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Spatio-Temporal Analysis of Changes in the Channel of River Ganga in Prayagraj

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Abstract

Rivers are lifeline of human civilization and any hydro-geomorphological changes may lead to substantial impact on human society. Such changes must be taken care of in order to strengthen our society. Spatio-temporal changes in the channel of rivers is one such aspect that has significant impact particularly at micro-level. Present paper analyses the spatio-temporal changes in the channel of river Ganga in order to evaluate the impact of this change so that the city of Prayagraj may get prepared for the future changes. Ganga and Yamuna are the two major rivers flowing through Prayagraj city, meeting at Sangam where the city is situated. Entire landscape of the city lies almost in the doab of these two rivers and played a vital role in the foundation and development of the city. The river has been subjected to several sequential changes over time related to bed forms, bank erosion, aggradations, meandering, and shifting of channel due to changed land use pattern and increased population pressure across the entire Ganga plain. There are many studies that have proved the shifting of channel of river Ganga upstream, particularly in alluvial plains. Although it is a natural process for a river of such geomorphic vigour, but, shifting of river channel and bank erosion posed a potential threat for large settlements of the city. Since Prayagraj is located at the bank of not only river Ganga but also Yamuna, thus being bounded by two rivers, in case of a shifting in the channel of river Ganga upstream the city will have severe implications on fluvial processes in and around the city affecting the urban geomorphology and population of the city. In the present paper, an attempt has been made to present an account of the spatio- temporal changes in meandering and hence, changes in the channel of Ganga River in Prayagraj district using geo-spatial techniques so that the probable impacts on the city of Prayagraj could be predicted well in advance. Multi-temporal Landsat and Google imageries have been used for the study. Present study has identified significant spatio-temporal changes upstream in the district in the channel of river Ganga which has been affecting the city downstream in several ways.

Keywords: River Ganga, Shifting Channel, Sangam, Urban geomorphology, Prayagraj.

Introduction

Ganga is the second largest river in India by discharge covering Uttar Pradesh, Madhya Pradesh, Rajasthan, Bihar, West Bengal, Uttarakhand, Jharkhand, Haryana, Chhattisgarh, Himanchal Pradesh and Delhi and draining a total area of 8,61, 452 q.km i.e., almost 26% of total geographical area of India. While meandering of the river causes erosion on the outer banks and deposition on inner banks, it also gradually led to spatio-temporal changes in channel of the river which has severe impacts downstream. Sand mining, infrastructure construction on riverbanks, cutoffs,

embankments, reservoir construction and land use alterations have changed the natural fluvial dynamics of rivers which influence the natural meandering capacity and channel of river Ganga in the alluvial plains downstream.

Bank erosion, down cutting, bank accretion and meandering are natural processes for a river with alluvium especially in the low land alluvial plains (Nigam, Katiyar& Mittal, 2016). River bank erosion, low gradient in the lower reaches, high sediment load and anthropogenic causes have caused large scale channel shifts and morphological changes of the Ganges river course (Majumdar & Mandal, 2018). Understanding the processes attribute to channel shifting and assessing river morphological change has long been of interest to geologists, geomorphologist and engineers (Sarma, 2005; Sarker et al., 2014; Wang et al., 2016; Dewan et al., 2017). Studies of channel morphology are essential to evaluate the natural and human influences on morphometric parameters and channel dynamics (Friend and Sinha, 1993; Graf, 2000). Development and migration of meander leads to river bank erosion causing river channel migration resulting into various natural and socio-economic hazards in terms of steering, flood hazard, trouncing of riparian land and structure and mechanism of riparian and aquatic ecosystem (Majumdar & Mandal, 2018).

Objective

The present paper is a study to detect and assess the changes in channel of river Ganga in Prayagraj from the point it enters (Soraon) to the Sangam. Present study depicts that any spatio-temporal change in the meandering and channel of the river upstream within the district has a detrimental impact at city and proved hazardous during the annual floods. It has also aggravated the process of multiple bank erosions all along the course of river Ganga within the district consuming the river-side agricultural lands and posed threat to infrastructures. Shifting locations of Sangam is also a potential impact of this change.

