Chapter 11
Contemporary and Future Flood Characteristics and Associated Environmental Impact: A Study of Ajay River Basin, India

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Abstract Since 1956, a prominent transformation in flood characteristics of Ajay River Basin (ARB) has been observed in terms of area affected by the flood, the number of villages affected, breaching of the embankment, sand splay over agricultural land, soil nutrients, and crop productivity through different governmental reports, articles, and map. The projected climatic data by the World Resources Institute (WRI) on the depth of flood inundation up to 2080 have been analysed and found a significant rise in future flood height and areas affected by such floods at different flood return periods. In particular, about 0.5 m increase in inundation depth has been observed in 2080 at the 2-year return period, and a maximum rise of ~2 m in 2080 at the 500-year return period. The study also assessed the non-structural measures of flood control will be more effective than embankment-like structural measures for the lower region of ARB.

Keywords Ajay River Basin · Flood depth · Embankment · Sand-splay · Return period · Climate change

1 Introduction

Flood in the Ajay River Basin (ARB) is an inevitable phenomenon since the pre-historical period, and behaviour of the basin's flood has also been changed over time (Mukhopadhyay & Mukherjee, 2005; Mukhopadhyay, 2010). Ajay basin covers almost four percentage (~690 km^2) of the total flood-prone area of West Bengal (~17,500 km^2) (Roy, 2021), spatially which is concentrated on the downstream or lower region of the ARB, in particular below the Illambazar and after the confluence point of Hinglo tributary (Mukhopadhyay, 2010). Flood history of the ARB since the 1950s reveals that the major flooding years are 1956, 1959, 1970,

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Fig. 11.1 A typical view of artificial embankment along the Ajay River near Bhedia

1971, 1973, 1978, 1984, 1995, 1999, 2000, 2005, and 2007, whereas, the most devastating experience has been observed in 1978, 1995, 1999, and 2000 (Mukhopadhyay, 2010). The economic strength of the basin area is predominantly depending on the different agricultural production, whereas, frequent floods are becoming a major problem for this region. Therefore, zamindari *bundhs* (embankments) were constructed to protect the fertile agricultural land and major settlements within the flood-prone areas (Majumdar, 1942; Mukhopadhyay, 2010). Recently, the Director of Irrigation and Waterways Department, Government of West Bengal, has made attempts to control the flood problem by repairing the old embankments and constructing new embankments, and about 10,400 km long embankment has been completed across the state (IWD-GoWB, 2019) (Fig. 11.1). In particular, a total of 136 km of embankment has been constructed along the Ajay River as of IWD-GoWB (2019), of which 81 km and 55 km are aligned along the right bank and left bank of the river, respectively (Roy, 2020).

Although, such engineering structures are failed to prevent the floods of this region and consequently welcome numerous new problems like altering channel geomorphology, increasing the flood frequency and duration of water-logged conditions particularly at the confluence zone of major tributaries, breaching of embankment and sand splay, soil fertility loss, etc. In this regard, eminent engineer Mr. S.C. Majumdar (1942) was warned about the long-term effect of embankment construction and told that the ‘construction of embankment as flood controlling measures would be like mortgaging the future generation’. The negative impacts of river regulation by embankment have been also ensured by Pethick and Orford (2013), Vlad et al. (2013), Rogers et al. (2013), and Chaudhuri et al. (2020). Rogers et al. (2013) have estimated that the mean annual sedimentation rate (2.3 cm $year^{-1}$) in and around the embanked channel of the central Ganga-Brahmaputra delta is almost two times higher than natural inter-tidal channels of Sundarbans. Chaudhuri et al. (2020) have also ensured the statement with similar findings in addition to highlighting the negative impact of embankment-induced polder land on decreasing length of the tidal channels over time; in particular, about 59% fall in drainage network has been observed in 2013 than 2003. Vlad et al. (2013) have also listed the impact of embankment on increasing floodplain soil salinity, hydrological regime, changes in floodplain land use and significant alteration of the riverine biodiversity.

Globally, the behaviours of floods have drastically changed by changing climate, shifting land use/land cover change, water abstraction of trunk rivers, construction of dams and fragmentation of channels, and different river training programmes within the drainage basin (Habersack et al., 2015). Therefore, the basin-scale future prospect of floods is essential to understand, with the integration of past flood records for sustainable flood management based on non-structure measures instead of heavy river engineering. The primary objectives of this chapter are to evaluate the history of floods and related environmental problems in ARB and also to understand the future trends of floods in climate change scenarios up to 2080 based on modelled data archive.

