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RESEARCH ARTICLE

Study of meandering of river Ganga near Allahabad (India), using remote sensing and GIS techniques

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ABSTRACT : The present work deals with Sinuosity Index which determines the meandering and sinuosity of the river Ganga. The study depends upon using TM and ETM+ acquired through 1990, 2000 and 2010 years. Remote sensing and Geographical System Information (GIS) analysis, and sinuosity index were used in this study to investigate and classify the river into straight, sinuous and meander category. The analysis of the Landsat imaginary revealed the migration of the river coarse with time and space. The study reveals that the length of the river falls in only two categories *i.e.* sinuous and meander. The study measures the various sift of selected segments in many part of the river. The study reveals that Landsat images/remote sensed images can be successfully used to classify lengths of the river.

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Key Words :
Remote sensing, GIS, landsat MSS.TM. ETM+, Meandering, Sinuosity index

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River meandering is an inherent characteristic of drainages in an alluvial plain. A river meandering through an alluvial plane has a series of consecutive curves of reversed order connected with short straight stretches crossing. Most rivers in the world are subject to meandering due to natural and human activities. Natural Cause of meandering is the excess of total change during floods, when excess of turbulence is developed and also because of valley slope stream load discharge, bed and side resistance. However, human activity includes Dam construction, Settlement, Agriculture farming causes meandering.

Freely meandering rivers have attracted a great deal of attention from river scientists and engineers over the last century. Earlier works have demonstrated about mender platform geometry, bend flow, bend-migration dynamics, and lateral accretion sedimentlogy (Leopold *et al.*, 1964; Ikeda *et al.*, 1981 and Knighton, 1998). A number of river in India like Ganga (Singh, 1996) Kosi (Wells and Dorr, 1987) Brahmaputra river (Kotoky *et al.*, 2005) and many other river shows special temporal shifting of their channels.

Satellite images show river channels, both active and fossil, very well. Since meanders are to be recognized on their shape on satellite images, it is easy to delineate. Once they have been delineated, their metrics and spectral behaviour can be analyzed. Research on the remote sensing of river meandering has flourished since the 1972 launch of Landsat (Bukata *et al.*, 1995; Jensen, 1999 and Pati *et al.*, 2008). Among the earliest reported results from analysis of remote sensing data for rivers are for temporal variation in water properties (Bennett and Sydor, 1974; Moore and North, 1974; Rango and Anderson, 1974; Rango and Salamonson, 1974; Ritchie *et al.*, 1974; Rogers and Smith, 1974; Johnson, 1975 and Maul and Gordon, 1975). Critical advantages regarding use of the satellite data are the cartographic consistency of the satellite data, the ability to computationally manipulate the digital data, and the fact that satellite detectors measure physical properties that can be inverted to meaningful physical measurements under the proper conditions (Wang *et al.*, 1995 and Dekker *et al.*, 1997). Many of the Historical cities is located along the Ganga river. Therefore, the meandering of river Ganga has been a central concern of attention from river scientist and engineers over the last century.

Experimental Methodology

Measurements pertaining to the Ganga river bank shifting in time and space have been carried out using remote sensing and GIS, field observation and sinuosity index were used in this study to investigate meandering. Three sets of imagery were used for this study; Landsat MSS, TM, ETM^+ images acquired on years 1990, 2000 and 2010, respectively. All the three time Landsat images were georeferenced to UTM coordinate system to investigate the change in river course. The images were subjected to geometric correction and used to delineate the river course using on screen visual interpretation. Vector files of stream of river flow of three mentioned years were digitized from satellite data by using the measurement tool in Arc GIS 9.4 to investigate the meandering of the river.

The total length of river was divided into equal segment that is of 5 km except the last segment which is of 4 km. Straight line has been drawn along the river for each segment and measurement has been taken. Also the straight line distance between two points (*i.e.*, 5 km for each) was measured. Meandering of river in the present paper is calculated by sinuosity index, which determines whether a channel is straight or meandering. The sinuosity Index is the distance measured between two points. The sinuosity ratio is the distance between two points on the stream measured along the channel (L max) divided by the straight line distance (L r) between the two points. "If the sinuosity ratio is 1.5 or greater the channel is considering to be meandering one."

Brice (1964) and Ahmed *et al.* (2009) used the sinuosity index (SI) to separate straight from sinuous and meandering channels. The sinuosity index (SI) can be calculated as follow :

$$\text{Sinuosity index } Z \frac{\text{Length of channel}}{\text{Length of meander belt}}$$

According to sinuosity index channel can be classified into three classes: Sinuosity Index < 1.05 called straight, Sinousity Index 1.05 – 1.50 called sinuous, Sinousity Index > 1.5 called meandering.

