CHAPTER - I

CHAPTER ONE

INTRODUCTION

1. Overview

Rivers play a major role in the economy of a country by sustaining agriculture, industry, energy generation and providing biological resources. Rivers are a interest to almost all living beings since we rely on them for transport, recreation, food, power, water supply, disposal of waste etc (Bridge, 2003)[14]. River basins occupy about 69% of the land area and are play a major role in transporting tons of sediments annually and are important constituent of hydrological cycle possessing various organic as well as inorganic matters supporting various biotic systems (Gupta, 2007)[34].

Ganges, the major river of Indian subcontinent is associated with many myths and reality with the land and people of India and is revered as mother and worshipped as a goddess. Our ancient civilization nurtured and flourished in the Gangetic plains. An ideal combination of fertile soils, moderate climate and abundant source of water has made this region perfect for human colonization. The Ganges river and its tributaries flow through three countries: India, Nepal, and Bangladesh. The Ganges Basin river system remains the main source of freshwater for half the population of India and Bangladesh and nearly the entire population of Nepal. The Ganges delta mainly lies in the tropical wet climate region and covers about 25% of India's total territory supporting around more then 300 million people. It is one of the largest rivers of the world and also one of the largest perennial water systems amongst all the 14 major rivers of our country. The Gangetic plain forms the largest alluvial tract in the world. It rises from the Gangotri Glacier near Gaumukh in the Uttarkashi district of Uttaranchal at an elevation of about 4200 m above the (msl) and traverses a total length

of about 2525 km from its source and ends into the Bay of Bengal draining a total amount of around 8,61,404 sq km (plate 1.1), (Mirza and Mirjā , 2004)[53].

Ganges, flows for a distance of about 1450 km in U.P, 550 km in Bihar and 523 km in West-Bengal (Arya et al. 2009)[4,5]. The Gangotri glacier is the main source of the Ganges and is also one of the largest glaciers in the Himalayas, about 30 km long and 2 to 4 km wide. The end part of the glacier resembles a cow's mouth and hence is termed as Gaumukh (plate 1.2).

The Ganges originates after the confluence of six rivers- the river Alaknanda meets Dhauliganga at Vishnuprayag, river Mandakini at Nandprayag, Pindar at Karnaprayag, Mandakini at Rudraprayag and finally Bhagirathi at Devprayag. At Devprayag the Bhagirathi river meets the Alaknanda, which has its source in the Satopanth Glacier, located 15 km North of Badrinath, in the Chamoli district. Hereafter, from this confluence, the river is known as the "Ganga river" (plate 1.3 a-b) (Status paper on the river Ganga, state of environment and water quality, national river conservation directorate, ministry of environment and forests, 2009)[98].

Flowing through the great alluvial Indo-Gangetic plains, the Ganges is bordered by the Himalayas to the North and the Vindhyan-Satpura ranges to the South. The main source of water in the basin is the direct seasonal rainfall from the Southwest direction and from the glacial snow melt during the Summer. The main channel receives a number of major tributaries from the Northern as well as from the Southern direction. The main North bank tributaries are the Gandak, the Ghaghara, the Kosi and the Buri-Gandak, while the main South bank tributaries are the Son, the Yamuna, the Chambal and the Damodar (Arya et al. 2009)[4,5] , (Rashid and Kabir, 1996)[72] and (Shukla, 2009)[85].

Plate 1.1: Gangotri glacier near Gaumukh – source of the river Ganga

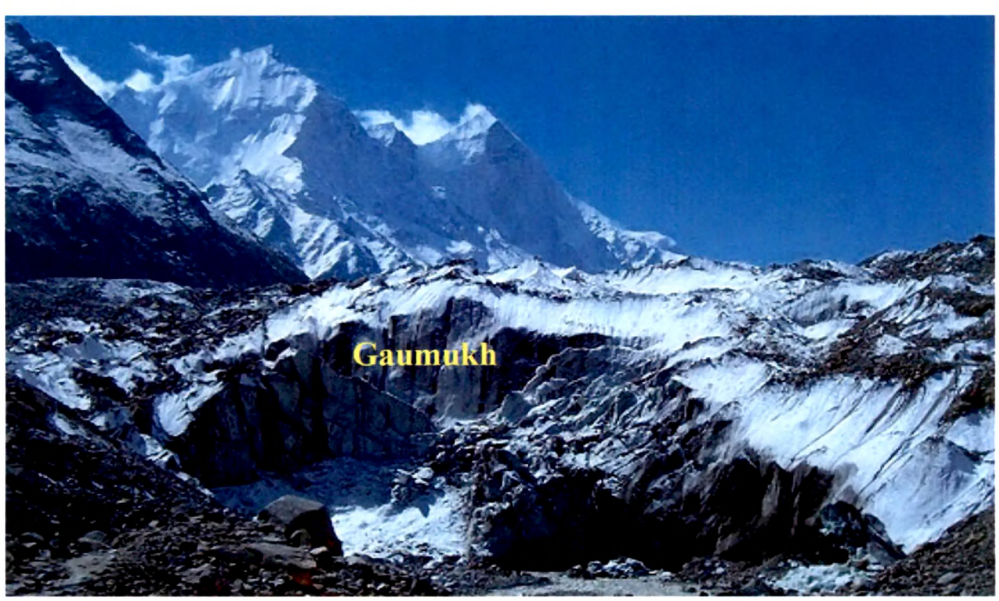

Plate 1.2: "Gaumukh" the end part (snout) of the Gangotri glacier and the source of river Bhagirathi

