

Erosion induced channel migration and its impact on dwellers in the lower Gumti River, Tripura, India

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Abstract River channel migration due to erosion has emerged as a serious environmental issue. The present study is an attempt to assess the pattern of channel migration in lower reach of the Gumti River and its impact on local inhabitants. For this study Survey of India topographical sheets and Landsat 8 imagery were used to derive the vector layers of the river channel of 1932 and 2016 respectively. Different sections were drawn over the superimposed vector layers of these 2 years to measure the extent of migration. Survey was carried out on the local people to assess the vulnerability of river channel migration. The whole study reveals that large scale migration of the Gumti River has taken place during the period 1932–2016 with maximum extent of 533.42 m in Kushamara Village owing mainly to the sandy and sandy loam nature of bank soil. Channel migration has created detrimental socio-economic problems as victims were bound to shift their houses partially (73.53%) and permanently (26.17%). Moreover, Gumti channel migration has led to loss of productive agricultural lands when around 27.78% of the surveyed victims have already lost their double cropped lands amounting to more than four acres each.

Keywords Gumti River · Bank erosion · Channel shifting · Soil loss · Socio-economic condition

1 Introduction

Bank erosion is a natural and dynamic process of river. Its erosional work is controlled by a number of factors like channel gradient, water discharge, flow velocity, nature of bank material, amount of sediment load etc. Moreover, presence or absence of vegetal cover largely controls the stability of river bank soil. Erosion is considered to be the most active agent behind the lateral expansion of river channel. Besides, the amount of sediment supply to the river is largely governed by the erosional work of the river. These sediments, in turn get deposited on the river bed and results in the formation of channel bars which gradually increase with the passage of time. Consequently, channel becomes constricted and accelerates the process of bank erosion. Thus, due to the collective and constant processes of degradation and aggradation river channel becomes unstable which leads to channel migration [1, 2]. Moreover, existence of meandering channel results in the generation of helical flow due to the formation of pool and refill formation along the outer and inner part of the meander bend respectively. Such helical secondary current leads to increase flow velocity and channel depth along the outer bank which encourage bank erosion [3]. Consequently channel gets migrated along the outer bank of the river [4]. Frequent migration of channel generates adverse interference to human being, especially to the inhabitants of the river bank, as they have to reallocate their houses with changing position of the bank. Moreover, lateral migration of river bank results in the failure of huge fertile land every year [5]. Thus proper monitoring and

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assessment of bank line shifting is required to reduce its vulnerability. Remote sensing and GIS techniques are considered to be greatly effective in this regard [6–14] due to its cost efficiency and better accuracy. Gumti is the largest river of Tripura whose lower course is characterised by frequent migration due to the combined effect of erosion and sedimentation. Thus, the present study aims to analyze the pattern of migration of the lower Gumti River and to assess the impact of this migration on the local people.

2 Study area

The River Gumti is formed of the confluence of two streams namely, Raima and Sarma which originated from the Longtarai and Atharamura hill ranges respectively. For the present study a 48 km stretch of the Gumti River in its lower course (within Tripura State), from Udaipur town up to Srimantapur (near Bangladesh border) has been selected (Fig. 1, Table 1) where the river maintains an average width of about 70 m. Geomorphologically the study area is characterised by floodplain with some caps of tillas (residual hillocks) and adjacent lungas (narrow elongated valleys).

The study area falls under Alluvium and Tipam group of geological formations and is still under the process towards attaining maturity. The whole area is influenced by tropical monsoon climate. Peak discharge of the Gumti River is normally observed during the months of July to September due to the influence of monsoonal rainfall which increases the probability of channel migration during this period. The surrounding areas of the lower Gumti River is considered to be one of the densely populated (> 750 persons/km²) regions of Tripura and thus becoming more vulnerable to channel migration.

3 Methodology

The present study has been carried out on the basis of geospatial technology and intensive field work. A 48 km stretch of the Gumti River in its lower course has been selected for this study and the whole stretch has been segregated into 4 reaches for detailed study. Survey of India topographical sheet and Landsat 8 imagery have been used to generate the vector layers of the river channel of 1932 and 2016 respectively. The data sets were imported in ARCGIS 10.1 software, processed and geo-referenced using the following steps: Projection Type: UTM, Datum name: WGS 84, UTM zone: 46, UTM row: Q. The active part of the channel (part of the channel in contact with water) has been considered to generate the vector layers of 1932 and 2016 through digitization. The generated vector

