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Research Article

CHANNEL DYNAMICS AND SETTLEMENT VULNERABILITY: A MICRO STUDY OF DEOHA RIVER, PILIBHIT DISTRICT, UTTAR PRADESH

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ABSTRACT
Rivers of the Western Ganga plains in India are highly dynamic in nature and their flood plains are densely populated. The present study incorporates Deoha river, also known as Garra river, a left bank tributary of river Ganga, situated on the western part of Uttar Pradesh. This river shows frequent channel migration due to high water discharge during monsoon period, leading to serious problems to the flood plain inhabitants in terms of flood, displacement of land and associated resources and property damage. The aim of the present study is to investigate the nature of spatio-temporal shifting of Deoha river and assess settlement vulnerability due to migration of Deoha river. For this purpose a 50 km segment of the river from Duni barrage to Tihuliya village in Pilibhit district, U.P has been selected. Further, different temporal satellite images, GIS platform and statistical techniques have been applied for quantification of channel migration and associated settlement vulnerability over a period of 37 years since 1979 up to 2016. The present study indicates that the river is highly dynamic and has shifted in both direction, towards left and right of the channel, but overall right hand shifting is dominant than leftward shift. The dynamic nature of the river also causes serious devastation to settlements located within the zone of active floodplain of Deoha river. The study also helps to contribute towards sustainable management of river valley and risk assessment of settlement.

Keywords*: *Channel Migration, Sinuosity Index, Settlement Vulnerability

INTRODUCTION
River dynamics is an inherent core part of fluvial geomorphology. It helps to understand river form and processes, and, therefore, the nature of the river. In India, dynamics of individual rivers of Gangetic plain got wide attention of researcher such as migration of Kosi river (Geddes, 1960; Arogyaswamy, 1971; Wells and Dorr, 1987; Sinha, 2009), hyperavulsive Baghmati river (Jain and Sinha, 2004), and few studies in the western Ganga plains (Richards *et al.*, 1993). The study focuses on quantification of shifting of Deoha river, a tributary of river Ganga. It attempts to make future prediction of channel centerline shift and identify vulnerable settlements along the study reach.
The Deoha river in its past was a major tributary of Ramganga river but in course of time due to process of river capturing it became a tributary of Ganga river (Roy and Sinha, 2007). It is a single thread typical meandering river with some partial braiding in few pockets along its course. The sinuosity of the river is 1.73 as of 2016. The study area extends from 28.48^0 North to 28.23^0 North latitude and 79.43^0 East to 79.51^0 E longitude (Figure 1). This river is very dynamic in nature as evident from different valley floor geomorphic features such as abandoned channels, meander scrolls, meander cut-off, oxbow lake etc. The river changes it courses very frequently over its wide active flood plain, average width 3 km and creates hazardous condition to settlements situated on the active floodplains.

MATERIALS AND METHODS
Database and Methodology
The study has been completed in three stages. At first stage planform dynamics and shifting of the river is assessed. In second stage identification and mapping of different geomorphic features and units are done. At the final stage, based on findings settlement vulnerability has been mapped. In order to measure the rate and direction of channel migration of Deoha river shifting of channel centerline is considered (Deb

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and Ferreira, 2014). For this purpose, at first right and left banks of the channel are digitized on different satellite images of 1979, 1989, 2000, 2008 and 2016 (Table 1). Here channel is recognized as an area where vegetation cover is less than 10% (Lawler, 1993; Tiegs and Pohl, 2005) or on the basis of changes in vegetation types (Richard *et al.*, 2005). Further, to measure channel migration, channel centre lines are drawn which is the exact midway from the bank lines and superimposed in Arc GIS 10.1. The amount of lateral migration are then computed across eighteen equidistant cross sections drawn at an interval of 2.5 km along the study area and linear regression method is applied to predict the future trend of channel migration (Deb and Ferreira, 2014) (Figure 2). The sinuosity index is calculated by dividing the channel lengths by valley length (Leopold *et al.*, 1964).