Experimental Findings and Discussion

Migration of river's courses is detected from 1990, 2000 and 2010 satellite data. The Shift of Ganga river in the Allahabad region based on the Landsat data and sinuosity index is summarized in Table 1. After the calculation of Sinuosity ratio of Ganga, it has been found that at the segment A, C, F, G and for H has sinuosity ratio greater than 1.5 in year 1990. Whereas in year 2000 sinuosity ratio at segment A, E, F, and G is greater than 1.5 indicating that meandering is continue in many part of study area. Also Sinuosity ratio at segment A, B, E, F, G and H was found to be meander in year 2010.

The analysis of Landsat images revealed the migration of river course with time and space. The river's course is sinuous at some part and is more meander at others. The change of position was observed and

Table 1 : Sinuosity index of different segments of different years satellite data

Segment No.	Lmax (km)	Lr (km) 1990	Lr (km) 2000	Lr (km) 2010	P (Sinuosity Ratio)1990	P (Sinuosity Ratio) 2000	P (Sinuosity ratio) 2010
A	5	2.13	3.01	2.09	2.47	1.66	2.39
B	5	4.52	4.13	3.23	1.11	1.21	1.54
C	5	3.56	4.35	4.22	1.40	1.15	1.18
D	5	3.06	4.14	4.32	1.63	1.20	1.15
E	5	4.03	2.62	3.11	1.24	1.90	1.60
F	5	2.54	2.57	2.18	1.97	1.94	2.29
G	5	2.14	2.11	2.29	2.33	2.36	2.18
H	4	2.01	-	1.44	1.99	-	2.78

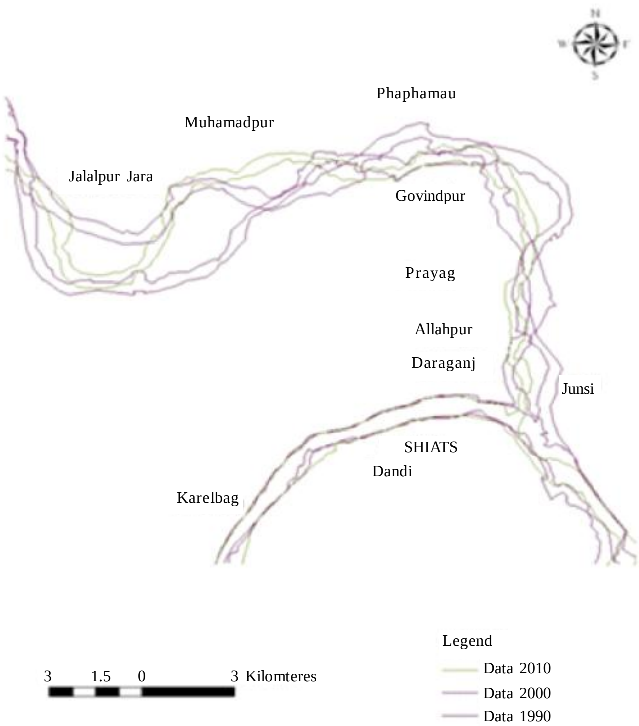

Fig. 1(a): The shift in the position of Ganga river in three different year (1990, 2000, 2010)