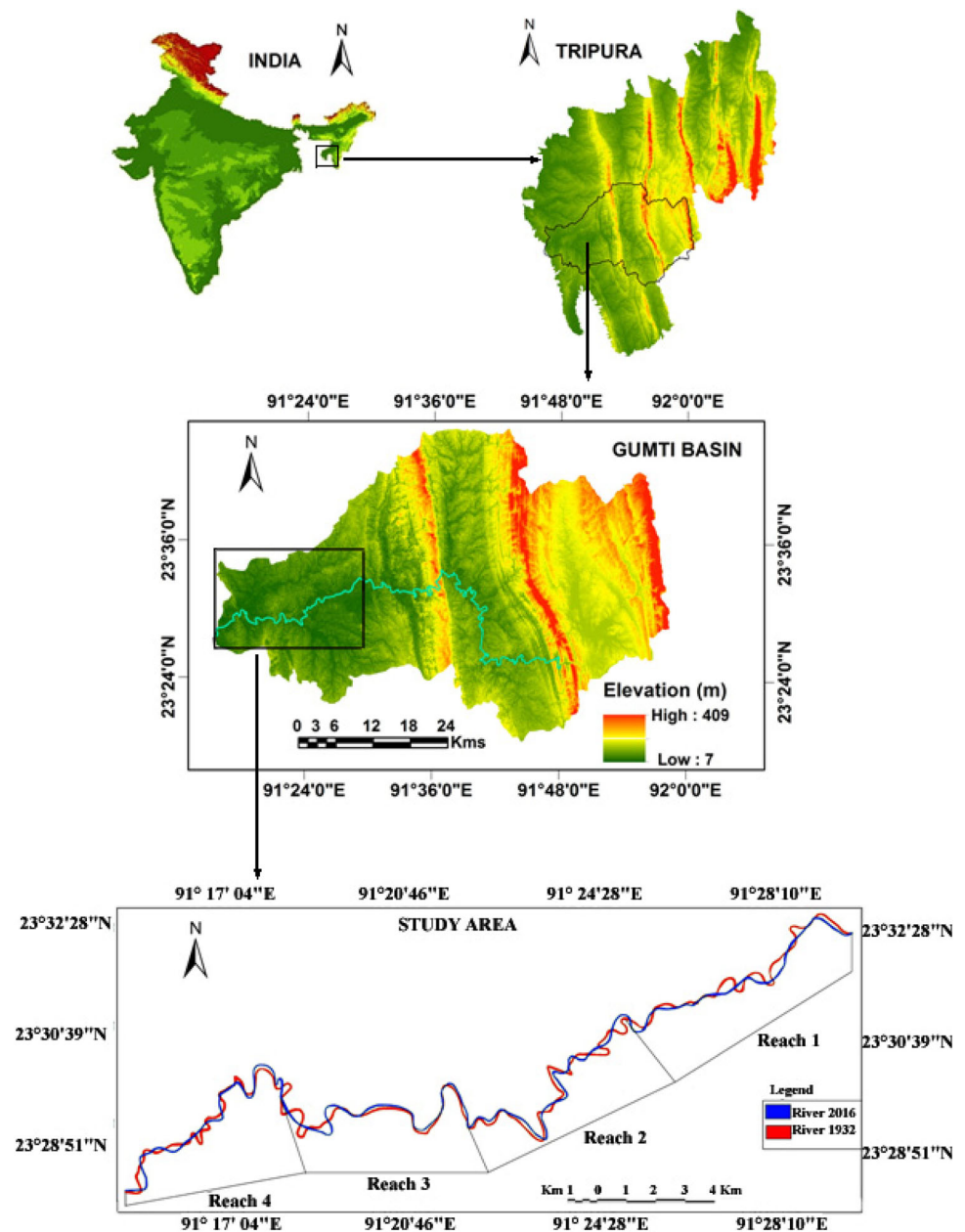
layers were then overlaid under GIS environment. Total 22 sections have been drawn on the superimposed layer of the channel to measure the extent of channel migration. For convenience of the study alphabets were assigned to each section for documentation of the generated data. Areas covered by the polygons of 1932 and 2016 have been considered as areas under erosion and deposition respectively (excluding the unchanged area) while area lies in between them has been considered as historical migrated area. Bank soils were collected from different erosion prone sites of the river and Hydrometer test was carried out to identify their nature and composition. As it is very difficult to take cross-sections at all the erosion prone sites of the Gumti River due to high depth and velocity, even in pre-monsoon period, therefore, six sites have been selected to take cross-sections and to measure flow velocity. Cross-sections across the river at all the sites have been taken in the month of March for three consecutive years (2014–2016). The position of the bank and stretch of erosion was recorded by GPS to detect changes and to quantify soil loss. Clinometer was used to measure river bank angle. All the cross-sections were then overlaid and plotted in graph. The area lies in between two consecutive profiles of bank has been measured from graph according to scale and the obtained area has been multiplied with the length of eroded bank stretch to estimate the volume of soil loss from the river bank. Flow velocity at different depths along the cross-sections has been measured to draw the isovel lines. In order to assess the vulnerability of channel migration questionnaire based schedule survey was carried out on the local people. For that purpose, the households located within 500 m distance from the erosion prone stretches of the Gumti River have been targeted as the occupants residing immediate along the river bank are practically experiencing this hazard of channel migration. Out of every two households, one has been surveyed to keep the sample size around 50%. Pearson's correlation matrix was used to show relationships between different aspects associated with the problem of channel migration. The matrix was prepared exclusively on the basis of primary data obtained from the field survey. Finally, the derived information and generated data were cartographically represented and analyzed to prepare the present paper.

4 Results

4.1 Channel migration

Lateral erosion is one of the major reasons behind channel migration. It is generally observed in the lower course of the rivers due to diminishing channel gradient and