Plate 1.3 (a): Confluence of Alaknanda and Bhagirathi at Devprayag

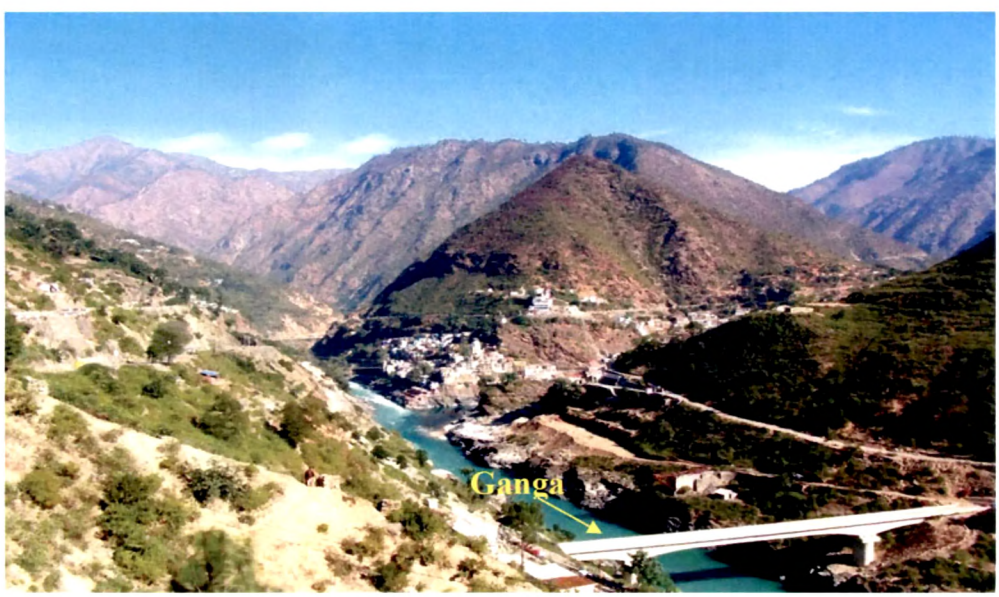

Plate 1.3 (b): Ganga at Devprayag

1.1. Physiography and Geography of the Gangetic plains

The process of alluvium deposition forming the Great Plains took millions of years and was laid down during the successive geological eras. The Gangetic alluvial plains are actually large floodplains of the Indus and Ganga-Brahmaputra river systems running parallel to the Himalayan mountains, from Jammu and Kashmir in the West to Assam in the East and drains most of the Northern and Eastern India. The main geomorphological features are the natural levees, flood-plains, sand-bars, river islands, channel-bars, point-bars, ox-bow lakes, meander scars, cut-off meander, braided and meandering channel patterns, palaeo-channels etc. The Gangetic basin on the basis of its general physiography is divided into three parts as mentioned below:

1. **The Upper Ganga Plain-** This region extends up to Allahabad, with Yamuna river as its Western limit. The Yamuna, the Ramganga, the Gomati and the Ghaghara are the major tributaries of the Ganges in this region. This is more or less a flat region with small streams in between, features developed due to river action, levees, dead arms of the river channels and ravines. The course of the stream is from Northwest to Southeast. The average gradient is low due to which the erosive power is less, but in spite of less linear erosion the region experiences high areal erosion which is mainly in the form of soil erosion. The geomorphological features found here are ox-bow lakes, flood-plains, sand-bars, braided channels etc. The rivers are characterized by wide floodplains and carry huge sediment load during monsoon when the amount of water discharge is very high. This is one of the major reasons for the frequent channel changes in this region and also gives rise to various depositional features.