Study Area

Prayagraj city is among major cities of Uttar Pradesh which is located at 25º45'N and 81º 4'E in the southern part of the state. As per the Census of India 2011, the total area of the district is 5,482 sq km and population is 5,954,000. The city region of Prayagraj has area 82 sq km with population of 1,117,094 which is 32nd most populous city in India. It is situated in Confluence of Ganga and Yamuna Rivers which is called Sangam (Figure1). Ganga enters in Prayagraj from Soraon Tehsil near the border of Kaushambi. It meets with Yamuna River after flowing nearly about 33km in Prayagraj.

The Confluence of Ganga and Yamuna called 'Sangam' which is very sacred place for Hindus. The study area has been shown in Figure1. The alluvial reach of 25.94 km of river Ganga in the flood plain starts from Lat.25°28′52.27″ N, Long.81°45′15.64″ E to Lat.25°25′1.77″ N, Long.81°53′31.79″ E and is taken for the study indicating the points where Ganga enters the city up to Sangam. Prayagraj city lies on the right bank of this alluvial reach. On its left bank, agricultural land is found while on the right bank Prayagraj city is situated and river flows almost next to the settlement.

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Methodology

The present study is based on interpretations done on the basis of Landsat satellite imageries for which images of different years (1984, 1994, 2004 and 2014) have been taken from USGS to detect and assess changes in the channel morphology of river Ganga from entrance of river Ganga in Prayagraj district to Sangam at Prayagraj city. Google earth images have also been used in present study for the purpose. Remote sensing and GIS techniques have been used to process the satellite data to get the result.

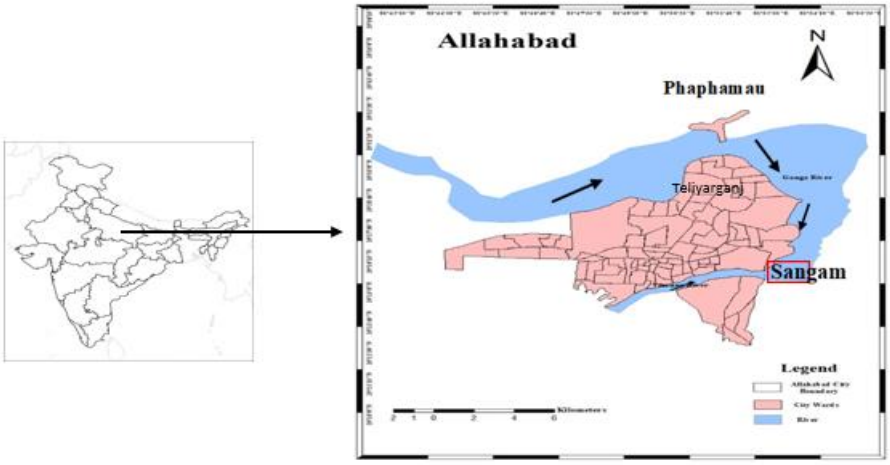

Figure1: Study Area - River Ganga in Prayagraj

Result and Discussion

Present study depicts that any spatio-temporal change in the meandering and channel of the river upstream within the district has a detrimental impact at city and proved hazardous during the annual floods. It has also aggravated the process of multiple bank erosions all along the course of river Ganga within the district consuming the river-side agricultural lands and posed threat to infrastructures. Shifting locations of Sangam is also a potential impact of this change.

The study reveals that River Ganga is flowing in NW-SE trend with an aspect angle of 202.5 degree taking sharp southward turn following the Allahabad Fault to meet Yamuna at Sangam. It has nearly three and a half meandering loops. The shifting behavior can be observed more towards the left bank than its right bank.