Fig. 1 Location of the study area



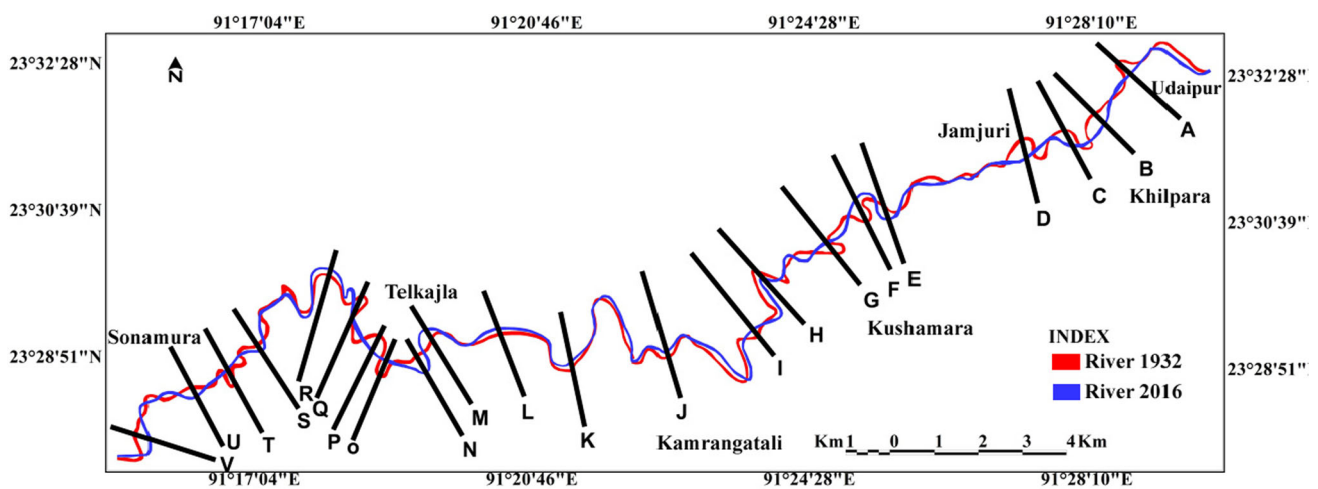
consequent reduction in flow velocity. Thus, side cutting remains higher than down cutting which initiates channel migration. In the present study, 22 sections have been drawn across the superimposed vector layers of the Gumti River of 1932 and 2016 (Fig. 2); the extent of migration was computed as 137.48–533.42 m (Table 2) which was maximum at section F of the Kushamara village with highest degree of soil loss (3643 MT) indicating thereby age long history of sufferings of the local people from channel migration.

4.2 Area captured by the Gumti River during 1932–2016 periods

River bank erosion is governed by a group of physical factors among which bank soil type and rate of water discharge play the principal controlling role [15]. River always tries to maintain an equilibrium state. Thus, if erosion takes place along the inner bank of the river it is compensated by deposition along the outer bank. The complex interaction of erosion and deposition proceeds over the passage of time which leads to channel migration, the extent of which depends on magnitude of that interaction. Based on the superimposed vector layers of the

Table 1 Geographical extent and morphological appearance of four study reaches

Reach	Coordinate	Place name	Value of sinuosity Index		Morphological appearance	
			1932	2016	1932	2016
Reach 1	Starting point-91°29'36"E and 23°32'29"N, end point-91°25'13"E and 23°30'51"N	Udaipur to Kakraban	1.53	1.25	Meander	Sinuuous
Reach 2	Starting point-91°25'13"E and 23°30'51"N, end point-91°22'05"E and 23°28'53"N	Kakraban to Chandul	1.78	1.54	Meander	Meander
Reach 3	Starting point-91°22'05"E and 23°28'53"N, ending point-91°18'21"E and 23°29'22"N	Chandul to Ghrantali	1.7	1.66	Meander	Meander
Reach 4	Starting point-91°18'21"E and 23°29'22"N, ending point-91°15'23"E and 23°27'38"N	Ghrantali to Srimantapur	1.85	1.64	Meander	Meander

**Fig. 2** Location of different sections across the superimposed vector layers of 1932 and 2016 to measure the extent of channel migration

years 1932 and 2016, all reaches of lower course of the Gumti River have been grouped into four areal classes i.e. area under erosion, area under deposition, area under historical migration and area remained unchanged (Fig. 3). During this period of study, the area under erosion (143.24 acres) and deposition (146.34 acres) were found highest in Reach-2 (B) and Reach-4 (4) respectively whereas, the area under historical migration (144.85 acres) was highest in Reach-1 (A) as both the processes of degradation and aggradation prevailed evenly (Table 3). This fact reveals that the Reach-1 (A), extending from Udaipur to Kakraban had suffered from channel migration over this span of time. Most of the unchanged channel position (40.97 acres) was found in Reach-3 (C) (from Chandul to Ghrantali) as nearly half of the reach is passing through tilla-lunga formation where tillas (residual hills) have protected the river bank from shifting.

4.3 Controlling factors of channel migration

The process of bank erosion and consequent channel migration is governed by the interaction of different physical and anthropogenic factors among which the nature of bank soil and channel form are the two major factors which have governed this process in the lower Gumti River.

4.3.1 Nature of bank soil

The nature and composition of bank soil largely control the rate of bank erosion and subsequent channel migration. Several scholarly works have been done to analyze the role of bank material on the rate and magnitude of river bank erosion [16–21]. Soil texture is an important physical property of soil which indicates the degree of coarseness or fineness of soil depending on the proportion of particle size fraction i.e. sand, silt and clay [22]. It has been found that

Table 2 Direction and extent of migration of the lower Gumti River along the cross-sections during 1932–2016 periods

Sections	Direction of migration	Migration (m) (Base year 1932)
A	South-eastward	377.48
B	South-eastward	352.49
C	South-eastward	297.60
D	Southward	479.90
E	Southward	284.59
F	North-westward	533.42
G	North-westward	407.32
H	South-eastward	253.87
I	North-westward	202.17
J	North-westward	142.73
K	Northward	148.71
L	North-westward	137.48
M	North-westward	284.20
N	South-eastward	461.10
O	North-eastward	379.60
P	South-westward	389.72
Q	South-westward	364.32
R	North-eastward	145.72
S	South-eastward	188.48
T	North-westward	389.24
U	South-eastward	254.63
V	South-eastward	358.30

in the six selected erosion prone sites along the lower Gumti River, bank soil is sandy to loamy sandy in texture with percentage of sand ranges from 76.27 to 89.74% which indicates non-cohesive nature of soil (Fig. 4).

