STUDY OF SPATIO-TEMPORAL CHANGES IN THE WETLANDS OF NORTH BIHAR THROUGH REMOTE SENSING

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Abstract
The northern part of the state of Bihar, India, has innumerable south flowing streams that are subject to annual inundation. The interfluves bear numerous water bodies and marshy lands. A systematic study of wetlands of north Bihar was undertaken for the period 1984 –2002 through remote sensing data. The observations are very interesting and alarming. Rapid changes in surface water regime have been detected. There is a contradictory trend in eastern and western parts of the study area, the former showing expansion of surface water and the latter revealing rapid shrinkage of the same. These changes can neither be singly explained by the occurrence of annual flooding and resultant sedimentation, nor by changes in the monsoon rainfall, in the absence of marked deviations in their patterns. Such changes are expected on geological time scale, but the present study shows changes on human time scale. This paper aims to identify the quantum of these changes as an indicator of heightened seismicity and geological activity. Our hypothesis is that the data on rapid changes in the surface water bodies suggests very significant neotectonic changes within the zone, hitherto undetected.

Additional Keywords: interfluves, wetlands, geological activity, neo-tectonic changes, seismicity.

Introduction
A detailed study of the wetlands and related channel flows, eg. river meanders, abandoned channels, interfluves, braided streams, alluvial deposits, and other fluvial features, over time and space, requires an understanding of the hydro-geological framework of a region. The aim of the present work is to study the variations in these surface water configurations and seek explanations for the same in the light of neotectonism in the study area, so as to understand and make predictions about surface water availability in this agricultural land.

North Ganga Plain is a major physiographic unit of the Indian landmass, covering about 56980 km^2. The study area in the Mid Ganga basin has a flat terrain (MSL <150 m) and a southerly to southeasterly slope. The basin was formed during late Paleogene-Neogene times and is related to the upheaval of the Himalayas *vis a vis* flexural downwarp of the Indian Lithosphere under the supracrustal load of the Himalayas (Wadia, 1961). The entire segment abounds in buried faults and grabens. Generally recognized as “a water-surplus area”, this quadrilateral region is bounded by a northern piedmont belt where water oozes to the surface, followed by a broad belt of swampy lands, depressions and lakes, and finally an aggregation of alluvial fans as all these northern streams bend to form confluence points with the Ganga (Singh & Kumar, 1970). Hence, the surface is characterized by palaeo levees, swamps or flood basins locally called “Chaurs”, relict palaeo channels aggraded in varying degrees, meander belts, ox-bow lakes and cut-off loops (Ahmad, 1971). Its fluvial geomorphology is dominated from west to east by the Ghagra-Gandak Interfluves, the Gandak-Kosi Interfluves and the western Kosi Fan Belt (Figure 1). According to a study in 1976 on Wetlands in Bihar, by Govt. of Bihar, natural wetlands of more than 100 ha each covered about 46 828 ha (Directory of Wetlands, Govt. of Bihar).

The plain is subject to frequent channel avulsions, flooding and resultant sedimentation. These events have influenced the pattern of its wetlands, most of which originate from the meandering action of the streams. The rivers appear to be aggrading, thereby increasing the annual overspills. Aggradations can be caused by neotectonics that warp riverbeds. Although insufficient data exists to quantify this relationship, evidences of spatio-temporal changes in surface water bodies in the study area have been drawn to reach tentative conclusions.

Materials and Methods
Remote sensing techniques have been used to observe the changes in the surface water bodies of North Bihar Plains, located approximately between 25^{0}15’N to 27^{0}31’N and 83^{0}20’E to 87^{0}15’E. Satellite imageries of IRS-WiFS Sensor (Indian Remote Sensing- Wide Field Sensor) have been obtained for March 1984 and March 2002. The image processing was done on ERDAS- IMAGINE Version 8.3. FCC (False Color Composite Image) was classified, and the classified images were recoded to generate the desired results to see the marked changes in the spatial extent of surface water bodies in the study area. Blue color was used for demarcating water bodies and the

remaining classes of land use had been modified to black color for purpose of clarity in the frames (Figures 2 and 3). Changes in pixels were calculated. Upon superimposition of the physical and geological maps of Bihar state over the images, a comparative picture of the changing trends in each broad interfluvial zone was obtained. These images were then analyzed for aggradation changes, meanders and water bodies' alterations.

References of topographical sheets were obtained to corroborate the findings with ground realities. For inter-zonal comparisons, the region was demarcated into three broad areas- Ghagra-Gandak Zone, Gandak-Kosi Zone, and Western Kosi Fan Belt (Figure 1a). Sample field studies were conducted in the Gandak-Kosi interfluve which covers the maximum geographical area. Study was conducted on the Kabar Tal- an important wetland and a habitat of migratory birds- that has been subject to marked shrinkage within the last decade. Local farmers were also interviewed for their observations of shrinking water bodies in the area to aid in the findings.