Detection of shifting in the channel of river Ganga for different years between 1994 to 2014 has been depicted in Table1 to Table4 and Figure2 to Figure7 based on Landsat satellite and Google Earth imageries with respect to base year1984.

Table1 clearly shows that with reference to the year 1984, channel of river Ganga shifted 945.7 m on the left bank and 920.1 meters on right bank in the year 1994. It shifted 1432.3 m and 1380.2 m on the left and right bank, respectively in year 2004. In year 2014, 1303.2 m shifting took place on the left bank while 971.2 m shifting took place on right bank.

From the result, it is clear that shifting is substantial in the river channel which is more prominent on the right bank of the river while on the left bank it is rather less than the right bank.

Figure3 to Figure 5 depicts shifting of river channel in the different years i.e., 1994, 2004 and 2014 with reference to base year 1984.

Table1: Shifting of Channels of River Ganga from 1994 to 2014

CHANGE DETECTION IN THE CHANNEL OF RIVER GANGA FOR PEAK VALUES				
YEAR	**SHIFTING TOWARDS LEFT BANK w.r.t. 1984 DATA**		**SHIFTING TOWARDS RIGHT BANK w.r.t.1984 DATA**	
	X (UTM)	**SHIFT (m)**	**Y (UTM)**	**SHIFT (m)**
1994	**583950**	**945.7**	**2816423**	**920.1**
2004	**579117**	**1431.3**	**2818340**	**1380.2**
2014	**580104**	**1303.5**	**2818186**	**971.2**

Source: Landsat Satellite Image, USGS

Table2 clearly showed that with reference to the year 1984, Ganga shifted 945.7 m on the left bank and 920.1 m on right bank in the year 1994. The area marked in red circle has witnessed the maximum shift on the both bank of the river (Figure2).

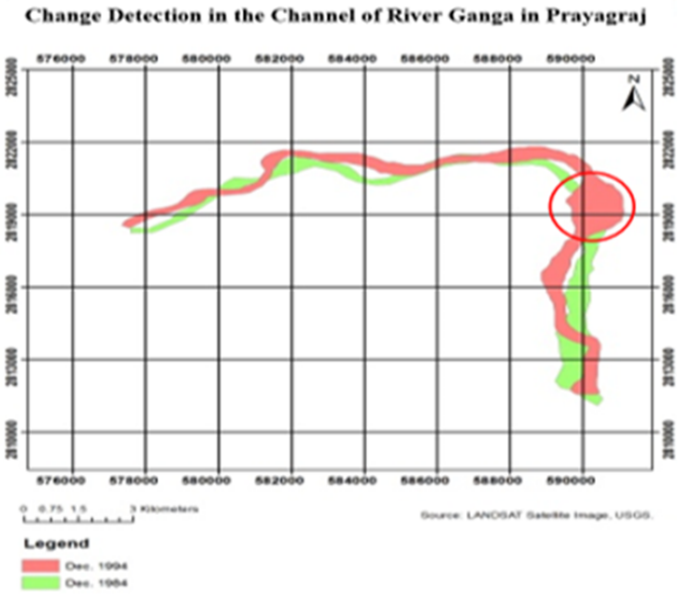

Figure2: Changes in the Channel of River Ganga in 1994 w.r.t. 1984 in Prayagraj

Table2: Change Detection in the Channel of River Ganga for Peak Values, 1994

CHANGE DETECTION IN THE CHANNEL OF RIVER GANGA FOR PEAK VALUES				
YEAR	**SHIFTING TOWARDS LEFT BANK w.r.t. 1984 DATA**		**SHIFTING TOWARDS RIGHT BANK w.r.t. 1984 DATA**	
	X (UTM)	**SHIFT (m)**	**Y (UTM)**	**SHIFT (m)**
1994	**583950**	**945.7**	**2816423**	**920.1**