4.3.2 Channel form

River channel form determines the distribution of flow energy over the channel. Flow energy is more or less equally distributed over the channel, if the profile is symmetrical and the zone of maximum velocity is generally found in the centre. On contrary, in an asymmetrical channel, the zone of maximum velocity tends to be shifted from the centre towards the deeper side [23]. Possibility of erosion increases to that bank of the river which is closer to the asymmetrical portion of the channel i.e. along the deeper side of the channel. Similar condition has been observed along most of the selected erosion prone sites of the Gumti River where value of the highest isovel is found to range between .4 and .5 m/s during pre-monsoon season (Fig. 5). Thus, it is obvious that during monsoonal period the value of isovels increases manifold due to high water discharge. Higher velocity is found to concentrate along the

deeper part of the channel. Maximum quantity of soil loss is also found in that bank which is located closer to the deeper and asymmetrical part of the channel (Fig. 6).

4.4 Quantity of soil loss at selected erosion prone sites

The ultimate outcome of erosion is soil loss from the river bank, the amount of which depends on erodibility i.e. resistance power of soil against direct impact of flow velocity. Along with natural factors, the increasing number of inhabitants along the river bank also triggers this process. Soil that is removed from the river bank is directly added to the river water and boosted the sediment supply to the river. Moreover, every year farmers used to lose their productive agricultural lands due to bank failure and consequent channel migration. From the overlaid cross sections of three consecutive years it has been found that nearly 429–3195 metric tonnes of soil were lost from different erosion prone sites during 2014–2015 which increased to 439–3643 metric tonnes in 2015–2016 period (Fig. 6; Table 4). Maximum loss was found at Kushamara where long stretch (around 400 m) of the river bank is highly prone to erosion (Fig. 6).

4.5 Impact of channel migration on socio-economic condition of the dwellers

Frequent migration of channel appears to be hazardous for the people residing along the banks of the rivers. Growing population pressure over the river floodplains and its improper utilization has increased the vulnerability status of channel migration [24–26]. Several studies have been carried out to assess the impact of channel migration on socio-economic condition of human being [27–33]. The outcome of all the studies reveals significant impact of channel migration on day to day life of human being. The major issues that came out from the survey on local people have been discussed below.

4.5.1 Displacement of households

Channel migration has adverse impact on the people residing immediately along the bank of the River Gumti. They have to shift and rebuild their houses with the changing position of the bank line. Result of the survey reveals that 38.24 and 26.47% of the affected surveyed families had to reallocate their houses for once and twice respectively in order to cope up with channel migration (Fig. 7a). Moreover, 20.59 and 14.7% of them were displaced for three times and more than that respectively. It has also been identified that 26.47% of the affected dwellers had shifted permanently to other safer places

Fig. 3 Reach-wise representation of areas captured by the Gumti River during 1932–2016. **a** Reach 1, **b** reach 2, **c** reach 3, **d** reach 4