2. **The Middle Ganga Plain-** It extends from the Yamuna River in the West to the state of West Bengal in the East. The Ganges forms the major channel and receives numerous smaller as well as larger streams from both the

Northern as well as the Southern direction. They cover an area of around 1,44,409 km^2 and are spread over eastern Uttar-Pradesh, and the whole of the Bihar plains. The major tributaries are the Ghaghara, the Gandak, and the Kosi system in the North, while the Son, the Punpun, the Mohani etc drain the Southern middle Ganga plains. The rivers have developed highly sinous and meandering courses and are known for causing erratic flash floods and frequent changes in the river course. Significant changes have been observed in the courses of the Kosi, the Ghaghara, the Sone, and the Ganga etc. At many places the river shows braided nature and exhibits different morphological features such as braid-bars, sand-bars, islands, water-bodies etc. In the Northern part the region is characterized by the presence of numerous palaeo-channels, ox-bow lakes, water-bodies and ponds which are formed in response to the frequent channel changes. These features are less seen in the Southern middle Ganga plains. Other features include natural levees, ravines, badlands, flood-plains, meander loops, eroded river banks and sand-bars.

3. **The Lower Ganga Plain-** It includes whole of Bihar and West Bengal (excluding the Purulia district and the mountainous parts of Darjeeling) from which it flows into Bangladesh and more or less forms a wide deltaic region. Due to the low relief which is about 30 mt to 12 mt, the areas frequently get inundated by local rainfall and high tides. This region is drained by two major rivers the Ganges and the Brahmaputra and other minor tributaries such as the Mahananda, the Tista, and the Karatoya etc (Bharatdwaj, 2006)[10].

Geographically the area is very rich and fertile providing a constant supply of water for irrigation purposes. The major crops cultivated here are rice, sugarcane, potatoes, oil seeds and wheat. Other cultivation includes legumes, chilies, sesame, mustard, sugarcane and jute.

the Ganga plain were uplifted and thrusted basin wards and the Ganga basin shifted Southwards in response to the thrust loading in the orogen. Also it was found that the Ganga foreland basin has been dominated by transverse river systems since the Pliocene due to the erosionally driven uplift whereas the Indus foreland basin is dominated by longitudinal river systems due to tectonically driven uplift. The foreland basin sediments rest on these basement ridges and number of basement faults such as the Morada fault, the Bareilly fault, the Lucknow fault and the Patna fault (Sastri et al. 1971)[77] and (Rao 1973)[70] and these faults have a bearing on the course of the river Ganga (Sinha et al. 2005)[92]. At the junction of the Siwalik hills and the Gangetic plain, there are conjugate system of tear faults extending directly up to the alluvium. These are the Sarda tear fault system, the Gandak tear fault system etc and show a Northeast-Southwest and Northwest-Southeast orientation. The Northwest-Southeast lineaments are large have a control on the fan formation and the river alignment (Singh and Ghosh 1994)[84]. From middle Miocene (25 Ma) onwards the deposition of the eroded material brought from the Himalayas got started. This sedimentation started in the flexure developed in front of the Himalayas. The rate of erosion was very clearly observed during the upliftment in the Pliestocene time (1 Ma). Many geo-physical studies and investigations like the gravity, seismic and magnetic surveys have been carried out for studying the sub-surface geology of the Gangetic basin. The metamorphic basement exhibits a number of ridges and basins over which the thickness of the sedimentary layer is highly variable. Geo-physical data have shown that the Ganga basin is characterized by three main sub-surface ridges, Delhi-Haridwar ridge in the West, Faizabad ridge in the middle and Mongyr-Saharsa ridge in the East. Two important depressions namely the Gandak and the Sarda deep exist in this region. (Singh, 1996)[85] and (Sinha et al. 2005)[92] (fig 1.1).

1.3. Mythological importance of the Ganges

Ganges occupies a unique position in the cultural ethos of India. Probably, India is the only country in the world where a river is bestowed the status of a Goddess. The ancient Vedic script that forms the core of Hinduism was written on the banks of the river Ganges. Apart from the Vedas, it is also invoked in the Puranas, and in the two Indian epics the Ramayana and the Mahabharata and is considered to be the holiest of all shrines. Many important pilgrimage places such as Rudraprayag, Rishikesh, Haridwar, Allahabad and Varanasi are located on the banks of the Ganges (plates 1.4 and 1.5) (Parua, 2010)[62].

2. Study Area

Since ages, Ganges holds a very important position in the lives of the people of India. Not only historically and mythologically but scientifically also it plays a very important role for various river related studies. The present study is confined to the fluvio-geomorphology of the river Ganga flowing through the parts of U.P Bihar border and the state of Bihar.

