

The River Response to Urbanization: A Study of Patna Regional Development Area

Khushbu Sharma and Padmini Pani, New Delhi

Abstract

River morphological study is very challenging field of study as fluvial geomorphology deal with a system response that is always in dynamic condition. Moreover, alluvial rivers are more dynamic in nature as well as self-adjusting in any response to the change in the environment. The present study deals with the response of the river channel with changing condition in an urban metropolitan and its nearby area, based on the border limit of Patna Regional Development area using change detection. These responses can be in form of change in expansion, shrinking, avulsion of the river channel. There is total area loss of 15 sq. km and 21 sq. km gain in the study area in year 2014 as compare to base year 1988. The Ganga – Gandak confluence near Patna has shifting zone of confluence. The phenomenon of avulsion is visible in the study area of about seven sq. km As per rapid urbanization the city is experiencing unplanned growth with higher variability in land-use and land-cover dynamics.

Keyword: River system response, land-use land-cover dynamics, change detection, river confluence.

1. Introduction

River system, responses in different way with changing surrounding elements (changes in riparian coverage, impervious expansion). These responses can be in form of change in expansion, contraction, avulsion of the river channel (Gregory 1977; Slaymaker et al., 2009; Konard et al, 2005; Chin & Gregory, 2005; Kang & Martson, 2006; Chin, 2006; Gurnell et al., 2007; Gu et al., 2011; Owens et al., 2009; Charlton, 2008). Human has direct impact on river, as there are very few rivers in pristine condition. In urban area river has altered not only in chemical qualities but in physical parameters also (Groover & Harington, 1966).

2. Review of Literature

Human impact on the river has been major concern of geomorphologists since 1950s. It has been well established in literatures that the process of erosion and deposition is resulted as per natural system response, but human has altered the steady state condition, this type of change is highly observable in urban areas (Strahler, 1956; Schumm, 1969; Wolman, 1967; Diao, 1999; Leopold, 1973). The urban influences can be notified with the change in stream channel. Further, the land use and land cover change leads to changes in channel pattern, change in thresholds and flood triggering (Gregory, 2006; Chin & Gregory 2005). By time more scholars have

contributed to this field of study. Gregory by his number of publications, that are, 'River Channel Change' (1977), 'Environmental effect of River Channel Change' (1987), 'Identification of River Channel Change due to Urbanization' (1992), 'Urban Channel Change Adjustments in Management Context : An Australian example' (2000), 'Human Role in Changing River' (2005). Other scholars i.e. Tunner (1990), Trimble (1997), Messerli (2000), Schneider (2003), P. Konnard (2005), A. Chin (2006), Lenton (2008), Slaymaker (2009), Ifatimehin (2012), Larson (2013), Copper (2013), Ejenma (2014), Singh (2014).

3. Study Area

The area selection for the study was done by taking consideration of Patna Regional Development Area (PRDA) which has been delimited by Patna Regional Development Authority, Patna, Bihar. The main urban centre Patna is located at coordinates of $25^{\circ}35'38.74''\text{N}$ and $85^{\circ}8'15.23''\text{E}$ with an elevation of 53 meters (173 feet) above the sea level. Patna is located at southern bank of Ganga River and it has confluence of other three rivers in its vicinity- Sone, Gandak and Punpun in Middle Ganga Plain (Shah & Dhar, 2012). These three cities

