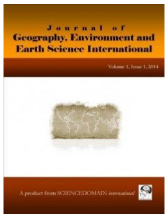

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Delineation of Channel Migration Zone and Its Change in Post Farakka Barrage, a Case in Kalindri River of Eastern India

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Migration of river channel is a natural process but sometimes it can create problems such as land ownership conflict, land loss and loss of infrastructure. Present study deals with the river Kalindri of Malda district which is considered as a branch of Pullahar. The principle objective of this work is to delineate channel migration corridor of the river Kalindri. For the demarcation of channel migration zone (CMZ), construction of historical migration zone (HMZ), erosion buffer (EB), avulsion potential zone (APZ) etc. is performed. The results clearly display that the river has a historical channel migration zone of 218.24 km^2 with average lateral width of 3.37 km in between 1924 to 2015. After Farakka Barrage project (1973), volume of water and river energy is reduced significantly and it causes squeezing of wide channel migration zone (1.63 km). Total 74 number of villages fall under present channel migration zone and out of them 27% villages are prone to high frequency channel migration problem.

Keywords: Hydrological modifications; historical channel migration; channel migration zone; erosion buffer and avulsion potential zones.

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1. INTRODUCTION

The lateral shifting of river channels within flood plain regions is a natural event [1-3] but increasing anthropogenic interference has made it semi natural [4]. Lateral migration of river channel some times put forwarded challenges to the engineers, scientists, planners and managers on how to best accommodate societal needs coming from the river directly and indirectly [5]. Alluvial courses are very migration prone and if hydrological properties, sediment characters, active tectonics, etc. adjusted they can easily modified themselves. Migration of the river channel determined by several aspects such as properties of soil, river bank geometry (e.g. channel width, meander wavelength, meander length, amplitude, sinuosity, radius of channel bend etc), discharge frequency [6,7,8,9], river bank resistivities, riverine vegetation cover, [10], etc. [11]. Various human activities or natural instabilities can stimulate the rate of river channel migration. For example, the elimination of vegetation cover in flood plain can assists to accelerate the rate of migration [12]. A lot of rivers all over the world such as Ganga, India [13,14,15,16], Kosi, India [15,17], Gandok river, India [15,18], Meghna river, Bangladesh [15,19] and so many other rivers deeply imprinted evidences for spatio-temporal channel shifting [15]. Lateral shifting of sinuous alluvial river channel sometimes responsible for arising conflicts between bank erosion and human activities near river banks [20]. Lateral shifting of a river usually occurs within a corridor [21], so, it sometimes generates problems to those who live in the corridor. Due to the river channel migration every year many people forced to leave their homes, crop land etc. [22-25]. In the river Kalindri channel shifting rate is 3.89 metre/year and many people displaced due to shifting [4].So, identification of river channel migration zone is a vital and very important job as channel migration zone able to provide a general idea to the people about the shifting tendency of the river. In general channel migration zone (CMZ) is the corridor or belt where the active river channel is prone to shift over time. Several scientific studies related to delineation of channel migration zone have been carried out by different eminent scholars and scientists over different river basins such as Yang et al. [26] carried out their study on channel migration of the river Yellow in China, Mukherjee and Pal [9] delineated channel migration corridor of river Ganga alongside Malda district. Rot and Pam [27] had identified the Channel migration Zone of Dungeness River in Wasington. The present work wishes to delineate channel migration zone for last 90 years as general and post Farakka state in particular. This work also wants to investigate is the discharge change invited squeezing the channel migration corridor? Village wise channel appearance frequency is also to be investigated for focusing the vulnerable villages. Predicted migration corridors are also identified for understanding future channel migration vulnerabilities.

