Floods in the Ganga-Brahmaputra-Meghna delta and their management using social engineering

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Floods in GBM Delta

- Bengal is the ultimate outlet of 89,000 cumec water carried by the GBM system during the monsoon months (Rudra, 2018).

- The Ganges, Brahmaputra and Meghna (GBM) basin and numerous minor rivers provide the main freshwater flow into the northern and central part of Bangladesh. During the monsoon period (June– October), the volume of water often exceeds the carrying capacity of these rivers, and fluvial flooding occurs.

- Bangladesh is well know as 'land of rivers' and there are about 230 rivers network within the country including 54 international rivers flowing across the country and finally reach to the Bay of Bengal. The combined catchment area of three major river systems e.g. the Ganges, the Brahmmaputra and the Meghna is approximately 1500000 km^2 of which only 7.5 percent lies within Bangladesh (Dewan et al., 2003).

- The country has a long history of destructive flooding. In the **19th century**, **six major floods** were recorded: 1842, 1858, 1871, 1875, 1885 and 1892. **Eighteen major floods** occurred in the **20th century**. Those of 1951, 1987, 1988 and 1998 were of catastrophic consequence. More recent floods include 2004 and 2010.

Flood year	Flood damages
1987	57,300 square kilometres (22,100 sq mi) of land, (about 40% of the total area of the country), seriously affected regions were on the western side of the Brahmaputra, the area below the confluence of the Ganges and the Brahmaputra and considerable areas north of Khulna.
1988	Inundated about 82,000 square kilometres (32,000 sq mi) of land, (about 60% of the area), flood lasted 15 to 20 days.
1998	About 75% of the total area of the country was flooded, including half of Dhaka. It was similar to the catastrophic flood of 1988, 30 million people were made homeless and the death toll reached over a thousand, 700,000 hectares of crops were destroyed, 400 factories were forced to close, and there was a 20% decrease in economic production
1999	The 1999 floods, although not as serious as the 1998 floods, were still very dangerous and costly. The floods occurred between July and September, causing many deaths, and leaving many people homeless. The extensive damage had to be paid for with foreign assistance.
2004	Flood was very similar to the 1988 and 1998 floods with two thirds of the country under water
2005	Dozens of villages were inundated when rain caused the rivers of northwestern Bangladesh to burst their banks
2007	2007 affected 252 villages in 40 districts causing millions of people became homeless.
2017	Unpredicted early heavy rain caused flooding in several parts of Bangladesh and damaged pre-harvested crops in April. The April flood continued until the last week of August and caused substantial damage to housing, property, and infrastructure.

Flood nature in GBM delta

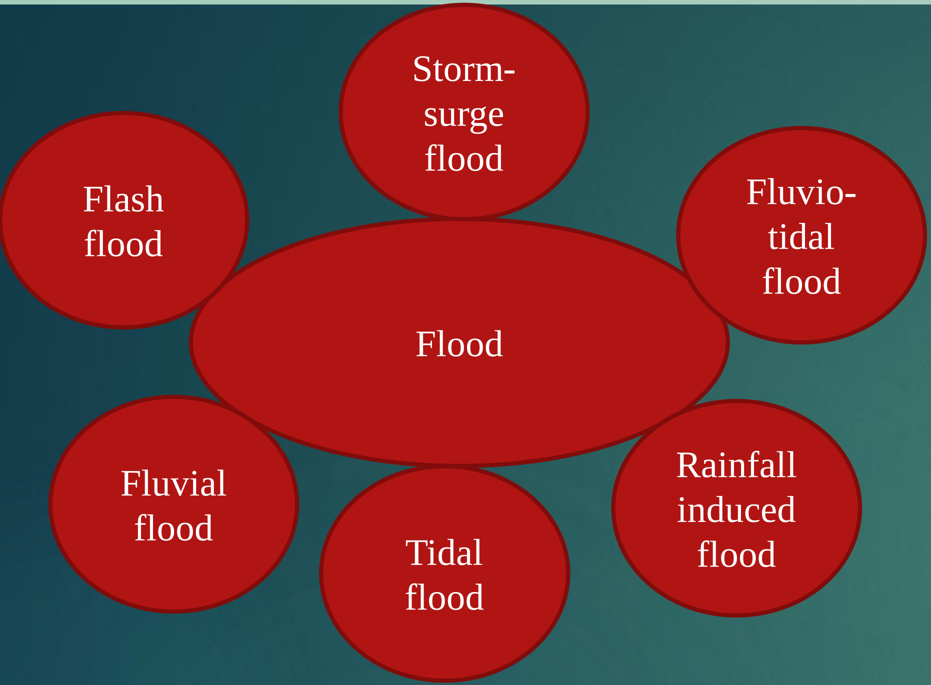


Fig: Different types of flood in GBM delta

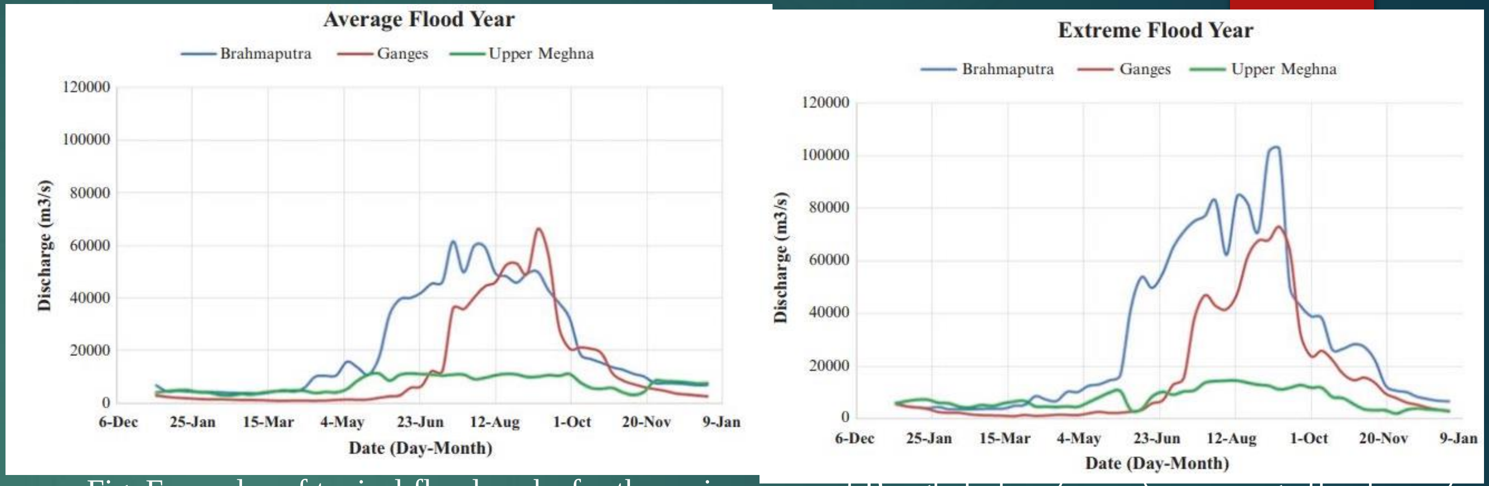


Fig. Examples of typical flood peaks for the major rivers of Bangladesh in (upper) an average flood year (year 2000) and (lower) an extreme flood year (year 1998);Source: Bangladesh Water Development Board (BWDB)

Table 8.1 Fluvial flooding extents, as percentage of the national area, from 1954 to 2014 (60 fluvial flood events in 60 years) (BWDB 2015)

Extreme flood year (flooded area >24%)		Average flood year (flooded area 20–24%)		Dry year (flooded area <20%)	
No. of events	Percentage	No. of events	Percentage	No. of events	Percentage
15	25	9	15	36	60

- During the monsoon period (June– October), the volume of water often exceeds the carrying capacity of these rivers, and fluvial flooding occurs.
- The number of historical flood events from 1954 to 2014, categorized by extent shown in the table.
- Twenty-five per cent of all flood events occurred during extreme flood years and caused significant damage. Two typical examples of fluvial floods, one for an average flood condition (year 2000) and one for an extreme flood condition (year 1998), are shown in Fig.
- The **Brahmaputra** water level starts rising from the early monsoon (June–July) and **reaches its first peak in the third week of July**. It then falls and rises again and, in an average flood year, attains its **second peak in the first week of August**. The **Ganges** has a **single peak** of flood level occurring in the **second week of September**. For the **Upper Meghna**, the **first flood peak** occurs in the **second or third week of May**, and, in an average flood year, a **second peak** occurs **close to the second peak of the Brahmaputra**.

- Tides along the Bangladesh coast are semi-diurnal. The 18.6-year lunar nodal cycle has no influence along the Bangladesh coast, but the 4.4-year lunar perigean cycle modulates the tide by 4 cm (Sumaiya 2017).

- Tidal range is greatest along the Noakhali coast, immediately east of the Lower Meghna estuary , and declines to the east and west (Ahmed and Louters 1997).

- The mean tidal range at Hiron Point near the Sundarbans (west coast) is around 3 m, increases up to 6 m near Sandwip (west coast) and then decreases to 3.6 m further east (Cox’s Bazar).

- Coastal flooding due to tides is more pronounced in the central and eastern parts of the coast compared to west coast, reflecting the tidal range. The construction of polders since the 1960s has eliminated significant tidal flooding in these areas.

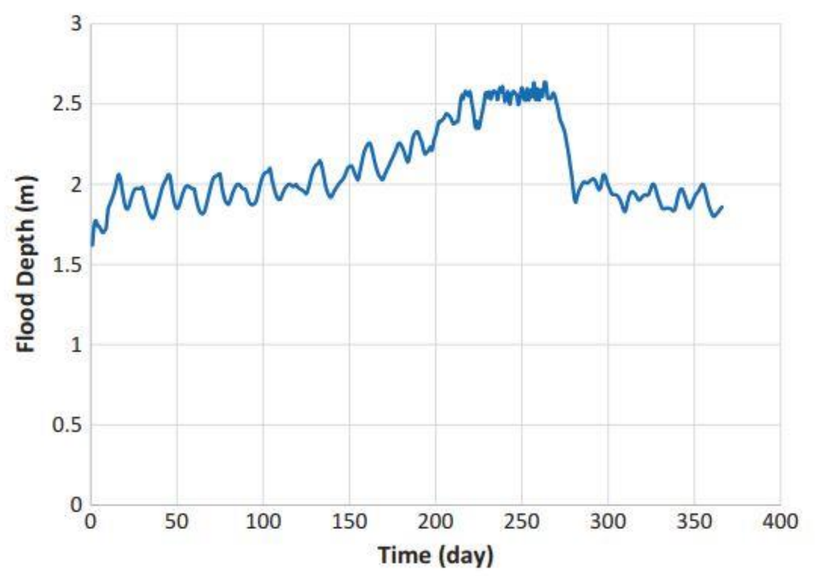


Fig. 8.3 A typical flood hydrograph showing the fluvio-tidal characteristic of floods (Source: model simulation)

Compound flooding caused by the combination of fluvial flows and high tides. This is important in coastal Bangladesh, but has not been described previously. A typical hydrograph of fluvio-tidal flooding shows both rising and falling due to fluvial effects from the monsoon combined with tidal variation due to tidal effects .

The coastal region of Bangladesh is well known for storm surge flooding with major events going back several centuries or more (Alam and Dominey-Howes 2015).

1991 cyclone occurred at high tide, generating extreme water levels exceeding 8 m in a few places. For the Bangladesh coast, when a cyclone makes landfall during high tide, it has more potential for generating extensive storm surge flooding and associated damage

The extent of flash floods is in the northern and eastern parts of Bangladesh.

Triggering factors

Natural factors

- Location and Topographic Expression
- Excessive monsoon rainfall in the plains and catchment areas of three major river systems
- Synchronization of peak flows of the major rivers
- Tidal effect
- Drainage congestion

Anthropogenic factors

- Dams and barrages on River
- Unplanned development with poor engineering
- Deforestation

- The average height of the land is 25 feet or 8 meters (Huq1986).
- The 1987 flood was predominantly caused by local rainfall (Miah,1988).
- The three major river catchments area are also one of the rainiest areas of the world where every year on average, the Ganges Basin receives 140cm, Brahmmaputra basin receives 210 cm and Meghna basin receives 400 cm rainfall respectively (Mirza,1998).
- The different timing of the flood peaks of the major rivers are mainly due to variations in rainfall in the upper catchments and the travel time to reach the discharge measurement points considered. Synchronisation of the peaks across the three rivers is rare, but has occurred: the floods of 1988 and 1998 being examples (Islam and Chowdhury 2002).
- During peak synchronisation, the second peak of the Brahmaputra is delayed or may occur as a third peak coinciding with the single peak of the Ganges. This triggers significant fluvial flooding in Bangladesh.
- The dams and barrages altered the hydrological characteristics of a river (Islam et al. 2022b) as well as the nature of floods was also altered from low-frequency high magnitude to high-frequency and low-magnitude mainly in the Indian part of GBM delta.