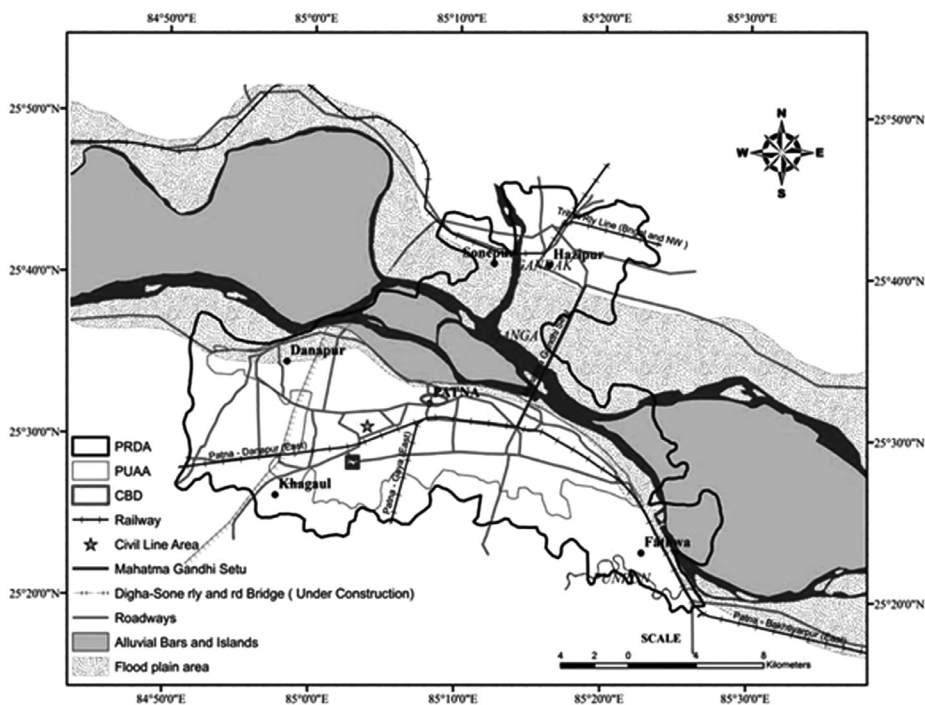


Fig. 1 : Location of Patana Regional Development Area, Bihar

are located in the flood plain of Ganga in three different districts of State of Bihar i.e. Patna District (Patna), Vaishali District (Hazipur) and Saran District (Sonepur). The Patna Regional Development Authority has selected the region based on functional relation between these centers and the river Ganga and Gandak in between acts as binding force for those functions. These functions and connectedness makes the PRDA as state primate metro-pole (CEPT, 2012) Patna is also one of vulnerable city to both urban and fluvial hazards as per its location in flood plain of Middle Ganga Plain (Mittal et al., 2014; Singh 2014; Singh, 1971; Shah & Dhar, 2012).

4. Objective

The objective of the paper is to analyze Land Use and Land Cover change from 1988 to 2014 in the study area and it's over all river channel change from 1988 to 2014 using change detection techniques.

5. Methodology And Data Sources

In order to fulfill the desired objectives In which the LU/LC map is prepared based on visual interpretation, which is the fastest method for integrating structural information (Girard & Girard, 2003). This interpretation is used for area with haphazard developmental pattern that helps in easy pixel differentiation (Shalaby & Tateishi, 2007; Bhattacharya, 2011). The legends of the features and segmentation has been done using the image enhancement and different band combinations of satellite imagery data

of LANDSAT 5 and 8 for 1988 to 2014 in ERDAS IMAGINE 2014 and ARCGIS 10 .

6. To analyze overall river change in selected area from 1988 to 2014, change detection (using Delta Cue Wizard) in ERDAS 2014 environment was done, which helped to identify difference in the condition of an object or observable fact by observe changes most accurately to identify the difference in two-time scale image and it also gives scope of eliminating the changes in study area that is insignificant by using threshold mechanism, filtering and image to image registration in order to remove sensor noise (Singh, 1989; Macleod and Congation, 1989).

7. Results And Discussion

The city of developing countries requires numerous amenities. Even there is need of continuous replacement of the natural landscape and undeveloped zone into parts of well developed urban landscape (Dutta, 2012; Kundu, 2011). However, to analyze the transformation is often difficult as it is very essential to understand the process that results those changes. The study area has been also expanding and transformed as per different function by time.