1.1 Study Area

One of the renowned river of Malda district in West Bengal is the Kalindri an offshoot channel of River Phulhar which is bifurcated from Phulher at Nazirpur, Manikchak (87°53'48" East and 25°08'13" North) through process of avulsion. It is flowing mainly southeast and joins Mahananda river at Nimasari Ghat (88°8'07" East long. and 25°02'42" North lat.) opposite of the town of Old Malda after flowing 55.35 kilometres distance. According to GSI report 2008 there are several fault line within the region and the river Kalindri situated within a triangle formed by several fault line which is a vital reason behind the river avulsion and migration. Kalindri mainly is flowing over the 4 CD blocks (Ratua-I, Ratua-II, Manikchak and English Bazar) of Malda district [28]. Kalindri river and associated old channels of the river has been selected for the study. Over the time period the river Kalindri showing a long history of evolution and channel change. A reference is found in the Ramacharita by Sandhyakara Nandi of the River Kalindri in which it has been stated that Madanapala defeated his enemy on the bank of the Kalindri river [29]. Carter [30] in his settlement report has described the course of river Kalindri in the District of Malda as it is existed in 1935: "The Kalindri has always been connected with the Ganges by navigable Channel, down which the flood water of Ganges passes". Due to lateral shifting of the river 4 numbers of sizable ox bow lakes have been formed which are proves as resource pool to the people living surrounding region of those lakes. The river is still showing sinuous character as indicated by high sinuosity value which is 2.25 in the present year. But according to perception of people rate of shifting is quite slowed down after construction of Farakka Barrage. Average discharge during monsoon season of the river Kalindri varies from 12 to 42 m^3. During pre monsoon season it varies

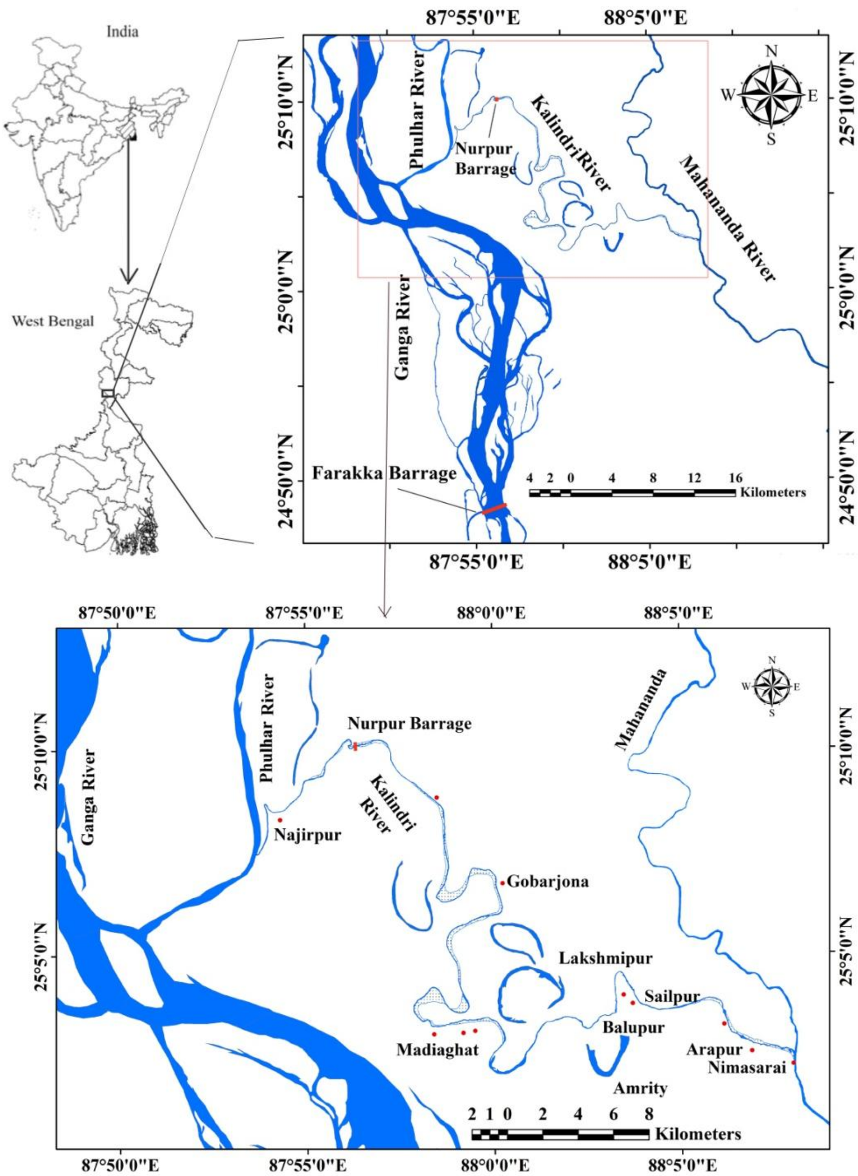

Fig. 1. Location map

from 1.58 to 5 m^3 [28]. Both the bank of the river is made by alternative deposition of sand silt and clay [31].

2. MATERIALS AND METHODS

2.1 Materials

Toposheets of Survey of India (78 C/4 ,1972 and 72 0/16 1974), Renells' Drainage map (1781), U.S Army maps (1955, 1982), Landsat 5 images (2005), Google image (2015), Cadastral map of Revenue survey, Govt. of West Bengal (1951) have been used to prepare the drainage maps of different periods. The specific details of primary data, and maps used in this study listed in Table 1.