Consequences of flood

Hydro-geomorphic

Environment

Economic

Social

Hydro-geomorphic impacts

River Bank and estuary erosion
Channel oscillation and meandering in Bengal Basin
Stream sinuosity
Channel braiding in the Bengal Basin

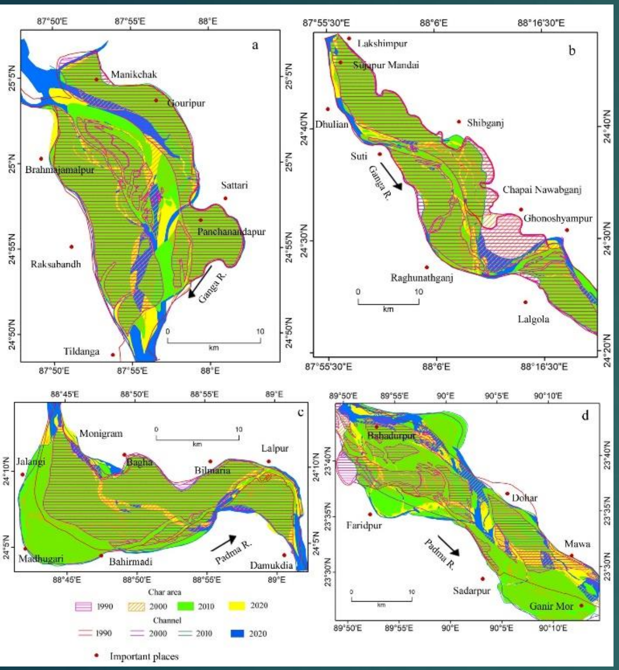


Fig. Morphological dyanamics of channel bars of Ganga-Padma River during 1990-2020, a. Rostampur Char, Ganga River, India b. Radhakantapur Char, Ganga River, Bangladesh c. Char Bhabananda Diar, Padma River, Bangladesh d. North Char Janajat, Padma River, Bangladesh

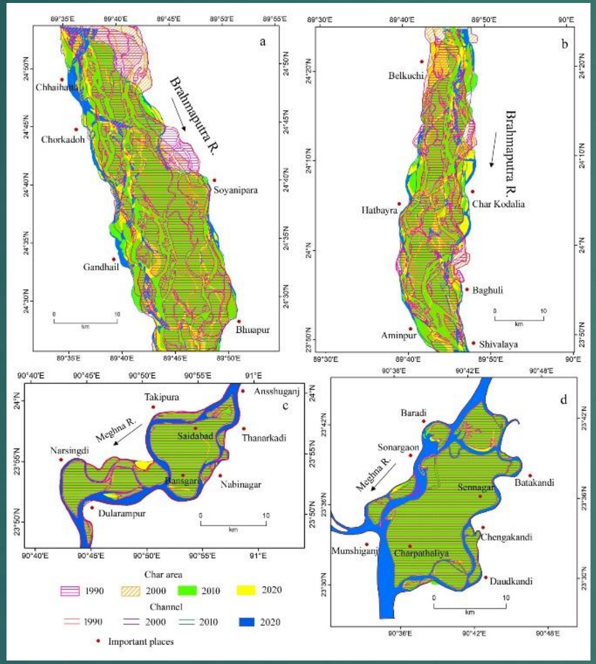


Fig. Morphological dynamics of channel bars of Padma River in Bangladesh during 1990-2020, a. Nischintapur Char, Brahmaputra River b. Char Kodalia, Brahmaputra River, Bangladesh c. Charmodhu, Meghna River, d. Kalitola Char, Meghna River

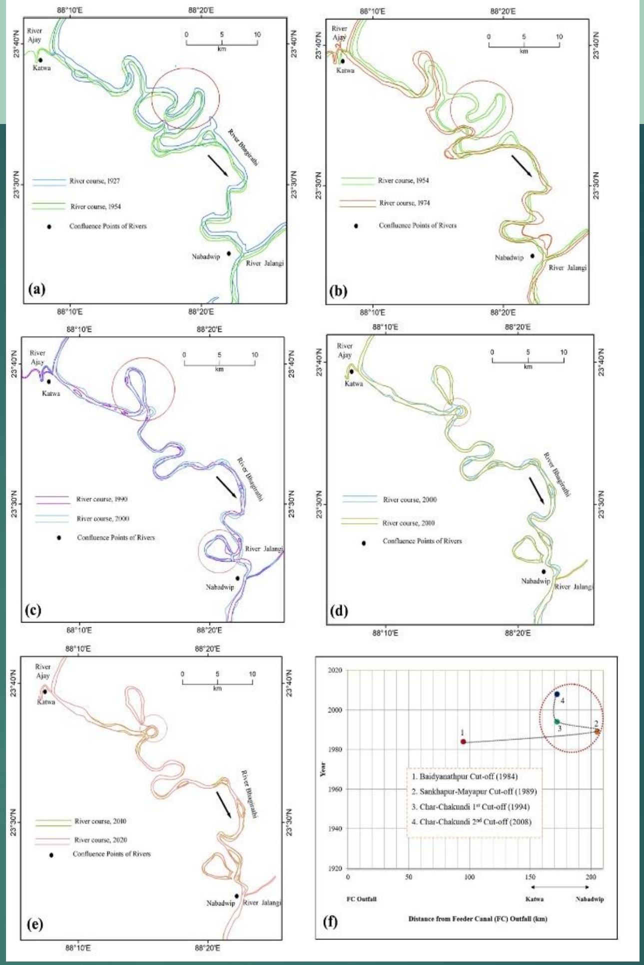


Fig. a-e Channel oscillation of river Bhagirathi in the lower reach during 1927-2020, f. Space-time specificity in channel cut-off

- In 1989 in Bhagirathi river a chute cut-off has been occurred triggered by the flood impulse of 1989 (Basu et al. 2005). As a result, a reduced length of 9 km has made the channel more straightened.

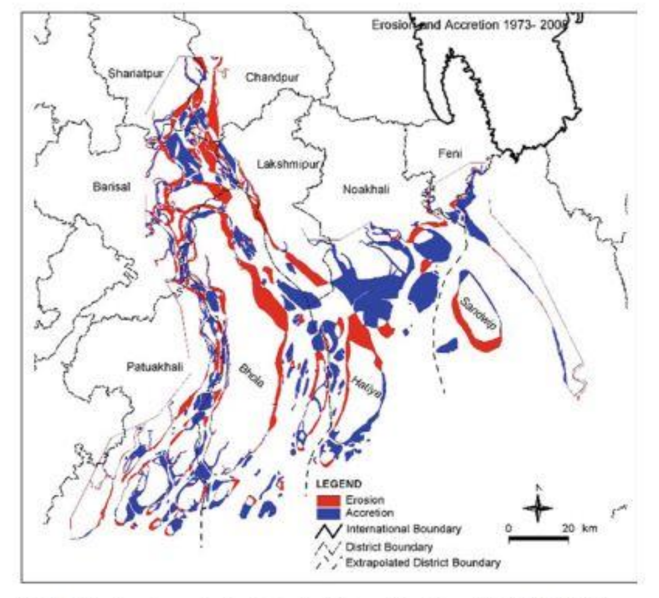


Fig. 7.14 Erosion and accretion in the Meghna Estuary during the period of 1973–2008. *Source* Sarker et al. (2011)

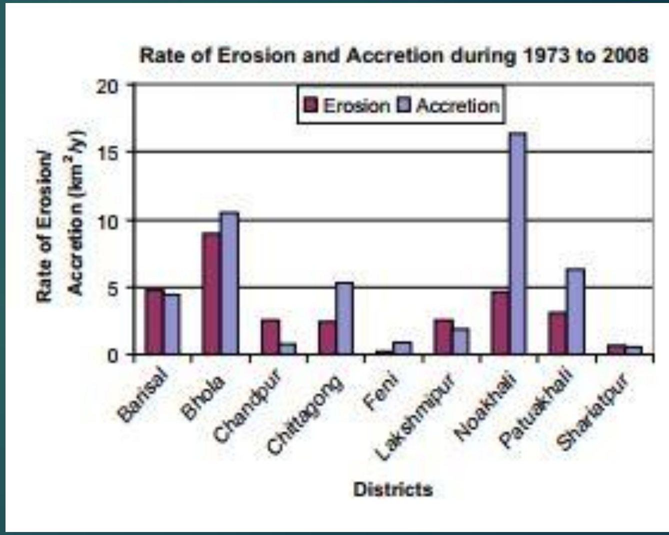


Fig. District-wise distribution of erosion and accretion during the period of 1973–2008. Source Sarker et al. (2011)

Economic impact

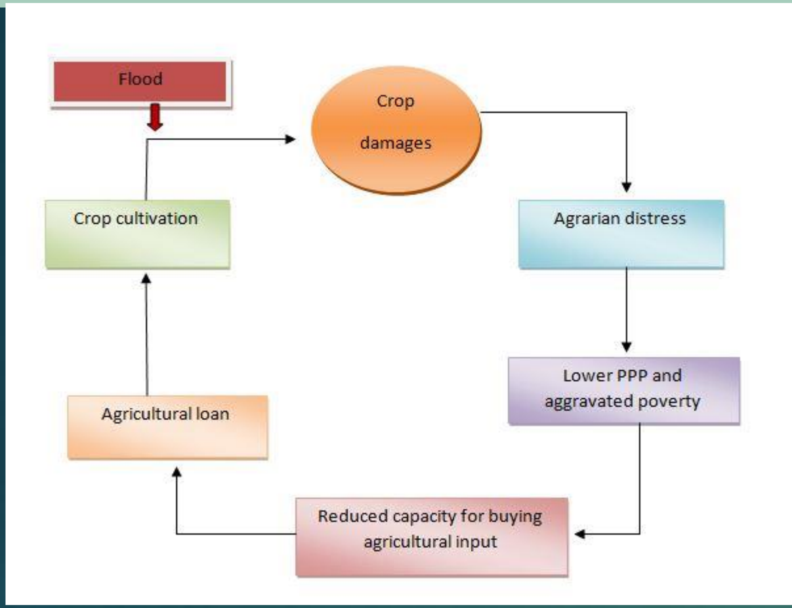


Fig. Vicious cycle of flood and agrarian distress
(Source: Field Survey, 2017–2018; Note: PPP stands for purchasing power parity)

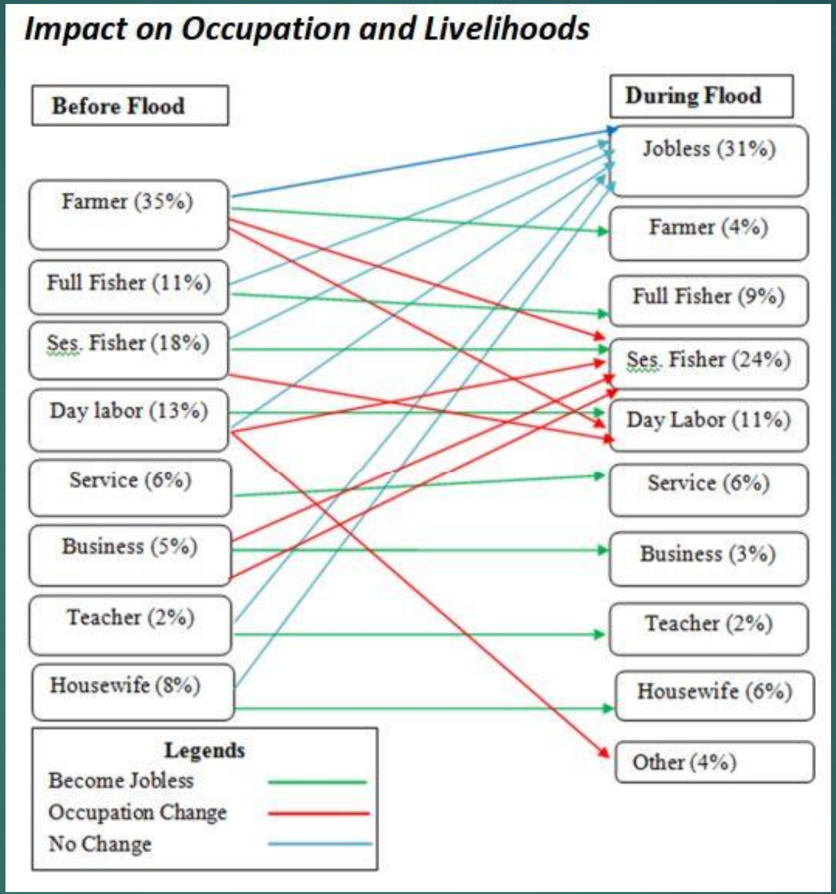


Fig. Shifting of Occupations due to Flash Floods in the Tanguar Haor of Sunamganj, Bangladesh

Fig. Flood inundated agricultural fields at Anduli-I (India)

Dilapidated kutcha house due to flood in Hijal (India)

- The lower-income leads to agricultural poverty and lower capacity for buying agrarian inputs. However, to run the agrarian system they borrow money at a higher interest rate from mahajans (persons who lend money at a high-interest rate).

- Occupation and income of the poor are the two most crucial sectors on which flood have significant impacts
- Flash floods not only force people to change their occupations but also negatively affect people's income.
- Early flash flood causes damage to paddy production and post-monsoon flash flood is a hazard for vegetable production.
- Early flash floods increases fish production as water comes early and inundates the whole area and stays longer period.

- The farmers were aware of ecological benefits of flooding of their farmland as each flood used to replenish agricultural land with a layer of new silts. The farmers used to cut the bank of the river and allow silt-laden flood water to submerge the field. This was described as ‘overflow irrigation’ by Willcocks (1930).

- Migration and receipt huge amount of remittances which help to enhances the per capita income.

- Migration is considered a survival strategy and affected households for the char people of Bangladesh very often have no alternative but to move to nearby towns or cities (Khatun et al., 2021) .

