International Soil and Water Conservation Research ∎ (∎∎∎∎) ∎∎∎–∎∎∎

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Contents lists available at ScienceDirect

International Soil and Water Conservation Research

journal homepage: www.elsevier.com/locate/iswcr

Original Research Article

Impact of dam on inundation regime of flood plain wetland of punarbhaba river basin of barind tract of Indo-Bangladesh

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ARTICLE INFO

Article history:
Received 31 January 2017
Accepted 4 May 2017

Keywords:
Delimitation of wetland
Damming on river
Seasonal regime
Flow modification
Flood plain modification
Wetland deterioration

ABSTRACT

Present study raises a serious issue of wetland loss and transformation due to damming and water diversion. At present study, it is noticed that overall rainfall trend (−0.006) of the study period (1978–2015) remains unchanged but riparian wetland area is attenuated after damming both pre monsoon (March to May) and post monsoon season (October to December). Total wetland area in pre- and post-monsoon seasons is respectively reduced from 42.2 km^2 to 27.87 km^2. and from 277.86 sq.km. to 220.90 sq.km. in post dam period. Transformation of frequently inundated wetland area into sparsely inundated wetland is mainly triggered by flow modification due to installation of Komardanga dam and Barrage over Punarbhaba and its major tributary Tangon river. Sparsely inundated seasonal wetland area is rapidly reclaimed for agricultural practice. This extreme issue will invite instability in socio-ecological setup of the neighbouring region.

1. Introduction

Impact of dam on hydrological alteration of river flow modification is well documented in varied spatial scale and unit by a host of scholars (Leopold, Wolman, & Miller 1964; Petts, 1984; Williams & Wolman, 1984; Graf, 1999, 2006; Brandt, 2000; Thoms & Sheldon, 2000; Gain & Giupponi, 2014; Pal, 2015; Pal, 2016a, 2016b). Most of the works established the fact that in dam after condition flow volume is reduced and sometimes altered flow is sub critical in reference to environmental flow (Adel, 2001; Richter, Baumgartner, Wigington, & Braun, 1997; Olden & Poff, 2002; & Gain & Giupponi, 2015; Pal, 2016b). They also documented the socio-ecological impact of dam in its downstream reach, growing water scarcity and ecological modification and re-adjustment. Water development, mostly related to dams and diversions, contributed to the declines of more threatened and endangered species than any other resource-related activity (Losos, Hayes, Phillips, Wilcove, & Alkire, 1995). Adel (2001) has carried out a detailed investigation on Farakka water diversion-induced social-ecological consequences. Apart from hydro-geomorphological modifications of channel due to dam installation, its impact on flood plain, flood plain connectivity, nutrient exchange between river and flood plain etc. have also documented by the scholars (Guy, 1981; Ward and Stanford, 1995; Finger, Schmid, & Wüest, 2006, 2007; McCartney, 2009). First and foremost impact of water level lowering in flood plain region is decreasing flood plain command area as well as quality habitat for flood plain ecology (Light, Vincent, Darst, & Price, 2006; Ligon, Dietrich, & Trush, 1995). Most explicitly, it ultimately hampers the renewal of soil fertility and restricts free fish flow to the flood plain, diversity of fish production (Grift, Buijse, Van Densen, & Klein Breteler, 2001) on which primary producers of the human ecological tropics are depended on. Along with dam and reservoir induced hydrological alteration, climate change effects on flow change in Lower part of Brhmaputra river basin is also investigated by Gain and Giupponi (2015). However, the study is concerned addressing different drivers of flow change; dam is thought to be the most dominant driver exerts most explicit and well detected impacts. Study related to connectivity of main river with its flood plain reveal that loss of connectivity compel dearth of water scarcity in the flood plain. Flood plain wetlands are mostly depending on such timing, frequency and magnitude of inundation. Due fast change of flood plain character in last 50 years, more than 70% flood plain wetland is either lost or converted to other forms (Constanza et al., 1997). However, wetland is considered as a heart of the environment, lungs of the hydrological system because it helps to purify natural water and biodiversity supermarket because of it is a good abode

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Peer review under responsibility of International Research and Training Center on Erosion and Sedimentation and China Water and Power Press.

http://dx.doi.org/10.1016/j.iswcr.2017.05.003
2095-6339/

of diversified species specially rare and endangered species (Cowardin, Carter, Golet, & LaRoe, 1979a). Most important contribution of wetland is its irreplaceable services like water purification, nutrient recycling, recharging of water, carbon sequestration etc. (Curie, Gaillard, Ducharne, & Bendjoudi, 2007). But in most part of the world there is no definite boundary of wetlands as it is a transitional part of terrestrial and aquatic land. In US, Australia, New Zealand some relevant works addressing wetland delimitation and conversion are carried out by Cowardin, Carter, Golet, and LaRoe (1979b); Tiner, (1990, 1993); Adam (1992); Johnston and Barson (1993); Clarkson (2013); Johnson and Gerbeaux (2004). In Indian sub continent, estimate of wetland and wetland loss is found at large scale from the report of NRSA. But small scale work is very rare and these are confined in some regional pockets of India where large size recognized wetlands are found, more specifically, these are based on some wetlands of national and international importance. For example, East Kolkata wetland is well reported by Kundu, Pal, and Saha (2008); National park of Assam is studied by Parihar, Panigrahy, and Parihar (1986), Mathur et al. (2005).

