Change Detection in course of River Ganga near Kanpur using Remote Sensing & GIS techniques

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Abstract— The River Ganga, lifeline of India has been a source for irrigation, navigation, drinking water, power generation, etc. In the developing countries like India the increasing population and rapid urbanization have posed various types of problems and environmental issues like soil erosion, sedimentation, water pollution etc. In the wake of changed land use pattern and increased demographic pressure, the river has been subjected to a several sequential phenomena such as bed forms, turbidity, bank erosion, aggradations and scouring, shifting of its course, formation of meandering channels and so on. The Kanpur stretch of river is a glaring testimony of such phenomena. In the present paper we have analysed the shifting of river Ganga using Remote Sensing and GIS techniques. For the change detection, we have used Landsat satellite images of 12 different years starting from 1973 to 2015. Multi-temporal maps are generated for 12 different years and shifting of river course is calculated using these satellite images. Finally shifting in course of river Ganga near Kanpur city for 12 years are given in meters.

Index Terms— River course, Change detection, Remote Sensing, GIS, Ganga River, River meander, Satellite images, Landsat-8 .

1 Introduction

THE Ganges popularly known as holy Ganga is the second largest river in the Indian subcontinent by discharge. The Ganga basin outspreads in India, Nepal and Bangladesh over an area of 10,86,000 Sq.km. In India, it covers states of Uttar Pradesh, Madhya Pradesh, Rajasthan, Bihar, West Bengal, Uttarakhand, Jharkhand, Haryana, Chhattisgarh, Himachal Pradesh and Union Territory of Delhi draining an area of 8,61,452 Sq.km which is nearly 26% of the total geographical area of the country. The basin lies between east longitudes 73°2′ to 89°5′ and north latitudes 21°6′ to 31°21′ having maximum length and width of approx. 1,543 km and 1024 km [1]. Changes in river channel such as bank erosion, down cutting, and bank accretion are natural processes for an alluvial river . Regional developments such as sand mining, infrastructure construction on the riverbanks, artificial/natural cutoffs, bank revetment, reservoir construction and land use alterations have changed the natural geomorphologic dynamics of rivers [2-5]. Change detection of riverbanks is such a study that is facilitated by application of RS, GIS and GPS. Remote sensing and GIS techniques are widely used for detection and monitoring of changes of the physical enviroment [6]. In the present paper we have used RS and GIS techniques to detect the changes in River Ganga course near Kanpur city (India).

2 Theoretical Background

Rivers which flow over gently sloping ground curve back and forth across the landscape, are called meandering rivers. Meandering rivers are mostly found in low-land alluvial plains. They have a single, rather permanent, sinuous channel without large longitudinal width variations. A meander forms when moving water in a stream erodes the outer banks and deposits on inner banks, thus, widens the valley. River meandering is characterized by a succession of alternating meander loops.A meander loop is the channel reach between two inflection points and consists of a pair of loops in opposite directions. Meandering is basically a fluid mechanics problem in which velocity plays a leading role. The motion of fluid in a curved channel is generally based on the equations of motion [7].

2.1 Meandering geometry

Langbein and Leopold [8] suggested the sine generated wave for the prediction of river meandering. For a river which deviates by an angle $d\theta$from its previous direction in progressing an elemental distance *dx,* the graphing of the meanders can be done by the approximation:

$$\frac{d\theta}{dx} = \sigma\sqrt{(2(1 - cos\theta_m)[1 - \left(\frac{\theta}{\theta_m}\right)^2]} \quad (1)$$

With a close approximation of

$$\frac{d\theta}{dx} = \sigma\sqrt{(2(cos\theta - cos\theta_m)} \quad (2)$$

Where angles θ and θ_m are deviations from the central axis with the downstream direction as zero.

With this simplification, the angle θ is the (angle of point flow direction. with the average flow direction)

$$\theta = \theta_m sin\frac{\sigma\sqrt{(2(1-cos\,\theta_m)}}{\theta_m}x \quad (3)$$

Or,

$$\theta = \theta_m \sin(2\pi\frac{x}{L}) \quad (4)$$

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Where L is the total path distance along a meander, and θ_m is the maximum angle, the path makesfrom the mean down valley direction and σ is standard deviation of changes in direction per unit of distance of the river and is inverse proportional to the meander length. Referring to figure 1.