8. The Changing Land-Use and Land-Cover

The study area has faced huge transformation in its Land-Use and Land- Cover in last 26 years (1988-2014). The Built-up area has expanded from 80 square kilometers to 141square kilometers with increase of 61

square kilometers. As per population of Patna (urban area) has also increased from 0.56 million to 2.05 millions in 2011 and about 43.07% of Patna district lives in urban area in 2011. This increase has invaded the natural land cover and transformed the land (can be visualized by comparing Map in fig. 2A and 2B see page 279). There has both positive and negative transformations i.e. fall in fallow land coverage, fall in others water bodies, increase in built up area. As the area also covers Ganga river valley, the change in areal coverage of fluvial features like mid channel bar, alluvial island and point bar i.e., 24 to 30 square kilometers, 23 to 19 square kilometers and 18 to 16 square kilometers respectively can be noticed. So, The LU/LC cover analysis of area revealed that there has been expansion in built-up area with falling vegetation cover and even there is fall in fallow land and water bodies in interior of the city.

9. Urban Expansion of Patna in Patna Regional Development Area

Urban expansion in spatial context is generally regarded as urban sprawl, which can be defined as expanding of city in new tracts invading vegetation coverage and agricultural land and even various geomorphic features (Gandhi et al., 2012 & Mohoparta et al., 2014). The city area of Patna has been expanding in south and west direction (shown in Figure-3 see page 280). The city has developed initially linear fashion along the river channel backed up in its curvilinear depression (Singh, 1971; Gandhi et al., 2012). This religious hub has

further grown as political business hub in medieval and British rule (Singh, 1971). However, the riverside of the city has been protected by heavy embankment since city was established as British military base. In spite of its location in flood prone area still city has flourishing as per heavy protective embankment (Singh, 2014). The river has been used for navigation for other nearby town area. Further, opening of Mahatma Gandhi Setu in May, 1982, has emerged Hazipur of Vaishali district and Sonapur of Saran district as industrial hub as city lacks area for settling any new industry as per dense residential coverage in core area.

10. The Evaluation of changes in study area using Change detection

The expansion of built up area affects the hydrogeology of the area and also affects the river morphology as it disturbs discharge and sediment flow in river basin from the surrounding area (Wolman, 1967; Leopold, 1973; Konard, 2005; Gregory & Chin, 2005; Kang & Martson 2006; Ejenma et al., 2014). The city has been also facing such impact, as there has been fall in ground water level and reduction in number of tals and pounds (CEPT, 2006). There has been continuous change in both urban and river variables. The said transformation has been shown with help of change detection technique in figure-4 (see page 280) and values of identified changes in table-I. The analysis shows the change ranging between loss up to -4 square kilometers to gain up to 4 square kilometers. The river channel layer of 1988 shows loss of feature

i.e., Channel course, depositional features (channel bars like stable and unstable bar including numbers alluvial islands, point bar) and also loss of inland water bodies and vegetation coverage. Whereas, the river channel layer of 2014 shows gain of features i.e., depositional features like mid channel bar as the number of streams in the braid has increased in the study area (can also be visualized by comparing figure 2 A and B). There has been total change 36 square kilometers in the study area. So, the result of the change detection using delta cue shows that there has been significant change in river plan-form in study area.

Table I : Overall Change in Study Area (1988- 2014)

Sl. No.	Change in kilometers	Area (square kilometers)
1	-4 (loss of features)	0
2	-3 (loss of features)	2
3	-2 (loss of features)	6
4	-1 (loss of features)	7
5	1 (gain of features)	9
6	2 (gain of features)	8
7	3 (gain of features)	4
8	4 (gain of features)	0
9	No major change of features	367
	Total change (1-8)	36

6. Conclusion

As river is a complex unified system that effectively responses to changing environment as it is well established that urban area in contemporary time are zone of radical landscape transformation there is need for assessment of land for development and even monitoring of geomorphologic process response system (Larson et al., 2013; Owens, 2009; Cooke, 1976; Gregory 1977; Slaymaker et al., 2009; Konard et al, 2005; Chin & Gregory, 2005). The LU/ LC changes have been noticed in Patna and different scholars have significantly notified change of river course for the mentioned period (1980s to 2010s). Ultimately, the study of environmental change can only be ascertained realistically with improved understanding of reciprocal relation of the landscape variables and the drivers of change (Slaymaker et al., 2009; Vochth & Hangelveld, 1982; Diao, 1999; Slaymaker et al., 2009; Findlay & Taylor, 2006).

