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Emerging conflict between agriculture extension and physical existence of wetland in post-dam period in Atreyee River basin of Indo-Bangladesh

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Abstract Alarming wetland loss and modification of wetland landscape in the Atreyee floodplain is an ensuing concern in post-dam condition (after the construction of a dam over Atreyee river in 2012). The nature of the conflict between the changing wetland and agriculture landscape in the altered hydrological state in post-dam period is investigated and illustrated. Agriculture and wetland maps are prepared from multi-temporal satellite images using frequency approach. The result clearly exhibited that agriculture land is increased substantially (4316.95–8047.53 km^2) and wetland is declined (1098.25–592.88 km^2) in the post-dam state. Out of the lost, 268.33 km^2 of wetland area is transformed into agricultural land and the transformation rate is high from low-frequency water presence (wetland with irregular water appearance) wetland to agricultural land. The consistency and stability of agriculture land are gradually increased over time when it is decreased in case of wetland. Extension and perforation of agricultural practices toward wetland areas are caused for wetland loss and fragmentation of wetland. It causes physical and ecological vulnerability of the same. Increasing number of wetland patches (25,839–31,769), decreasing frequency of agriculture patches (94,280–16,296), dwindling of large core wetland area (656.10–212.04 km^2), doubling of large core agriculture land (2270.87–3822.88 km^2), etc., are some of the evidences signifying growing conflict between wetland and agriculture land. Aggressive growth in agriculture land has been emerging as a strong reason for wetland loss and transformation.

Keywords Atreyee River basin · Wetland loss and modification · Agricultural expansion · Water and agriculture presence frequency · Wetland fragmentation and land use conflict

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1 Introduction

Wetlands are diverse ecology not only with ample variation in spatial and temporal scales but also in terms of habitat size, ecology, hydrology and geomorphology (Halls 1997; FAO water reports 2008). It helps to satisfy a variety of needs for hunting and gathering, spirituality, water resources and irrigation service to the agriculture (FAO water reports 2008). Similarly, floodplain wetlands are large and diverse (Bai et al. 2013), life-sustaining water resources (Panigrahy et al. 2012), species-rich habitats and these habitats can play a vital role in ecosystem services such as flood protection, water quality preservation, food chain support and carbon sequestration (Asselen et al. 2013; Li et al. 2014). In spite of immense such valuable goods and services, wetlands have been drained to for agricultural land worldwide (Verhoeven and Setter 2009; Mabwoga and Thukral 2014). During the twentieth century, more than 50% of wetland in North America, Europe, Australia and New Zealand were lost, converted or degraded (Millennium Ecosystem Assessment 2005). The estimated 58.2 million hectares of wetlands in India, 40.9 million hectares are held in rice cultivation (Anonymous 1993). Williams (1991) has reported that globally, 160,600 km^2 of wetlands had been drained by 1995, principally due to agriculture and food production. In New Zealand, this proportion is 90%. Wetland is a crucial step of the global cycles of nitrogen and sulfur (Deevey 1970) which is essential for agricultural sustainability. Economically backward rural people have a close affinity with the wetlands for harvesting foodstuffs and nutrition from there (Millennium Ecosystem Assessment 2005; Pal 2016a). But the rapid conversion of wetland not only has made them vulnerable but also pushes the healthy diverse habitat toward marginality and extinction.

While dealing with the reasons behind wetland loss and conversion, scholars have condemned diverse factors in different regions. Yin et al. (2012) Liu et al. (2012), Talukdar and Pal (2016) and Das and Pal (2017a) accused agricultural encroachment is the major reason of wetland extinction in the riparian floodplain region. Mondal (2017) and Ziaul and Pal (2017) reported that wetland adjacent to the urban area is converted into a built-up land. In spite of the benefits of waste management, pollution control and moderation of temperature, wetland reclamation through urbanization is an aggressive trend in India (Mitsch 1994; Wu et al. 2010). For this, municipal corporations are getting overburdened with the cost of pollution management, sewage treatment (Fazal and Amin 2011). Recent studies developed by Pal (2016b, c), Das and Pal (2017b) reported that discharge attenuation, reduction of spilling frequency and magnitude are also the vital reasons for squeezing wetland area, wetland loss and conversion. Talukdar and Pal (2017a) reported that construction of the dam over the river has reduced the flood command area and the wetlands recharged by inundated water have become inconsistent and in some cases, they become wiped out in Punarbhaba River basin of Barind tract adjacent to the Atreyee river, the present interest of study. Attenuation of flood frequency in post-dam period is also well reported by Pal (2016a) and Pal and Saha (2017). Pal and Akoma (2009) and Das and Pal (2017b) documented that lowering of groundwater is linked with drying out wetland. Groundwater level very near to surface or above surface helps to support perennial characters to the wetland (Cowardin and Laurer 1976; Hoque and Burgess 2012; Mondal and Pal 2017). A gradual lowering of the groundwater level is one of the major reasons behind the transformation of wetland. Apart from wetland loss or transformation qualitative degradation of wetland habitat, water quality, inlet and outlet system, etc., are also some bigger issues (Asselen et al. 2013; Luan and Zhou 2013). Due to an encroachment of agriculture land, built-up land within wetland often fragments the continuity of wetland. According to Murungweni (2013), people interference into the wetland through cultivation and construction has resulted in the fragmentation of landscape, biodiversity of the wetland. Large wetland transforms into smaller one indicating breaking down of ecology and ecosystem (Abdu-Raheem 2014; Nindi et al. 2014; Pal and Saha 2017). It also causes breaching of biodiversity in wetlands. Fragmentation of wetland sometimes helps to manage wetland properly, but most of the cases, it becomes a forwarding step of wetland conversion and loss (Das and Pal 2017a, b). However, among different causes, in IWMI Research Report, McCartney et al. (2010) stated that agriculture remains the greatest threat to natural wetlands. Most of the previous work (Pal and Akoma 2009; Talukdar and Pal 2016; Das and Pal 2017b) clearly condemned that in a riverine floodplain, agriculture has appeared as a prime aggressive factor of wetland loss and vulnerability.

