Chapter 14
An Account of the Flood History in the Ghatal Region of West Bengal, India

Sayoni Mondal and Priyank Pravin Patel

Abstract Floods, being the most common natural disaster, affect millions of people worldwide. Out of 3290 lakh hectare (3,290,000 km^2) land area in India, 40 million hectares have been declared as flood prone, with an annual average of 75 lakh hectares being affected, either directly or indirectly. West Bengal is considered as one of the most flood-prone states in India, with its southern portion being severely affected by floods annually. Although natural factors are probably the usual causes of floods, the Silabati (also called Silai) River basin, near its mouth in the vicinity of Ghatal town of Paschim Medinipur district, experiences annual flooding partly due to its regional setting within the subdued Bengal fan, while much of the inundation here occurs due to direct anthropogenic interventions into the channel and the floodplain. The various natural and anthropogenic causes of flooding in the region have been explained in this study with a special emphasis on the embankment circuits of the area that make the river flow constrained, thereby causing siltation and rising of the river bed with resultant flooding. An analysis of the extent, recurrence and duration of flooding in the region has also been done to highlight the severity of the event and the annual suffering of the resident communities in the region. The formulation of the Ghatal Master Plan in the region has not been much of a success, with non-structural mitigation measures being a viable means to reduce floods in the region.

Keywords Flood · Inundation · Ghatal Master Plan · Embankment circuit · Anthropogenic intervention

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1 Introduction

Floods have been identified as the single most harmful natural disaster affecting economies worldwide (Borrows & Bruin, 2006). Annually, about 170 million people get afflicted by floods (Das, 2019), with the United Nations reporting that nearly 2.3 billion people were affected, with 157,000 recorded deaths due to flooding, from 1995 to 2015 (Hoque et al., 2019). Out of 3290 lakh hectare (3,290,000 km^2) land area in India, 40 million hectares have been declared as flood prone, with an annual average of 75 lakh hectares being affected, either directly or indirectly (Gangwar, 2013). Their causative natural factors comprise of catchment hydrology and physiography-related attributes like the general elevation and slope of the region, soil type, precipitation received and land-use pattern, all of which determine the susceptibility level of a region to floods (Blistanova et al., 2016; Sahana & Patel, 2019). Although the average frequency of flood events is 2.33 years (Leopold et al., 1964), such events have severely increased in recent years due to global issues like climate change, rapid urbanisation and poor river management programmes (Das, 2019). Floods have also occurred due to marked land cover/use changes within river corridors (cf. Banerji & Patel, 2019) due to faulty agricultural practices and the resultant siltation of active channels consequent upon their degradation, which have been progressively constrained by embankments to enable infrastructural development (Mondal et al., 2016; Patel et al., 2020; Sahana et al., 2020). Big floods can potentially set back development goals and hamper economic development in any region (Patel & Dasgupta, 2009), and thus flood hazard preparedness and management has been the most obvious way of combating such disasters (Behanzin et al., 2015).

2 Locational Setting and Causes of Flood in the Ghatal Region

West Bengal is one of the most flood-prone states in India, with almost 42% of its geographical area being affected by floods every year. Ghatal Block in Paschim Medinipur District is one of the most flood-affected regions of the state, experiencing annual flooding (Mitra & De, 2016). This region is part of the Bengal Basin and resembles a subdued fan system that is characterised by palaeo-deltas, which merge with the oldest part of the Ganga delta further east (Kar & Das, 2020). As such, the Silai River (also called Silabati River) in this section shows a sudden decline in its channel gradient, which is also reflected in the river's high sinuosity and thereby its marked erosion of its banks in its middle and lower courses (Naskar & Patel, 2019).

From a hydrological viewpoint, watersheds like the Silai (that are situated in transition zones straddling both plateau fringes and alluvial plains) are sensitive to short-duration high-intensity rainfall events and land-use changes and show a more pronounced effect of overland flow in causing floods (Sahoo & Sivaramakrishnan, 2014). The average elevation in the lower part of the Silai basin ranges between 9 and 11 m, while it is even less near the river's mouth further to the south-east, where it is just 4–5 m around the confluence of the Silai with the Darakeswar. This lowland landscape enables annual water stagnation during the monsoon, which is exacerbated by voluminous run-off from the upland tracts of the Silai and tidal ingress into the Rupnarayan that retards floodwater outflow. The critical physiographic location of the block forms a closed area surrounded by rivers on all sides, with the Silai and the Old Cossye in the south and south-east, respectively, and the Darakeswar and its tributary, the Jhumi, in the north and north-east (Mitra & De, 2016). Ghatal Block gets inundated two to three times in a single monsoon, and a little excess rainfall compared to the normal scenario creates a flood-like situation.