References

- Bhattacharya, K. (2011): The Lower Damodar River: India Understanding the Human Role in Changing Fluvial Environment, Springer, Heidelberg, Germany.
- C.E.P.T. (2006): Patna City Development Plan: Appraisal Report, Govt. of Bihar
- C.E.P.T. (2012): Improving Draft Master Plan for Patna- 2031, Final Report, Dept. Of Urban Development and Housing, Govt. of Bihar

- Charlton, R., (2008): Fundamentals of fluvial geomorphology. Routledge Publication, London.
- Chin, A. & Gregory, K. J. (2005): Managing urban river channel adjustments, *Geomorphology*, Vol. 69: 28-45.
- Chin, A. (2006): Urban transformation of river landscapes in a global context, *Geomorphology*, Vol.79:460-487.
- Cooke, R.U. & Doornkamp, J.C. (1974): *Geomorphology in Environmental Management*, Oxford University Press.
- Diao, C. (1999): *Urban Geomorphology*, Southwest China Normal University Press.
- Dutta, V. (2012): Land Use Dynamics and Peri- Urban Growth Characteristics: Reflection on Master Plan and Urban Suitability from a Sprawling North India City, *Environment and Urbanization ASIA*, Vol. 3(2):277-301.
- Ejenma, E., Amangabara, G.T., Chikwendu, L. & Duru, P.N. (2014): Analysis of pattern of encroachment on flood vulnerable areas by settlement around River Kaduna, Kaduna South LGA, Nigeria, *Journal of Environment and Earth Science*, Vol.4(3):21-25.
- Findlay S.J. & Taylor, M.P. (2006): Why Rehabilitate Urban River System?, *Area*, Vol. 38(3): 312-325.
- Gandhi, S. et al. (2012): Study of Urban Sprawl of Patna City using Remote Sensing and GIS, *International Journal of Remote Sensing and GIS*, Vol. 1(3):144-153.
- Girard and Girard (2003): *Processing of remote sensing data*, Oxford & IBH Publishing, New Delhi.
- Gregory, K.J. (1977): Channel and network metamorphosis in Northern New South Wales, In: Gregory, K.J. (ed.) *River Channel Changes*, Wiley, UK: 389–410.
- Gregory, K.J. (2006): The human role in changing river channels. *Geomorphology*, Vol. 79:172-191.
- Groover, N.C. & Harrington, (1966): *Stream Flow Measurement Records and Their Uses*, Dover Publication, New York, USA.
- Gu, C., Hu, L., Zhang, X., Wang, X., & Guo J. (2011): Climate change and urbanization in the Yangtze River Delta, *Habitat International*, Vol.35: 544-552.
- Gurnell, A. (2007): Urban rivers: Hydrology, Geomorphology, Ecology and Opportunity of change, *Geography Compass*, Vol. 5(1):1118-1137.
- Ifatimehin, O.O., Essoka, P.A. & Ahmed, A. (2012): Analysis of Land use Change and hydrological Implications on River Niger, Lokoja, Nigeria, *Confl. Jour. of Environmental Studies*, Vol. 7:112-119.
- Kang, R.S. & Martson, R.A. (2006): Geomorphic effect of rural to urban land use conversion on three streams in the central Redbed plain of Oklahoma, *Geomorphology*, Vol.79:488-506.
- Konard, C.P., Booth, D.B. & Burges S.J. (2005): Effects of urban development in Puget Lowland, Washington, on inter-annual stream flow pattern: Consequences for channel flow & streambed disturbances, *Water Resource Research*, Vol.41:1-15.
- Kundu, A. (2011): Politics and Economics of Urban Growth, *Economic & Political Weekly*, Vol. 46(20):10–12.
- Larson, K. L., Polsky, C., Gober, P., Chang, H., & Shandas, V. (2013): Vulnerability of water system to the effects of climate change and urbanization: A comparison of Phoenix, Arizona and Portland, Oregon (USA), *Environmental Management*, Vol. 52:179-195.