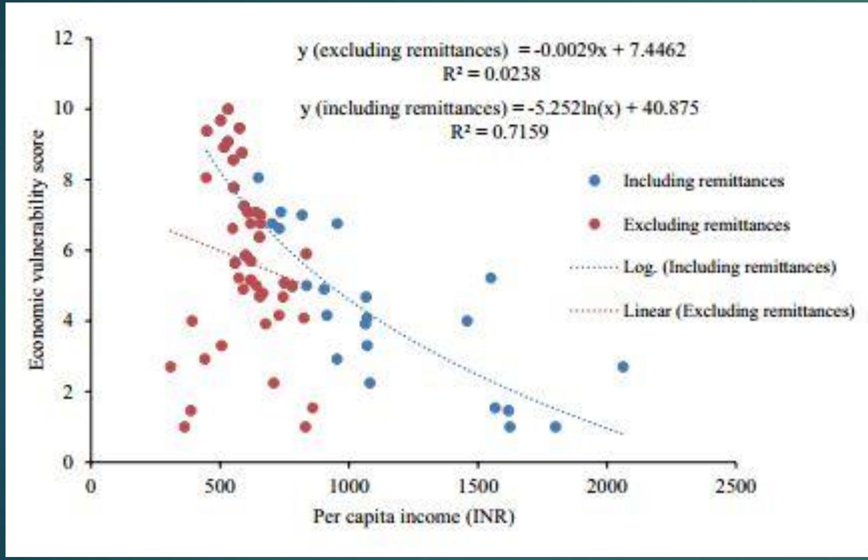


Fig. Relation between per capita income and economic vulnerability

In the lower Mayurakshi Basin it has been shown that there is negative relation with per capita income and economic vulnerability and the remittances enhances the per capita income of the region.

Table 18.6 Use of remittance money

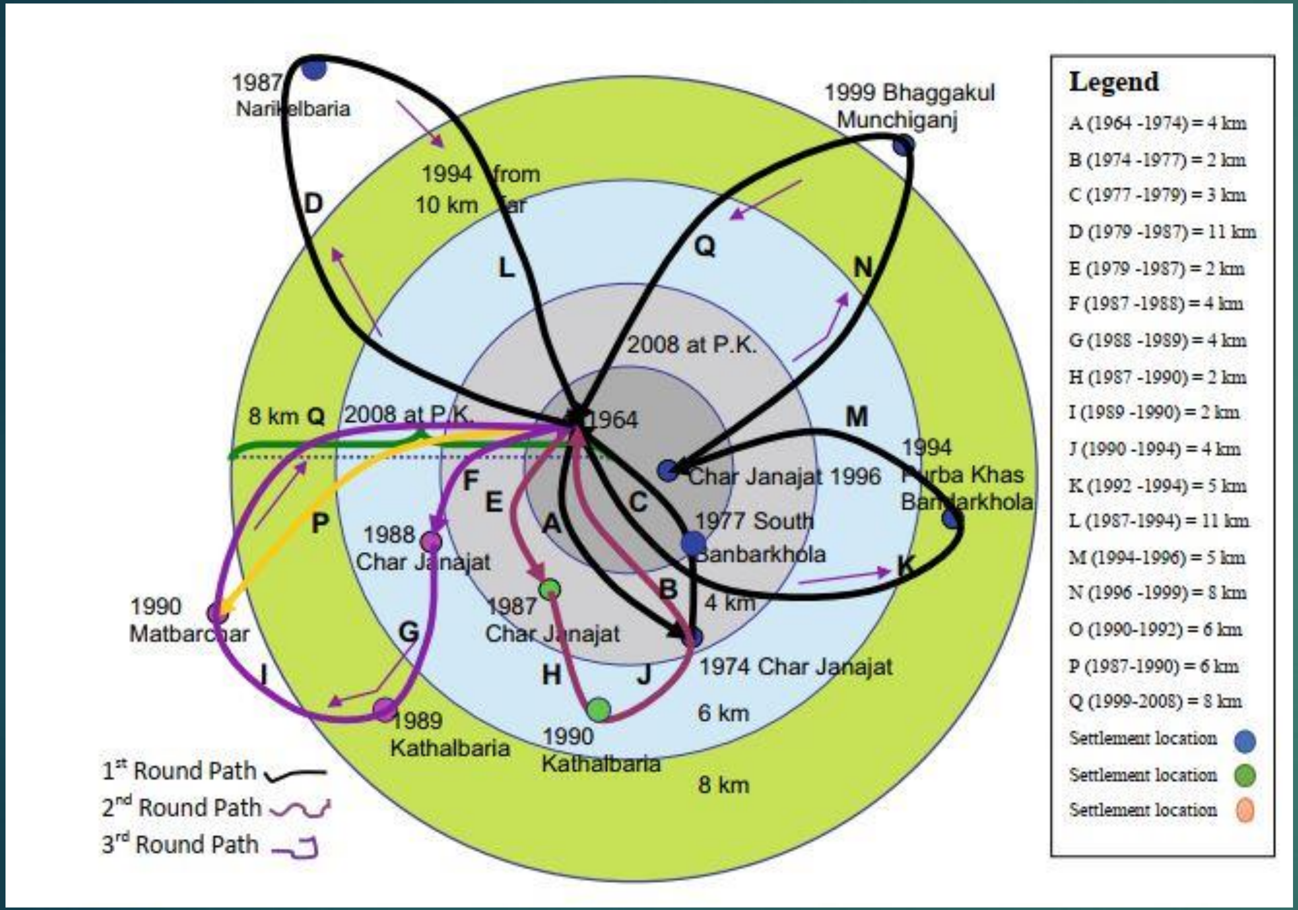
Use of remittance	Teligari Char (Jamuna) % of respondents	Malakandi Char (Meghna) % of respondents	Char Tepurakandi (Padma) % of respondents
Household expenditure	68.09	26.32	25.49
Medical treatment	17.02	10.53	9.80
Educational expenditure	31.91	36.84	19.61
Repairing house	29.79	0.00	5.88
Construction of house	34.04	42.11	21.57
Children’s marriage	4.56	15.79	1.96
Repayment of loan	3.65	36.84	11.76
Investment in livestock	38.30	42.11	23.53
Investment in agriculture	59.57	15.79	15.69
Buying new lands	10.64	36.84	29.41
Savings	25.53	5.26	15.69
Buying boat	2.13	0.00	3.92
Business	2.13	10.53	0.00
Leasing in land	4.86	2.35	1.96
Buying farming equipment	7.89	1.84	1.96
Lending money for interest	3.58	2.86	1.96
Donating for community level infrastructure	3.15	2.01	1.23

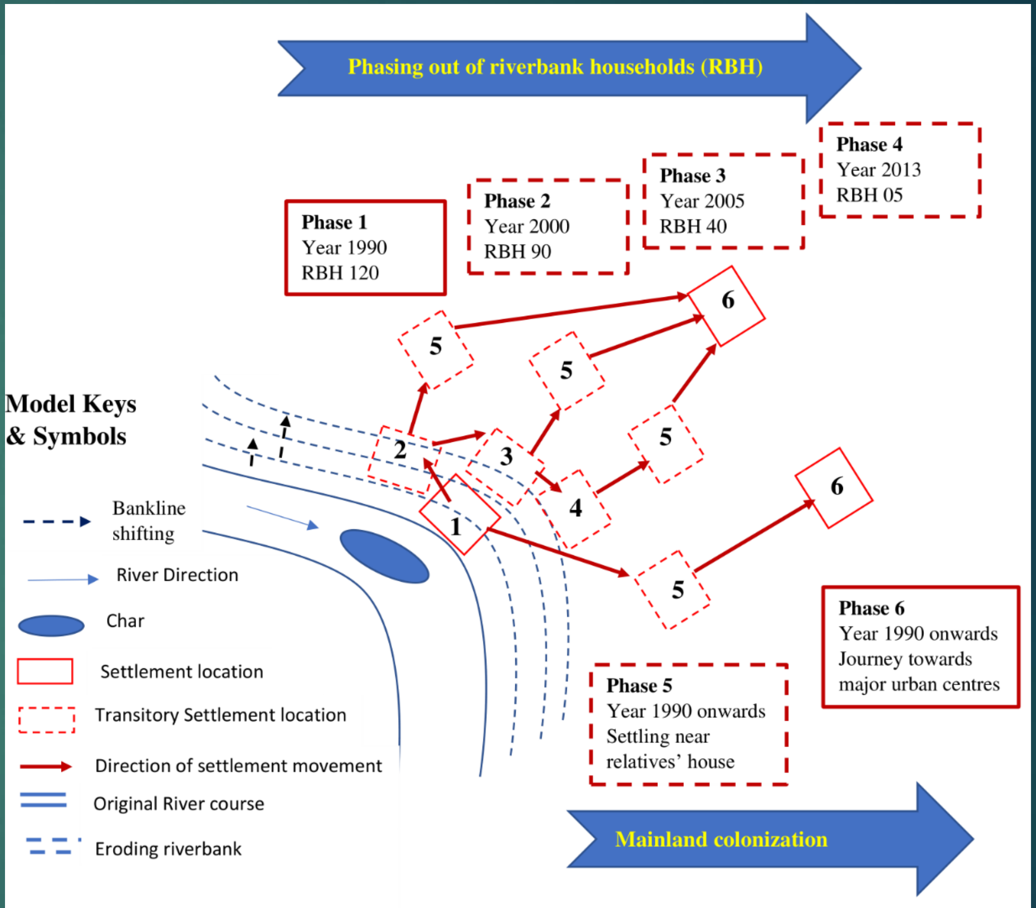
Multiple answers were considered and the percentage is calculated with respect to the total number of respondents
Source Field Study (2019)

Khatun et al. (2021) also collected from the field survey that the remittances uses for the betterment of the socio economic condition which indicates that flood is not only curse.

Social impacts

- Displacement





Bank erosion and displacement. a. Cyclic displacement of Omar Ali's family around char Janajat in Bangladesh (Based on Islam, 2021), b. Model of the linear movement of the people due to riverbank erosion along the Bhagirathi River (Islam and Guchhait, 2022).

History of flood management

The flood management issue in Bangladesh did not receive much attention before 1954 and 1955 disastrous floods. After two consecutive big events , then East Pakistan government sought the assistance of the United Nations to tackle flood problem.

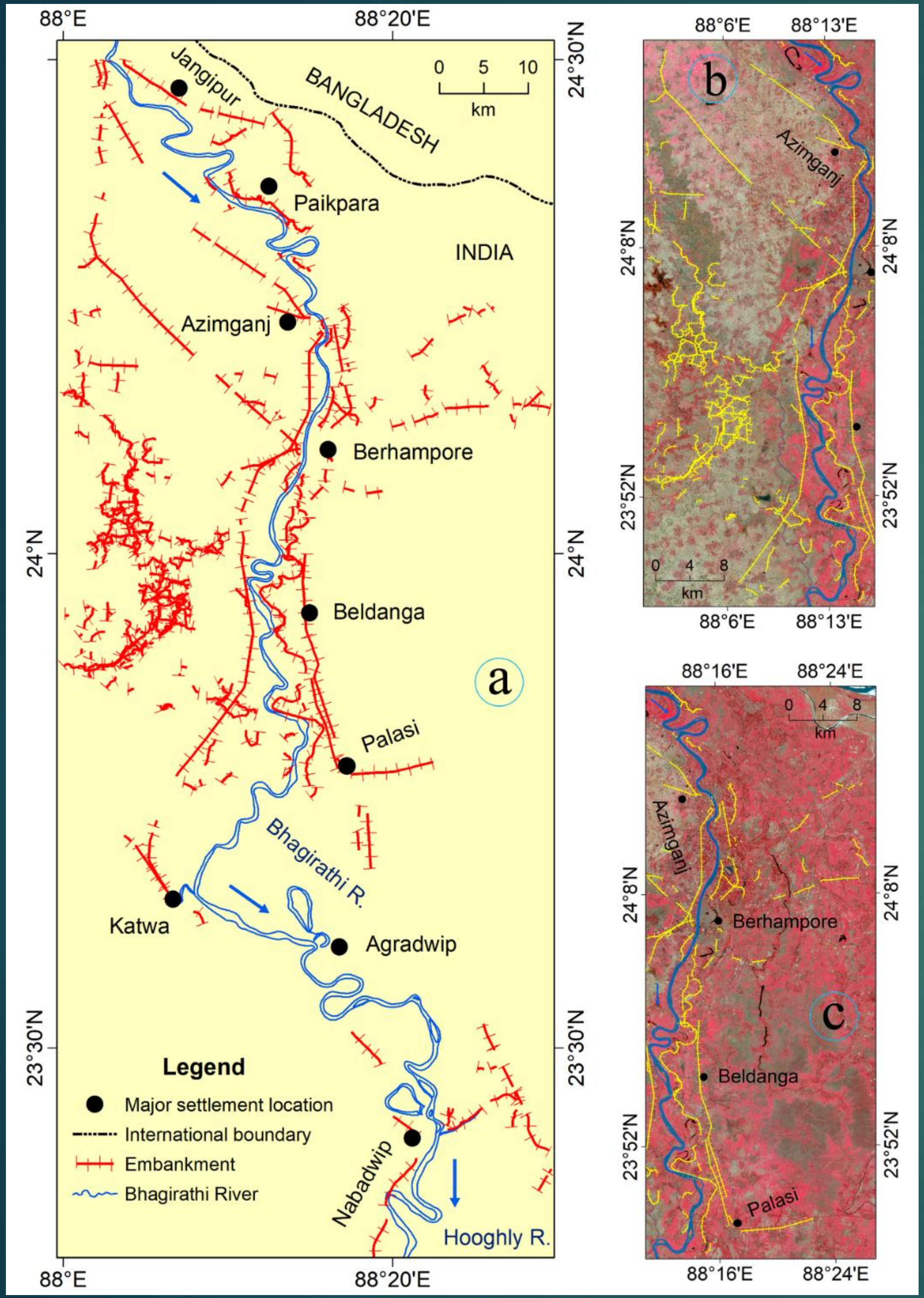
In 1964, a Master Plan was drawn up by the US International Engineering Company Inc.(lEe) under the aegis of Water and Power Development Authority (WAPDA), proposing large scale flood control, drainage and irrigation (FCDI) programs. These programs were based on the experience gained in a century of flood protection works on the lower Mississippi river. Three types of projects were envisaged on the Master plan such as flood embankment with gravity drainage; flood embankments with sluice drainage and flood embankments with pump drainage.