3 Disrupted Rivers and Embankments

Ghatal Block is further criss-crossed by a number of smaller tributaries and distributaries of the Silai, which join/rejoin the main river and drain a significant amount of its discharge during the monsoon (Fig. 14.1). The Ketia Khal, a distributary of the Silai, emerges from the main channel near Nischintapur village. It flows almost parallel to the main channel for a considerable distance before the off-take of the Katan Khal (a human-made canal) from it. Both these channels join the main Silai further downstream, near Surajnagar. The Ketia carries almost 80% of the monsoonal flow of the main channel. The Parang, Tamal, Kubai, Donai and Buriganga are some of the notable right bank tributaries of the Silai that augment its total discharge, which ultimately accumulates near Ghatal town, causing floods. A small distributary of the Old Cossye River, the Kanki Khal, also links up with the main Silai during heavy rains when the main Kangsabati channel overflows and contributes additional discharge (WAPCOS Limited, 2009). Similar conditions prevail on the left bank of the channel, where the Darakeswar and Jhumi join the Silai to form the Rupnarayan, downstream of Ghatal town.

Within the above locational and topographic setting, the mean annual rainfall of 153–155 cm between June and September often causes floods (Fig. 14.2), with meander shifting induced bank erosion occurring concurrently (Pal, 2014). The situation is worsened by the haphazard network of high embankments along these channels (Kar & Das, 2020) that restrict channel-floodplain connectivity. These were constructed to safeguard valuable agricultural lands from flood spills (Kar & Das, 2020) but were hardly built taking the morphological, hydraulic and geotechnical attributes of the rivers into consideration (Pal, 2014). The ensuing siltation of the river bed due to in-stream deposition of the considerable sediment volume derived via soil loss from the upstream areas has caused the river to rise and flow on a more elevated level than the surrounding region (i.e. through convex floodplains, which are typical of any deltaic lowlands), with multiple instances of embankment breaching and bank overtopping causing sustained floods and waterlogging in the region as the excess water cannot easily drain back to the channel and gets stagnated

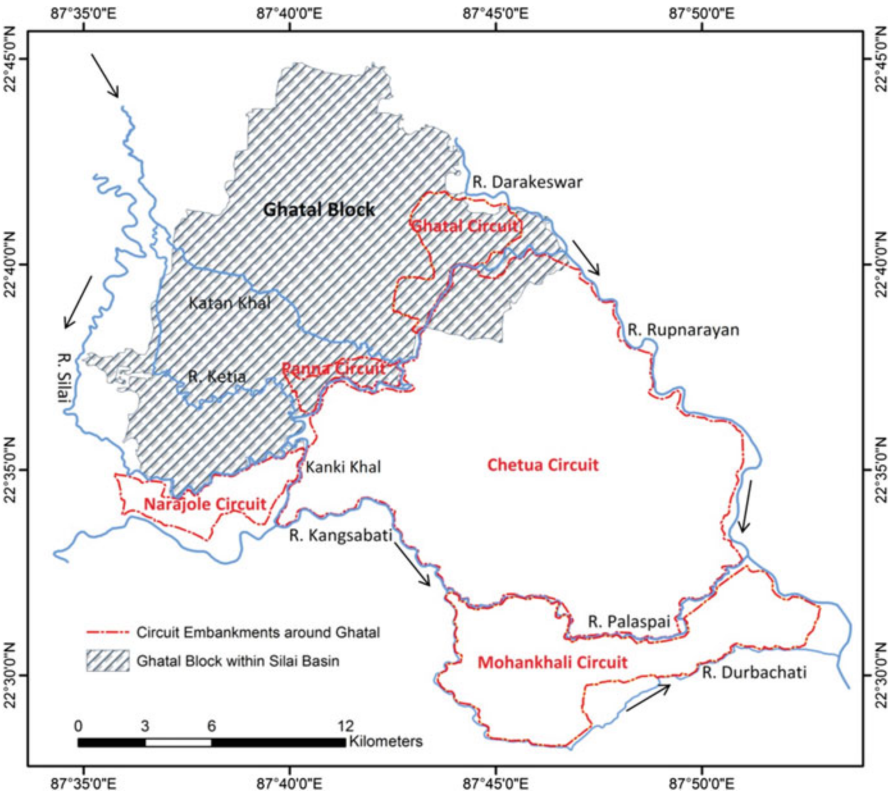

Fig. 14.1 Location of Ghatal Block, with its drainage system and embankment circuits