Bihar lies in the Eastern part of the country approximately between 22°58'10" and 27°31'15" North latitude and 82°19'50" and 88°17'40" East longitudes in the lower and the middle Gangetic region extending up to 483 km from West to East (Arya et al. 2009)[4,5]. Geographically, it is the third largest state of India, covering an area of about 99,200 km^2. It holds a transitional position culturally, economically as well as climatically since it lies mid-way between the humid West-Bengal in the East and the sub-humid Uttar-Pradesh in the West. Bihar is bordered by Nepal on the North, Jharkhand on the South, West-Bengal on the East and Uttar-Pradesh on the West and thus is a complete landlocked state. The Bihar plains are divided into two parts by the river Ganges which flows through the middle from West to East. Bihar derived its

Plate 1.4: Ganga aarti ritual at Haridwar

Plate 1.5: Ganga ghat at Banaras

name from 'Vihara' meaning "abode", and the word "Vihara" is derived from the word "Brahmavihara" meaning "sublime attitudes". It has been a very important religious centre for the Hindus, Jains and most importantly the Buddhists and is thus considered as the land of Buddhism and Jainism. The world famous Nalanda University of the 5th century A.D which gave great intellectuals not only to our country but also to the whole world is located in Bihar. Other famous centre for studies includes the Vikramshila University. For the location map of the study area (ref fig 1.2 and 1.3).

2.1. Climate

Since Bihar is far off from the sea, it enjoys a humid, subtropical monsoon type of climate. It extends from 22° to 27° North latitudes having a tropical to sub-tropical location. The Himalayan Mountain ranges on the North significantly effects the distribution of monsoonal rainfall. Broadly, the climate of Bihar can be divided into three distinct divisions:

- Winter- November to February. The temperature ranges from 5° to 10° C
- Summer- March to mid-June. The temperature ranges as high as 35° to 40° C.
- Monsoon- mid-June to October

The onset of monsoon starts when thunderstorm from Bay of Bengal passes through Bihar and sometimes is as early as the last week of May. Similar to other Northern parts of India, Bihar witnesses thunderstorms and dusty winds in Summer. During monsoon the rainfall often surpasses 1800 mm in few parts of the state. The mean annual rainfall is around 1,270 mm. The South-West monsoon normally retreats in early October and one of the important features of this retreating monsoon is the invasion of tropical cyclones originating in the Bay of Bengal along with typhoons originating in the South China Sea.