The Master Plan failed to deliver expected benefits and was entangled with faulty design and construction, poor maintenance of the structures and implementation delays. Noting the failure of the Master Plan the World Bank got involved with the agriculture and water development programs and suggested a shift in strategy from large scale embankment to small scale Flood Control Development projects(FCD) like low lift pump, shallow tubewell and improved cropping practices. Such small scale projects continued until Bangladesh was again devastated by the successive floods of 1987 and 1988.

Soon after the catastrophic floods of 1988, the Government of Bangladesh requested the World Bank (WB) to coordinate and formulate plans that could mitigate the flood problems of Bangladesh. Accordingly, the World Bank prepared a Flood Action Plan, which incorporated structural and non-structural options of flood control, but the structural measures formed the basis for long-term comprehensive flood protection. The implementation of the plan has not progressed as expected due to various delays and controversies over the engineering controls to be the best solution for flood protection in Bangladesh (Alam,1990).

So far, Bangladesh has spent a good amount of foreign aid and internal resources in the construction of the engineering controls. The major types of water control projects constructed so far in Bangladesh are (1) Flood embankments along the river which are constructed in the form of roads and railways, (2) Submersible flood embankment, (3) Polders with drainage regulators Polders with pump irrigation and drainage, (5) Gravity irrigation projects with pumping stations along the major rivers.

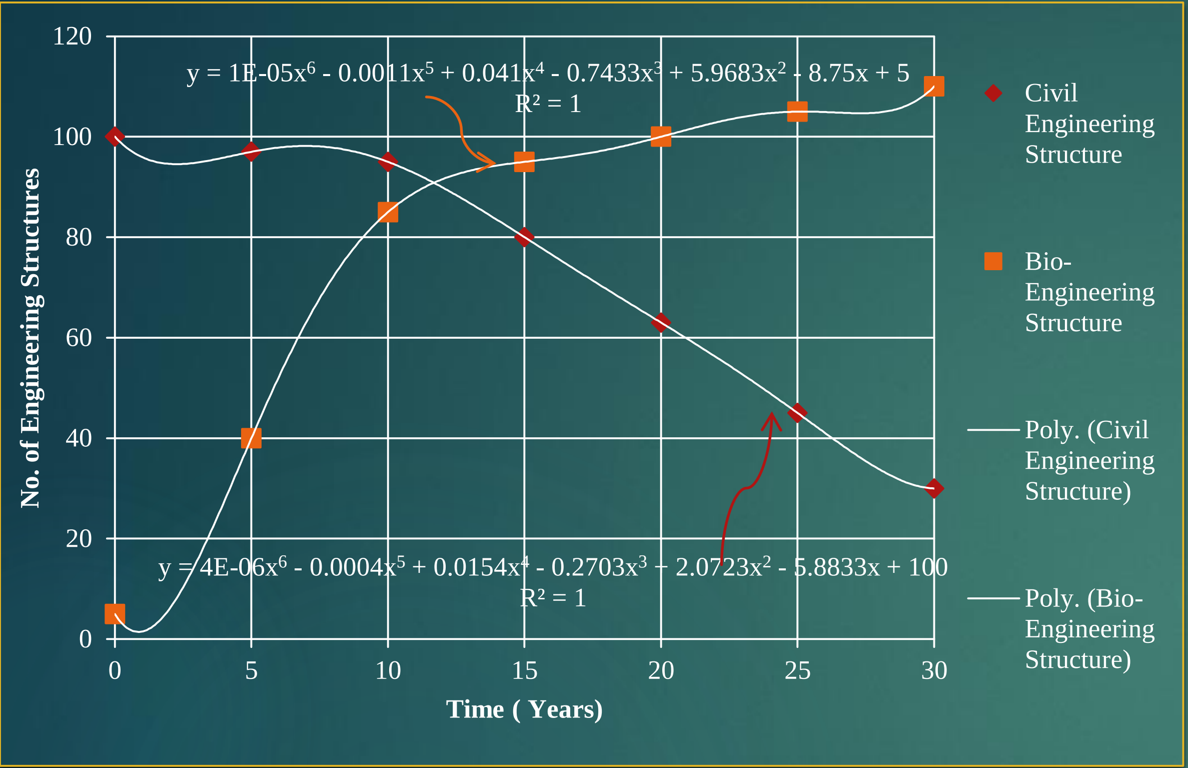
Civil engineering (Structural) measures in GBM delta



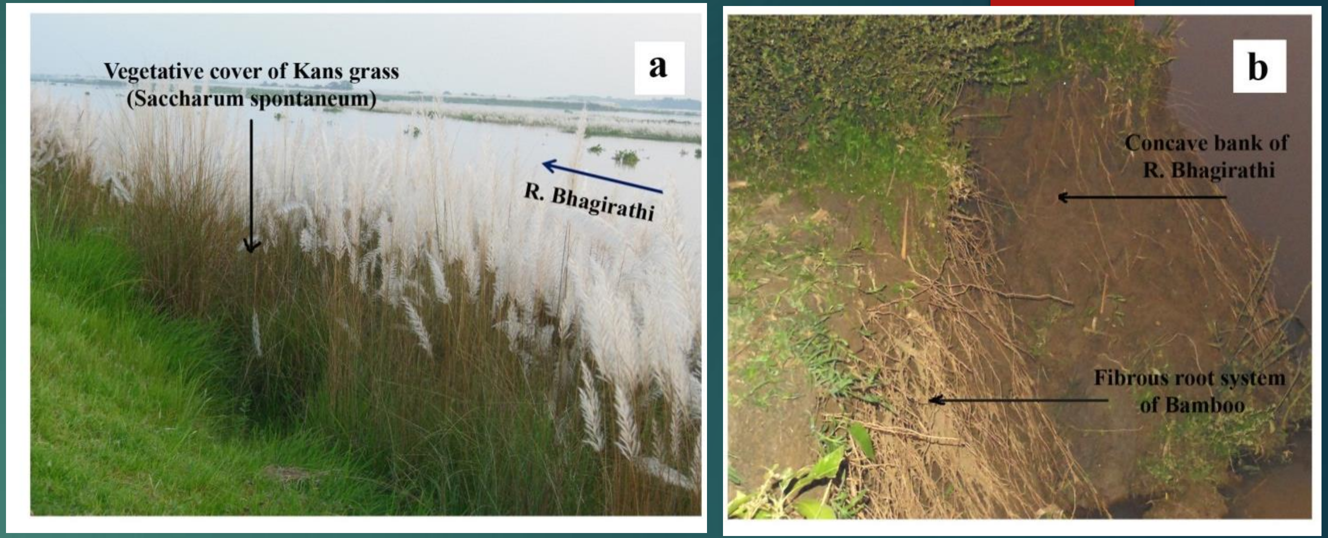
- To date, more than 10,000-km-long embankment in West Bengal is maintained by Irrigation and Waterways Department. In Bangladesh, the total length of the embankment is reportedly 7555 km.

- In the post-independence era, some dams/reservoirs were built with twin purposes of flood control and irrigation.

Bio-engineering measures



Comparative effectiveness of bio-engineering and civil engineering practices over time (Based on Howell, 1999). It proves that bio-engineering structures are increasing at the expense of civil engineering structures.



Evaluation of bio-engineering measures a. Natural bank protection with kans grass along the left bank of the Bhagirathi River, b. Bamboo root penetration deeper into the soil reduces the rate of riverbank erosion along the Bhagirathi near Rukupur village. It is observed that places without bamboo root penetration have an accelerated rate of bank line shifting.

- Mangroves can effectively attenuate waves and hence effectively contribute to nature-based flood defence.
- The Sundarbans mangrove forest covers an area of about 10,000 km2 (3,900 sq mi), of which forests in Bangladesh's Khulna Division extend over 6,517 km2 (2,516 sq mi) and in West Bengal, they extend over 3,483 km2 (1,345 sq mi) across the South 24 Parganas and North 24 Parganas districts.

Social engineering

- The focus has shifted from hard engineering to soft engineering (non-structural) measures.
- For example, early flood forecasting, restructuring and strengthening the economic base of a community, and preparation of flood zonation maps are being prioritized in recent times to make the community flood resilient (Mohanty et al. 2020; Costache et al. 2022).
- It is also observed flood vulnerability varies greatly depending on the socio-cultural fabric of a community based on religion, caste composition, age-sex structure, ethnicity, and majority and minority relations (Mishra 2010).
- For example, the presence of a higher number of women or the elderly population in a community may hinder flood management works (Enarson et al. 2009; Islam and Ghosh 2021a).
- Thus, understanding community traits and behavioural dynamics become more relevant in the context of flood management, especially in densely populated tropical region.

A case study of proposing social engineering methods in GBM delta (Lower Mayurakshi River Basin)

Database uses for the case- study

Primary data

➢Primary data are concerned with the collection of data vis-à-vis socio-economic vulnerabilities by river floods (especially income, occupational adversities, and occupational shifting, family budget, fragility in an agrarian economy, depleting wealth and resource base, deteriorating health and education conditions, changing demographic characteristics, and neighborhood characteristics).

Secondary data

➢ District Census Handbook, Murshidabad from 1961 to 2011

➢Topographical maps (Survey of India- 72 P/16, 78 D/4, 73 P/13, and 79 A/1)

➢ District Resource Map of Murshidabad, GSI

➢Satellite Images (Landsat 5 TM, Landsat 8 OLI/TIRS, SRTM DEM-30m);Google Earth Imageries

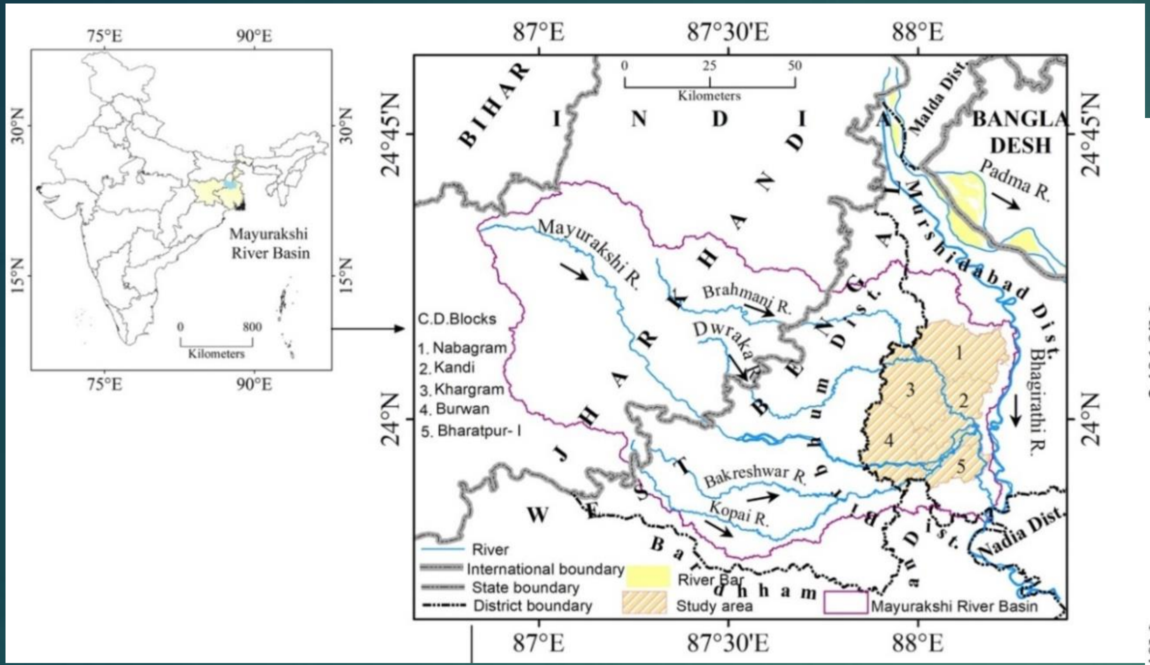
➢ Disaster Management Plan (2016-17)