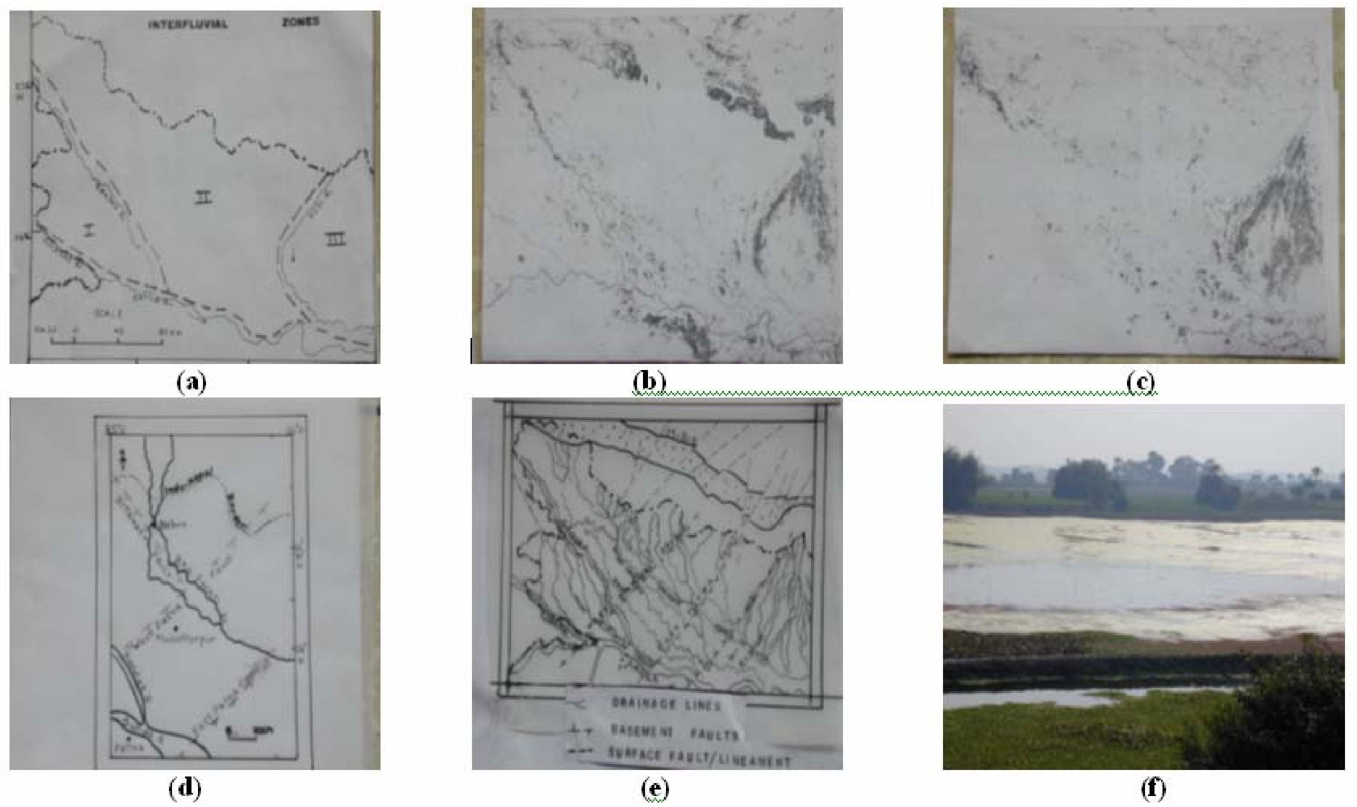

Figure 1. (a) North Bihar Plains : Interfluvial Zones(I – Ghaghra Gandak Zone;II – Gandak Kosi Zone;III – Kosi Fan); (b) Surface water configurations (North Bihar Plains)- recoded image, 1984 (c) Surface water configurations (North Bihar Plains) - recoded image, 2002 (d) avulsion of River Bagmati at Belwa; (e) drainage and underlying faults/lineaments; and (f) Kabar Lake.

Results and Discussion

Both sets of data were collected in the dry month of March. The table below, derived from reductions in pixels of the two study periods, indicates that surface waters decreased mostly in the Ghagra-Gandak interfluves in the 18-year period. There has been massive sedimentation in the western part of the study area, which has almost obliterated the surface waters, including the channel flow of the middle and lower Gandak River. Only in the upper reaches in the northwest are water deposits visible. However, towards east, the rate of decrease slowed down. On the other hand, surface waters increased in spatial density, covering most of the visible section of the Kosi Fan and it's downstream section (almost 8% increase over the 1984 image). The Kosi carries a heavy silt load as it debouches on to the Bihar Plains, and the images revealed spillage of the river and its tributaries more to the east. The Kosi itself shifted westwards in its mid-section. Apart from this exception, surface water decrease was noted even on the northern piedmont section and the succeeding marshy lands to its south.