Source: Landsat Satellite Image, USGS

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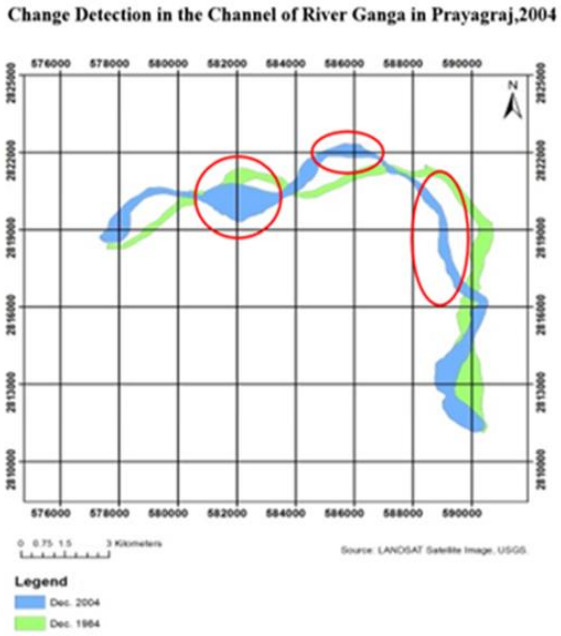

Figure3: Change Detection in the Channel of River Ganga in 2004 w.r.t. 1984 in Prayagraj

Table3: Change Detection in the Channel of River Ganga for Peak Values, 2004

CHANGE DETECTION IN THE CHANNEL OF RIVER GANGA FOR PEAK VALUES				
YEAR	**SHIFTING TOWARDS LEFT BANK w.r.t. 1984 DATA**		**SHIFTING TOWARDS RIGHT BANK w.r.t. 1984 DATA**	
	X (UTM)	**SHIFT (m)**	**Y (UTM)**	**SHIFT (m)**
2004	**579117**	**1431.3**	**2818340**	**1380.2**

Source: Landsat Satellite Image, USGS

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The channel of Ganga shifted 1431.3 m and 1380.2 m on the left and right bank, respectively in the year 2004. Areas marked in red circle have witnessed more shift in the course of the river (Figure3).

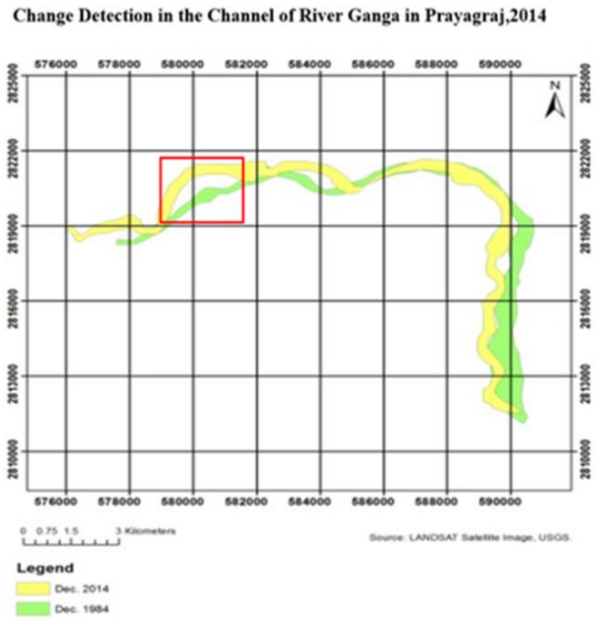

Figure4: Change Detection in the Channel of River Ganga in 2014 w.r.t. 1984 in Prayagraj

Table4: Change Detection in the Channel of River Ganga for Peak Values, 2014

CHANGE DETECTION IN THE CHANNEL OF RIVER GANGA FOR PEAK VALUES				
YEAR	**SHIFTING TOWARDS LEFT BANK w.r.t. 1984 DATA**		**SHIFTING TOWARDS RIGHT BANK w.r.t. 1984 DATA**	
	X (UTM)	**SHIFT (m)**	**Y (UTM)**	**SHIFT (m)**
2014	**580104**	**1303.5**	**2818186**	**971.2**

Source: Landsat Satellite Image, USGS

In the year 2014, 1303.5 m shifting took place on the left bank while 971.2 m shifting took place on right bank and area marked in red rectangle has witnessed maximum channel shifting (Figure4).