2.2 Methods

2.2.1 Methodology for delineating river channel migration zone (CMZ)

The methodology related to delineation of Channel Migration Zone (CMZ) has been well documented in the work of Rapp and Abbe [32] and as well as Wasington Department of Natural resources [33]. Thatcher and Swindell [34] &

Montana State Library [35] also put forwarded a clear cut idea about CMZ demarcation. The CMZ is the summation of numerous diverse components of the river scenery, some which may not be relevant and apply in every CMZ study. In the context of Kalindri river the CMZ has been demarcated by overlapping the Historical Migration Zone and Erosion Buffer and Avulsion Potential Zone (APZ).

Channel Migration Zone (CMZ) = Historic Migration Zone (HMZ) + Erosion Buffer (EB)- Disconnected Migration Area (DMA)

2.2.2 Methodology for delineating of historical channel migration zone (HCMZ)

The methodologies that have been followed to identify the CMZ are based on the study of Thatcher and Swindell [34] and Rapp and Abbe [32]. For the identification of HCMZ of River Kalindri, the polygon layers of the bankful river courses for the years 1924,1955, 1973,1977 1982, 2010 and 2015 are taken into consideration . All the hard copies of maps scanned and converted into digital format. The secondary maps were registered with the UTM projection (India) and digitized all the river for different period. GCP has been also collected using GPS for geo-referencing. Previous maps were registered based on the past hard copies which already possessed coordinates collected from recognized sources. After vectorization all the selected maps overlapped in a single frame to produce to HCMZ.

2.2.3 Methodology for identification of Erosion buffer (EB) and avulsion potential zone (APZ)

One of the integral parts of the present research work is demarcation of Erosion buffer (EB). For that first foremost 27 cross sections over the Kalindri river have been drawn. Migration rate has been calculated along the section line from 1924 to 2015.Following the methodology of Dalby, [36], FEMA [37] and Washington DNR [33] the migration rate is also interpolated for next 100 years. Through the help of migration rate erosion buffer has drawn. The Avulsion Hazard Zones (APZ) are envisaged the locations of rapid channel modification by capture of a relict channel or low topography within the floodplain. The Avulsion Potential Zone has been prepared based on digitized channel courses that are marked beyond the boundaries of the CMZ.

2.2.4 Disconnected migration area (DMA)

Disconnected Migration Area (DMA) is the the portion of the CMZ where man-made structures physically eliminate channel migration. In the present study there does not exist any man made structure which helps to restrict the channel migration.

3. RESULTS AND DISCUSSION

3.1 Historical Channel Migration Zone (HCMZ)

Fig. 2 shows the Historic Channel Migration Zone (HCMZ) of Kalindri river for 1924 to 2015 and

Table 1. Data types and their sources

Data type	Source
Drainage Map of J.Rennel (1767)	Rennell, J. (1781)
Drainage Map of 1855 based on revenue survey map	Revenue Survey Map(1855)
Drainage Map,1924	Survey of India Toposheet
Drainage Map,1955	U.S.Army
Drainage Map,1961	U.S Army map(sheet no NG 45-11)
Drainage Map,1977	Landsat image, Path/Row-139,43,1977
Drainage Map,1973	Landsat image MSS, Path/Row-139,43,1973
Drainage Map Map-1982	U.S Army
Drainage Map, 2005	Landsat image, Path/Row-139,43,2005
Drainage Map,2010	Google Earth Image,2010
Drainage Map,2015	Landsat image , Path/Row-139,43,2005
Mouza map,2001	Landuse Map-2001 Land and Land reform Department, Govt. of India