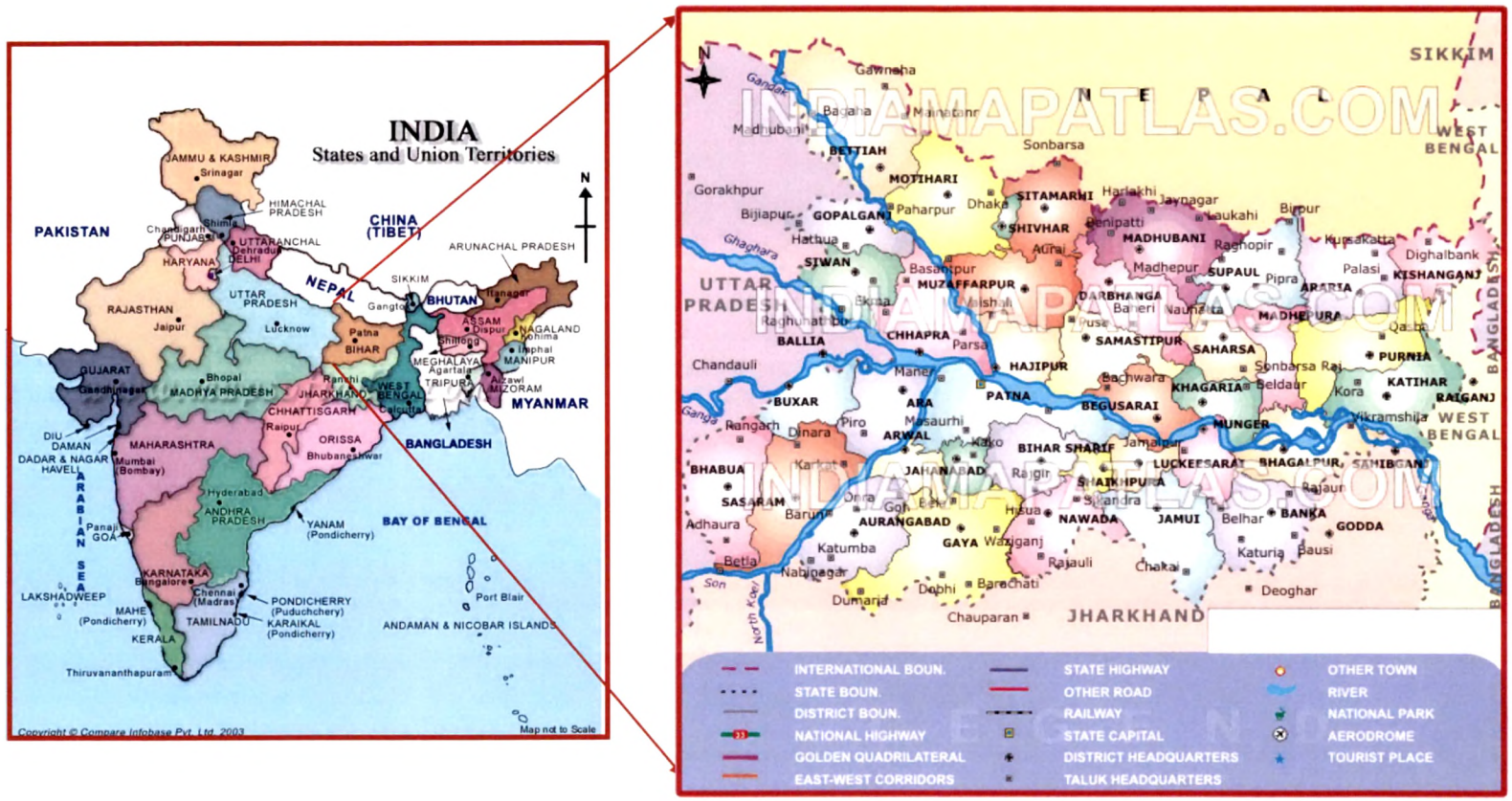

Fig 1.2: Location map of the study area

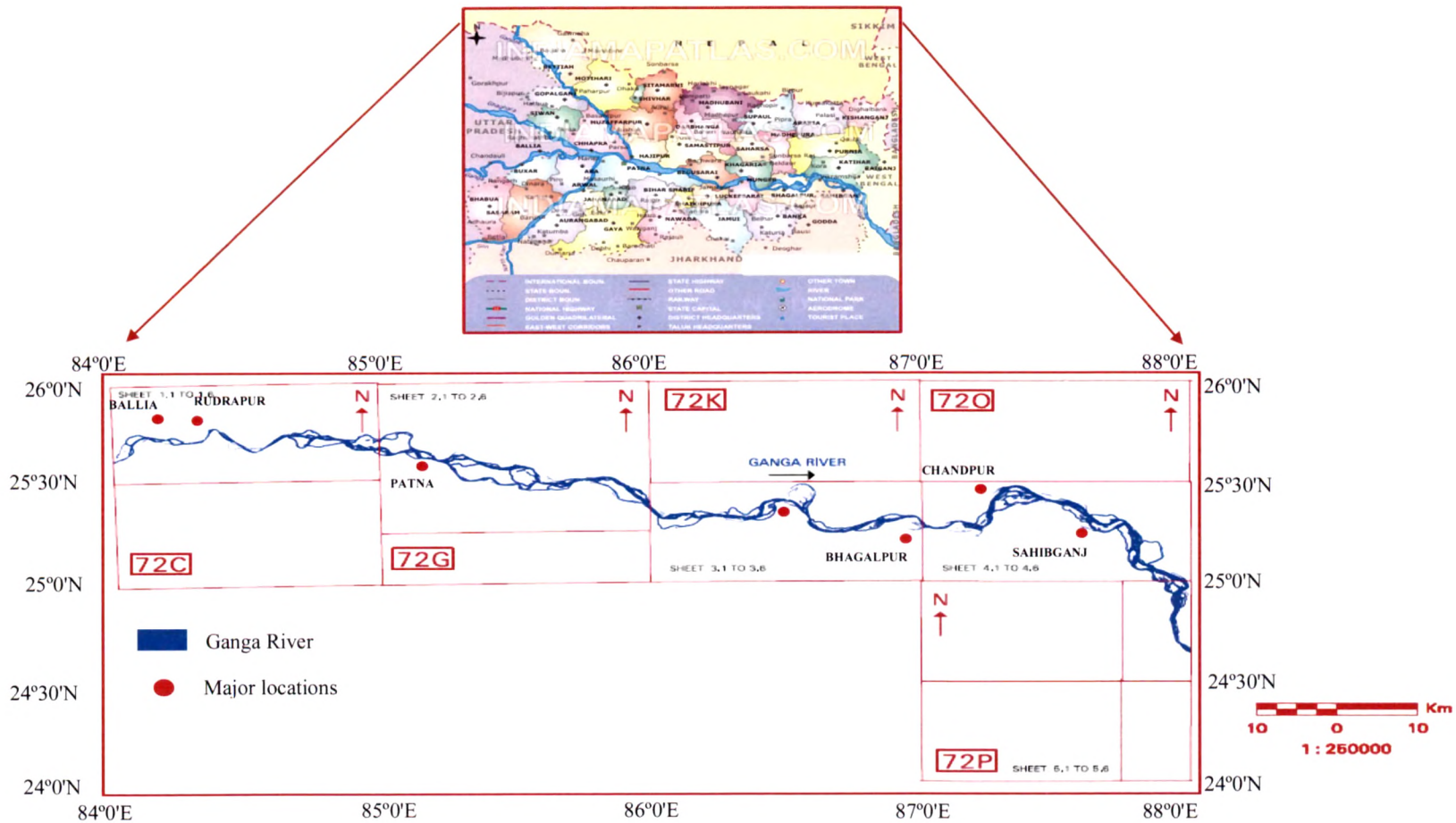

Fig 1.3: Location map of the study area

2.2. Geology

Bihar being located in the Indo-Gangetic plain, is blessed with fertile soil and is thus the backbone of agricultural and industrial development. The Indo-Gangetic plain in Bihar consists of a thick alluvium of drift origin. The soil is mainly loamy and is rejuvenated every year by constant deposition of silt, clay and sand brought by streams but mainly by floods in Bihar. This soil is deficient in phosphoric acid, nitrogen and humus, but potash and lime are present in sufficient quantity. The most common soil in Bihar is Gangetic alluvium of Indo-Gangetic plain region, piedmont swamp soil which is found in Northwestern part of West Champaran district and Terai soil which is found in Northern part of Bihar along the border of Nepal. Clayey and loamy soils is also very common in Bihar.

2.3. Physiography

Bihar lies in the middle and lower Gangetic plains with the Ganges flowing from West to East.

The Middle Gangetic Region covers the Eastern Uttar Pradesh and the whole of the Bihar state. The channels here are not deeply incised and the exposed sediments are mainly of the flood-plain deposits (Sinha et al. 2005)[92]. The North middle Gangetic plains are drained by many major rivers such as the Ghaghara, the Gandak, the Kosi and their numerous tributaries, while the South middle Gangetic plains are drained by the Punpun, the Son, the Mohani and their tributaries. These rivers are responsible for causing erratic flash floods during monsoon which brings about frequent large scale channel changes. The rivers throughout their course have developed meandering as well as braided patterns. Significant changes have been noted in the course of the rivers Ganges, the Ghaghara, the Sone, the Kosi etc. The morphological features include the islands, sand-bars, pools, braid-bars, riffles etc. The North middle Ganga plain shows

include the Punpun which comes from the South and joins the Ganges in the Patna district, Harohar and the Kiul meets at Munger. Other tributaries include the Falgu, the Budhi, the Chandan, the Orhani, and the Burhi Gandak. Most of these rivers are snow fed, which come from the Himalayas.

2.4. Flora and Fauna

2.4.1. Flora