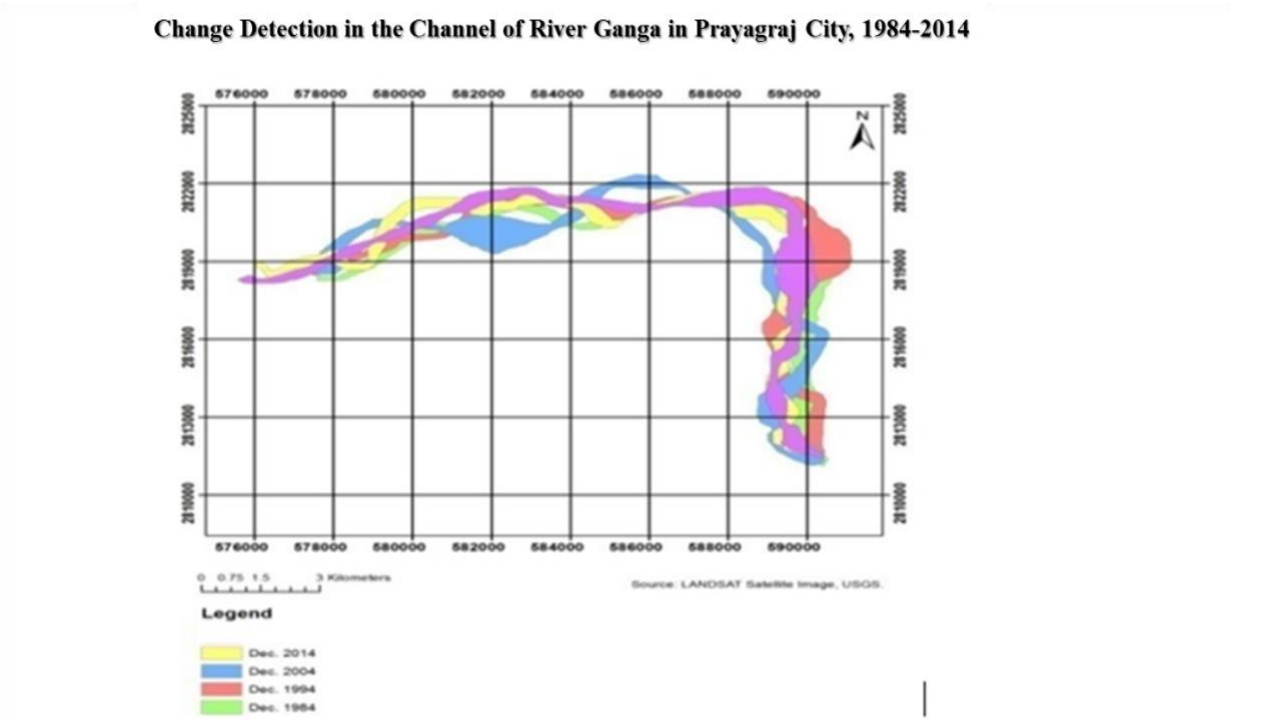

Figure5: Change Detection in the Channel of River Ganga in Prayagraj City, 1984-2014

In the year 2014, the Ganga shifted 1303.5m on left bank while 971.2 m on the right bank as depicted in Figure4.

