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Exploring geospatial changes of wetland in different hydrological paradigms using water presence frequency approach in Barind Tract of West Bengal

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Abstract The Barind tract of West Bengal is composed with old alluvial soil, relatively undulating plain with good number of riparian wetlands. The main source of water of these wetlands is rain water and inundated water from river because most of the natural wetlands are located alongside the river. Under this condition any kind of river flow modification may influence the present wetlands condition. A good number of dam/reservoirs have been constructed on river Atreyee, Punarbhaba, Tangon etc. and it causes flow modification in those rivers in their downstream. The main objective of this paper is to find out the consequence of such river flow modification on areal extent of wetland, seasonal dynamics of wetland, temporal trend and their vulnerability. For doing this work Landsat image of pre-monsoon and post-monsoon season since 1988–2016 have been collected from USGS website. After that water presence frequency approach is used for wetland mapping and detecting change in pre and post dam regime. From the analysis it is found that in post dam condition both quantitative and qualitative degradation are being happened and their rate varies in different interfluves zones. It is also found that the degree of vulnerability has been increased in post dam condition. Considering the ecological values and their capability of livelihood support scientific delineation of wetland boundary according to their degree of vulnerability is essential.

1 Introduction

Wetland is diversified rich ecosystem provides various irreplaceable ecological services to the ecosystem and human society [1, 2]. Wetlands exhibit vast diversity according to their geographical location, genesis, water regime, chemistry, dominant species, soil and sediment characteristics [3, 4]. Based on hydrological, ecological and geological criteria wetlands are categorized into marine (coastal wetlands) estuarine (including deltas, tidal marshes and mangrove swamps), Lacustrine (Lakes) Riverine (along river and streams) and palustarine (marshes, swamps and bogs) etc. [5]. Different emerging vectors have added which are majorly responsible for regulating dynamics of wetland [6, 7]. Flow regulation by dams, disturbs the natural hydrological regime of the river as well as riparian wetland and it causes instability on adjusted natural wetland ecology by changing inundation magnitude, frequency, duration and timing [8, 9]. It is sometimes compounded by other structural modifications such as channelization and levee banks that results the loss of connectivity between lotic and lentic water bodies [10, 11]. Lowering of groundwater table disrupts the interaction between surface and subsurface water components and often shortens the hydro-period of the floodplain wetland. This dearth of conjugation often turns perennial wetlands into non-perennial, seasonal wetland into ephemeral [12]. Various hydrological methods and models have been developed to identify accurate boundary and category of wetlands but there are no uniformity of

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application of these methods [13]. With growing advance technologies like remote sensing provides greater advantages over any other traditional methods of wetland identification [14]. Numerous indices have designed to delineate surface water bodies from remotely sensed imageries e.g. Water Ratio Index (WRI) [15], Normalized Difference Vegetation Index (NDVI) [16], Automated Water Extraction Index (AWEI) [17], Normalized Difference Water Index (NDWI) [18, 19], Modified Normalized Difference Water Index (MNDWI) [20], etc. Some other methods for identifying wetland depressions and quantifying their nested hierarchical bathymetric/topographic structure are high resolution light detection and ranging (LiDAR) data. This contour tree method allows identified wetland depressions to be quantified based on their dynamic filling-spilling-merging hydrological processes [21]. In addition, wet land depression properties, such as surface area, maximum depth, mean depth, storage volume etc. can be computed for wetland categorization. In a review of current wetland delineation methods for marshy & swampy areas, prevalence indices and dominance ratios of hydrophytes is used to identify variety of wetland situations [22–25]. But, in areas with a high density of ephemeral and seasonally flooded wetlands, wetland delineation is very difficult and traditional mapping protocols may underestimate occurrence of wetlands when single-date base-imagery is utilized [26]. Therefore, continuous monitoring of multi-dates imageries within a certain period can be performed to solve this problem. Our projected study area, the parts of Barind tract of West Bengal, is composed with old alluvial soil, relatively undulating plain with good number of riparian wetlands [2]. The Barind tract of west Bengal is a distinct physiographic unit comprising a series of uplifted blocks of terraced land covering 2637.66 sq mi (679038.39 ha) area delimited by 24°52′20″–26°29′16″N. latitudes and 87°47′32″–89°00′29″E. longitudes. It is an interfluves region of Atreyee, Punarbhaba, Tangon and Mahananda. Geomorphologically it is divided into active flood plain, inactive flood plain, extended flood plain, uplands, piedmont and fan, swampy water logged area etc. [2]. The barind tract is mainly composed of alternating sand, silt and clay layer with average elevation of 35–50 m from mean sea level (msl). Average annual rainfall of this region is 1250 mm occurring mainly from late June to October and temperature ranges from 10 to 35 °C. Major sub watersheds fall under the study area are Punarbhaba, Kulik, Atryee, Tangon and Nagar (Fig. 1). Most of the rivers directly or indirectly merge with river Mahananda. Rivers of this region frequently inundate the proximate area and constructions of dam over the major rivers have altered the hydrological regime. In 1992 dam was constructed over Punarbhaba river, in 1989 it was over Tangon river and

over Atryee river in 2011 [27]. The main source of water of the flood plain wetlands is rain water and inundated water from river because most of the natural wetlands are located alongside the rivers and they are seasonal in behaviour. These wetlands are more dynamic ecosystem with high spatio-temporal complexity [12]. Being a tropical climatic zone, the hydrological system of the rivers are highly variable and their associated floodplain wetlands represent spatio-temporal hydrological fluctuation due to annual phases of flood and drought pulses [12, 28, 29]. The actual area of wetlands highly fluctuates seasonally and yearly in the flood plain landscape. Under this condition identification of actual stable wetland area is very difficult. Given this background, the objective of this study is to delineate wetland area over different hydrological phases from multi-temporal Landsat Imageries using Water Presence Frequency (WPF) approach [26]. Water presence frequency method is very good technique for the identification of such types of periodic inundated wetlands where occurrence of inundation within a certain period can be measured using time series Landsat data [30]. Instead of traditional single-date mapping, multi-dates satellite imageries of same season has the potential to improve the identification of wetlands in areas that contain high densities of temporary wetlands. Using multiple images of multiple dates and years, it is possible to determine the distribution of inundation frequency gradient and duration of inundation of each depression [26]. Another objective of this study is to detect change of water presence area over different hydrological phases. These phases are recognized based on the major hydro-engineering structures i.e. construction of dam over major rivers of this region for flow regulation. For last three decades drainage system of this region is deeply affected due to man-induced modifications of the channel (construction of dams on the river) which directly influenced water supply to the wetland via connective streams or lateral overland spread of water through natural spilling and these are many cases caused for wetland deterioration [8].