To demarcate geomorphic units such as valley margin, active flood plain and inactive flood plain SRTM DEM and LISS III data are used. Consequently, valley margin has been demarcated on the basis of break of topographic break in slope in Arc GIS 10.1 from SRTM DEM with spatial resolution of 30m. The delineation of active floodplain is done from LISS III images by band combination of 432. Further, in stream and flood plain geomorphic features such as different types of bars, oxbow lakes, palaeo-channels, meander scrolls etc. and settlements are demarcated from high resolution Google Earth Pro images through visual image interpretation techniques (Figure 3). Finally, settlement vulnerability has been mapped based on fluvial dynamicity, extent of active flood plain and location of the settlements along the valley floor.

Fig. 1: Study Area

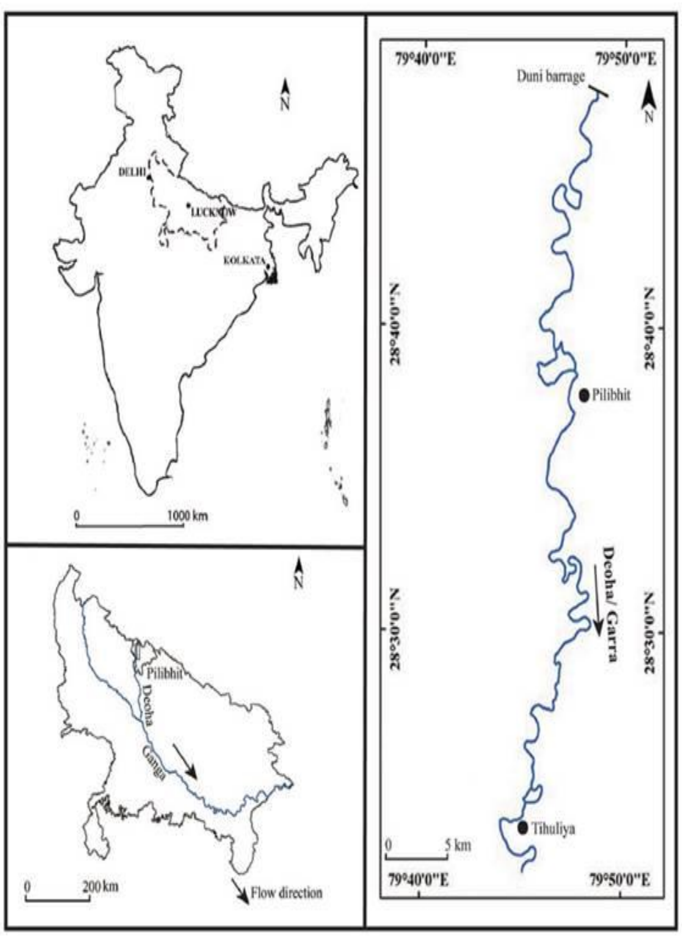


Fig. 2: Cross-Sections along Deoha River

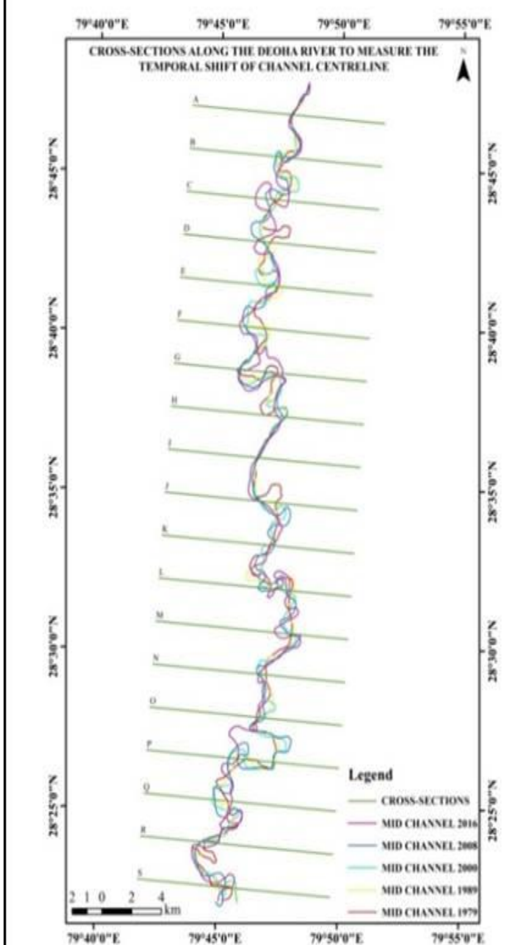


Table 1: Sources of Satellite Images

Satellite Images	Date	Sources
LANDSAT MSS	April 2, 1979, April 27, 1989;	http://earthexplorer.usgs.gov
LANDSAT ETM+	October 23, 2000;	http://earthexplorer.usgs.gov
IRS LISS III	October 9, 2008;	http://bhuvan.nrsc.gov.in
LANDAST OLI/TIRS	February 27, 2016;	http://earthexplorer.usgs.gov
GOOGLE EARTH	May, 2016	Google Earth Pro 7.1