2 Study area

The Atreyee river is an Indo-Bangladesh trans-boundary river with diverse aquatic ecosystems (Adel 2013). The lower part of the basin is characterized by a good number of rainfed and flood water fed wetlands, and they are mainly located along the riparian floodplain corridor of the lower Atreyee River basin (Fig. 1). Most of the wetlands are seasonal and highly irregular in water appearance. Water supply to the floodplain wetlands relies on

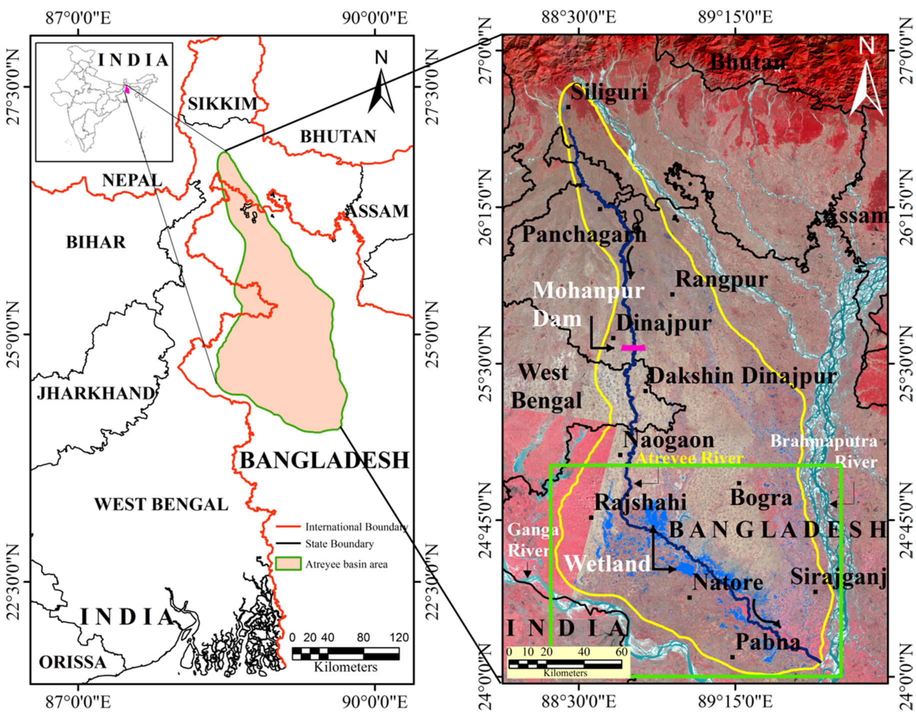

Fig. 1 Atreyee River basin of Indo-Bangladesh in reference to its surrounding administrative and physical units. Location of Mohanpur dam is denoted in the map, lower part of Atreyee River basin is highlighted using a rectangle

frequency, duration, the magnitude of inundation of the rivers (Talukdar and Pal 2017b). For enhancing irrigation supply, Mohanpur rubber dam was constructed over Atreyee river at Mohanpur in 2012. The period of time after the construction of the dam (2012 onward) is considered as a post-dam phase. Along with this direct water lifting and diversion of water from the river through river lift irrigation projects, it has reduced downstream river flow by 18.26%; flood frequency by 100% (Pal 2016a). Naturally, the flood command area will be reduced and wetlands outside the present flood limit will suffer from water scarcity in post-dam period (2012 onward). Inconsistent water supply due to rare flood incidents pushes the wetlands toward a crisis of physical existence and facilitates farmers to reclaim wetlands for agriculture (Das and Pal 2017b). Increasing population pressure has raised the demand for agriculture land and direct conflict arises between wetland and agriculture land. Considering this issue, the present paper intended to scientifically delineate the wetland and agriculture land of Lower Atreyee River basin. The present work wants to investigate the emerging conflict between agriculture extension and the crisis in the physical existence of wetland in a post-dam period in Atreyee River basin. The role of flow regulation through Mohanpur dam is also tested in this work breaking the entire study period into two halves (pre- and post-dam periods). Not only the direct land transformation is investigated, but the focus is also given on intra-landscape modification like fragmentation, enlargement, modification of landscape shape, etc. The present work also wants to investigate the rate of wetland and agriculture land area change in pre- and post-dam phases. Here, it is hypothesized that areal extent of agriculture land will be increased and wetland area will be decreased. Hastening the rate of such increase and decrease does indicate incident of damming has a significant role on reviving the land use conflict between wetland and agriculture.

3 Materials and methods

Since 1987–2016, 14 selected Landsat TM and OLI images (post-monsoon season) have been considered for the wetland and agricultural land extraction and mapping in both pre- and post-dam periods (before and after 2012). Details about the dataset with their dates of the acquisition have been given in Table 1. Primarily for delineation of wetland and agricultural land, 3, 4 and 5 band combinations are used as these bands have the ability to discriminate land–water interfaces (Deka et al. 2011).

Table 1 Frequency of satellite images of post-monsoon season taken for pre-dam (1987–2012) and post-dam (2012 onward) phases and specification of the sensors

Period	Satellite	Sensor	Date of acquisition	Spatial resolution (m)	Path/row
Pre-dam	Landsat 5	TM	08.12.1987, 08.11.1988, 11.11.1989, 29.10.1990, 08.12.1993, 16.10.1997, 04.11.1998, 25.12.1999, 07.11.2005, 01.12.2008, 23.12.2010 Total frequency = 11	30	138/43
Post-dam	Landsat 8	OLI	29.11.2013, 31.10.2014, 07.12.2016 Total frequency = 3		

3.1 Methods for agricultural land mapping

Agriculture is a leading appearance of land management (Dale and Polasky 2007). The extension of agriculture in natural dry land areas may affect wetlands negatively (Junk et al. 2013). In this study, to detect the agricultural land Landsat images of different years since 1987–2016 of the post-monsoon season have been used. However, to delineate the agricultural land NDVI images are prepared from each selected raw image (Eq. 1) (Townshend and Justice 1986) and for consistency analysis of the agriculture land, agriculture presence frequency (APF) approach is used (Eq. 2) separately for pre- and post-dam periods. Post-monsoon images are taken because in this time agriculture land is covered with mature crops and shows spectral proximity to vegetated land.

$$\mathrm{NDVI} = \frac{(\mathrm{IR\ band}\ -\ R\,\mathrm{band})}{(\mathrm{IR\ band}\ +\ R\,\mathrm{band})} \tag{1}$$

where IR = near-infrared band (band 4 of MSS and TM), R = red band (MSS band 2, TM band 3). A value between 0 and 1 indicates vegetation coverage (including cropland), value nearer to 1 means greater canopy density. Seasonally, this value slightly differs to some extent in the present study area because of dominant deciduous species. The entire range of NDVI indicating vegetation is not taken into consideration for cropland. For this, 232 filed references and 567 Google references are used for defining a threshold for cropland. In this study, the threshold range for delineating agriculture land during the post-monsoon season ranges between 0.02 and 0.5.