2 Geographical Set-up of the Study Area

Ajay River (AR) is the right bank tributary of the Bhagirathi-Hooghly River (BHR) in West Bengal (WB), India. The river originates from the highlands of the Chhotanagpur plateau and meets with the BHR at Katwa (WB) after completing a run of ~299 km over the three major geological units like high-grade metamorphic Archaean gneiss, semi-consolidated formation of Gondwana basin, and Quaternary sediments of marine-estuarine-fluviatile origin in the upper, middle, and lower sections of the basin, respectively (Niyogi, 1984, 1985). The area of the basin extends latitudinally from 23°25′N to 24°35′N and longitudinally from 86°15′E to 88°15E and is enclosing an area of ~6050 km^2 within the three states of Eastern India, i.e. Jharkhand (~53%), Bihar (~6%), and West Bengal (~41%) (Fig. 11.2). The basin area is also classified into upper and lower sections based on state boundary; in particular, the area under Jharkhand and Bihar is known as upper ARB, and the area under West Bengal is known as lower ARB. The major tributaries of ARB are Dakua (48 km), Parth (80 km), Jainti (87 km), Hinglow (180 km), Tumuni (192 km), Kunur (252 km), and Kundur (293 km), and the figures within first brackets are showing the distance of confluence point of respective tributaries from the source head of trunk river. The average annual discharge capacity of the river is about 2036 million m^3 (Niyogi, 1984).

The range of the elevation varies from 335 m at the extreme western upland of the basin to 16 m at the confluence zone. Geomorphologically, the entire has been classified into three physiographic zone, namely, (a) dissected erosional plain with

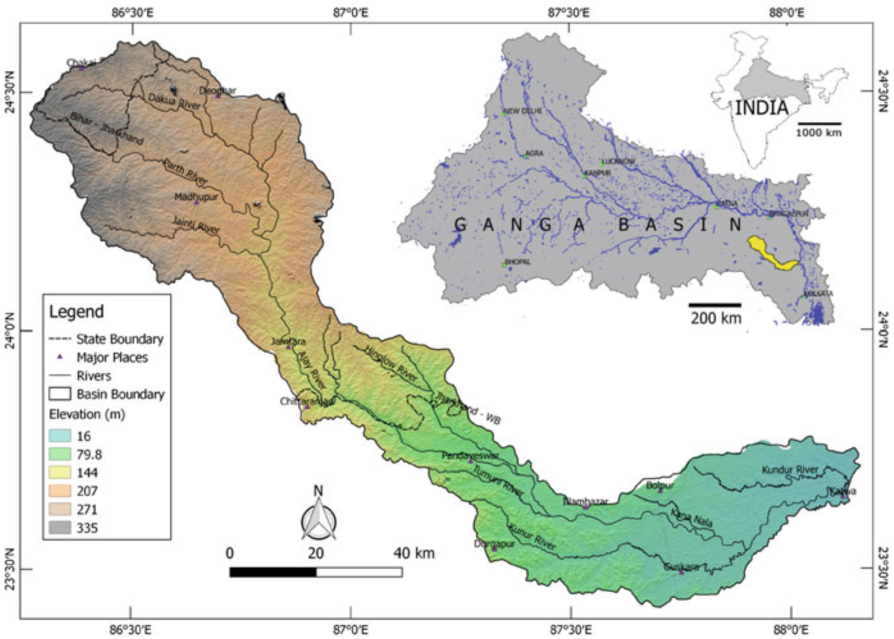

Fig. 11.2 Location of the Ajay River Basin in the lower Ganga basin of India

monadnocks in the upper part of the basin, (b) erosional plain with broad swells and depression mainly over the Gondwana basin, and (c) riverine aggradation plain with extensively developed alluvial fans, which merge with the Bhagirathi delta proper (Niyogi, 1984). However, Bagchi and Mukherjee (1979) have classified the same in the name of as 'plateau proper' (>120 m), 'plateau fringe' (36–120 m), and 'marginal plain' (>36 m), respectively.

The primary climate of the basin is monsoon type, and 85% of rainfall occurs mainly during mid-June to October. The mean annual rainfall amount is 1380 mm with a mean annual temperature of 25.8° C (IMD, 2014). However, over the basin area, significant variation in rainfall amount has been observed annually as well as monthly. The type of soils and their texture over the basin are clearly associated with the lithological characteristics and pedogenic processes (Niyogi, 1985). Red-yellow and red soils with sandy loam to loamy texture have been observed on the Archaean gneiss and the areal coverage of these soil types is about 40% and 25%, respectively. The downstream area or lower basin area mainly covers by younger alluvial, older alluvial, and lateritic soils, which are about 6%, 19%, and 10% of the total basin area (Niyogi, 1985). The land use/land cover scenario of the basin reveals the intensive nature of human interference with 70–80% of agricultural land and up to 10% of agricultural waste at block level even in the uppermost areas. The basin area is covered by dry peninsula type of sal forest of only 9.9% on an average, which is temporally lost at a very high rate. The residential area has covered almost 5% of basin with six to seven major urban centres.

Administratively, the upper basin area comprises four districts of Jharkhand and a small section of Bihar, and LAB is composed of two districts of West Bengal. As per the Census of India (2011), the entire basin comes under a highly populated part of India, in particular, the districts (Jamui, 568 person/km^2; Gridhi, 493 person/km^2; Deogha, 602 person/km^2; Jamtara, 437 person/km^2) in the upper basin area are characterised with low population density in comparison with the districts (Barddhaman, 1099 person/km^2, and Birbhum, 771 person/km^2) of the lower part of the basin. The difference in topography and soil characteristics between the upper and lower sections of the basin might be the major cause behind this disparity.