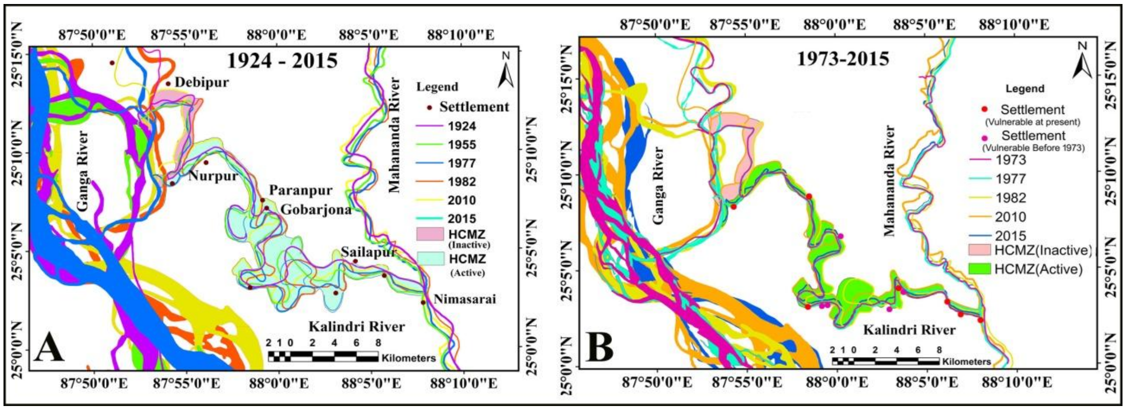

Fig. 2 Historical channel migration zone (HCMZ) – (A) HCMZ since 1924-2015 and (B) HCMZ during period of 1973 - 2015

1973 to 2015 respectively. There are two well-defined HCMZs (active and inactive) based on the existence of flow at present. Inactive Channel Migration Zone is the upper part of Kalindri river from Debipur to Najirpur. This section was active before1973 but does not carry any water at present. HCMZ area during 1924 to 2015 has recorded 111.18 Km^2. During period 1973 to 2015 area under HCMZ was 33.34 Km^2 which was relatively large during 1924 to1973 (see Table 2). Width of the HCMZ is also declined 1.63km in post farakka barrage period which was 1.74km during pre farakka barrage period. Disconnection of some oxbows from main river is one of the major reasons for this in direct view.

3.2 Erosion Buffer for Predicting Future Channel Corridor

To get an idea about the future course of the river Kalindri erosion buffer has been drawn. First of all the migration rates throughout the cross various sections for the entire segment of the Kalindri River from 1924 to 2015 has been calculated. After that the Erosion buffer for the period of 1973 to 2015 has been also calculated. The area under Erosion buffer was 62.24 km^2 during period of 1924-1973. But area under Erosion Buffer during 1973 to 2015 is 44.82 km^2 which indicates 27.98% area decreased within last 42 years. During 1924 to 1973 the average width of the Erosion buffer was 1.77 km but after 1973 it is reduced to 1.51km.

3.3 Avulsion Potential Zone (APZ)

Diversion of flow from an existing river course onto the floodplain, eventually resulting in a new course can be defined as channel avulsion [38, 39]. Kalindri river is basically a product of avulsion process of river Phulhar [28]. The potentiality of avulsion is generally becoming very high at river curvature and at the condition of low lying land. The APZ mapping has been prepared with the help of channel bends which are highly prone to cutoff beyond the CMZ. Avulsion sites are also identified through the primary field survey. Total area covered by the Avulsion potential Zone is 14.39 km^2. Fig. 4 represents the APZ of the region. In the present river, there are several bend in the channel which is very much prone to cut-off (see Fig. 4).

3.4 Channel Migration Zone (CMZ)

During 1924-2015 the area under Migration was 218.24 km^2. After 1973 CMZ area has reduced into 78.16 km^2 which was 140.08 km^2 during 1924 to 1973 (see Table 2).Therefore it is clear that the CMZ area decreased over the post farakka barrage period. Before construction of Farakka barrage the width of the migration corridor was 3.37 km but at present the wandering rate is reduced and width of the migration corridor is 1.63 km.

3.5 Affected Villages due to Channel Migration of Kalindri (Since 1924-2016)

Channel Migration Zone of the Kalindri River has been draped over the mouzas concerned in the study area (see Fig. 6). During 1924 to 2015, 26 number of mouzas of English Bazar, 29 mouzas of Ratua-I, 16 mouzas of Ratua-II and 24 mouzas of Manikchak CD block have been affected by lateral shifting of channel of Kalindri

River. All the mouzas affected by channel migration categorized into four zones based on their frequency of appearance. Atagama (JL.No.17), Nagharia(JL.No.25), Lakshmighat (JL.No.26), Jot Basanta (JL.No.47), Narahata (JL.No.26), Jotgopal(JL.No.49) and Uttar Gobindapur (JL.No.51) are some mouzas in English Bazar which are frequently affected by lateral migration of Kalindri River for several times during 1924 to 2015. After, 1973 the numbers of villages are covered by Channel migration zone of high inundation frequency has been reduced. During period 1924 to 1973, 38 villages are affected almost every single time of the sample years by the river channel but it is reduced in to 20 in post Farakka period.