Because of varying altitude and resultant climatic conditions a vast variety of plant as well as animal life is found in this region. Bihar has a total forest area of 6,764.14 km^2, which is 7.1% of its total geographical area. One of the important floral variety found here is "Bauhinia acuminate" locally known as "Kachnaar" (plate 1.6) The sub Himalayan foothills of Someshwar and Dun of the Champaran district is a vast belt of moist decidious forest also showing presence of Scrub, Grass and Reeds. In this region the amount of rainfall exceeds 1,600 mm and thus this area is rich in Sal forest type. The areas with hot and dry Summer have decidious forest. The major trees are Banyan, Pipal and Bamboo. The main crops of this region are Paddy, Wheat, Lentils, Sugarcane and Jute and the main fruit varieties includes Mangoes, Banana, Jackfruit and Litchis.

2.4.2. Fauna

The famous freshwater Ganges river Dolphin, locally known as the "Susu" and scentifically known as "Platanista Gangetica" are now considered as one of the most endangered species (plate 1.7). They mostly prefer to live in deep waters near the confluence of two or more rivers. Its length ranges from 2.3 to 2.6 mts with its tail almost 46 cm in width. The females are larger then the males and the colour varies from lead grey to black. The eye and optic nerve of the Ganges river Dolphin are degenerated. The Ganges river dolphins are incapable of forming images on the retina

Plate 1.6: Floral variety named "Kachnaar"

Plate 1.7: Ganges fresh water Dolphin

since they lack eye lens but they do function for light detection. It is believed that the Ganges river Dolphin lack the true visual apparatus because of its habitat. Since the water in which it lives is highly turbid because of mud, the visual apparatus in such conditions becomes almost useless and thus these animals are adopted accordingly.

Apart from the Ganges river Dolphins, the state also shows the presence of animals like the Tigers, Gaur (India wild Ox and also Bihar's state animal), Deer, Bears, Wolves, Chital (spotted Deer), Crocodiles, Sambars (Asiatic Deer), Panther, wild Dogs, Boars, Elephants, Hyenas, Sloth Bear, Leopard, Chinkaras and Nilgai. The major bird species includes Peacocks, Pheasant, Kites, Eagles, Hose Swifts, and Palm Swifts. The migratory birds include Pochards, red crested Pochards and the Coots. The varieties of resident birds mainly include the bronze winged Jacanas, Pond Herons, Egrets, Swamp Partridges etc.