RESULTS AND DISCUSSION

The temporal satellite images of the study area show that Deoha river has undergone significant changes during the time span between 1979-2016. The river has gone through critical changes morphological and planform characteristics due to erosion and accretion of river bank and resultant shifting of the river channel. These have been discussed with an attempt to predict the future trend of channel shifting based on linear regression technique.

Planform Dynamics

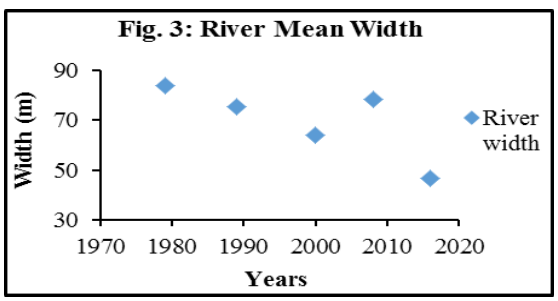
The Deoha river has undergone major planform changes during the study period of 37 years (Table 2). The actual length of the river varies from 83.22 km to 91.64 km, whereas, axial length varies from 47.33 km to 48.42 km.

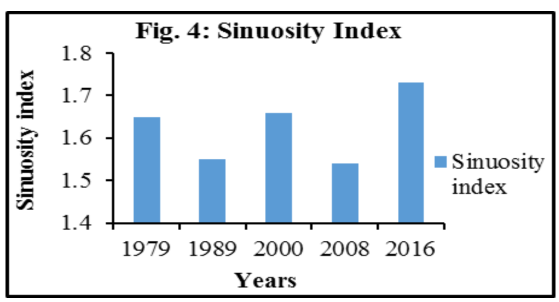
Table 2: Planform Characteristics of Deoha River, 1979-2016

Planform	1979	1989	2000	2008	2016
Actual length (km)	83.22	83.28	88.02	91.64	89.27
Axial length (km)	47.38	47.33	47.33	48.42	47.48
Mean width (m)	83.88	75.53	64.15	78.38	46.78
Sinuosity	1.65	1.55	1.66	1.54	1.73

Source: Personal Computation

In addition, mean width of the river shows a general decline in trend, which varies from 83.89 m as in 1979 to 46.78 m in 2016, whereas, sinuosity index indicates highly meandering characteristics of the river (Figure 3 & Figure 4)..





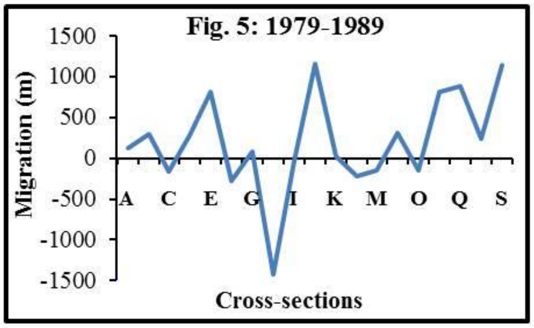
Shifting of Channel Centreline and Sinuosity

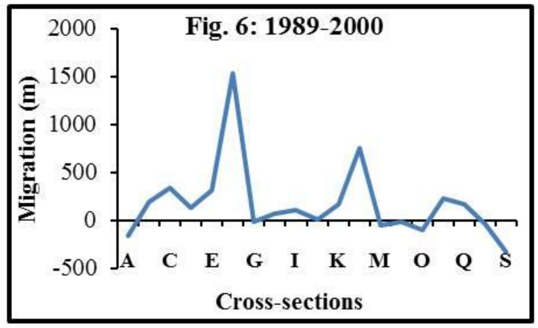
Time Period: 1979-1989

Changes in channel centerline during the time period (1979-1989) across different cross-sections shows maximum rightward and leftward migration with 1160 m and 1429 m at cross section J and H respectively. Minimum right and leftward migration is 23 m and 143 m along the cross section K and M respectively. Average yearly shifting rate is 45.30 m/year. An overall change in channel centreline shows rightward migration of channel midline during this time period. Midline migration rate also vary spatially throughout the time period with migration rate being highest in the middle part than in upper and lower part of the study area. The sinuosity declines slightly from 1.65 in 1979 to 1.55 in 1989 (Figure 5).