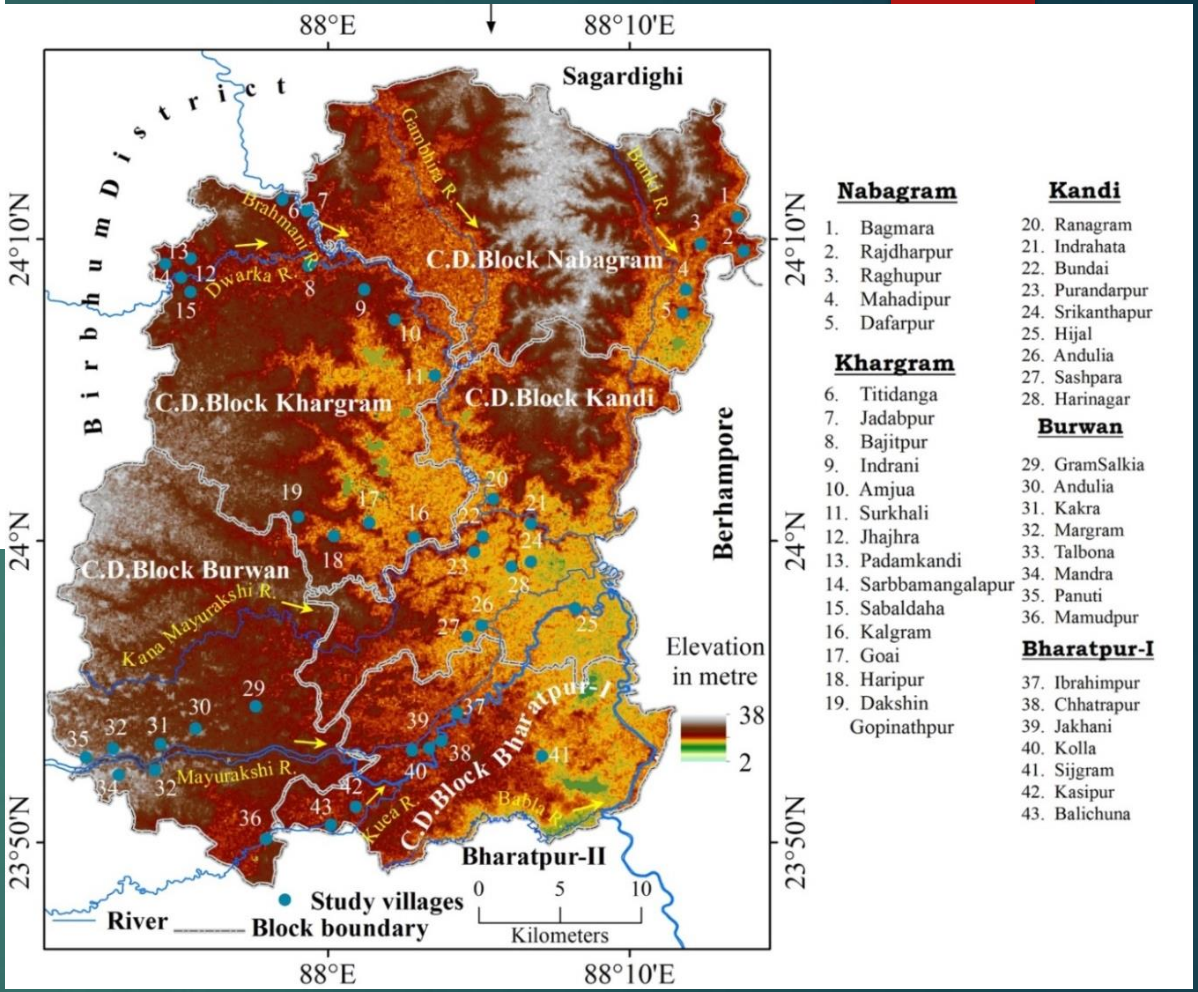
➢Annual Flood Reports (2014-2016)

➢ Meteorological data especially rainfall from IMD for Murshidabad and Birbhum district (1901-2016)

➢ Flood discharge data for Mayurakshi, Dwaraka, Brahmani and Kuye rivers from Kandi Final Report, 2012

Sampling design and data collection





•The Mayurakshi Basin covering an area of about 9,596 sq.km in the States of Jharkhand and West Bengal .

C.D Block	No. of victimized villages	No. of sample villages
Nabagram	45	5
Khargram	139	14
Kandi	83	9
Burwan	76	8
Bharatpur I	68	7

10% sample villages from each block have been selected by purposive sampling aided by pilot survey and some secondary database.

Cont.

- The present project has been executed taking a statistically significant sample size (n) for each village using simple random sampling as a particular area is homogeneous in terms of population. The sample size has been determined using the formula of United Nations Framework Convention on Climate Change (UNFCC).
- Formula :

$$n \geq \frac{1.645^2\, NV}{(1-N)x0.1^2 + 1.645^2\, V} \quad \text{and} \quad V = \frac{p\,(1-p)}{p^2}$$

Where n stands for sample size; N for total number of households of the villages as per 2011 Census p for proportion of the households having economic marginalization (loss of crops and building damage minus coping capacity) due to the flood of 2000 as derived through the pilot survey in the field.

C.D. Blocks	Sub-blocks	Villages	Total Households (2011)	p	Sample Households	C.D. Blocks	Sub-blocks	Villages	Total Households (2011)	p	Sample Households
C.D. Block Nabagram	Nabagram North	Bagmara	427	0.855	42			Purandarpur	1109	0.701	105
		Rajdharpur	746	0.807	60		Kandi south-east	Srikanthapur	881	0.737	89
	Nabagram South	Raghupur	459	0.85	44			Hijal	2713	0.607	165
		Mahadipur	167	0.875	32			Harinagar	269	0.902	27
		Dafarpur	1228	0.655	128		kandi south west	Andulia-I*	521	0.865	40
C.D. Block Khargram	Khargram north east	Indrani	1885	0.565	188			Sashpara	1045	0.771	75
		Amjua	392	0.86	40	C.D. Block Burwan	Burwan east	Gram Salkia	715	0.773	72
		Surkhali	801	0.755	80			Mamudpur	90	0.878	27
	Khargram north west	Titidanga	433	0.85	44		Burwan west	Andulia-II*	116	0.9	24
		Jadabpur	184	0.845	40			Kakra	98	0.865	30
		Bajitpur	82	0.915	20			Margram	106	0.8	42
		Jhajhra	175	0.857	36			Talbona	69	0.855	28
		Padamkandi	603	0.8	61			Mandra	320	0.787	60
		Sarbbamangalapur	97	0.895	24			Panuti	221	0.835	44
		Sabaldaha	828	0.809	60	C.D. Block Bharatpur-I	Bharatpur I east	Sijgram	1185	0.815	59
	Khargram south	Kalgram	401	0.86	40		Bharatpur I north west	Ibrahimpur	195	0.845	40
		Goai	294	0.893	30			Chhatrapur	108	0.835	36
		Haripur	762	0.764	76			Jakhani	95	0.861	30
		DakshinGopinathpur	208	0.84	42		Bharatpur I south west	Kolla	240	0.82	48
C.D. Block Kandi	Kandi north	Ranagram	445	0.797	60			Kasipur	249	0.815	50
		Indrahata	505	0.8	60			Balichuna	75	0.89	24
		Bundai	389	0.795	60			Total households			2382

Using the *structured questionnaire survey* encompassing 2382 rural households, both the quantitative and qualitative data have been collected on different dimensions of flood hazard (frequency, depth and duration 1998-2018) and vulnerability of agriculture, occupation, and income

Using the unstructured *questionnaire survey*, 10 randomly selected fishermen of wetlands such as Belun *bil*, Patan *bil*, and Kurul *bil* were primarily enquired about the nature of fishing in the *bils* and how the wetlands are used for economic pursuits and profit level of fisherman, etc.

Similarly, another 35 farmers were randomly surveyed using an *unstructured questionnaire* to know their experience of floriculture in selected seven villages from C.D. Block Kolaghat and another 25 farmers were randomly surveyed in the five villages from C.D. Block Nakashipara, West Bengal.

To study the feasibility of this strategy (market-oriented agriculture) in the study area, we randomly selected five villages located above the average annual flood level (>20 m) and 5 *focus group discussions* (FGDs) each consisting of 10-15 members were organized in the 5 villages of five different blocks. Another 3 FGDs each consisting of 10-15 members were organized in the 3 villages i.e., Amjua, Churigram, and Jamuni of C.D. Block Khargram for feasibility analysis of commercial fishing in the wetlands.

(a) Identification of suitable location for crops using geospatial techniques

The DEM-based solution has been embraced to find out the three flood vulnerable zones- (1) high, (2) medium, and (3) low. The elevation data has been processed with the help of the algorithms of the raster processing system available in the spatial analyst tool of ArcGIS 10.4 software. Using the algorithms of the spatial analyst tool (fill, flow direction, flow accumulation), an elevation map has been prepared. Moreover, the elevation map has been validated using 43 GPS elevation points stored in the Garmin GPS etrex–10 device during the field survey in the villages (N= 43). Finally, based on the elevation map and identification of the vulnerability of a crop area to flood, suitable cropping combinations have been modelled.

(b) Identification of potential fishing area using buffering

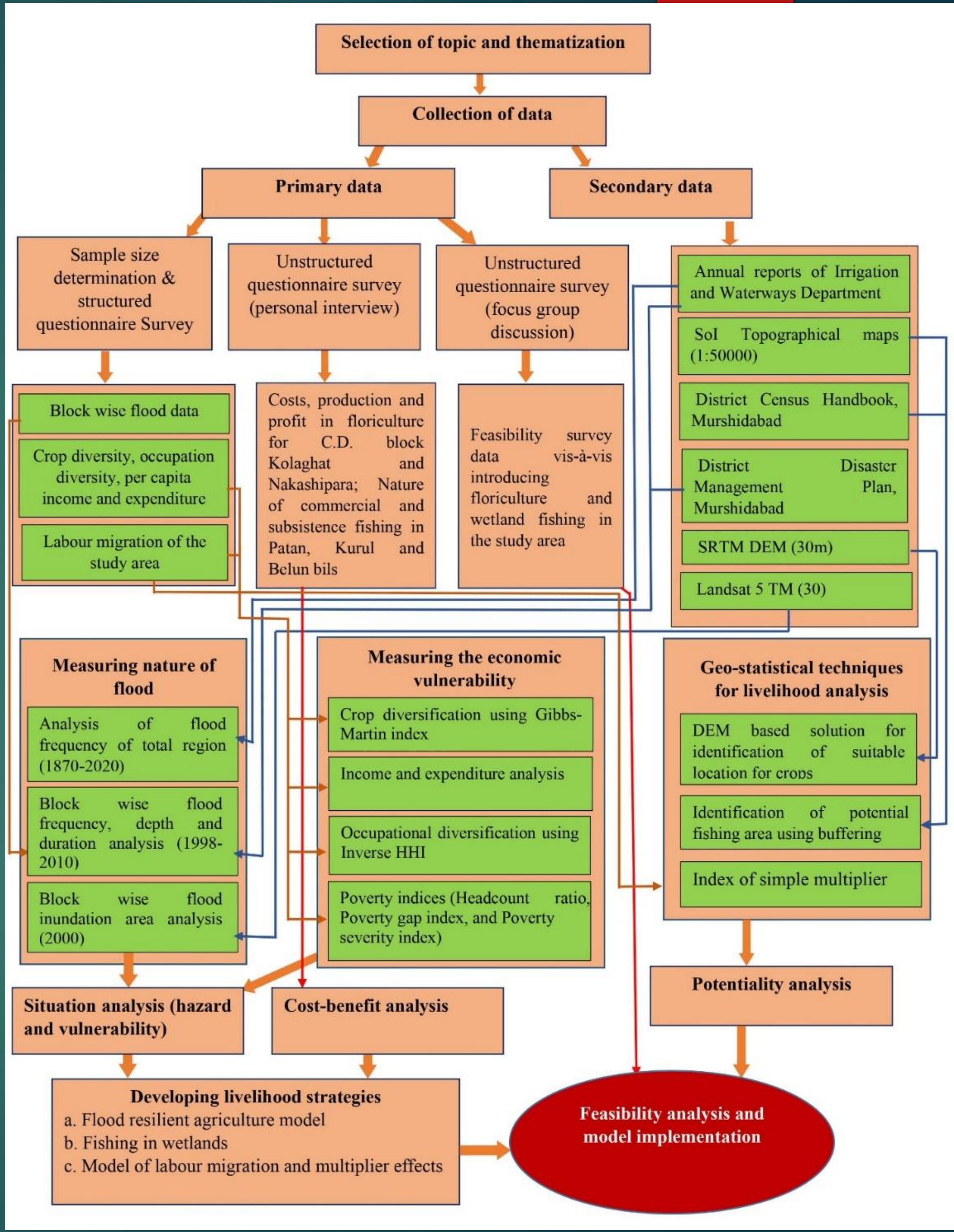
Potential fishing area for commercial development has been estimated using buffering in ArcGIS. The principle of spatial proximity analysis has been applied to find the allegiance of the villages to access the wetland areas. From the geocentre (as derived from ArcGIS 10.4) of each *bil*, three buffers having 1 km radius have been drawn for this purpose.

(c) Measuring the impact of labor migration

One of the significant facets of this remittance economy is the economic multiplier. The simple multiplier (M) has been computed using Eq. 6 of Marglin and Spiegler [40].

$$M = \frac{1}{1-MPC}$$

Where, MPC stands for marginal propensity to consume.