for around 2–3 months (Das & Bandyopadhya, 2015). An increase in the impervious urbanised area in the lower Silai basin from 14.2 km^2 in 1971 to 25.6 km^2 in 2005 to almost 37.5 km^2 in 2014 has also feasibly contributed towards greater run-off (Pal, 2014).

A number of embankment circuits are still present in the region, such as the abandoned Ghatal and Panna circuit on the left bank of the river, whereas the functional Chetua circuit and the abandoned Narajole circuit are on the right flank. These abandoned circuits are locally called *Chatal* and are a quite levelled strip of land that serve as the main transport route during the monsoon when they are used as flood causeways as the main roads get submerged. The functional Chetua circuit embankment on the right bank protects that side from inundation and thus diverts the overflowing discharge onto the left bank where the abandoned circuits are usually unable to restrict such high flows within the Silai-Darakeswar interfluve (Kar & Das, 2020). Further explanations of the other causes and effects of floods in this region have been documented by Dolui and Ghosh (2013).

Along with embankment breaches, riverbank erosion has been another cause of concern in the lower reaches. Non-cohesive bank materials initiate rotational

Fig. 14.2 Flood inundation in and around Ghatal town (**a**) Ghatal municipality office, (**b**) Ghatal bridge, (**c**) inundated land near the Bhasapool (wooden bridge across the river) and (**d**) houses built on bamboo poles/canes to raise their height above the water surface). (Source: Ghatal Municipality)

failures, while slab or block failures are prominent in regions having cohesive banks (Pal, 2014). Bank toe scouring and undercutting increase bank steepness, which further triggers bank erosion and instability in regions buffeted by the greater hydraulic force of floodwaters. The thalweg orientation and the location of depositional sandbars affect the severity of riverbank erosion in the region, along with the low gradient and high sinuosity of the channel in the lower course (Pal, 2014). A viable proposal for mitigating the above and also reducing the possible severity of the occurring floods has been proper river channel and riparian zone management using nature-based principles such as live vegetation buffers (Mondal & Patel, 2018) and complete hydromorphological assessments of the river network (Mondal & Patel, 2022).

4 Documenting the Near-Annual Flood Phenomenon in Ghatal

The Ghatal Master Plan (GMP), which was formulated in 1976 with the noble objective of restoring the economic, social and commercial viability of the region, identified 1270 km^2 area out of the total area of 1659 km^2 of the GMP as flood prone, with the most affected central, eastern and southern parts covering an area of

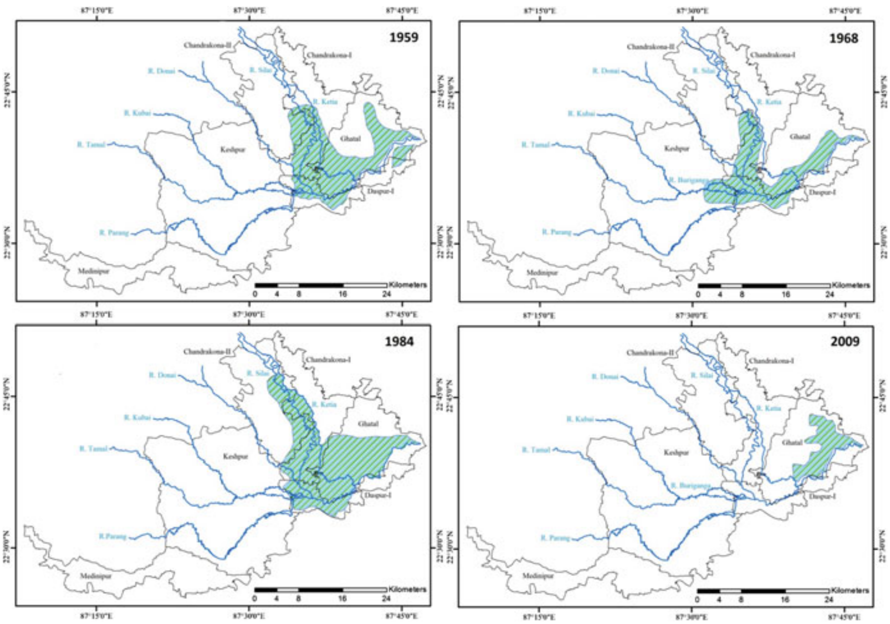

Fig. 14.3 Historical flood inundation extent maps of the lower Silai basin area around Ghatal. (Source: Ghatal Municipality)