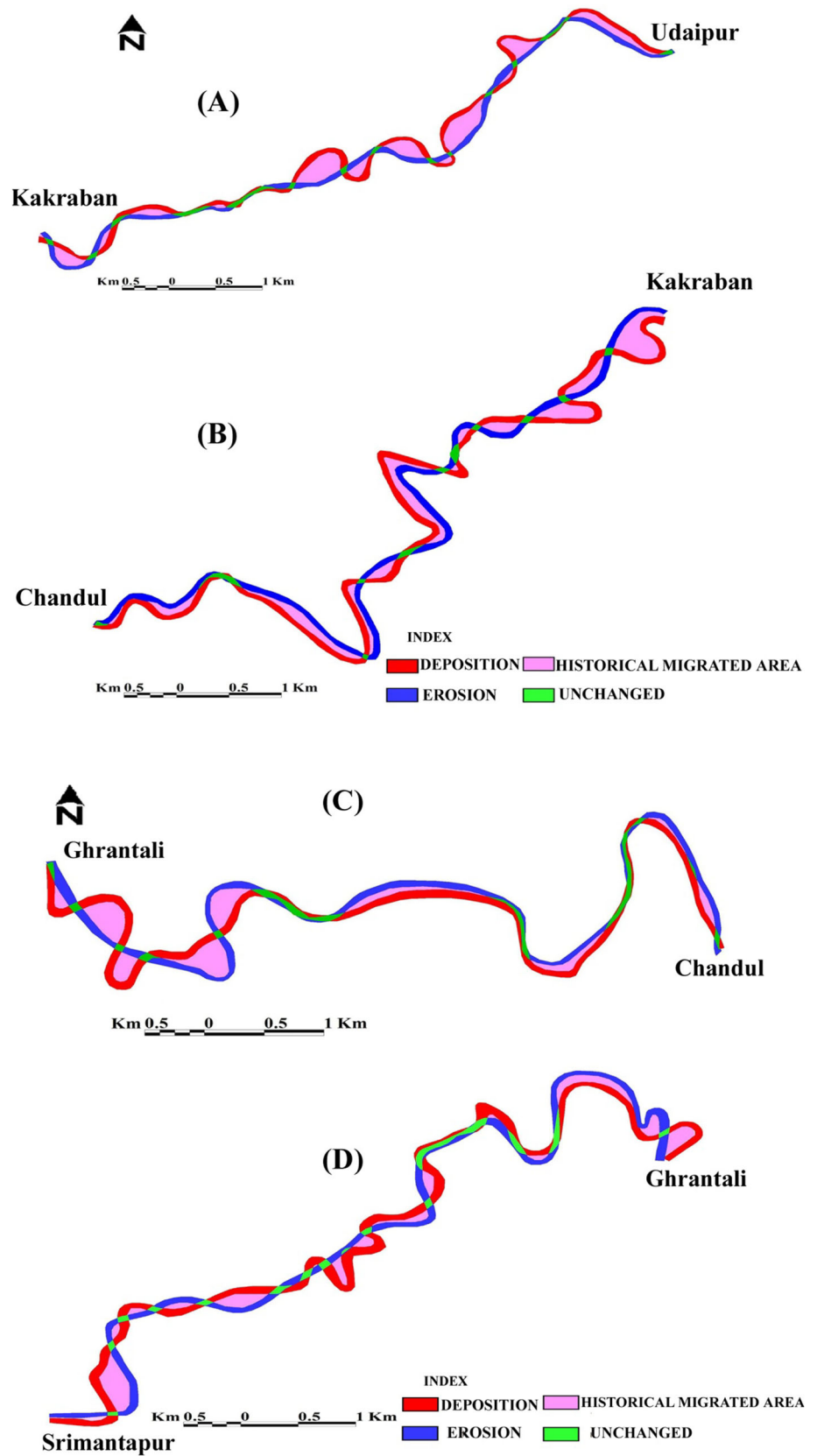
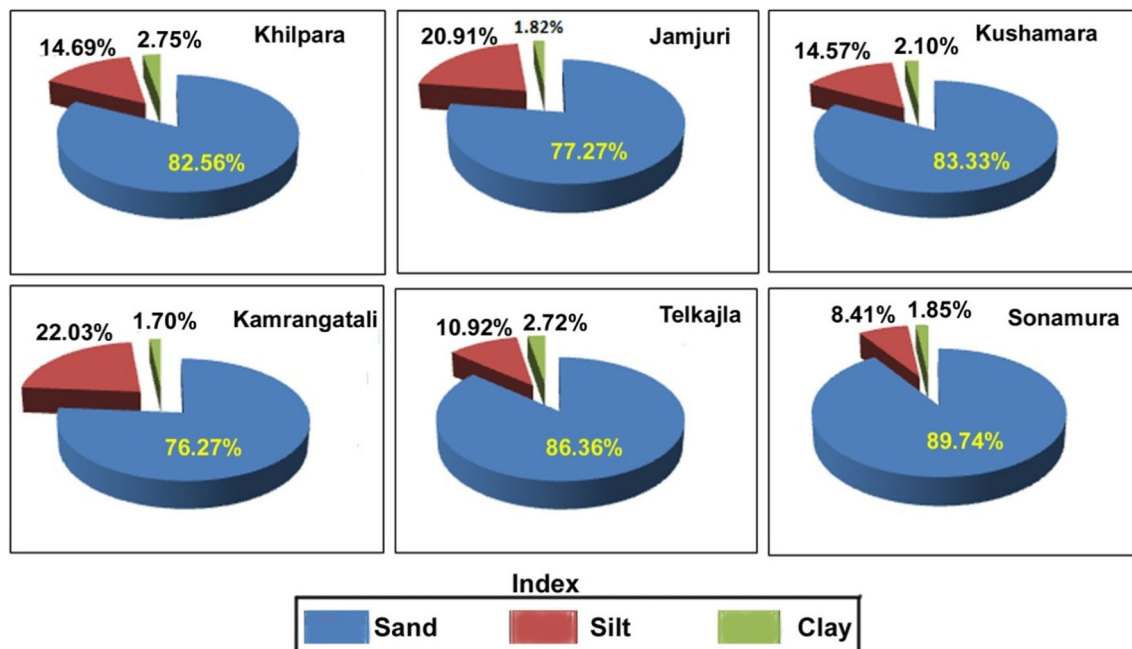


Table 3 Reach-wise variation in different areal classes during 1932–2016

Reach	Areal coverage (acre)			
	Erosion	Deposition	Unchanged	Historical migrated area
Reach 1 (A)	141.83	144.00	37.46	144.85
Reach 2 (B)	143.24	131.10	21.40	116.49
Reach 3 (C)	126.00	99.50	40.97	114.85
Reach 4 (D)	135.61	146.34	38.69	81.00

**Fig. 4** Composition of bank soil of the Gumti River at six selected erosion prone sites

located far away from the bank of the Gumti River (Fig. 7b). The remaining 73.53% had shifted partially for this problem.

4.5.2 Loss of agricultural land

Loss of productive agricultural land is a major consequence of channel migration. Major percent (38.89%) of the surveyed victims had lost below two acres of cropland while 33.33 and 27.78% of them had lost 2–4 acres and above that respectively due to erosion and consequent migration of the Gumti River in its lower course (Fig. 7c). Most of the lost agricultural lands (64.71%) were double cropped in nature (Fig. 7d) used to grow rice in summer and vegetables in winter season. Production of vegetables was a profitable venture for the affected families but loss of large amount of cropland has flung them towards economic backwardness. According to the survey, 48.57% of the victims faced an annual financial loss of Rs. 20,000–40,000 due to missing of their productive agricultural lands

through channel migration, while, 40% had to face a financial loss of above Rs.40,000 per annum due to this problem. This amount is quite large considering economic status of the surveyed households.

4.5.3 Alteration in occupation

As the main occupation of the people of the study area is agriculture, therefore, loss of productive agricultural lands has adversely affected the socio-economic condition of the distressed families. They had to find out alternative source of income which forced them to change their occupation. According to the survey, about 30.30% of the affected families had permanently altered their occupation from agricultural activities to other non-profitable activities, like daily labouring while 21.22% of them have partially changed their occupation (Fig. 7e).

