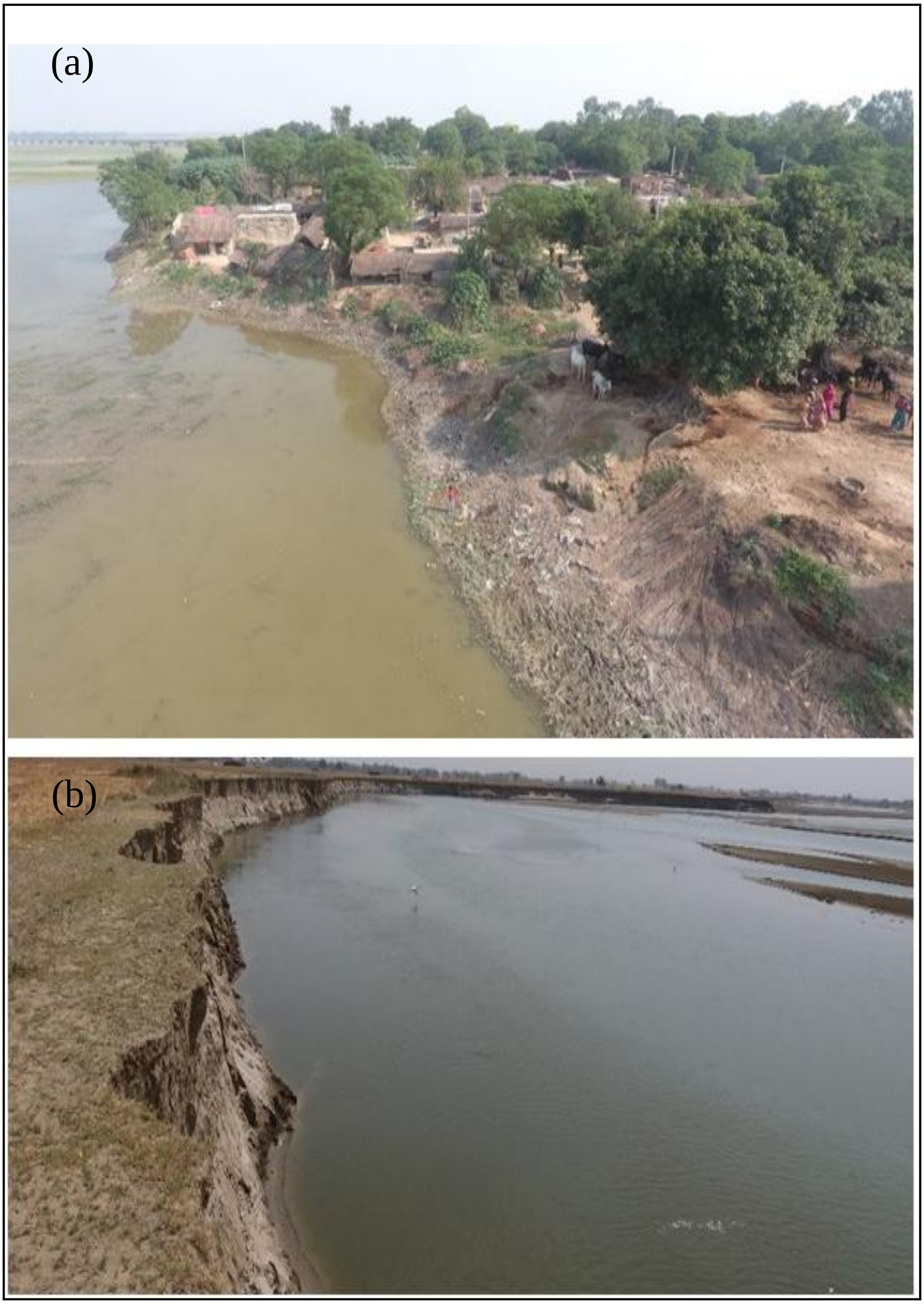

Figure 1.1 (a) Eroded village and (b) Eroded bank along the Ramganga river

It shows dynamic nature in lower reach due to frequent floods and flat topography of the region. In each channel shifting, a large number of the population of that area got affected, as the loss of land, life, and property, so that they had to settle elsewhere. This area has remained underdeveloped due to infrastructure damage by the meandering river [19]. Numerous engineering structures, e.g. the bridge, roads, gas pipelines, and settlement along the river bank, are damaged due to the meandering nature of Ramganga (Fig 1.1, a&b).