793 km^2 and being spread across Chandrakona-I, Chandrakona-II, Daspur-I and Ghatal Blocks (WAPCOS Limited, 2009). Almost the entire lower course of the Silabati River, mostly in the vicinity of Banka, Khirpai, Rashikganj, Surajnagar and the towns of Chandrakona and Ghatal, gets inundated annually, and historical flood maps have been used to identify such zones (Fig. 14.3). The flood situation in Ghatal town is even more grim, with 12 out of its 17 wards being declared as fully flood prone, most of which are located on the left bank.

The inundation history and flood depth in the area reveal the degree of devastation caused (Table 14.1). Daspur-I Block, which is affected by floods each year, recorded an annual crop damage worth approximately Rs. 4.12 crores in 2011 alone (Mal & Mandal, 2013). The GMP had an initial plan of multipurpose flood management strategies like construction of new embankments on the left bank of the Silai from Banka to Bandar for a length of 42 km, resuscitation of existing streams and palaeochannels, construction of new river sluices, augmenting the river carrying capacity, framing regulations and flood proofing for floodplain development and improvement of the overall drainage network in the region. However, over time, this overambitious project has taken a go-slow attitude, with the result that the misery and distress of the resident community continues to prevail and may increase in the coming years.

A detailed picture of the socio-economic vulnerability of the region to floods has been portrayed by Sahoo and Sivaramakrishnan (2014), highlighting the various

Table 14.1 Inundation and damages caused due to flooding in Ghatal Block

Year of flood	Inundation for more than a month		Inundation for more than 15 days		Total damage (Lakh rupees)
	Area submerged (km^2)	Flood depth (m)	Area submerged (km^2)	Flood depth (m)	
1959	100.0	2.0	184	1.5	Not available
1967	100.0	2.5	69.3	1.5	Not available
1968	350.0	2.5	307.64	2.0	Not available
1973	208.0	3.0	150	2.0	247.64
1974	61.0	3.0	102.83	2.0	191.85
1975	104.0	2.5	110	2.0	309.50
1976	55.17	2.5	108	2.0	52.79
1977	100.0	3.5	130	2.0	1361.92
1978	710.0	3.5	356	2.0	5174.19
1999	78.39.0	3.0	100	2.0	8585.34
2000	80.0	3.0	120.85	2.0	16313.09
2007	232.5	3.0	400	2.0	49923.05
2013	200.0	3.0	125	2.0	4515.70
2015	700.0	3.5	330	2.0	10000.0

Source: Ghatal Municipality

flood adaptability measures and coping strategies of the local residents. With floods being an annual event in the region and about 65% of the population getting affected at least once every year, the local cultivation pattern has also undergone changes, with people shifting to *rabi* crops for sustenance and avoiding *kharif* crops. Almost 70% of the residents are directly or indirectly dependent on agriculture, and most plots are intensively cultivated following a double-cropping pattern for vegetables during winter. Since the majority of the area remains waterlogged even after the monsoon, inhabitants temporarily resort to pisciculture during that period (Sahoo & Sivaramakrishnan, 2014). Local household adaptation measures followed here include raising the house plinth levels, using landfill materials to raise the floor base, building stairs up to the raised floor level from the ground (Pater, 2018) and constructing homes on strong pillars to allow complete security and protection from higher flood events (cf. NOAA, 2012).

Comprehensive flood management therefore requires detailed information regarding all aspects of flooding, i.e. hydrological, physiographical, geotechnical, economic, social as well as political (Tehrany et al., 2014; Mondal & Patel, 2021). With forecasting and early warning being the only strategy to reduce its ill effects, flood management programmes should aim to identify areas that are more susceptible to flooding so that early warning can significantly reduce the chaos caused (Sahana & Patel, 2019). Here, the flood-susceptible zones were identified using the flood extent maps obtained from the European Commission Joint Research Centre's Global Surface Water dataset (Pekel et al., 2016) that accurately identifies the flood-affected tracts in the region.