3 Used Database and Methodology

To understand the contemporary as well as old flood characteristics, numerous literatures, reports, articles, and unpublished works have been studied and/or reviewed to collect secondary data regarding major flood years, magnitude, and damages. In particular, the annual flood reports from the Director of Irrigation and Waterways Department, Government of West Bengal, is one of the important sources of such flood data. A simple frequency method has been followed to analyse the trends of floods for the last 107 years, where the flood record has been categorised on a decadal basis since 1900. Mukhopadhyay (2010) initially summarised the major flooding years based on old reports and perception studies on the floodplain dwellers and also prepared the flood intensity map by overlapping layers of flood extend in different years. To get the values of channel geometry of Ajay and Kunur rivers, a geomorphic survey was done in 2012 along with some measurements using remote sensing data, e.g. DEM.

To assesses the flood risk globally, the World Resources Institute (WRI) has developed a digital platform cum tool 'Aqueduct Floods' (www.wri.org/data/aqueduct-floods-hazard-maps), a modelled raster data (spatial resolution ~0.80 km^2) archive for empowering the researchers, planners, policymakers, and different stakeholders to understand the flood risk at present and in the future up to 2080 (Winsemius et al., 2013; Wrad et al., 2013, 2020). WRI performed the simulation using Global Flood Risk with IMAGE Scenarios (GLOFRIS) model (Winsemius et al., 2013) to assess the changing flood risk under climate change scenario. To analyse the flood hazard, an inundation map has been prepared to show the flood extend as well as depth of water at different return periods (2, 5, 10, 25, 50, 100, 250, 500, and 1000). With the help of hydrological model, PCRaster Global Water Balance (PCR-GLOBWB) (Sutanudjaja et al., 2018), WRI has also introduced the long-term simulations for the periods of 2030, 2050, and 2080 based on the simulation on available data for the period of 1960–1999 and presented as 2010 baseline data (Ward et al., 2020). To incorporate the future climate change, WRI also used the combination of a representative concentration pathway (RCP) (van Vuuren et al., 2011) for RCP4.5 and RCP8.5 scenario and ran different projection models of different renowned organisations, e.g. Geophysical Fluid Dynamics (NOAA), Met Office Hadley Centre, etc.

For the present study, such database has been used to assess the flood risk of ARB in the future. In particular, flood inundation data for the years of 2010 (baseline), 2030, 2050, and 2080 at the return periods of 2, 10, 25, 50, 100, and 500 in the condition of RCP4.5 under the projection model of Geophysical Fluid Dynamics (NOAA) have been downloaded and analysed in geoinformatics platform.

4 Contemporary Flood Characteristics (1950s–2000s)

4.1 Trend in Flood Frequency During the Twentieth Century

In the last 107 years, a total of 17 major floods have been recorded over the lower ARB, which progressively increased over time (Table 11.1 and Fig. 11.3). The maximum number of floods (3) have been noticed during the decades of the 1970s and 1990s. Nevertheless, about 72% of flood events happened after 1956 only, and this year could be denoted as the period of separation between the embanked and the non-embanked basin. Therefore, such analysis reveals the role of embankments in increasing flood probability.

Table 11.1 Decadal frequency of the major floods over the ARB since the beginning of the twentiethcentury

Range of time	Flood frequency		Cumulative flood frequency	
	Frequency	% of Frequency	Frequency	% of cumulative frequency
1900–1910	0	0	0	0
1911–1920	2	12	2	2
1921–1930	1	6	3	4
1931–1940	1	6	4	5
1941–1950	1	6	5	6
1951–1960	2	12	7	8
1961–1970	1	6	8	10
1971–1980	3	18	11	13
1981–1990	1	6	12	14
1991–2000	3	18	15	18
2001–2007	2	12	17	20
Total	**17**	**100**	**84**	**100**

Source: Flood Record Data, and Perception survey of local people, Mukhopadhyay (2010)