$$\mathrm{APF}_j = \frac{\sum_{i=1}^{n} I_j}{n} \times 100 \tag{2}$$

3.2 Methods for wetland mapping and consistency analysis

A good number of indices (NDWI, MNDWI, WI) are available for delineating wetland, but all may not be suited for all regions (Das and Pal 2016), while for the present study Normalized Differences Water Index (NDWI) (McFeeters 1996) is used considering the fact that (1) it maximizes the reflectance of water body in a green band and (2) minimizes the same in near-infrared band, and therefore, land water discrimination is identified (Sun et al. 2012). Das and Pal (2016) also reported that this method is suitable in the Barind region where the present study area belongs. NDWI is calculated using Eq. (3).

$$\mathrm{NDWI} = \frac{(\mathrm{Green\ band} - \mathrm{NIR\ band})}{(\mathrm{Green\ band} + \mathrm{NIR\ band})} \tag{3}$$

where positive NDWI value (0–1) stands for the water body.

According to Borro et al. (2014) a wetland map, which is produced from the single-date image, cannot represent the average wetland extent in the region where the appearance of the wetland is highly erratic. For this, multi-dates NDWI images are integrated using water presence frequency (WPF) approach (Eq. 4). Same years are taken as used for agriculture presence frequency mapping. Each integrated map is classified into three categories (low < 33%; moderate 33–67% and high > 67%) based on the frequency gradient. High-frequency water presence class indicates consistent agriculture land, and low class indicates irregularly appeared wetland.

$$\mathrm{WPF}_j = \frac{\sum_{i=1}^{n} I_j}{n} \times 100 \tag{4}$$

WPFj = Water presence frequency of jth pixels in a time period; I_j = jth pixel having water in the selected NDWI images; n = number of images. This value ranges from 0 to 100%. The value near to 100% indicates high-frequency water body with greater stability, and value near to 0 shows low-frequency water body with high instability, and this class may be prone to conversion.

3.3 Method for analyzing trend of wetland and agricultural area

Least square regression method ($y = a + bx$) is used for estimating the trend of areal extent (year wise) of wetland and agriculture land in pre- and post-dam periods. Reversal of the trend of these two land uses/covers indicates conflict, and unidirectional trend indicates no conflict. Similarly, degree of change is another vital factor. If degree of change of areal extent of agriculture land is increased and wetland area is decreased significantly in the post-dam period, it clearly indicates that flow alteration through dam has a crucial role on such trend. Coefficient of determination (R^2) is calculated for assessing the degree of change, and p test is carried out to show whether the change is significant or not.

3.4 Methods for validating wetland and agriculture land maps

Kappa coefficient (k) is a good determiner frequently applied for validating classified satellite imageries (Maingi and Marsh 2002; Congalton and Green 2009), and it is a more sophisticated technique and thus provides better inter-class bias than overall accuracy (Foody 1992; Ma and Redmond 1995). The value of Kappa lies between 0 and 1, where 0 represents agreement due to chance only, and 1 represents the complete agreement between the two datasets. K is calculated following Eq. (5). Apart from Kappa coefficient, overall accuracy, producer accuracy, user accuracy is also calculated for the same purpose. For justifying this work 100 reference sites of each frequency classes have been chosen over the relatively better resolution Google Earth images (2017) for pre- and post-dam phases each showing whether wetland and agricultural land are there or not. Stratified random sampling is used to distribute reference sites in different frequency class zones both for WPF and APF maps. For reference site selection Google earth image of the latest year of pre-dam (2010) and post-dam phase (2016) is taken into consideration.

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} \times x_{+i})} \tag{5}$$

where N = total number of pixels; r = number of rows in the matrix; X_{ii} = number of observation in row i and column i; x_{i+} and x_{+i} are the marginal totals for row i and column i, respectively.

3.5 Method for analyzing interaction between agriculture and wetland

To appraise the inter-class (high to moderate or low inundation frequency wetland as well as agricultural land) transformation of both wetlands and agricultural land in between pre- and post-dam periods in seasonal scale (mainly post-monsoon season), change detection technique is applied in Arc GIS (version 10.3) environment. This technique helps to understand the spatio-temporal transformation pattern of land use/land covers.

3.6 Indices of landscape fragmentation analysis

To know the intra-landscape class modification (fragmentation, integration, extension) several fragmentation indices are frequently used. These indices also explicitly indicate the interaction of agriculture land and wetland (conflict or co-existence). Fragmentation refers to the intersecting landscape might be divided into parts but shows clear belonging to the same system before partitions (Huising 2002). In Fragstat software we have computed different fragmentation indices such as number of patches (NP), patch density (PD), largest patch index (LPI), landscape shape index (LSI), landscape division index (LDI), aggregation index (AI), normalized landscape shape index (NLSI), etc., for interpreting landscape change of both pre- and post-dam periods. Fragstat software supports spatial pattern analysis, for a categorical map like different types of land use/land covers separately. Definitions and other specifications of the selected matrices used in this work are presented in Table 2.

4 Results and analysis

4.1 Delineation of wetland

Figure 2a, b shows the water body maps of pre- and post-dam periods. It is clearly exhibited from the maps that wetland area is mainly concentrated in the very proximate area of the main river in the lower catchment of Atreyee River basin. The total calculated wetland area was 1098.25 km^2 in pre-dam phase and decreased to 592.88 km^2 in the post-dam period. Large wetlands are squeezed into smaller size wetland or fragmented into smaller one. The result also portrays that the areal extent of low-, moderate- and high-frequency inundated areas were, respectively, 546.28, 366.8 and 185.17 km^2 in pre-dam and 277.95, 184.01 and 183.92 km^2 in the post-dam condition of the post-monsoon season. Wetland area in each frequency class is declining significantly (Table 3). Deeper wetlands are concentrated only in few large core wetlands (Fig. 2b). Smaller wetlands of the pre-dam period have lost at a very momentous rate. Out of total wetland area of the post-dam period, 46.88% low-frequency wetland is prone to susceptibility because of their very infrequent and inconsistent appearance.