Work plan of the case study

Nature of flood in Lower Mayurakshi River Basin

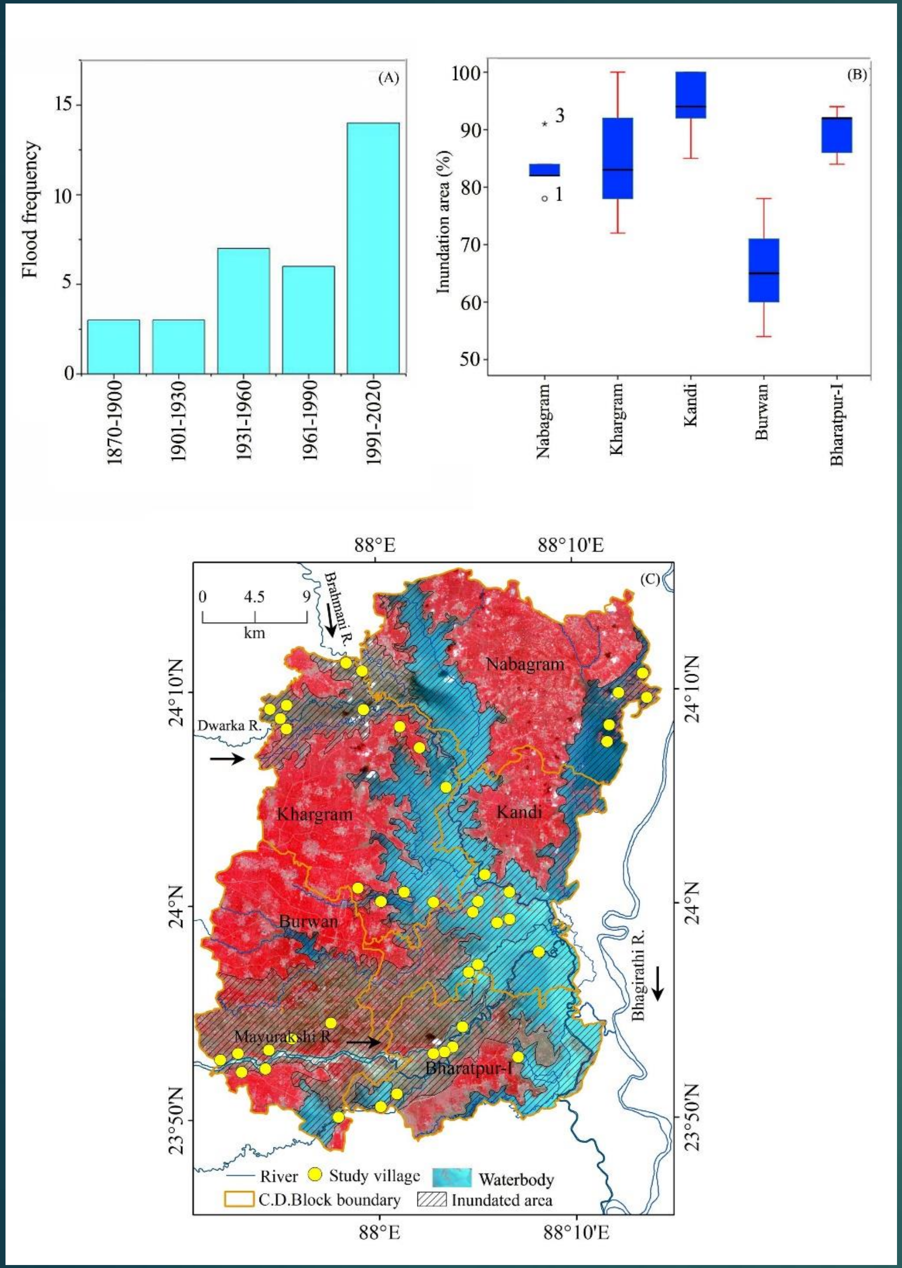


Fig. Nature of flood in the study area, A. Flood frequency during 1870–2020, B. Variation of flood inundation area in different C.D. blocks during 2000, C. Spatiality in the flood inundation area during 2000

		Nabagram	Khargram	Kandi	Burwan	Bharatpur-I
Flood frequency	Average	9	10	12	9	11
	Range (highest-lowest)	10-8	11-8	15-9	10-8	13-9
	SD	0.84	0.85	2	0.93	1.29
	Skewness	-0.51	-0.43	0.48	0.00	0.00
	Standard error	0.37	0.23	0.67	0.33	0.49
Flood depth (m)	Average	0.91 (2.13)	1.28 (3.09)	1.35 (3.43)	0.53 (1.89)	1.73 (3.72)
	Range (highest-lowest)	1.46-0.57 (2.83-1.70)	2.89-0 (5.34-1.41)	2.44-0.32 (6.07-1.48)	1.24-0 (2.91-1.17)	2.32-1.01 (5.37-2.28)
	SD	0.35 (0.42)	0.78 (1.05)	0.74 (1.61)	0.45 (0.63)	0.39 (1.03)
	Skewness	1.10 (1.37)	0.47 (0.40)	0.06 (0.24)	0.29 (0.34)	-0.61 (0.31)
	Standard error	0.16 (0.19)	0.21 (0.28)	0.25 (0.54)	0.16 (0.22)	0.15 (0.39)
Flood duration (days)	Average	4.60 (20.20)	8.29 (22.29)	11.67 (40.22)	3.25 (15.38)	11.57 (30.29)
	Range (highest-lowest)	10-2 (26-16)	32-0 (67-14)	22-2 (80-11)	9-0 (45-7)	16-6 (41-18)
	SD	3.21 (4.49)	7.61 (13.22)	7.97 (24.27)	3.06 (12.22)	3.64 (9.71)
	Skewness	1.66 (0.61)	2.47 (3.41)	-0.13 (0.26)	0.92 (2.60)	-0.50 (0.13)
	Standard error	1.44 (2.01)	2.03 (3.53)	2.66 (8.09)	1.08 (4.32)	1.38 (3.67)

The major floods recorded in the study area since 1870 exhibit that the flood frequency has gradually increased.
The nature of floods during the last 20 years (1998–2017) shows that 11 years recorded floods with at least one flood event per year in the different C.D. blocks.
However, Kandi experienced floods twice in 2006 and 2015 and 3 times in 2007. Moreover, Khargram also experienced flood two times in 2007.

Flood resilient agriculture model

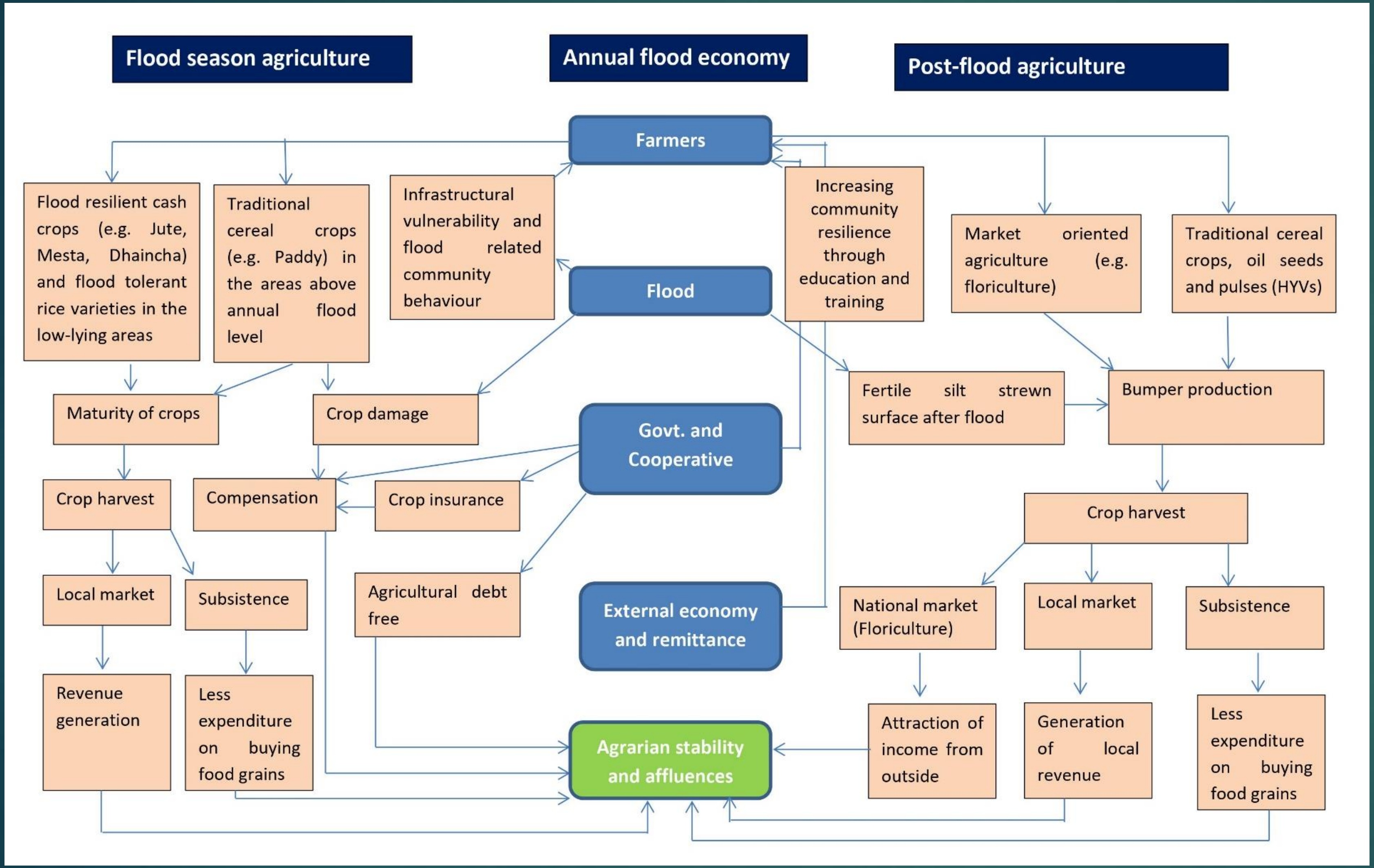


Fig. Flood resilient agriculture model proposed by the researcher

- Based on the field observation at the extensive interviews with the farmers, this investigation proposes a flood resilient agriculture model where there are four major drivers of the annual flood economy – flood, framers, Govt. and cooperative and external economy and remittance which determine the agrarian stability and affluence.

- During the flood season, there is an emphasis on growing of flood resilient crops like jute, *mesta* on the low-lying land that may reduce the crop vulnerability.

- The traditional crops e.g. paddy may be grown on the land above annual flood level that may reduce risk of crop failure. Despite, the crop is damaged by the floodwater crop insurance and freeing the agricultural debt by the Govt. is needed. In the post-flood period, this model proposes market-oriented agriculture coupled with the existing traditional crops

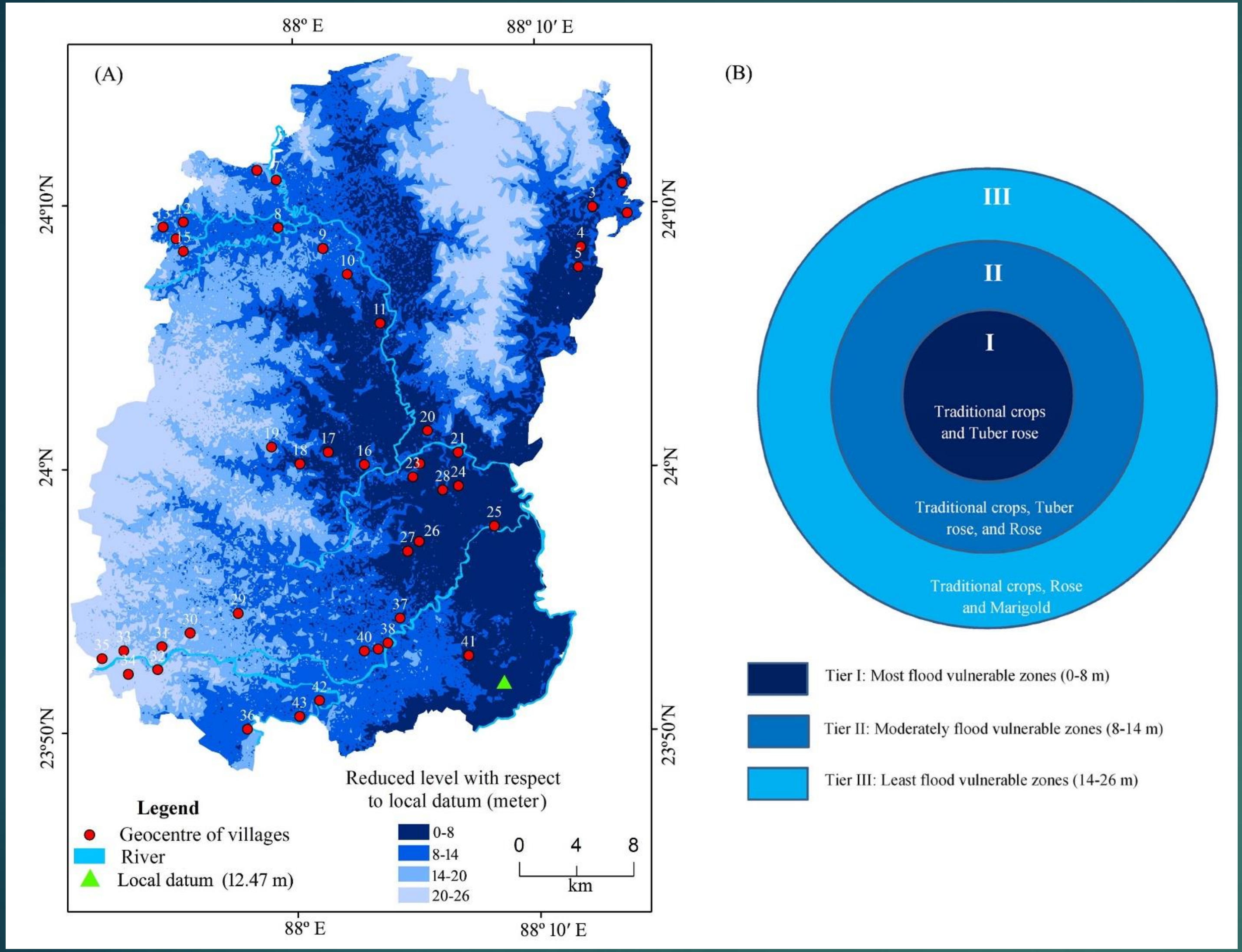


Fig. Location of the villages and wards in the different relief zones and proposed crop combinations in the different flood vulnerable zones

This model takes care of traditional agriculture i.e. the villages proposed under this scheme will be also cultivating the majority of the land (85%) for traditional crops which will help them for subsistence while the floriculture will help them earn money.

This model is also dealing with the types of flowers to be cultivated in the different flood vulnerable zones which are dependent on the local relief. There are four relief zones reduced to the local datum of 12.47 m.

The zones are 0-8 m, 8-14, 14-20 and 20-26 m. The majority of the villages are located below 14m. Thus, three flood vulnerable zones are delineated as i) most flood vulnerable zone (0-8 m), ii) moderately flood vulnerable zone (8-14 m)and leas flood vulnerable zone (14-26 m) .

Tier-I having the most flood vulnerability may be used for the combination of traditional crops and tuber rose because the tuber rose may withstand the water logging or food condition for about two weeks.

The second zone having moderate flood vulnerability may be used for tuber rose, rose coupled with traditional crops.

In the tier-III, marigold can be cultivated along with the rose and traditional crops.