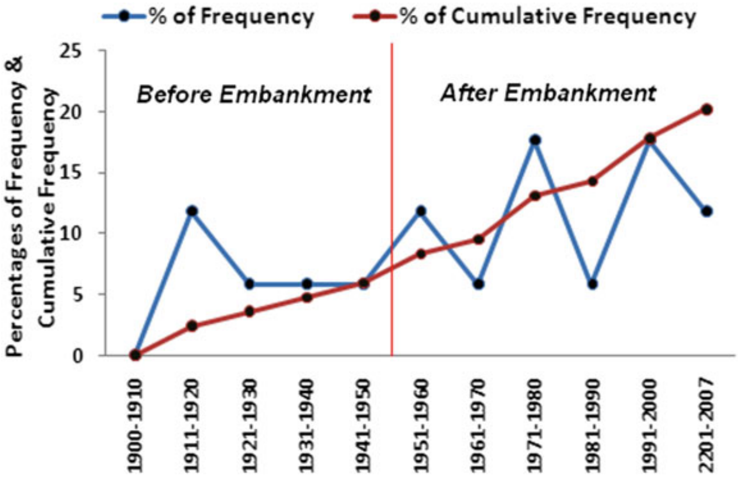

Fig. 11.3 Showing the frequency trend of major floods over ARB from 1900 to 2007

4.2 Spatial Extension of Flood over the Lower ARB

The spatial extension of the flood is confined along the narrow strip of the two banks at the western part of the lower ARB, but below the Illambazar up to Mangalkote, much wider areas are affected by the flood. The right bank of the river is more affected by floods than the left bank. The spatial extensions of flood-affected areas gradually increased from 1956 to 2007 (Figs. 11.4a, b). The flood intensity map is also revealing that over 60% of flood-affected areas are concentrated surrounding the embankment (Fig. 11.5). The significant role played by Kunur River Basin (KRB) in such distinguished distribution of flood areas could be perceived from the flood intensity map. The detailed geomorphic study by Roy and Mistri (2016) shows that the downstream decreasing trend of the channel carrying capacity and the rising trend of channel bed slope of Kunur River are playing crucial roles in creating havoc flood around the confluence zone of Ajay and Kunur rivers. In addition, the trend of the hydraulic gradient of groundwater is also towards the confluence zone, which is also helping to keep saturating the regional soil of this region and causing floods by generating maximum direct runoff (Roy & Mistri, 2016).

4.3 Trend in Flood-Affected Area Since 1956

The area affected by the flood has been significantly increased since 1956 even after the initiation of structural control of flood over the lower ARB in form of embankment construction (Table 11.2 and Fig. 11.6). Average ~ 33% of the lower ARB has been severely affected by flood in every major annual flood event, and the overall

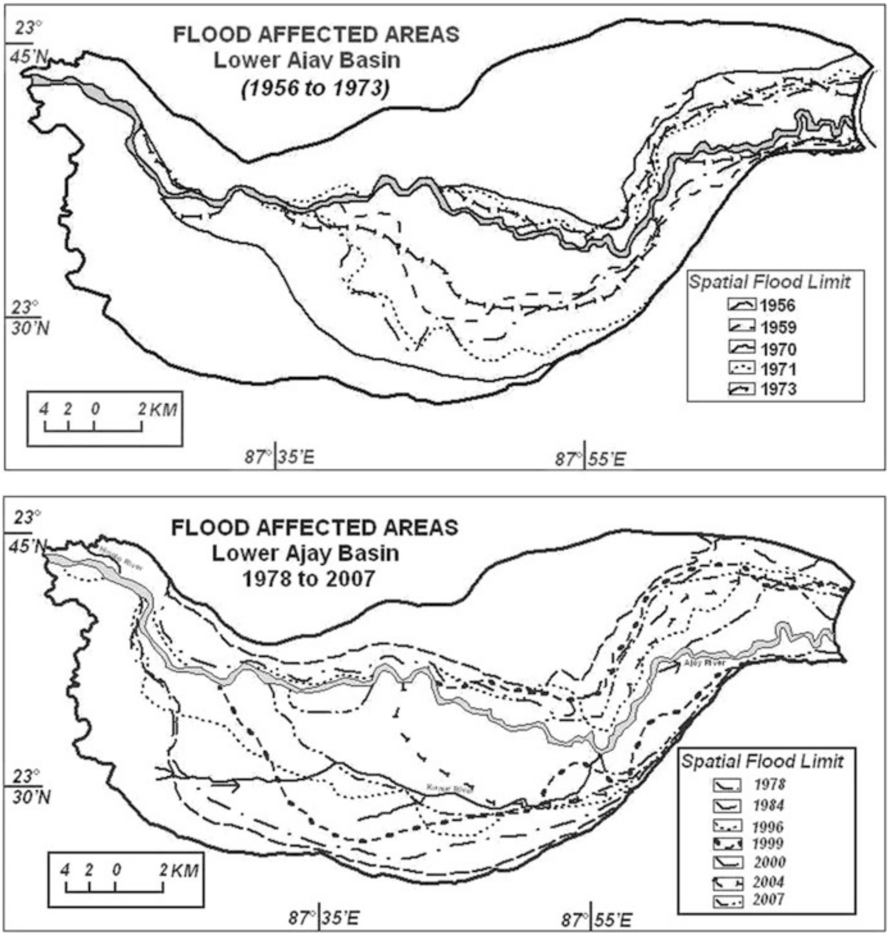

Fig. 11.4 (**a**, **b**) Progressive change of flood-affected areas in lower ARB from 1956 to 2007. (Source: Mukhopadhyay, 2010)

trend of the flood-affected area is also rising. A noticeable amount of mouzas (village-level administrative units) also experienced the disaster by losing a huge amount of agricultural land by floodwater inundation and sand splay (Tables 11.2 and 11.3). Statistically, the number of mouza affected ($r = 0.95$, $p < 0.1$) and area of sand splay ($r = 0.79$, $p < 0.1$) are also positively correlated with the area of flood affected in the lower ARB at 99% level of significance. Breaching of the embankment is the main cause of sand splay across the lower ARB. Due to the poor structure and lack of maintenance of the existing embankment, breaching occurred on the side