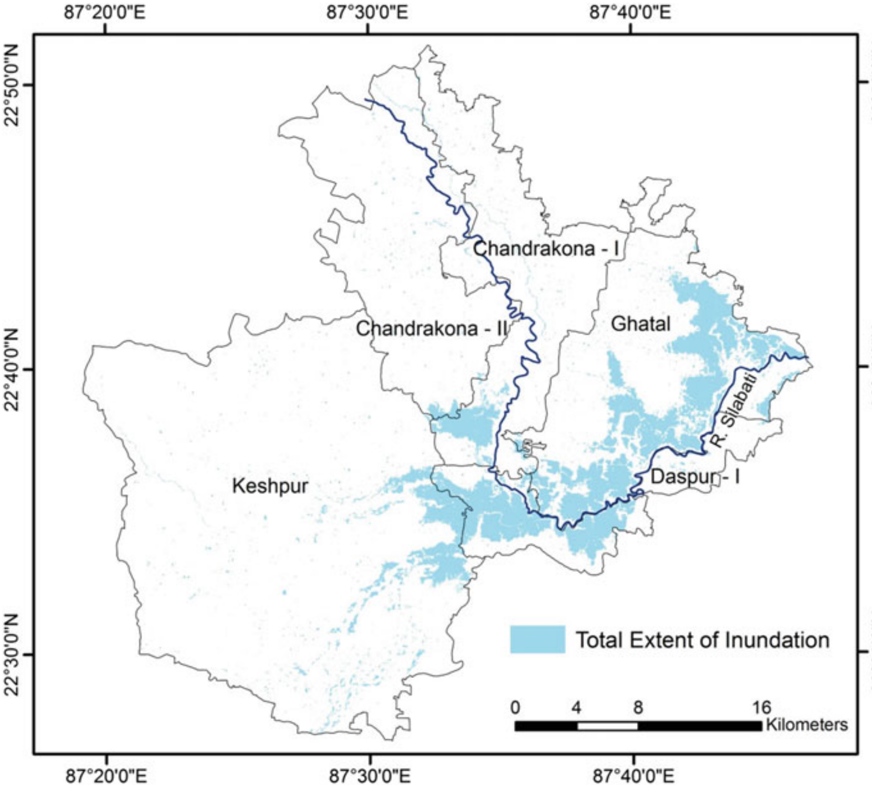

Fig. 14.4 Flood inundation extent in the downstream section of the Silai River (1985–2020). (Source: Global Surface Water dataset (see Pekel et al., 2016, for details))

Almost the entirety of Ghatal Block on the left bank of the Silai is flood prone (Fig. 14.4), with the right bank being far less affected due to the presence of the Chetua circuit embankment along the southern part of Daspur-I Block, which also covers parts of Keshpur Block. Similar patterns have been captured in the Google Earth imagery showing more or less exact inundation extents that occurred in the 2009 flood which devastated the region quite severely (see Fig. 14.8). While the flood recurrence map shows the frequency with which water gets stranded in the extreme low-lying parts of the region, explaining the inter-annual variability in the presence of water (Fig. 14.5), the flood seasonality map (Fig. 14.6) shows the duration for which water usually stagnates herein, and this in turn determines the temporal change in land use and occupation structure as this stranded, sediment-free water enables pisciculture as the only means of sustenance in the aftermath of floods. Much of the region on the left bank receives at least a month of inundation, with low-lying zones experiencing water accumulating for longer duration. Another parameter of utmost importance here is the flood transition map (Fig. 14.7), which depicts the change in seasonality of the three main water classes (viz. permanent water, seasonal