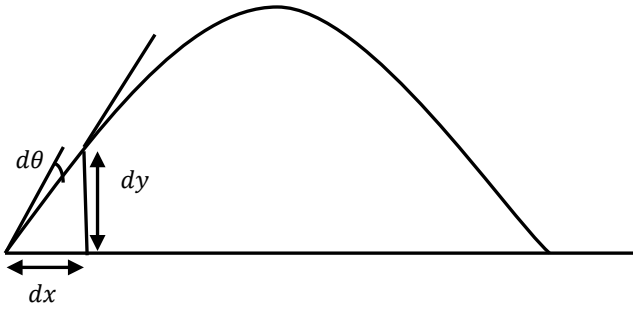

Fig. 1. Meandering geometry3 Study area and data resources

3.1 Description of study site

In the present study, 45 km alluvial reach of river Ganga in flood plain starting from 26°49'18.44"N, 80° 7'11.91"E to 26°28'15.68"N, 80°22'29.05"E has been taken. This river reach is bounded by Bilhaur - Bangarmau highway bridge to Kanpur - Lucknow railway bridge on river Ganga. The study sites are virgin sites having no disturbance of any tributary or hydraulic structure except barrage near Kanpur which was effectively intervened the flow from 2006. This reach of the river has shown clear one and half meander loop having nearly twenty four km. wavelength. Other small meander curves are also available for study

3.2 Data Resources used in this study

The details of the satellite images for the study area used for the investigations are given in the Table 5.1.

TABLE 1
SATELLITE DATA USED IN STUDY

S. No.	Product id	Imaging Sensor	Satellite	Year of Pass
1	Lm11550421973023	MSS	Landsat- 1	1973
2	Lm21550421977029	MSS	Landsat-2	1977
3	Lm31550421979352	MSS	Landsat-3	1979
4	Lt51440421988019	TM	Landsat-4	1988
5	Lt51440421993224	TM	Landsat- 5	1993
6	Lt51440421996345	TM	Landsat-5	1996
7	Lc71440422000364	ETM	Landsat-7	2000
8	Lt51440422006340	TM	Landsat-5	2006
9	Lt51440422008362	TM	Landsat-5	2008
10	Lt51440422010351	TM	Landsat-5	2010
11	Lc81440422013247	OLI	Landsat-8	2013
12	Lc81440422015077	OLI	Landsat-8	2015

4 RESULTS AND DISCUSSION

River Ganga is flowing in North-East direction with an aspect angle of 147.21 degree. In this study area Ganga has meandering loop of nearly one and a half sinusoidal wave in about 40 km of straight length. The shifting behavior has a remarkable reaches near Kanpur. Detection of shifting in river Ganga using satellite images for different years is given in table 2.

TABLE 2
CHANGE DETECTION IN RIVER GANGA COURSE FOR PEAK VALUES

Year	Shifting towards East w.r.t 1973 data		Shifting towards West w.r.t 1973 data	
	Y (UTM)	Shift (m)	Y (UTM)	Shift (m)
1977	2946000	1573	2952000	2731
1979	2952000	4777	2953000	2619
1988	2952000	4203	2955000	3336
1993	2955000	3080	2967000	2826
1996	2952000	5072	2962000	910
2000	2952000	4778	2952000	1729
2006	2933000	3760	2952000	1428
2008	2933000	3675	2940000	1573
2010	2952000	1509	2952000	2651
2013	2942000	801	2958000	1172
2015	2952000	2563	2958000	1429

As seen in the table 2, from point with UTM Northing 2952000, river flows exactly towards Easting and at this point river is showing maximum erosion and shifting behaviour with its right bank never eroded. Second noticeable shifting is in year 2006, at UTM Northing 2933000 it was due to construction of barrage and due to closer of previous course. In the following years, river flows in same path from barrage to Kanpur - Lucknow Railway Bridge. From 1993 to 1996, river has shifted towards west in upstream of 2952000 m Northing in approximately 4000m. In the year 2006, 2962000 m, nearly 3760 m shifting is detected from satellite images. For all other points, temporal maps show that river changes its course every year with smaller magnitudes.Multi-temporal maps are generated using satellite images to detect the changes in river, which are shown in figure 2 and 3. Due to space constraints only 2 out of 12 maps of study area are shown here.

