# CHAPTER - V

# CHAPTER FIVE

# RESULTS AND DISCUSSION

The present study was carried out to depict the fluvio-geomorphological and the bankline changes of the Ganga river in Bihar region. The amount of erosion and deposition occurred over past few years was also mapped and estimated. Entire study was done on two scales: 1: 250,000 scale for the years 2000 and 2004 and 1: 50,000 scale for the year 2006. The data used were IRS 1D LISS III for the year 2000 and IRS P6 LISS III for the year 2004. For 1:250,000 scale i.e. for the years 2000 and 2004 the study was done for the whole Ganga river stretch falling in Bihar. Here, the area was divided into four main segments or regions and a detailed study was done for each of these segments. These four segments included many major and minor towns and villages throughout the river course. Firstly, the demarcation of various fluvio-geomorphological features in form of different thematic layers was done using topographical maps. Artificial linear features such as roads, railways and major towns, demarcated from the topographical maps were used as the base reference maps. It was followed by geo-referencing of images, interpretation of different thematic layers in form of maps, and statistical analysis for the pre-monsoon as well as post-monsoon satellite data of years 2000 and 2004. All the layers were compiled and a comparative study was carried out. A detailed statistical analysis regarding the different parameters was done for the years 2000 and 2004 so that a recent status regarding the river channel could be obtained. Its comparison and superimposition with the layers based on SOI maps has yielded long term changes. Comparison between 2000-2004 shows short term changes which have occurred recently. From this study we could get an idea regarding

the changes that have been occurring in this region almost over the past century and also we could locate the areas which are under major or minor riverine changes. It was also found that these changes are not uniform and show a great deal of variability with time and space.

In the second phase of the study a detailed investigation and analysis was carried out for these selected locations only at 1:50,000 scale. It was found that there were seven such areas which have undergone more changes or very marginal change. These were Ballia, Rudrapur, Patna, Sahri, Monghyr, Bhagalpur and Sahibganj. This study was carried out for the year 2006 using IRS P6 LISS III satellite data. During the entire course of the study, for more accurate investigations both pre-monsoon as well as post-monsoon satellite data was used rather then considering a single season data which may not provide us with that accurate results. A detailed field study throughout the entire Ganga river course in Bihar was also carried out.

Total amount of the area under erosion and deposition for the whole Ganga river stretch covering Bihar was also calculated for 2000 and 2004 whereas for 2006 erosion and deposition for each selected location was calculated.

Thus, broadly the regions are described as under:

1. regions around West of Ballia upto East of Chappra for 2000 and 2004 on 1:250,000 scale
2. from Chappra to Sahri for 2000 and 2004 on 1:250,000 scale
3. from East of Sahri upto Bhagalpur for 2000 and 2004 on 1:250,000 scale and
4. from East of Bhagalpur upto Sahibganj for 2000 and 2004 on 1:250,000 scale from this seven important areas were sited which were studied in detail on 1:50,000 scale for the year 2006 and these were

1. Ballia

2. Rudrapur

3. Patna

4. Sahri

5. Monghyr

6. Bhagalpur and

7. Sahibganj

For the detailed study three main parameters were taken into consideration

1. Shifting of the river course

2. Estimation of erosion and deposition occurred and

3. fluvio-geomorphological changes occured

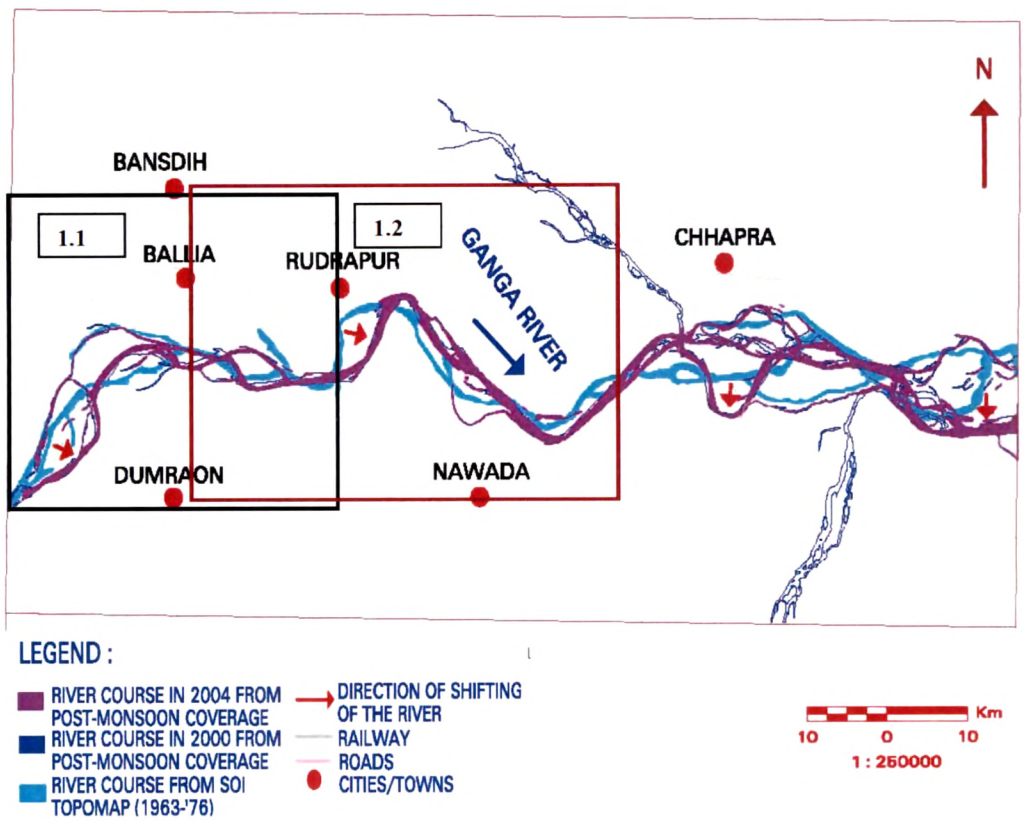
Each of these on 1:250,000 as well as 1:50,000 is discussed in detail below:

## A1. Shifting of the river course

**Changes mapped at 1:250,000 scale for the year 2000 and 2004 taking SOI as base reference maps**

**Section 1: Regions covering in and around Ballia and Rudrapur**

The SOI topographical maps covering this section were of the year 1963-'76. This region comprises of the area covering from West of Ballia to the East of Chhapra. In order to study the shifting of the river channel, a detailed mapping of the water course was done on the SOI maps and the post-monsoon satellite data of the year 2000 and 2004 covering this region and comparative study was carried out as (ref fig 5.1 and table 5.1). For satellite data only post-monsoon data was used because maximum change in the river course is generally seen after monsoon season since this area is a flood prone region. The river shows a prominent, distinct shift at various locations throughout its course between the years 1963-'76 to 2004. Whereas between the years




| | |
|---|---|
| 1.1 | Region in and around Ballia showing more change |
| 1.2 | Region in and around Rudrapur showing more change |

**Fig 5.1: Shifting of the Ganga river course near Ballia and Rudrapur on 1:250,000 scale from SOI to 2000 and 2004**

2000 to 2004 shifting of the banks varies marginally in dimension as well as in direction which means the river has more or less maintained its course. The shift direction is mainly in the South and Southeast and North and Northwest direction. At few locations it does show a shift towards the Northeast direction. Near Ballia, the shift is mainly in the Southern direction by around 1-2.5 km, whereas towards little West of Ballia the river shows a Northward shift. Again near Dumraon, the river shows a prominent change towards the South and Southeast direction. Maximum shift in this area is been observed near Rudrapur where the river has showed a distinct shift of around 1-4 km in the Southern and the Eastern direction. Moving towards East from Rudrapur, near Chhapra and West of Chhapra the river has shown shifting towards the Southern direction.

**Changes mapped at 1: 50,000 scale for the year 2006 taking SOI as base reference maps**

**Section 1.1: Regions covering in and around Ballia**

This region covers the area for a stretch of about 45 km from Ballia up to Rudrapur. It also includes few km upstream of Ballia.

The direction of the flow of the Ganga river is towards East in this region. Comparison of the river course during 1963-'76 (SOI) with post-monsoon IRS-1D data of the year 2000 and IRS-P6 data for years 2004 and 2006 shows a very prominent distinct shift of about 3 km upstream of Ballia and the shift direction is mainly towards North and Southeast (ref fig 5.2 and table 5.2). Little downstream of Ballia shows a shifting of about 1-2 km in the Southern direction. The shifting varies in direction as well as in dimension. Maximum shift in this region is observed near Ballia which is up to 3 km.

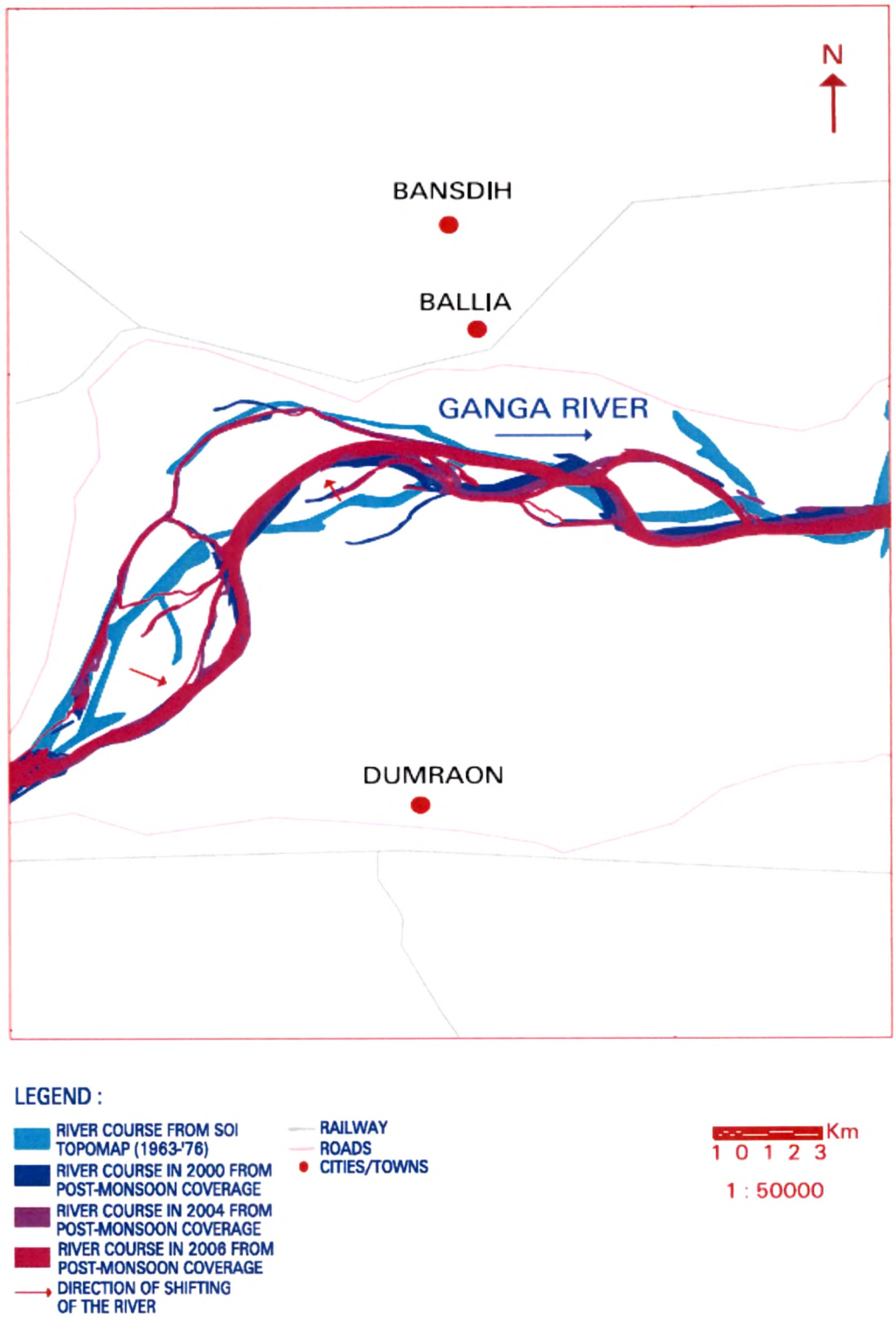



**Fig 5.2: Shifting of the Ganga river course near Ballia on 1:50,000 scale from (SOI) to 2000, 2004 and 2006**

**Section 1.2: Regions covering in and around Rudrapur**

It covers the area of about 55 km downstream from to Rudrapur and covering parts around Nawada. SOI maps were of the years 1963-'76.

The flow direction of the Ganga river is towards East and the comparison of the river course during 1963-'76 (SOI) with post-monsoon IRS-1D satellite data of the year 2000 and IRS-P6 data for years 2004 and 2006 shows a distinct shift of about 2-5 km mainly towards the South and the shifting varies in direction as well as in dimension. From (fig 5.3 and table 5.3) it is clearly observed that near Rudrapur the river shows a very distinct shift in the Southeast direction and this shift was found to be up to almost 5 km which can be considered a very major shift. On the southern or the right bank near Nawada the river shows a distinct shift in the Northern direction. This shift was found to be around 2-3 km and then again downstream of Nawada the shift direction is towards the South around 2 km.

## A2. Estimation of erosion and deposition along both the bank-lines from post-monsoon data

**Changes mapped at 1:250,000 scale for the year 2000 and 2004 taking SOI as base reference maps**

**Section 1: Regions covering in and around Ballia and Rudrapur**

Detailed mapping of the area under aggradation and degradation showed that both the bank-lines have undergone aggradation as well as degradation although the amount does vary with locations. From (fig 5.4), it is clear that the Northern or the left bank has undergone much more aggradation then degradation which indicates the shrinking of the river bed whereas conversely the Southern or the right bank shows much more degradation then aggradation which indicates the widening of the river bed.

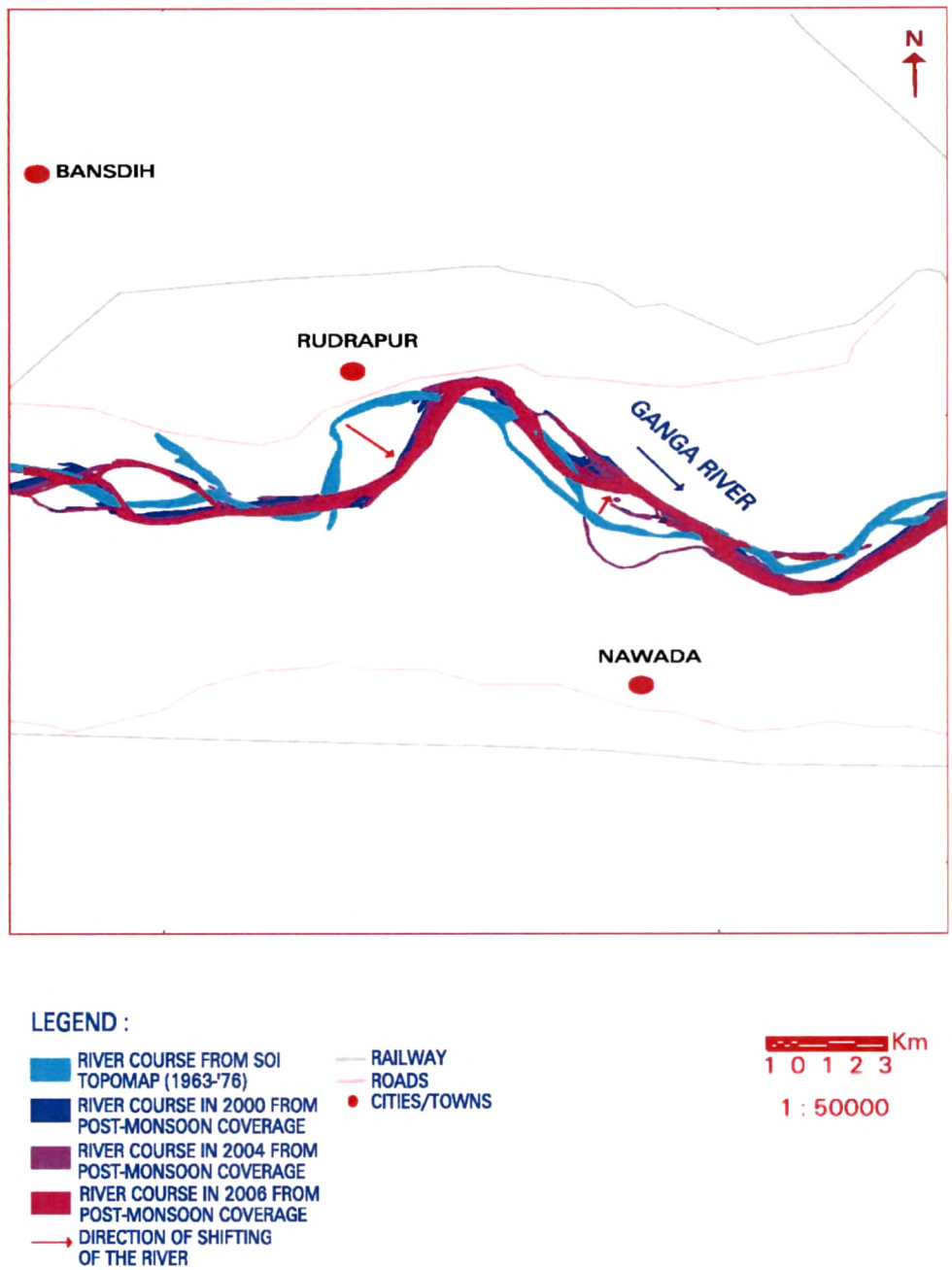



**Fig 5.3: Shifting of the Ganga river course near Rudrapur on 1:50,000 scale from (SOI) to 2000, 2004 and 2006**

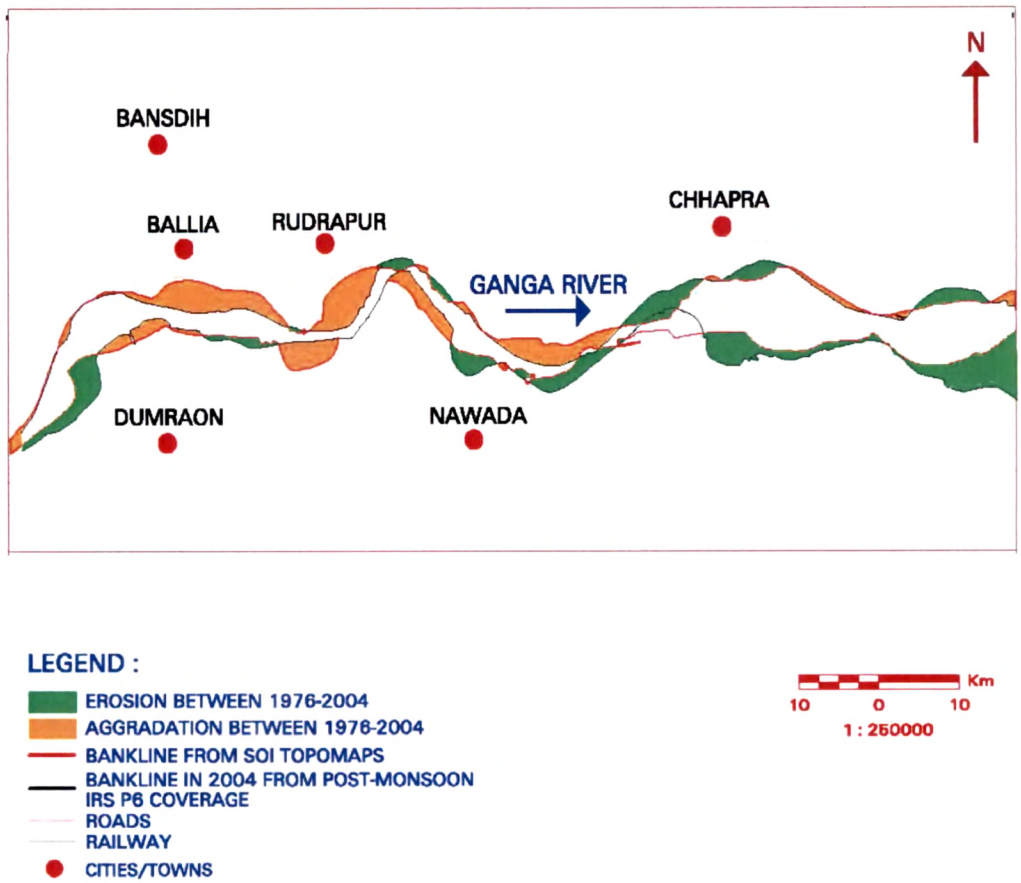



**Fig 5.4: Bankline change and erosion/deposition near Ballia and Rudrapur from on 1:250,000 scale from (SOI) to 2000 and 2004**

Amount of sediment deposition is much higher near Ballia and Rudrapur where the shifting of the bank-lines towards the Southern direction is also very prominent. The region near Ballia and Rudrapur has shown more aggradation then degradation on both the banks. On the Southern bank near Dumraon, the river has undergone erosion as well as deposition and the shift is mainly in the East and Southeast direction. The erosion and deposition undergone by the river at various locations also supports the shifting of the river channel as discussed in the previous section. Near Nawada the Southern bank shows very prominent degradation and the Northern bank has also comparatively undergone more degradation then aggradation.

**Changes mapped at 1: 50,000 scale for the year 2006 taking SOI as base reference maps**

**Section 1.1: Regions covering in and around Ballia**

From the detailed comparative mapping, interpretation and analysis of the erosion and deposition occurred in this region it was observed that the amount of aggradation is much more then degradation on both the banks. The Northern or the left bank has undergone excessive aggradation then compared to the Southern or the right bank. Dominance of aggradation indicates the shrinking of the river bed. As seen from (fig 5.5), it is clear that the Northern bank in and around Ballia has suffered excessive aggradation whereas amount of degradation is very less. However, on the Southern bank little upstream and downstream of Dumraon the river does show high rate of erosion. The amount of erosion and deposition undergone in this region was calculated and was found to be 23.0 sq km and 56.0 sq km respectively (ref bar chart 5.1).

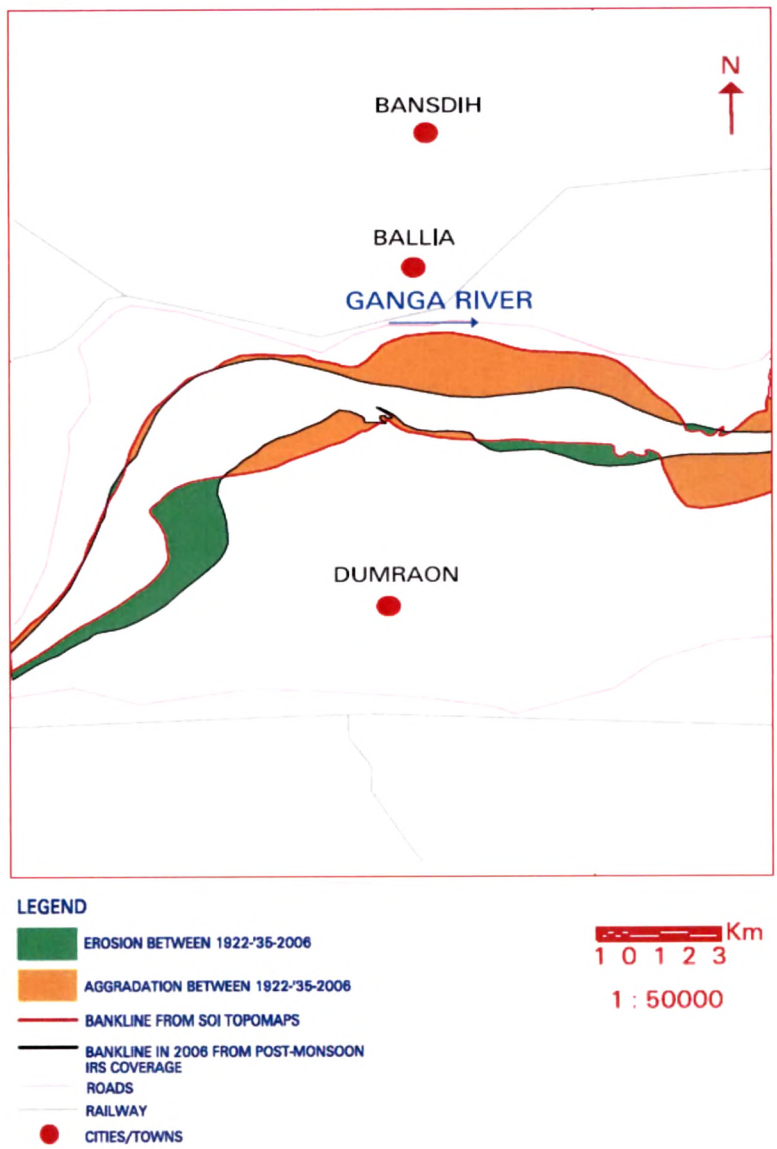
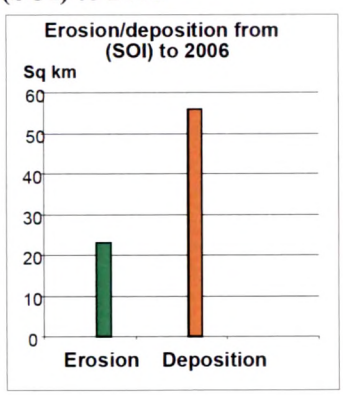



**Fig 5.5: Bankline change and erosion/deposition near Ballia on 1:50,000 scale from (SOI) to 2006**




**Bar chart 5.1: Erosion and deposition along both the banks of the Ganga river near Ballia**

**Section 1.2: Regions covering in and around Rudrapur**

From (fig 5.6) it is observed that both the banks have undergone high amount of aggradation than compared to degradation. The amount of degradation is very less on the left bank compared to the right bank. Dominance of aggradation along the bank-lines in this area indicates shrinking of the river bed. The amount of erosion and deposition along both the banks of the Ganga river for this region was found to be 29.0 and 82.0 sq km respectively (ref bar chart 5.2).

## A3. Fluvio-geomorphological changes as depicted from pre-monsoon and post-monsoon data

**Changes mapped at 1:250,000 scale for the year 2000 and 2004 taking SOI as base reference maps**

**Section 1: Regions covering in and around Ballia and Rudrapur**

Various fluvial features namely river with water, sand-bars, flood-plain, ox-bow lakes, water-bodies, meander scars, river islands etc have been interpreted from the IRS satellite images. Presence of ox-bow lakes near Dumraon and Nawada as well as the presence of numerous small and large water-bodies suggest and indicate the remnants of the old Ganga river course (ref fig 5.7 to 5.11 and plate 5.1 and 5.2). The number and size of the water bodies vary with the season as well the location. Few locations show prominent presence of water-bodies whereas in few regions they are totally absent. Near Rudrapur the river channel shows a sharp meandering pattern in years 2000 and 2004. This pattern is also seen during 1963-76 but it is less prominent then compared to 2000 and 2004. Such pattern suggests that the river may be controlled by some basement structure like fault or fracture in that region. At some locations the river shows a straight pattern which also indicates the presence of some basement structure. The river also shows braided pattern at many locations.

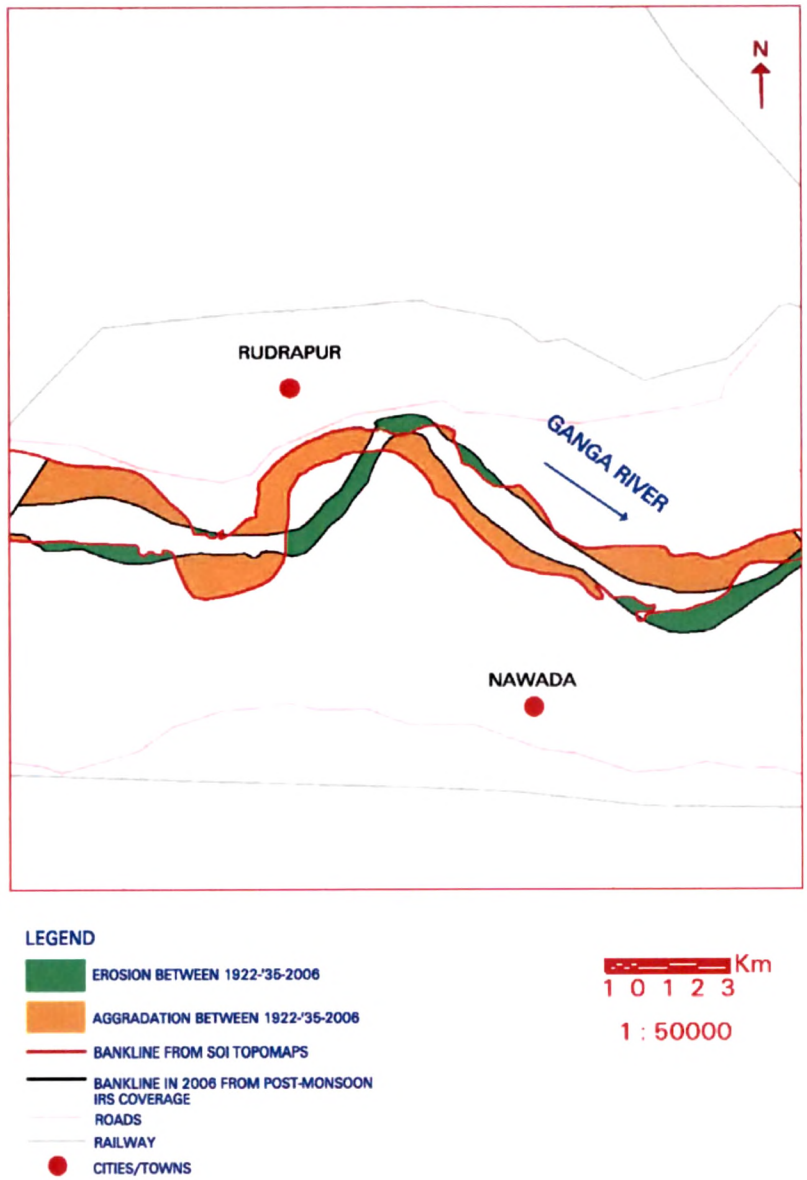
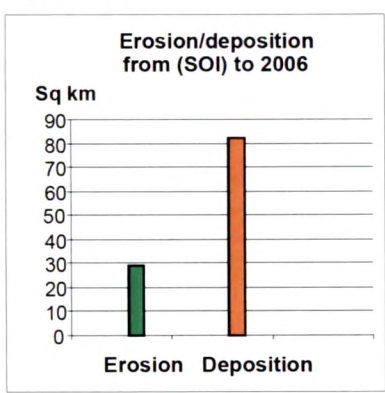



**Fig 5.6: Bankline change and erosion/deposition near Rudrapur on 1:50,000 scale from (SOI) to 2006**




**Bar chart 5.2: Erosion and deposition along both the banks of the Ganga river near Rudrapur**

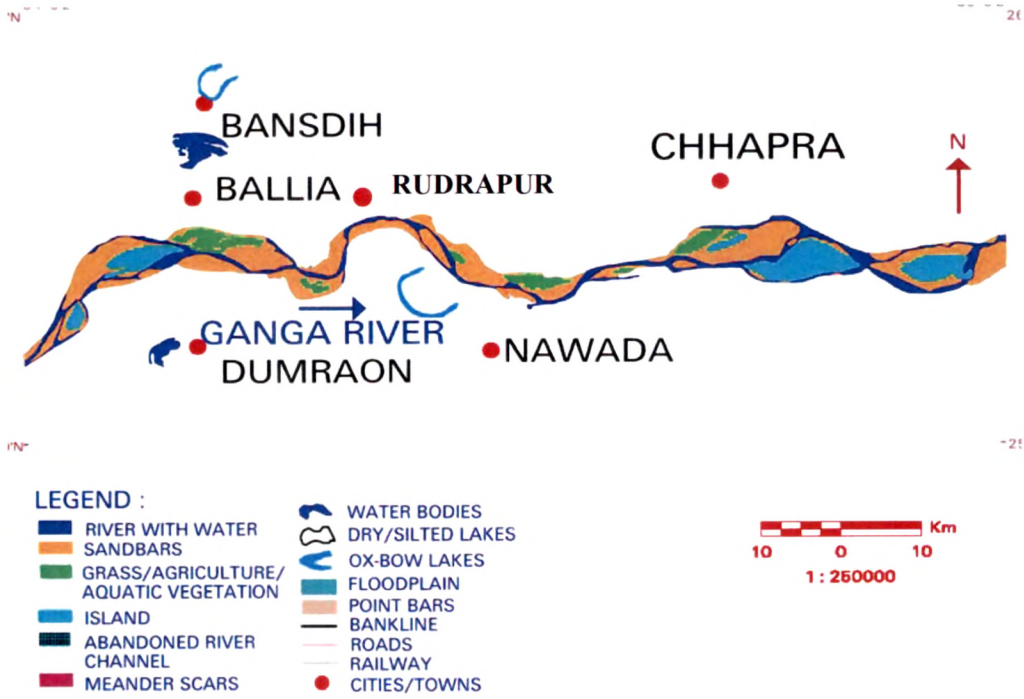



**Fig 5.7: Fluvio-geomorphology of the Ganga river near Ballia and Rudrapur on 1:250,000 scale from SOI maps**

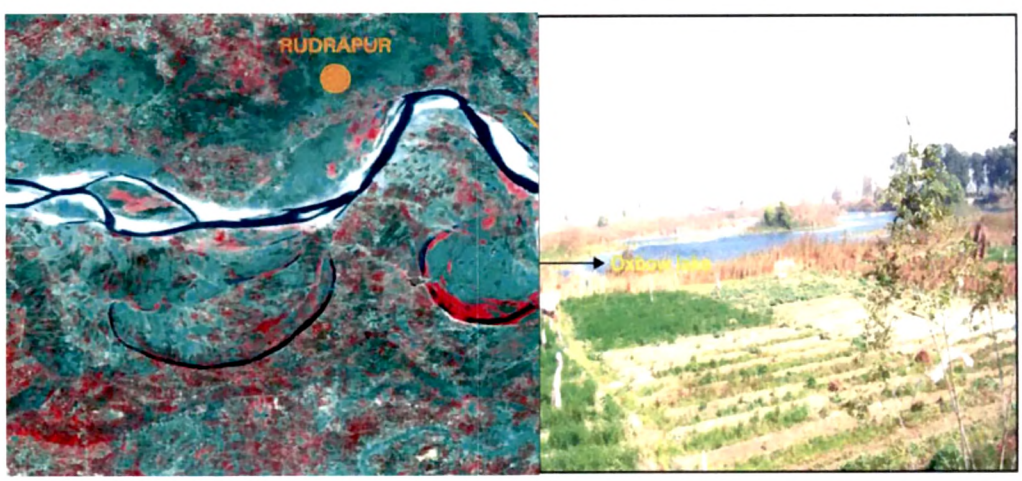



**Plate 5.1: IRS FCC image / field photograph showing the ox-bow lake near Rudrapur**


**Fig 5.8: Fluvio-geomorphology of the Ganga river near Ballia and Rudrapur on 1:250,000 scale from IRS 1D pre-monsoon data-2000**