4.2 Identification of agriculture land

Figure 2c, d vividly displays agriculture presence frequency pattern of pre- and post-dam states. Agricultural map of the pre-dam state (Fig. 2c) shows that a large part of the riparian floodplain corridor was out of post-monsoon agriculture indicating water stagnation over the region and frequent chance of flood incidents. But in the post-dam period, a large part of the wetland area turned into agriculture land due to the reduction of flood magnitude and frequency (Fig. 2d). Total agriculture land during the pre-dam period was 4316.95 km^2, and it has substantially increased in the post-dam period (8047.53 km^2). The areal extent of the low-, moderate- and high-agriculture-frequency areas are, respectively, 1960.77, 1203.88 and 1152.30 km^2 in pre-dam and 3421.85, 2890.41 and 1735.26 km^2 in post-dam condition during the post-monsoon season

Table 2 Descriptions of the measures of Fragstat indices for landscape fragmentation studies

Indices	Sign	Value	Explanation	References
Number of patch	NP	$1 \leq NP \leq N_{max}$	Number of patches of a specific class	Turner et al. (1989)
Patch density	PD	$0 < PD$	Number of patches of a specific class per unit area (standardized to 100 ha in Fragstat)	McCarigal and Marks (1995)
Mean contiguity	CONTIG MN	$1 \leq N \leq 1$	Spatial connectedness of cells within a grid to yield an index highlighting configuration of the patch outline.	Johnson et al. (2007)
Total core area	TCA	$0 \leq CORE \leq 1$	Amount of area whose boundary started from patch edge to interior in specified distance	McCarigal and Marks (1995)
Aggregation index	AI	$0 \leq AI \leq 1$	Ratio between actual edge and total amount of possible edge	Bregt and Wopereis (1990)
Normalized landscape shape index	NLSI	n/a	With the LSI increasing the landscape is also becoming more complex	Johnson et al. (2007)

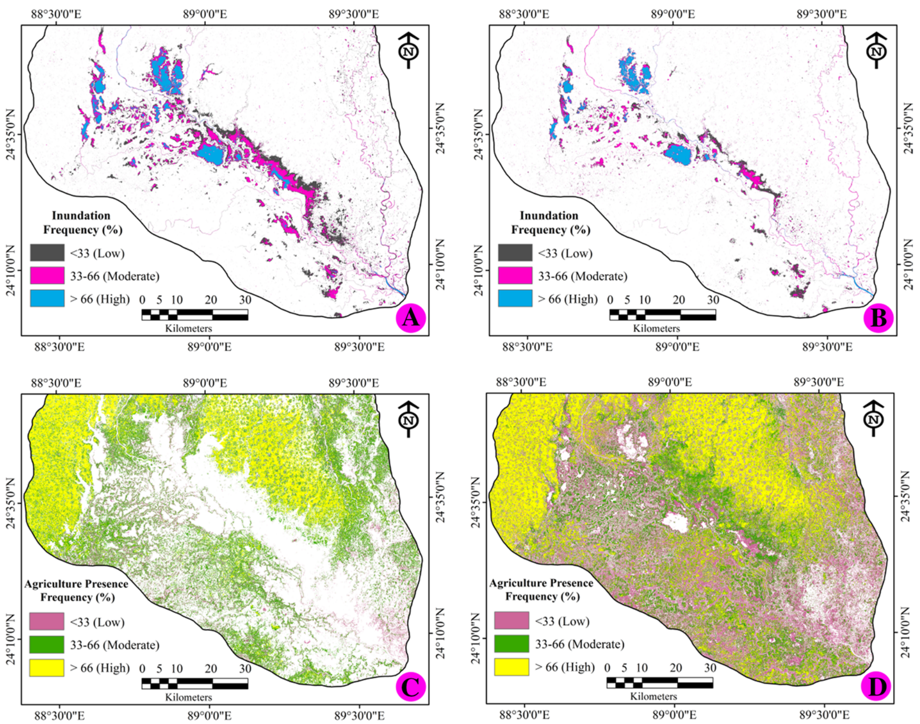

Fig. 2 Wetland and agricultural land of post-monsoon period within lower Atreyee River basin based on frequency approach in pre-dam (1987–2012) and post-dam periods (2012 onward): wetland distribution in the pre-dam (**a**), wetland distribution in post-dam (**b**), distribution of agriculture land in pre-dam (**c**) distribution of agriculture land in and post-dam (**d**)

Table 3 Area and percentage of area under different agriculture and water presence frequency (WPF) zones in Atreyee River basin in pre-dam (1987–2012) and post-dam (2012 onward) periods in post-monsoon season (October–December)

	Pre-dam (1987–2012)			Post-dam (2013–2016)		
	Pixel	Area (km^2)	% to total area	Pixel	Area (km^2)	% to total area
WPF zone (%)						
< 33 (low)	606,980	546.28	49.74	308,828	277.95	46.88
33–66 (moderate)	407,557	366.8	33.40	204,466	184.01	31.04
> 66 (high)	205,742	185.17	16.86	145,467	130.92	22.08
Total	1,220,279	1098.25	100.00	658,761	592.88	100.00
APF zone (%)						
< 33 (low)	2,178,629	1960.77	45.42	3,802,060	3421.85	42.52
33–66 (moderate)	1,337,649	1203.88	27.89	3,211,573	2890.41	35.92
> 66 (high)	1,280,337	1152.30	26.69	1,928,067	1735.26	21.56
Total	4,796,615	4316.95	100.00	8,941,700	8047.53	100.00

(Table 3). From an absolute areal point of view, it is observed that agriculture land has increased in all frequency classes indicating the extension of agriculture land. But from the relative areal point of view, it is noticed that part of the low agriculture presence frequency class is moved to the moderate frequency class pointing out the fact that consistency of agriculture activities becomes high in the post-dam period. The area entirely out of agriculture at very adjacent areas to the main river in pre-dam state is characterized by low to moderate agriculture presence frequency class in changed hydrological paradigm (post-dam). Over the period of time agricultural land has got stability of existence.