2 Materials and methods

2.1 Materials

Landsat satellite imagery is used here for monitoring wetland and preparing relatively reliable wetland inventories. Total 52 numbers of LANDSAT TM, LANDSAT ETM + and LANDSAT 8 OLI imageries included in this study, (Pre-monsoon & Post-monsoon season) for a 28 years period from 1988 to 2016. Images have been obtained from the US Geological Survey (USGS) Global Visualization Viewer. Path/row of the adopted images is
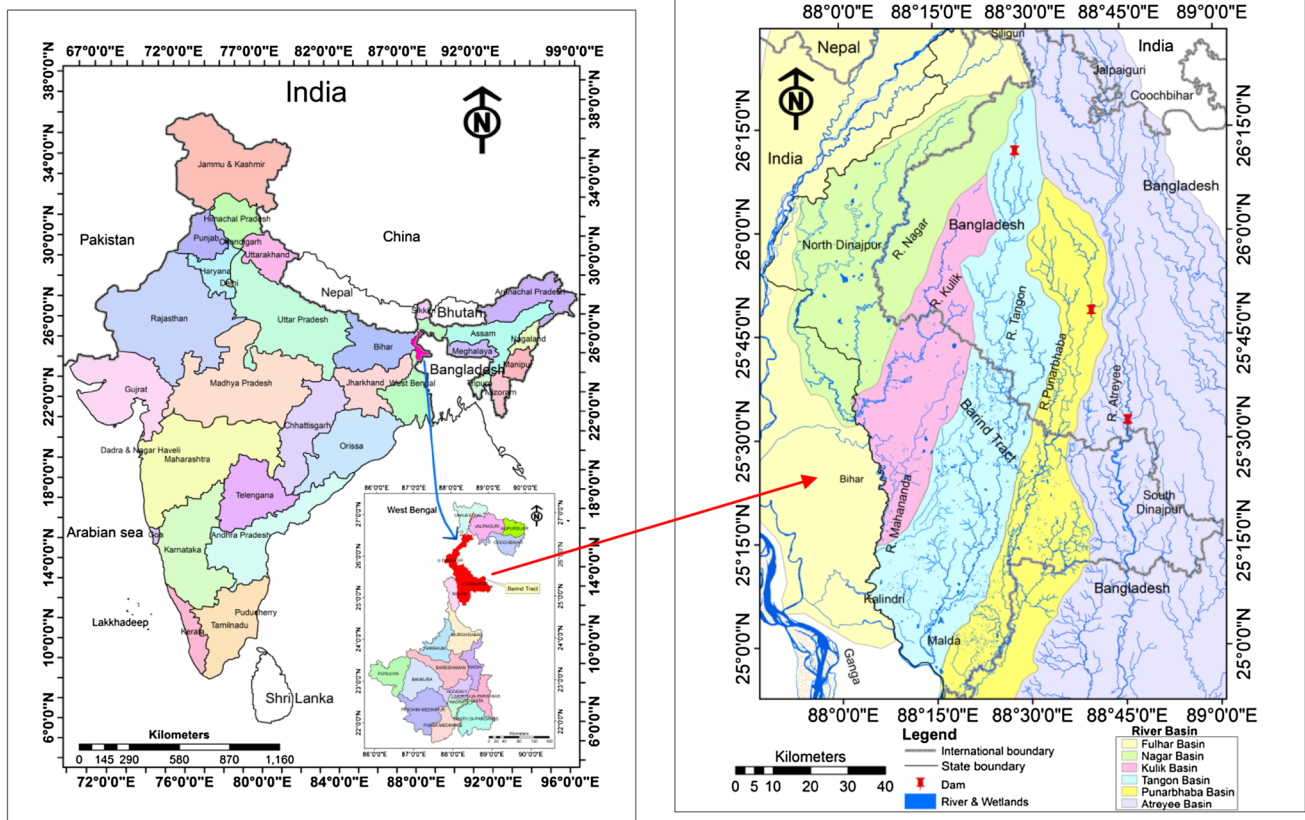
Fig. 1 Location of study area

139/43; spatial resolution is 30 m. The obtained Landsat data (Level 1 Terrain Corrected (L1T) product) were pre-georeferenced to UTM zone 45 North projection using WGS-84 datum. The other necessary image corrections have also been carried out for this study. The basin area is delineated using Google earth images. Arc GIS 9.3 and ERDAS IMAGINE 9.2 are used for image analysis and relevant mapping.

2.2 Methods

2.2.1 Extraction of water body

Normalized Difference Water Index (NDWI) is used for detecting water body from Landsat imagery of each year for both pre-monsoon and post-monsoon seasons. Amongst other indices, this method represents better approach for delineating wetland for this region [30]. For accuracy assessment, they set both theoretical and manual thresholds for water bodies and is compared with wetland patches delineated from relatively high resolution google earth imageries of the concerned region. This literature established that manual threshold set by the authors provide greater accuracy level (0.24%) [2]. Procedure of NDWI calculation is,

$$NDWI = \frac{Green\,band - NearInfra\,\mathrm{Re}d\,band}{Green\,band + NearInfra\,\mathrm{Re}d\,band}$$

where water body is detected by positive value (0–1). Based on the fact that water has strongest absorption while vegetation has strongest reflectivity at near infra-red, this equation is employed here. NDWI proved to work well in separating water body and vegetation but also possesses some limitations when it comes to soil and built up area [20].

2.2.2 Delineation and classification of wetlands

Frequency based approach is adopted here for delineating and classifying wetlands. Water presence frequency (WPF) method is very useful for this region because of high presence of seasonal wetland with high temporal dynamicity. It helps for the identification of wetlands which are seasonal or ephemeral because it counts frequency of water presence of recurrence time interval. Analysis of training pixels from multi-season imageries provides the greatest accuracy [12, 26].

In frequency approach, in order to prepare wetland distribution map, first wetlands are extracted from Landsat imagery. After extraction of wetlands from Landsat

imagery of each year, composition of all extracted images is done for scaling the area with different frequencies of water presence in wetlands. We calculated the water presence frequency of each pixel in seasonally-flooded wetland from the used multi-temporal imageries. Frequency structures of images used for this work are illustrated in Table 1.

$$WPF_{sj} = \frac{\sum_{i=1}^{N_s} BFP_{ij}}{N_s}$$

where, WPF_{sj} is the water presence frequency value of the pixel j for the sets and represents the proportion of Fig. 1 with WPF equal to 1 in the pixel j (WPF_{ij}) in relation to the total number of images in the analyzed set of images (N_s). The pixel value of each WPF map was reclassified into three equal frequency classes: low frequency class (>0.33), moderate frequency class (0.33–0.66) and high frequency class (>0.66). It may also be expressed as percentage. High frequency class means the wetlands are relatively stable wetland because here the concerned pixels frequently appeared as water body. Downscaling frequency indicates lowering frequency of water presence in the pixels and therefore, the wetland of this kind shows less stability of wetland and these can be treated as quite vulnerable for rapid transformation to other land uses (Table 2).