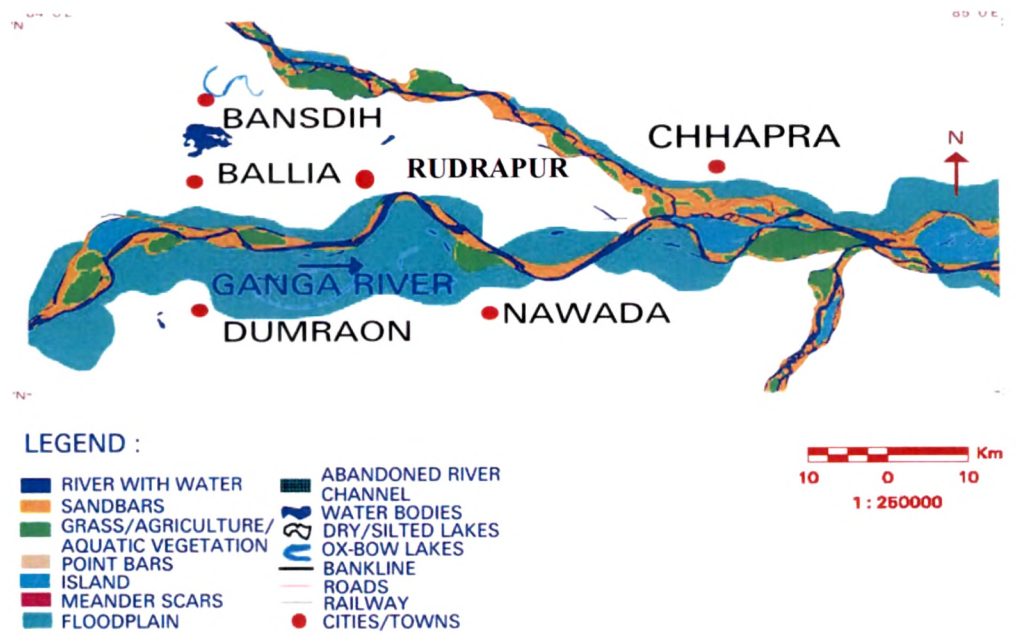



**Fig 5.9: Fluvio-geomorphology of the Ganga river near Ballia and Rudrapur on 1:250,000 scale from IRS 1D post-monsoon data-2000**

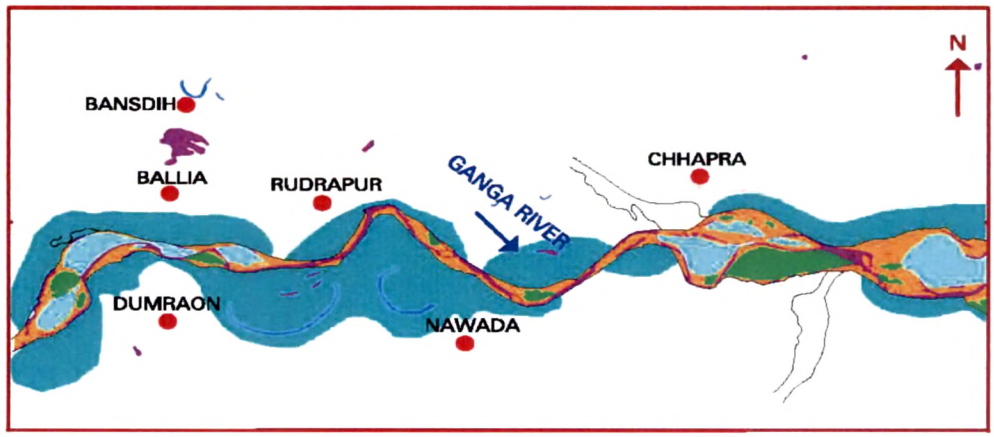



**Fig 5.10: Fluvio-geomorphology of the Ganga river near Ballia and Rudrapur on 1:250,000 scale from IRS P6 pre-monsoon data-2004**

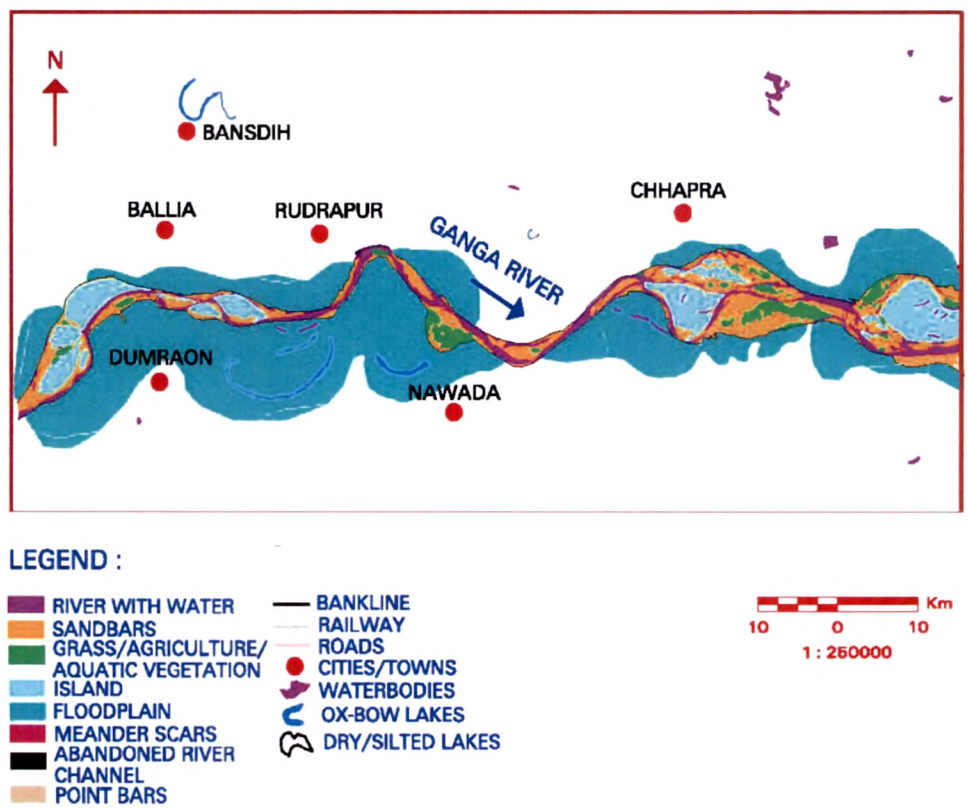



**Fig 5.11: Fluvio-geomorphology of the Ganga river near Ballia and Rudrapur on 1:250,000 scale from IRS P6 post-monsoon data-2004**

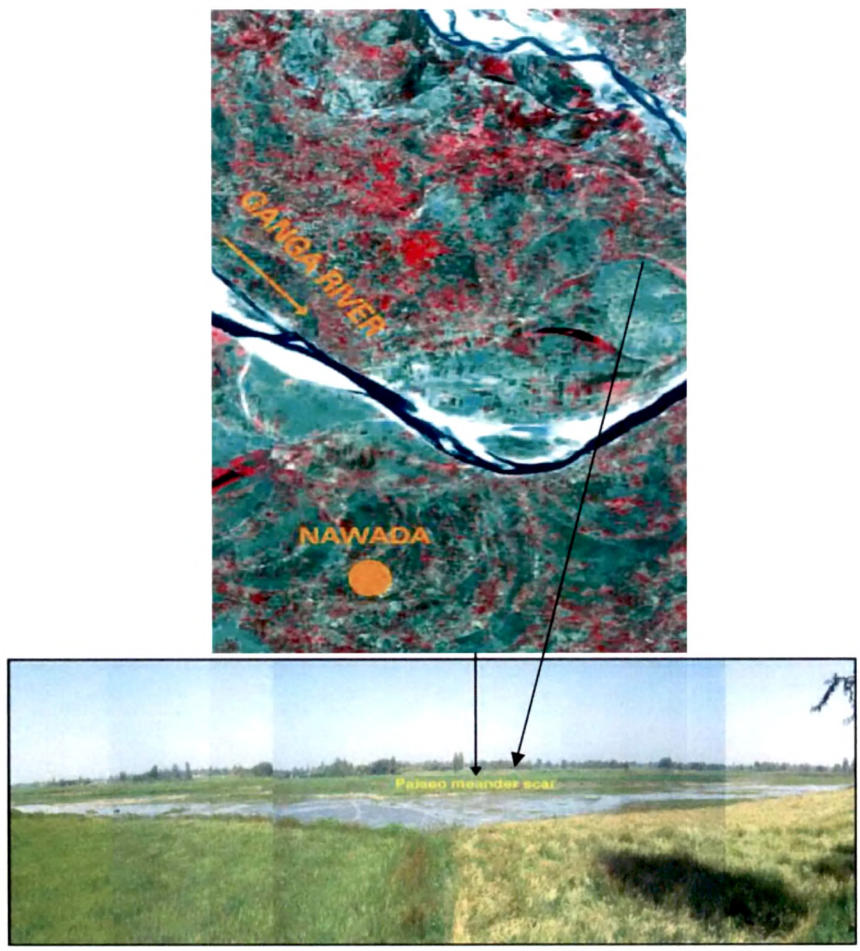



**Plate 5.2: IRS FCC image / field photograph showing the palaeo meander scar near Rudrapur**

Near Ballia and West of Ballia it is visible in 2000 and 2004 whereas it is not present during 1963'-76, and near Chhapra and East of Chhapra this pattern is seen throughout all the years. From the analysis it was seen that the length of the river bank 134 km. The surface water area shows increase in its amount during the post-monsoon season of both the years which also may be a monsoonal effect but at the same time the overall comparison shows that the surface water area has decreased significantly in 2004 then compared to 2000 which is visible in both the seasons which means that the total surface water area in this region has gone down. The area under sedimentation or the amount of sand-bars shows a significant decrease during the post-monsoon season of both the years. Overall also the region has shown more presence of sand-bars in 2000 then compared to 2004 which means that the area of sand-bars has decreased in 2004 then compared to 2000. The amount of flood-plains has almost remained constant when compared on the same seasonal basis for each year i.e. pre-monsoon season of both the years shows almost the same area and in the same way the post-monsoon season of both the years also show almost similar results. But the total area of flood-plains has increased in 2004 then compared to 2000. The island area has shown a significant increase in the post-monsoon data of 2004 then compared to all other data and width of the river shows marginal increase in 2004 then compared to 2000 (ref table 5.1).

**Changes mapped at 1: 50,000 scale for the year 2006 taking SOI as base reference maps**

**Section 1.1: Regions covering in and around Ballia**

Comparison of fluvial geomorphological features interpreted using IRS P6 LISS III pre-monsoon and post-monsoon data of years 2000, 2004 and 2006 (ref fig 5.7 to 5.15). Various fluvial features namely river with water, sand-bars, flood-plain, ox-bow lakes, water-bodies, meander scars, river islands etc have been interpreted from the post-

monsoon IRS satellite images. The sandbars are mainly composed of sand/silt. Ox-bow lakes are seen very prominently on the Southern direction of the river Ganga which clearly represents the remnants of the old Ganga river course. The region shows a wide flood-plain which is a highly fertile stretch of land. The river course is divided into a number of branches to form a distinct braiding pattern. The length of the river bank is 45 km. From (table 5.2) it is clear that the amount of sand-bars deposition has considerably decreased in the post-monsoon season then compared to pre-monsoon season because of the inundation due to rainfall whereas the flood-plain area has moderately increased in post-monsoon season than compared to the pre-monsoonal data. Width of the river seems to be almost constant throughout both the seasons showing almost no change. But here one thing has to be noted that the area covered by the islands during the post-monsoon season has shown a sudden increase from 8 sq km in pre-monsoon season to 40 sq km in post-monsoon. The reason behind this drastic increase during the post-monsoon season is that, after monsoon season many small and minor connecting streams which are normally in dry condition also gets activated because of seasonal rainfall. Because of this activation the many streams get interconnected and merged leaving patches of land in between which forms an island. This type of island formations is generally seen after monsoon season. Normally during the pre-monsoon or dry season because of the deactivation of many smaller streams the area which was once an island remains as dry detached patches of land with vegetation cover since because of rain water the soil becomes very fertile promoting vegetation growth.

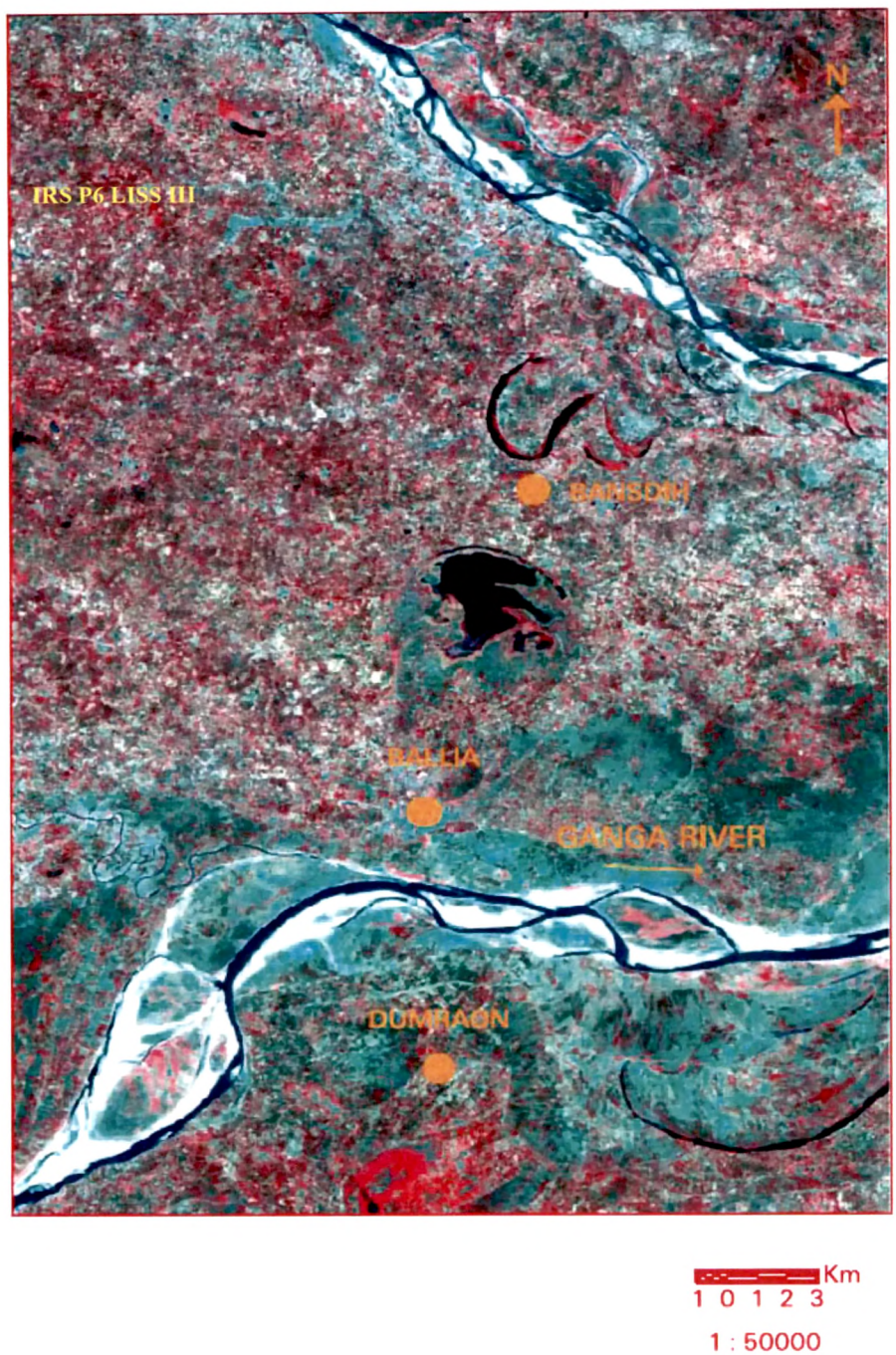



**Fig 5.12: Pre-monsoon satellite image showing Ganga river course near Ballia in 2006**

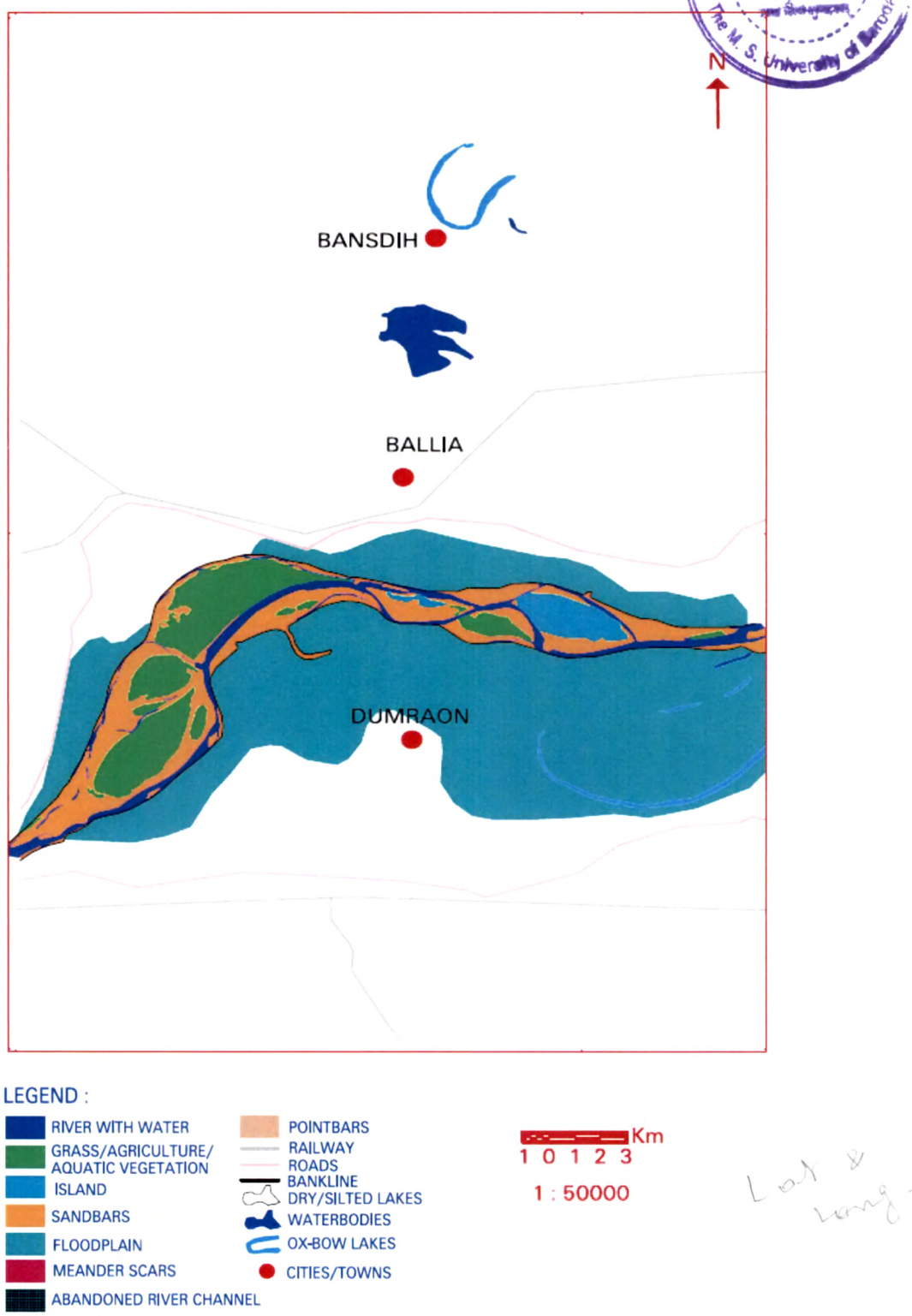



**Fig 5.13 Fluvio-geomorphology of the Ganga river near Ballia from IRS P6 pre-monsoon data of 2006**

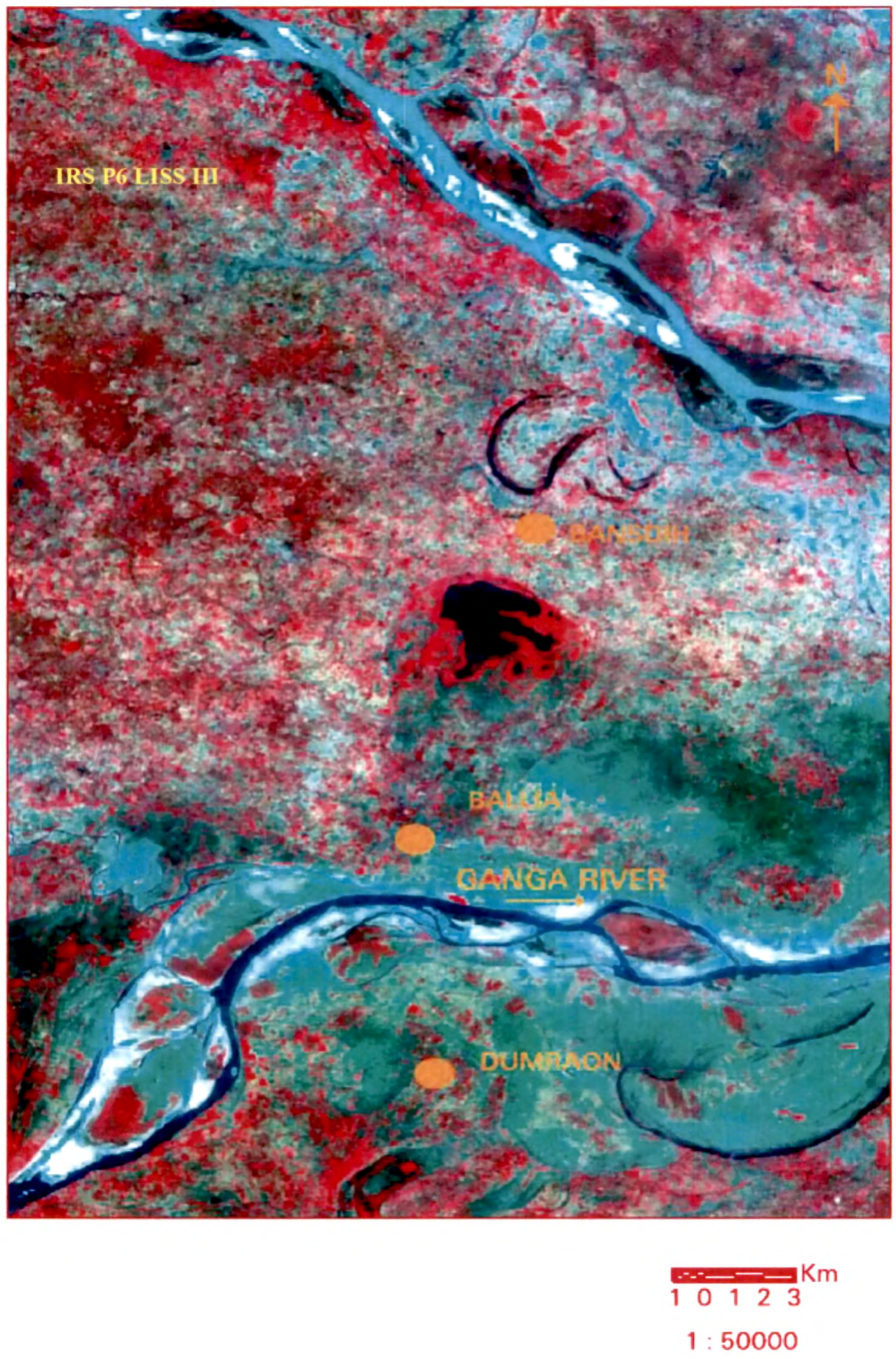



**Fig 5.14: Post-monsoon satellite image showing Ganga river course near Ballia in 2006**

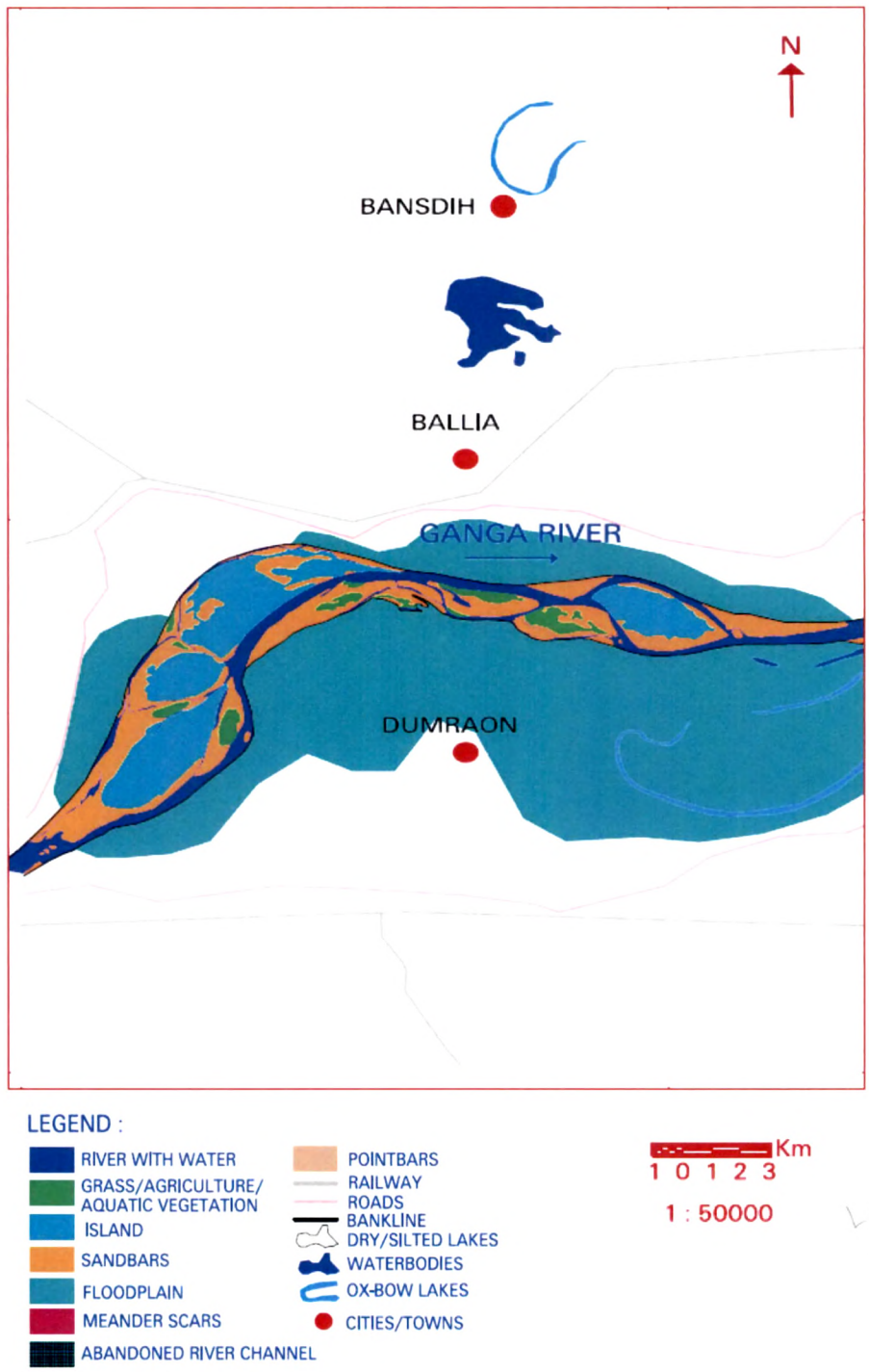



**Fig 5.15 Fluvio-geomorphology of the Ganga river near Ballia from IRS P6 post-monsoon data of 2006**

**Section 1.2: Regions covering in and around Rudrapur**

Various fluvio-geomorphological features such as sand-bars, very wide flood-plain, river-island, island with vegetation cover, water-bodies etc are prominently seen. This region shows distinct presence of two major ox-bow lakes on the right bank and one on the left bank which are present since SOI year till date which strongly indicates and represents the remnants of the old Ganga river course. Near Rudrapur, the Ganga river course shows a typical sharp meandering pattern as (ref plate 5.3 and 5.4) and towards the East of Rudrapur the river almost shows a straight pattern which suggests that the river may is controlled by some basement structure such as fault or fracture. This is one of the regions where the river shows a very distinct meandering pattern. Apart from this meandering pattern the river at certain places downstream of Rudrapur shows a braided pattern. Regarding the comparison of various other parameters and fluvial features it is seen that the length of the river bank is 55 km. The area of the sand-bars has significantly decreased in post-monsoon season. The area has a very wide flood-plain but shows reduction during the post-monsoon season. Width of the river has also decreased in post-monsoon season than compared to the pre-monsoon season. This region shows very less area of islands and also this amount is found to be constant during the pre-monsoon as well as the post-monsoon season which indicates that no new channels have been reactivated due to the effect of rainfall in this region. For details (refer fig 5.7 and 5.16 to 5.19 and table 5.3).