4.3 Trend of wetland and agricultural land

Table 4 represents the trend of both wetland and agricultural land area, in pre- and post-dam phases based on least square regression. The outcome specifies that in case of pre-dam phase, there is declining trend of wetland loss, but the degree of lowering wetland area is very poor as indicated by the very low coefficient of determination ($r^2 = 0.049$). But, this declining trend of wetland area has become prominent in the post-dam period as indicated by the stronger coefficient of determination ($r^2 = 0.788$). On the other hand, agricultural land was in increasing trend ($r^2 = 0.47$) since from pre-dam phase, but this rate is hastened in the post-dam period and it is pointed out by the stronger coefficient of determination ($r^2 = 0.745$). For assessing the level of significance, p value is calculated for all the least square regressions done here. Excluding the least square value calculated for wetland in pre-dam state ($p = 0.0698$), remaining cases' trends are significant. Insignificant trend of wetland area in the pre-dam phase indirectly proves the role of the dam for hastening the rate of wetland loss.

4.4 Sensitivity analysis of agriculture land and wetland maps

Calculated Kappa coefficients for the wetland of pre- and post-dam periods are, respectively, 0.92 and 0.89 (Table 5). Kappa coefficient > 0.8 indicates a good level of agreement between reality and model (Mansour et al. 2000).The same is 0.81 and 0.84 for agriculture lands for the same periods. Overall accuracy level and individual category specific accuracy levels are > 90% indicating the good level of performance of the classified wetland and agriculture land maps.

Table 4 Trend analysis of agriculture land and wetland area in pre- and post-dam phases in Atreyee River basin; coefficient of determination (R^2) and p value is given to each regression trend for understanding the degree and level of significance

Landscape	Phase	Linear regression	r^2	p value	Remarks
Agriculture land	Pre-dam	$125.1x + 3212$	0.47	0.0456	Significant
	Post-dam	$377.7x + 4047.$	0.745	0.0486	Significant
Wetland	Pre-dam	$-27.96x + 1252.$	0.049	0.0698	Not significant
	Post-dam	$-172.5x + 854.7$	0.788	0.0452	Significant

p value < 0.05 indicates statistically significant

Table 5 Accuracy assessment of WPF maps and APF maps for pre- and post-dam states in Atreyee River basin

Map types	Year	Class	Omission error (%)	Commission error (%)	Producer accuracy (%)	User accuracy (%)	Overall accuracy	Kappa coefficient
WPF	Pre-dam	Stable	4	4.00	96	96.00	95	0.92
		Moderate	2	8.41	98	100.00		
		Unstable	9	2.15	91	97.85		
	Post-dam	Stable	3	6.73	97	93.27	93	0.89
		Moderate	7	10.58	93	89.42		
		Unstable	11	3.26	89	96.74		
APF	Pre-dam	Stable	11	16.82	89	83.18	87	0.81
		Moderate	13	11.22	87	88.77		
		Unstable	14	9.47	86	90.53		
	Post-dam	Stable	8	9.803	92	90.19	89	0.84
		Moderate	11	11	89	89		
		Unstable	12	10.204	88	89.79		

4.5 Interaction between the dynamics between agriculture land and wetland/ conversion pattern of landscape

Figure 3a, b represents the nature of intra-class wetland and agricultural land alteration between pre- and post-dam phases of post-monsoon season, and Fig. 3c demonstrates the conversion of wetland into the agricultural land. From intra-class wetland and agriculture land transformation, it is found that 324.12 km^2 wetland area and 1880.19 km^2 agricultural land have remained unchanged; 159.45 km^2 wetland area and 383.91 km^2 agricultural land are totally turned into other land uses. About 230.19 km^2 wetland area and 2052.86 km^2 agricultural land area are transformed into one to another frequency class within same land type (Table 6).

Table 7 shows the conversion of wetland into agricultural land in post-dam phase and from this, it is clear that vast area of wetland in the riparian floodplain area of Atreyee River basin is captured by permanent agriculture land in a post-dam situation. Even the larger part of 436.24 km^2 low water presence frequency class is also seasonally used for agricultural activities. About 225.03 km^2 low water presence frequency is transformed into low APF followed by 193.36 km^2 from low WPF to moderate APF. But on the contrary, no such significant evidence is recorded where agricultural land is transformed into water bodies.

4.6 Indices of wetland and agricultural landscape in pre- and post-dam period

Figure 4a–d, respectively, represents fragmentation patterns of agriculture land and wetland in pre- and post-dam states. Spatial extents of large, medium and low core landscape, the pattern of edge, frequency of patch are well illustrated in the figures. A good number of new agriculture patches are nucleated in the riparian flood corridor of the lower reach of the basin. The average size of the large, medium and small core agricultural landscape has increased in post-dam condition. For example, the large