2.2.3 Change detection of water presence area in wetlands and estimation of wetland loss

For estimation of wetland loss we have subdivided entire temporal spectrum of time series data for each season into three phases in reference to construction of dams over the major rivers in this region. Duration of Phase-I is extended between 1988 and 1992 when two dams were constructed on river Punarbhaba and Tangon in the year 1989 and 1992 respectively and Phase-II is extended from 1993 to 2011 when one dam was constructed on river Atreyee in 2011 and finally, Phase-III is extended from 2013 to 2016

(Table 3). For change detection composite image of 2nd phase is deduced from 1st phase, 3rd phase is deduced from 2nd phase etc. This process is carried out after classifying each image into three inundation frequency classes i.e. permanent or near to permanent with high WPF (>66%), seasonal with moderate WPF (33–66%) and ephemeral with low WPF (<33%).

2.2.4 Instability analysis

For instability analysis of wetland area of different years, year wise total water presence areas for both pre-monsoon and post-monsoon seasons have been considered. Instability is calculated with the following the equation of Cuddy and Della Valle [31].

$$IX = CV \times \sqrt{1 - R^2}$$

where, R^2 is coefficient of determination and CV is Coefficient of variation of selected time series water presence area. Less IX value indicates less instability and vice versa.

3 Results and discussion

3.1 Results

3.1.1 Phase wise categorization of wetlands based on WPF

Integrating multi temporal satellite data into a single one has the potential to improve the accuracy of wetland mapping [28]. As the projected area has large aggregation of seasonal and ephemeral wetlands, single date mapping may mislead the operation and only represents the wetland extension of that particular year without giving a representative average wetland of the concerned season or month. Based on this frequency approach, water presence area is classified into three frequency classes (i.e. high, moderate and low). High frequency indicates relatively stable or permanent part of

Table 1 Frequency structure of the dataset

Season	Phase-I	Phase-II	Phase-III	Total year
Pre-monsoon (March–May)	1988, 1989, 1990, 1991, 1992 Total frequency = 5	1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011 Total frequency = 18	2013, 2014, 2015, 2016 Total frequency = 4	26
Post-monsoon (October-December)	1988, 1989, 1990, 1991, 1992 Total frequency = 5	1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011 Total frequency = 18	2013, 2014, 2015, Total frequency = 3	25

Table 2 Water presence area under different water presence frequency classes (Area in hectare); values within parenthesis indicates % of wetland area to total geographical land

Phase	Pre-monsoon			Post-monsoon			Wetland area (hectare)		
	Low	Moderate	High	Low	Moderate	High	Permanent	Seasonal	Total
I (1988–1992)	4741.44	2923.15	1343.29	9295.82	6678.96	4298.21	9006.4 (1.33)	11268.43 (1.66)	20274.83 (2.99)
II (1993–2011)	2412.69	1655.05	1086.31	5515.60	5245.57	2457.13	5156.01 (0.76)	8171.91 (1.2)	13327.92 (1.96)
III (2012–2016)	1052.93	996.06	508.65	3145.75	2419.89	1598.03	2557.93 (0.38)	4605.34 (0.68)	7163.27 (1.05)

Table 3 Direction of wetland loss and instability analysis

Phase	Season	Y = a + bx	r^2	CV (%)	IX
I	Pre-monsoon	Y = −0.143x + 285.7	0.654	51.85	30.49
	Post-monsoon	Y = −0.080x + 160.1	0.882	25.47	8.74
II	Pre-monsoon	Y = −0.009x + 18.40	0.072	47.82	46.06
	Post-monsoon	Y = −0.002x + 5.378	0.015	35.91	35.63
III	Pre-monsoon	Y = 0.003x − 6.209	0.023	43.01	42.50
	Post-monsoon	Y = −0.033x + 67.67	0.135	43.06	40.06

wetland, moderate frequency class indicates moderately stable and low frequency class indicates instable wetland highly susceptible to either loss or transformation. It is clear from the result that most widespread water presence areas are found in post-monsoon season while water presence area is the lowest in pre-monsoon period. Due to abundant rain water supply to the river and spilling of traversing channels, some of the fragmented wetlands become united storage pool in monsoon period and extensive wetland area appeared. Phase wise total water presence area measured from WPF maps of both the seasons. The WPF maps of the phase-I (1988–1992) represents that the total water presence area for the pre-monsoon was 9007.88 ha, while it was 20272.99 ha in post-monsoon (Table 2). On the other hand, the total water presence area in response to the pre-monsoon and post-monsoon seasons of phase-II (1993–2011) were 5154.05 and 13218.3 ha respectively (Figs. 2a, b, 3c). In phase III (2012–2016) areal extent of wetlands of pre and post monsoon periods were 2557.93 ha and 7163.27 ha consecutively. It is clear that WPF area is 3 times higher in post-monsoon period in every phase (Fig. 2d–f) in respect to its previous one. For the pre-monsoon season of phase-I, the low frequency wetland class carried the largest extent (52% or 4741.44 ha) while moderate and high frequency zone comprises 32 and 16% respectively. But, the scenario of the post-monsoon season for phase-I differs from pre-monsoon and it is observed that the at three wetland classes area of water presence frequency recorded as 45.85, 32.94 and 21.16% to the total WPF area correspondingly. From the result it is focused that total wetland area and stable or high frequency wetland areas have declined with very steady manner.

3.1.2 Sensitivity analysis of the wetland maps

137 ground control points we have selected from the field for validating the current phase wetland map extracted from Landsat images. 163 sites also randomly selected from the relatively higher resolution Google earth images of the concerned phases and cross checked with actual situation. From the analysis, it is found that over all accuracy is 86.57% in phase I, 89.62% in phase II and 92.38% in phase III. Here, it should be mentioned that total 163 sites selected from Google earth images are not equally same for all the phases because of shift of wetland area and transformation over phases.