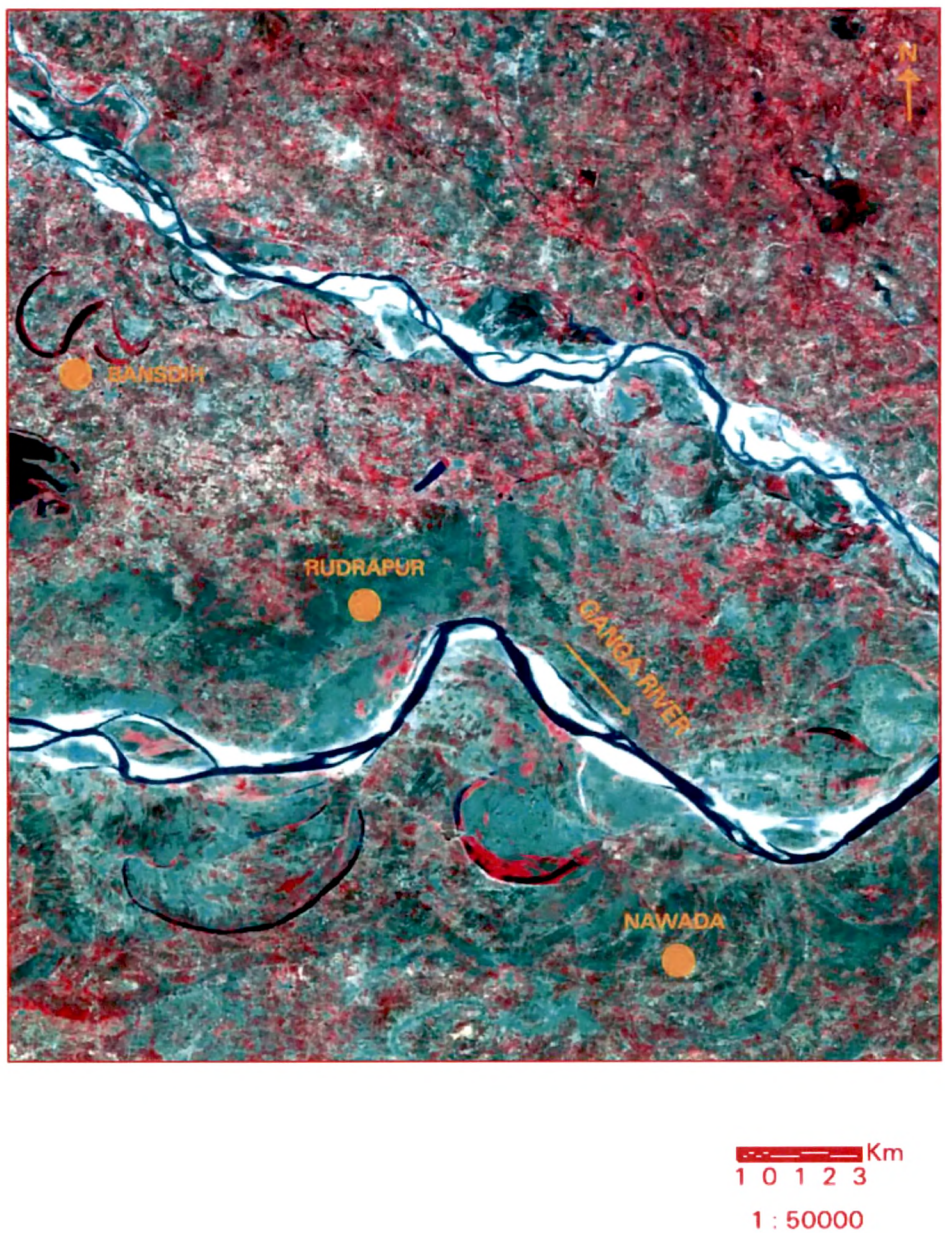



**Fig 5.16: Pre-monsoon satellite image showing Ganga river course near Rudrapur in 2006**

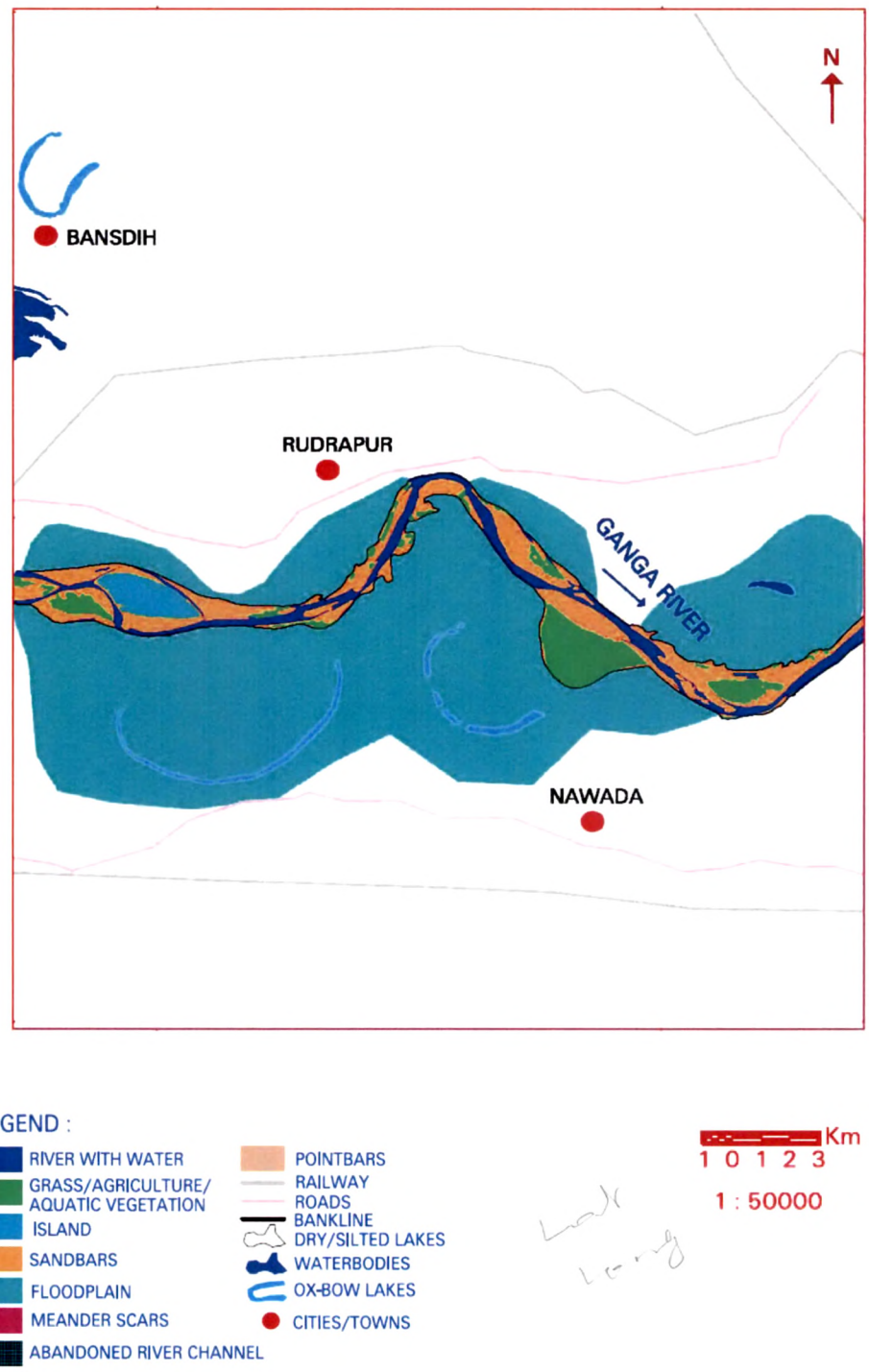



**Fig 5.17: Fluvio-geomorphology of the Ganga river near Rudrapur from IRS P6 pre-monsoon data of 2006**

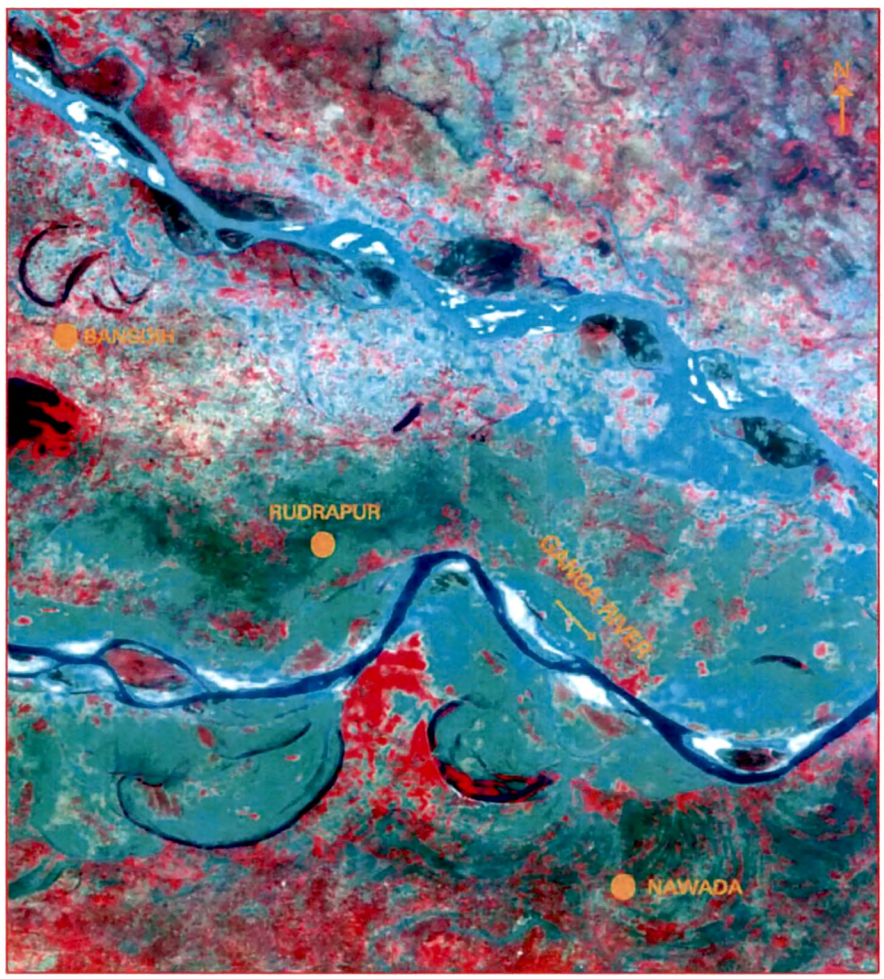



**Fig 5.18: Post-monsoon satellite image showing Ganga river course near Rudrapur in 2006**

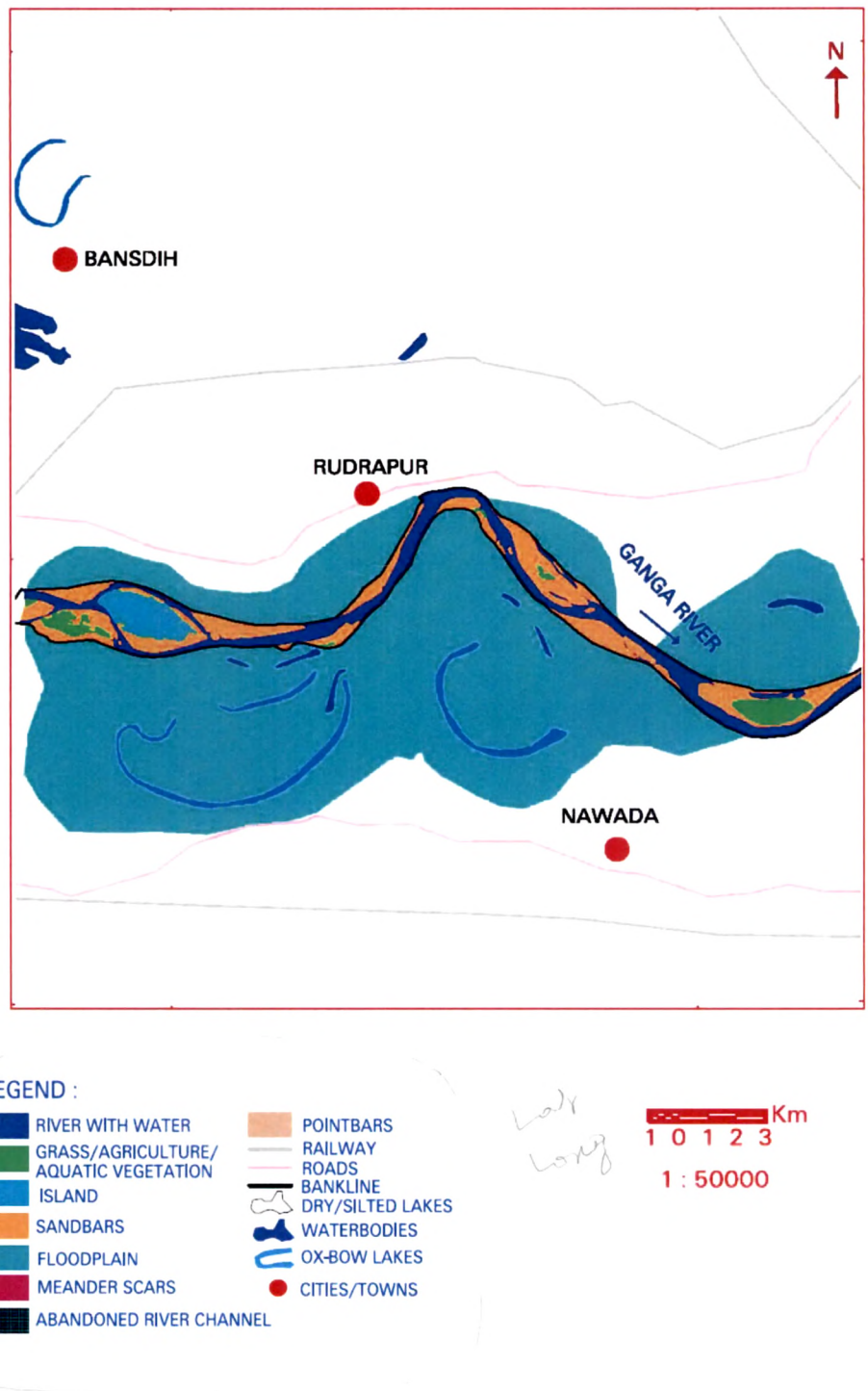



**Fig 5.19: Fluvio-geomorphology of the Ganga river near Rudrapur from IRS P6 post-monsoon data of 2006**


**Plate 5.3: IRS FCC-2006 image / field photograph showing a typical meandering pattern near Rudrapur**

**Plate 5.4: A general view of a meandering pattern as seen in field**

**Table 5.1: Salient features regarding the various fluvio-geomorphological changes using IRS 1D LISS III and IRS-P6 LISS III pre-monsoon and post-monsoon satellite data for the years 2000 and 2004 on 1:250,000 scale covering regions in and around Ballia and Rudrapur**

| Sr no | Features (region covering regions in and around Ballia and Rudrapur) | Observations from pre-monsoon satellite data | | Observations from post-monsoon satellite data | |
|---|---|---|---|---|---|
| | | 2000 pre-monsoon data | 2000 post-monsoon data | 2004 pre-monsoon data | 2004 post-monsoon data |
| 1 | Geomorphological features | River with water, sandbars, island, agriculture, water bodies, flood plain, ox-bow lakes | | River with water, sandbars, island, agriculture, water bodies, flood plain, ox-bow lakes | |
| 2 | River pattern | Braided and complex asymmetrical meandering | | Braided and complex asymmetrical meandering | |
| 3 | Shifting of the river Channel | Distinct up to 1-2 km in Ballia and 1-3 km in Rudrapur | | Distinct up to 1-2.5 km in Ballia and 2-4 km in Rudrapur | |
| 4 | Length of the river bank | 134.00 km | | | |
| 5 | Surface water area of the river | 100.00 sq km | 150.00 sq km | 87.00 sq km | 121.00 sq km |
| 6 | Area of the sandbars | 183.00 sq km | 165.00 sq km | 152 sq km | 147.00 sq km |
| 7 | Area of the flood plain | 710.00 sq km | 751.00 sq km | 708.00 sq km | 760.00 sq km |
| 8 | Width of the river | From 1.0 km to 9.0 km | From 1.0 km to 9.5 km | From 0.8 km to 9.4 km | From 0.8 km to 10.3 km |
| 9 | Area of the island | 91.00 sq km | 92.00 sq km | 118.00 sq km | 131.00 sq km |

**Table 5.2: Salient features regarding the various fluvio-geomorphological changes using IRS P6 LISS III pre-monsoon and post-monsoon satellite data for the year 2006 on 1: 50,000 scale covering regions in and around Ballia**

| Sr. No. | Features (regions covering Ballia) | Observations near Ballia from 2006 pre-monsoon satellite data | Observations near Ballia from 2006 post-monsoon satellite data |
|---|---|---|---|
| 1 | Geomorphological features | River with water, sandbars, island, grass/agriculture, lakes, ox-bow lakes floodplain | River with water, sandbars, island, grass/agriculture, lakes, ox-bow lakes floodplain |
| 2 | River pattern | Typical complex asymmetrical meandering | Typical complex asymmetrical meandering |
| 3 | Shifting of the river channel | Shifting of the river towards N and SE about 1-2 km | Shifting of the river towards N and SE Maximum about 1-3 km |
| 4 | Length of the river bank | 45.00 km | |
| 5 | Surface water area of the river | 21.00 sq km | 29.00 sq km |
| 6 | Area of the sandbars | 52.00 sq km | 43.00 sq km |
| 7 | Area of the floodplain | 260.00. sq km | 267.00 sq km |
| 8 | Width of the river | From 1.3 km to 5.0 km | From 1.0 km to 5.7 km |
| 9 | Area of the island | 8.00 sq km | 40.00 sq km |

**Table 5.3: Salient features regarding the various fluvio-geomorphological changes using IRS P6 LISS III pre-monsoon and post-monsoon satellite data for the year 2006 on 1: 50,000 scale covering regions in and around Rudrapur**

| Sr. No. | Features (regions covering Rudrapur) | Observations near Rudrapur from 2006 pre-monsoon satellite data | Observations near Rudrapur from 2006 post-monsoon satellite data |
|---|---|---|---|
| 1 | Geomorphological features | River with water, sandbars, island, grass/agriculture, floodplain | River with water, sandbars, island, grass/agriculture, floodplain |
| 2 | River pattern | Typical complex asymmetrical meandering | Typical complex asymmetrical meandering |
| 3 | Shifting of the river channel | Distinct and up to 4 km in the S direction | About 2-5 km towards the S direction |
| 4 | Length of the river bank | 55 km | |
| 5 | Surface water area of the river | 28.00 sq km | 36.00 sq km |
| 6 | Area of the sandbars | 49.00 sq km | 35.00 sq km |
| 7 | Area of the flood plain | 390.00 sq km | 384.00 sq km |
| 8 | Width of the river | From 1.0 km to 4.6 km | From 0.6 km to 3.5 km |
| 9 | Area of the island | 7.00 sq km | 7.00 sq km |

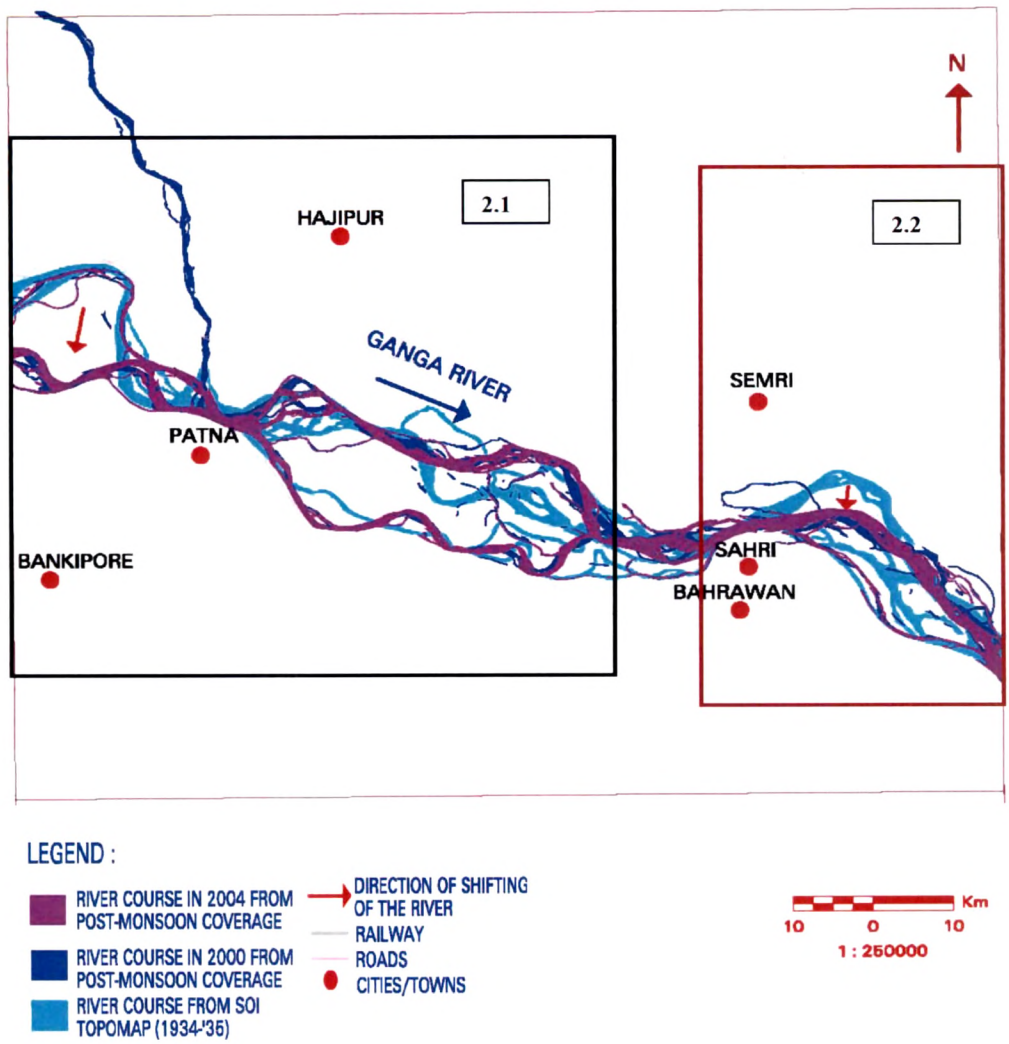
## B1. Shifting of the river course

**Changes mapped at 1:250,000 scale for the year 2000 and 2004 taking SOI as base reference maps**

**Section 2: Regions covering in and around Patna and Sahri**

The SOI topographical maps covering this river section were between the year 1922-'35. This region comprises of the area covering from west of Patna to the East of Sahri.

Detailed mapping, interpretation and comparison of the river water courses of SOI, 2000 and 2004 shows that the river in this region has undergone major and prominent shifting especially near West of Patna since 1922-'35 to 2004. Again, since Patna is the capital of Bihar and also one of the major and important regions of our country and major change occurring in or around these regions holds a special importance. Towards West of Patna the river shows a prominent shift in the ~~in the~~ Southern direction in 2000 as well as in 2004 (ref fig 5.20), when compared with the SOI maps of 1922-'35. The amount of this shift was calculated up to 9.5 km which is a very major shift not only in this region but throughout the Ganga river stretch (ref table 5.4). Towards the East of Patna, the river at some few points does show a minor shifting in the Northern direction also but this shift is not very prominent. Again, moving towards the East of Sahri, comparison of the river courses show that the river has shown a distinct shift of around 0.6-3.8 km in the Southern direction since 1922-'35 to 2000 and 2004. Thus it can be said that this region is prone to river shifting and the shift is mainly in the Southern direction and vary in direction as well as in dimension.




2.1 Region in and around Ballia showing more change

2.2 Region in and around Rudrapur showing more change

**Fig 5.20: Shifting of the Ganga river course near Ballia and Rudrapur on 1:250,000 scale from SOI to 2000 and 2004**

**Changes mapped at 1: 50,000 scale for the year 2006taking SOI as base reference maps**

**Section 2.1: Regions covering in and around Patna**

This window covers the area for a stretch of about 100 km from downstream of Rudrapur to Patna and covering few km downstream of Patna. SOI maps were of the years 1922-'35.

Comparison of the river course during (SOI) maps with the post-monsoon IRS-1D satellite data of the year 2000 and IRS-P6 data for years 2004 and 2006 shows a major shift of about 2-10 km just around West of Patna and the shift direction is mainly towards South (ref fig 5.21 and table 5.5). 10 km shift is a very major shift not only in this region but also if we compare the shifting in past few years for the whole Ganga river course. Also it has been observed that exactly near the Patna city the river has not showed any major change but if we go towards West of Patna the river shows a very major shifting. At few locations the river shows a shift towards the Northern direction also which may be around 2-3 km but is not very major like the 10 km shift.

**Section 2.2: Regions covering in and around Sahri**

This region covers the area in and around Sahri which is about 40 km downstream of Patna. The SOI maps were of the year 1922-'35.

Comparison of the river course during 1922-'35 (SOI) with the post-monsoon IRS-1D satellite data of the year 2000 and IRS-P6 data for years 2004 and 2006 (ref fig 5.22 and table 5.6) shows a distinct shift of about 1-4 km near East of Sahri and the shifting is in the Southern direction. In pre-monsoon the shifting was measured up to 0.6 to 3.8 km whereas during post-monsoon it was measured 0.9 to 4 km which is also a major bank-line shift of this region.

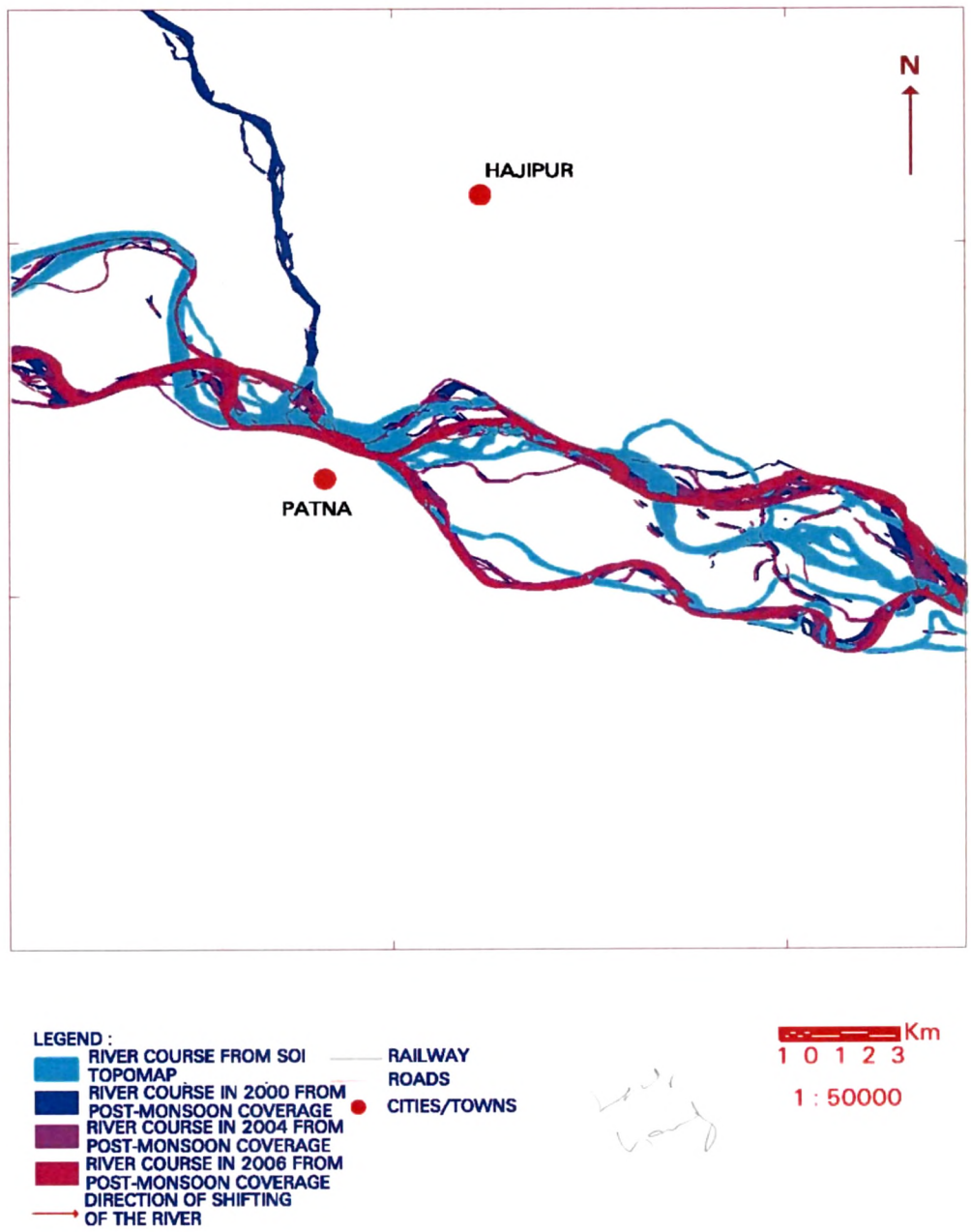



**Fig 5.21: Shifting of the Ganga river course near Patna on 1:50,000 scale from (SOI) to 2000, 2004 and 2006**

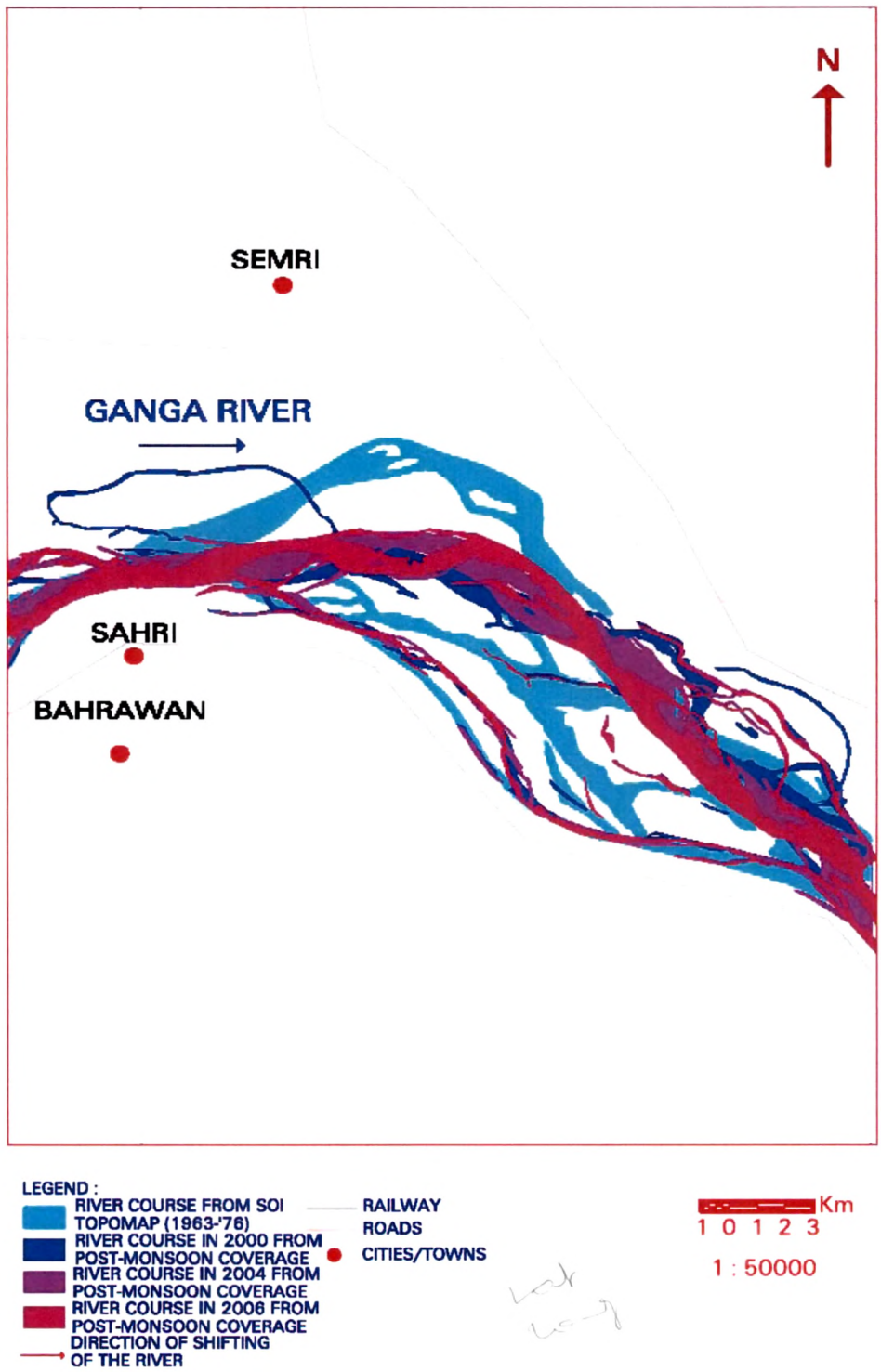



**Fig 5.22: Shifting of the Ganga river course near Sahri on 1:50,000 scale from (SOI) to 2000, 2004 and 2006**

## B2. Estimation of erosion and deposition along both the bank-lines from post-monsoon data

**Changes mapped at 1:250,000 scale for the year 2000 and 2004 taking SOI as base reference maps**

**Section 2: Regions covering in and around Patna and Sahri**

Comparison of the bank-lines in this region from 1922-'35 to 2004 shows that the Northern or the right bank has undergone much more amount of aggradation than degradation whereas the right or the Southern bank shows high rate of degradation then compared to aggradation (ref fig 5.23). On the whole this region has experienced more erosion then deposition which indicate widening of the river bed. The region in the West of Patna has undergone very high rate of erosion which also supports the bank-line shifting in the Southern direction between this period of time. Towards the East of Patna on the Northern bank, as seen near Sahri and the regions around it, the river shows quite high rate of deposition than compared to erosion.