It is published in the Hindustan newspaper that seven bridges have become useless due to shifting of river Ramganga and near about Rs 1000 Crore of government money is wasted due to unpredictable behaviour of Ramganga river [20]. Therefore present work can be used to identify the most stable reach for construction of infrastructure facilities, e.g. bridge, school, settlement, roads etc. The present study provides recent and reliable information on the channel planform dynamics that will help as a decision support tool for designing and implementation of drainage development works in the study area.

1.3 Research Objectives

The overall objectives of the present research work are to know the mechanism of channel planform dynamics of lower Ramganga river and to understand its morphological evolution as well as to model its future scenario in the current hydrological conditions. The present work has four specific objectives as given below:

1. The first objective is to analyse the channel planform dynamics occurring in the lower reaches of the Ramganga over 237 years (1780-2017). This objective seeks to answers the following questions:

a. How much is the channel sinuous in a different segment?

b. How flood plain topography plays a vital role in the shifting of planform?

2. The second objective explores the application of microwave remote sensing data to quantify the morphological changes that occurred during the monsoon season. This objective finds the answers to the following questions:

a. How can the real-time monitoring of channel planform be done during the monsoon?

b. How much channel planform changes during the monsoon period?

3. The third objective explains the morphological evolution of the Ramganga river due to hydrological events. This objective seeks to answer the following questions:

a. How has the morphological evolution been taken place in different years?

b. How is this morphological evolution correlated with the hydrological events of different recurrence interval?

4. The fourth objective is to develop a physically-based predictive model in a GIS environment for forecasting channel planform for the next 100 years (2020-2120) in present hydrological conditions. This model answer to the question

a. Where is the highly stable reach in the Ramganga river for the establishment of engineering structures (e.g., bridge, roads, etc.)?

b. What will be the impact of climatic change on the river morphology due to increased discharge?

c. How many rural settlements will be eroded by the channel planform

1.4 Benefit to the society

Channel planform dynamics has increased basic understanding of fluvial morphological processes in the study area. In addition to this knowledge, it is also potentially relevant to society. The settlements along the river are exposed to the river erosion, so there is a strong need for predictive modelling of channel planform dynamics to protect the rural area in the flood plain of Ramganga river. River dynamics may affect the site selection, design, and maintenance of structures such as highways, bridges, pipelines, railways, flood control works, buildings, dams, transmission lines, navigation channels, and river embankment built on the floodplain. The study provides recent and reliable information on the channel planform dynamics and will help as a decision support tool for designing and implementation of drainage development works. Analysis of these dynamics will be useful to provide information for future management activities like construction of bridges, roads, embankments and other infrastructure activities.

1.5 Thesis structure

The thesis is organized into eight chapters. The first chapter is an introductory chapter which explains the background of the study and represents the problems addressed in this research.

Chapter II synthesizes the literature review regarding the modelling of channel planform dynamics of meandering rivers. The background to the topics of meandering planform, rates of meander migration, the radius of curvature, understanding hydrological events as a driver of morphological changes and the Geoinformatics based modelling of the event is discussed which providing insight for theory building.

Chapter III is an overview of the study area, including the selection of study channel reaches, geomorphology, geology, and hydrological characteristics of the reaches explained in details.

Chapter IV describes the historical channel planform dynamics of the Ramganga river, followed by the natural causes of channel dynamics in the lower reaches explained through the use of historical topographic maps and Landsat archives data.

Chapter V describes how the flood is the leading cause of changing river morphology. In this chapter, we used microwave remote sensing data for real-time flood inundation mapping and monitoring, coupled with hydrological data to quantify the morphological changes due to this flood.

Chapter VI assessed the role of hydrological events frequency on the morphological evolution of the Ramganga river and established the correlation between the flood discharge and the morphological indices.

Chapter VII discusses the development of a physically-based meander migration model. This model investigates the impact of channel migration on the Ramganga river morphology and finds a morphologically stable site for the drainage development works. This model also identified the potential rural settlements, which are prone to erosion in the next 100 years.

Chapter VIII comprises the conclusions and major findings of the present research work. In addition, the limitation of the study and future scope of the research areas is also discussed in this chapter.