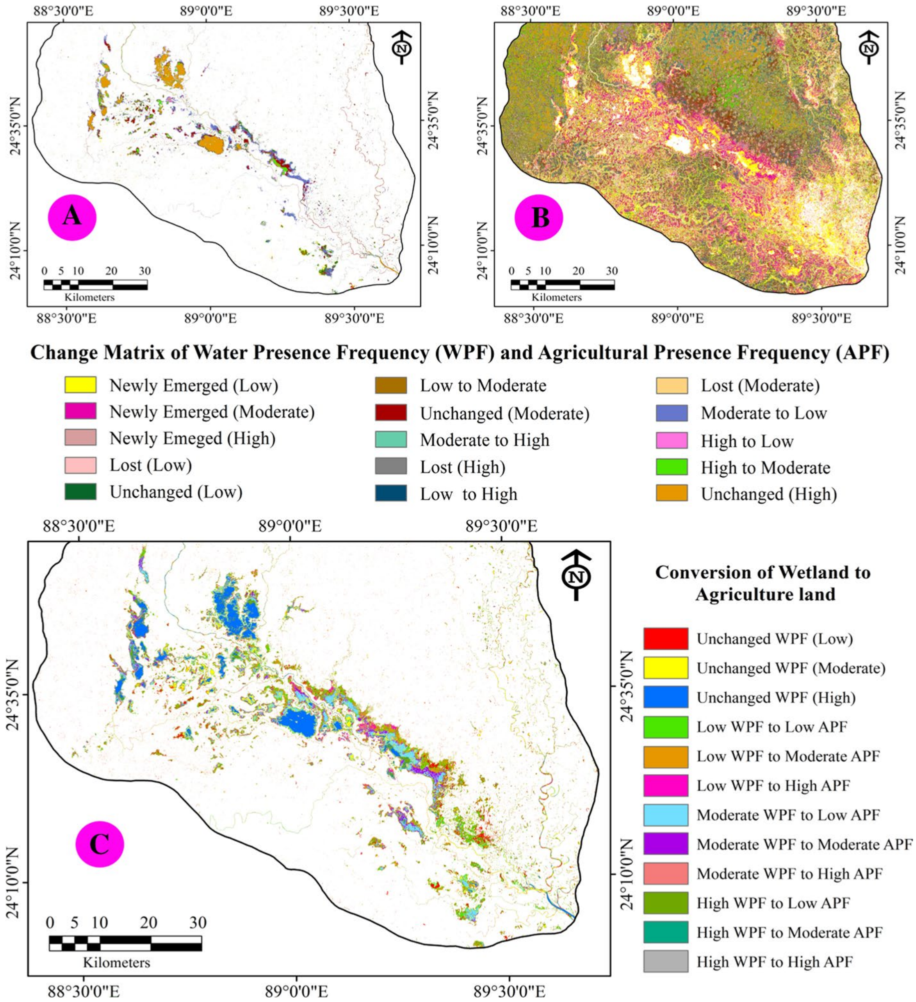

Fig. 3 **a**–**c** Change of wetland and agriculture land in post-dam condition in the lower Atreyee River basin showing intra-class changes of WPF (**a**), intra-class changes of APF (**b**) conversion of wetlands into agriculture land (**c**)

core agricultural landscape is increased from 2270.87 to 3822.88 km^2, the medium core landscape is increased from 103.25 to 178.72 km^2, and small core landscape is enhanced from 538.49 to 732.33 km^2 (Table 8). The increase of small core area indicates the formation of new agriculture patches mainly in the lower catchment. Coalescence of small patches and the formation of larger agriculture patches are very prominent in the areas where agricultural lands existed previously. On the contrary, wetland patch area and patch density have increased (patches: 25,839–31,769; patch density: 2.54–3.12/100 ha), but the number of large core (> 500 acres) wetland has declined (656.10–212.04 km^2) indicating fragmentation of large core wetlands. The frequency of

Table 6 Intra-frequency (high, moderate and low) class change detection between pre- and post-dam phases of wetland and agriculture land separately showing area under different classes in Atreyee River basin

Nature of shifting	Wetland		Agriculture land	
	Pixel count	Area (km^2)	Pixel count	Area (km^2)
Newly emerged (low)	25,079	22.57	2,607,551	2346.80
Newly emerged (moderate)	5447	4.9	1,639,982	1475.98
Newly emerged (high)	69	0.06	324,106	291.70
Unchanged (low)	95,659	86.09	843,218	758.90
Unchanged (moderate)	124,841	112.36	500,904	450.81
Unchanged (high)	139,631	125.67	744,978	670.48
Lost (low)	4511	4.06	353,095	317.79
Lost (moderate)	2773	2.5	59,575	53.62
Lost (high)	139	0.13	13,884	12.50
Low–moderate	25,602	23.04	654,144	588.73
Low–high	634	0.57	328,172	295.35
Moderate–low	158,243	142.42	246,359	221.72
Moderate–high	8572	7.71	530,811	477.73
High–low	11,494	10.34	104,932	94.44
High–moderate	51,229	46.11	416,543	374.89

Table 7 Conversion of wetland area to agricultural land in Atreyee River basin in post-dam period (2012 onward)

Shifting wetland to agriculture land	Pixel count	Area (km^2)
Low WPF to low APF	250,036	225.03
Low WPF to moderate APF	214,844	193.36
Low WPF to high APF	19,836	17.85
Moderate WPF to low APF	194,712	175.24
Moderate WPF to moderate APF	83,162	74.85
Moderate WPF to high APF	5308	4.78
High WPF to low APF	34,315	30.88
High WPF to moderate APF	1763	1.59
High WPF to high APF	90	0.08

agriculture patches has augmented (94,280–16,296) and conversely, the numbers of wetland patches have increased (25,839–31,769) in post-dam period. Perforation of agriculture land in the large core wetlands and consequent fragmentation and transformation is very clear. Aggregation index (AI) for agriculture land is increased (83.77–88.89) and for wetland, it is declined (89.52–83.88) in the post-dam period showing coalescence of agriculture land and the fragmentation of wetlands. Mean contiguity index shows the same trend. All these clearly exhibit that the control of water through dam has brought a significant change in the texture of wetland scape and pattern in the study area, and extension of agriculture land and nucleation of new patches of agriculture land have disrupted the spatial structure and composition of the wetland.

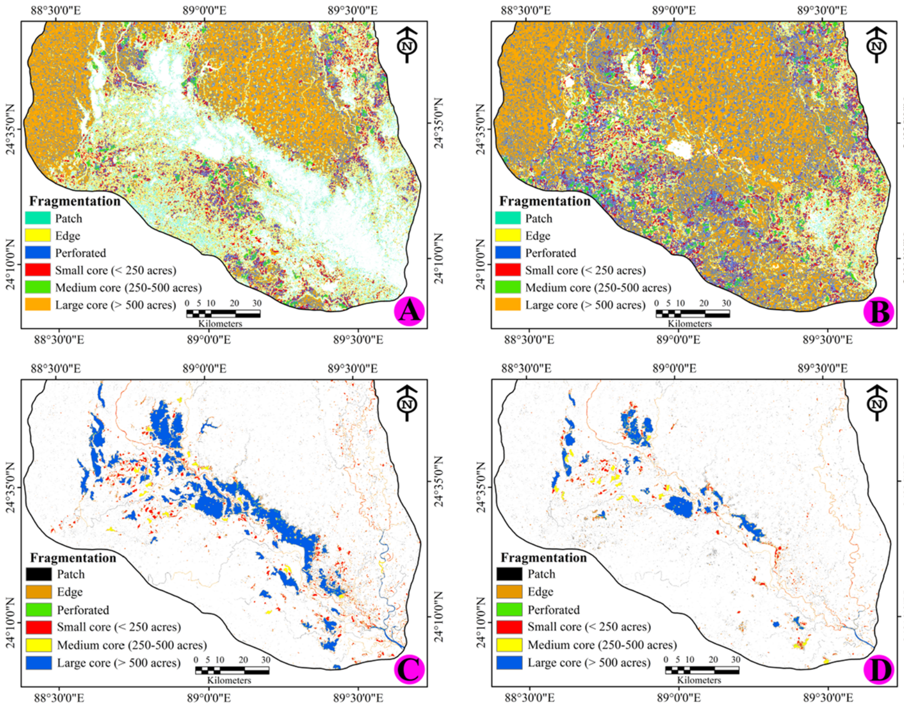

Fig. 4 Fragmentation of agricultural land and wetland of the lower Atreyee River basin in different phases: agriculture land in pre-dam (**a**), agriculture land in post-dam (**b**), wetland in pre-dam (**c**), wetland in post-dam phase (**d**)