3. Aims and Objectives

The Ganga basin in Northern India is one of the world's largest fluvial basins, alluvial tract and a very active region with a view to understand large river processes and landforms (Sinha et al. 2010)[96]. The present study is related to river systems and its morphological changes taking place in the Gangetic region around Bihar. The main aim of the work is to bring in account as to how much morphological change has taken place in the past few decades, (around 40 to 90 years). Gangetic rivers show certain specific characteristics since they undergo large seasonal variations in flow as well as in the amount of sediment carrying capacity. High magnitude floods are common phenomena and thus the river exhibits morphological characteristics related to high magnitude flooding. Tectonically, the region is very active and large magnitude earthquakes are also responsible in bringing about sudden drastic riverine changes. The aim of the fluvio-geomorphological studies is to describe and analyze the different

landform features which are created by the effect of flowing water and thereafter to develop an understanding of the ways in which the surface processes operate and control the development of these landforms (Gordon et al. 2004)[28]. Massive and rapid urbanization and industrialization has lead to major issues such as flood, erosion, pollution etc. Climatic pattern is continuously changing because of environmental imbalance which is caused by few natural factors but the most of them are anthropogenic. Erratic flash and flooding has brought about erosion, drastic channel migration which takes toil over people's life and property. Since years, Bihar is experiencing problems related to shifting and migration of the Ganga river and its tributaries. This in turn is responsible for causing large scale morphological changes in the river system. Because of the dynamicity of this river national resources including infra-structure, general development of the region, network communication etc are all drastically affected. Thus, there is a tremendous need to understand and apply fluvio-geomorphological approach which will help in controlling the factors responsible for causing these changes or imbalance. Further, this study will be helpful in understanding the dynamic landforms and the riverine environment system which will help in providing an assessment regarding the amount of erosion and deposition that has taken place on both the banks of the river Ganges.

Keeping in view the aims of the study the following objectives were considered.

A. **Mapping of the fluvio-geomorphological landforms of the Ganga river in Bihar region using multi-date and multi-season remote sensing satellite data.**

A general approach on the geomorphic evolution of an area can be obtained by detailed geomorphological mapping of the landforms by using remote sensing techniques. Necessary supporting data are always crucial for the regions that are usually under

severe environmental threat. Approaches and methods to map the variability of different parameters are important tools to properly guide spatial planning (Bocco et al. 2001)[13]. Fluvial region is highly dynamic and thus use of remote sensing and aerial photographs play a very important role for carrying out detailed study. Synoptic view given by remote sensing techniques helps in visualizing the complexity of the fluvial environment and the dynamicity of the landforms of that area (Philip, 1994)[67].Through mapping it is possible to get a complete past and present database on the status of the Ganges river on the basis of which further river related studies can be carried out. Also two season data have been used i.e. pre- as well as post-monsoon seasons because sometimes a region in response to monsoon may show drastic changes as an effect of high rainfall. In such cases comparison with pre-monsoon helps us to get the knowledge about the actual river condition.

B. Identification of the migration pattern and areas under river changes

Floods of high magnitude are one of the major problems in Bihar. Heavy flooding causes abrupt changes in the flow pattern of the river channel. It also causes extensive damage to the lives of people and property. High magnitude earthquakes are also responsible for the sudden and gradual change in the flow pattern of the river Ganga. So there is a need to identify these areas and find out the reasons behind such drastic migration so that further measures to control it can be taken which will be helpful in saving lives and property.

C. Mapping the areas under aggradation and degradation along the banks of the Ganga river.

Gangetic plains are a vast alluvial tract made up of as sand, silt and clay. The Gangetic river basin is a region experiencing heavy floods during monsoon. Bank erosion and degradation is one of the major problems of this region. Widespread erosion, transfers

huge amount of sediments and other dissolved material in different parts of the Gangetic basin. The Ganges supplies tons of sediments annually to the Bay of Bengal. These sediments are mostly derived from the lesser and higher Himalayas (Rahaman et al. 2009)[69]. The phenomenon of transportation and deposition of the suspended load also contributes towards the change in the flow pattern and in the meandering and braiding of the river channel erosion is mainly caused by the rapid flow of water through soft, disintegrated rocks which also leads to the bankline shifting. This study will be helpful in bringing out the areas which are severely affected so that proper measures can be taken to control further degradation and aggradation which also will be helpful in controlling the river migration problems.

D. Database creation on the fluvio-geomorphological status of the Ganga river in the past and the present using remote sensing and GIS techniques

By getting the complete information on the past and present status of the river, many geomorphological parameters can be inferred which will help in studying the river behavior, identifying the problematic areas which show drastic changes, its migration pattern, the reasons behind it and finally the measures that can be taken to control it. The study will be helpful in understanding the past and the present status of the Ganga river, areas experiencing major riverine changes, problems associated with river channel changes, floods, erosion and deposition etc caused due to natural or anthropogenic activities.

4. Methodology

The entire study was carried out using multidate and multi season IRS satellite data and then integrating this data using ERDAS imagine software and GIS. The study was done in three phases. The first phase of the study comprised of the creation of base reference maps from SOI sheets. For this the required survey of India topographical

maps (SOI) were acquired on 1:250,000 scale and a detailed mapping was carried out for the whole Ganga river course falling in Bihar from which a complete fluvio-geomorphological status was obtained. The SOI maps used for the study were ranging between the years 1922 to 1976.