Table Distribution of land among floriculture and traditional crops

Villages	Elevation (m)	Irrigated area (bigha)	Non irrigated area (Bigha)	Total area (Bigha)	Irrigated land (%)	Proposed tuberrose area (bigha)	Proposed Rose area (Bigha)	Proposed Marigold area (Bigha)	Total land for floriculture (Bigha)	Land remaining for traditional crops (Bigha)
Sijgram	20	2224.0	444.8	2668.7	83.3	222.4	0.0	0.0	222.4	2446.3
Ranagram	20	1389.2	338.8	1728.0	80.4	138.9	0.0	0.0	138.9	1589.1
Kalgram	20	600.5	105.3	705.7	85.1	60.1	0.0	0.0	60.1	645.7
Surkhali	20	1950.4	150.5	2100.9	92.8	195.0	0.0	0.0	195.0	1905.9
Dafarpur	20	2599.8	1633.1	4232.9	61.4	260.0	0.0	0.0	260.0	3972.9
Raghupur	20	495.2	255.0	750.2	66.0	49.5	0.0	0.0	49.5	700.7
Rajdharpur	20	1341.8	733.2	2074.9	64.7	134.2	0.0	0.0	134.2	1940.8
Jakina	25	444.8	303.2	748.0	59.5	44.5	22.2	0.0	66.7	681.3
Balichuna	25	510.0	120.1	630.1	80.9	51.0	25.5	0.0	76.5	553.6
Ibrahimpur	25	644.9	391.4	1036.4	62.2	64.5	32.3	0.0	96.7	939.6
Mamudpur	25	454.4	7.4	461.8	98.4	45.4	22.7	0.0	68.2	393.7
Dakhin Gopinathpur	25	1161.6	71.2	1232.8	94.2	116.2	58.1	0.0	174.3	1058.6
Amjua	25	810.3	0.0	810.3	100.0	81.0	40.5	0.0	121.5	688.7
Indrani	25	2379.6	37.1	2416.7	98.5	238.0	119.0	0.0	356.9	2059.7
Talbona	35	541.2	14.8	556.0	97.3	0.0	54.1	27.1	81.2	474.8
Mandra	35	559.0	215.0	773.9	72.2	0.0	55.9	28.0	83.8	690.1

Computed from the Google Earth, Census of India (2011) and field data (2017-2019)

Table: Distribution of income among floriculture and traditional crops

Village	Income tuberose (INR)	Income from Rose (INR)	Income from Marigold (INR)	Total income from floriculture (INR)	Income from traditional crops (INR)	Total income from Floriculture and traditional crops (INR)
Sijgram	1779156	0	0	1779156	931115	2710271
Ranagram	1111379	0	0	1111379	589285	1700664
Kalgram	480372	0	0	480372	233280	713652
Surkhali	1560320	0	0	1560320	667480	2227799
Dafarpur	2079833	0	0	2079833	1619772	3699606
Raghupur	396159	0	0	396159	315311	711470
Rajdharpur	1073424	0	0	1073424	600236	1673660
Jakina	355831	133437	0	489268	270286	759554
Balichuna	408020	153007	0	561027	193765	754792
Ibrahimpur	515955	193483	0	709438	361356	1070795
Mamudpur	363541	136328	0	499869	157470	657339
Dakhin Gopinathpur	929312	348492	0	1277805	571921	1849726
Amjua	648206	243077	0	891283	313429	1204712
Indrani	1903697	713886	0	2617583	988850	3606434
Talbona	0	324696	108232	432928	148860	581788
Mandra	0	335371	111790	447161	248753	695915

Source: Computed from the Google Earth, Census of India (2011) and field data (2017-2019)

- The study hence proposes that those villages having at least 50 bigha land with irrigation as an estimate of 10 % of the total irrigated land may opt for agriculture .
- It is observed that there is a huge gap between the income generated from the traditional crops and the proposed floriculture

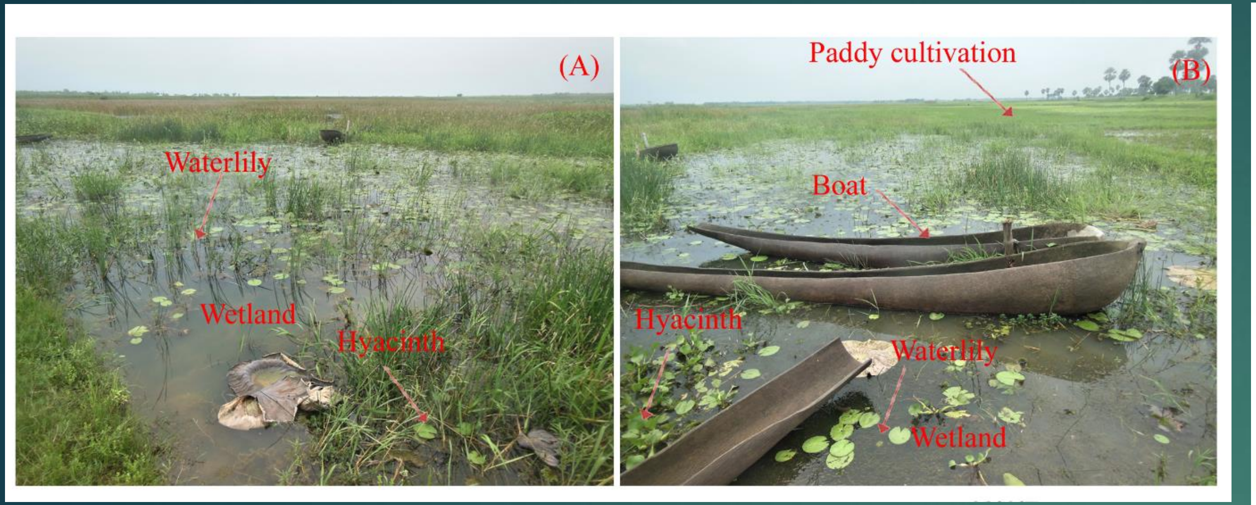
Table: Estimated Agricultural income differential and number of households to be supported with a minimum income

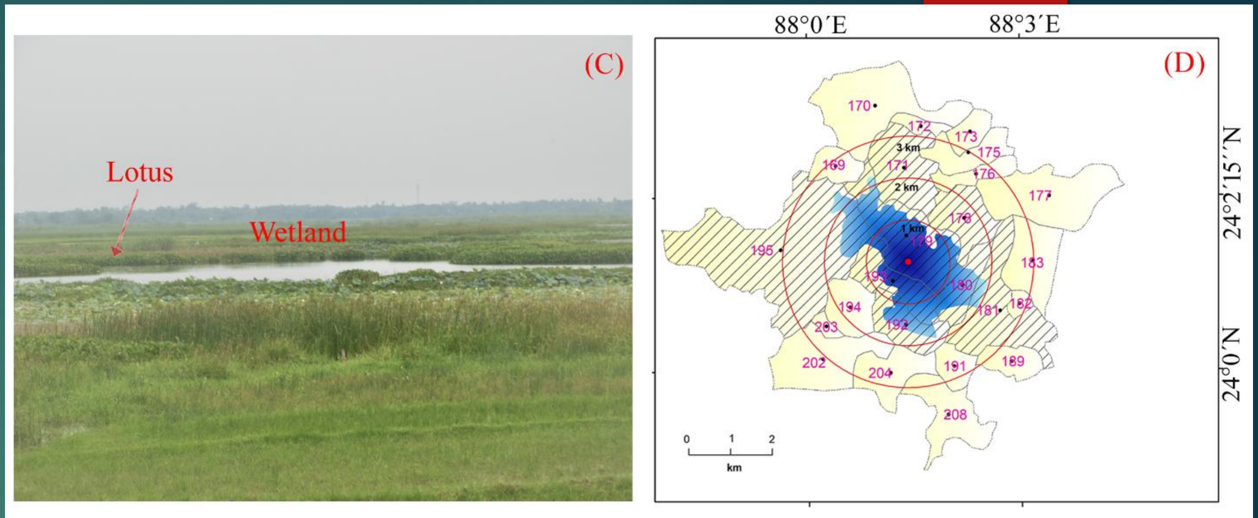
Village	Existing agricultural income per bigha (INR)	Proposed agriculture income Per bigha from (INR)	Agricultural income differential per bigha (INR)	Number of households to be supported by the income of INR 6000	Number of total households
Sijgram	381	1016	635	271	1185
Ranagram	371	984	613	170	445
Kalgram	361	1011	650	71	401
Surkhali	350	1060	710	223	801
Dafarpur	408	874	466	370	1228
Raghupur	450	948	498	71	459
Rajdharpur	309	807	497	167	746
Jakina	397	1015	619	76	95
Balichuna	350	1198	848	75	75
Ibrahimpur	385	1033	649	107	195
Mamudpur	400	1423	1023	66	90
Dakhin Gopinathpur	540	1500	960	185	208
Amjua	455	1487	1032	120	392
Indrani	480	1492	1012	361	1885
Talbona	314	1046	733	58	69
Mandra	360	899	539	70	320

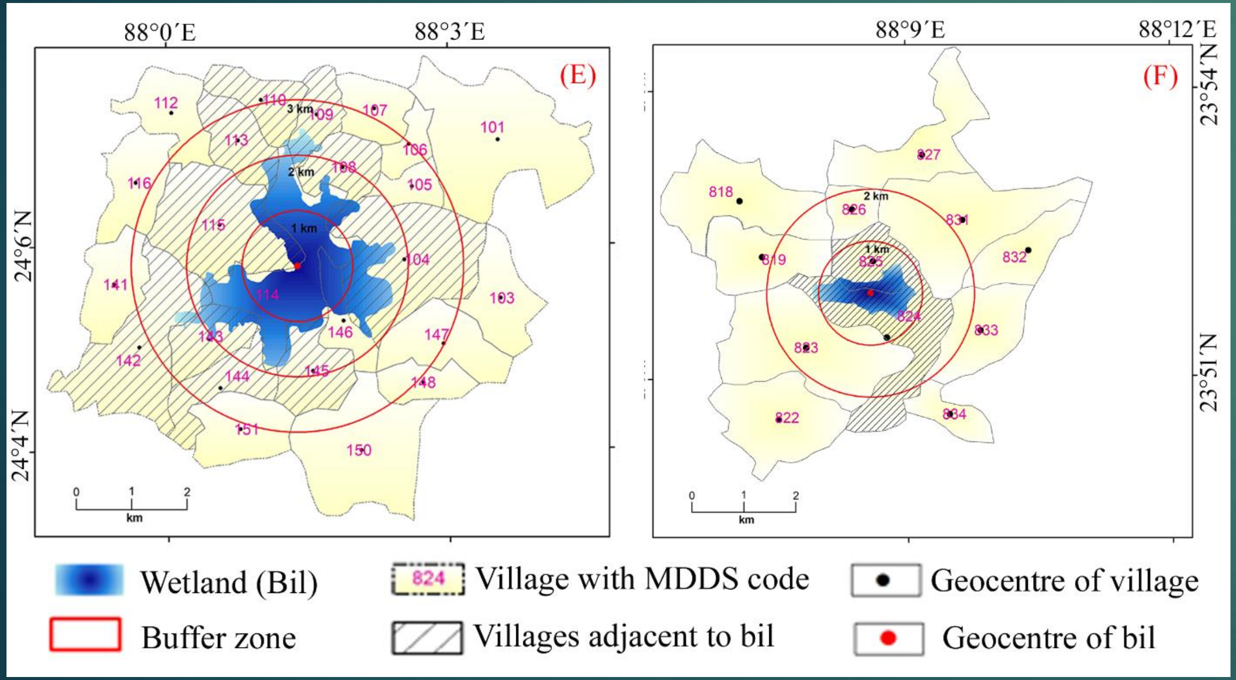
- The income differential (per bigha per month) is about INR 3450 to INR 3700 for raising marigold, about INR 5450 to INR 5700 for rose and about INR 7450 to INR 7700 for tuber rose.

- This income differential may act as the stimulus to change their choice in crop selection. Taking the account of households in the respective villages it is observed that with the support of monthly income about INR 6000 a good number of households ranging from about 18 % of the total households (Ranagram) to 100% (Balichuna) may be gainfully employed in the local economy

Fishing in Wetlands







- To save the economy, fishing could be another option as the area is characterized by huge *bil* (palaeo channel area).

- For example formula of 20:40:40 may be adopted i.e. 20% of the costs to be borne by the fisherman, 40% to be taken as loan from Bandhan bank or similar organization and the rest to be given by the Govt. The second problem is a serious issue because the huge *bil* area is disputed in terms of its ownership.