**Changes mapped at 1: 50,000 scale for the year 2006 taking SOI as base reference maps**

**Section 2.1: Regions covering in and around Patna**

In this region, especially near West of Patna the river has undergone excessive erosion during 2000 and 2004 when compared with 1922-'35 (ref fig 5.24). A huge area has been under erosion between these years. This also suggests that the river has shifted in the Southern direction in past few years. Also the amount of erosion on both the banks is much higher then deposition and dominance of degradation suggests the widening of the river bed in this region. This area shows marked decrease in the rate of deposition and there are only few locations from East of Patna which has undergone

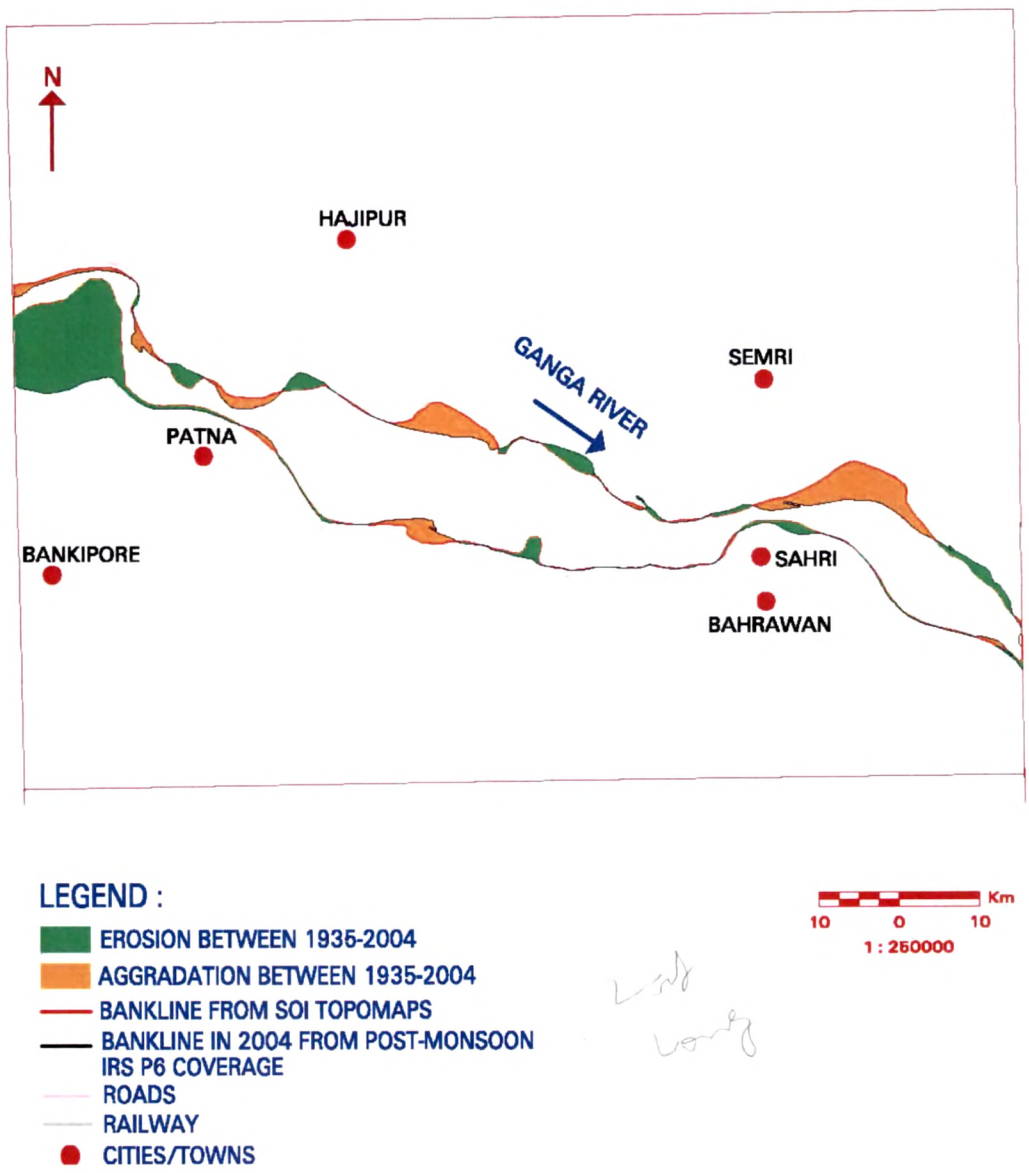



**Fig 5.23: Bankline change and erosion/deposition near Patna and Sahri on 1:250,000 scale from (SOI) to 2000 and 2004**

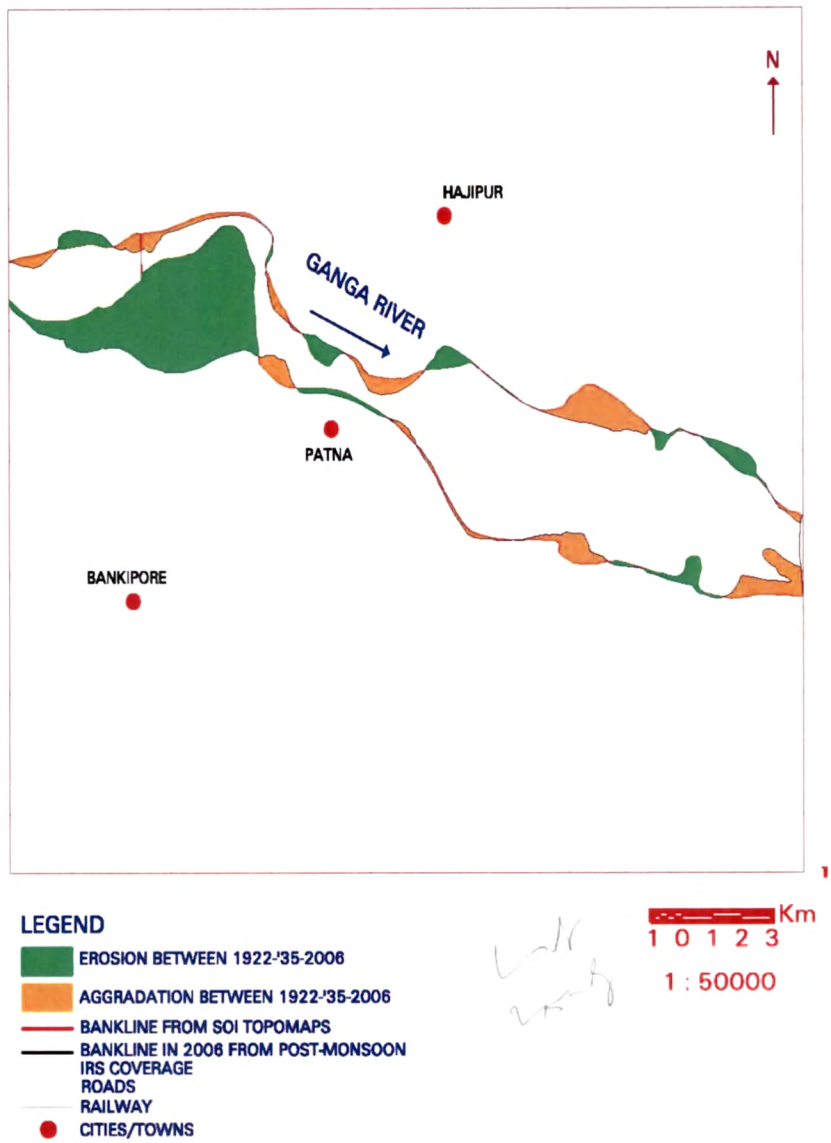
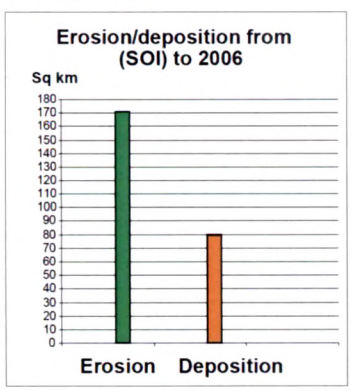



**Fig 5.24: Bankline change and erosion/deposition near Patna on 1:50,000 scale from (SOI) to 2006**




**Bar chart 5.3: Erosion and deposition along both the banks of the Ganga river near Patna**

prominent aggradation. The amount of erosion and deposition was found to be 171.0 sq km and 80.0 sq km respectively (ref bar chart 5.3).

**Section 2.2: Regions covering in and around Sahri**

From the (fig 5.25) it is clear that the Northern bank has undergone heavy sedimentation the compared to degradation whereas the Southern bank has undergone very little aggradation as well as degradation. Dominance of aggradation on the northern bank indicates shrinking of the river bed. The amount of erosion and deposition along both the banks of the Ganga river for this selected location was found to be 18.0 and 40.0 sq km respectively (ref bar chart 5.4).

## B3. Fluvio-geomorphological changes as depicted from pre-monsoon and post-monsoon data

**Changes mapped at 1:250,000 scale for the year 2000 and 2004 taking SOI as base reference maps**

**Section 2: Regions covering in and around Patna and Sahri**

As seen from (fig 5.26 to 5.30) the whole Ganga river stretch in this region shows presence of numerous small and large water-bodies in the Northern direction which indicates the remnants of the past river course. Whereas the Southern part which is the present direction in which the river has shifted in past few years shows only few water-bodies. A huge island has been formed little East of Patna which has become much more distinct in 2004 than compared to the previous years. The island was present during 1922-'35 but it was quite small in size as well as not much discrete compared to 2000 and 2004. Also, the total area covered by islands in this region has considerably increased in 2004 post-monsoon season than compared to the other data. Braided pattern which is formed due to the union of many small and big streams especially after monsoon is also very well seen throughout the river course in this region (ref plate 5.5).

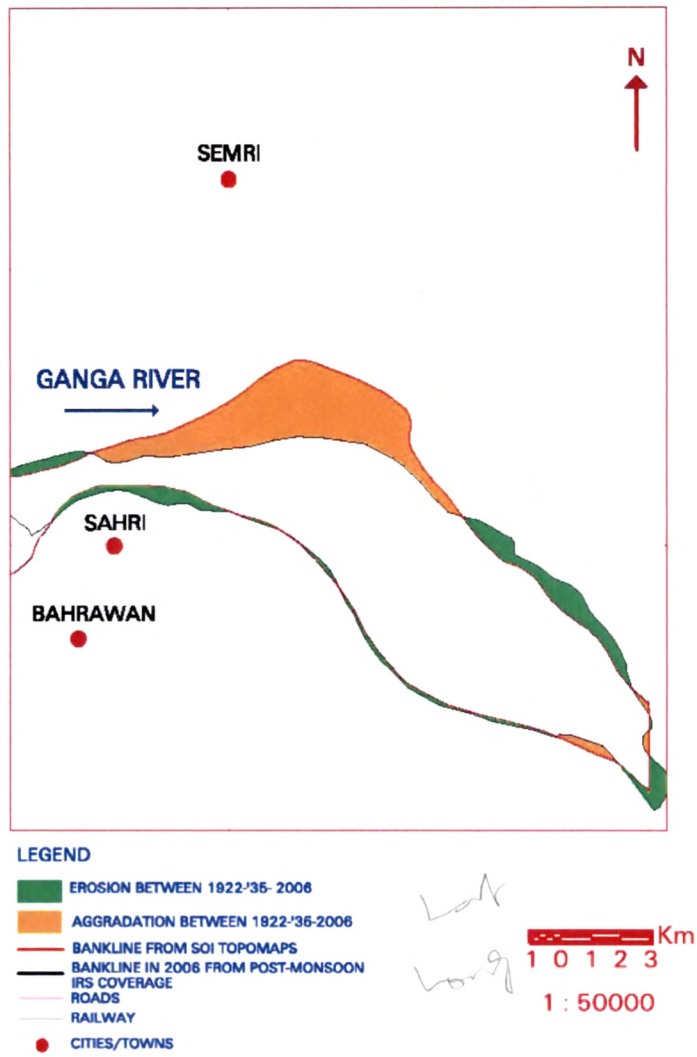
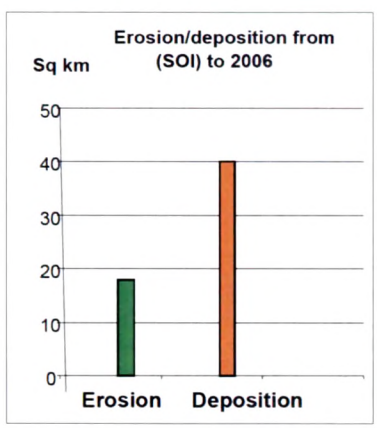



**Fig 5.25: Bankline change and erosion/deposition near Sahri on 1:50,000 scale from (SOI) to 2006**




**Bar chart 5.4: Erosion and deposition along both the banks of the Ganga river near Sahri**

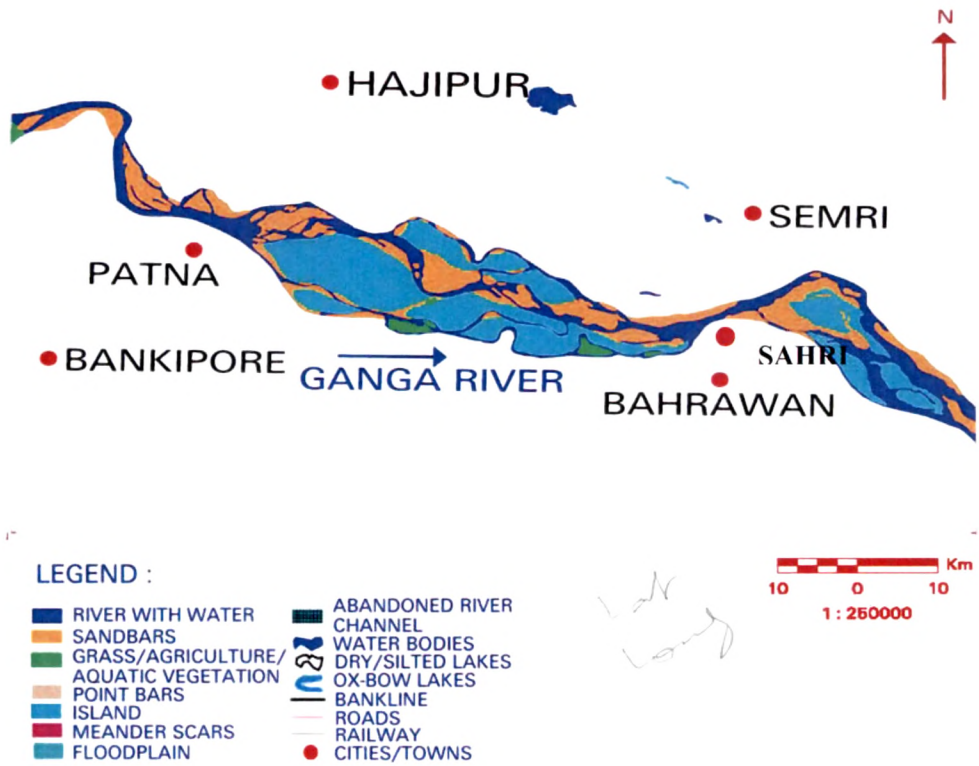



**Fig 5.26: Fluvio-geomorphology of the Ganga river near Ballia and Rudrapur on 1:250,000 scale from SOI maps**


**Plate 5.5: IRS FCC image / field photograph showing a typical braided course near Patna**

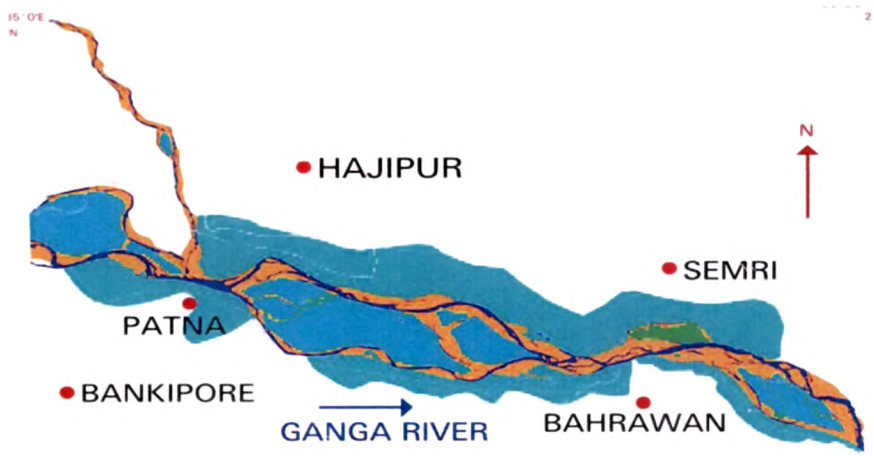



**Fig 5.27: Fluvio-geomorphology of the Ganga river near Patna and Sahri on 1:250,000 scale from IRS 1D pre-monsoon data-2000**

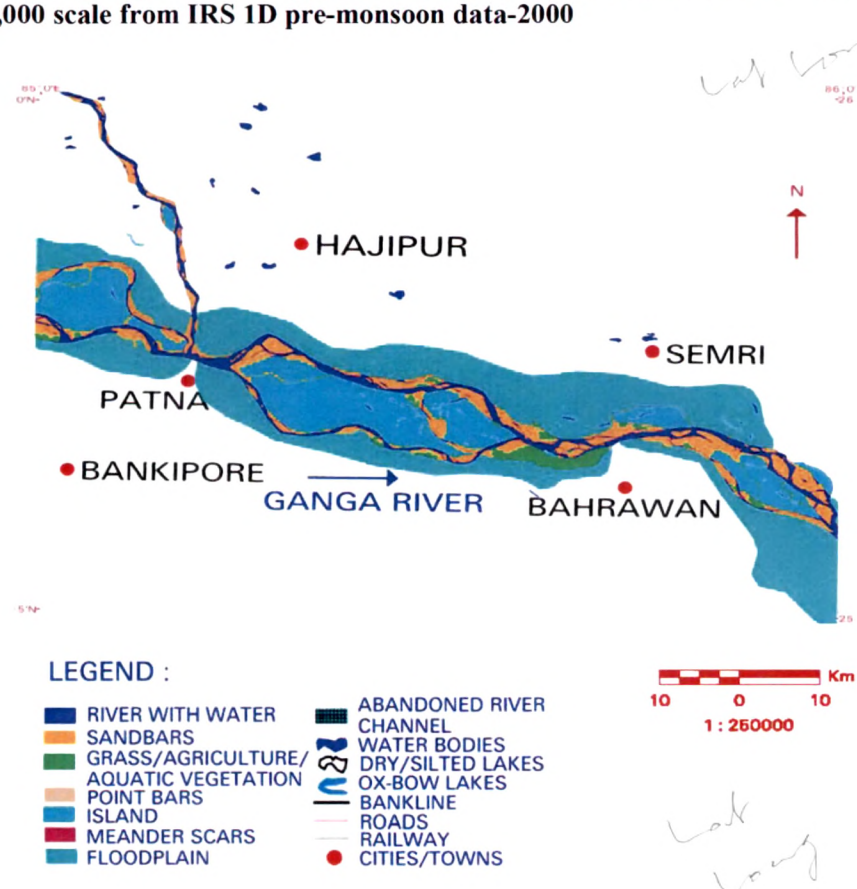



**Fig 5.28: Fluvio-geomorphology of the Ganga river near Patna and Sahri on 1:250,000 scale from IRS 1D post-monsoon data-2000**

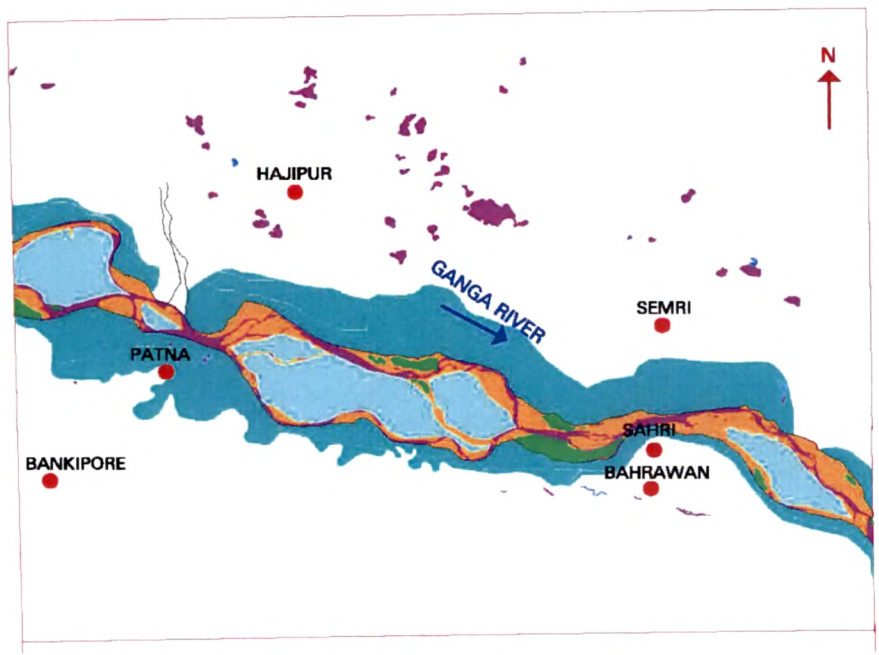



**Fig 5.29: Fluvio-geomorphology of the Ganga river near Patna and Sahri on 1:250,000 scale from IRS P6 pre-monsoon data-2004**

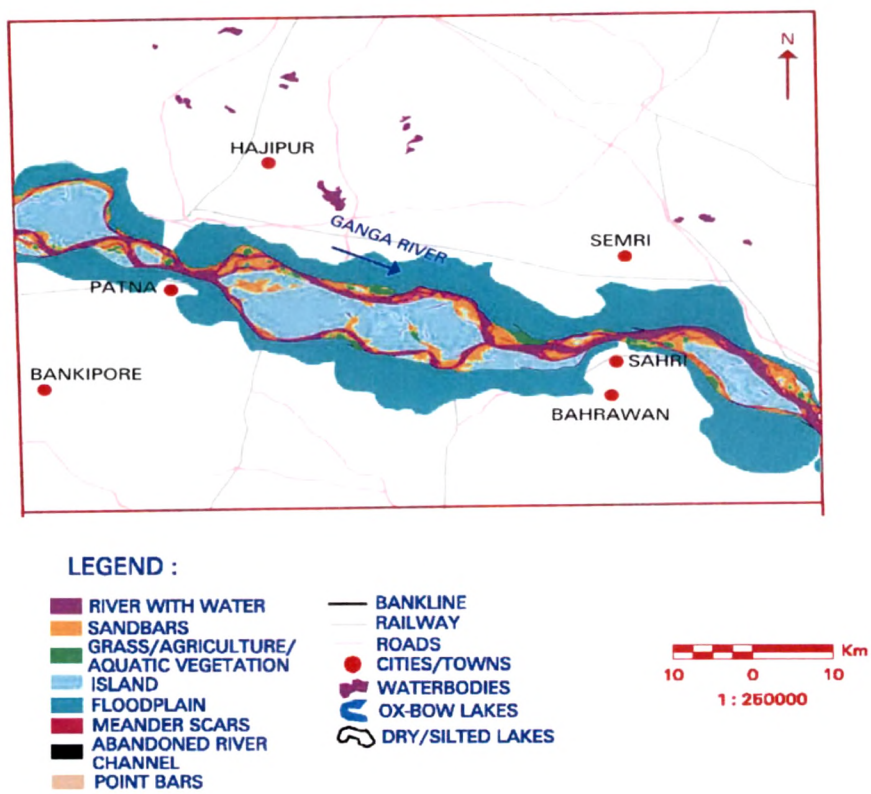



**Fig 5.30: Fluvio-geomorphology of the Ganga river near Patna and Sahri on 1:250,000 scale from IRS P6 post-monsoon data-2004**

Asymmetrical meandering pattern is also visible in the west of Patna. The length of the river bank is found to be 132 km. Surface water area has significantly increased during the post-monsoon season of 2004 than compared to 2000. The area of sand-bars has reduced in 2004 than in 2000. This change is again very well seen during the post-monsoon period than compared to pre-monsoon. Many times it happens that during monsoon or after the monsoon period the total number of ground exposed sand-bars is relatively less since they are covered by water. This may be one of the reasons why the area of sand-bars (refer plate 5.6) are usually less in post-monsoon than compared to pre-monsoon season. The area of flood-plain show increase during the post-monsoon season of both the years than compared to the pre-monsoon period and also in 2004 the area of the flood-plains have significantly increased than compared to 2000. It may be due to heavy inundation during 2004. Width of the river is constant during both the seasons in 2000 but in 2004 the width has marginally increased than in 2000 (refer table 5.4 for details).

**Changes mapped at 1: 50,000 scale for the year 2006 taking SOI as base reference maps**

**Section 2.1: Regions covering in and around Patna**

The region shows various distinct fluvial features such as river water, sand-bars, islands, flood-plain, water-bodies etc (refer plate 5.7). The main distinct feature of this region is the huge island which has been formed near Patna city (ref in plate 5.8 and 5.9). This island has become wider and bigger in 2004 and 2006 than compared to 2000 as well as the historical data it has been seen that during 1922-'35 the main channel used to flow in the Northern direction which has shifted during these years in the southern direction leaving a huge island area in between the main channel and the other minor as well as major streams which are still active and also forms a distinct

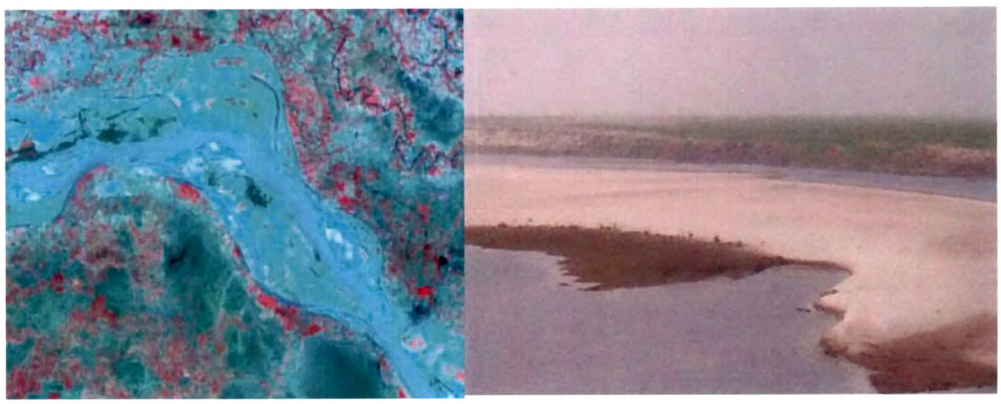


**Plate 5.6: IRS FCC-2006 image / field photograph showing a huge sand-bar near Sahri**

**Plate 5.7: IRS FCC/field photograph showing the water-body near Patna**

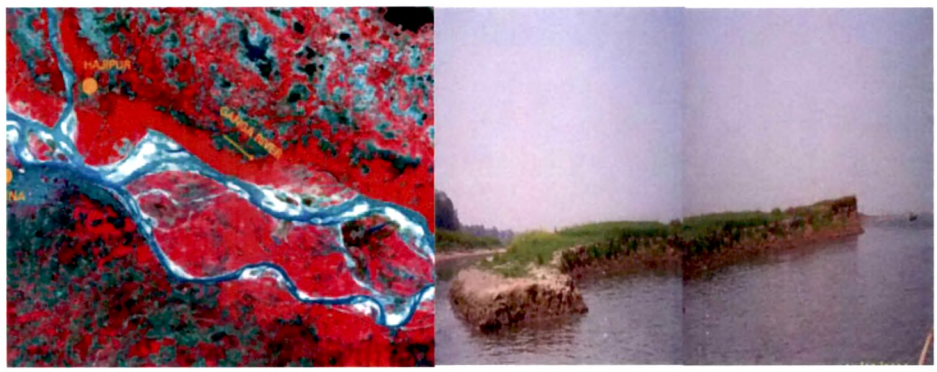


**Plate 5.8: IRS FCC-2006 image / field photograph showing the new huge river island formed near Patna**

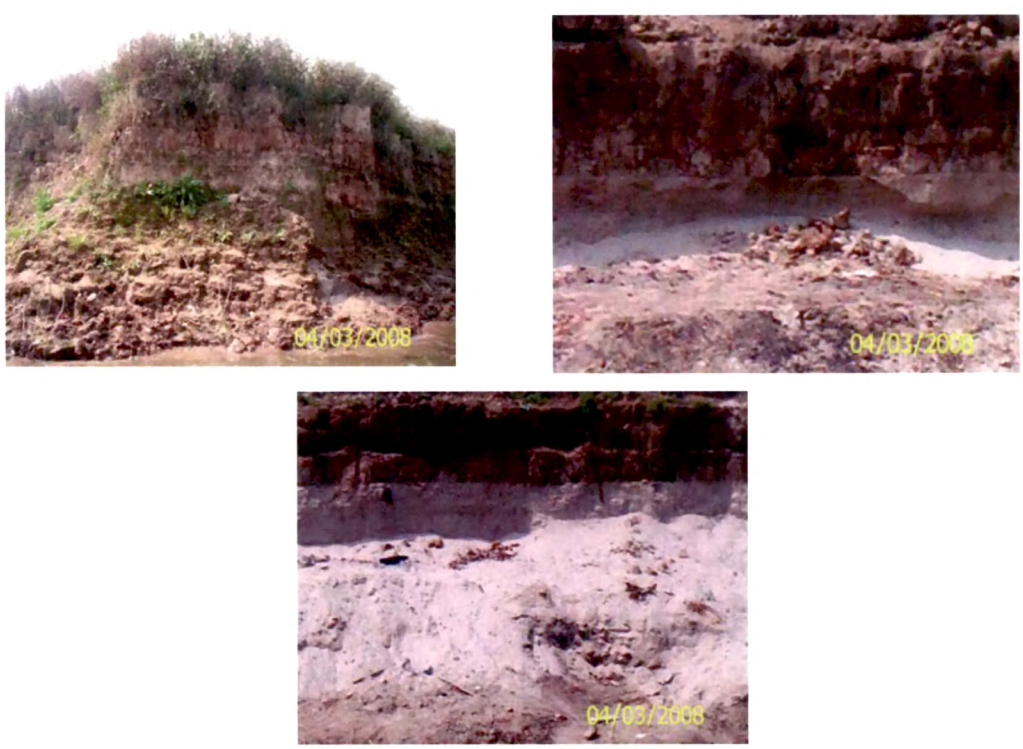



**Plate 5.9: IRS FCC/field photograph showing excess rate of erosion near Patna**

braided pattern. Braided pattern is distinctly seen throughout the river course in this region. Also, a prominent island in the west of Patna as seen in the years 2000 and 2004 is totally absent during 1922-'35.which is also a very major change in this region. If we compare the other parameters in 2006 between pre-monsoon and post-monsoon seasons it is seen that the length of the river bank is around 99 km. Area of sand-bars shows a drastic decrease during post-monsoon. The area of flood-plain in this region also shows a marked decrease in the post-monsoon season then compared to pre-monsoon data whereas the island area has increased in the post-monsoon season in comparison to the pre-monsoon season. Width of the river shows only a marginal increase during the post-monsoon season (refer fig 5.31 to 5.34 and table 5.5).

**Section 2.2: Regions covering in and around Sahri**

For the comparative picture regarding the fluvial geomorphological features interpreted using 1922-'35 (SOI topomaps) and IRS post-monsoon data of years 2000, 2004 and 2006 (ref fig 5.26 to 5.30 and 5.35 to 5.38). Fluvial geomorphological features namely river with water, sandbars, floodplain, water-bodies, river islands and grass/agriculture/aquatic vegetation have been interpreted from the post-monsoon IRS satellite images. The sandbars are mainly composed of sand/silt. The river course shows a distinct braiding pattern throughout its course in this region which is seen during all the years since 1922-35 to 2006. length of the river bank is around 41.5 km. Area of sand-bars has reduced which may be due to the monsoonal effect since the number of exposed sand-bars may be less during this season. Area of flood-plain in this region shows nominal decrease during the post-monsoon season. Width of the river has marginally increased during the post-monsoon season and the area of island in post-monsoon season has also increased to a considerable extent (refer table 5.6 for details).