In the second phase the fluvio-geomorphological dataset was generated for the pre-and post-monsoon IRS 1D LISS III and RESOURCESAT-1 (IRS-P6) LISS III satellite image of year 2000 and 2004. Different thematic layers were prepared, compiled and compared.

In the third and the final phase, from the comparative study carried out between the years 2000 and 2004 the areas which were under major and severe riverine changes were depicted and it was found that there were seven such areas throughout the entire course of the Ganga region, namely Ballia (near U.P-Bihar border), Rudrapur (near U.P-Bihar border), Patna, Sahri, Monghyr, Bhagalpur and Sahibganj. Detailed fluvio-geomorphological status for these areas was obtained using RESOURCESAT-1 (IRS-P6) LISS III on 1:50,000 scale for the year 2006. A detailed ground truth all along the Ganga river course in Bihar was carried out in Pre-monsoon season during March 2008. Ground control points and field photographs were collected at various places in Ballia, Rudrapur, Patna, Sahri, Monghyr, Bhagalpur and Sahibganj. For the flow diagram of the methodology adopted (ref fig 1.5)

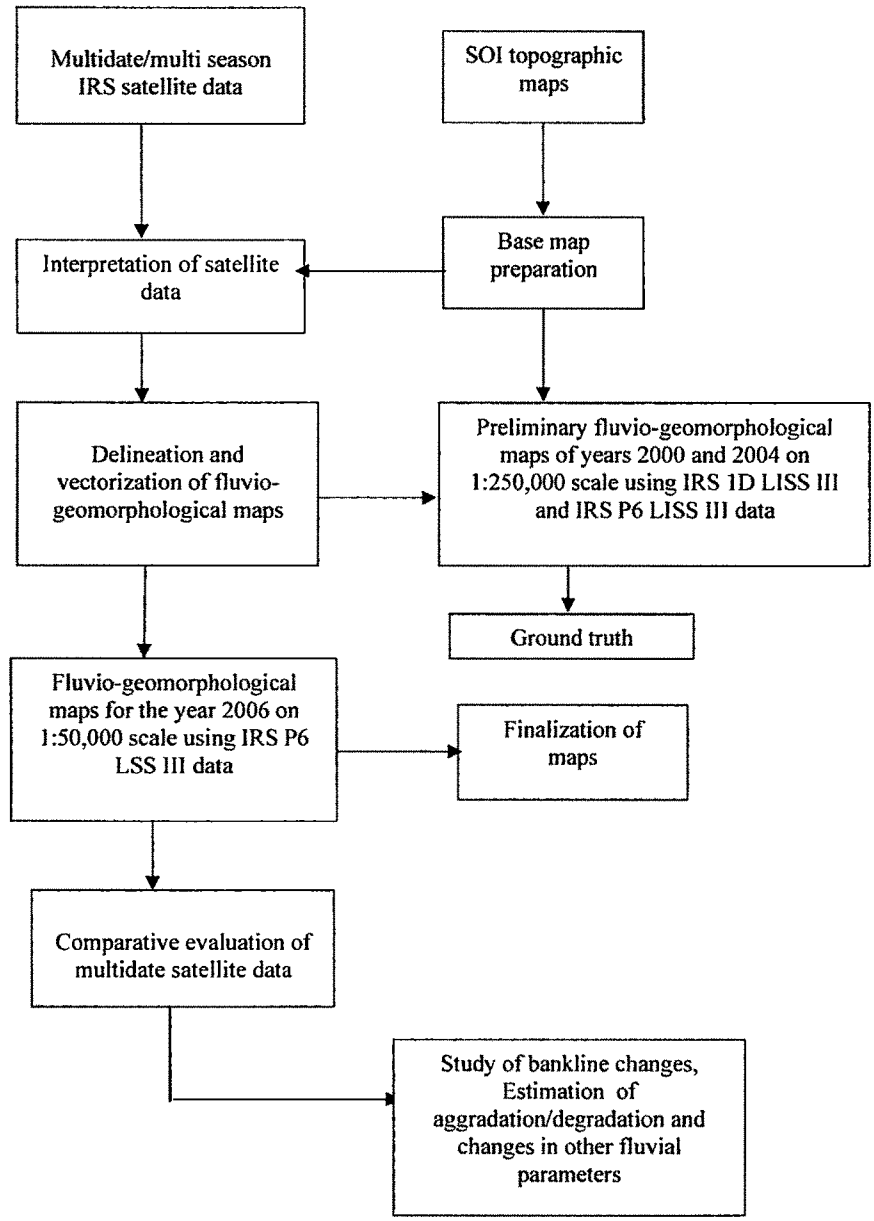

Fig 1.5: Flowchart of the methodology