3.1.3 Identification of permanent and seasonal wetlands in different hydrological paradigms

Higher dynamics of water presence area between two seasons is found in every phase of hydrological paradigms which signify inter annual variability of floodplain wetlands. We have classified total water presence areas into two major categories viz. permanent and seasonal. It is considered that the water presence area sustains even up to pre monsoon or summer period it can be treated as permanent. In order to identify seasonal wetland area WPF map of pre-monsoon season is deducted from WPF map of post-monsoon. Extra part beyond perennial water presence area is treated as seasonal wetland. Inter-hydrological phase wise comparison reveals seasonal water presence area gap gradually increases over recent phases (Fig. 3a–c). In phase-I, permanent and seasonal water body area were 9006.4 and 11268.43 ha respectively and seasonal gap of water presence area was 24% while in phase-II,
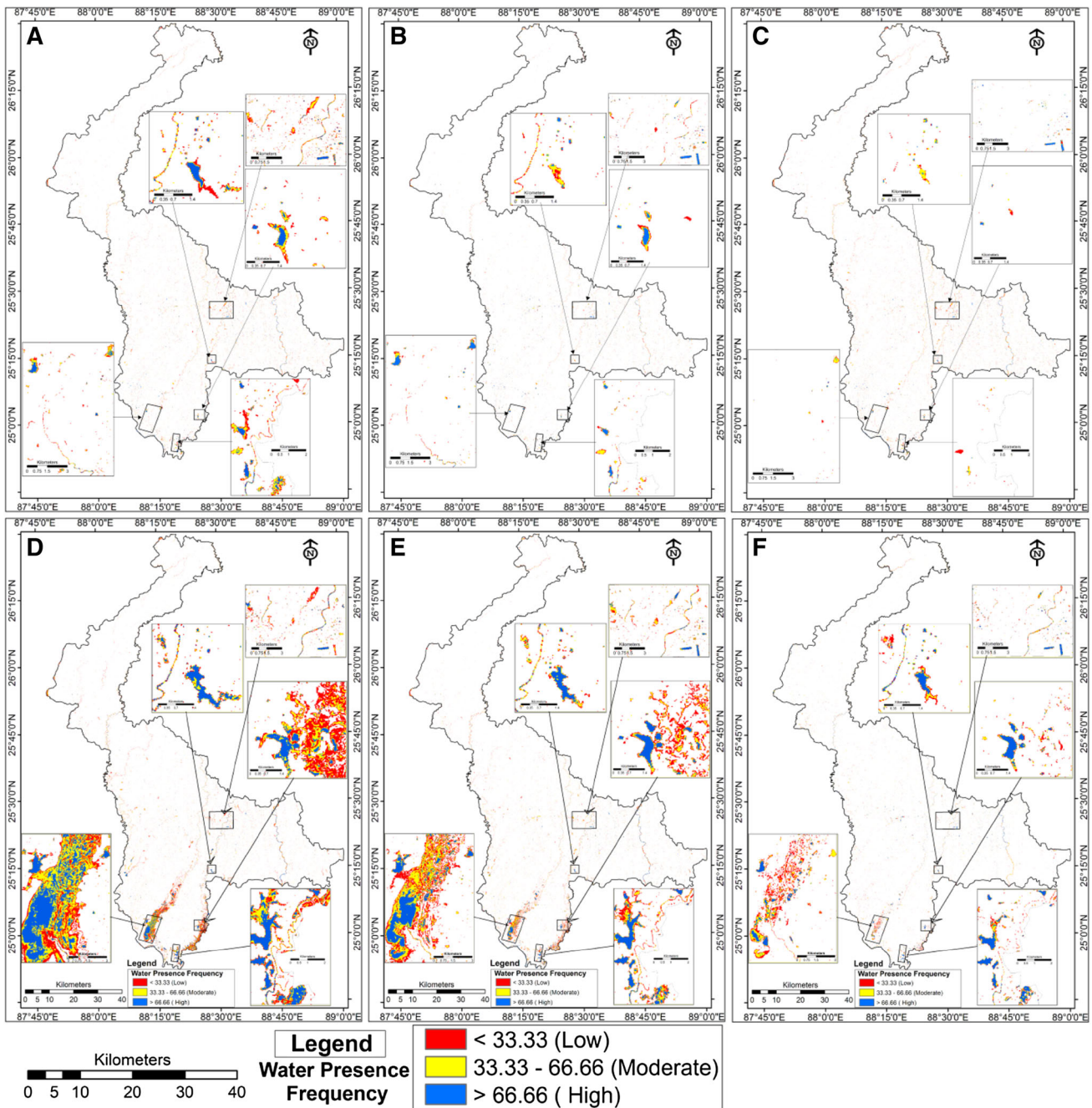
Fig. 2 Water presence area of phase-I (a), II (b), III (c) in pre-monsoon season and water presence area of phase-I (d), II (e), III (f) in post-monsoon season

seasonal and permanent wetted area were reduced to 8171.91 and 5165.01 ha respectively (Table 2) but gap of seasonal water presence area is further increased to 57%. It is also increased to 78% in phase-III.

3.1.4 Trend and instability analysis

Trend of seasonal water presence area exhibits the fluctuations of areal extent and pattern of instability of wetland