5 Discussion

Information from above result exhibits that the nature of wetland-agriculture land interaction in the study area is highly lopsided and aggressive. Millennium Ecosystem Assessment (2005), FAO water reports (2008) rightly demonstrated that rising demand for food production compel to increase agriculture land, but often, this is done in the cost of the death of wetland. This type of result is very evident in the Gangetic floodplain where more than > 50% of wetland is lost in the last century (Williams 1991). It is guesstimated that 50% of world wetlands have been lost since 1990 (Wang et al. 2011) owing to anthropogenic pressure (Marti-Cardona et al. 2013). In moribund deltaic floodplain of India since 1916–2011, 111 numbers of wetlands covering 35.79 km^2 of wetland area have been naturally or artificially destroyed and agricultural invasion is the prime reason (Pal 2011) behind. Twenty-seven perennial wetlands have converted into seasonal or deleted completely (Pal 2011). Wetland loss is more prominent due to urban expansion only in some isolated urban centers of the moribund deltaic region like Kalyani, Krishnanagar, Berhampur, Kandi, Nabadwip, etc. Mondal (2017) explained the mechanism and form of urban expansion, and stress on wetland is explained taking Berhampur town as a case study. Ziaul and Pal (2017) established the same in case of Chatra wetland of Diara physiographic unit of West Bengal. 90% of the wetland area was lost due to the invasion of agriculture in New Zealand and Western USA. In Barind region of India and Bangladesh, agricultural

Table 8 Proportion of area of landscape fragmentation of post-monsoon season in pre- and post-dam periods

Landscape fragmentation	Agricultural land condition in different phases				Wetland condition in different phases			
	Pre-dam (1987–2012)		Post-dam (2013–2016)		Pre-dam (1987–2012)		Post-dam (2013–2016)	
	Pixel	Area (km^2)	Pixel	Area (km^2)	Pixel	Area (km^2)	Pixel	Area (km^2)
Patch	543,709	489.33	178,007	160.20	93,418	84.07	99,088	89.17
Edge	1,320,841	1188.75	1,073,875	966.48	255,496	229.94	139,103	125.19
Perforated	1,109,949	998.95	2,429,872	2186.88	18,227	16.40	13,436	12.09
Low core	598,327	538.49	813,710	732.33	117,970	106.17	63,360	57.02
Medium core	114,724	103.25	198,583	178.72	29,715	26.74	29,454	26.50
Large core	2,523,199	2270.87	4,247,653	3822.88	729,005	656.10	235,601	212.04
Number of patch (NP)	94,280		16,296		25,839		31,769	
Patch density (PD) (number/1 km^2)	9.253		1.6		2.54		3.12	
Mean contiguity (CONTIG MN)	0.145		0.155		0.2		0.18	
Total core area (TCA) (km^2)	5589.67		8047.53		1119.44		6113.55	
Aggregation index (AI) (%)	83.77		88.89		89.52		83.88	
Normalized landscape shape index (nLSI)	0.2		0.42		0.1		0.16	

expansion and reclamation of wetland is well explained by Das and Pal (2017b). So the conflict exists between wetland and agriculture land is concomitant with the knowledge base of the previous scholars, but role of damming over water and wetland transformation is quite new addition.

The economic base of the study region stands on agriculture. More than 70% of the people depend on agriculture for their livelihood. Growing population pressure influences agricultural development in two ways, i.e., (1) through horizontal expansion of agriculture land and vertical development of agriculture gearing up the multi-cropping system as well as agricultural intensification (Das and Pal 2017b). Second approach is strongly controlled by the seasonal rainfall pattern and scarcity of irrigation service widely and sufficiently (Shahid 2011; Pereira et al. 2002). For example, canal irrigation system covers only 19% of the total agricultural region. In case of this irrigation practice, tail part of the canal often does not receive any water. Groundwater-based irrigation covers only 79% of the total agricultural land, but failure of lifting water during lean season and very merge amount of water yield in this season are the major constraints for intensification of agriculture. Keeping these constraints in mind, people think that land reclamation and horizontal expansion of agriculture is the alternative cheap option. All land uses or covers cannot be transformed to agriculture land, and therefore, people find those areas which are not apparently providing any sort of tangible valuable goods to the people. Pasture lands, shrubs, wetlands those are treated apparently as wasteland are prone to conversion (Das and Pal 2017b). Therefore, the direct conflict continues between wetland and agriculture land. In most of the cases, agriculture becomes a winter defeating wetland. Lack of endeavor from individual and governmental ends for making promising productive wetland create lopsided conflict between wetland and agriculture (Mondal and Pal 2016). Control of water through damming has made the situation more favorable to the farmer in short-term planning as water availability within the wetland is reduced. Semi-wet condition in wetland facilitates farmers in two ways, i.e., (1) fertile wetland bed accelerates crop production and (2) demands very less or no water for the growth of crops. Mondal and Pal (2017) focused on this issue in Ahiron wetland of West Bengal, a wetland of National importance.