Time Period: 1989-2000

For the period 1989 to 2000, maximum rightward migration of centerline was 1533 m and leftward is 335 m along the cross sections F and S respectively, whereas, minimum rightward and leftward migration is 13 m at cross sections J and N respectively (Figure 6). Average yearly migration rate is 22.79 m, which is about half of the time span of 1979-1989. Channel migration rate is highest in upper-middle part than in lower part of the study reach during the given time period. Overall, rightward migration is dominant during the time period of 1989-2000. The sinuosity which was 1.55 in 1989 which increased to 1.66 by 2000.





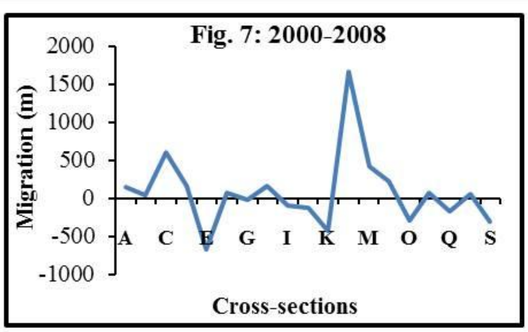
Note: '+' value indicate rightward and '-' value indicate leftward migration of channel centerline

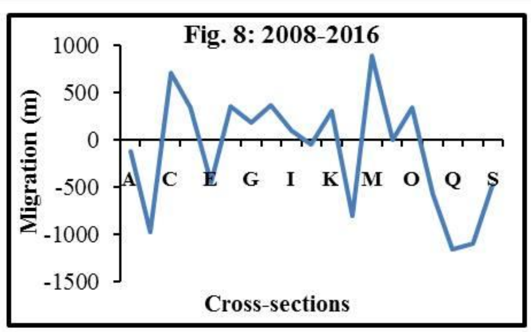
Time Period: 2000-2008

Maximum right and leftward migration during this period is 1660 m and 672 m at the cross-sections L and E respectively (Figure 7). Minimum rightward migration is 40m at B, whereas, minimum leftward value is found to be 16 m at cross section G. Average yearly migration rate is 37.53 m. which indicates increase in migration rate in compare to preceding time span. Channel migration rate is greater in the lower-middle part of the study area than in compare to upper part for the given time period. Overall, rightward migration is dominant in this time period with much variation in magnitude of migration. Sinuosity also slightly reduces to 1.54 by 2008.

Time Period: 2008-2016

Mid-channel change during 2008-2016 shows maximum rightward shifting with 896 m. along the cross section M and maximum leftward migration with 1163 m. at cross-section Q. Minimum rightward migration is 2 m. at N and minimum leftward shift is 45 m. at J cross-sections. Average yearly migration rate observed is 61.09 m. During this period migration rate increases nearly two fold compared to previous time span. Overall rightward and leftward migration is more or less same during this time period. Channel migration rate is higher in upper and lower part than in middle part of the study area during this time period. Sinuosity index increased to 1.73 m in 2016 (Figure 8).





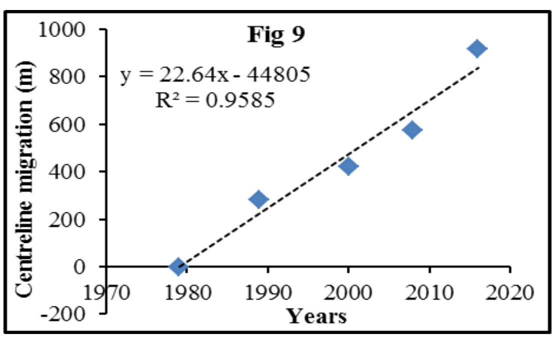
Note: '+' value indicate rightward and '-' value indicate leftward migration of channel centerline