areas in different phases of the study area. Year wise trend shows higher variability of water presence area for both the seasons in every phase. But average water presence area continues to decrease from phase-I to phase-II to Phase-III. In phase-I for pre-monsoon, average water presence area was 11083.6 ha and it was quite low in Phase-II (8942.29 ha) and phase-III (4535.18 ha). Continuous declining trend is found in both the seasons but this rate is quite strong during pre-monsoon season (R^2 value
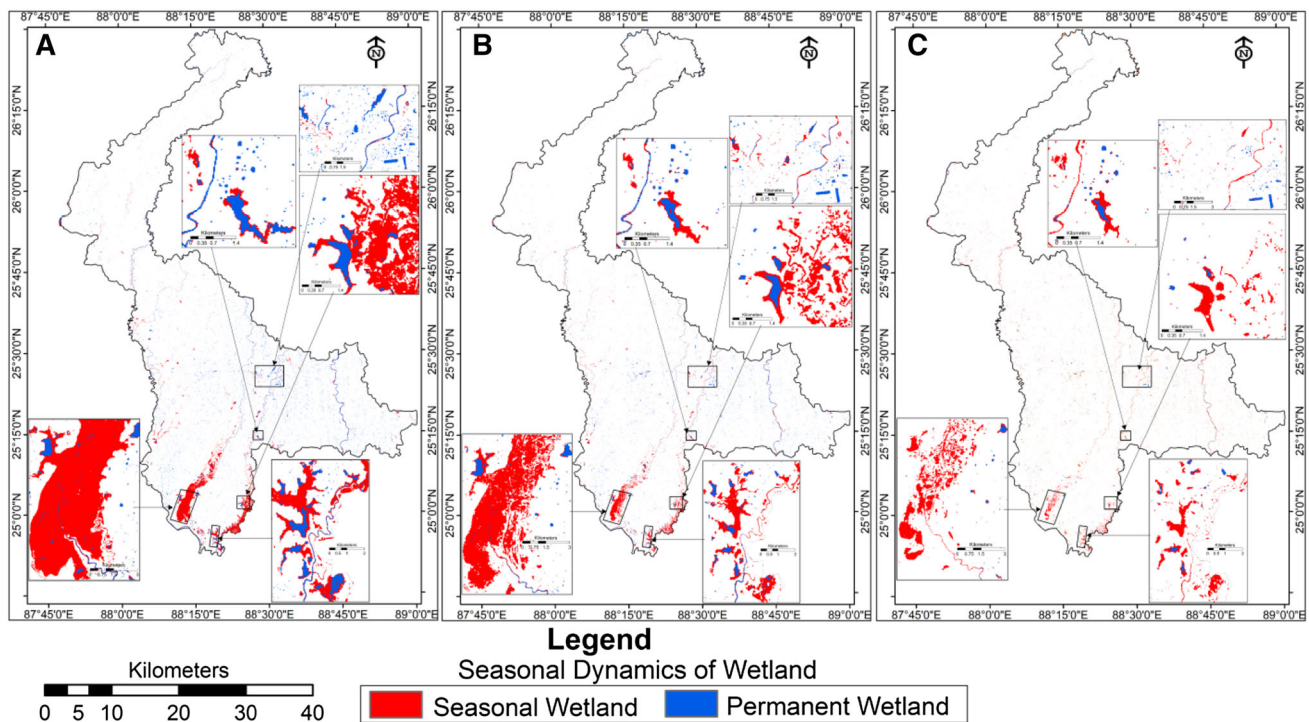
Fig. 3 Seasonal dynamics of wetlands; **a** phase-I (1988–1992), **b** phase II (1993–2011) and **c** phase III (2012–2016)

increased from 0.654 to 0.704). The scenario of the post-monsoon season differs from pre-monsoon and it is observed that declining trend is slower than pre-monsoon season due to having monsoon rainfall effect. In post-monsoon season, average wetland area was reduced from 18283.49 ha in phase-I to 15510.57 ha in phase-II and 11113.66 ha phase III respectively. One fact is observed that immediate after installation of dam, water presence area is reduced significantly.

But from the trend analysis, it is revealed that beyond this general trend of wetland change, few years (1996, 2001 and 2013) register quite abnormal expansion of wetland area due to excessive rainfall and massive flood incidents. This figure also illustrates that even in the core wetland part; continuity of wetland area is squeezed over the period of time.

Range of variability approach (RVA) is one of the frequently used method developed by Richter et al. [32] used for describing the ecological threshold limits of variability of the ecological components e.g. flow amount. Quarterlies deviation is also quite similar kind of approach for the same. Here phase wise seasonal wetland area for the concerned years and their respective 3rd and 1st quartiles have been calculated and presented in Fig. 4a, b. The main aim for this is to see how many years wetland area fall within the range of 1st and 3rd quartiles. If it is within this range it can be stated that the fluctuation of wetland area is normal and natural. Form the figures it is clear that over the

advancing phase wetland area frequently fails to attain this range. This failure rate would be much higher (40%) in both the seasons if all the phases are judged in reference to the deviation limits of the 1st phase.

Instability index depicts same trend of instability hike in post dam condition and seasonal variation of instability is quite similar to the result of co-efficient of variation as stated (Table 3). Wetland extent is more instable during pre monsoon (30.49–46.06) than post monsoon.

3.1.5 Estimation of wetland overall loss

Wetlands are subjected to rapid change in the study area due to modification of hydrological regime by anthropogenic causes. Review of multi temporal NDWI and a comparative analysis reveal that total 13206.94 ha water body areas have decreased since 1988–2016 (Fig. 5). Phase wise wetland loss of various categories (high, moderate and low water presence frequencies) is also calculated and shown in Table 2. There are serious hydro-ecological implications for the floodplain wetlands in study area due to alteration in the inter-seasonal and inter-annual periodic water presence frequency change. Wetlands of fringe area are relatively more variable than the deeper part. It is found from the hydrologic gradient of WPF zone that smaller size wetlands are inconsistent in terms of hydrological regime and shallower wetland are more prone to loss (Table 4).
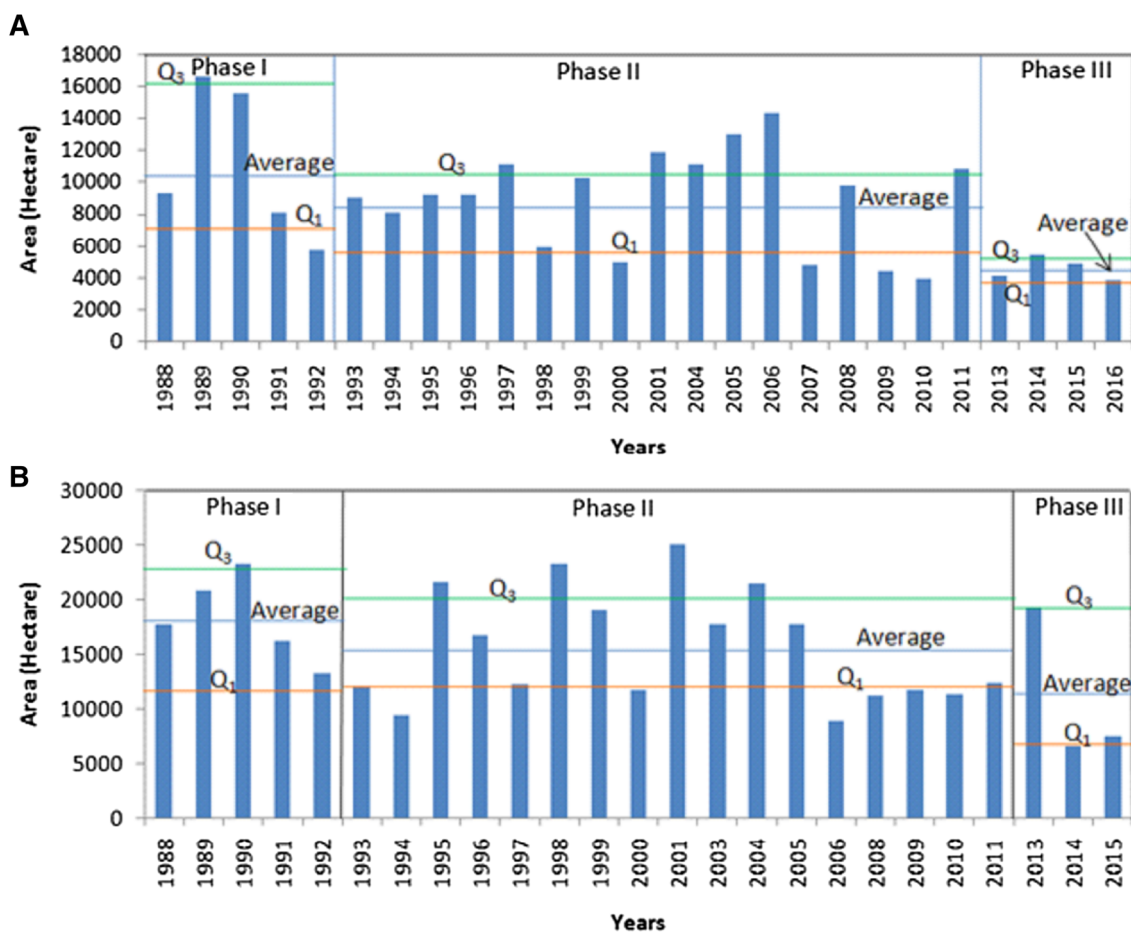
Fig. 4 Trend of water presence area in pre-monsoon (**a**) and post-monsoon season (**b**)
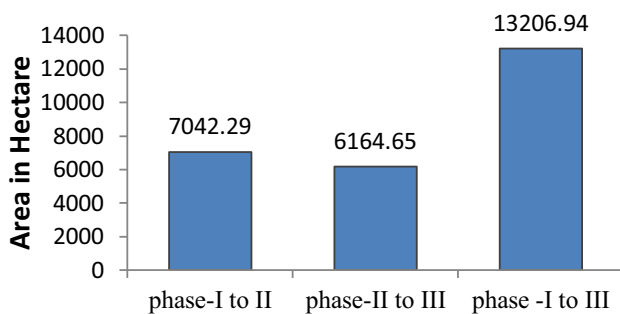