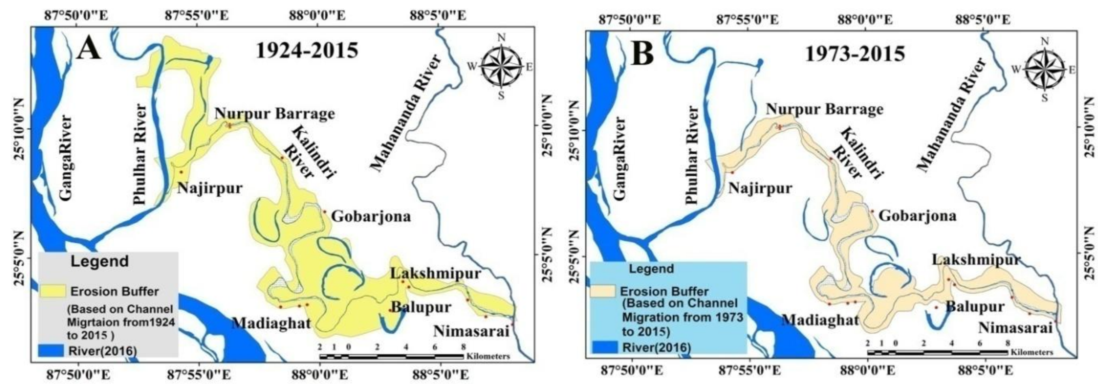

Fig. 3. (A) Erosion buffer area of the part of the Kalindri River - as per the total migration in between 1924 – 2015, (B) Erosion Buffer Area of the part of the Kalindri River - as per the total migration in between 1973 – 2015

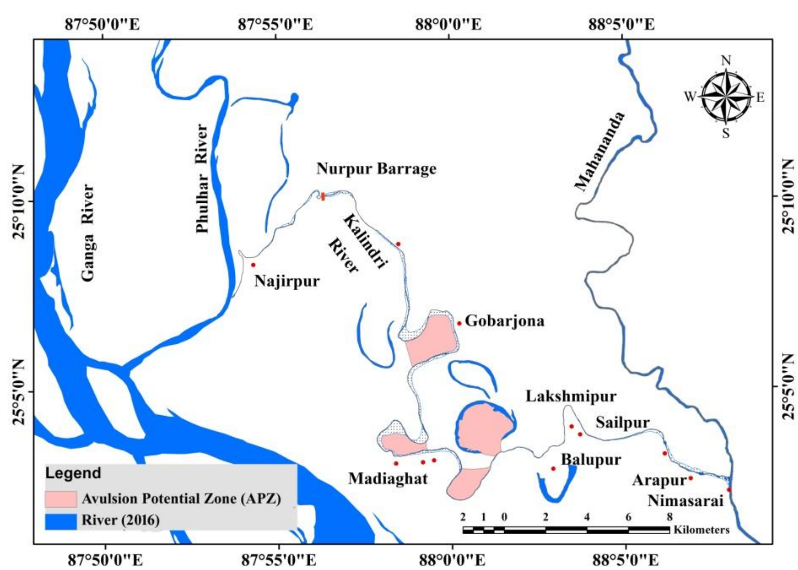

Fig. 4. Avulsion potential zone (APZ)

Table 2. Area under EB and CMZ

Year	EB(Area in Km^2)	HCMZ (Area in Km^2)	CMZ(Area in Km^2)	CMZ (Width in Km)
1924-2015	107.06	111.18	218.24	3.37 Km
1924 -1973	62.24	77.84	140.08	1.74 Km
1973 -2015	44.82	33.34	78.16	1.63 Km