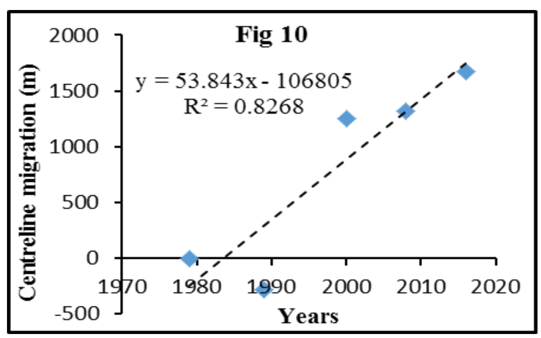
It is observed that during the study period the maximum and minimum shifting of Deoha river was 2197 m and 21 m respectively. The rightward shifting of the river is dominant for most of the sections (Figure 3, 4, 5 & 6). Further, to know the nature of channel shifting and future prediction, linear regression method has also been applied. The assessment shows that Deoha river is migrating linearly only for 4 cross-sections out of 19 and for the rest of the section it is migrating abruptly (Table 3).

Table 3: Shifting of Channel Centerline and its Prediction

Cross Sections	1979-1989	1979-2000	1979-2008	1979-2016	1979-2020	
					Shift	R^2
A	124	-37	102	-21	18.24	0.020
B	294	494	534	-440	62.168	0.037
C	-167	177	574	1484	1245.4	0.743
D	281	419	574	917	927.8	0.959
E	809	1129	457	1676	446.554	0.002
F	-278	1255	1321	355	1957.86	0.827
G	83	65	49	231	181.412	0.567
H	-1429	-1362	-1203	-837	-1339.76	0.189
I	-37	71	-25	70	51.942	0.227
J	1160	1173	1044	999	1336.46	0.405
K	23	187	-251	53	-32.17	0.022
L	-221	537	2197	1393	1988	0.669
M	-143	-199	224	1120	768.64	0.518
N	313	300	520	522	621.6	0.863
O	-148	-244	-533	-189	-408.048	0.416
P	819	1052	1127	557	1074.1	0.296
Q	882	211	886	-277	232.934	0.020
R	247	211	261	-829	-377.78	0.265
S	1148	813	504	33	398.524	0.019

Source: Personal Computation
Note: '+' value indicate right ward and '-' value indicate left ward migration