Kabar Tal (Figure 1f), recognized internationally as a bird sanctuary, covered 6786 ha in 1984, but in 2002 revealed shrinkage to 6043 ha. Before the channel flows of the Gandak and Bagmati developed in this area, the spill waters of Ganga and Kosi used to drain into the Kabar Tal., subjecting the water body to annual cycles of waxing and waning. As a part of its flood control strategy, the State government had constructed a canal in the decade of the fifties, to drain out the excess floodwaters into the Ganga River during the monsoons. However, in the succeeding decades, lack of maintenance caused the sediment deposits to choke this outlet. Recoded images reveal a gradual drying up of the wetland on its western flanks, and formation of newer water bodies towards the Kosi in the east. In fact, this new build-up of fresh water areas marks the beginning of increased surface water in the east of the Kabar Tal area. To be noted here is the presence of the Malda- Saharsa Ridge and basement fracture, which are already stated to be geologically active. It leads credence to the influence of neotectonism in the accumulation of surface waters in east of Kabar Tal, and the corresponding westward shift of Kosi system towards this area (Figures 1b and c).

Table 1. Changes in surface water configurations in interfluvial zones

Interfluvial Zones	March 1984 (ha)	March 2002 (ha)	Increase/ Decrease (ha)	Rates of change (%)
Ghagra-Gandak Zone	724.14	409.44	-314.70	-43.40
Gandak-Kosi Zone	1206.90	750.65	-456.26	-37.80
Western Kosi fan	2091.96	2251.92	+159.96	+7.65
Total surface water area	4023.00	3412.00	-611.00	+15.19

Analysis of the Changes

A close scrutiny of the drainage system indicated the following :-

- Almost all the streams are in a state of perpetual in-equilibrium, shifting widely within their meander belts and, as in the case of Bagmati river, abandoning their entire course by avulsions (Figure 1d).
- Kosi has shifted markedly to the west, in keeping with the general lateral migration of the streams.
- Although meandering, many streams flow through linear aligned courses.
- Sharp knee-bends of a number of adjacent streams have definite orientation and alignments, the major directions being NNE-SSW to N-S, WNW-ESE to E-W, NW- SE, and NE-SW.
- These alignments converge with the major lineaments, and derangement of drainage along certain linear stretches is also noted (Figure 1e).

Response of each region to sedimentological adjustments and neotectonics is different in magnitude. The study area is an established sedimentation sink. The upstream areas of all the tributaries lie in metamorphic rock areas that are criss-crossed by faults and thrusts. Aggradation has been the result of increased alluvial deposits. The high sediment load during monsoons and frequent spillage lead to changes in channel configurations, which are further influenced by changes in local slope conditions (Sarker, *et al.*, 1999). Further, the lineament map revealed that the entire segment between Ganga and Himalayan Foothills has two sets of faults having different down-throw blocks-one almost parallel to the Himalayas and the other oblique. The oblique faults also have the highest potential for earthquakes. The northward progress of the Indian plate has been geologically proved to generate the greatest horizontal compressive stress in the NNE-SSW direction, which coincides with general trend of these faults, and also provides the motive force for neotectonic activity. Recent earthquakes in 1934 and 1988 indicate that these faults are active and responsible for neotectonism in the study area (Sinha, *et al.*, 1996). The western part of the study area is geologically stated to be uplifting in the upstream area, with the result that the general slope is tilting in Southeast direction (McVicar *et al.*, 2001). This also could have contributed to the draining out of the tectonic sags and the surface depressions of the western part of the study area towards east and southeast. Further, movement along the Malda-Saharsa Ridge (G.S. I. Sp. Pub., 1993) is stated to be responsible for the westward shift of the Kosi. This is crucial towards explaining the gradual sedimentation and shrinkages of the numerous water bodies in the interfluves west of the Kosi Fan.

Conclusion

The rapid changes in the surface water configurations cannot be merely explained by aggradation processes within a short span of eighteen years. Neither has there been any noticeable change in the rainfall regime, which otherwise would have affected the volume of channel flows. Recent earthquakes epicentered on the basement faults and lineaments indicate the tectonic volatility of this region. Excessive sedimentation, along with the northward plate movement of the southern peninsular block, subject the faults to constant strains and stress resulting in local isostatic adjustments. The degree to which the element of isostatic equilibrium is functional in the study area requires further, immediate research to comprehend the magnitude of this problem, and seek solutions for socio-economic adjustments to theses changes. Continuous monitoring of both satellite-generated data and ground patterns of surface water is required. The present images helped to identify the trend of morphological changes of the dynamic water configurations only. Using higher resolution images, future studies particularly for the less dynamic sections of channel waters can be carried out.

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