Fig. 5 Total wetland loss in different phase

Figure 6a, b represents total wetland loss in different phases. During the 1980s to the 2016, large areas of wetlands were lost each year but maximum loss was in the 2nd phase to 3rd phase.

3.1.6 Intra wetland conversion status

A large area of wetlands were converted to other land uses even inter class conversion is also significantly high. Change detection of wetland classes (WPF) and its areal

extent are given in form of change matrix. The most salient change in the wetland class has been the quick augment in the area under seasonal and ephemeral wetlands classes. Low and moderate WPF area is highly converted to agriculture land (Fig. 7a–c). In phase-I to II about 4401.86 ha ephemeral (low WPF) water body completely converted to non-water body (Table 4). From phase-II to III 2821.253 ha more such wetland area is converted to non-water body. Such non water body is occupied by either agriculture land, high way or built up lands. Table 4 shows change matrix since phase I to phase III.

3.1.7 Identification of major river basin as hydrological units and estimation of wetland area

Intensive discharge modification happens in different times over different years and expectedly different basins will react diversely on that connection. Keeping this view in mind, basin wise wetland estimation and concerned loss is calculated for the major river basins like Atreyee (A), Punarbhaba (P), Tangon (T), Kulik (K) and Nagar (N). Inter seasonal variability of WPF is also measured for

Table 4 Change matrix showing the total wetland area (in hectare) converted from one type to next in different phases and wetland loss

| Phasal change	Water presence categories	Non-water body	Ephemeral (Low WPF)	Seasonal (Moderate WPF)	Permanent (High WPF)	Permanent	Seasonal	Ephemeral
Phase-I (1988–1992) to Phase-II (1993–2016)	Non-water body	668551.6	4401.86	421.08	30.82	256.98	1268.1	2328.75
	Ephemeral	622.61	1884.53	1053.71	108.87			
	Seasonal	59.75	206.22	575.84	228.29			
	Permanent	5.22	31.81	216.04	481.47			
Phase-II (1993–2011) to Phase-III (2013–2016)	Non-water body	672790	2821.25	423.88	142.58	577.66	658.99	1359.76
	Ephemeral	476.25	686.34	423.97	238.84			
	Seasonal	98.24	131.86	171.96	254.07			
	Permanent	40.37	30.28	50.29	99.05			
Phase-I (1988–1992) to Phase-III (2013–2016)	Non-water body	668515.2	5871.31	1471.06	318.97	834.64	1927.09	3688.51
	Ephemeral	523.31	515.31	549.23	238.53			
	Seasonal	127.68	126.69	189.85	212.26			
	Permanent	47.68	30.05	61	81.34			
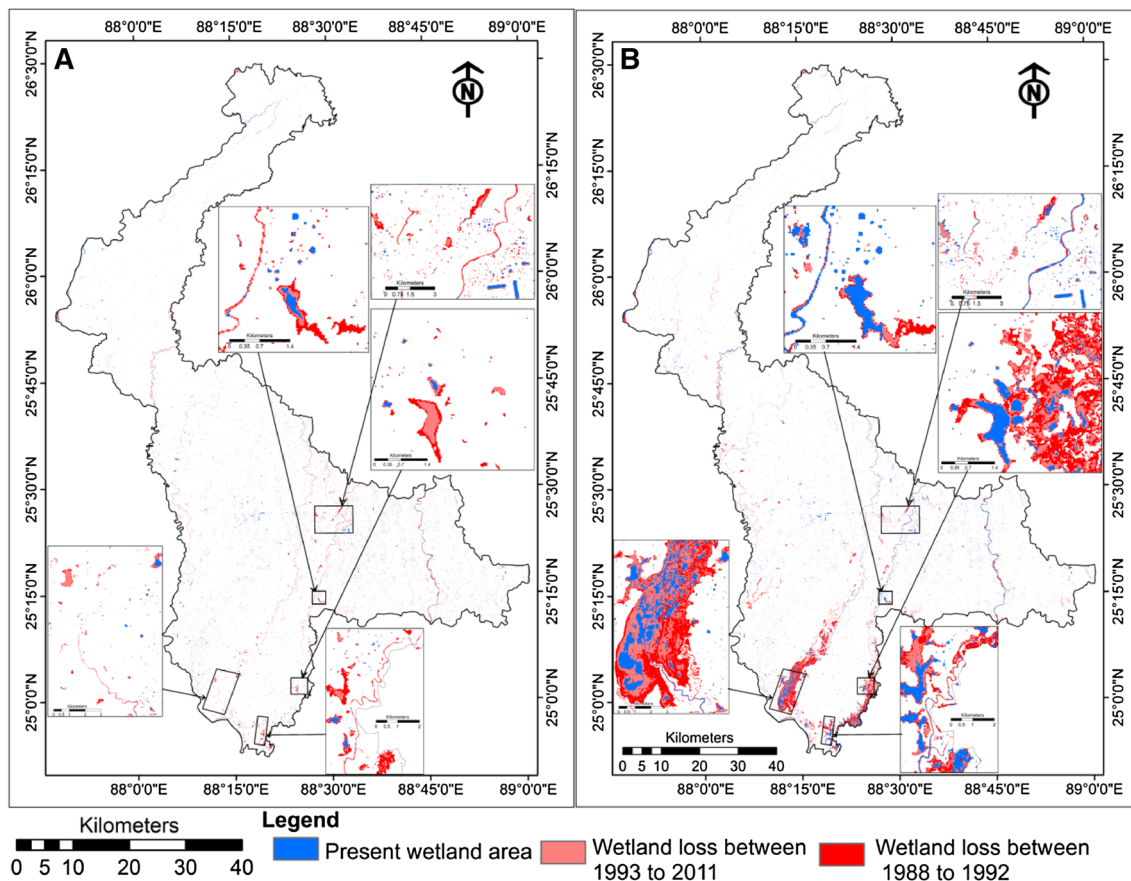
Fig. 6 Wetland loss in pre-monsoon season (**a**) and post-monsoon season (**b**)