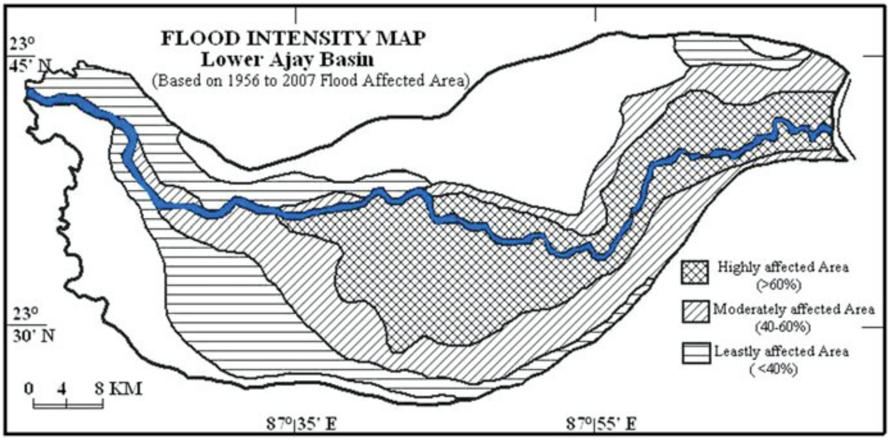

Fig. 11.5 Flood intensity map in lower ARB. (Source: Mukhopadhyay, 2010)

Table 11.2 Flood-affected area of the lower Ajay River Basin from 1956 to 2007

Year	Affected area (km^2)	% of total lower basin area	Affected number of mouzas			Extent of sand splay in hectares	Maximum extension of sand splay from river embankment (distance in km)
			Entirely affected	Partially affected	Total		
1956	680.00	24.14	153	32	185	231.45	0.38
1959	584.34	20.74	120	27	147	269.63	0.38
1970	812.24	28.83	186	36	222	693.48	0.47
1971	642.71	22.81	130	31	161	762.11	0.78
1973	639.02	22.68	124	36	160	1193.2	1.12
1978	1680.00	59.64	307	67	374	3421.32	2.42
1984	305.72	10.85	78	20	98	865.55	0.68
1995	1380.82	48.99	227	49	276	1245.67	1.4
1999	1408.00	49.98	237	60	297	2567.23	2.12
2000	1488.00	52.82	263	106	369	3788.25	2.57
2006	764.23	27.12	152	46	198	2143.56	1.35
2007	972.79	34.53	214	79	293	2421.57	1.76

Source: Department of Irrigation and Waterways, Govt. of West Bengal (2001)

of the embankment at different places in the study area. The number of breaching points was also rapidly increasing downstream of the basin (Fig. 11.6). It is also confirmed that the breaching points are more concentred on the right bank of the river and the numbers are also increased with time; in 1978 it is 12, in 1999, it is 22, in 2000, it is 25, and in 2005, it is 8 in number.

Table 11.3 Sand splay cover and loss of cultivated land due to post-flood hazard

Name of the mouza	Area covered by sand splay (% of total area)	% of land loss to the total cultivated area	Name of the mouza	Area covered by sand splay (% of total area)	% of land loss to the total cultivated area
Bhedia	33.58	18.40	Itanda	42.43	39.89
Brahmandihi	21.66	32.00	Nabagram	16.43	30.7
Malocha	38.08	25.67	Natunhat	18.60	23.99
Maliara	44.03	21.52	Bira	17.30	24.82
Basudha	32.07	23.59	Narenga	20.32	29.84
Gitgram	58.92	30.80	Srikrishnapur	38.20	51.92
Natungram	36.74	44.66	Husainpur	48.25	26.66
Rasulpur	33.82	36.58	Vepura	44.46	40.00
Haripur	38.12	43.00	Pandura	21.39	17.08

Source: Burdwan and Birbhum Zilla Parishad Office and Handbooks (2001)

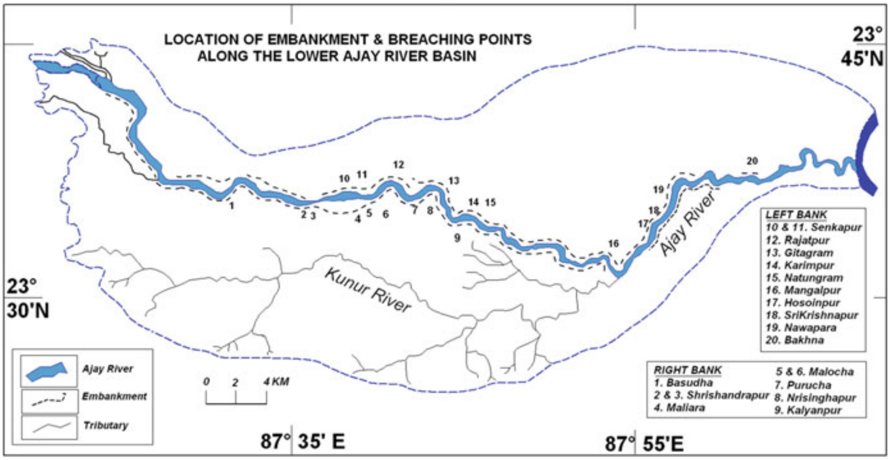

Fig. 11.6 Location of breaching points along the right and left bank embankments of the lower ARB