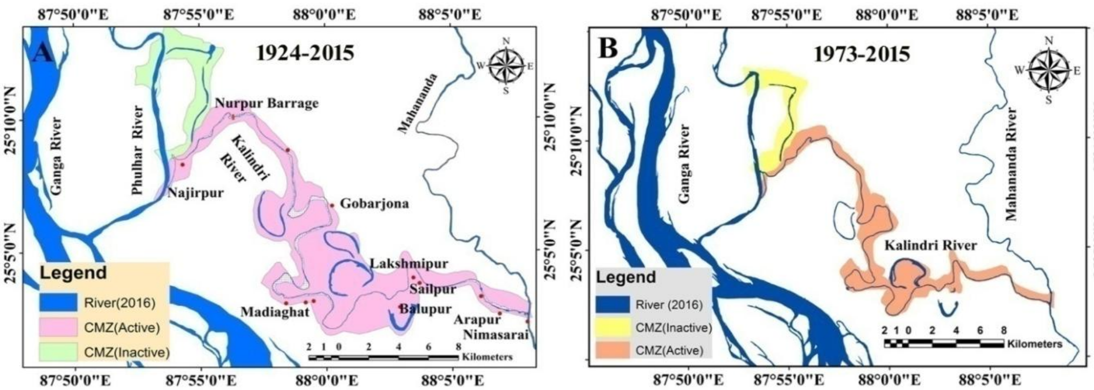

Fig. 5 (A) Channel Migration Zone 1924-15, (B) Channel Migration Zone 1973-2015

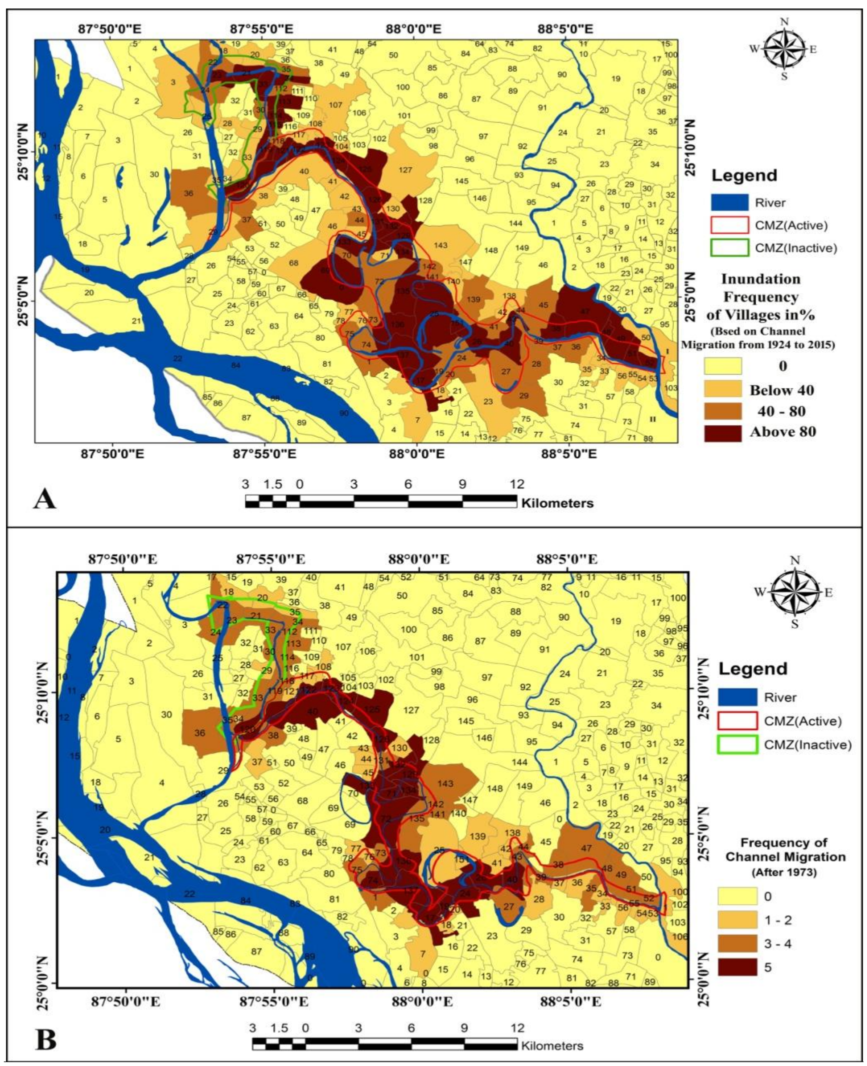

Fig. 6. Frequency of villages susceptible to channel migration of Kalindri river – (A) since 1924-2015 and (B) since 1973-2015 (values within the village boundary indicate Jurisdiction List Number or JL No.)

