An overview of the spatio-temporal variation of the Gangetic riverine wetlands – diaras along the Patna urban agglomeration

1. Introduction

The Indo-Gangetic Plain, 2525 km long, is the cradle of Indian civilization and it is hardly a wonder that the river Ganges is one of the most revered rivers in the world. An elongated, shallow, and asymmetrical fore-basin with a gentle easterly slope, trending in the west-east direction as a response to the Himalayan orogeny, the basin is a repository of six distinct regional geomorphic episodes ranging from the Late Pleistocene to the recent Holocene which is manifested in its myriad cyclic phases of sedimentation ranging from shallow marine to estuarine and deltaic to fluvial to the recent. (Dewey and Bird, 1970; Suess, 1893-1909; Singh, 1996; Sinha and Sarkar, 2009).

The riparian state of Bihar is bisected by the holy Ganges, which is in its old stage as it lazily moves to keep its date with the Bay of Bengal and as such the geomorphology is characterized by numerous but ever-changing shapes, sizes, and locations of doabs or diara lands and Ox-bow lakes not to mention the bowl-shaped depressions- tals /chaurs and massive flood plains along natural levees or banks on either side. Although the jury is still out with respect to the extent of diaras and tals in the state, conservative estimates peg them at 0.863 mha and 80000 -100000 ha respectively. The state government has also listed nine chaurs/tals/riverine wetlands in the state covering an estimated 12,500 ha as protected areas with specific qualifying as bird sanctuaries owing to their rich fauna of the winged variety.

Mr. L.S.S. O'Malley, an ICS of erstwhile Bihar and Orissa, wrote in the Gazetteer of Patna in 1907, "From June-September under the combined effect of the melting Himalayan snows and the monsoon rains, it becomes a mighty stream several miles wide. Many broken columns under the pressure of flooded river create chars /chuawar (wetland) and diaras, valuable government assets".

The rain-bearing winds of the south-west monsoon characterized by its rate, frequency, and total precipitation in the catchment areas in this part of the subcontinent is responsible for the volume of discharge in the Ganges-Brahmaputra River system, which has been estimated at 1.7×10^9 Tons (Milliman and Meads, 1983). The heavy discharge in the Ganges river system, inclusive of its tributaries, is concomitant with unwieldy baggage of sediments, which is deposited on its onward journey choking the channel and initiating bank line erosion in its wake. Pattanayak and Dayal (2012) have candidly mapped the cycle of bank line shifts characterized by erosion and deposition along the bank in the last four decades.

The phases of degradation and aggradation have long served as tools to demystify the secret (upheavals) of channel geomorphology of a particular reach (Garde, 2006;

Mondal and Satpathi, 2012) and are usually limited by monsoon conditions and characterized by sediment supply. The Late Quaternary climate changes in India are marked by phases of weak and strong monsoon, which is manifested by episodic responses of aggradation and reduced sediment supply and degradation, incision and increased sediment supply to ocean respectively (Rajaguru et al., 1993; Mishra et al., 2003; Singhvi and Kale, 2009). However, remote satellite imagery coupled with geographical information system has proved to be a game-changer of sorts by leveraging spectral and radiometric analysis capacity of RSI for providing fresh insights with respect to fluvial geomorphic systems in space and time and analytical and data integration capability of GIS (Walsh et al., 1998; Ghosh, 2012; Ghoshal et al., 2010).

Faced with the scourge of a burgeoning population and depleting resources fuelled by an inherent ambition to play catch up, 'Development', a much-abused term in recent times, has been used as the proverbial sword to reclaim hitherto lush virgin green-lands and water bodies to cater to our greed. As a result, it is hardly surprising that a number of these virgin lands and water bodies have been reclaimed for agriculture and related activities at the best or have been transformed into concrete jungles at the worst. A large number of dried up water bodies reclaimed as barren land parcels are currently serving as landfill sites. The age-old bureaucratic approach of "one size fits all" results in encouragement and application of dry-land farming techniques where water reigns the roost for a larger part of the year. So instead of following the age-old countryside wisdom of promoting pisciculture as means of livelihood, the government ends up wasting limited resources by teaching local farmers and peasants about the advanced methods of 'rice farming '. It appears that the 'blind spot' for wetlands endures, which has given its right place would have been nothing short of a boon for the poor and the entrepreneurs besides shoring up the fragile ecology of the region already doomed by the unrealistic flood control regime.

According to Dr. Ashok Ghosh, Chairman of BSPCB, around 75% of water bodies and wetlands in the state have vanished. Till the 1980s, more than 2.50 lakh ponds were in the state which came down to less than 90 thousand presently. Further, he added, the water bodies and wetlands are allowed to die an unnatural death. Kabar Lake in Begusarai, one of the largest freshwater lakes of South Asia, is an archetypical case of water bodies vanishing due to human interference".

2. Methodology

2.1 Study Area

The study area encompasses a 35.85 km long stretch (25042'15" N - 25037'28" N latitude and 84051'51" E - 85012'31" E longitude) of the Ganges nested between the upstream confluence point of the Sone in the west and the downstream point of the Gandhi Setu in the east. The two main tributaries, the peninsular origin, river Sone and the Himalayan origin river Gandak join the Ganges along its South and North banks, hereafter flowing in a SW-NE direction and NNW-SSE respectively. Further, downstream beyond the study area, it is met by the river Punpun. In the study area, the aggraded land of diara and Patna Urban agglomerated land with the aforementioned coordinates under reference was measured.