different river basins. Major two wetland patches over the study area is located in the confluence reaches of Punarbhaba and Tangon rivers. In Tangon river basin dam was constructed in 1989 and therefore expected impact will be maximum in phase I to phase II. Table 5 depicts the wetlands of different kinds located over different river basins.
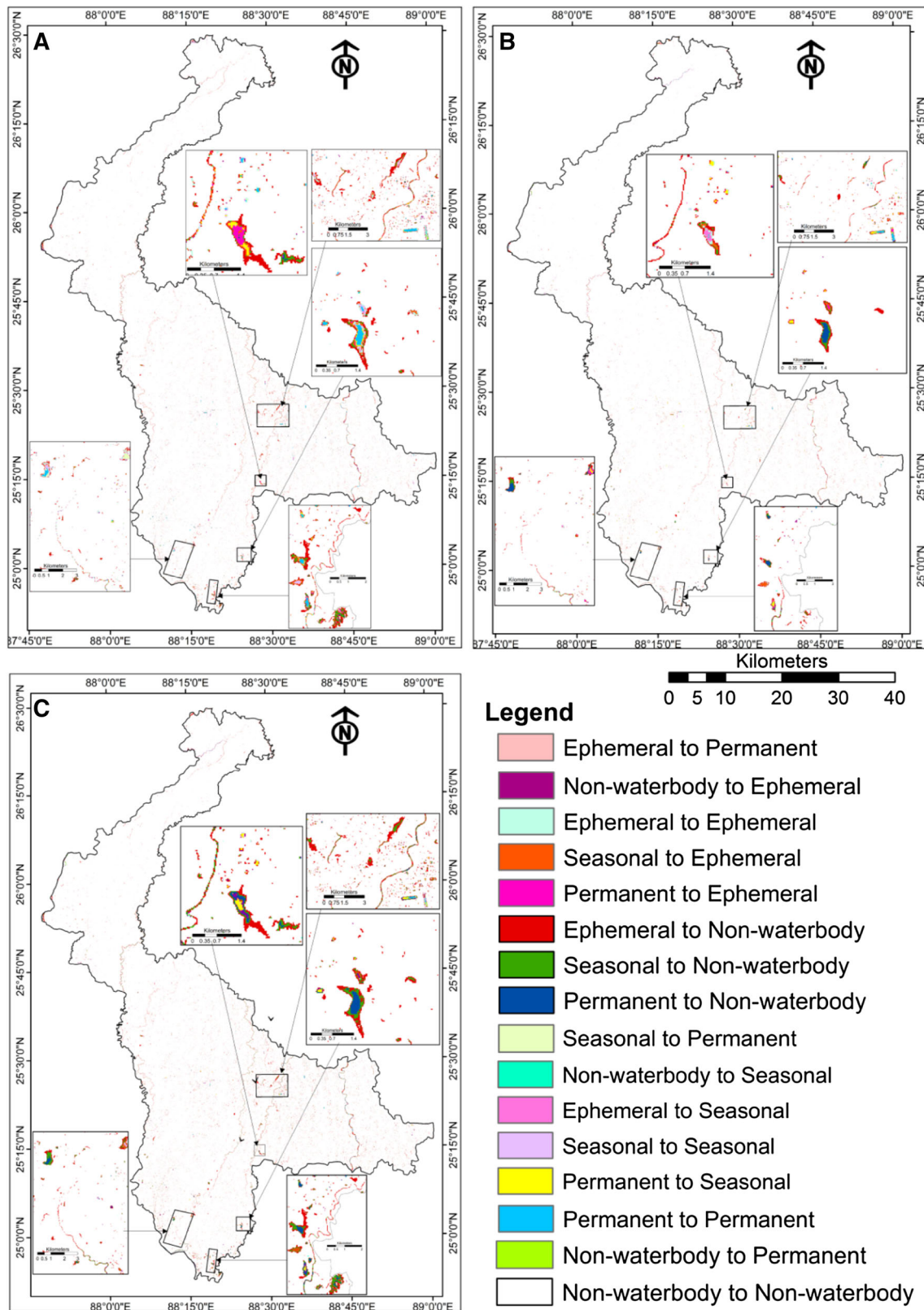
Fig. 7 Change matrix since Phase I to II (**a**), Phase II to III (**b**) and Phase I to III (**c**)

It is clear that in phase I, wetland area was 9571.4 ha and it is reduced to 5934.6 ha in phase II. Punarbhaba river is also highly affected in terms of squeezing of wetlands in this phase because there is linkages between two rivers. From phase II to III, this river basin have experienced maximum wetland loss (>30%) as controlling of flow through dam was started since 1992. In case of Atreyee river basin since phase I to II 15.52% wetland was lost but after construction of dam over this river on 2011, since phase II to III 31.51% wetland is lost. Lifting of water through sluice gates over Kulik river has also reduced discharge on the river and its effect is exercised on wetland extent. In both phase I to II and II to III, extent of wetland are reduced by 32.49% and 21.23% respectively (Table 5). Seasonal wetland is more vulnerable in compare to perennial almost in all cases.