3.6 Discussion

Result clearly states that in post Farakka barrage period, areal extent and lateral spread of CMZ is declined. At present water flows within the previously scoured wide valley of Kalindri. Some of the possible reasons behind such incidents are (1) attenuation of discharge, (2) loss of one of the connection with Fulahor river,(3) growing sediment loads etc. Average discharge in monsoon in Pre Farakka period was 54.42 to 60 cumec but now it is 12 to 42 cumec [28]. In pre-monsoon season, almost 233.33% discharge is declined in recent period after Farakka barrage. In monsoon, this rate is 78.87% [28]. Wide course of the left oxbow lakes also proves that discharge was far greater in river Kalindri than present. Average width of the oxbow lakes is 335m but width of the present active channel is 39m at Najirpur while emanating from river Fulohar and 210 m at Nimasaraighat while meeting with river Mahananda. Attenuating discharge has slowing down the rate of channel migration. Construction of Nurpur barrage over Kalindri river under Farakka barrage project regulates water to the Kalindri. Moreover, closing one connection with river Phulhar also curtailed discharge to the river. Cumulative deposition of sediment within channel and aggradations is also responsible for loosing energy for channel shift. Suspended sediment load measured at the source and confluence points of the river states that entrainment of only suspended sediment is 127.29 $x10^{14}$ kg/year greater than release to the river Mahananda. So such amount of suspended load is settled down along with other types of loads and eroded materials from surrounding region every year triggering aggradations. Changing state of river scenario is collectively responsible for squeezing the channel migration corridor.

4. CONCLUSION

This work articulated the changing extent of channel migration corridor after Farakka barrage project considering the time periods since 1924 to 2015. Analysis clearly revealed that channel migration corridor is reduced from 218.24 km^2 to 140.08 km^2 in post Farakka barrage period. Discharge attenuation is considered as major reason behind quite stabilizing channel and squeezing migration corridor. Such incidents apparently will encourage people to enter into the historical migration corridor for safe living and harnessing resources. A good number of existing villages have got rid of from channel migration vulnerabilities. Along with these benefits, some upcoming burden people have to bear. For example, incident of regular flood plain renewal may be affected and it may reduce fertility of the soil. Wetland resources may also be affected due to this emerged situation.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Leopold LB, Wolman MG, Miller JP. Fluvial processes in geomorphology. Dover publications, New York; 1964.
2. Yang CT. On river meanders. Journal of Hydrology. 1971;13:231-253.
3. Thorne CR. Geomorphic analysis of large alluvial rivers. Geomorphology. 2002; 44:203-219.
4. Das S, Pal S. Character and Cardinality of Channel Migration of Kalindri River, West, Bengal, India. International Research Journal of Earth Sciences. 2016;4(1):13-26.
5. Giardino JR, Lee AA. Rates of channel migration on the Brazos River. Final report submitted to the Texas water development board, Texas A & M University. 2011;8-9.
6. Brice JC. Stream channel stability assessment. Report FHWA/RD-82/021. US Department of Transportation Federal Highway Administration, Washington, DC.1982;42.
7. MacDonald TE, Parker G, Leuthe DP. Inventory and analysis of stream meander problems in Minnesota. St Anthony Falls Laboratory. University of Minnesota, Minneapolis, MN, USA.1991;37.
8. Garcia MH, Bittner L, Nino Y. Mathematical modeling of meandering streams in Illinois: A tool for stream 64 F.D. Shields, Jr, A. Simon and L.J. Steffen management and engineering. Unpublished report, University of Illinois, Urbana, IL, Us. 1994; 49.
9. Mukherjee K. Pal S. Channel migration zone mapping of the River Ganga in The Diara Surrounding Region of Eastern India. Environment Development and Sustainability, 2017;1–23. DOI:10.1007/s10668-017-9984-y.
10. Motta D, Abad JD. Langendon EJ. Gracia MH. A simplified 2D model for meander migration with physically-based bank

evolution. Geomorphology. 2012;10:163-164.