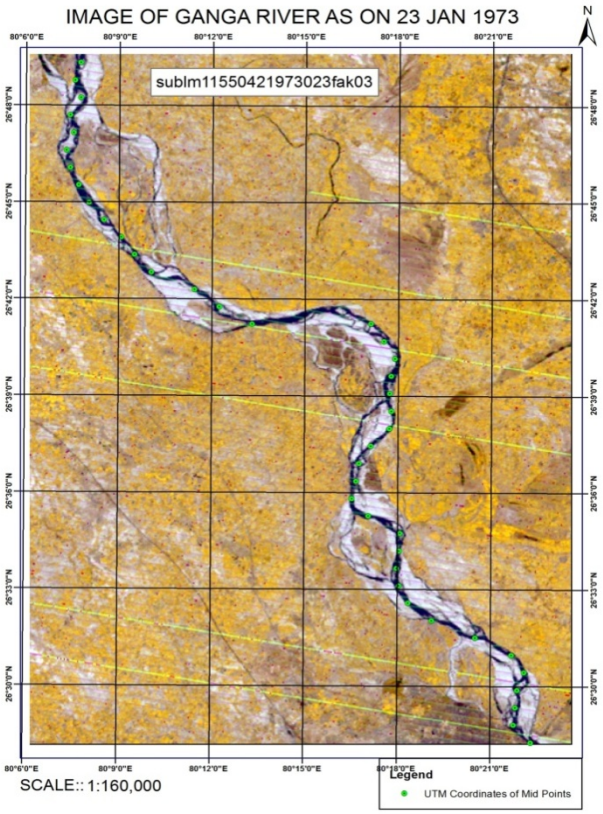

Fig. 2. Map Showing Ganga river of study area for 1973

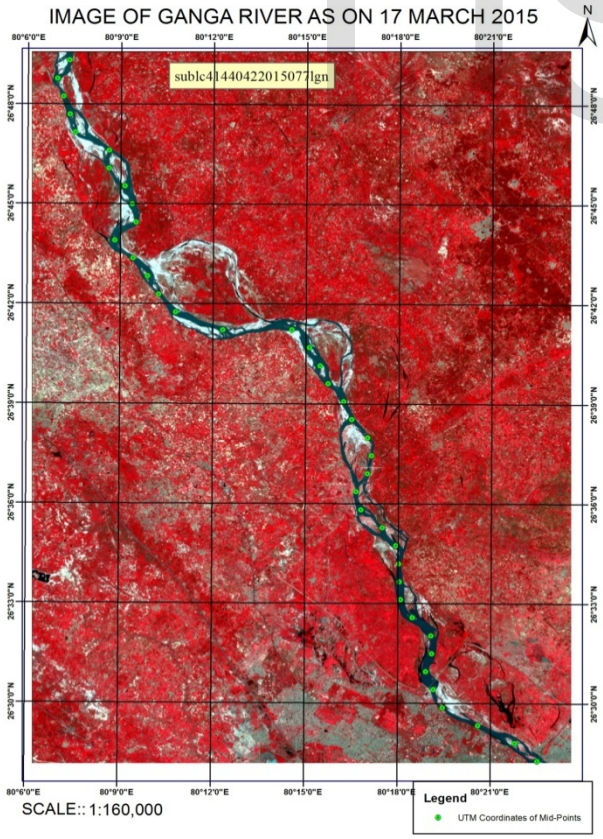

Fig. 3. Map Showing Ganga river of study area for 2015.

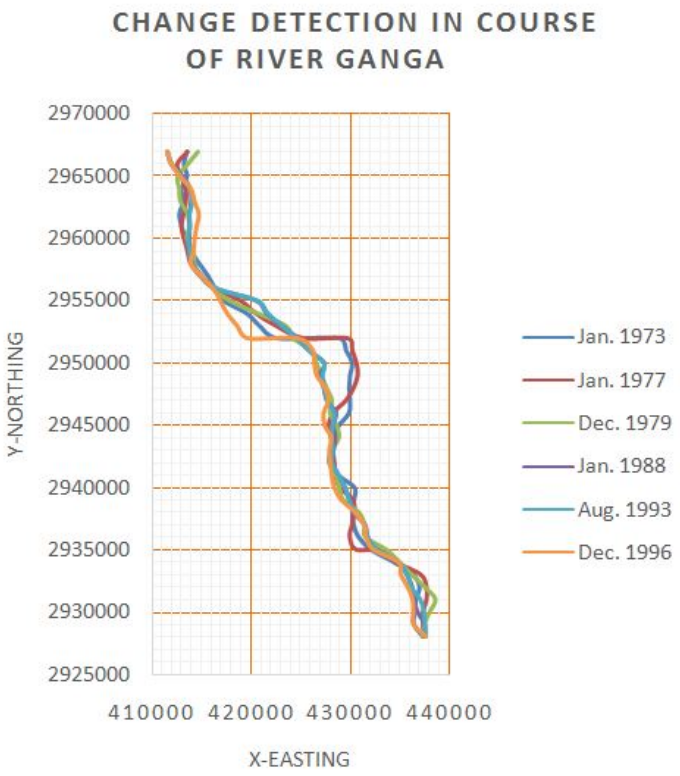

Fig. 4. Planimetric geometry of course of river Ganga in different for years, 1973, 1977, 1979, 1988, 1993, and 1996.