3.1.8 Sensitivity analysis of wetland map model

For analyzing sensitivity analysis of the wetland maps generated from Landsat image, 227 random wetland coordinates we have selected and among them 103 is selected for field verification and rest 124 is tested from relatively higher resolution Google earth image. During field survey it is investigated (1) whether the sites possess water body or not and (2) what are the depths of water body and level of turbidity in water. Turbidity level data has not been tested in laboratory but interpreted visually.

From the analysis it is clearly observed that all 103 coordinates, selected for field investigation, register the presence of wetland and rest 124 sites tested from Google earth image shows the accuracy level is 98.38%. From this result it is evident that water presence area map is valid. In 87% cases, depth of water in wetland is accordant with scale range of NDWI value. We have also asked the people reside nearby the wetland regarding the stability of wetland. From their answer, it can be inferred that in 93.20% cases (out of 103 coordinates tested from field) the expectation becomes true. The area where water presence is consistent in the map is strongly supported by the concerned respondents.

3.2 Discussion

If we seriously observe the major reasons behind gradual wetland loss over phases, alteration of river flow regime, change of rainfall in monsoon period, encroachment of agriculture land towards wetland, restricting interaction between ground water and wetlands etc. can be condemned. But, out of all these constellation of dam over the rivers is the primary dominant vector of riparian water body loss and transformation. Discharge analysis of the rivers mentioned that range of water attenuation varies from 20 to 67% in both pre and post monsoon seasons. Natural spilling frequency is reduced significantly and small tie channels those were previously connected rivers

Table 5 Areal extent of different wetland types in the concerned river basins and phasal changes

| Phase	River Basin	Wetland area (hectare)			% to geographical total area			Phasal change (%) of water l presence area		
		Permanent	Seasonal	Total	Permanent	Seasonal	Total	I to II	II to III	I to III
I (1988–1992)	A	1688.17	95.38	1783.55	1.93	0.1	1.94	15.52	–	–
	P	2366.73	3760.88	6127.61	2.4	3.81	6.21	37.90	–	–
	T	2816.97	6754.43	9571.4	1.56	3.67	5.21	38.00	–	–
	K	891.47	438.28	1329.75	0.87	0.42	1.29	32.49	–	–
	N	645.6	259.59	905.19	0.43	0.18	0.62	22.10	–	–
	F	502.08	150.63	652.71	0.9	0.27	1.17	26.72	–	–
II (1993–2011)	A	1257.73	248.98	1506.71	1.37	0.27	1.64	–	31.51	–
	P	1153.44	2651.98	3805.42	1.17	2.69	3.86	–	31.46	–
	T	1814.48	4120.12	5934.6	0.99	2.24	3.23	–	34.79	–
	K	408.16	489.55	897.71	0.39	0.48	0.88	–	21.23	–
	N	266.44	438.72	705.16	0.18	0.29	0.48	–	3.78	–
	F	255.76	222.56	478.32	0.45	0.4	0.86	–	4.37	–
III (2012–2016)	A	647.12	297.65	944.77	0.7	0.32	1.03	–	–	47.03
	P	441.17	1436.34	1877.51	0.44	1.45	1.9	–	–	69.36
	T	842.32	1762.47	2604.79	0.46	0.96	1.41	–	–	72.79
	K	279.01	336.42	615.43	0.27	0.33	0.6	–	–	53.72
	N	128.13	542.84	670.97	0.08	0.37	0.45	–	–	25.88
	F	220.18	229.62	449.8	0.39	0.41	0.81	–	–	31.09
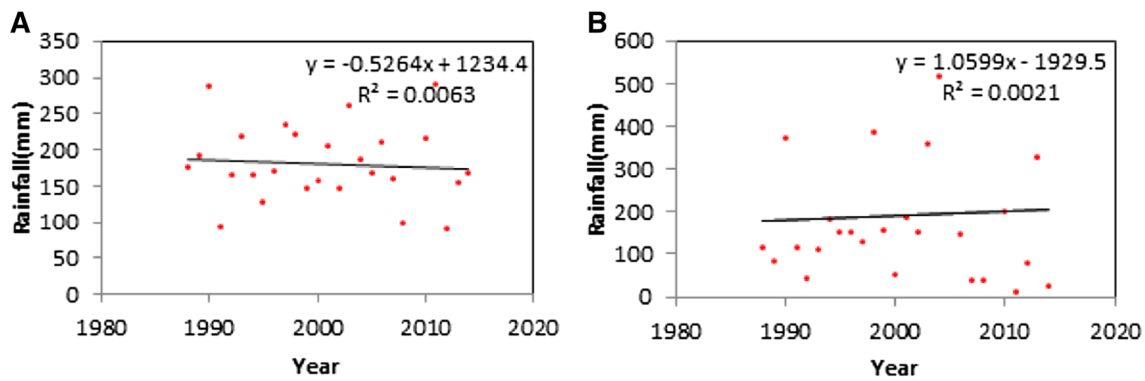
Fig. 8 Rainfall in pre-monsoon (**a**) and post-monsoon season (**b**)

and water bodies have been lost. The threat of river regulation projects to these riparian wetlands have been well documented which show that dam construction has altered the hydrology of the majority of wetlands of southern confluence part of Punarbhaba and its tributary Tangon river. No significant change of rainfall is observed in the study area. Least square regression models (Fig. 8a, b; $r^2 = 0.006$ for premonsoon and 0.002 for post-monsoon) of the rainfall proves that there is no significant change of rainfall. Therefore, this factor is not valid so far directly for deteriorating water body.

Continuous loss of riparian wetland accelerated corresponding environmental degradation. Invisible ecological services of the wetlands have curtailed which is irreparable. This alteration of hydrological regimes often results reduction of summer flood frequency, intensity and thereby augmentation of low flows. Reduction of water level results low stabilization of water in late summer and winter seasons. This ultimately causes unchecked wetland loss in the marginal part of these riparian wetlands. Marginal part of the wetland with infrequent hydro-duration and shallower depth, seasonal complete drying out of land etc. encourage fast invasion of peasants to the fringing wetland part with agriculture. It also transforms this fringe wetland part into agriculture land.

4 Conclusion

It may be concluded that Water Presence frequency based approach is very good method to identify and classify stable wetland zone on the basis of frequency of water presence. Here using this approach wetland of multi temporal phases for the entire area as whole and concerned river basins of the region is calculated. Vividly it is found that over time wetland area has been squeezing and it's a matter of concern from ecological point of view. Wetland loss may curtail several types of ecological goods and services which are essential for the survival of the people

and also not possible to purchase from the market. Such wetland inventories can be important in landscape and water planning, and it can play an important role in documenting and anticipating conflicts over wetland resources.

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