- Leopold, L.B. (1973): River channel change with time: An example. *Bulletin of The Geological Society of America*, Vol. 84:1845–1860.
- Lenton, T. M., Held, H., Krigler, E., Hall, J.W. Luth, W., Rahmstorf, S. & Schellenhuber, H.J. (2008): Tipping Elements in the Earth's Climate System, *Proceedings of the National Academy of Science*, Vol. 105 (6): 1786-1793.
- MacLeod, R.D. and Congalton, R.G. (1998): A Quantitative Comparison of change detection algorithm for monitoring eelgrass from remotely sensed data, *Photogrammetric Engineering and Remote Sensing*, Vol. 64 (3): 207-216.
- Messerli, B., Grojean, M., Thomas, H., Nunez, L. & Christain, P. (2000): From Nature-dominated to Human-dominated Environmental Change, *Quaternary Science Reviews*, Vol. 19:459-479.
- Mittal, N., Mishra, A. Singh, R., Bhawe, A. G. & Valk V. M. (2014): Flow regime alteration due to climatic change in the Kangsabati River, India. *Ecohydrology & Hydrobiology*, Vol. 2014:1-10.
- Mohapatra, S.N., Pani, P. & Sharma, M. (2014): Rapid urbanization & its implication on Geomorphology: A Remote Sensing and GIS based study, *Geography Journal*, Hindawi Publication, Vol. 2014:1-10.
- Owens, P.N. & Taylor, K. G. (2009): Sediments in urban river basins: A review of sediment–contaminant dynamics in an environmental system conditioned by human activities, *Soils Sediments Journal*, Vol. 9: 281-303.
- Schneider, Kenneth. R, (2003): *On Nature of Cities: Towards Creative and Enduring Human Environment*, Authurs Choice Press.
- Schumm, S.A., (1969): *River Metamorphosis*. *Proceedings of the American Society of Civil Engineers, Journal of the Hydraulics Division*, Vol. 95:255–273.
- Shah, S. & Dhar, Y.R. (2012): Hydro-geological aspect of arsenic contamination of Maner block, Patna, Bihar, India, *Exilir Geoscience*, Vol. 49:10060-10066.
- Shalaby & Tateishi (2007): Remote sensing and GIS for Mapping and Monitoring Land-cover and Land-use change in the Northwestern coastal zone of Egypt, *Applied Geography*, Vol. 27:28-41.
- Singh, A. (1989): Digital change detection techniques using remotely sensed data, *International Journal of Remote sensing*, Vol. 10(6):989-1003.
- Singh, R.L. (1971): *India: Regional Geography*, National Geographic Society of India, Varanasi.
- Singh, V. (2014): Gangetic Floods: Landscape Transformation, Embankments, and Clay Brick-Making, In Ursula, M. et al. (ed.): *Asian Environments: Connections across Borders, Landscapes, and Times*, RCC Perspectives, Vol. 3: 23–28.
- Slaymaker, O., Spencer, T. & Embleton-Hamann, C. (ed.) (2009): *Geomorphology and global environmental change*, Cambridge University Press.
- Strahler, A.N., (1956): The nature of induced erosion and aggradations. In Thomas, W.L. (ed.): *Man's role in changing the face of the earth*. University Of Chicago Press, Chicago: 621-638.
- Trimble, S.W., (1997): Contribution of Stream Channel Erosion to Sediment Yield from Urbanized Watersheds, *Science*, Vol. 278:1442-1444.

- Turner, B.L. (1990): Two Types of Global Environment Change: Definition & Spatial Scale Issues in their True Dimensions, Global Environmental Change, Vol. 1:14-22
- Voth, C. De. & Hengeveld, H. (eds.) (1982): Role of water in urban ecology, Elsevier Scientific Publishing Company, New York.
- Wolman, M.G. (1967): A cycle of sedimentation and erosion in urban river channels. Geografiska Annaler, Vol.49(A):385-395.