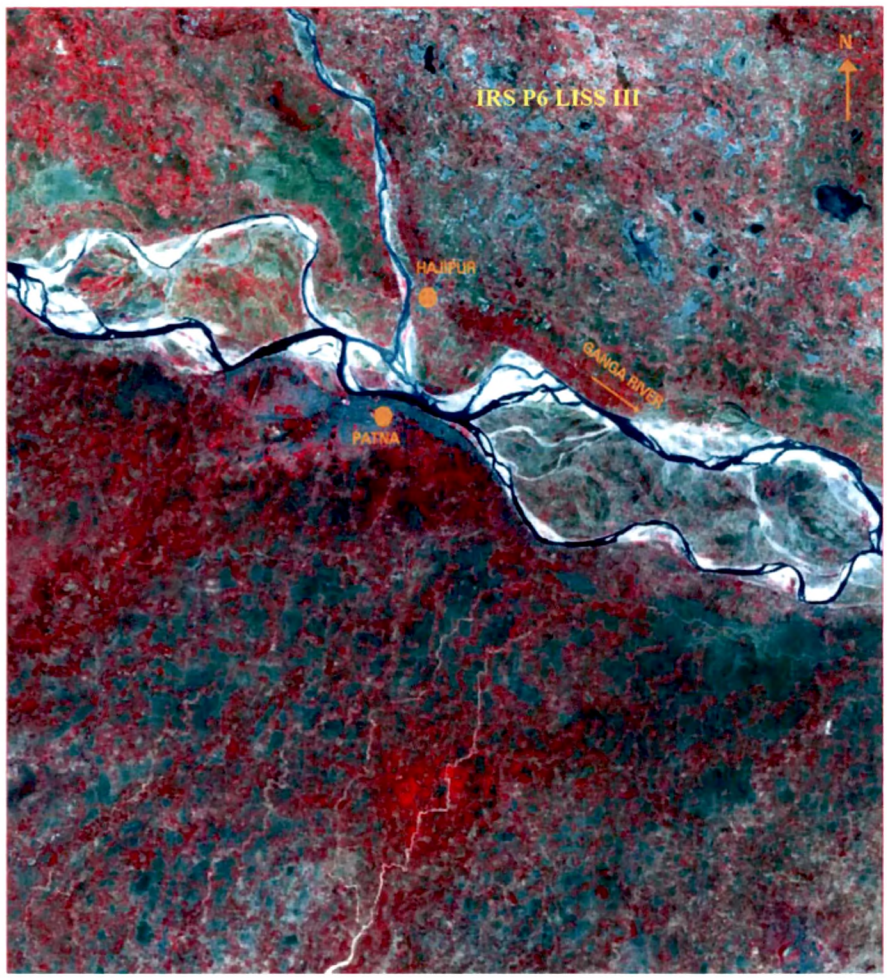



**Fig 5.31: Pre-monsoon satellite image showing Ganga river course near Patna in 2006**

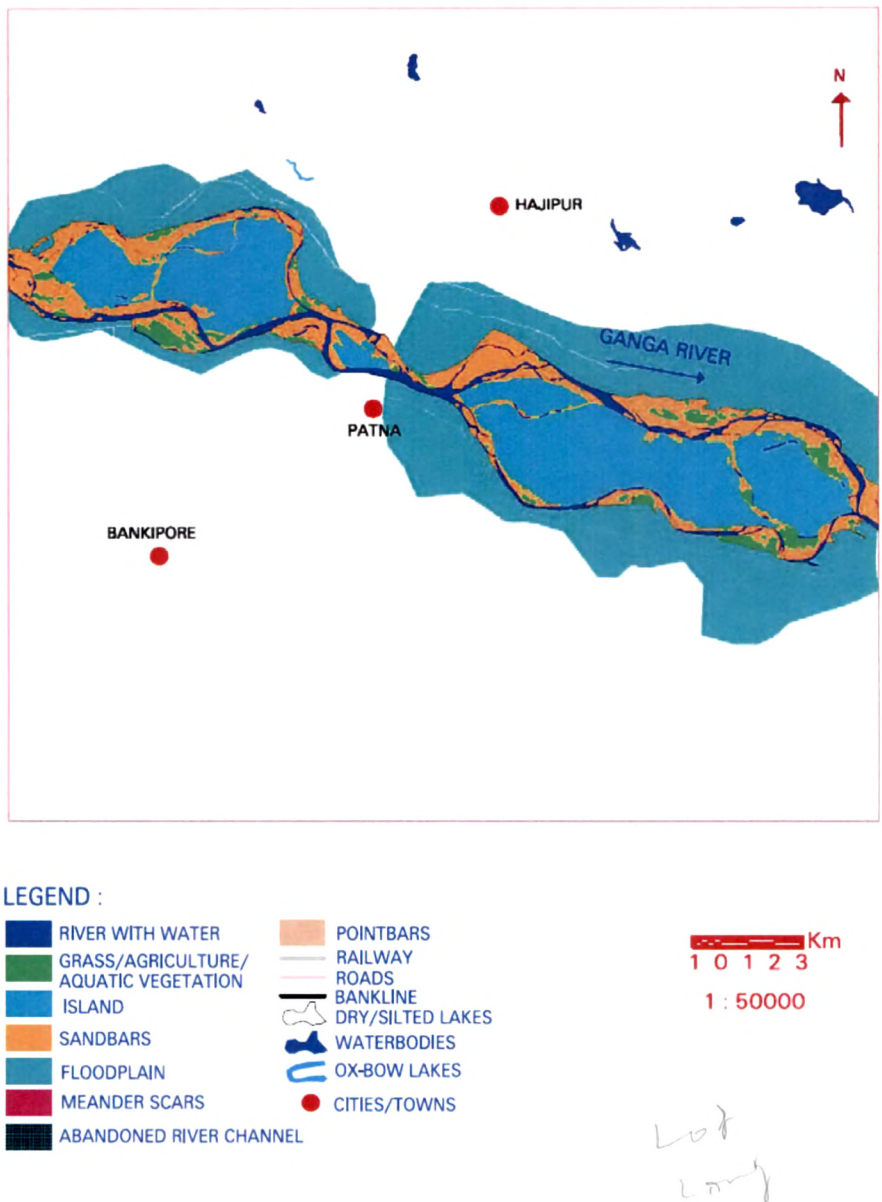



**Fig 5.32: Fluvio-geomorphology of the Ganga river near Patna from IRS P6 pre-monsoon data of 2006**

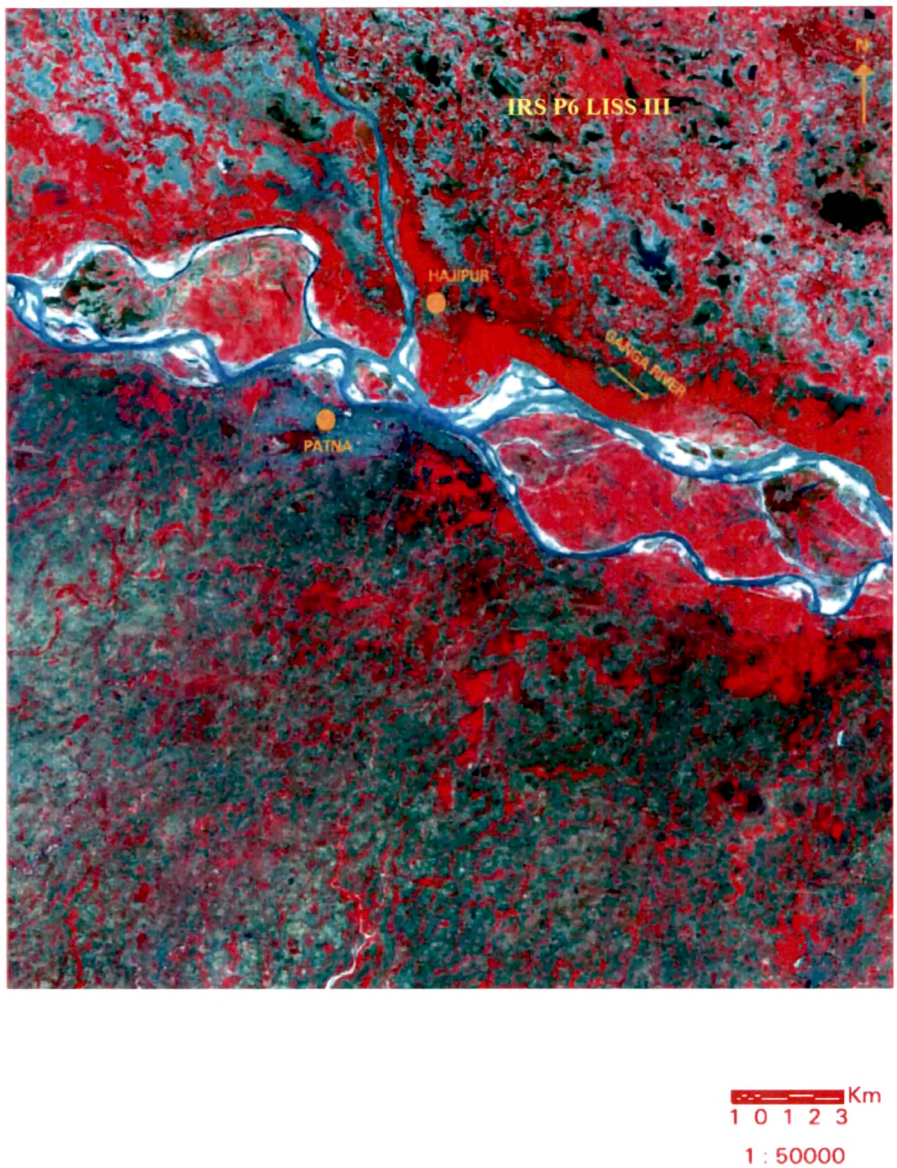



**Fig 5.33: Post-monsoon satellite image showing Ganga river course near Patna in 2006**

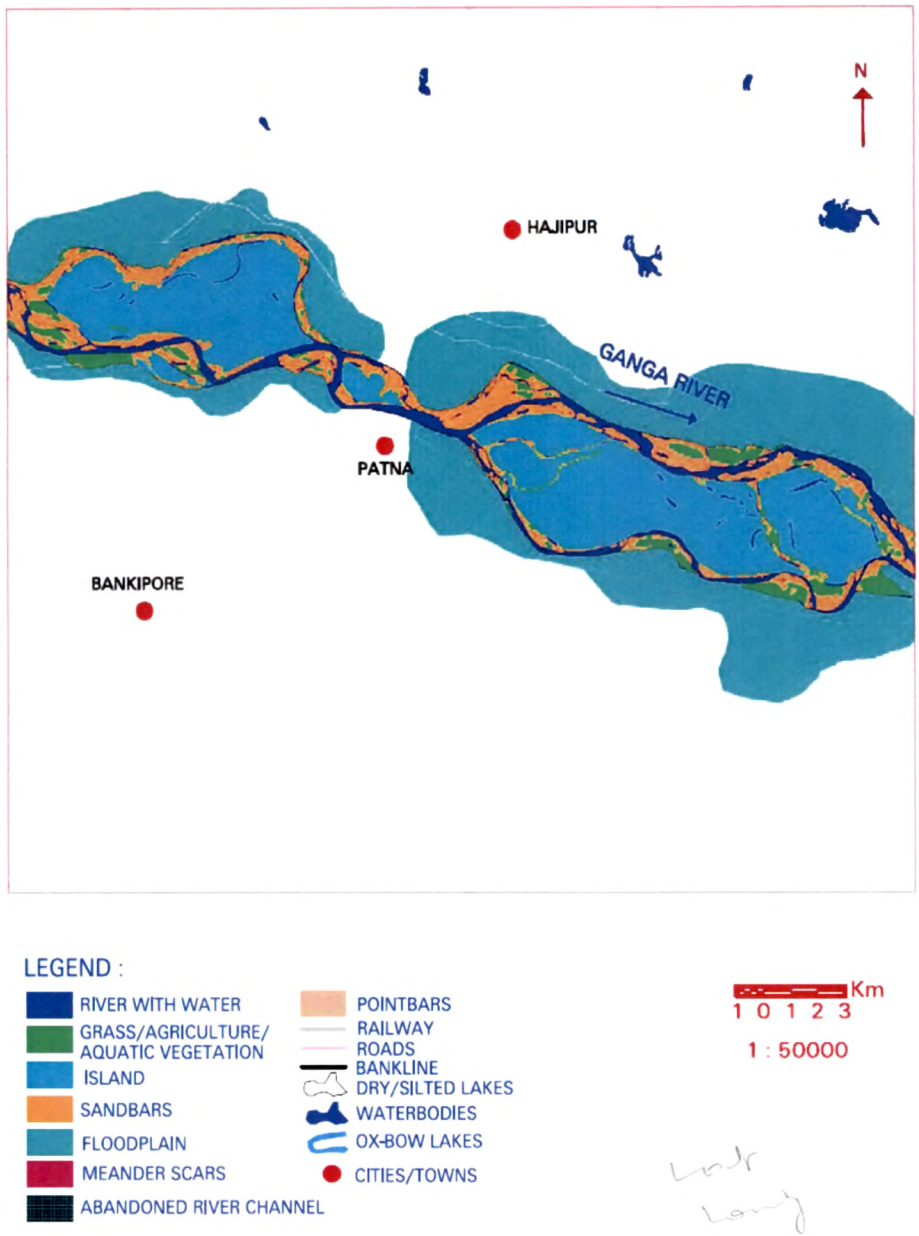



**Fig 5.34: Fluvio-geomorphology of the Ganga river near Patna from IRS P6 post-monsoon data of 2006**

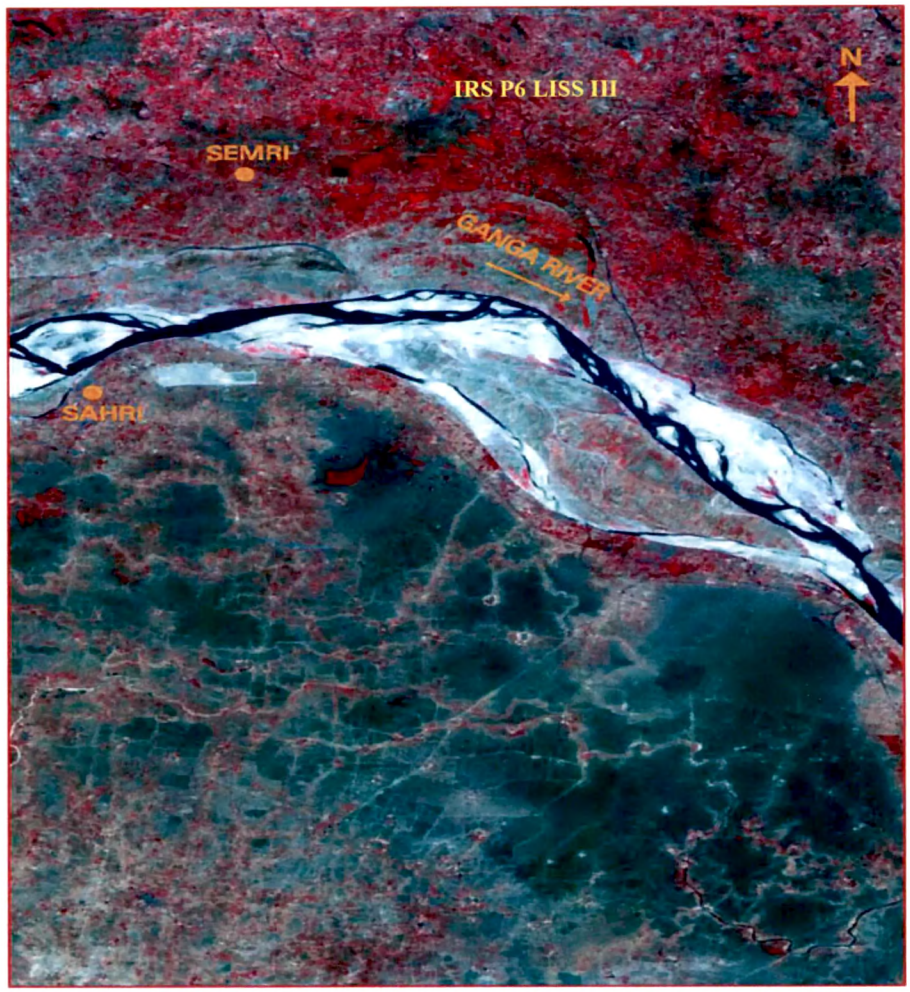



**Fig 5.35: Pre-monsoon satellite image showing Ganga river course near Sahri in 2006**

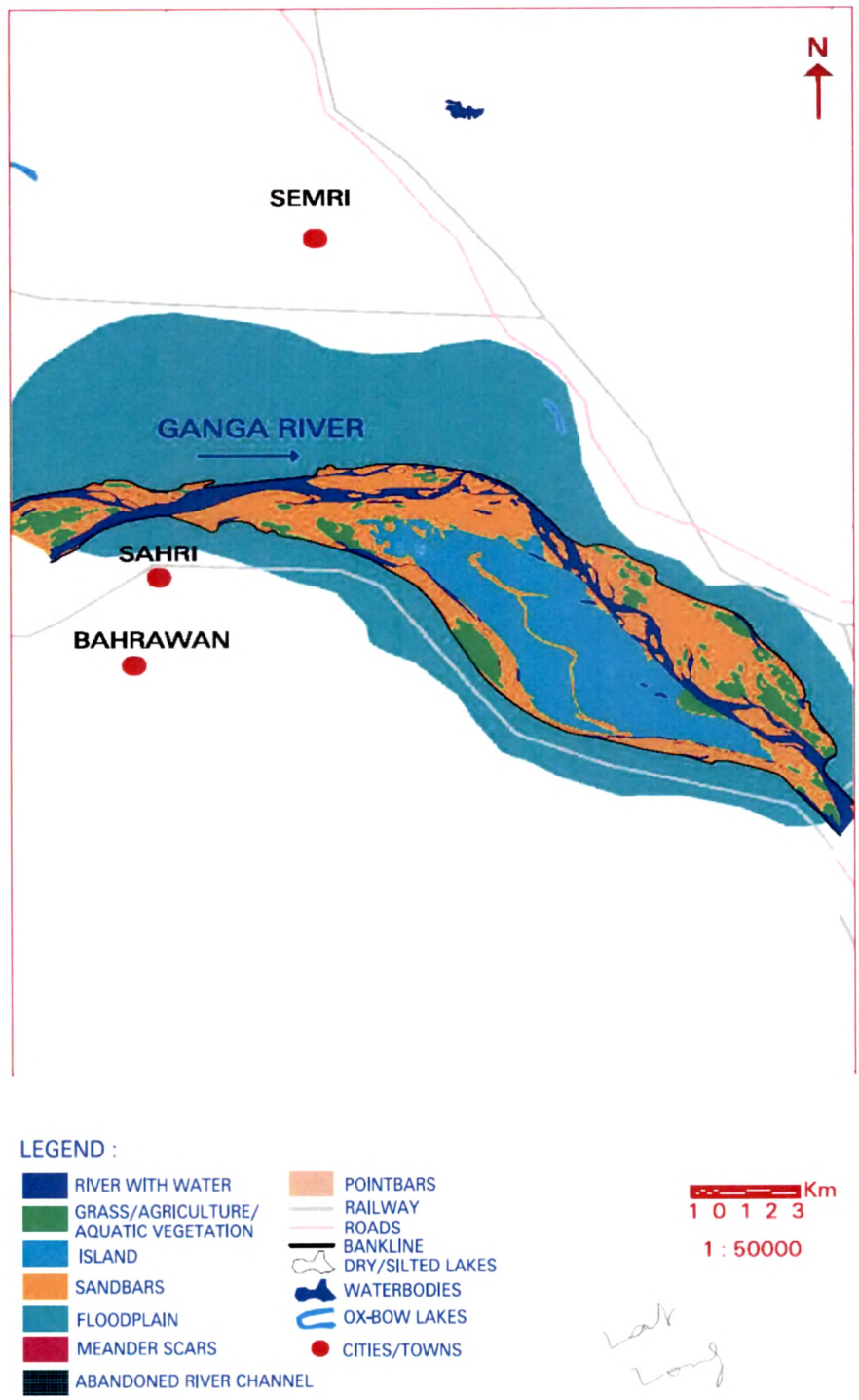



**Fig 5.36: Fluvio-geomorphology of the Ganga river near Patna from IRS P6 pre-monsoon data of 2006**

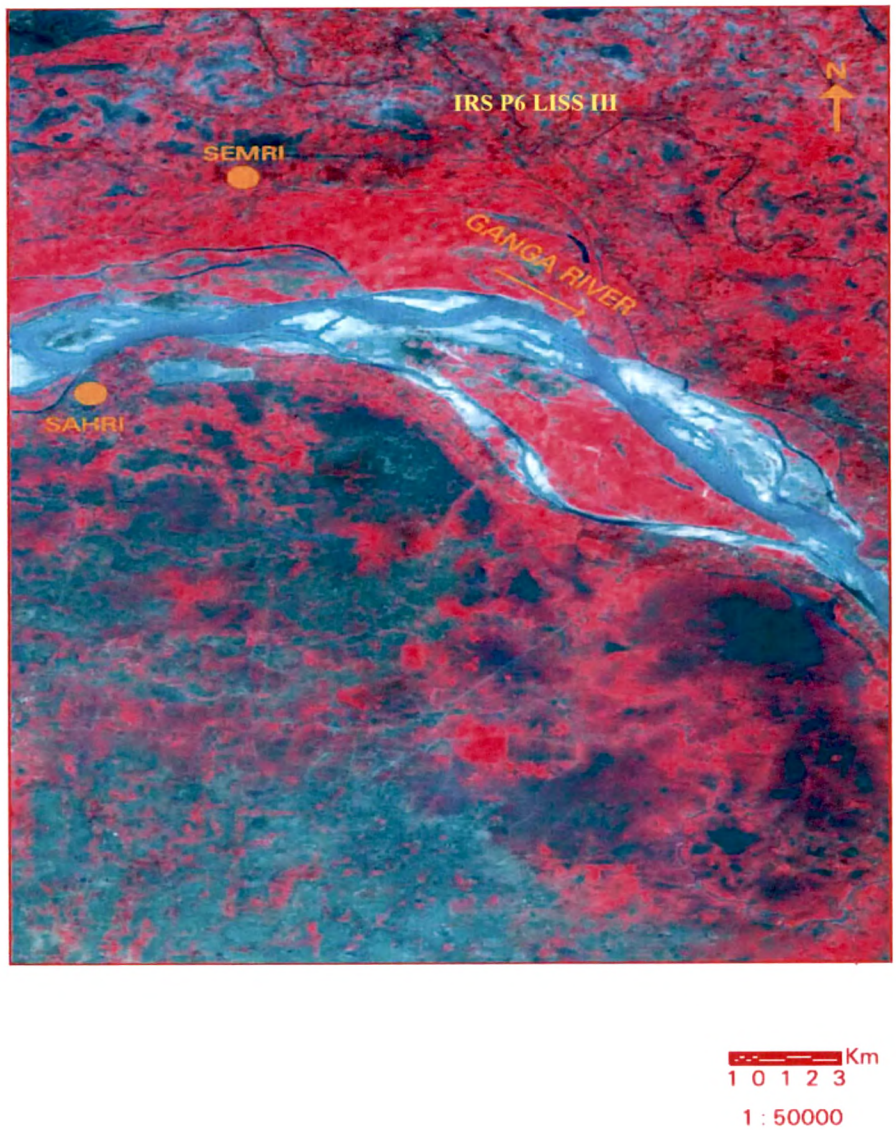



**Fig 5.37: Post-monsoon satellite image showing Ganga river course near Sahri in 2006**

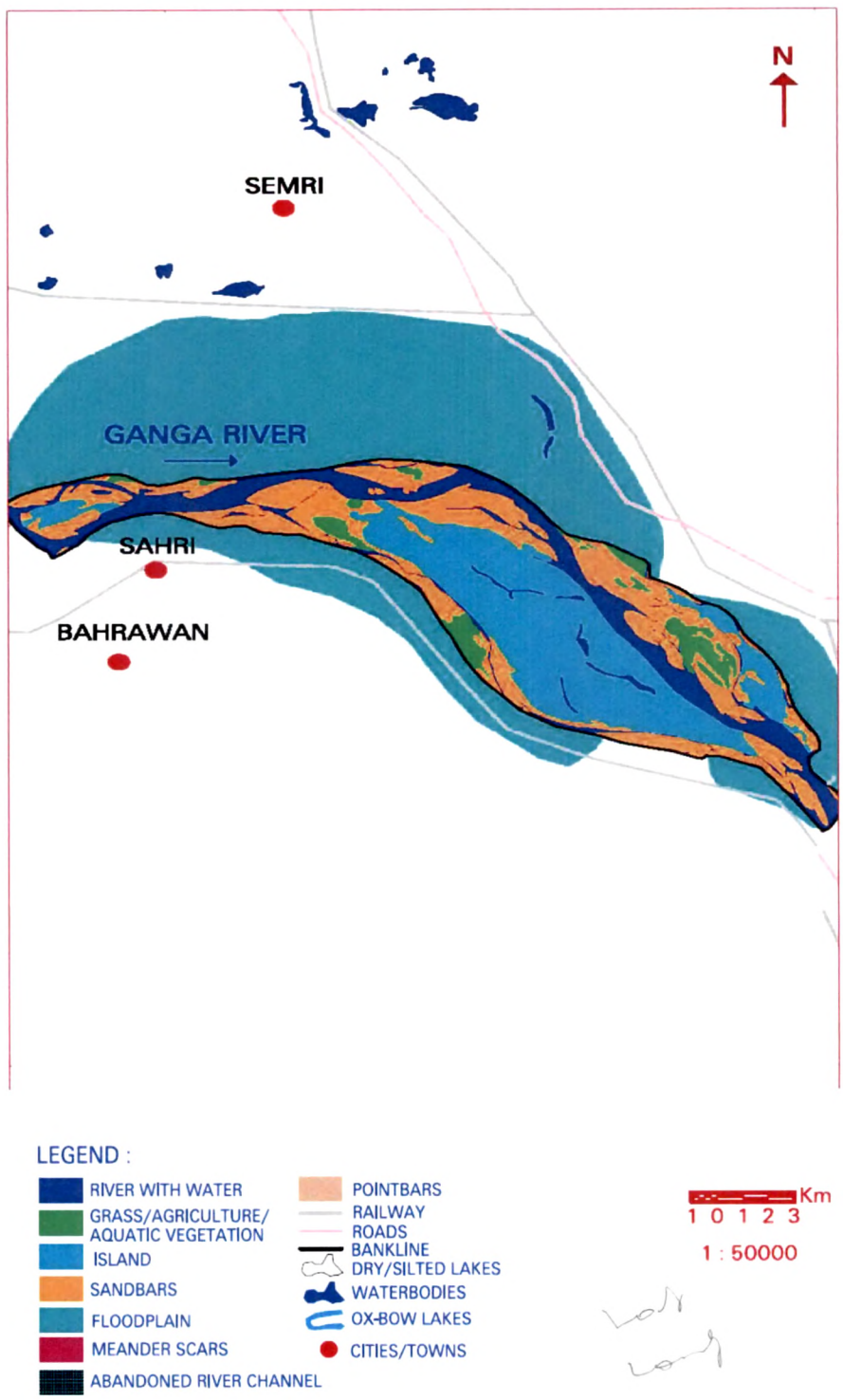



**Fig 5.38: Fluvio-geomorphology of the Ganga river near Patna from IRS P6 post-monsoon data of 2006**

**Table 5.4: Salient features regarding the various fluvio-geomorphological changes using IRS 1D LISS III and IRS-P6 LISS III pre-monsoon and post-monsoon satellite data for the years 2000 and 2004 on 1:250,000 scale covering regions in and around Patna and Sahri**

| Sr no | Features (Regions covering Patna and Sahri) | Observations from pre-monsoon satellite data | | Observations from post-monsoon satellite data | |
|---|---|---|---|---|---|
| | | 2000 Pre-monsoon data | 2000 Post-monsoon data | 2004 pre-monsoon data | 2004 post-monsoon data |
| 1 | Geomorphological features | River with water, sandbars, island, agriculture, water bodies, flood plain, ox-bow lakes | | River with water, sandbars, island, agriculture, water bodies, flood plain, ox-bow lakes | |
| 2 | River pattern | Braided and complex asymmetrical meandering | | River course divided into number of branches to form braided pattern | |
| 3 | Shifting of the river channel | Distinct up to 1-8 in Patna and 0.6 to 3 km near Sahri | | Distinct up to 1-9.5 km near Patna and 1-3.8 km near Sahri | |
| 4 | Length of the river bank | 132.00 Km | | | |
| 5 | Surface water area of the river | 128.00 sq km | 185.00 sq km | 144.00 sq km | 203.00 sq km |
| 6 | Area of the sandbars | 295.00 sq km | 216.00 sq km | 229.00 sq km | 165.00 sq km |
| 7 | Area of the flood plain | 824.00 sq km | 918.00 sq km | 830.00 sq km | 925.00 sq km |
| 8 | Width of the river | From 1.0 km to 12.0 km | From 1.00 km to 12.00 km | From 1.4 km to 12.7 km | From 1.3 km to 13.1 km |
| 9 | Area of the island | 383.00 sq km | 425.00 sq km | 401.00 sq km | 434.00 sq km |

**Table 5.5: Salient features regarding the various fluvio-geomorphological changes using IRS P6 LISS III pre-monsoon and post-monsoon satellite data for the year 2006 on 1: 50,000 scale covering regions in and around Patna**

| Sr. No. | Features (regions covering Patna) | Observations near Patna from 2006 pre-monsoon satellite data | Observations near Patna from 2006 post-monsoon satellite data |
|---|---|---|---|
| 1 | Geomorphological features | River with water, sandbars, island, grass/agriculture, lakes, ox-bow lakes floodplain | River with water, sandbars, island, grass/agriculture, lakes, ox-bow lakes floodplain |
| 2 | River pattern | Distinct braided pattern is seen | Distinct braided pattern is seen |
| 3 | Shifting of the river channel | Shifting of the river mainly towards S and at some locations towards N from 2-9.5 km | Shifting of the river mainly towards S and at some locations towards N from 2-10 km |
| 4 | Length of the river bank | 99.00 km | |
| 5 | Surface water area of the river | 86.00 sq km | 111.00 sq km |
| 6 | Area of the sandbars | 202.00 sq km | 148.00 sq km |
| 7 | Area of the floodplain | 672.00 sq km | 645.00 sq km |
| 8 | Width of the river | From 1.3 km to 15.12 km | From 1.4 km to 15.2 km |
| 9 | Area of the island | 367.00 sq km | 389.00 sq km |

**Table 5.6: Salient features regarding the various fluvio-geomorphological changes using IRS P6 LISS III pre-monsoon and post-monsoon satellite data for the year 2006 on 1: 50,000 scale covering regions in and around Sahri**

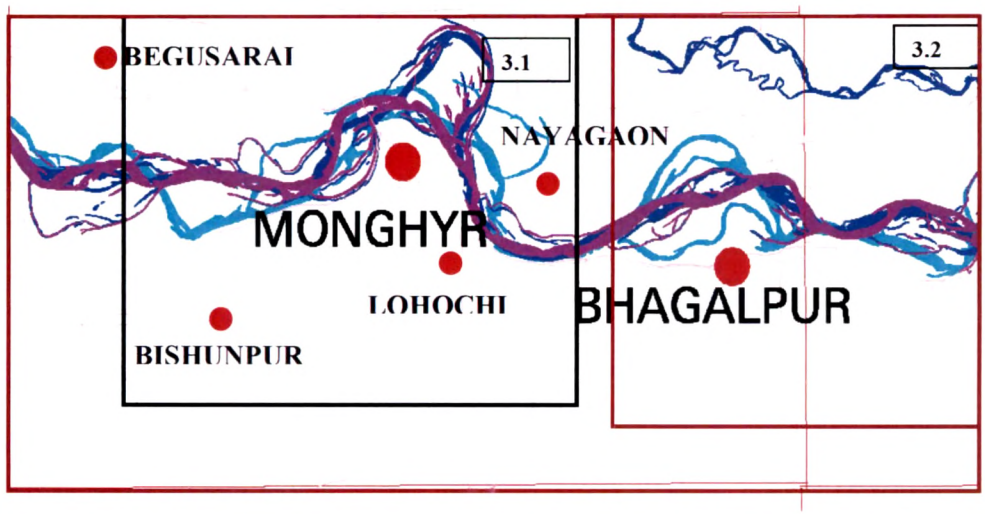
| Sr. No. | Features (regions covering Sahri) | Observations near Sahri from 2006 pre-monsoon satellite data | Observations near Sahri from 2006 post-monsoon satellite data |
|---|---|---|---|
| 1 | Geomorphological features | River with water, sandbars, island, grass/agriculture, water-bodies, floodplain | River with water, sandbars, island, grass/agriculture, water-bodies, floodplain |
| 2 | River pattern | Distinct braided pattern is seen | Distinct braided pattern is seen |
| 3 | Shifting of the river channel | Shifting of the river mainly towards S about 0.6 to 3.8 km | Shifting of the river mainly towards S about 0.9 to 4 km |
| 4 | Length of the river bank | 41.5 km | |
| 5 | Surface water area of the river | 31.00 sq km | 45.00 sq km |
| 6 | Area of the sandbars | 78.00 sq km | 61.00 sq km |
| 7 | Area of the floodplain | 248.00 sq km | 243.00 sq km |
| 8 | Width of the river | From 1.3 km to 8.6 km | From 1.3 km to 9.1 km |
| 9 | Area of the island | 57.00 sq km | 67.00 sq km |

## C1. Shifting of the river course

**Changes mapped at 1:250,000 scale for the year 2000 and 2004 taking SOI as base reference maps**

**Section 3: Regions covering in and around Monghyr and Bhagalpur**

The SOI topographical maps covering this river section were between the year 1935-'36. This region comprises of the area covering from west of Begusarai to Bhagalpur. This region has undergone tremendous changes since 1935-'36 to 2004 as in case near Patna. From the entire course of study it is noticed that this area has shown maximum changes as well as instability in context with river shifting and other fluvial changes (ref fig 5.39). From the mapping and interpretation it was observed that near Begusarai, the river has shown a shift of around 2 km in the Southern direction during the time period of 1935-'36 to 2004. The river has not shown any major change between 2000 and 2004. Moving towards East of Begusarai near Bishunpur again the river shows a very distinct shift in the Northern direction which was measured up to 4-5 km during this entire time period. Moving Eastwards near Monghyr and the regions surrounding it the river has shown a very distinct and prominent of 0.5-7.5 in the Northern direction by comparing the SOI data with 2000 and 1-9 km during SOI to 2004. Also one major change that has been noticed is this change or shift is more prominent between the years 1935-'36 to 2000 whereas in 2004 the river channel has shown a cut-off with the main channel due to which the continuity with the main river channel is not seen. Near Nayagaon and Lohochi the river has shown a Southwest shift of around 2-3 km during the years 1935-'36 to 2004, whereas between the years 2000 and 2004 the river flow is almost parallel. In the East of Nayagaon near Bhagalpur the river shows a prominent shifting of around 1.5 to 6 km in the Northern as well the Southern direction which again is a very major shift in this region.




LEGEND :

RIVER COURSE IN 2004 FROM POST-MONSOON COVERAGE

RIVER COURSE IN 2000 FROM POST-MONSOON COVERAGE

RIVER COURSE FROM SOI TOPOMAP (1934-'36)

DIRECTION OF SHIFTING OF THE RIVER

RAILWAY

ROADS

CITIES/TOWNS

Km
10 0 10
1 : 250000

LAT
LONG

3.1 Region in and around Monghyr showing more change

3.2 Region in and around Bhagalpur showing more change

**Fig 5.39: Shifting of the Ganga river course near Monghyr and Bhagalpur on 1:250,000 scale from SOI to 2000 and 2004**

**Changes mapped at 1: 50,000 scale for the year 2006 taking SOI as base reference maps**

**Section 3.1: Regions covering in and around Monghyr**

This region covers an area for a stretch of about 85 km downstream of Begusarai to covering regions around Monghyr.

Comparison of the river course during 1935-'36 (SOI) with post-monsoon IRS-1D satellite data of the year 2000 and IRS-P6 data for years 2004 and 2006 shows that during these years the Ganga river course near Monghyr has shown a very prominent shifting of around 9.7 km towards Northern direction. This is one of the most major shifting throughout the Ganga river course. A new channel taking a meandering pattern and connecting with the main stream has also seemed to have been formed in 2000, 2004 and 2006. Also it has been observed that this shifting was most significant during 2000. Towards the west of Monghyr near Bishunpur the river shows a distinct shift of around 5 km in the Northern direction whereas towards the East of Monghyr near Lohochi the river has shown a shifting in the Southwest direction of about 2-3 km. Thus overall it was seen at different locations that this area has undergone major bank-line changes from about 0.5 to 9 km in pre-monsoon season whereas 0.7 to 9.7 during post-monsoon season mainly in the North and Southwest direction at different locations (ref fig 5.40).