In most of the large-scale studies reveals total wetland area of India shows diversified results, as NRSA (1998) shows total wetland area is 5.31 3 m ha, MoEE (1990) reports total wetland area is 15.3 m ha. Seasonal fluctuation of wetland area and high rainfall dependency on expansion and squeezing of wetland withstand against accurate estimation of stable wetland area and so wetland characters is getting changed with fast rate and it is difficult to provide a viable wetland map (Borro, Morandeira, Salvia, Minotti, Perna & Kandus, 2014). Therefore, studies is also carried out by Ji, Zhang, and Wylie (2009); Liu, Song, Peng, and Ye (2012); Wu, Lane, and Liu (2014) in aim to provide more stable base of wetland area delimitation and estimate in highly dynamic wetland area extraction. Most of them adopted wetland area extraction indices like Normalized Difference Water Index (NDWI) (Gao, 1996; McFeeters, 1996), Normalized Difference Moisture Index (NDMI) (Wilson & Sader, 2002), Modified Normalized Difference Water Index (MNDWI) (Xu, 2006), Water Ratio Index (WRI) (Shen & Li, 2010), Normalized Difference Vegetation Index (NDVI) (Rouse, Haas, Schell, & Deering, 1973) and Automated Water Extraction Index (AWEI) (Feyisaa, Meilbya, Fensholtb, & Proudb, 2014) etc. for separating water bodies from non water bodies and executed frequency approach for providing more reliable wetland area. Enormous amounts of data at different spatial, spectral, and temporal resolutions are provided by different remote sensing satellites. These data have become primary sources and used extensively for extracting and detecting surface water and its changes throughout decades (Li et al., 2013; Tang, Ou, Dai, & Xin, 2013; Xu, 2006; Zhou, Hong, & Huang, 2011).

In the present work, thrust is mainly given on delimiting seasonal pattern of wetland and investigating impact of rainfall and dam or reservoir induced river flow modification on spatial dynamics of flood plain wetlands. Detected change is also tested for establishing exact role of dam on changing spatial extent of wetland in seasonal scale.

2. Study area

Punarbhaba River (length: 160 km.) basin, covering an area 5265.93 sq. km, is a sub basin of Mahananda River majorly in the Barind tract of India and Bangladesh. Elevation of this basin ranges from 89 m (at the source region) to 12 m (at the confluence) (Fig. 1). The average pre-monsoon (March-May) rainfall is 14.46% of annual rainfall, monsoon (June-September) is 70.16%, and post-monsoon (October-December) is 12.24%, with annual average rainfall ranges from 257.42 cm to 508.05 cm. The trend of average pre monsoon (March-May) rainfall is 0.00. Monsoon (June–September) is −0.046, and Post-monsoon (October- December) is 0.025. So it can be said that there is no significant changes of rainfall (1978–2014). Therefore, catchment agricultural area depends on either river water or subsurface water for irrigation purpose. Alluvial and laterite soil dominates the entire basin area. Inundation process renews soil make it suitable for intensive agriculture. For mitigating seasonal water scarcity for irrigation, Komardanga dam has been constructed over Punarbhaba river in 1992.

3. Materials and methods

3.1. Data used

Landsat-TM images represent valuable and continuous records of the earth's surface during the last 3 decades (USGS, 2014). Moreover, the entire Landsat archive is now available free-of-charge to the scientific public, which represents a wealth of information for identifying and monitoring changes in manmade and physical environments (Chander, Markham, & Helder, 2009; El Bastawesy, 2014).

LANDSAT TM and LANDSAT 8 OLI have been obtained from the US Geological Survey (USGS) Global Visualization Viewer. The obtained Landsat data (Level 1 Terrain Corrected (L1T) product) were pre-georeferenced to UTM zone 45 North projection using WGS-84 datum. Detail specification of the satellite imageries are mentioned in Table 1. The other necessary corrections have been carried out in this study. The basin area is delineated using Google earth. Arc GIS 10.1 and ERDAS IMAGINE 9.2 are used for the entire study.

Base map of this present study has been prepared from Google earth imageries, 2014. Three hours interval water level data since 1978–2014 have been collected from Haripur Gauge station (lat. 24°53'24"N and long. 88°19'16"E) at Malda (under Irrigation & Waterways Deptt. Govt. of West Bengal) over Punarbhaba river for analyzing seasonal hydrological divide in reference to the installation of dam.

3.2. Method for detecting seasonal flow regime

Water level data for pre monsoon (March to May) and post monsoon (October to February) periods have been considered. Flow regime of pre and post reservoir is being plotted on line graphs to illustrate season wise differences of flow following Richard and Julien (2003); Batalla, Gomez, and Kondolf (2004); Rödel and Hoffmann (2005); Graf (2006); Pal (2016b). Seasonal discharge gap between pre and post reservoir conditions have been calculated for both the seasons. Least square regression models for pre and post reservoir conditions have been generated and concerned coefficient of determination (R^2) have been calculated. Seasonal flow instability (IX) is also being calculated following Cuddy and Della Valle (1978) with the Eq. (1).

$$IX = CV \ x\sqrt{1-R^2} \quad (1)$$

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

3.3. Methods for wetland detection

Numerous methods are available for detecting water body and wetland from Landsat images e.g. NDVI (Townshend & Justice, 1986), NDWI (McFeeters, 1996), MNDWI (Xu, 2006), WI etc. Not all these methods are equally applicable for all spatio-temporal scale (Ji et al., 2009; Xu, 2006). The differentiation of water surface area

Please cite this article as: Talukdar, S., & Pal, S. International Soil and Water Conservation Research (2017), http://dx.doi.org/10.1016/j.iswcr.2017.05.003