Khushbu Sharma

Dr. Padmini Pani

Centre for the Study of Regional Development
School of Social science
Jawaharlal Nehru University, New Delhi

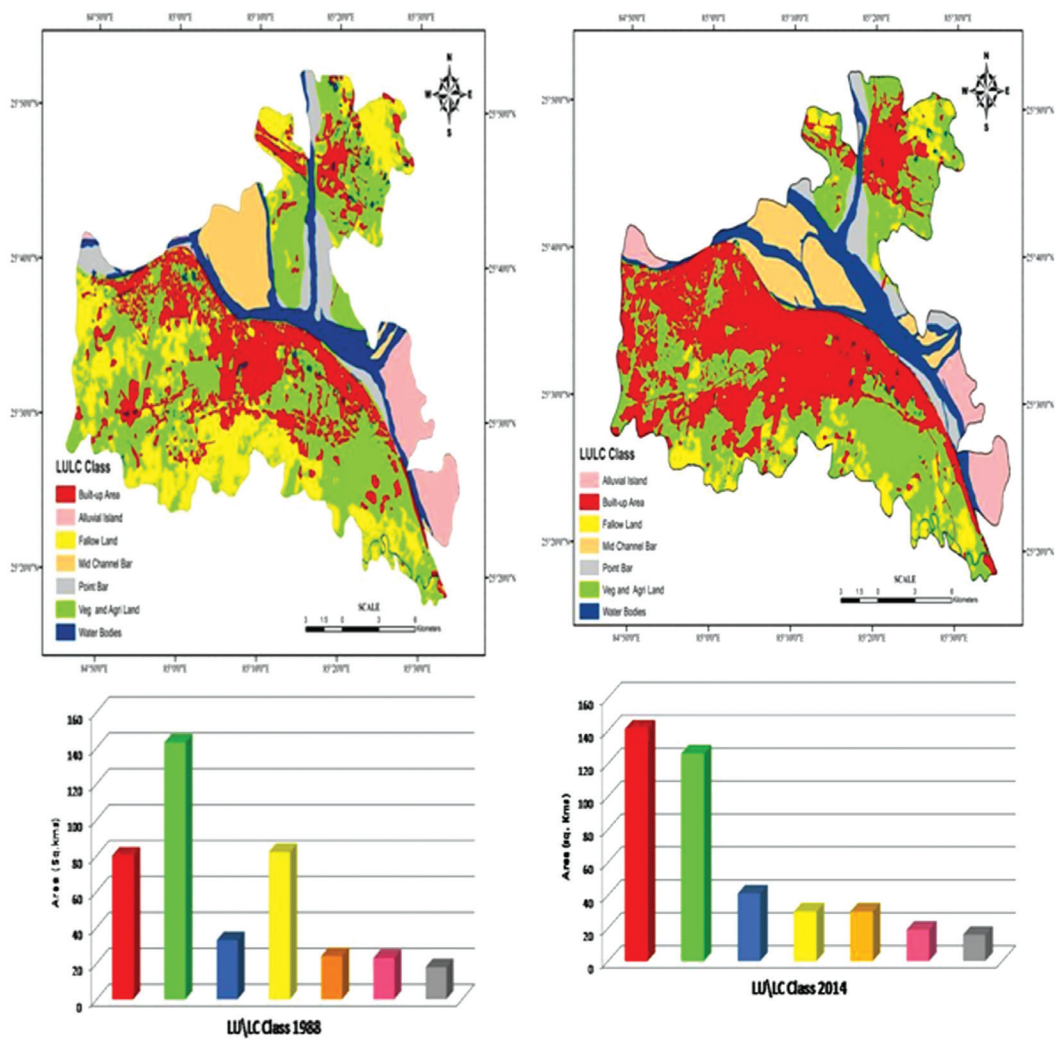


Fig. 2 : The Land Use Land Cover Map of Patna Regional Development Area (1988- 2014 see page 273 for the text)