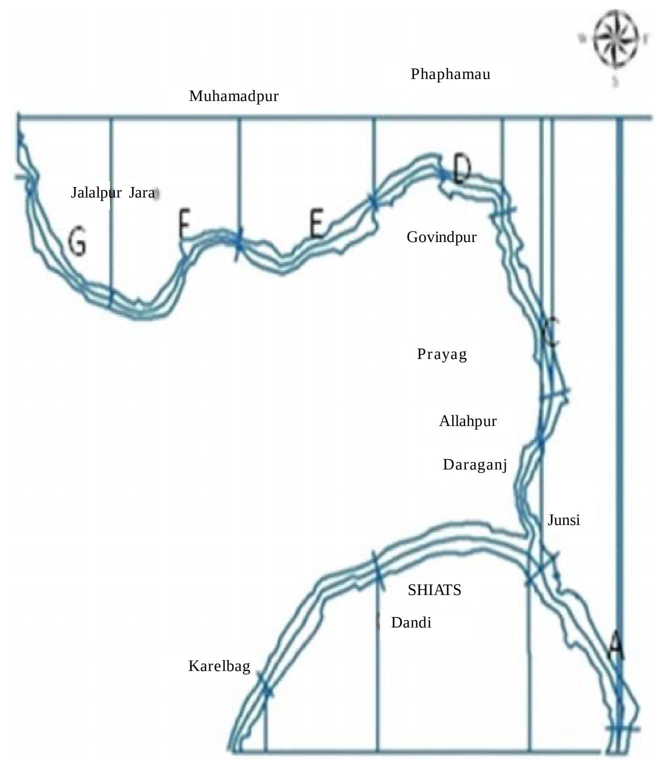

Fig. 1(c): Segments of active Ganga stream in year 2000

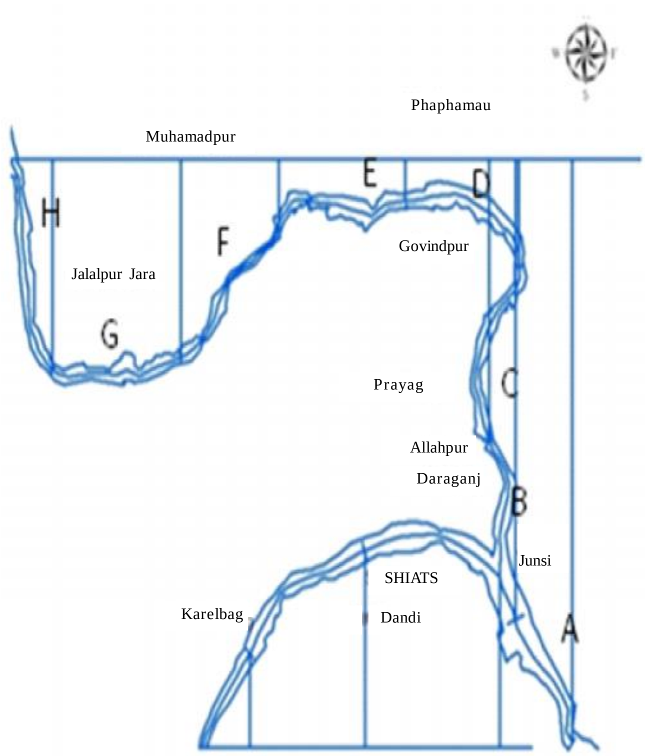

Fig. 1(b): Segments of active Ganga stream in year 1990

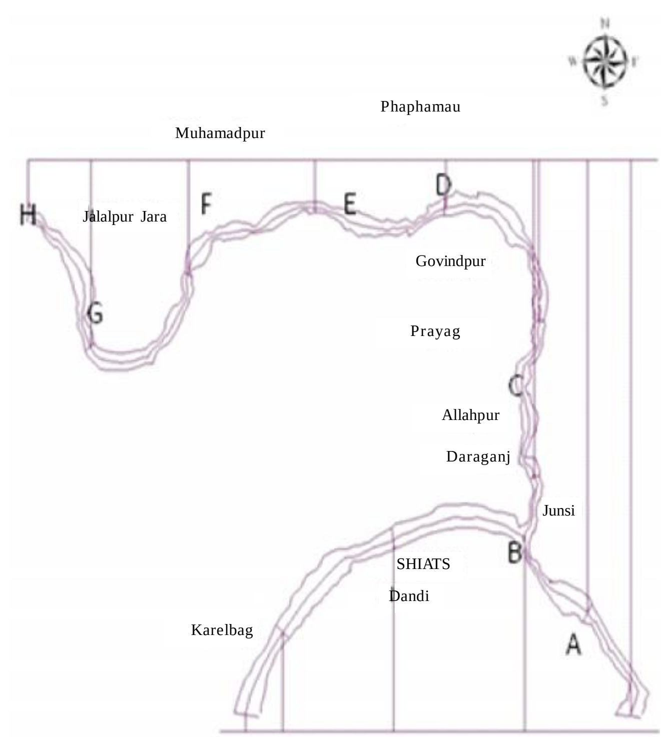

Fig. 1(d): Segments of active Ganga stream in year 2010

measured and come with the conclusion that meander in the river at segments 'A', 'F', 'G' is common in all the three dates' satellite data. The Maximum shifts of the western bank of the Ganga river are noted between Gyasuddinpur Kachhar to Rasoolpur Madiyadeeh Uparhar which is closer to the Ganga Vihar and Transport Nagar colony.

However it was also observed that river has started changing their courses at segments B and E in the period of 1990 to 2000. The man made activities in the study area such as construction of embankment and bridge accelerate the water current, affects the area with erosion at the clayey and sandy sediments. The maximum lateral eastward sift is observed related to the reduction in volume of discharge after the Tehri dam became operated in year 2006 (Pati *et al.*, 2008). The change of water discharge causes readjustment of river bank. A segment 'H' for the year 2000 was not coved in the study area.

It is also observed that meander in the river courses stop near the segment 'D' in the year 2000 and 2010 which is close to Govindpur and Rasulabad colony. There are no any major changes in the segments 'C' in year 1990 to 2010.

Change in river course in time and space may lead to change in land use in the vicinity of the river bank. Therefore, protection method in the study are in many parts is very much recommended to protect the river bank from further migration of courses. Providing awareness programs and rules for using the river banks is also very important.

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