Fig. 5 Channel Profile with isovel lines at six selected erosion prone sites of the Gumti River

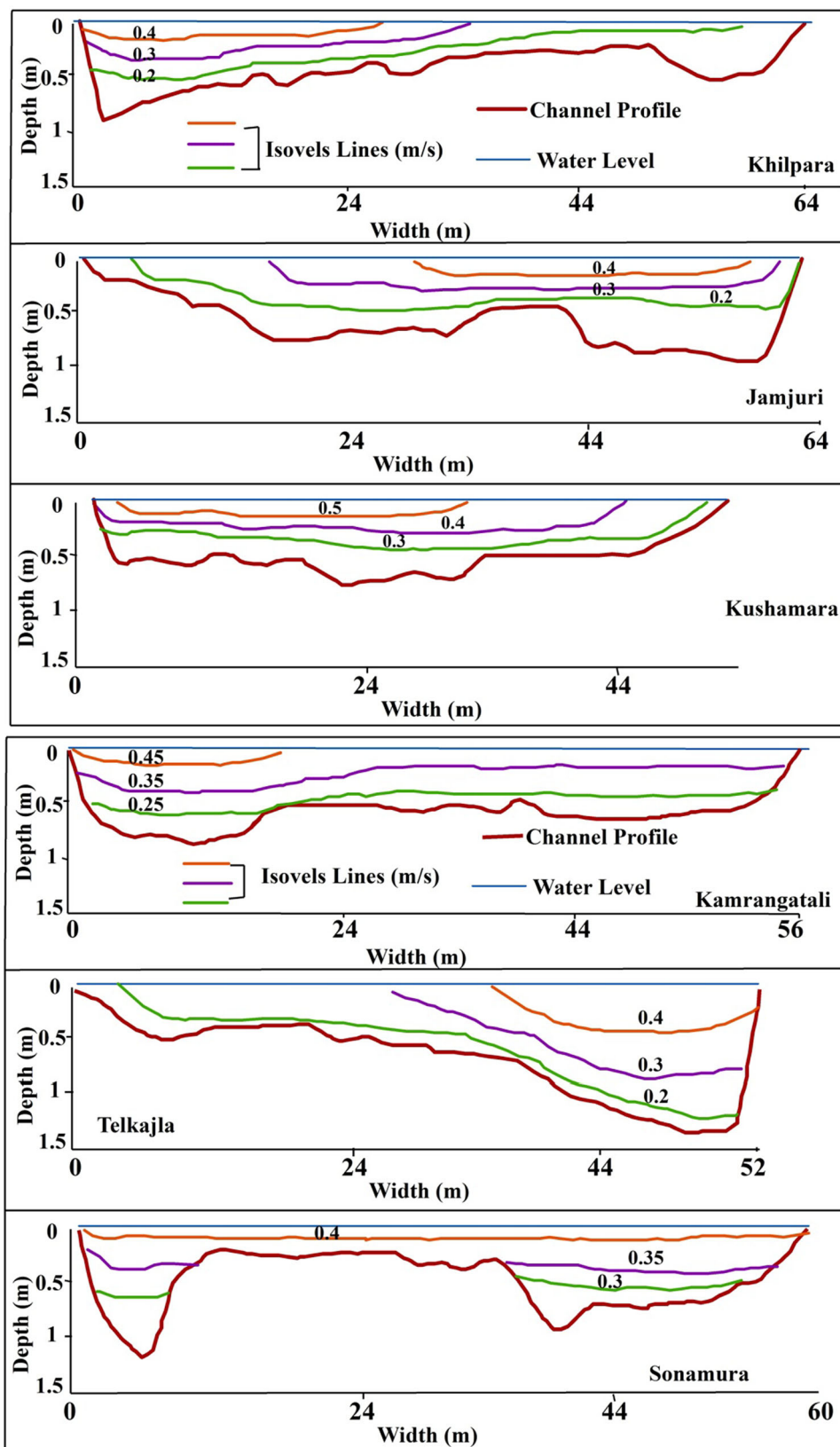


Fig. 6 Superimposition of cross-sections taken across the Gumti River during 2014, 2015 and 2016