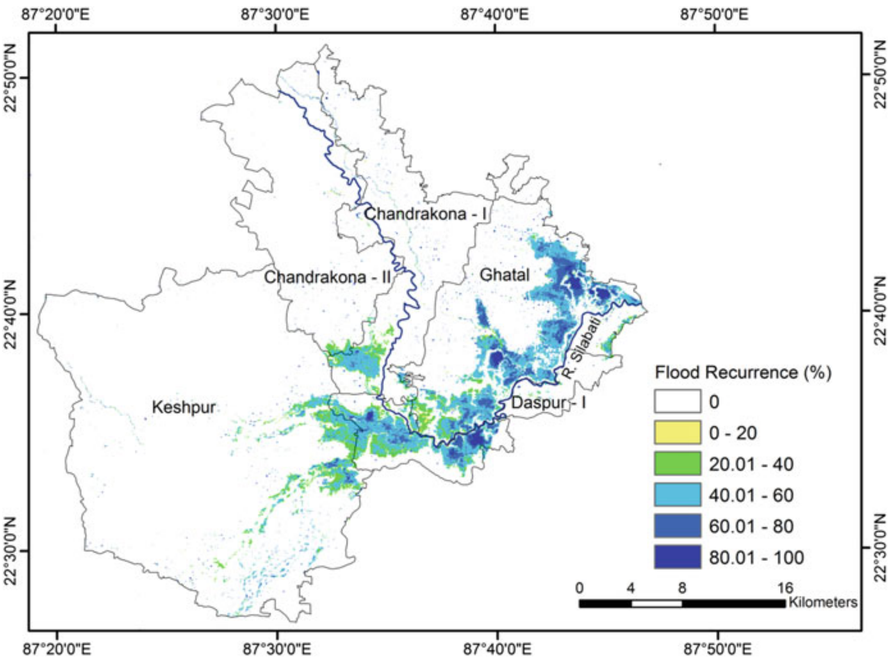

Fig. 14.5 Percentage of flood recurrence in the flood-affected region (1985–2020). (Source: Global Surface Water dataset (see Pekel et al., 2016, for details))

water and no water) in the region. Although no new parcel of land has been declared as permanently flood affected in the region in the examined time frame of this dataset (1985–2016 and extended up to 2020), the percentage of seasonal water coverage has increased, with new seasonal water surfaces cropping up and indicating a conversion of land into seasonal water and also conversion of water back into land surfaces, which denotes continued inundation depending on the severity of the monsoon.

Therefore, it is apparent that although the GMP had been prepared in accordance with the flooding issues prevalent in the region, such occurrences continue unabated, with attendant riverbank erosion. The lack of a secure and long-term flood management strategy still remains a problem, and questions on sustainable strategies to create resilience among such communities are seldom addressed in any flood management plan (Pater, 2018). The overemphasis on structural mitigation methods (river embankments and riprap boulders) has in many instances led to scenarios where these techniques have drastically failed, putting the efficacy of structural methods (given their high cost and adverse ecological impacts) under scrutiny. Quite recently, with the central policy on flood mitigation shifting from controlling to managing floods (NITI Aayog, 2021; PTI, 2021), non-structural methods (using live vegetation buffers to arrest high flood velocities) have been attempted,