11. Hickin EJ, Nanson GC. Lateral migration rates of rivers bends. Journal of Hydraulic Engineering. 1984;110:1557-67.
12. Randle TJ. Channel migration model ror Meandering River. University of Colorado, Denver; 2004.
13. Singh IB. Geological evolution of ganga plain-an overview. Journal Palaeontological Soc India. 1996;41:99-137.
14. Srivastava A, Singh RP. Surface manifestation over a subsurface ridge. International Journal of remote Sensing. 1999;20:3461-3466.
15. Pati JK, Lal J, Prakash K, Bhusan R. Spatio-temporal shift of western bank of the Ganga River, Allahabad City and its Implications. J Indian Soc. Remote Sensing. 2008;36:289-297.
16. Roy NG, Sinha R. Alluvial geomorphology and confluence dynamics in the Gangetic plains, Farrukhabad and Kannauj area,Uttar Pradesh, India. Current Science. 2005;88:2000-2006.
17. Wells NA. Dorr JA. Shifting of Koshi River, Northern India. Geology. 1987;15:204-207.
18. Mohindra R, Prakash B, Prasad J. Historical geomorphology and pedology of the Gandak megafan, Middle gangetic plains, India. Earth surface processes and Landforms. 1992;17:643-662.
19. Rahman MM, Hussain MA, Islam GMT, Haque MA. Hoque MM. Hydro - geomorphic characteristics around the Meghna bridge site in the Meghna river. Japan Bangladesh joint study Project on Floods, Phase II, Final report; 2004.
20. Larsen EW, Greco SE. Modeling channel management impacts on river migration: A case study of Woodson Bridge State Recreation Area, Sacramento River, California, USA. Environmental Management. Springer. 2002;30(2):209.
21. Richard AG, Julien PY, Baired DC. Statistical analysis of lateral migration of the Rio Grande, New Mexico. Geomorphology. 2005;71:139–155.
22. Islam MDF, Rashid ANMB. Riverbank erosion displaces in Bangladesh: Need for institutional response and policy intervention, Bangladesh. Journal of Bioethics. 2011;2(2):4–19.
23. Mann Z. River bank erosion forces hundreds of families to relocate, Irrawaddy; 2013.
Available: http://www.irrawaddy.org/refugees/first-japanese-newspaper-becomes-available-inrangoon.Html. [Accessed on 06 June 2015].
24. Mukherjee P, CRY of help for erosion victims. Business Standard; 2008.
Available: http://www.business-standard.Com/article/economy-policy /cry-of-help-for-erosionvictims-108021901020_1.html
[Accessed on 26 June 2015].
25. Rudra K. The Encroaching Ganga and Social Conflicts: The Case of West Bengal, India. Independent Broadcasting Associates, Littleton. 2005;4.
Available:http://www.ibaradio.org/India/ganga/extra/resource/Rudra.pdf
[Accessed on 04 June 2015].
26. Yang X, Damen MCJ, Van Zuidam RA. Use of Thematic Mapper imagery with a geographic information system for geomorphologic mapping in a large deltaic lowland environment. International Journal of Remote Sensing.1999;20:659– 6.
27. Rot B, Pam E. Delineation of the Dungeness River channel migration zone, river mouth to creek, James S'Klallam Tribe. 2008:1-20.
28. Das S. Changing hydro-geomorphological characterstics of Kalindri River, Malda District and their impacts on riparian livelihood: A geographical overview. Submitted in University of Gour Banga, Malda. 2017;1-185.
29. Sengupta JC. West Bengal District Gazetteers, Malda, Swaraswati Preess Ltd. Calcutta; 1969:5-6.
30. Carter MO. Field report on the Survey and Settlement operations in the District of Malda, Calcutta. 1939;1928-35.
31. Das S. Identification of erosion susceptible river bank sites of Kalindri River, Malda District, West Bengal. International Journal of Geology. Earth & Environmental Sciences. 2016;6(1):78-89.
32. Rapp CF, Abbe TB. A framework for delineating channel migration zones. Washington State department of ecology and Washington Department of Transportation, Final report; 2003.
33. Washington department of natural resources forest board manual. Section 2: Standard Methods for Identifying Bankfull Channel Features and Channel Migration Zones; 2004.
34. Thatcher T, Swindell B. Yellowstone river channel migration zone mapping. Final

report, DTM Consulting, Karin Boyd, Applied geomorphology, Inc.211 N Grand Ave, Suite C, Bozeman, MT59715. 2009; 406-587-6352:1-38.

35. Montana State Library. Channel Migration Zones. Geographic Information Clearing House; 2016. Available:http://geoinfo.msl.mt.gov/Home/data/montana_channel_migration_zones (Accessed on 19 September 2016)
36. Dalby C. Comparison of channel migration zones in plane-bed, pool-riffle and anabranching channels of the upper Yellowstone River: Poster Session delivered at the Montana Section AWRA annual meeting; 2006.
37. FEMA River Erosion Hazard Areas—Mapping Feasibility Study: Federal Emergency Management Agency. Technical Services Division, Hazards Study Branch; 1999.
38. Makaske B. Anastomosing rivers: A review of their classification,origin and sedimentary products. Earth-Science Reviews. 2001;53:149–196.
39. Makaske B, Maathuis BHP, Padovani CR, Stolker C, Mosselman E, Jongman RHG. Upstream and downstream controls of recent avulsions on the Taquari megafan, Pantanal,south-western Brazil. Earth Surf. Process. Landforms. 2012;37:1313–1326.

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