Fig. Nature of the present fishing in the wetlands, A. Waterlily and hyacinth occupying Belun Bil near Durgarampur village due to lack of care, B. Small boat used for fishing and paddy cultivation at the edge of Belun Bil near Durgarampur village, C. Large segment of Patan Bil near Kalgram covered by lotus, D. Buffering for Patan Bil and adjacent villages, E. Buffering for Belun Bil and adjacent villages, F. Buffering for Kurul Bil and adjacent villages

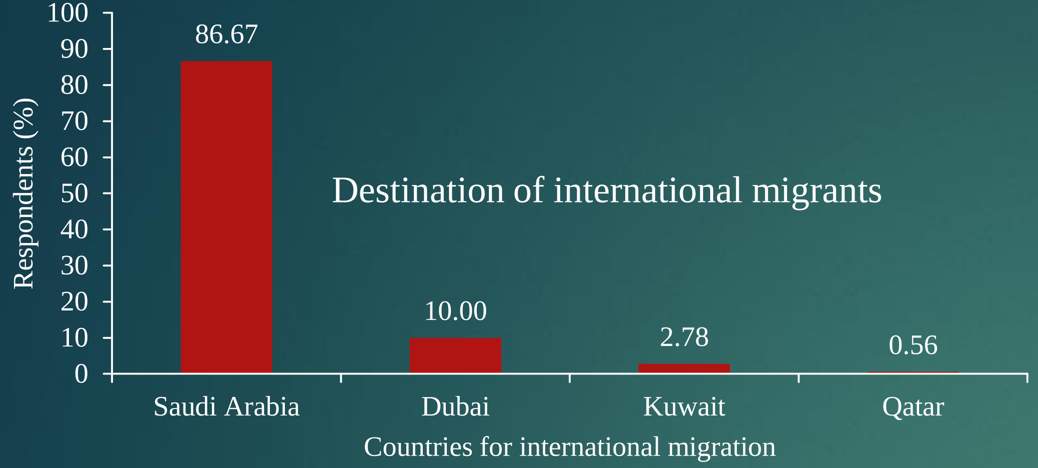
Table: Estimate of the potential fishing area, monthly profit and number of households to be supported by providing a minimum income of INR 6000 per month

Parameters	Patan Bil	Belun Bil	Kurul Bil
Total Wetland available for fishing (Acre)	1496	1532	261
Total profit from fishing of 1 acre (INR)	32219	32219	32219
Total Profit (INR)	48199624	49359508	8409159
Total Monthly Profit (INR)	4016635	4113292	700763
Minimum support income (INR)	6000	6000	6000
Number of households to be supported	669	686	117
Number of villages adjacent to Bil proposed to be supported under fishing	7	9	2

- After the preliminary scrutiny, it appears that the *bil* areas contain water throughout the year. As per the study conducted by the Dandapat and Islam (2009), fishing per acre per annum may generate a profit of about INR 32,219 at current price level (base year 2001 and the multiplying factor 3.19 as on July 2019 as per the consumer price index, Labour Bureau, Govt. of India) and the demand for fish in the local market is adequate.

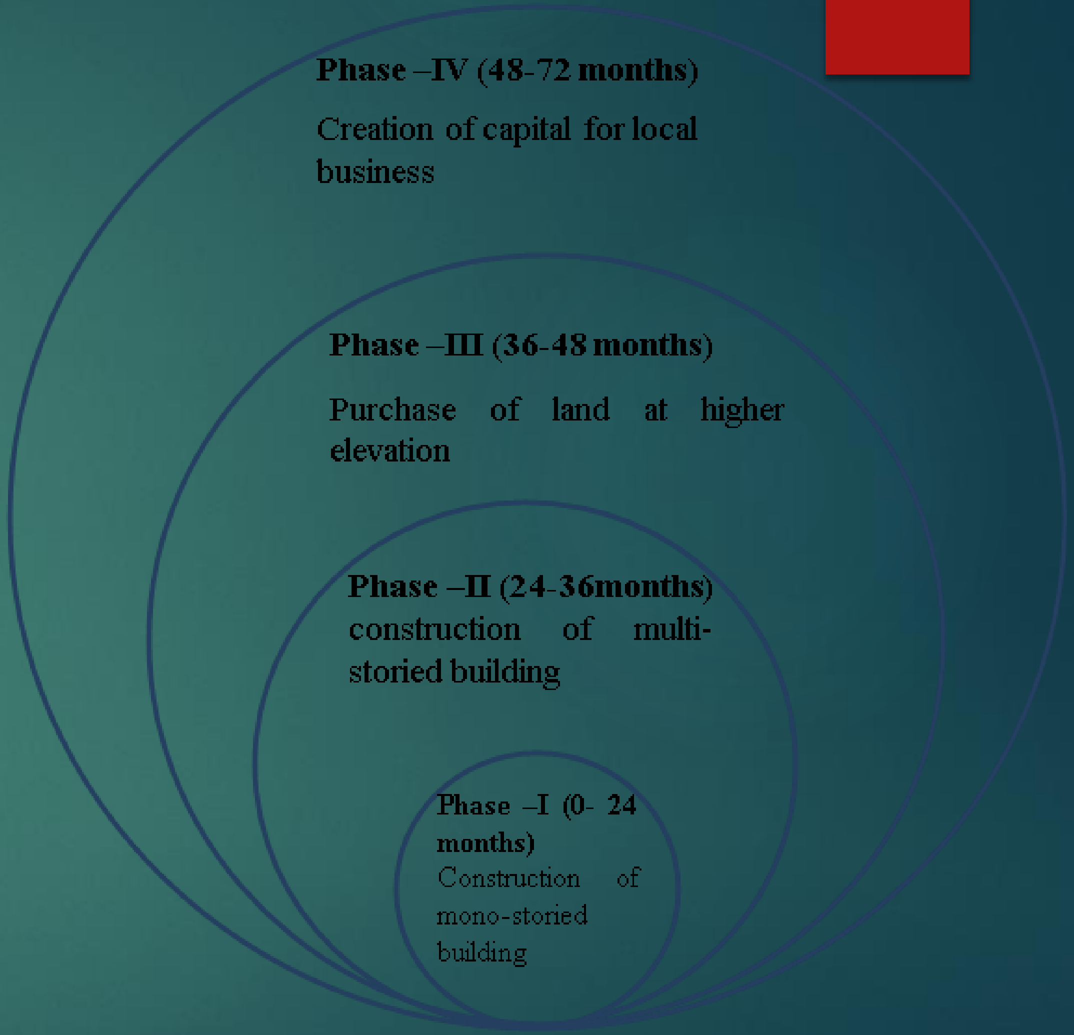
- Thus, fishing in these areas may generate a profit of about INR 4,81,99,624 for Patan *bil*, INR 4,93,59,508 for Belun *bil*, and INR 8,40,9159 for Kurul bil which may support at least 669 families in and around the Patan bil, 686 families for Belun *bil*, 117 families around Kurul respectively. The field survey suggested that the people in and around are ready for fishing in the bil area.

Model of labour migration and multiplier effects



	Hindu villages /wards	Hindu dominated villages/wards	Muslim villages/wards	Muslim dominated villages/wards	Total
Total Sample villages	18	10	5	12	45
Villages receiving remittances	7	5	3	9	24
Villages receiving remittances (%)	38.89	50.00	60.00	75.00	53.33
Total sample households	798	550	301	900	2549
Households receiving remittances	19	49	66	189	323
Households receiving remittances (%)	2.38	8.91	21.93	21.00	12.67

Labour migration and remittance across the different religious communities



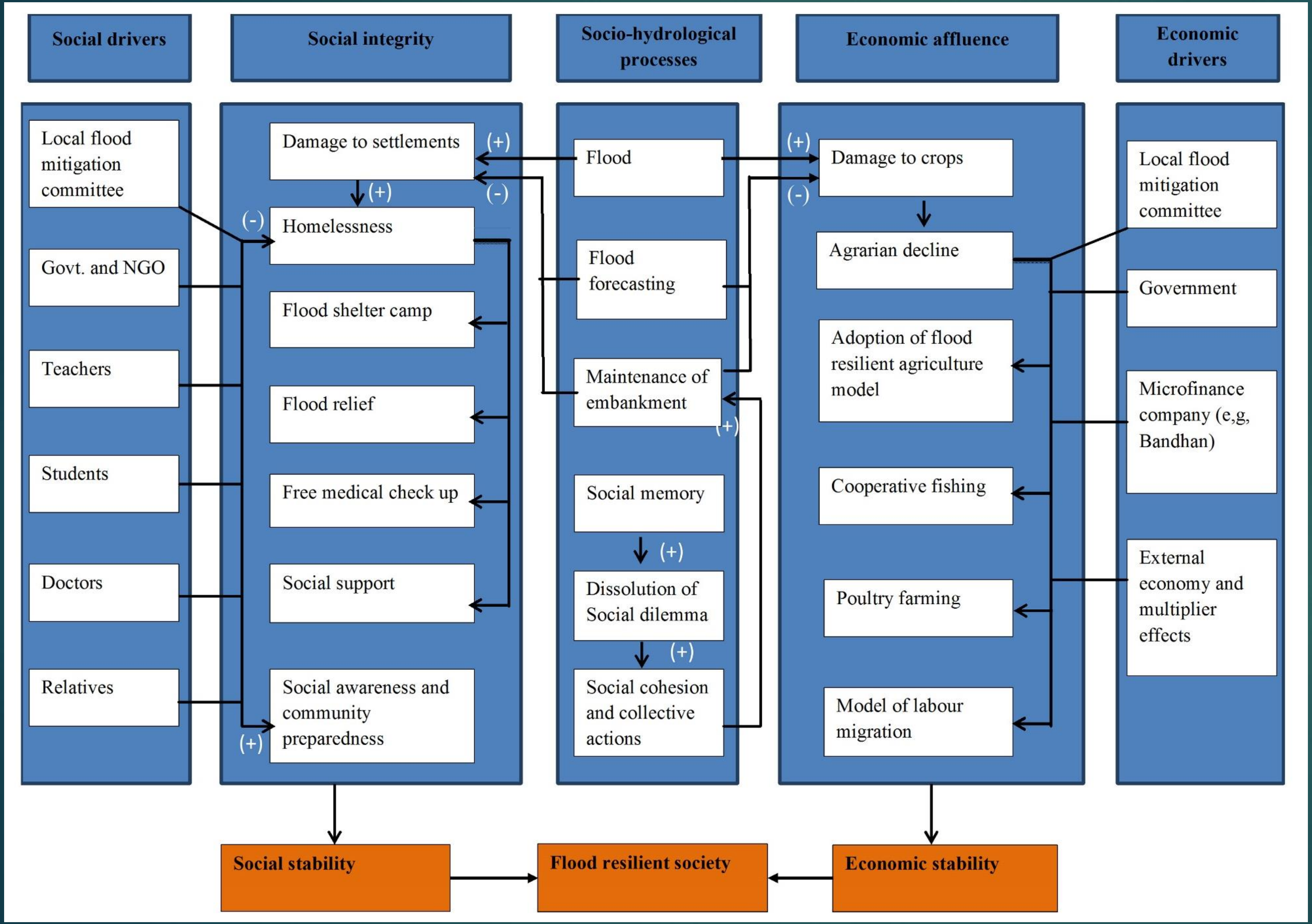
One interesting feature is that flood hazard has created a bond among the different groups of people. The field study shows that labour migrants generally follow a cycle of about 6 years. Within the 1-2 years they construct mono-storied building which is upgraded to the multi-storied in the following 1-2 years

Table: Estimation of simple multiplier due to receipt of remittance

Villages/Wards	Number of sample Households	Total households drawing remittance	% households drawing remittance	Per capita Remittances	Per capita savings on remittances	per capita expenditure	Marginal propensity to consume (MPC)	Marginal Propensity to Save (1-MPC)	Simple Multiplier
Jhajhra	36	2	5.56	3600	198	3402	0.945	0.055	18.2
Sarbbamangalpur	24	3	12.5	4000	228	3772	0.943	0.057	17.5
Goai	30	1	3.33	2750	215	2535	0.922	0.078	12.8
Haripur	76	3	3.95	4083	237	3846	0.942	0.058	17.2
DakshinGopinathpur	42	8	19.05	5375	279	5096	0.948	0.052	19.3
Mamudpur	27	3	11.11	2750	199	2551	0.928	0.072	13.8
Dafarpur	128	3	2.34	3853	268	3585	0.93	0.07	14.4
Amjua	40	2	5	3600	190	3410	0.947	0.053	18.9
Andulia-I	40	8	20	2560	190	2370	0.926	0.074	13.5
Kolla	48	4	8.33	3000	194	2806	0.935	0.065	15.5
Kasipur	50	6	12	3300	220	3080	0.933	0.067	15
K-13	94	18	19.15	3750	222	3528	0.941	0.059	16.9
Srikanthapur	89	3	3.37	2947	242	2705	0.918	0.082	12.2
Ibrahimpur	40	8	20	2000	180	1820	0.91	0.09	11.1
Surkhali	80	8	10	5000	272	4728	0.946	0.054	18.4
Raghupur	44	5	11.36	2933	194	2739	0.934	0.066	15.1
Titidanga	44	9	20.45	3208	202	3006	0.937	0.063	15.9
Indrani	188	10	5.32	4105	249	3856	0.939	0.061	16.5
Purandarpur	105	11	10.48	3625	263	3362	0.927	0.073	13.8
Hijal	165	81	49.09	3270	244	3026	0.925	0.075	13.4
Sashpara	75	28	37.33	3800	206	3594	0.946	0.054	18.4
Harinagar	27	8	29.63	3310	181	3129	0.945	0.055	18.3
Sijgram	59	4	6.78	3343	230	3113	0.931	0.069	14.5
K-8	73	11	15.07	3333	213	3120	0.936	0.064	15.6

The field investigation shows that due to the receipt of the remittance there is a huge scope for economic booming based on multiplier of spending. In other words, it may be argued that this booming is due to the minimum savings of around INR 200 per capita per month while the expenditure is around INR 3000-5000. In the study area, the economic multiplier in most of the villages is more than 10 while the highest has appeared up to 20 in Dakshin Gopinathur signaling the huge growth of the economy

Flood-society cohesion model



Societal development instead of mere economic development is the ultimate goal of this chapter. Thus, finally considering the perspective of the broader society, a flood-society cohesion model has been proposed where five major pillars are taken into account. They are social drivers, social integrity, socio-hydrological processes, economic affluence and economic drivers.

The social drivers include the local flood mitigation committee, Government and NGO, teachers, students, doctors, and relatives while the economic drivers are constituted by the external economy, micro-finance in addition to the role played by Government and flood mitigation committee. The social drivers aim to attain social integrity while the economic drivers target economic affluence of the society.

The most important part of this model is socio-hydrological process. Here, in socio-hydrological processes considered are flood, flood forecasting, and maintenance of embankment, social memory, social dilemma, and social cohesion. Flood poses a threat to the settlement and crops.

social cohesion is achieved through the bond of the individuals and communities i.e. the intra-group and inter-group social cohesion.


Thank you