Extension of settlement covers area, urban growth, construction of roads, railways, parks, storage units, power grids, railway car shed, public service centers, etc., are also the major reasons for wetland loss, degradation and fragmentation. Not only the peasants, some of the cases, developmental works of government are also responsible the same. Reluctance of people for giving their productive land for developmental works, government ultimately opt to chose the way of wetland conversion for executing the projects. Conversion of a unit of wetland through agriculture is not the economic benefits to the people as wetland can produce 2.5 times turnover than agriculture land (Millennium Ecosystem Assessment 2005). Moreover, people do not think about its socio-ecological impacts. Scholars working in this field investigated and proved many a negative impact of environmental land use conflicts as found between wetland and agricultural land in the present study area. It is found that 159.45 km^2 wetland is turned into agriculture land in post-dam scenario. Focuses on some of the effects of those reputed works can help to understand what the possible impacts in the present study area are. In Sordo River in the region of Trás-os-Montes of north of Portugal, there is a trend of land use conversion, especially extension of vine yard toward the land suitable for pasturing and forestry, and consequently, acceleration of land degradation triggered by soil erosion is started (Valle et al. 2014a). Pacheco et al. (2014) also reported that the deviation of actual land uses from natural land uses (environmental conflict) is linked to a more pronounced predisposition of soil to erosion. In the Uberaba River basin of Brazil, the conflict became so dense that some soil properties like organic matter content and the exchangeable potassium have changed appreciably (decreased drastically: 5 kg/m^3 per 10% increase in the conflict area) threatening the fertility of soil (Valera et al. 2016). The augment in soil erosion trims downs productivity of cropland and intensifies the levels of contamination of surface water bodies (lakes and rivers). In the effect, wildlife habitats may experience a loss above their tolerance limits, compromising the sustainability of ecosystems and the socioeconomic progress (Valle et al. 2010). Valle et al. (2015) also established that environmental land use conflict has significant impact on water quality (change of dissolved oxygen, water temperature, turbidity, total suspended solid, nitrates, phosphates, sulfates, electoral conductivity, etc.) which has straight forward effect on the distribution of biota specially on macroinvertebrate assemblages carrying out a study on the aforementioned field. Loss of wetland may indirectly hamper global cycle of potassium and sulfur which are indispensible for preserving fertility level of agriculture (Deevey 1970). Valle et al. (2014b) investigated the impact of land use conflict specially extension of agriculture land and application of chemical fertilizers on groundwater quality and found that biological and chemical nutrients residual suspended or dissolved in runoff are likely to infiltrate and contaminates the drinking water resources. This again invites threats to water bodies, wetlands and rivers endangering the aquatic ecosystems through eutrophication (Valle et al. 2015). Pacheco and Fernandes (2016) highlighted the increase of nitrate concentration in river water of the basin having high environmental land use conflict and sometimes it reaches above 50 mg/L. Valle et al. (2014a) proved the excessive contamination of nitrate in groundwater is likewise produced via the nitrification of N-fertilizers. In this section, it is to be mentioned that naturally, shallow or saturated wetland can be used for high water demanding paddy crop and therefore, no such direct environmental conflict exists. But conversion of ecologically rich, economically credible wetland with immense non-marketable services cannot be supportable. Concentration of bio-chemical fertilizer residues in the surrounding wetland has accelerated the exuberant growth of the water hyacinth in the present study area. Moreover, growing turbidity level within the wetland influenced by eroded materials from intensively used newly formed agriculture land hampers the comfortable aquatic lives and diverse ecosystem. Houlahan et al. (2006) reported that 40% of the rare aquatic species safely live in wetland. Wetland loss and fragmentation have also brought distress and hardship to the marginal people who are directly depend on wetland resources. The poor people directly used to harvest fishes, crabs, snails and different aquatic products like lotus, water lily and edible aquatic plants free of cost. But due to loss of the same, people force to depend on market economy for the same goods (Pal and Saha 2017). Loss of wetland in such a rapid rate may invite devastating flood with relatively smaller depression, chance of monsoonal crop failure in this consequence will be high. Microclimatic modification in the wetland surrounding regions will be the result. Pal and Ziaul (2016) reported that temperature at the place away from wetland is 1.5–2 °C higher in Chatra wetland of Diara region. Such change will expose the marginal people who have very less coping capacity with alternative mitigation measures.

This study also provides a valuable lesson that for fishing short-term benefits, long-term benefits of the wetland may be mortgaged. So, cohabitation with wetland should be the way. The methods used for this study are scientific enough. As seasonal wetlands are highly erratic in their appearance, wetland images of each year are considered and integrated for making wetland appearance continuum. Such type of maps possesses enough scientific values for wetland consistency analysis and devising decision regarding the use of the wetland with varying consistency in appearance. This method could be used for analyzing time series change of a landscape. Mukherjee and Pal (2017) applied this frequency approach for detecting the areas affected by channel shifting over a span of time in Kalindri river of Eastern India. While detecting agriculture land and wetland using different image based indices like Normalized Differences Water Index, Water Index, Normalized Differences Vegetation Index from satellite images, some errors could be entered in the analysis process (Pal and Saha 2017). For example, high moisture content within vegetation or soil reflects the area as wetland, but actually it is not like that. If any such kind of unwanted discrepancy occurs, through frequency approach irregularities could be identified and excluded if required. Considering the merits of the applied methodology, it can be applied in other seasonally inundated areas.

Based on the findings of this study, farmers, planners and concerned government offices can hold joint action plan. Considering the benefits of the wetlands in the long term, and benefits from replacing the wetland with agriculture land should be judged judiciously both from economic and ecological standpoints. We are now at very crucial phase because in spite of having worthy marketable and unmarketable benefits of the wetland, rampant wetland loss, conversion and fragmentations have been continued from dates back.

6 Conclusion

The present article clearly depicted the conflicting lopsided interaction between wetland and agriculture land. The aggression of agriculture land has appeared as a crucial cause of wetland loss and enhanced fragmentation of wetland landscape. Reduction of river flow in the post-dam state has facilitated the extension of agriculture land in the cost of the declining wetland area. Agriculture land is increased from 4316.95 to 8047.53 km^2, and wetland area has declined from 1098.25 to 592.88 km^2 in between pre- and post-dam conditions showing the reverse relationship between agricultural land and wetland. Low-frequency water presence area of wetland is augmented (546.28–277.95) in post-dam state and these areas are partly captured by seasonal agricultural activities. Patch frequency and density are increased for a wetland (patch frequency: 25,839–31,769; patch density: 5.54–3.12) and declined for agriculture land (patch frequency: 94,280–16,296) indicating fragmentation of wetland and extension and coalescence of agriculture land. Not only small core wetland, but large core wetland area is also extensively captured from agriculture land. Even the riparian floodplain corridor, a good habitat for wetland, is also perforated by agriculture land. The perception of people toward agriculture and wetland is another dimension of conflict between these two land units. Most of the people think agriculture land is a mean of production and wetland is a neutral staff. Acquainting productive efficiencies of the wetland to the farmers, capacity building of wetland uses can be an alternative approach to minimize the growing conflict between agriculture and wetland in post-dam circumstances and cohabitation with wetland. In very long term, wetland could provide life and livelihood supporting resources those cannot be purchased from market.

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