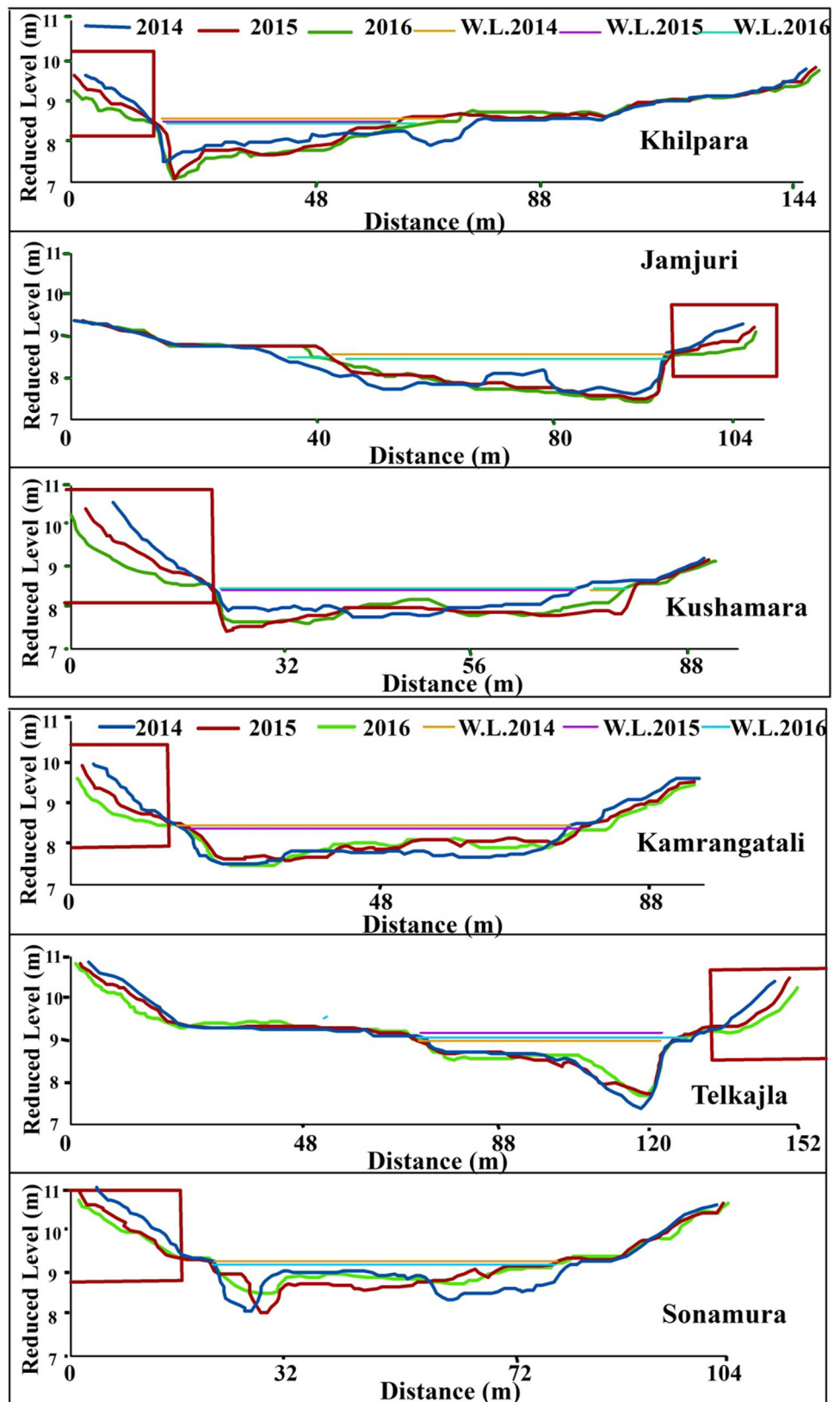


Table 4 Soil loss from river bank along the cross-sections during 2014–2015 and 2015–2016

Sites	Amount of soil loss (metric tonnes) from 2014 to 2015	Amount of soil loss (metric tonnes) from 2015 to 2016
Khilpara	968	940
Jamjuri	429	501
Kamrangatali	1470	916
Kushamara	3195	3643
Telkajla	2046	1072
Sonamura	530	439

4.6 Correlation matrix (Pearson)

Pearson’s correlation matrix has been used to find out the relationship exists between different aspects associated with the problem of channel migration of the Gumti River. For this purpose distance of houses of the surveyed respondents from the Gumti River, shifting of the houses, displacement type and frequency, amount of agricultural land lost, nature of croplands and amount of financial loss of the respondents have been considered as parameters (Table 5).