4.4 Dominant Impact on Agriculture

The lower ARB is basically well known as an agricultural hub for producing rice, wheat, sugar cane, oilseeds, and potato as major crops with high productivity. It is estimated that 62.58% of the total land is used for cultivation of which 40.27% is irrigated and 22.31% is non-irrigated. Forested land occupies only 13.17% of the total area and is mostly concentrated on the right bank than the left bank (Mukhopadhyay, 2010). However, due to frequent floods, embankment breaching and sand splay significantly affect the agricultural system by losing cultivated area

Table 11.4 Decreasing rate of rice production (kg/ha)

Name of the mouza	Before sand splay 1998	After sand splay 2000 (marginal area)
Bhedia	3750	1500
Natungram	4000	750
Maliara	3000	800
Srikrishnapur	4500	1500
Narenga	3600	1312
Gomra	3375	500

Source: Mukhopadhyay (2010)

Table 11.5 Nutrient status of the soil before and after flood of 2000

Name of the mouza	Ph		N_2 (kg/ha)		P_2O_5 (kg/ha)		K_2O (kg/ha)	
	Before	After	Before	After	Before	After	Before	After
Natungram	6.6	7.5	200	49.5	90	7.9	294	46
Gitgram	7.0	7.3	250	30.5	85	4.2	240	65
Maliara	7.1	7.1	280	39	21.2	4.2	316	59
Bhedia	6.9	6.9	330	26.4	45.5	3.6	305	72
Srikrishnapur	7.0	8.2	300	35	70	5.5	220	70

Source: Technical Report, Vol.7, Dept. of Soil Science, Palli Siksha Bhabana, Visva-Bharati

(Table 11.3), decreasing the productivity of rice (Table 11.4), and deteriorating soil fertility (Table 11.5). The agricultural land of riverside villages, like Bhedia, Brahamandihi, Malocha of Aushgram block; Kogram, Mangalkot, Halimpur of Mangalkot block and other different villages, have been seriously affected.

4.5 Effect on the Channel Geomorphology

Generally, the alluvial river system follows the thumb rule of downstream widening of channel (Knighton, 1987; Leopold & Maddock, 1953) and increasing the degree of lateral connectivity (Wohl, 2017). However, an inverse scenario has been observed for the downstream section of the Ajay River might be for the installation of the embankment and related alteration of flow pattern. Table 11.6 shows the downstream decreasing trends of channel width and width-depth ratio, which reveals the poor lateral connectivity between floodplain and channel and causing threat to the river ecology (Wohl, 2017) (Fig. 11.7). However, depth of the channel has been increased towards down, which is indicating incision of channel below the Illambazar to contain enormous volume of upstream water because of the higher stream power as the average unit stream power is inversely correlated with the channel width (Baker & Costa, 1987). As a result, the possibility of bank erosion and embankment breaching has been increasing in the lower ARB. In addition, the presence of embankment also induces to rise of the river bed by gradual siltation of

Table 11.6 Anomalies in channel geometry towards downstream of Ajay River

Cross-section site	Elevation (m)	Distance fromconfluence (km)	Channel width (w) (m)	Maximum depth(d) (m)	Width-depthratio (w/d)
Pandaveswar	65	130.28	1026	11.89	86.29
Jaydeb Kenduli	59	111.00	719	10.51	68.41
Bankati	58	106.27	518	9.39	55.17
Ramchandrapur	50	85.12	345	8.58	40.21
Bhedia	44	77.08	473	7.02	67.38
Paligram	36	59.42	273	11.48	23.78
Kalyanpur	29	50.31	316	10.68	29.59
Kogram	27	44.34	221	11.78	18.76

Source: Roy and Mistri (2016)

Fig. 11.7 Showing the contrast in channel width of Ajay River between near Pandaveswar (**a**) and Nabagram (**b**), ~130 km and ~6 km upstream reaches from the confluence, respectively

suspended sediment after restricting the spillover of floodwater over the floodplain area. Thereby, over time the channel area fails to accommodate the upcoming storm water and consequently increases the flood frequency as well as magnitude. Roy and Mistri (2016) have also observed that since 1956 the stage of discharge has also increased at different gauging stations of Ajay River.