**River section 3.2: regions covering in and around Bhagalpur**

This region covers the area for a stretch of about 70 km downstream of Monghyr covering regions around Bhagalpur. The SOI maps taken for study were of the years 1935-'36, 1969-'72. The flow of the water in this region towards East. Comparison of the river course (ref fig 5.41) during 1935-'36, 1969-'72 (SOI) with post-monsoon IRS-1D satellite data of the

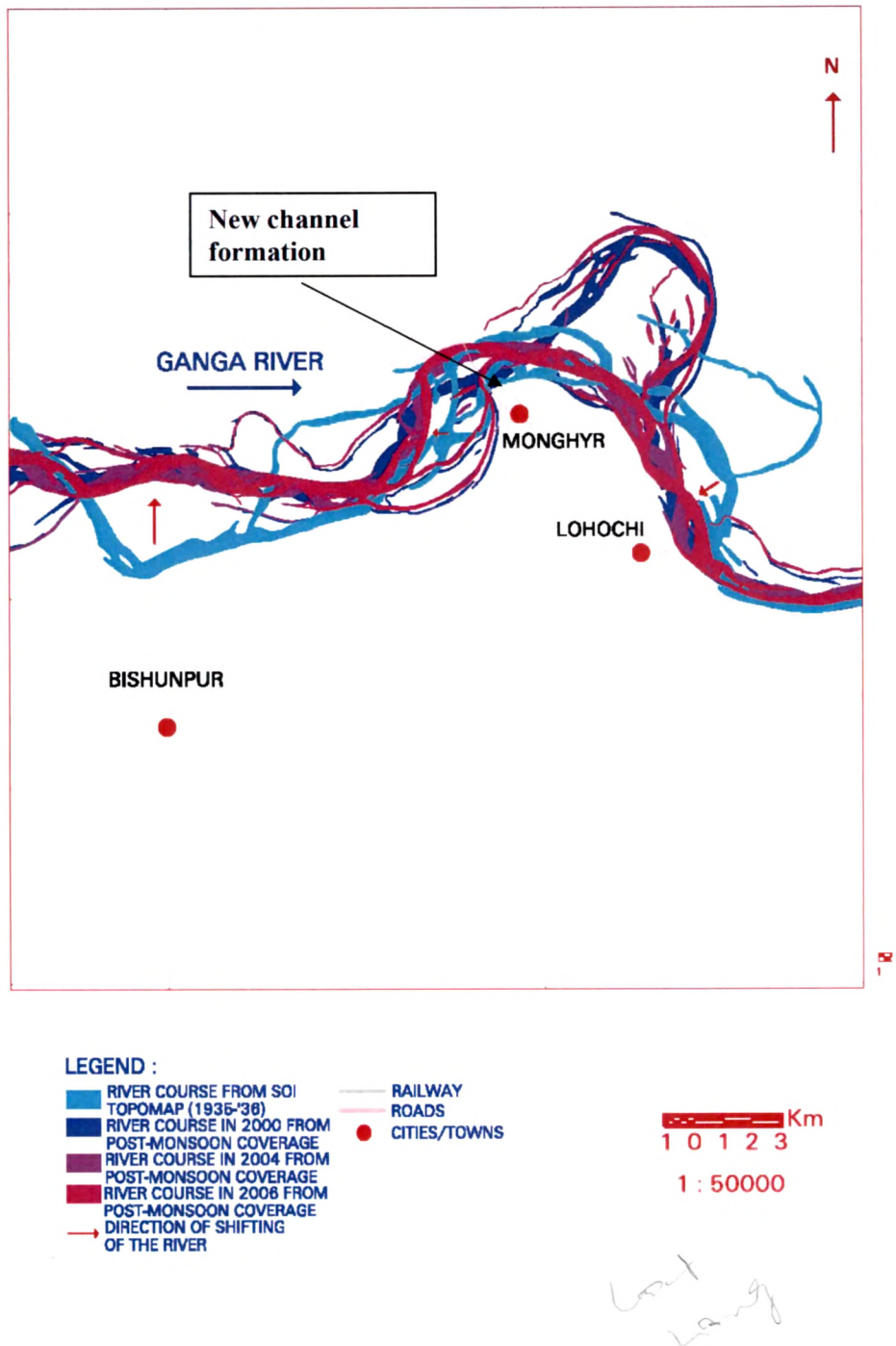



**Fig 5.40: Shifting of the Ganga river course near Sahri on 1:50,000 scale from (SOI) to 2000, 2004 and 2006**

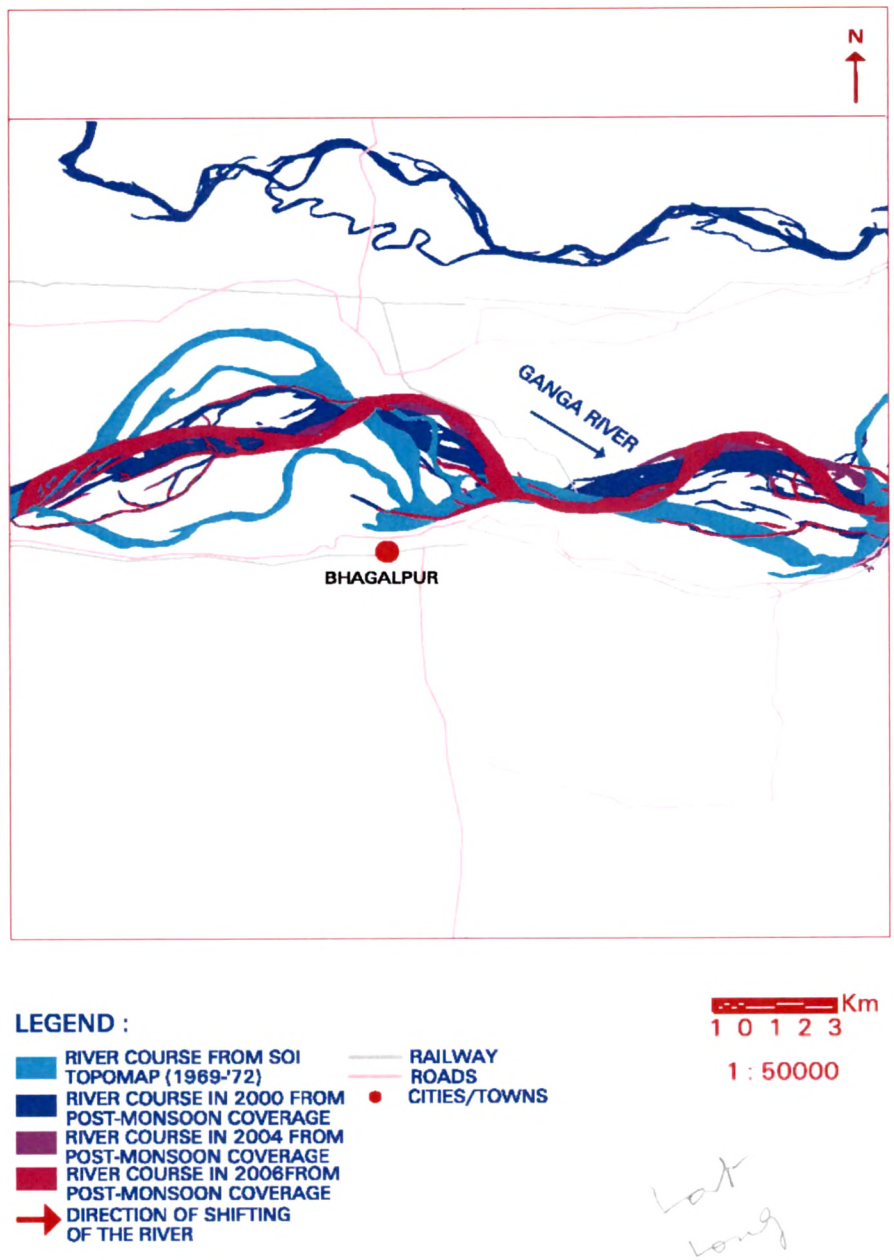



**Fig 5.41: Shifting of the Ganga river course near Sahri on 1:50,000 scale from (SOI) to 2000, 2004 and 2006**

year 2000 and IRS-P6 data for years 2004 and 2006 shows that the regions in and around Bhagalpur have undergone major river changes and the river has shown a prominent shift of about 2 to 6.5 km. The shift direction is towards North and South (ref fig 5.41). From the entire course of study it was observed that during pre-monsoon season the river shifting ranges from 1 to 6 km whereas during post-monsoon season the shifting varies around 2 to 6.5 km. It is observed that the shifting although not very prominent but has also occurred between the years 2000 and 2006 whereas between the years 2000 and 2004 the river more or less shows a parallel flow.

## C2. Estimation of erosion and deposition along both the bank-lines from post-monsoon data

**Changes mapped at 1:250,000 scale for the year 2000 and 2004 taking SOI as base reference maps**

**Section 3: Regions covering in and around Monghyr and Bhagalpur**

In this region the river has suffered excessive erosion as well as deposition on both the banks. Near Begusarai as well as Bishunpur the river has undergone prominent degradation as well as aggradation but the amount of degradation is much higher then aggradation which suggests the widening of the river bed in this region. Towards East around Monghyr the river once again shows prominent erosion as well as deposition but here the amount of deposition is slightly higher than compared to erosion which indicated the shrinking of the river bed. Near Bhagalpur the river shows dominance of aggradation than compared to degradation which once again suggests the shrinking of the river bed. From the comparison of the bank-lines of 1935-'36 and 2004 the prominent shifting of the river banks is also very clearly seen (ref fig 5.42).

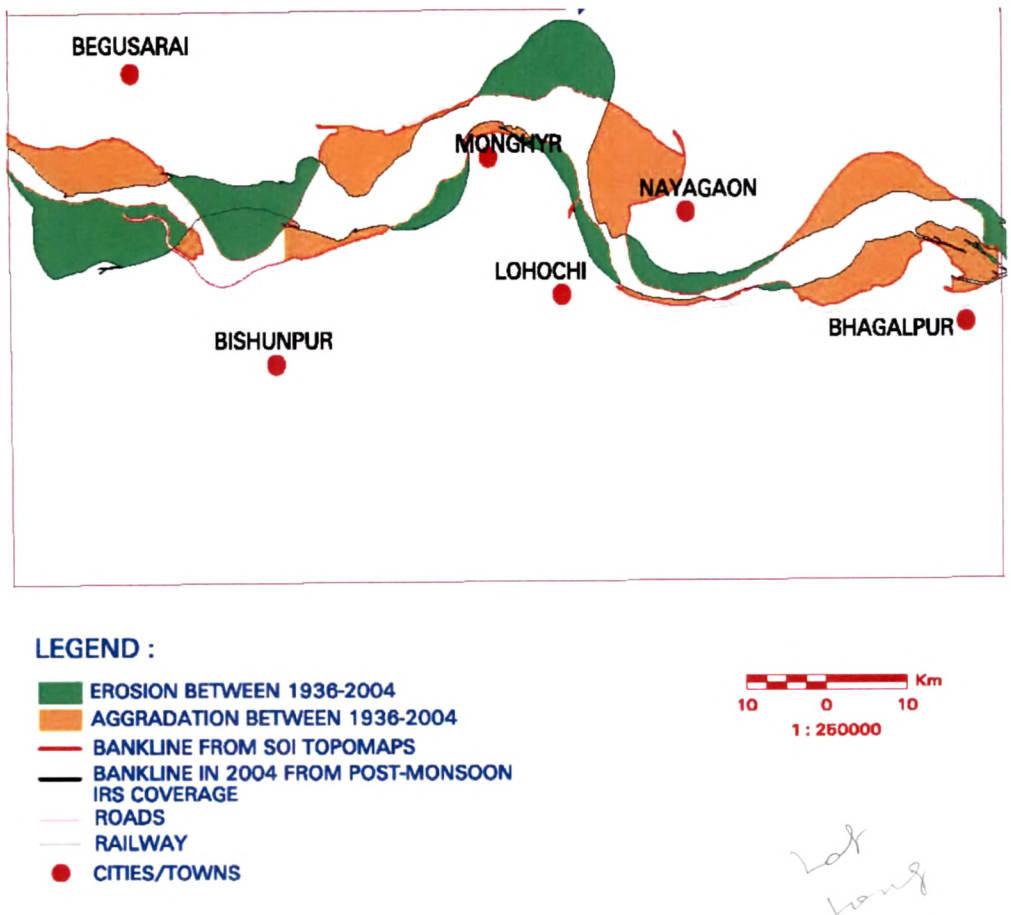



**Fig 5.42: Bankline change and erosion/deposition near Ballia and Rudrapur from on 1:250,000 scale from (SOI) to 2000 and 2004**

**Changes mapped at 1: 50,000 scale for the year 2006 taking SOI as base reference maps**

**Section 3.1: Regions covering in and around Monghyr**

In the regions near Monghyr both the banks have suffered almost equal amount of excessive aggradation as well degradation. There are huge patches of land degradation as well as area which have undergone heavy sedimentation. For erosion and deposition along the Ganga river course from 1935-'36 to 2006 (ref fig 5.43). The amount of erosion and deposition along both the banks of the Ganga river for this selected window was found to be 170.0 and 176.0 sq km respectively ref bar chart 5.5). Almost similar amount of degradation as well as aggradation indicates that at few locations where the amount of erosion is more the river bed must have undergone widening whereas the in the locations where deposition is little higher the shrinking of the river bed must have taken place.

**Section 3.2: Regions covering in and around Bhagalpur**

For erosion and deposition along the Ganga river course from 1935-'36, 1969-'72 to 2006 (ref fig 5.44). From the map it is seen that the Ganga river course in this region has undergone excessive aggradation than compared to degradation. Amount of degradation is very negligible as compared to aggradation. Near Bhagalpur and towards the East of Bhagalpur the region shows degradation along the Northern bank but the rest of the area shows aggradation and no degradation. Also the amount of degradation is very negligible on the southern bank than compared to the Northern bank. The amount of erosion and deposition along both the banks of the Ganga river for this selected window was found to be 60.0 and 162.0 sq km respectively (ref bar chart 5.6). Dominance of aggradation in this region suggests shrinking of the river bed.

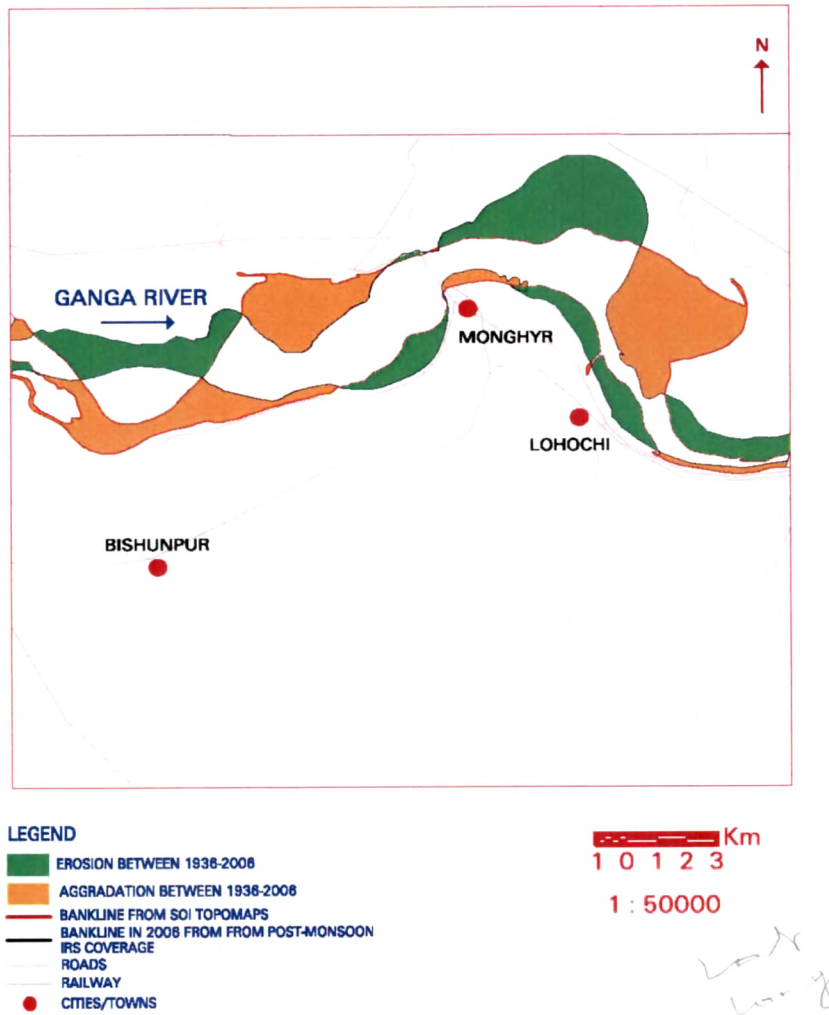
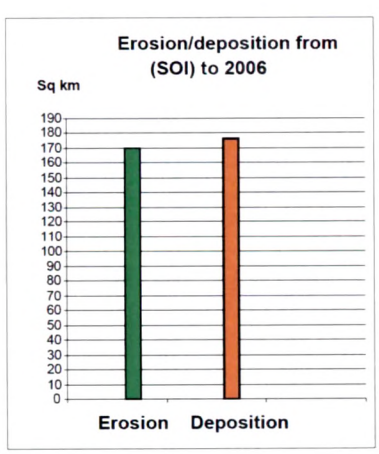



**Fig 5.43: Bankline change and erosion/deposition near Monghyr on 1:50,000 scale from (SOI) to 2006**




**Bar chart 5.5: Erosion and deposition along both the banks of the Ganga river near Monghyr**

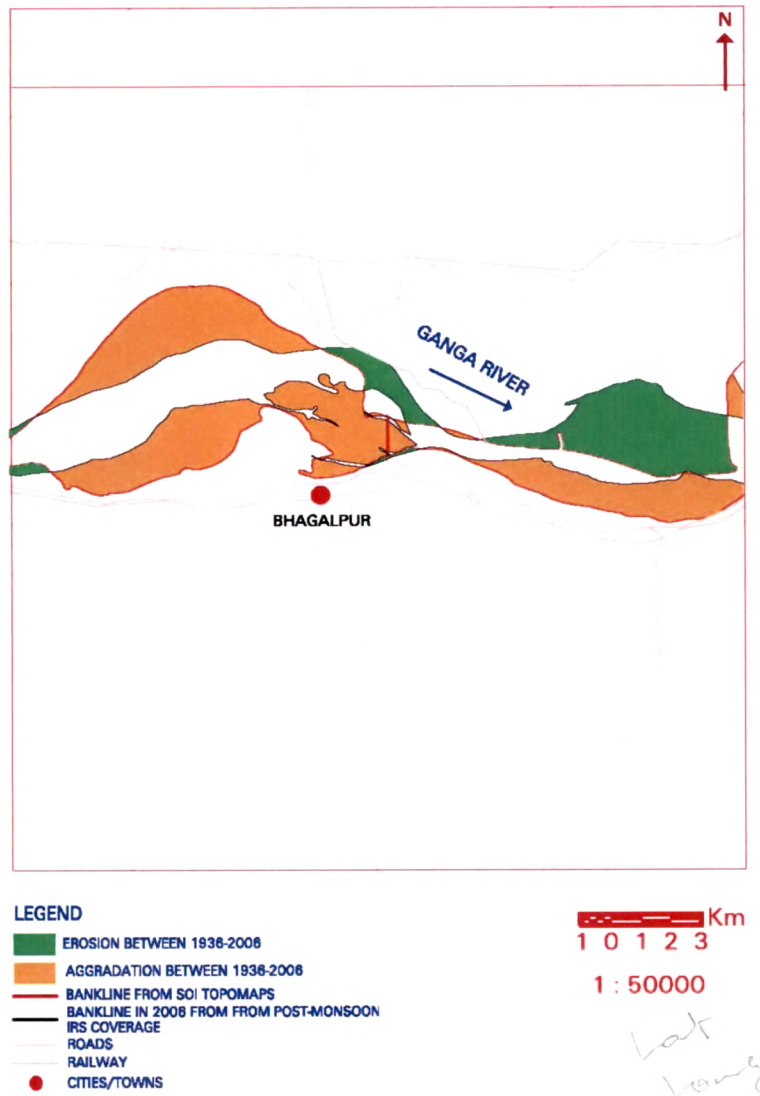
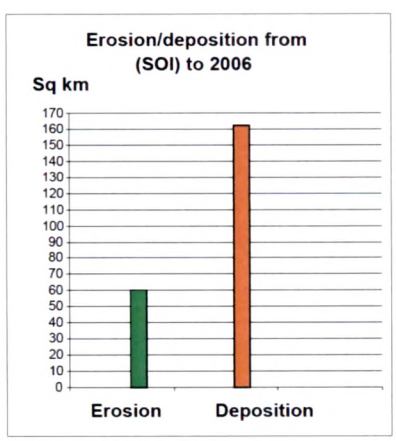



**Fig 5.44: Bankline change and erosion/deposition near Bhagalpur on 1:50,000 scale from (SOI) to 2006**




**Bar chart 5.6: Erosion and deposition along both the banks of the Ganga river near Bhagalpur**

## C3. Fluvio-geomorphological changes as depicted from pre-monsoon and post-monsoon data

**Changes mapped at 1:250,000 scale for the year 2000 and 2004 taking SOI as base reference maps**

**Section 1: Regions covering in and around Monghyr and Bhagalpur**

River in this region shows presence of various fluvial features such as ox-bow lakes, water-bodies, sand-bars, river-island, island with vegetation, cut-off meander and huge flood-plain. Presence of ox-bow lakes near Nayagaon indicates the remnants of the old Ganga river course. Also the region shows prominent presence of numerous water-bodies especially in the Northern direction which also suggests the old course of the Ganga river. The river in this region throughout its course shows distinct braiding pattern at various locations. Near Bhagalpur the braided pattern is seen clearly during 1935-`36 (ref fig 5.45 to 5.49) but this pattern is less distinct during 2000 and 2004. Near Monghyr it river shows very distinct typical meandering pattern which is one of the most significantly seen pattern not only in this region but throughout the whole Ganga river course in Bihar. Similar prominent meandering was also seen near Rudrapur. The meandering pattern near Monghyr is much more distinct in 2000 than compared to 2004 because the main river channel in 2004 shows a cut-off whereas during 2000 it was flowing as a continuous river channel making it more distinct. Regarding the other fluvial parameters it was observed that the length of the river bank is around 160 km. The surface water area show a very significant increase in 2000 post-monsoon season than compared to pre-monsoon data and similar trend is also seen in 2004. Also, the surface water area has increased in 2004 post-monsoon season than compared to that in 2000. Area of sand-bars have shown a very significant decrease in 2004 pre-monsoon as well as post-monsoon season than compared to 2000 pre-and

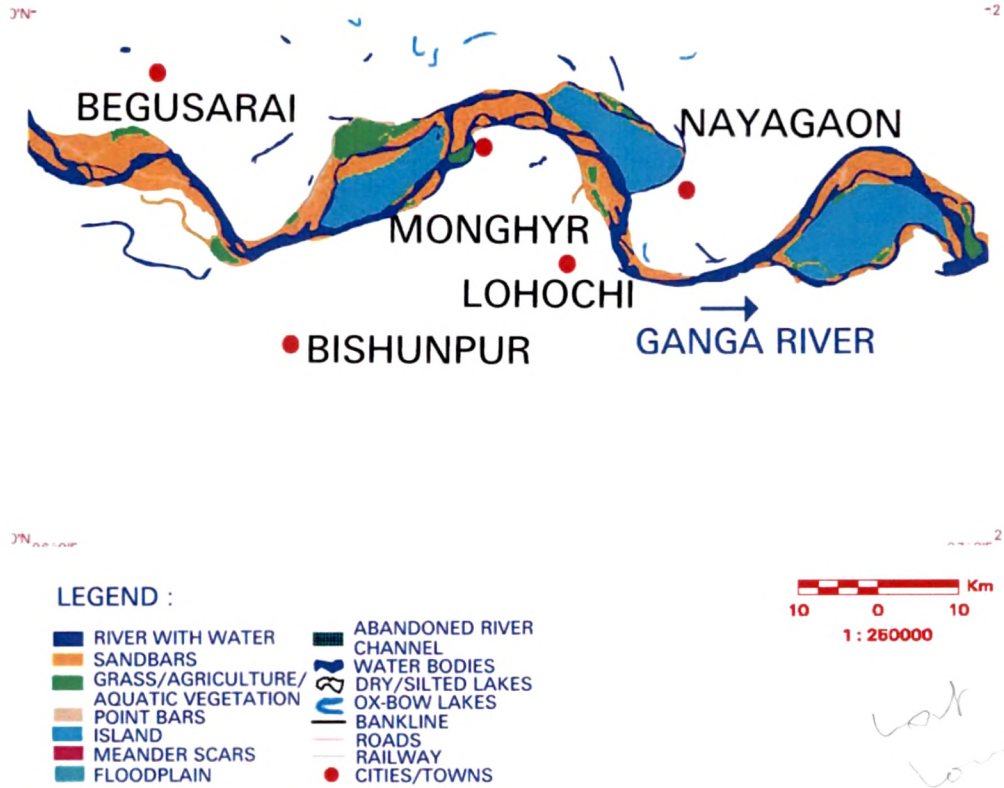



**Fig 5.45: Fluvio-geomorphology of the Ganga river near Ballia and Rudrapur on 1:250,000 scale from SOI maps**


**Fig 5.46: Fluvio-geomorphology of the Ganga river near Monghyr and Bhagalpur on 1:250,000 scale from IRS 1D pre-monsoon data-2000**

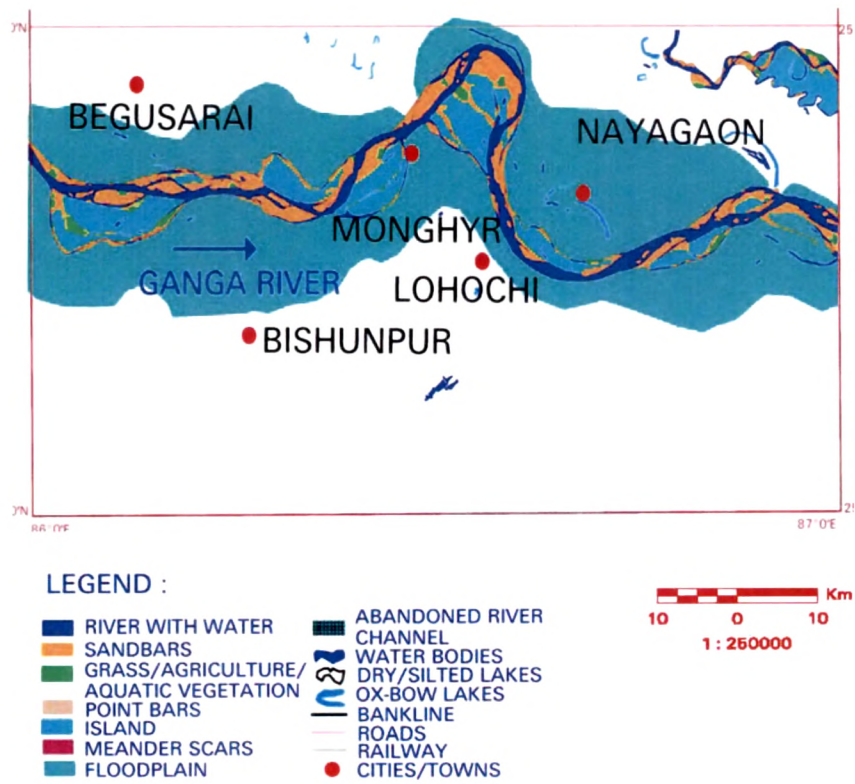



**Fig 5.47: Fluvio-geomorphology of the Ganga river near Monghyr and Bhagalpur on 1:250,000 scale from IRS 1D post-monsoon data-2000**

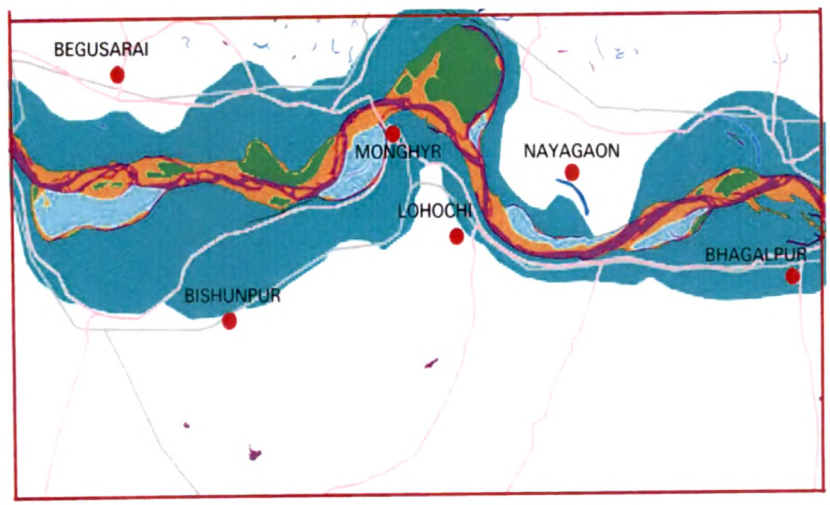



**Fig 5.48: Fluvio-geomorphology of the Ganga river near Monghyr and Bhagalpur on 1:250,000 scale from IRS P6 pre-monsoon data-2004**

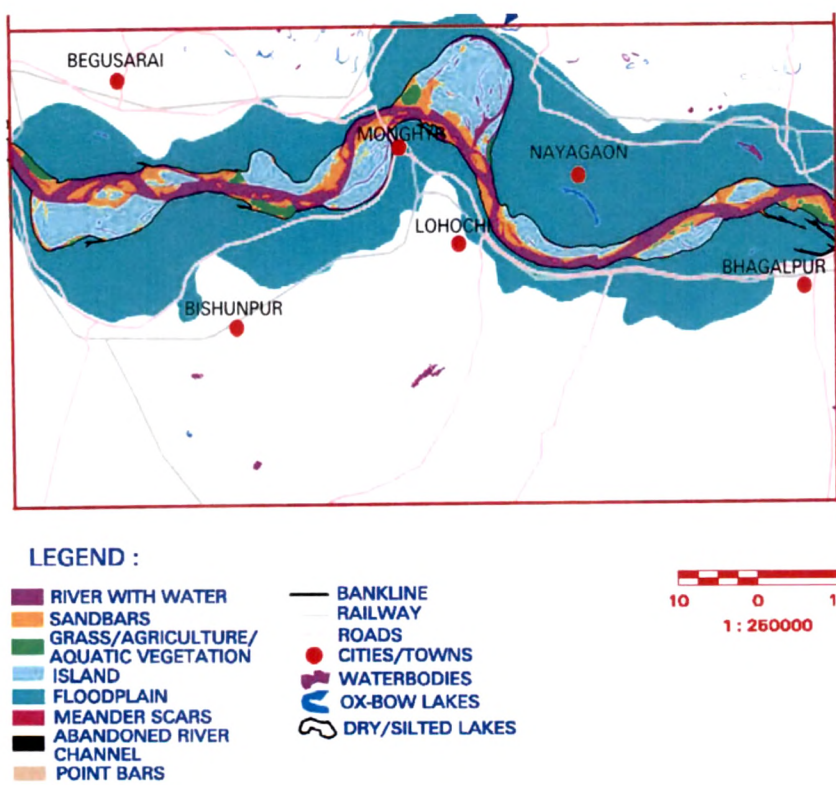



**Fig 5.49: Fluvio-geomorphology of the Ganga river near Monghyr and Bhagalpur on 1:250,000 scale from IRS P6 post-monsoon data-2004**

post-monsoon data. This region has one of the widest flood-plains throughout the Ganga river course which indicates that this region is under frequent inundation during the monsoon season. In 2004 there is a significant increase in the flood-plain area in both pre-monsoon as well as post-monsoon seasons than compared to 2000. Width of the river channel has also shown a marginal increase in 2004 pre-monsoon and post-monsoon data than compared to 2000 pre-monsoon and post-monsoon season data. Area of island show a very drastic increase during the post-monsoon seasons of both the years and also this area are much higher in post-monsoon season of 2004 than compared to 2000 post-monsoon data. The sudden increase in the area of islands suggests the reactivation of many connecting smaller and bigger streams during the monsoon season which generally are in a complete or partial dried state (ref table 5.7).