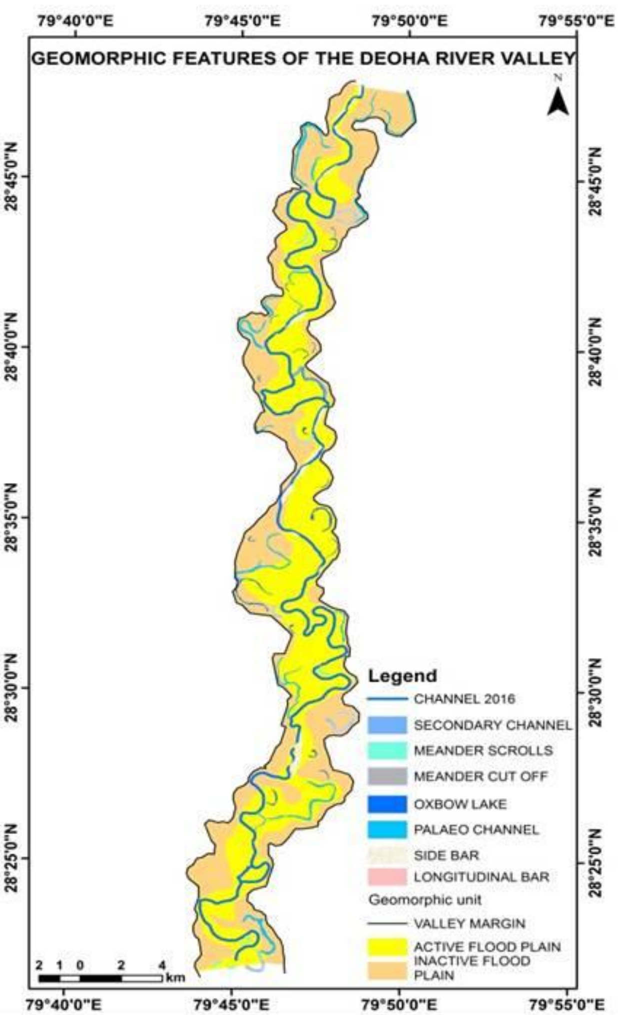


The value of R^2 shows a good linear correlation for sections C,D,F,N, medium at G,J,L,M,O and low correlations for sections A,B,E,H,I,K,P,Q,R,S as depicted in Figure 9 and 10 showing the linear regression analysis at cross-section D and F respectively.
Therefore, from the above discussion an inference can be drawn that the dynamic nature of Deoha river is due to high river bank erosion as validated by heavy suspended sediment load in the river (Sinha, 2007).

Geomorphic Features and Units

The geomorphic units of Deoha river valley includes active flood plain, inactive flood plain and valley margin. Deoha river has wide active floodplain with average width of 3 km and relatively narrow inactive flood plain. Large portion of valley floor area is covered by active flood plain. There are distinct instream geomorphic features such as bars such as side bar, longitudinal bar, point bar, whereas, oxbow lake, abandoned channel, primary and secondary channel, meander scrolls, meander cutoff characterizes active flood plain of the river. The inactive floodplain is characterized by palaeo channels and meander scars (Figure 11).

Fig. 11: Geomorphic Features



Settlement Vulnerability

The settlement vulnerability is recognized on the basis of proximity of settlement to the river, active flood plain, palaeo-channel on inactive flood plain and valley margin (Table 4). It is observed that on an average, the Deoha River migrates several hundred meters in both directions (eastward and westward).

Table 4: Settlement Vulnerability

Vulnerability	Area (Hectare)	Locational Factor
Highly vulnerable	306.71	Channel proximity and active flood plain
Moderate vulnerable	58.47	Near Palaeo channel on the inactive floodplain
Low vulnerable	1842.46	Near valley margin.

Source: Personal Computation

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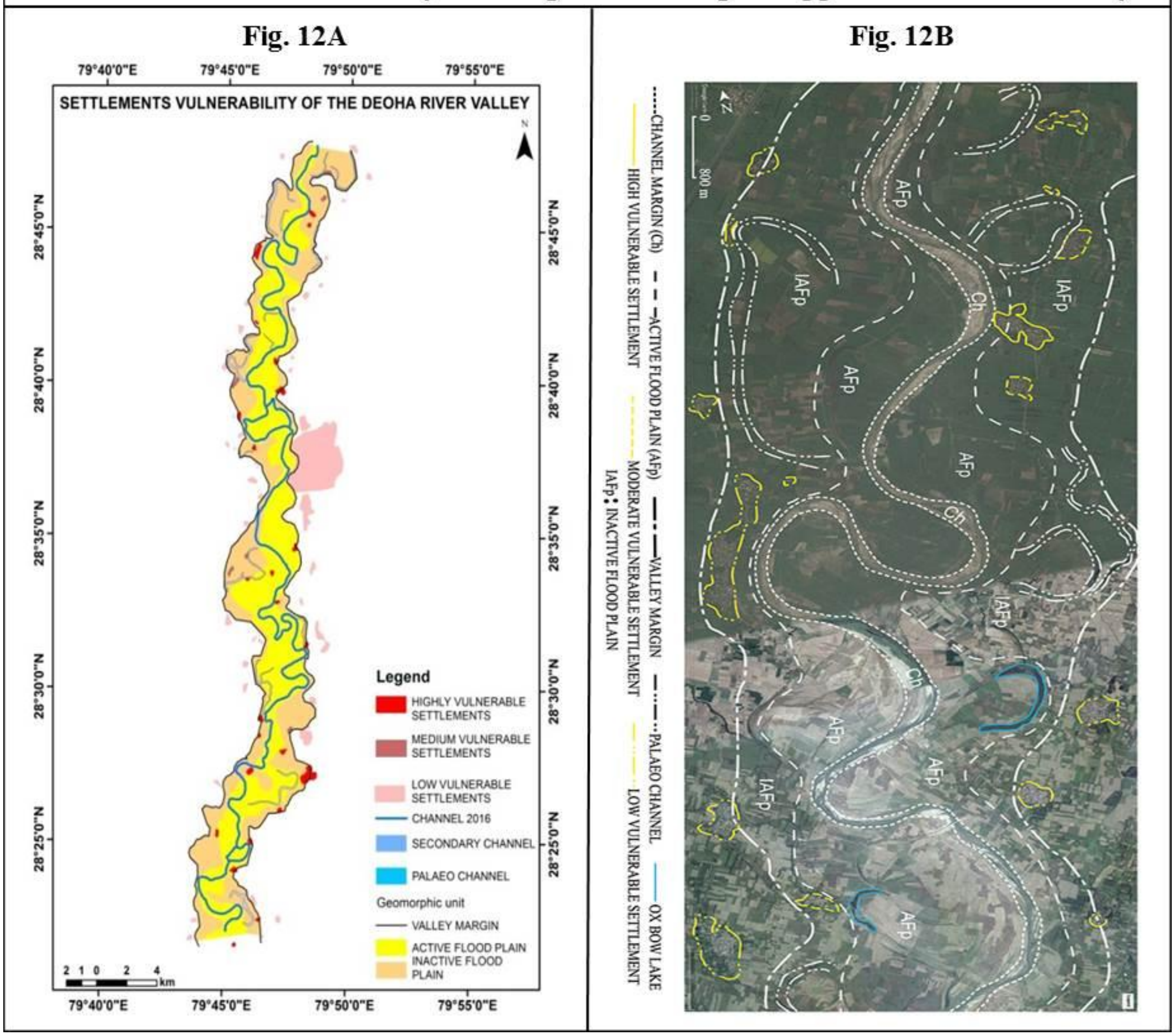
The frequent migration of river over its active flood plain indicates that the flood plain of the river is highly erosive and most of the shifting occurs during the flood period because of high stream power that is due to increase in water discharge and erosive geo-material of the river bank. These results into high vulnerability of settlements found within the active flood plain. Settlements which are highly vulnerable (Turakpura, Behri, Kurra, Himkarpur, Pakariya, Naugawan, Simaria, Tarachand etc.) are dispersedly spread over the active flood plain of Deoha river with an average area of 306.71 hectare.