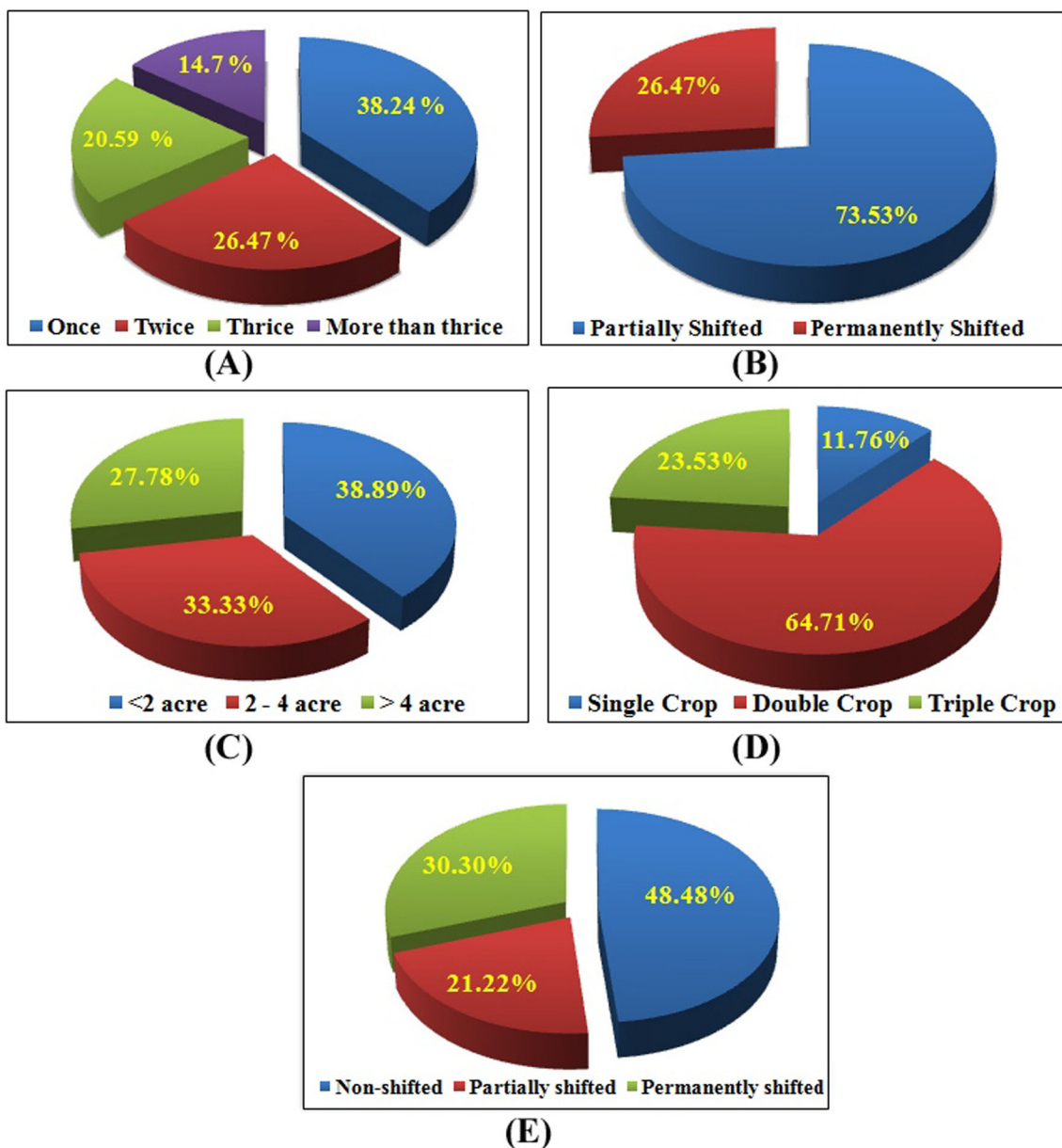


Fig. 7 Vulnerability status of channel migration of the Gumti River. **a, b** Status of displacement of households, **c, d** amount and nature of loss of cropland, **e** status of occupational alteration

Table 5 Correlation matrix (Pearson)

	Present_ Distance_ River	Shifting_ House_For_ Migration	Displacement_ Frequency	Displacement_ Type	Amount_ Land_Loss	Nature_ Cropland	Amount_ Financial_ Loss
Present_Distance_River Pearson Correlation	1						
Sig. (2-tailed)							
Shifting_House_For_ Pearson Correlation	-.637**	1					
Sig. (2-tailed)	.000						
Displacement_Frequency Pearson Correlation	.200	.750**	1				
Sig. (2-tailed)	.209	.000					
Displacement_Type Pearson Correlation	.386	.817**	.739**	1			
Sig. (2-tailed)	.013	.000	.000				
Amount_Land_Loss Pearson Correlation	-.359*	.025	.264	.058	1		
Sig. (2-tailed)	.021	.875	.096	.718			
Nature_Cropland Pearson Correlation	-.114	-.041	.086	-.018	.583*	1	
Sig. (2-tailed)	.478	.799	.592	.911	.000		
Amount_Financial_Loss Pearson Correlation	-.191	.066	.205	.039	.844**	.614**	1
Sig. (2-tailed)	.231	.683	.200	.808	.000	.000	

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the .05 level (2-tailed)

Table 5 shows that significant linear negative relationship exists between distances of respondents' houses from the Gumti River to displacement of the households. It reveals that as distance of the houses from the river decreases, the probability of shifting of houses increases manifold. Thus people who are residing nearer to the Gumti River are the worst sufferers from this channel migration. Correlation is significant at .01 level (2 tailed) between shifting of houses with frequency of displacement of households (Table 5). It indicates that recurrence shifting of houses due to channel migration has increased the frequency of displacement of the households. Significant linear relationship also exists between displacement frequencies with displacement type of households. It has been observed that displacement frequency is less for those households who have permanently shifted their houses in distant places from the River Gumti, but those who have partially shifted their houses are highly victimised by channel migration as they have shifted their houses in such a place which is located more or less nearer to the River Gumti. Thus, they have to shift their houses frequently keeping pace with changing position of river bank line. Moreover, it has been found that the amount of financial

loss is significantly correlated with the amount of land loss by channel migration (especially agricultural land) and nature of cropland. It signifies that the amount of financial loss of the farmers is largely governed by the quantity of loss of agricultural lands and therefore, higher loss of agricultural lands leads to more financial deficiency. Moreover, it also depends on the nature of croplands. Loss of triple cropped lands leads to more financial loss in comparison to the single or double cropped lands as these lands are the year round source of income for the farmers.

5 Discussion

River bank erosion and consequent channel migration has adverse effect on socio-economic conditions of the inhabitants residing along the bank line [34–36]. The present study reveals that during the periods 1932–2016 the River Gumti has migrated for about 137.48–533.42 m at various locations. Sandy to loamy sandy nature of bank soil indicate its non cohesive nature which eroded away easily, especially during high water discharge and the problem of channel migration prevailed. Moreover, asymmetrical

channel form and concentration of maximum velocity in the deeper part of the channel reveals that during high discharge period, immense pressure is being created on the bank located near the deeper part which leads to bank failure. Loss of large amount of bank soil indicates how bank erosion plays key role in frequent migration of the lower Gumti River.

The study reveals that channel migration is significantly affecting the overall socio-economic status of the dwellers residing along the bank of the lower Gumti River. The inhabitants have to relocate their houses frequently according to the changing bank line scenario of the Gumti River. The victims who did not have financial ability to purchase new plot in safer places to build their houses are most vulnerable to this hazard of channel migration as they had rebuilt their houses within the study area, relatively nearer to the bank of the Gumti River. Therefore, in future there is every possibility of repetition of the same tragedy. Moreover, from the present study it has also been found that frequent channel migration leads to loss of large scale productive agricultural lands located along sides of the lower Gumti River which causes significant economic loss to the local people.

6 Conclusion

Bank erosion is appearing to be a serious environmental issue for the dwellers residing along the banks of the lower Gumti River. Every year large quantity of soil is eroded away from the river bank. It not only results in the lateral migration of channel but also adds extra sediment to the river bed. Consequently, the river bed rises and increases the possibilities of flood hazard. Along with physical changes, erosion adversely affects human life. As per this survey, 73.53 and 26.47% of the victims of channel migration had shifted their houses partially and permanently respectively and consequently the socio-economic condition of the victims were awfully affected as they had to reconstruct their houses according to the changing bank line position of the Gumti River. Although the problem of bank erosion cannot be controlled absolutely but the extremity of it can be reduced. Thus, implication of proper management strategies to reduce this problem is the need of the hour. A buffer zone of 5 m can be made along side of the lower Gumti River and bamboo can be planted in this zone to reduce the magnitude of bank erosion as bamboo grows abundantly in Tripura.

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