**Changes mapped at 1: 50,000 scale for the year 2006 taking SOI as base reference maps**

**Section 3.1: Regions covering in and around Monghyr**

As seen from the comparative figures various fluvial features namely river with water, sand-bars, flood-plain, water-bodies, meander scars, river islands and grass/agriculture/aquatic vegetation have been interpreted from the post-monsoon IRS satellite images. The Northern bank of the Ganga river near Monghyr shows a very sharp meandering pattern. The river during its course also shows a typical braided pattern. Presence of large number of water-bodies and ox-bow lakes on the northern bank suggests the remnants of the old Ganga river course. Comparison of various fluvial parameters between the pre-monsoon and post-monsoon data of 2006 in this region shows that the length of the river bank is around 85 km. Surface water area has also considerably increased in post-monsoon then in pre-monsoon. Area of island is also increased to a noticeable extent whereas the area of sand-bars have decreased

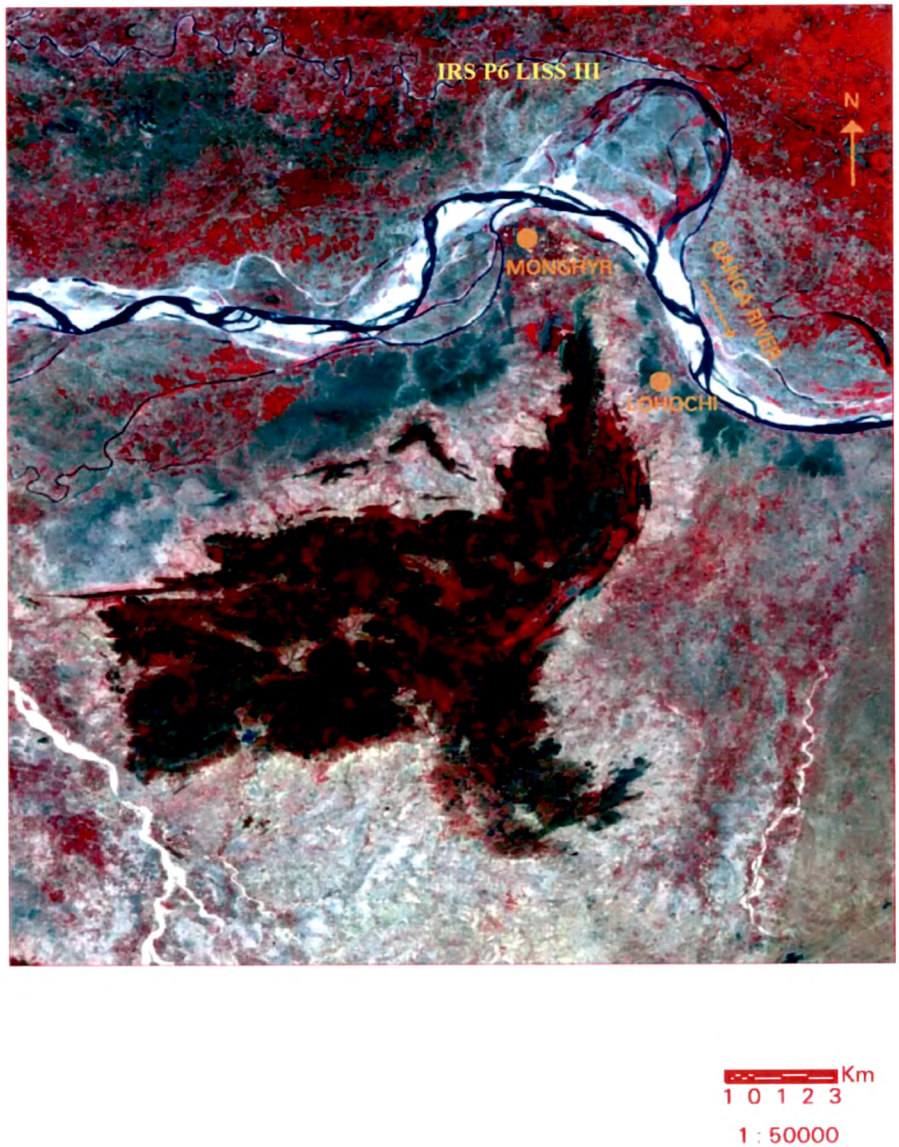



**Fig 5.50: Pre-monsoon satellite image showing Ganga river course near Monghyr in 2006**

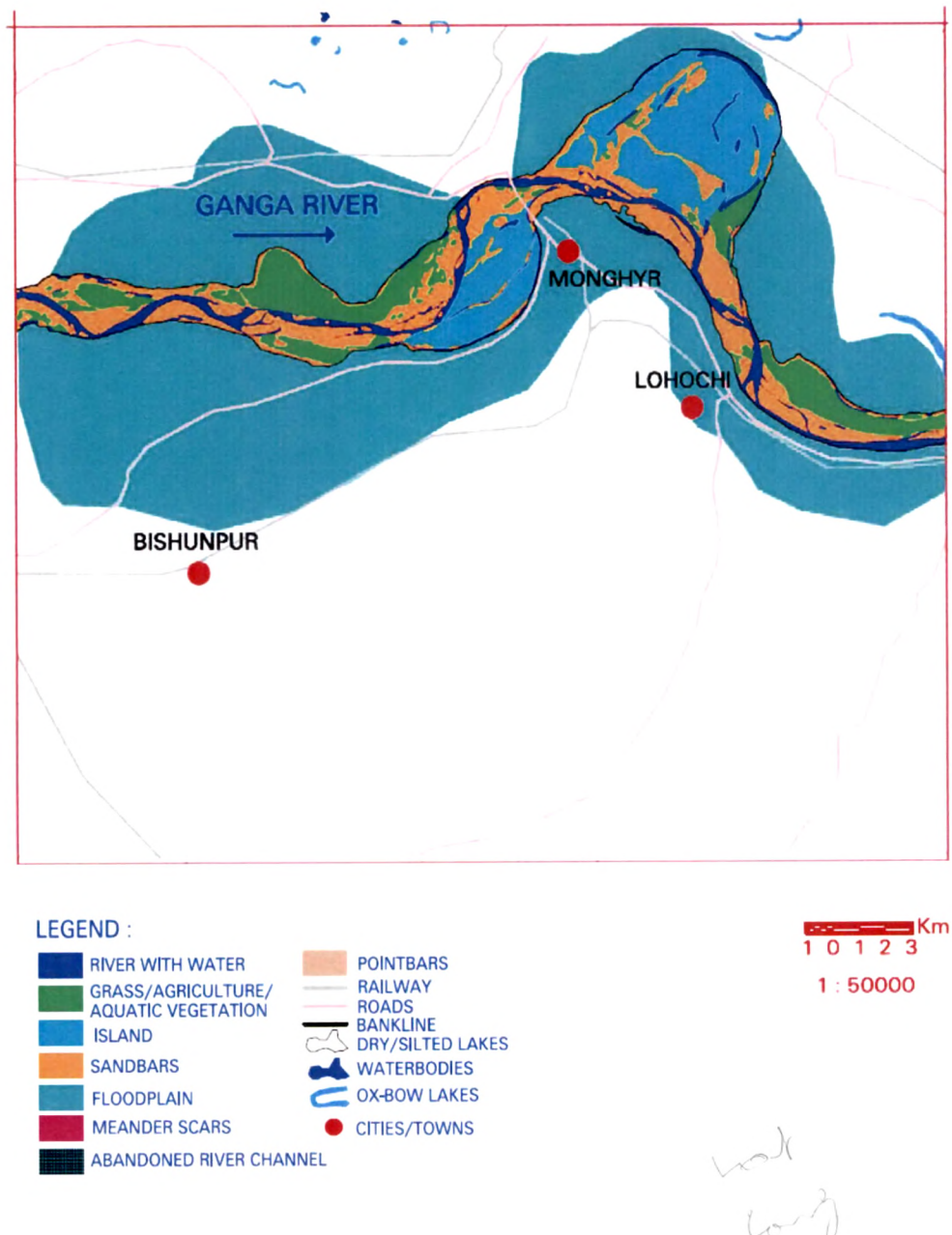



**Fig 5.51: Fluvio-geomorphology of the Ganga river near Monghyr from IRS P6 pre-monsoon data of 2006**

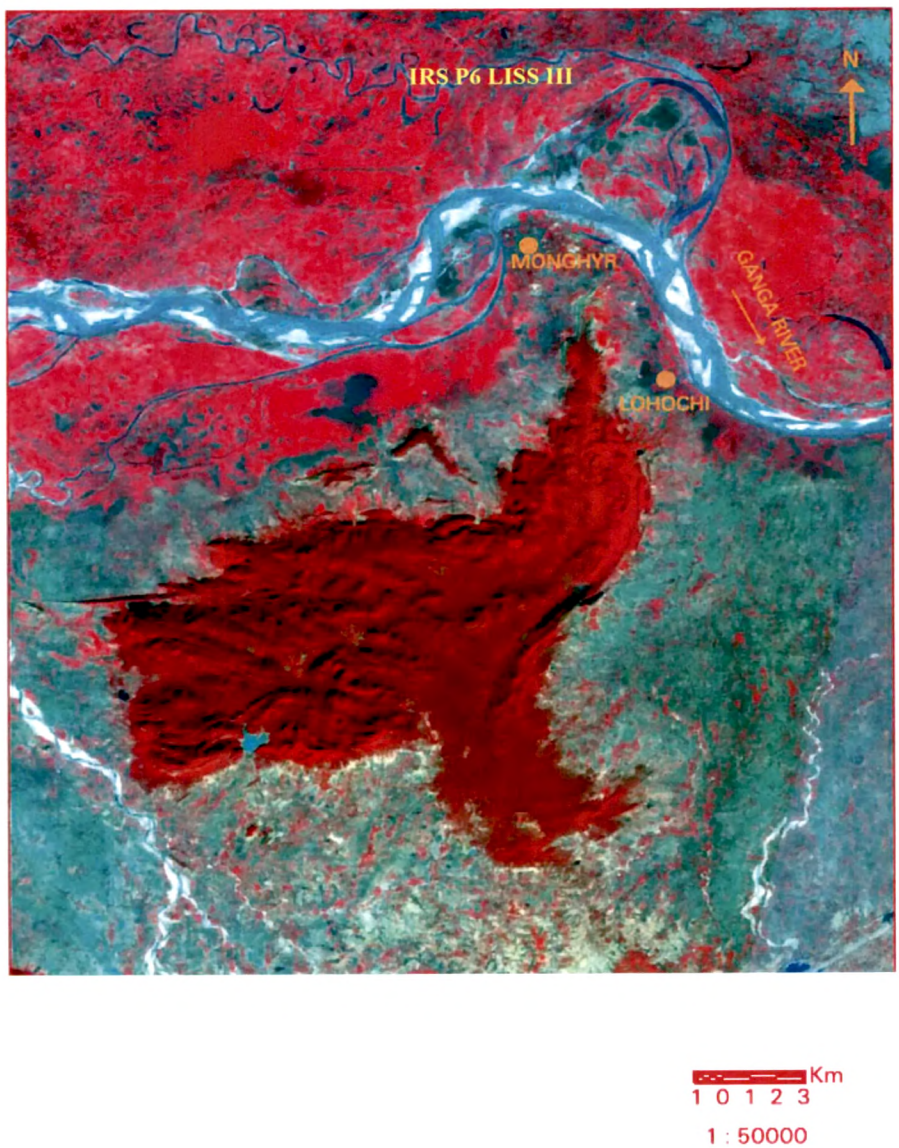



**Fig 5.52: Post-monsoon satellite image showing Ganga river course near Monghyr in 2006**

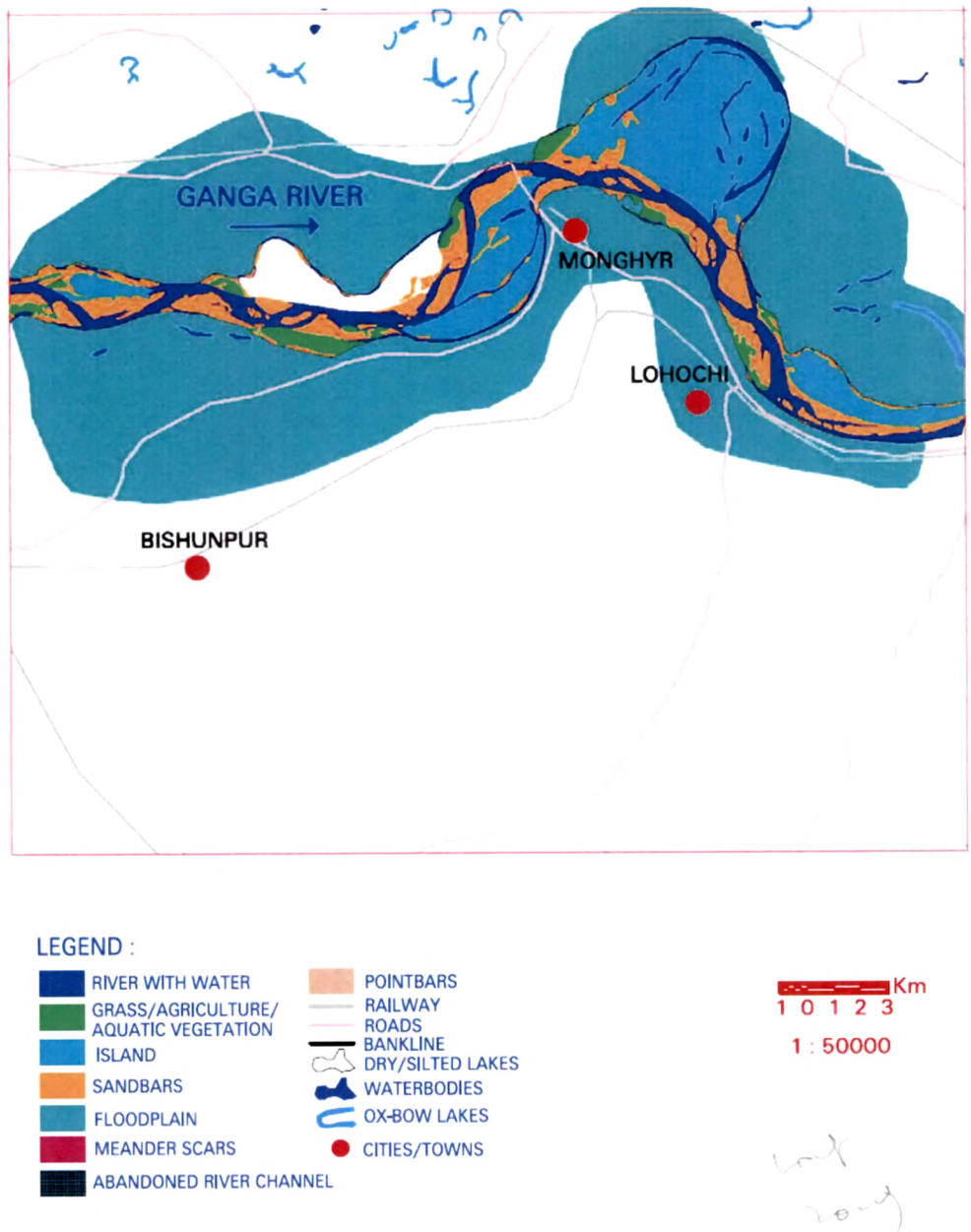



**Fig 5.53: Fluvio-geomorphology of the Ganga river near Monghyr from IRS P6 post-monsoon data of 2006**

considerably in post-monsoon as compared with pre-monsoon IRS satellite data. Area of island in post-monsoon shows a considerable increase then in pre-monsoon season which may be because of the reactivation of many minor as well as major tributaries and streams. Also the flood-plain area shows a significant increase in post-monsoon season which may be because of large amount of inundation due to rainfall. The sand-bars have shown a significant decrease during the post-monsoon season than compared to the pre-monsoon data and the width of the river has almost remained the same during both the seasons (ref table 5.8).

**Section 3.2: Regions covering in and around Bhagalpur**

Fluvial geomorphological features namely river with water, sand-bars, flood-plain, water-bodies, meander scars, ox-bow lakes, river islands etc have been interpreted from the post-monsoon IRS satellite images. The sandbars are mainly composed of sand/silt. In this region, the river throughout its course shows a distinct braided pattern. The length of the river bank is around 71.5 km. Surface water area is also considerably more in post-monsoon then in pre-monsoon. Area of island (ref plate 5.10) has increased to a noticeable extent in post-monsoon then compared to pre-monsoon whereas the area of sand-bars has decreased to a significant extent in post-monsoon as compared with pre-monsoon IRS satellite data. Area of flood-plain has also increased noticeably during the post-monsoon season than compared to the pre-monsoon season. Braiding pattern is very clearly seen in this region. Width of the river is almost constant during both the seasons (refer fig 5.54 to 5.57, plate 5.11 and table 5.9).

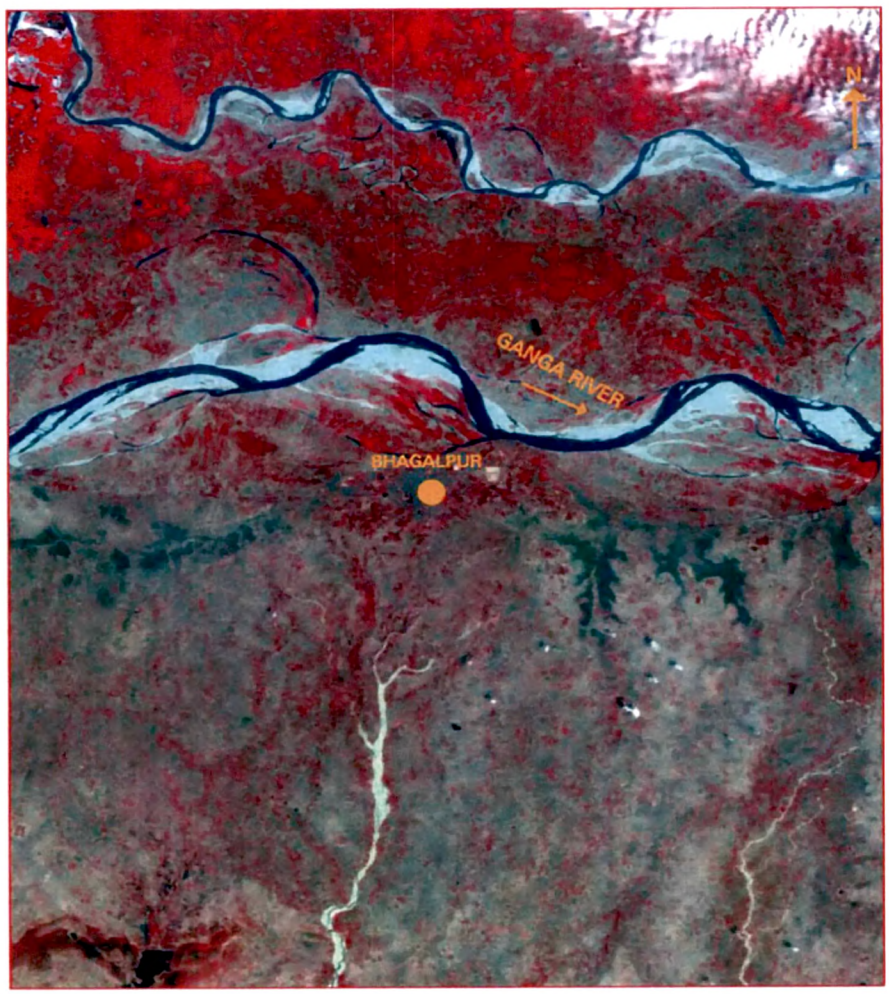



**Fig 5.54: Pre-monsoon satellite image showing Ganga river course near Bhagalpur in 2006**

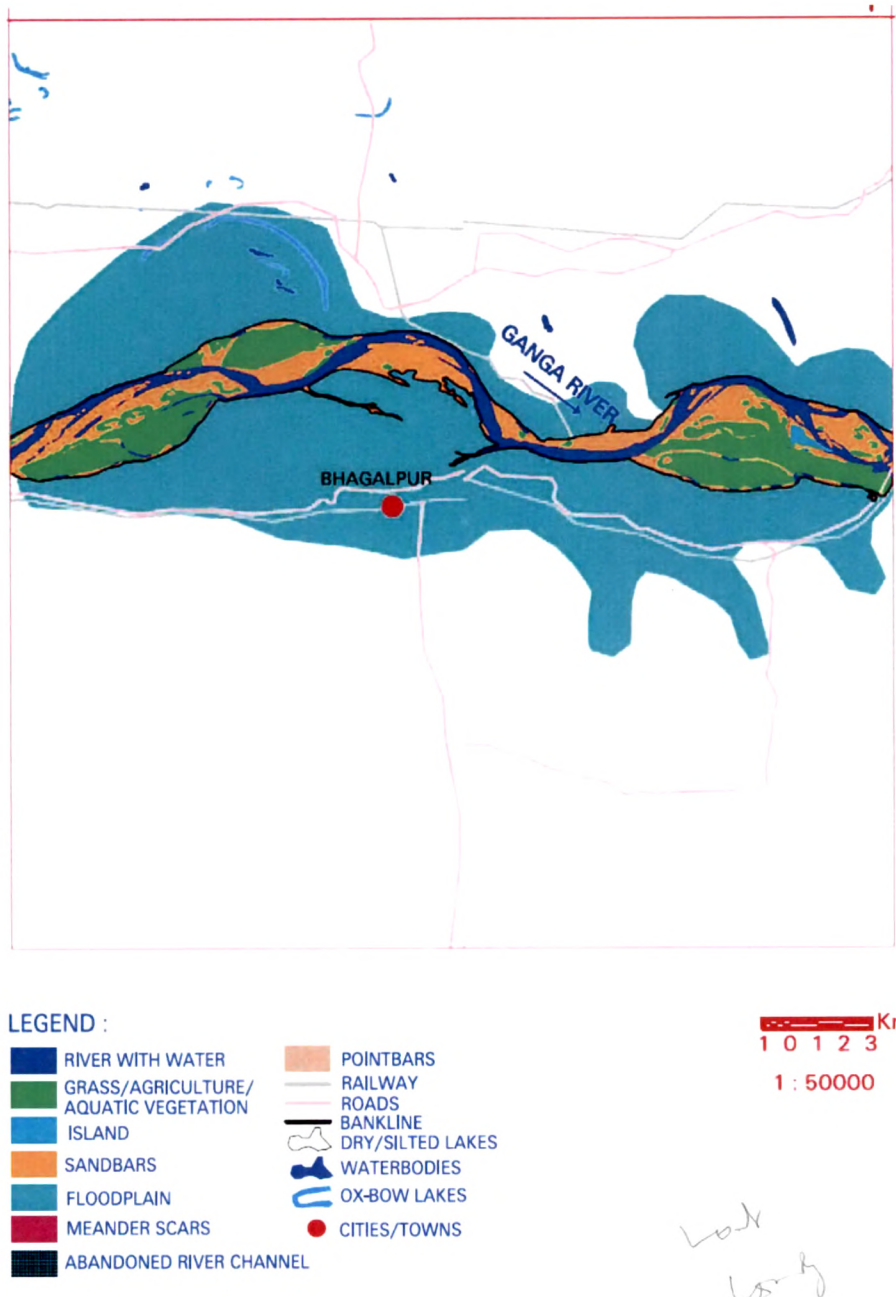



**Fig 5.55: Fluvio-geomorphology of the Ganga river near Bhagalpur from IRS P6 pre-monsoon data of 2006**

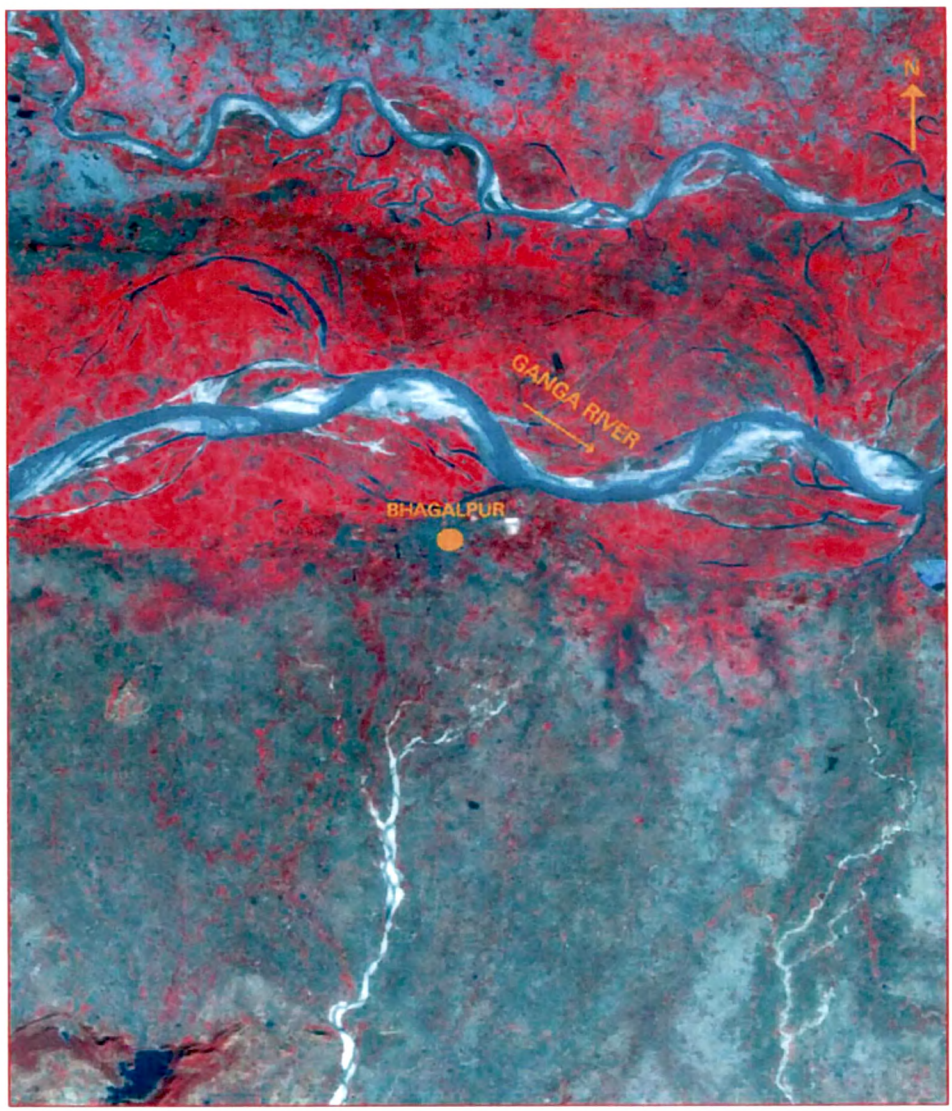



**Fig 5.56: Post-monsoon satellite image showing Ganga river course near Bhagalpur in 2006**

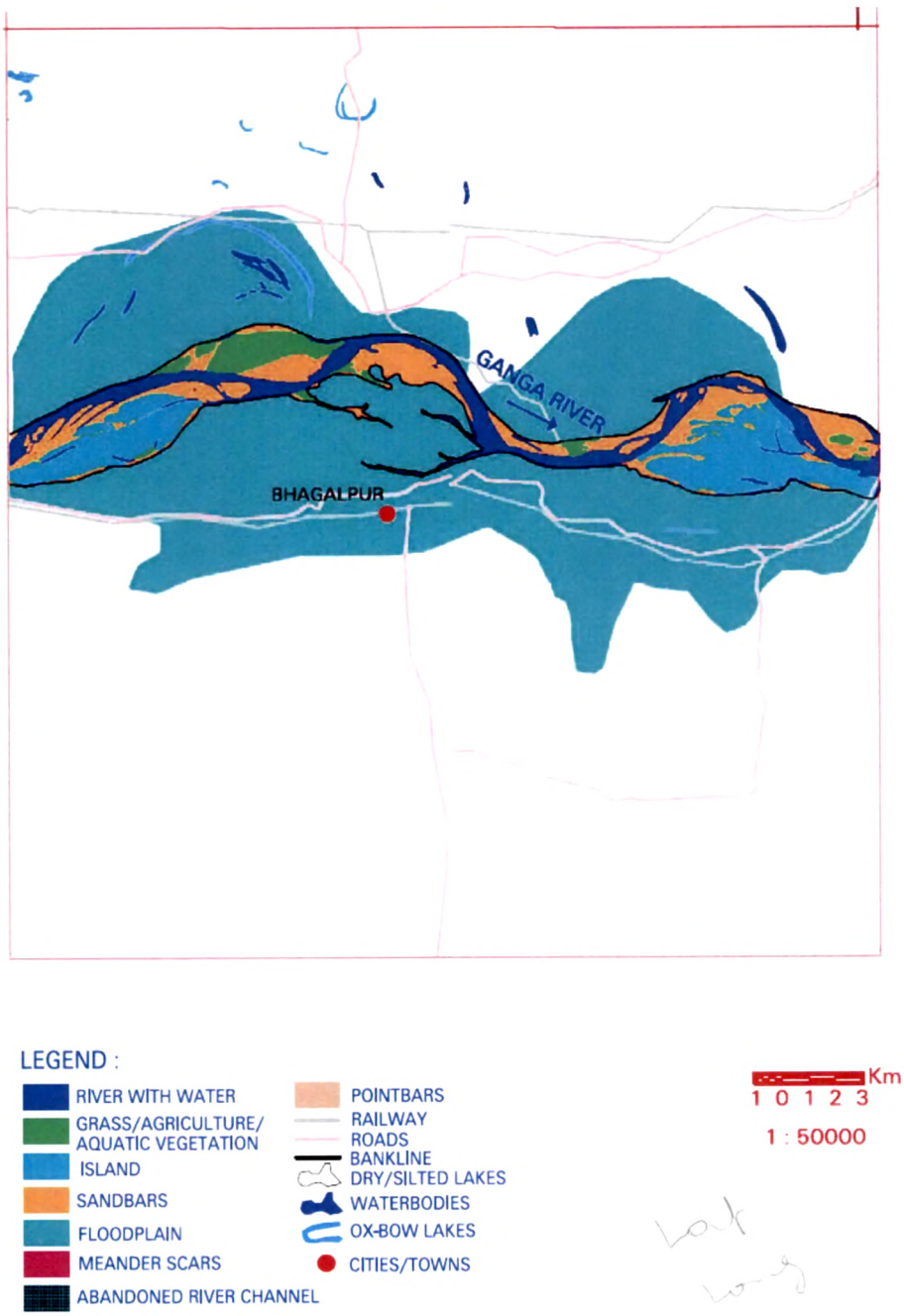



**Fig 5.57: Fluvio-geomorphology of the Ganga river near Bhagalpur from IRS P6 post-monsoon data of 2006**

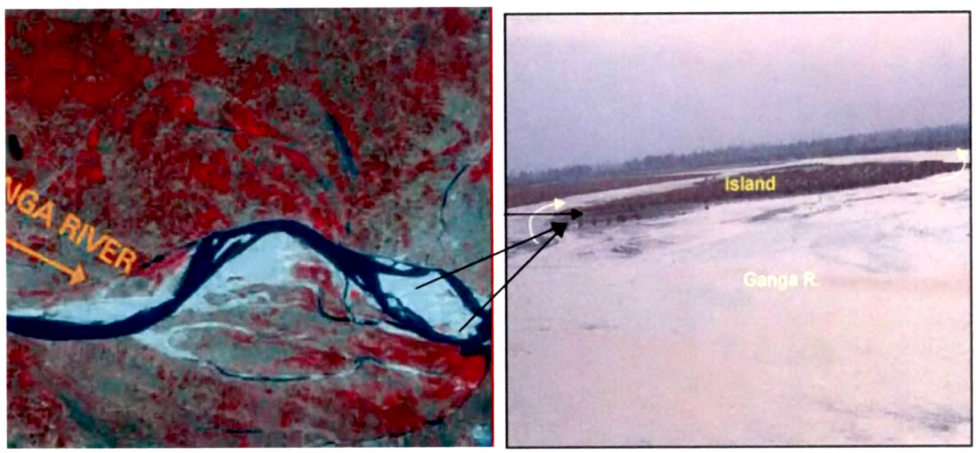



**Plate 5.10: IRS FCC image / field photograph showing river-island near Bhagalpur**

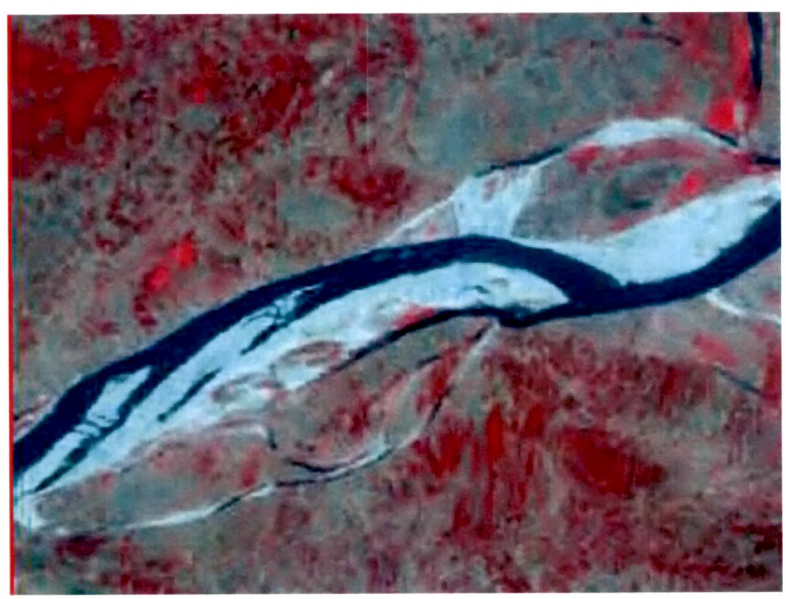


**Plate 5.11: IRS FCC image showing braided river pattern**

**Table 5.7: Salient features regarding the various fluvio-geomorphological changes using IRS 1D LISS III and IRS-P6 LISS III pre-monsoon and post-monsoon satellite data for the years 2000 and 2004 on 1:250,000 scale covering regions in and around Monghyr and Bhagalpur**

| Sr no | Features (Regions covering Monghyr and Bhagalpur) | Observations from pre-monsoon satellite data | | Observations from post-monsoon satellite data | |
|---|---|---|---|---|---|
| | | 2000 Pre-monsoon data | 2000 Post-monsoon data | 2004 pre-monsoon data | 2004 post-monsoon data |
| 1 | Geomorphological features | River with water, sandbars, island, agriculture, water bodies, flood plain, ox-bow lakes | | River with water, sandbars, island, agriculture, water bodies, flood plain, ox-bow lakes | |
| 2 | River pattern | Braided and complex asymmetrical meandering | | River course divided into number of branches to form braided pattern, meandering pattern also seen very distinctly | |
| 3 | Shifting of the river channel | Distinct and Shifting of the river up to 0.5-7.5 km near Monghyr and 1-5.9 km near Bhagalpur | | Shifting of the river around 0.5-9 km near Monghyr and 1.5 to 6 km near Bhagalpur | |
| 4 | Length of the river bank | 160 km | | | |
| 5 | Surface water area of the river | 131.00 sq km | 187.00 sq km | 130.00 sq km | 193.00 sq km |
| 6 | Area of the sandbars | 222.00 sq km | 177.00 sq km | 202.00 sq km | 115.00 sq km |
| 7 | Area of the flood plain | 1075.00 sq km | 1502.00 sq km | 1211.00 sq km | 1514.00 sq km |
| 8 | Width of the river | From 1.5 km to 12.00 km | From 2.00 km to 12.00 km | From 1.6 km to 13.1km | From 2.1 km to 13.00 km |
| 9 | Area of the island | 75.00 sq km | 187.00 sq km | 126.00 sq km | 253.00 sq km |

**Table 5.8: Salient features regarding the various fluvio-geomorphological changes using IRS P6 LISS III pre-monsoon and post-monsoon satellite data for the year 2006 on 1: 50,000 scale covering regions in and around Monghyr**

| Sr. No. | Features (regions covering Monghyr) | Observations near Monghyr from 2006 pre-monsoon satellite data | Observations near Monghyr from 2006 post-monsoon satellite data |
|---|---|---|---|
| 1 | Geomorphological features | River with water, sandbars, island, grass/agriculture, water-bodies, floodplain, ox-bow lakes | River with water, sandbars, island, grass/agriculture, water-bodies, floodplain, ox-bow lakes |
| 2 | River pattern | Distinct braided as well as sharp meandering pattern is seen | Distinct braided as well as sharp meandering pattern is seen |
| 3 | Shifting of the river channel | Very distinct Shifting is towards N or SW about 0.5 to 9 km | Shifting of the river mainly towards N and SW about 0.7 to 9.7 km |
| 4 | Length of the river bank | 85 km | |
| 5 | Surface water area of the river | 61.00 sq km | 89.00 sq km |
| 6 | Area of the sandbars | 118.00 sq km | 78.00 sq km |
| 7 | Area of the floodplain | 768.00. sq km | 792.00. sq km |
| 8 | Width of the river | From 2.0 km to 12.6 km | From 1.8 km to 12.5 km |
| 9 | Area of the island | 111.00 sq km | 177.00 sq km |

**Table 5.9: Salient features regarding the various fluvio-geomorphological changes using IRS P6 LISS III pre-monsoon and post-monsoon satellite data for the year 2006 on 1: 50,000 scale covering regions in and around Bhagalpur**

| Sr. No. | Features (regions covering Bhagalpur) | Observations near Bhagalpur from 2006 pre-monsoon satellite data | Observations near Bhagalpur from 2006 post-monsoon satellite data |
|---|---|---|---|
| 1 | Geomorphological features | River with water, sandbars, island, grass/agriculture, water-bodies, floodplain, ox-bow lakes | River with water, sandbars, island, grass/agriculture, water-bodies, floodplain, ox-bow lakes |
| 2 | River pattern | Complex, asymmetrical and braided | Complex, asymmetrical and braided |
| 3 | Shifting of the river channel | Very distinct Shifting is towards N or S about 1 to 6 km | Shifting of the river mainly towards N or S about 2 to 6.5 km |
| 4 | Length of the river bank | 70 km | |
| 5 | Surface water area of the river | 46.00 sq km | 58.00 sq km |
| 6 | Area of the sandbars | 68.00 sq km | 53.00 sq km |
| 7 | Area of the floodplain | 513.00. sq km | 546.00. sq km |
| 8 | Width of the river | From 0.7 km to 6.8 km | From 1.00 km to 7.00 km |
| 9 | Area of the island | 50.00 sq km | 56.00 sq km |

## D1. Shifting of the river course

**Changes mapped at 1:250,000 scale for the year 2000 and 2004 taking SOI as base reference maps**

**Section 4: Regions covering in and around Sahibganj**

The SOI topographical maps covering this river section were between the year 1969-'72. This region comprises of the area covering from Bhagalpur up to regions around Sahibganj.