5 Future Scenario of Flood Height and Affected Area (up to 2080)

The impact of climate change on increasing flood height has been clearly detected from the model data by WRI (Fig. 11.8). A gradual increase in the average flood height from 2010 to 2080 has been observed in every return period. The average increases in flood height for all the four periods (2010, 2030, 2050, 2080) show it is 0 m, 2.33 m, 4.93 m, 5.24 m, 5.79 m, and 6.35 m, for the return period of 2, 10, 25, 50, 100, and 500 years, respectively. In hydro-geomorphology, a 2-year return period is treated as the most probable as well as frequent flood level of a river system (Leopold et al., 1964), which is also increased by ~0.5 m in 2080. A maximum

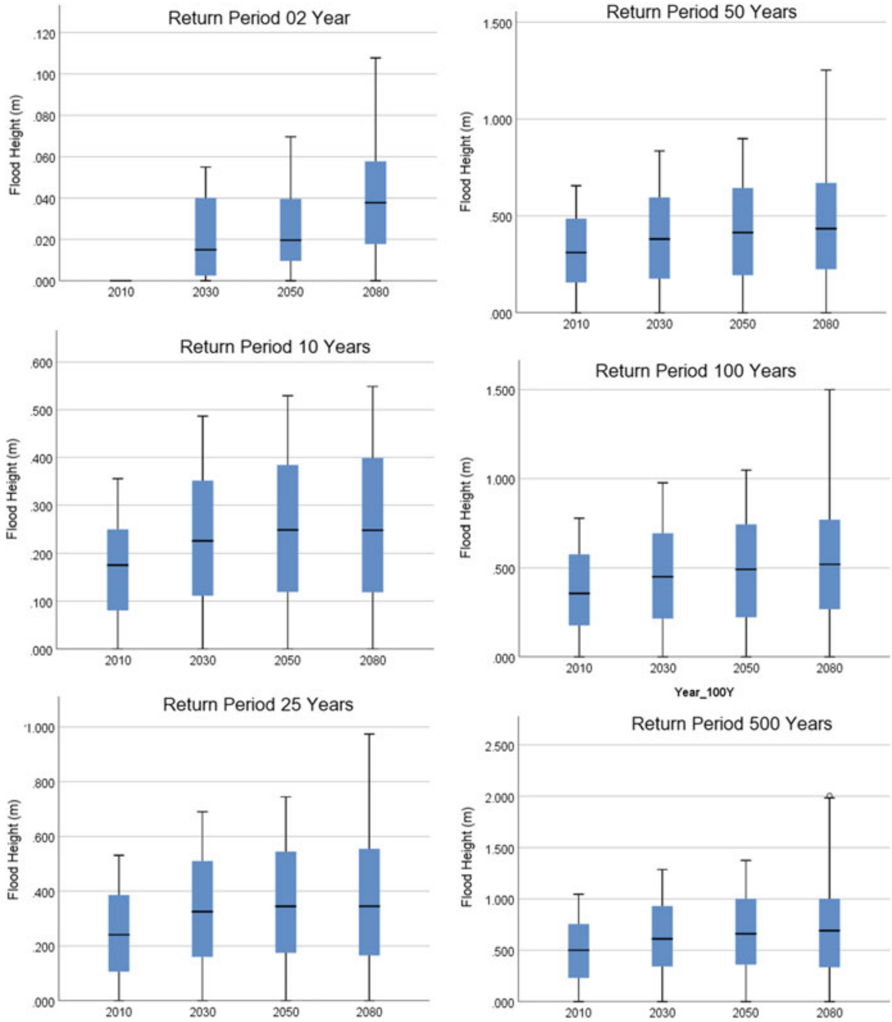

Fig. 11.8 Changing future scenario of flood inundation depth (m) over the ARB at different return periods

possible increase of ~2 m in flood height has been observed in 2080 at the 500-year return period, which would be a devastative situation for the ARB. With increasing flood height over time, the area affected by the respective flood height is also enhanced in different return periods (Table 11.7). For example, the area covered by flood height of above 0.5 m is nil at the 2-year return period; however, it reached up to ~7 km^2 at the 500-year return period (Fig. 11.9). Previously, Dhar (2010) also projected a significant change in Ajay River's flow pattern and soil moisture on four

Table 11.7 Changes in the spatial coverage of basin area (in km^2 and percentage) at different flood heights in different return periods

Flood depth (m)	2010						2030						2050						2080					
	Area under varying flood height (km^2) at different return periods						Area under varying flood height (km^2) at different return periods						Area under varying flood height (km^2) at different return periods						Area under varying flood height (km^2) at different return periods					
	2	10	25	50	100	500	2	10	25	50	100	500	2	10	25	50	100	500	2	10	25	50	100	500
0	6050	5728	5705	5683	5665	5622	5767	5713	5676	5654	5628	5586	5766	5707	5668	5642	5575	5575	5761	5704	5663	5641	5621	5571
0.001–0.250		32	32	37	42	39	283	32	42	39	41	35	284	32	43	41	29	29	290	33	46	40	38	32
0.251–0.500		290	31	35	32	41		306	32	39	45	42		31	32	39	43	43		31	35	42	43	46
0.501–0.750			282	295	31	35			300	29	31	42		281	307	35	42	42		282	303	35	36	39
0.751–1.000					281	31				288	306	33				293	36	36			2	290	31	43
1.001–1.250						282						31					34	34				3	279	30
1.251–1.500												282					292	292					3	284
1.501–1.750																								2
1.751–2.000																								3