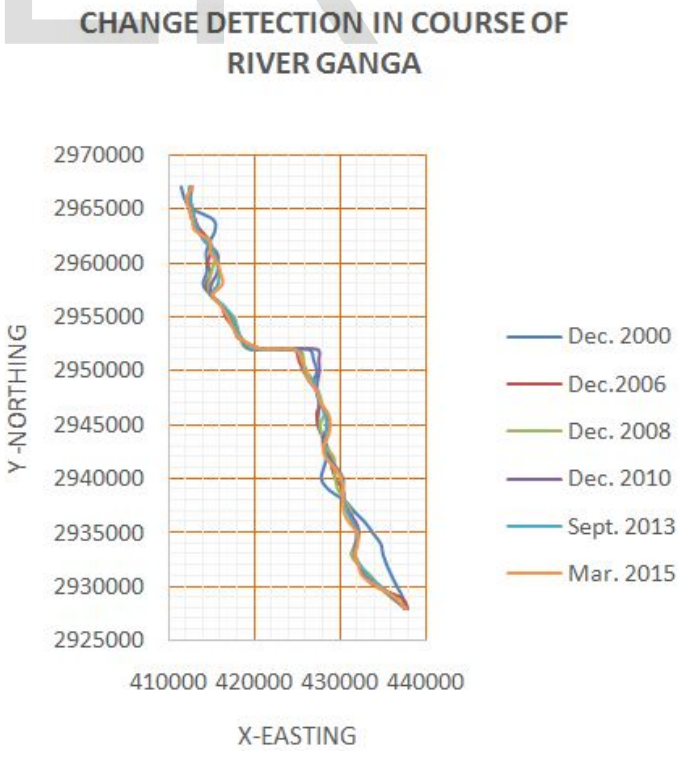

Fig. 5. Planimetric geometry of course of river Ganga in different for years, 2006, 2008, 2010, 2013 and 2015

The temoral change of river course can be seen in figure 4 and 5 respectively. Ganga river course for 6 different years is clearly indicating the shift in river course and meandering shape. Sinusoidal sine generated curve is clearly visible between Northing 2970000 and 2940000 values. River has contuniously shifted towards west from 1973 to 1996.

River almost flown in a confined manner without much chnge in course from year 2000 to 2015. Only noticable shifting occured towards west in 2006 and onwards with comparison to 2000, it was due to construction of barrage at Kanpur city.

4 Conclusion

The present study was carried out to detect the changes in the meandering pattern of the Ganga River near Kanpur city using RS and GIS technology. The change detection can be used in Water management and hydrolic studies. The various issues related to Ganga River meandering has been addressed in this study.

RS and GIS is a powerful technology for analysing both spatial as well as non-spatial data and can be used for the study of river meandering in an efficient way. Remote sensing data provides synoptic view of a relatively larger area. Availability of repetitive coverage in relatively short time interval enables effective study of meandering.Change detection in river meanders using satellite images can precisely replace the detailed field survey and observations.

In future, planimetric modelling can be correlated to hydraulic and DEM data to formulate river behaviour further.

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References

[1] Water Resource information system of India, "http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Ganga".

[2] Surian, N. (1999). Channel changes due to river regulation: the case of the Piave River, Italy. Earth Surf Proc Land 24:1135–1151.

[3] Surian, N. and Rinaldi, M. (2003). Morphological response to river engineering and management in alluvial channels in Italy. Geomorphology, 50:307–326.

[4] Kesel, R.H. (2003). Human modifications to the sediment regime of the Lower Mississippi River flood plain. Geomorphology, 56:325–334.

[5] Vanacker, V., Molina, A., Govers, G., Poesen, J., Dercon, G. and Deckers, S. (2005). River channel response to shortterm human-induced change in landscape connectivity in Andean ecosystems. Geomorphology 72:340–353.

[6] Aher S.P., Bairagi S.I., Deshmukh P.P (2012). River Change Detection and Bank Erosion Identification using Topographical and Remote Sensing Data, IJAIS, Volume 2 No.3, ISSN: 2249-0868.

[7] Julien P. Y., 2002, "River Mechanics", Cambridge University press. pp. 179–184, ISBN 0-521-52970-0

[8] Langbein, W.B. and Leopold, L.B., 1966. River meanders -- theory of minimum variance. U.S. Geol.Survey, Prof. Pap. 422-H, 15 pp.