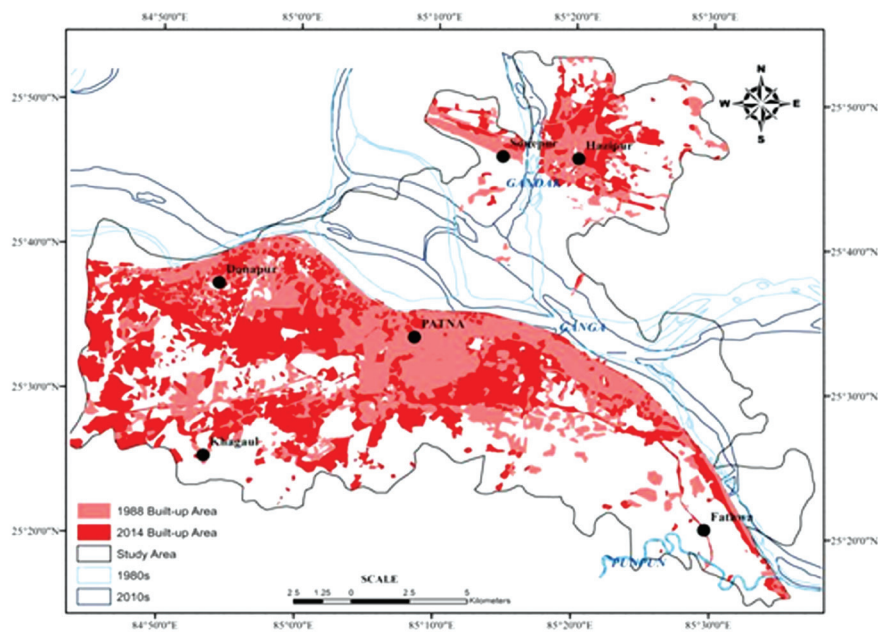


Fig. 3 : The Urban Expansion of Patna in Study Area From 1988 To 2014 (See pg. 274 for the text)

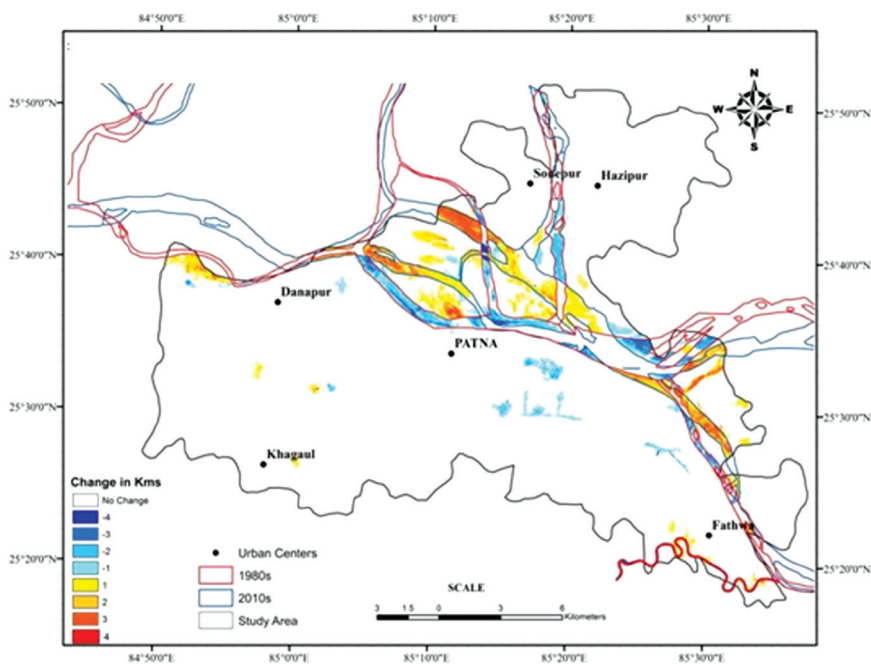


Fig. 4 : Overall Change Analysis in Study Area Using Change Detection (1988-2014) (See pg. 274 for the text)