Flood depth (m)	2010						2030						2050						2080					
	Percent of basin area under varying flood height at different return periods						Percent of basin area under varying flood height at different return periods						Percent of basin area under varying flood height at different return periods						Percent of basin area under varying flood height at different return periods					
	2	10	25	50	100	500	2	10	25	50	100	500	2	10	25	50	100	500	2	10	25	50	100	500
0	100.00	94.68	94.30	93.94	93.63	92.93	95.32	94.43	93.81	93.46	93.02	92.33	95.31	94.32	93.69	93.25	92.14	92.14	95.22	94.28	93.61	93.24	92.91	92.09
0.001–0.250	0.00	0.54	0.54	0.61	0.69	0.65	4.68	0.52	0.70	0.65	0.68	0.57	4.70	0.52	0.71	0.68	0.47	0.47	4.79	0.55	0.77	0.66	0.63	0.54
0.251–0.500	0.00	4.79	0.51	0.57	0.52	0.68	0.00	5.05	0.52	0.65	0.74	0.69	0.00	0.51	0.54	0.65	0.71	0.71	0.00	0.51	0.57	0.69	0.71	0.75
0.501–0.750	0.00	0.00	4.66	4.88	0.51	0.57	0.00	0.00	4.97	0.49	0.51	0.69	0.00	4.65	5.07	0.57	0.69	0.69	0.00	4.66	5.02	0.57	0.59	0.64
0.751–1.000	0.00	0.00	0.00	0.00	4.65	0.51	0.00	0.00	0.00	4.76	5.05	0.55	0.00	0.00	0.00	4.85	0.60	0.60	0.00	0.00	0.04	4.79	0.51	0.71
1.001–1.250	0.00	0.00	0.00	0.00	0.00	4.66	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.56	0.56	0.00	0.00	0.00	0.05	4.61	0.50
1.251–1.500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.66	0.00	0.00	0.00	0.00	4.82	4.82	0.00	0.00	0.00	0.00	0.05	4.70
1.501–1.750	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
1.751–2.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05

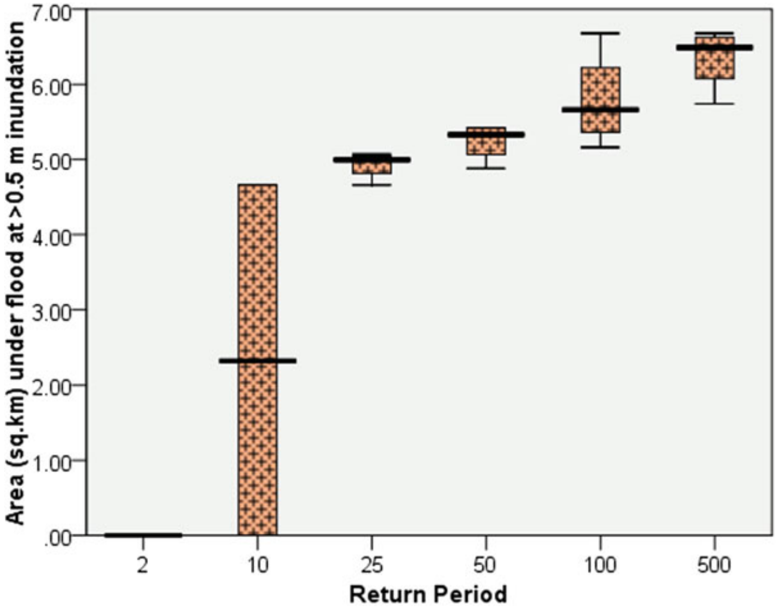

Fig. 11.9 Increase in spatial coverage of flood with the inundation depth of more the 0.5-m flood height at different return periods

different sub-watersheds during 2040–2050 under the impact of future climate change through the modelling of projected data from the Hadley Centre for Climate Prediction (UK).

6 Concluding Remarks

The impact of floods on the ARB (particularly in the lower section) has been increased with time to the expansion of flood-affected areas, flood height, reduction of soil nutrients and crop productivity, the number of villages affected, etc., which is revealed from the previously documented data as well as from the recently available digital modelled data by WRI under the changing condition of climate. The negative effect on channel geomorphology is also prominent for the trunk river by altering channel width, depth, and width-depth ratio. In particular, the enhancement of such effects has been observed since 1956, which is the year of artificial embankment installation alongside the Ajay River in the downstream region. Therefore, instead of structural measures for flood control through artificial embankment along the river, non-structure measures like restoration of floodplain through afforestation, regulation on land use, flood-prone area delineation, timely flood forecasting and warning, and disaster prevention measures would be more effective for the ARB. The projected data model is showing a prominent increase in flood inundation depth; in particular, about 0.5 m increase has been observed in 2080 at the 2-year return period, and a maximum rise of ~2 m in 2080 at the 500-year return period. Consequently, the area under floodwater is also positively increasing with rising inundation depth, although having some issues of underestimation of flood-affected areas in the modelled data in comparison with the previously documented data. Such anomaly may arise due to less information about present channel morphometry and the degree of connectivity of drainage network.

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