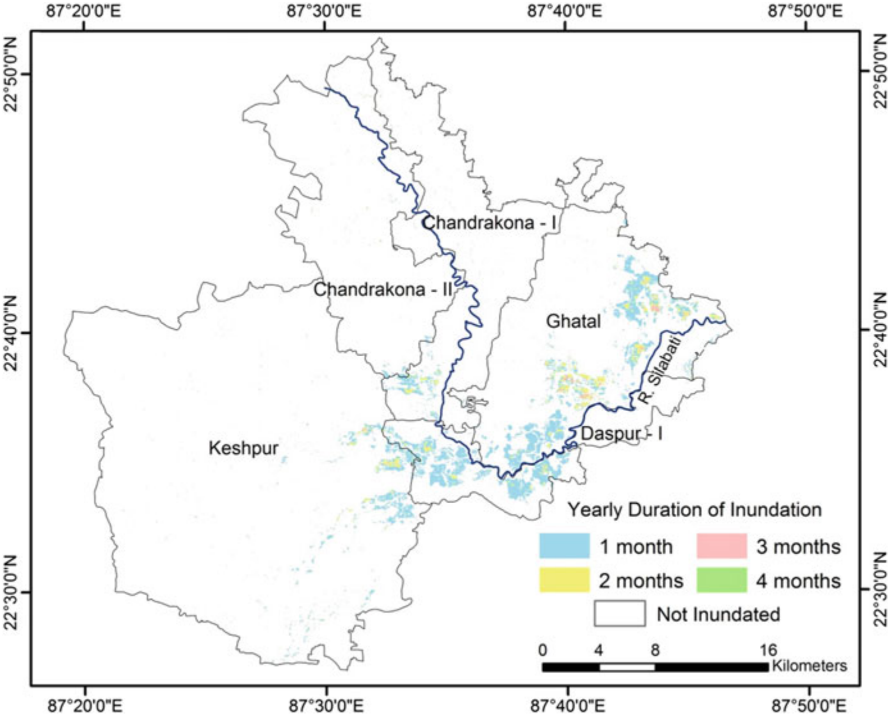

Fig. 14.6 Yearly inundation duration in the flood-affected reaches (1985–2020). (Source: Global Surface Water dataset (see Pekel et al., 2016, for details))

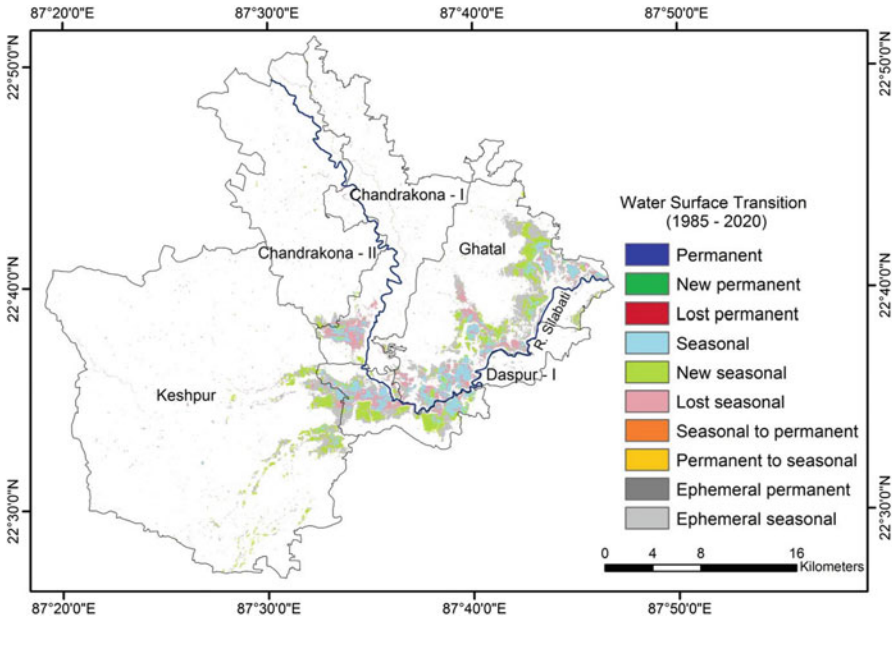

Fig. 14.7 Water surface transition from one land use class to another in flooded areas (1985–2020). (Source: Global Surface Water dataset (see Pekel et al., 2016, for details))

Fig. 14.8 Floodwaters of the Silai inundating Ghatal town and the western flank of the river. (Source: Google Earth, Image date: 13th September, 2009)

although on a piecemeal basis to control and abate the problems of flooding and riverbank erosion in the region (e.g. Mondal & Patel, 2020).

5 Conclusion

The Ghatal flood is a near-annual phenomena that has been in play for decades. Possibly there are no viable solutions to completely eradicate its occurrence given the low-lying nature of the local topography and the region's almost saucer-like situation, with multiple rivers draining into this region along all sides. The principal inundation is caused by the rise in the waters of the Silai and its distributaries, but this is augmented by the inflow of waters from distributaries of the Kangsabati to the south and from the Darakeswar in the north. Furthermore, the tidal effect of the Rupnarayan, into which the Silai drains, can retard its outflow and enable/prolong inundation. However, this natural situation has been markedly exacerbated by the construction of multiple embankments, which have dissociated the river from its floodplain and thus taken away those locations (primarily wetlands) that once could have accommodated overspills along the channel throughout the lower course of the river. This leads to a greater volume of water reaching the mouth area of the Silai, with the consequent inundation. Alongside the flood effect, riverbank erosion and collapse are common occurrences in this stretch, with regular embankment breaching. Nature-based solutions (using live vegetation buffers and proper zoning of the riparian corridor) have been proposed to mitigate this to an extent, and these measures need to be explored and adapted further herein, given the historical failure of only the structural measure-based approach that have been adopted so far for this purpose.

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