Fig.12: Geomorphic Units and Settlement Vulnerability.
A: For the Entire Deoha valley. B: Google Earth Image of Upper Part of Deoha Valley



The moderately vulnerable settlements like Surajpur, Jagat, Motiram, Naugawan, Pahanian etc. are located in the inactive flood plain besides the palaeo-channels of the river over a total area of 58.47 hectare. This indicates less probability of the river to inundate or erode these settlements as these areas is beyond the limit of flood water of current hydrological regime. But the presence of paleo-channels indicates flowing of the river in this zone in the recent past. If a change in hydrological condition of the river takes place there is possibility of reoccupying of these paleo-channels in future and leading to hazardious condition for the settlements situated along the palaeo bank side.

The settlements located adjacent to the valley margin (Majhalia, Andrain, Rampuria Sirsa, Patrasa, Mundia Hulas etc.) are all considered to be in lower vulnerable zone because the river valley margin is indicating the limit of hydrological influence zone of the river. Further, the river valley has widened due to geomorphological processes during the recent geological time period. The total area under low vulnerable zone is 1842.46 hectare (Figure 12 A & B).

Conclusion

The present study shows that Deoha river undergoes critical changes in planform and morphological characteristics during the study period of 37 years. Actual length of the river increases from 83.22 km in 1979 to 89.27 km in 2016 and sinuosity increases from 1.65 in 1979 to 1.75 in 2016. Mean width of the channel is continuously decreasing from 83.88 m in 1979 to 46.78 m in 2016 which is nearly half of that of 1979.

This indicates change in hydrological regime of the river. The frequent channel migration of the river has severely affected the livelihood of the people of the region. Shifting of channel is not comparable throughout the study reach i.e. sometime located in middle portion and also in upper and lower parts, indicating dynamic characteristics.

It can also be concluded that it is better to leave the active floodplain of Deoha river which is shifting abruptly rather than occupying these areas for habitation purpose. An appropriate protective measure is urgently needed for mitigating problems arising due to increase in hazard conditions in the surrounding bank line areas. The limitations of this study include climatic and hydrological data, bank properties, sediment concentration and change in river cross-sectional form.

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