***Figure 1**: Location map of study area*

2.2 Data analysis

The data used is 'Landsat Multispectral Imagery' from the year 1975, 1990, 2000, 2005, 2010, and ESRI world imagery 2014 from Arc map 10.1 user database. The GIS software used is Arc GIS v 10.1 (2012 release). The base map used is DeLorme - world base map provided by ESRI. For each of the imagery, major stable aggraded landforms were measured using 'Area Measure Tool' from the GIS software, besides any part, which is joined with either of the banks by any means is not taken into account as such landforms are not defined as 'Diaras'. Numbering is done separately for each image on a random basis starting downstream from the west. Overlaying of imaging is done whenever required.

3. Results and discussion

Table 1 represents the extents of aggradations of the river Ganges in the study area from 1975 to 2014 as per measurements.

Table 1: Total aggraded area as per the measurements

Sl No	Year of Imagery	No of fragment	Area (Km2)
1	1975	4	74.40
2	1990	7	204.58
3	2000	9	205.03
4	2005	10	239.05
5	2010	12	215.70
6	2014	6	254.44

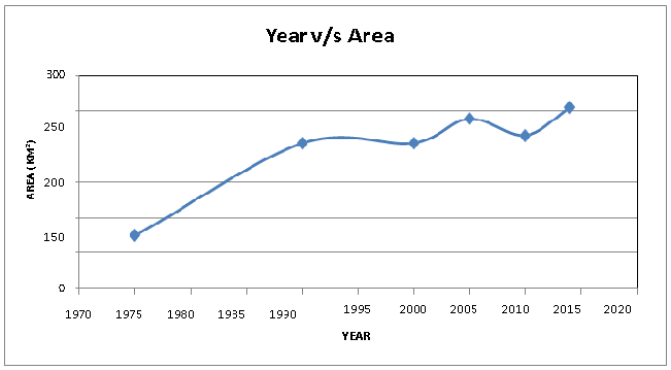

***Figure 2**: Time series of aggradations in the study area*

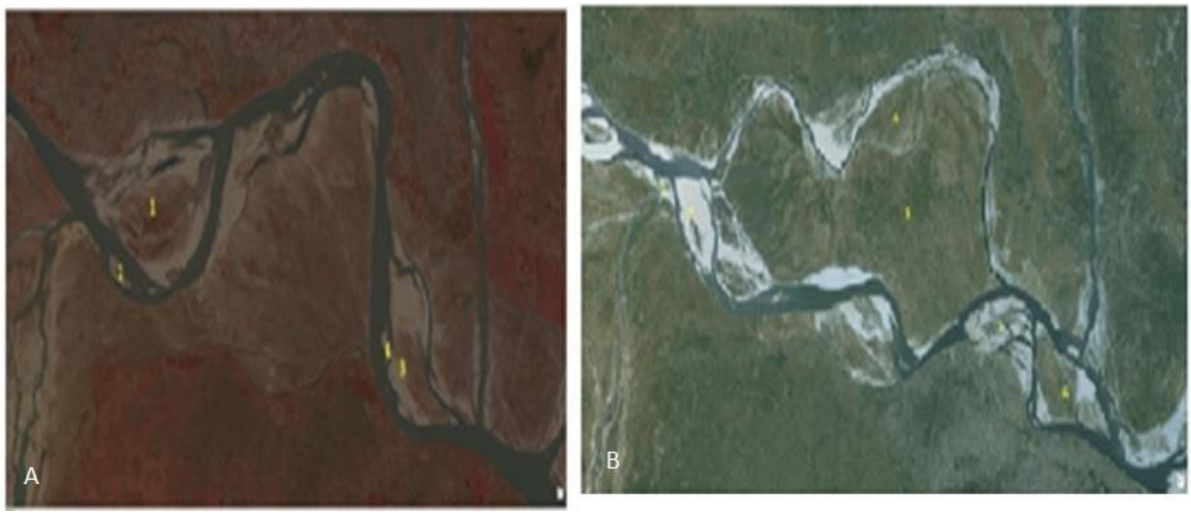

***Figure 2:** Difference between Diaras through LANDSAT Multispectral Imagery of 1990 (A) and 2014 (B) through ESRI world imagery*

The time-series graph of the aggraded land area shows an increasing trend of fluvial aggradation in the study area during the year 1975, 1990, 2000, and 2014, due to the decreased flow of the river Ganges, which results in the deposition of the sediment load of the river Sone and the river Gandak in the adjoining Diara region while a decrease in the area of Diara is observed in 2010, when the flow of the Ganges is high, which is not conducive to the deposition of sediments.

4. Conclusions

The findings are consistent with the fact that a spell of unsuccessful monsoon and drier weather enhances the sediment supply resulting in a greater sediment load in the river initially. Aggradation takes place in the area in which the supply of sediments is greater than the amount of material that the system is able to transport. Conversely, during a successful monsoon, the soil is bound to the roots more firmly and sediment is in short supply initially. However, the greater volume of discharge of the river results in the inundation of regions across the natural levees, and the concomitant degradation leads to a greater supply of sediments to the ocean.

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