Conclusion

The present study has been carried out to detect and assess the changes in the meandering pattern of the channel of river Ganga. The study found a substantial and widespread shift in the channel of river Ganga. In 2004, from point with UTM Easting 579117, river flows North Eastward and at this point the river shows maximum erosion and shifting behaviour towards the left bank. Again, at UTM Northing 2818340, the river is showing great shift towards its right bank during the same year. In 2014 another major shifting can be seen at UTM Easting 580104, as a result the river is eroding excessively on its left bank. Major shifts in river channel are observed during 2004 and 2014 mainly towards the left bank. For all other years there is minor shifting in the river course particularly downstream of UTM 586000 Easting towards its right bank in the west. The present study depicts how the river channel shifting is a quite regular phenomenon in the study area which may have multiple potential impacts.

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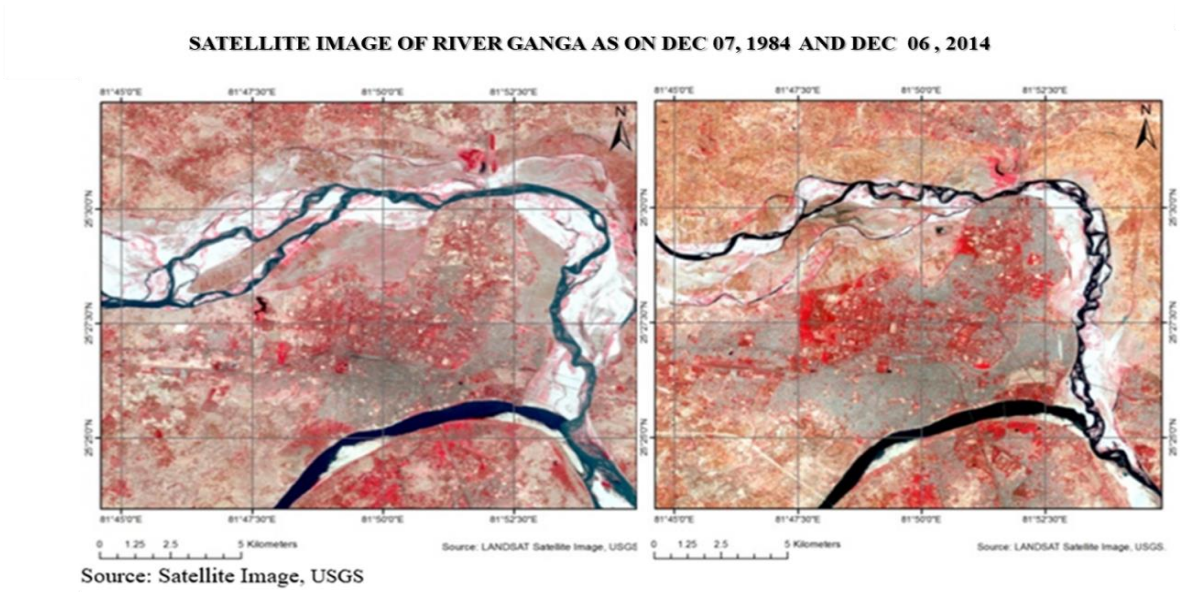

Figure6:Channels of River Ganga in Prayagraj City, 1984 and 2014

Figure7: Channels of River Ganga 1984 and 2014

The spatio-temporal change in the meandering and channel of the river upstream within the district has a detrimental impact at city and may prove hazardous during the annual flooding. It may also aggravate the process of multiple bank erosions all along the course of river Ganga within the

district consuming the agricultural lands and posing threats to infrastructures. Shifting locations of Sangam is also a potential impact of this change. The present study is a beginning towards a more in-depth study which may provide valuable inputs towards assessing the impacts of changes in the channel of river Ganga and may contribute to a more fruitful process of planning and decision making. Present study indicates that any spatio-temporal change in the meandering and channel of the river upstream within the district has a detrimental impact at city and proved hazardous during the annual floods. It has also aggravated the process of multiple bank erosions all along the course of river Ganga within the district consuming the river-side agricultural lands and posed threat to infrastructures. Shifting locations of Sangam is also a potential impact of this change.

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