Regarding the shifting of the river courses since 1969-'72 to 2004 it has been observed that this region does not show any major or distinct river shifting. The river course since these years has hardly undergone any major changes. Only towards the West of Sahibganj the region shows distinct shifting which is about 1 to 4 km in the Northern direction in pre-monsoon and around 2-5 km during post-monsoon season. Apart from this nowhere distinct shifting is seen (ref fig 5.58). The course of the river is almost parallel throughout the region. Here one striking feature is the roughly straight course of the river channel. This pattern is not seen throughout the region but at few locations towards the East of Sahibganj.

**Changes mapped at 1: 50,000 scale for the year 2006 taking SOI as base reference maps**

**Section 4.1: Regions covering in and around Sahibganj**

The flow of the water in this region towards east and then towards south-east direction. Comparison of the river course during 1969-'72 (SOI) with post-monsoon IRS-1D satellite data of the year 2000 and IRS-P6 data for years 2004 and 2006 shows a major shift of about 0.8 to 6.2 km and the shift direction is mainly towards North and South. This shift is actually towards the east of Bhagalpur and West of Sahibganj. But if we see near Sahibganj there is no major shifting during these many years. Throughout the

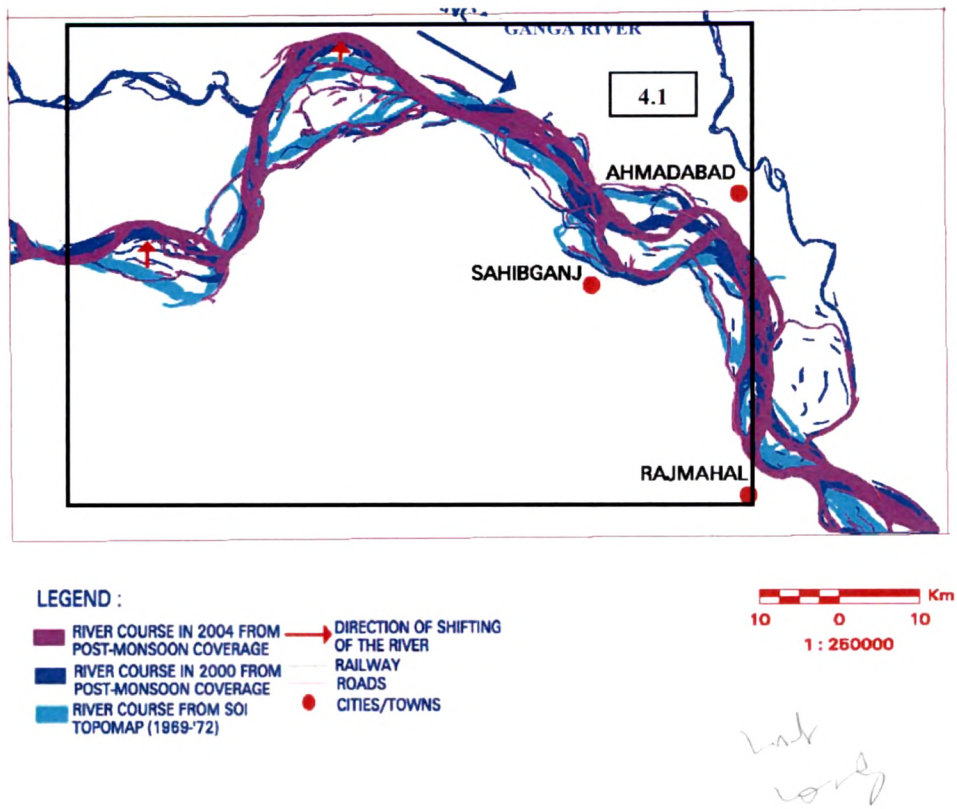



**Fig 5.58: Shifting of the Ganga river course near Monghyr and Bhagalpur on 1:250,000 scale from SOI to 2000 and 2004**

| | |
|---|---|
| 4.1 | Regions in and around Sahibgang |

region the river course shows very minor shifting. In this region the river shows a typical straight pattern near Sahibganj and also a very sharp meandering pattern which suggest that the river may be controlled by some basement structure due to which there are very minor shifting changes here (ref fig 5.59).

## D2. Estimation of erosion and deposition along both the bank-lines from post-monsoon data

**Changes mapped at 1:250,000 scale for the year 2000 and 2004 taking SOI as base reference maps**

**Section 4: Regions covering in and around Sahibganj**

From the (fig 5.60) it is very well seen that both the banks in this region have undergone very high rate of degradation than compared to aggradation. Again the rate of degradation is much more on the Northern bank than compared to the Southern bank. The Southern bank the does show some amount of aggradation but it is very less if we compare it with the amount of degradation it has undergone. Dominance of degradation indicates the widening of the river bed in this region.

**Changes mapped at 1: 50,000 scale for the year 2006 taking SOI as base reference maps**

**Section 4.1: Regions covering in and around Sahibganj**

For the amount of erosion and deposition along the Ganga river course from 1969-'72 to 2006 in this region (ref bar chart 5.7). The amount of erosion and deposition along both the banks of the Ganga river for this area was found to be 174.0 and 80.0 sq km respectively. In this region the amount of degradation is more compared to aggradation which suggests widening of the river bed (refer fig 5.61).

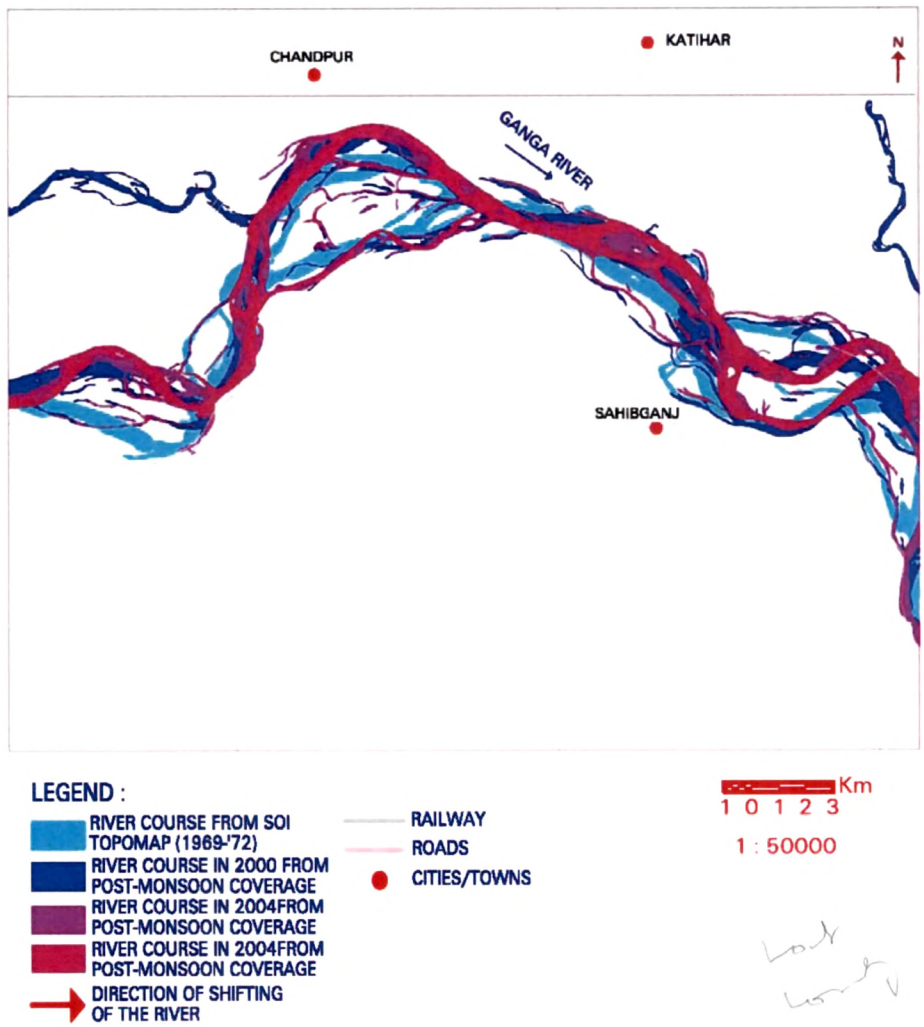



**Fig 5.59: Shifting of the Ganga river course near Sahibganj on 1:50,000 scale from (SOI) to 2000, 2004 and 2006**

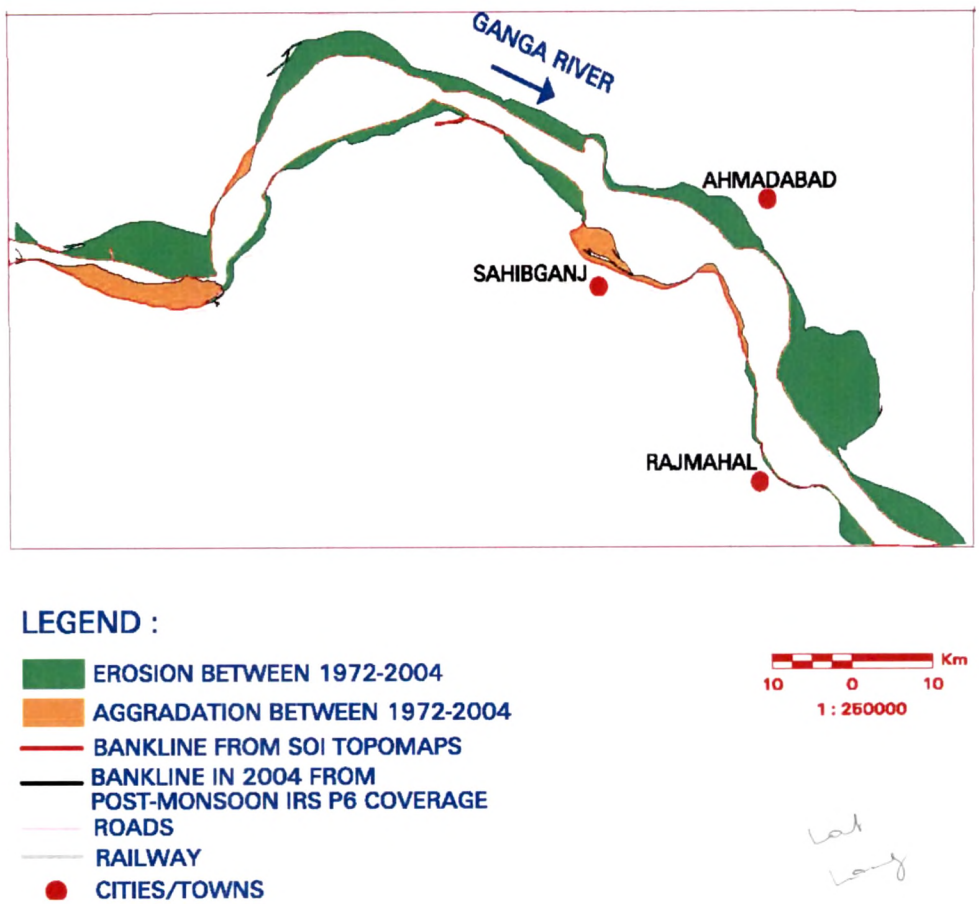



**Fig 5.60: Bankline change and erosion/deposition near Sahibganj from on 1:250,000 scale from (SOI) to 2000 and 2004**

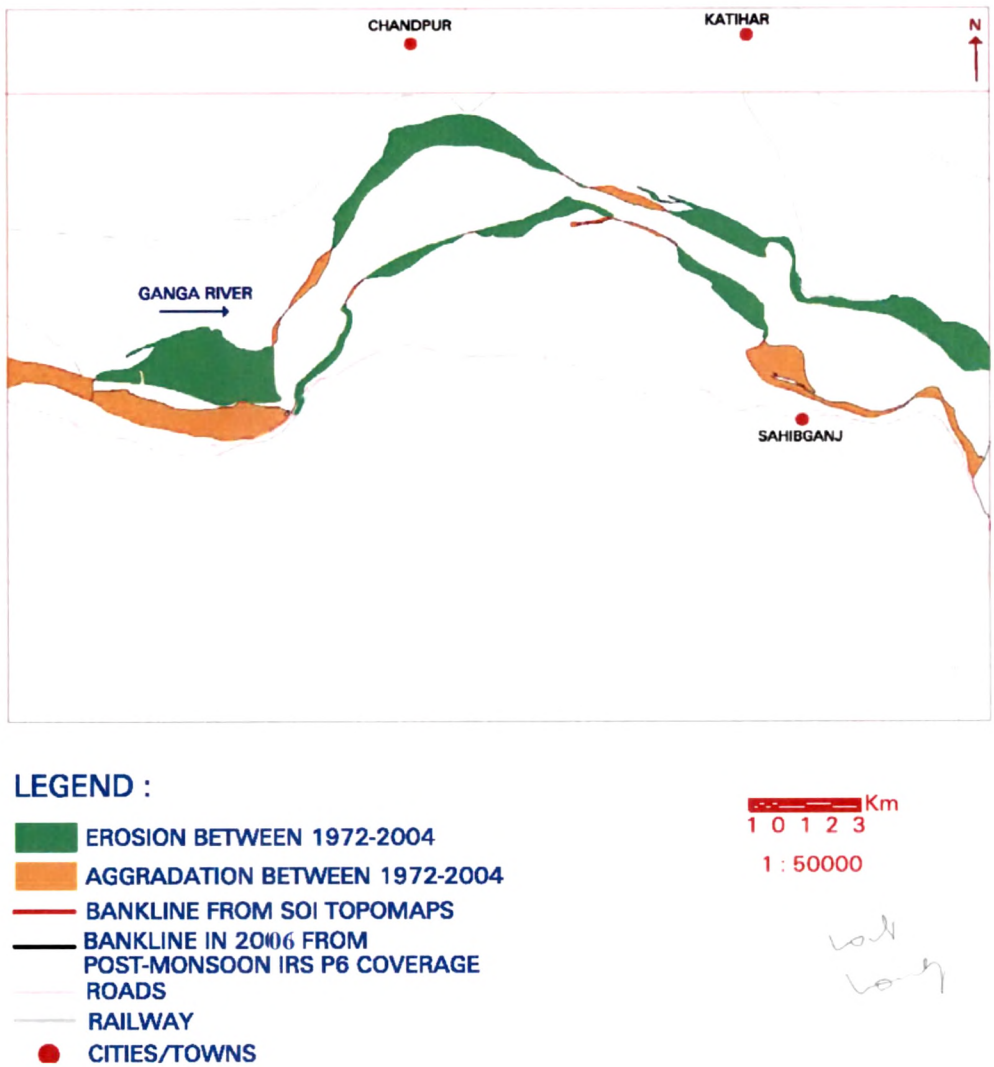
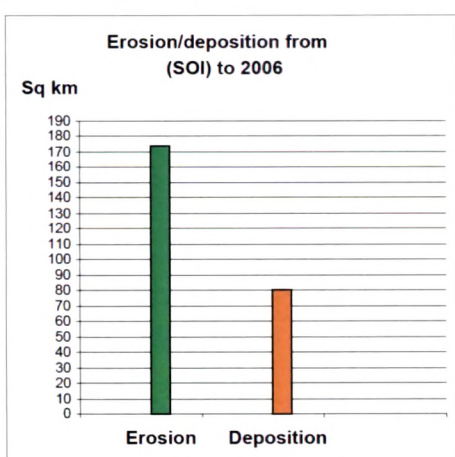



**Fig 5.61: Bankline change and erosion/deposition near Sahibganj on 1:50,000 scale from (SOI) to 2006**




**Bar chart 5.7: Erosion and deposition along both the banks of the Ganga river near Sahibganj**

## D3. Fluvio-geomorphological changes as depicted from pre-monsoon and post-monsoon data

### Changes mapped at 1:250,000 scale for the year 2000 and 2004 taking SOI as base reference maps

### Section 4: Regions covering in and around Sahibganj

River in this region shows presence of various fluvial features such as ox-bow lakes, water-bodies, sand-bars, river-island, island with vegetation, cut-off meander and huge flood-plain. Presence of ox-bow lakes and numerous water-bodies on the Northern as well as the Southern bank does indicate about the remnants of the old Ganga river course. Here the river shows a typical asymmetrical meandering pattern (ref plate throughout its course which points and suggest that the river might be controlled by some sub-surface structure. Huge flood-plain are formed in this region which shows that the region undergoes frequent inundation during the monsoon season. Also the flood-plain area has shown a distinct gradual increase from 2000 pre-monsoon to 2004 post-monsoon season where it is maximum. The length of the river bank is approximately 160.5 km. The surface water area shows increase in the post-monsoon seasons of both the years but the amount has decreased in 2004 post-monsoon than compared to the post-monsoon of 2000. Area of sand-bars show a very significant decrease in the post-monsoon seasons of both the years and this also as in the previous case has shown a decrease in its amount in 2004 post-monsoon than that in 2000 post-monsoon season whereas the amount is much higher during the pre-monsoon seasons of 2000 as well as 2004. But looking at the overall scenario it has been seen that the sand-bar area has considerably decreased in 2004 than in 2000. The total island area has increased in 2004 than compared to 2000. Regarding the width of the area it is well observed that it has significantly increased from 1–10 km in 2000 to 1-15.2 km in 2004

which is a very major change not only in this region but in our overall study also (ref fig 5.62 to 5.66 and table 5.10).

**Changes mapped at 1: 50,000 scale for the year 2006 taking SOI as base reference maps**

**Section 4.1: Regions covering in and around Sahibganj**

For the comparison of fluvial geomorphological features interpreted using 1969-'72 (SOI topomaps) and IRS post-monsoon data of years 2000, 2004 and 2006 (ref fig 5.67 to 5.70). Fluvial geomorphological features namely river with water, sand-bars, very wide flood-plain with vegetation (ref plate 12), water-bodies, ox-bow lakes, meander scars, river islands and grass/agriculture/aquatic vegetation have been interpreted from the post-monsoon IRS satellite images. Here the river shows a typical meandering pattern and also shows a straight pattern at certain locations which indicate that the river is controlled by a basement structure in this region. The presence of large number of water-bodies and ox-bow lakes indicates the old course of the Ganga river. The sandbars are mainly composed of sand/silt. The area of sand-bars shows almost no change during the pre-monsoon and the post-monsoon season. Length of the surface water channel has significantly increased in post-monsoon then compared to pre-monsoon data whereas length of the river bank shows moderate increase in post-monsoon than compared to pre-monsoon season. Surface water area is considerably more in post-monsoon then in pre-monsoon. Area of island has remained the same in pre-monsoon as well as in post-monsoon season. The region shows very wide flood-plains throughout its course (ref table 5.11) and the area is little higher in pre-monsoon season than compared to the post-monsoon season. The width of the river varies from 0.9 to 12 km.

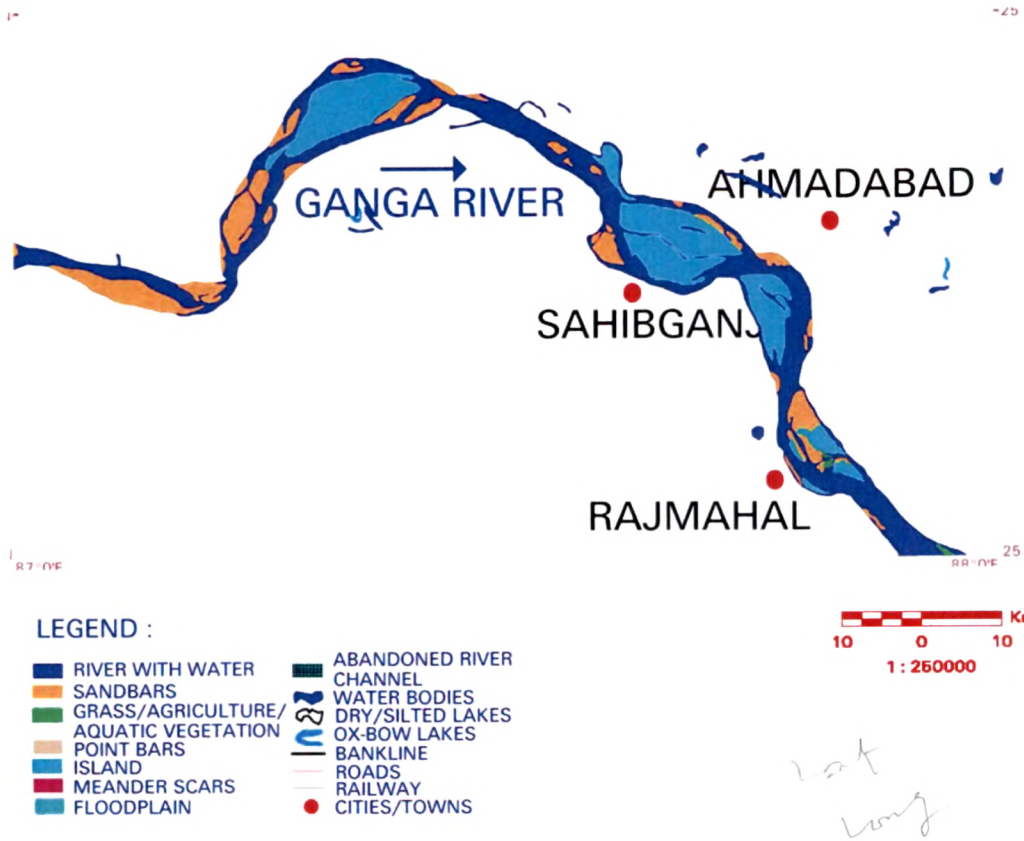



**Fig 5.62: Fluvio-geomorphology of the Ganga river near Sahibganj on 1:250,000 scale from SOI maps**

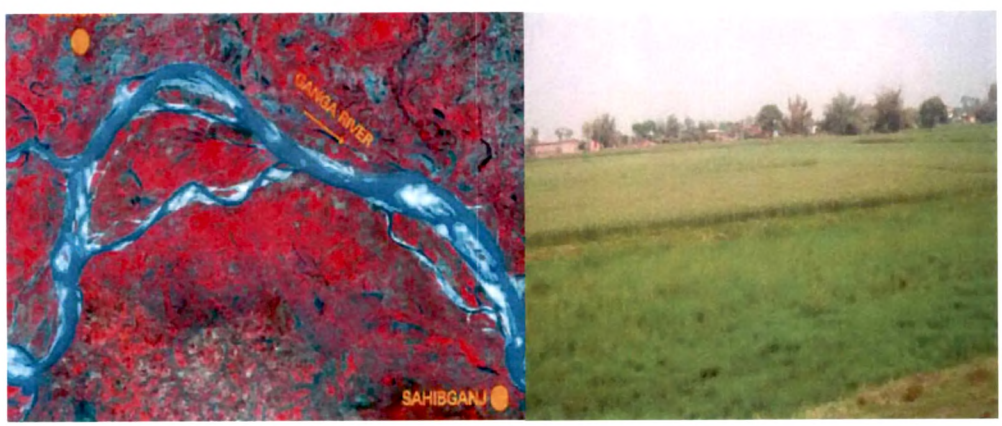



**Plate 5.12: IRS FCC image / field photograph showing vast flood-plain with vegetation near Sahibganj**

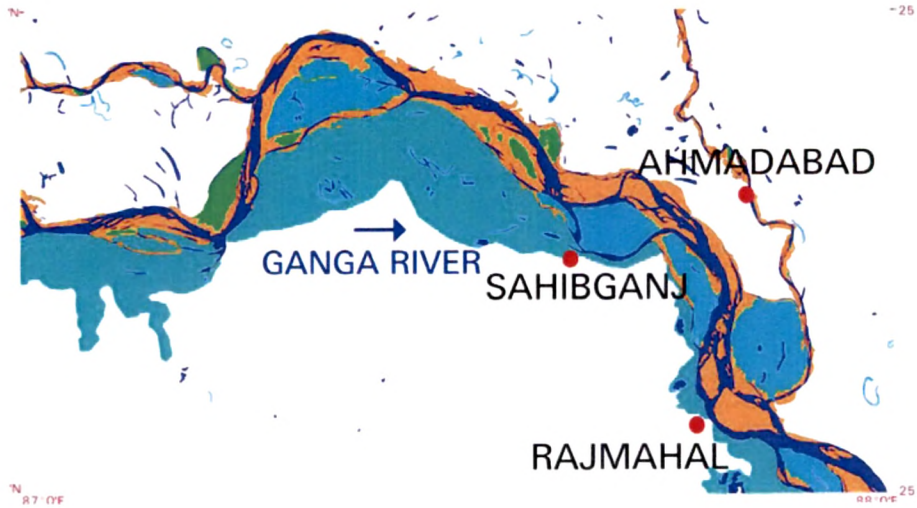



**Fig 5.63: Fluvio-geomorphology of the Ganga river near Sahibganj on 1:250,000 scale from IRS 1D pre-monsoon data-2000**

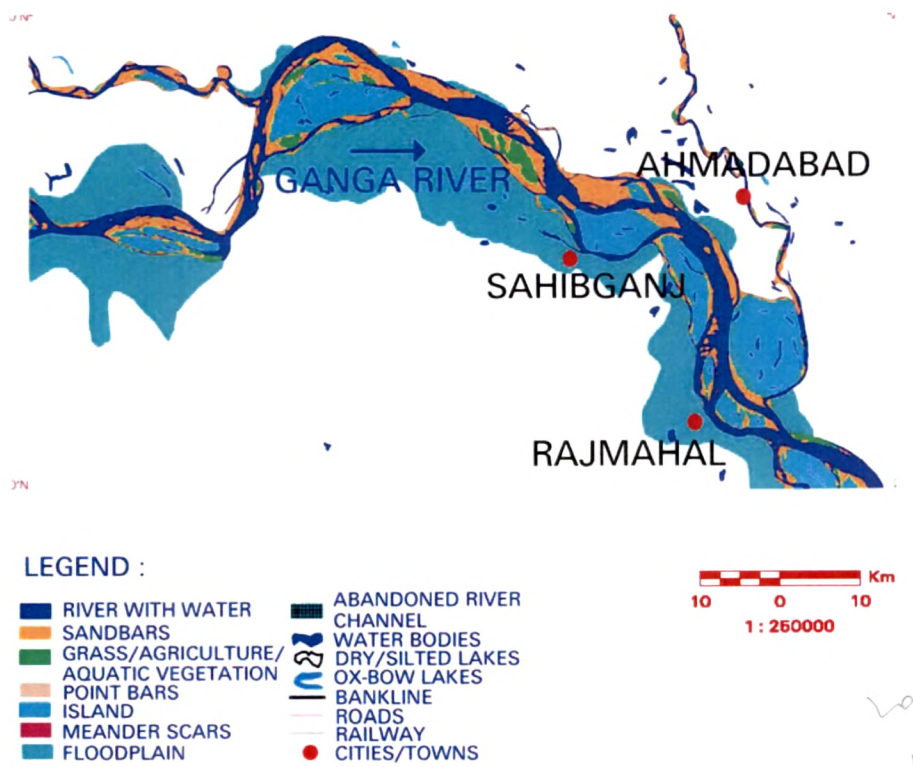



**Fig 5.64: Fluvio-geomorphology of the Ganga river near Sahiabganj on 1:250,000 scale from IRS 1D post-monsoon data-2000**

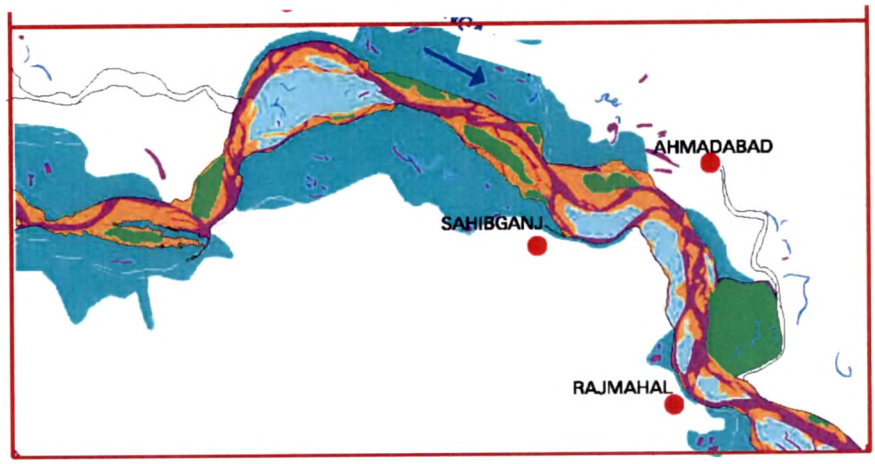



**Fig 5.65: Fluvio-geomorphology of the Ganga river near Sahibganj on 1:250,000 scale from IRS P6 pre-monsoon data-2004**

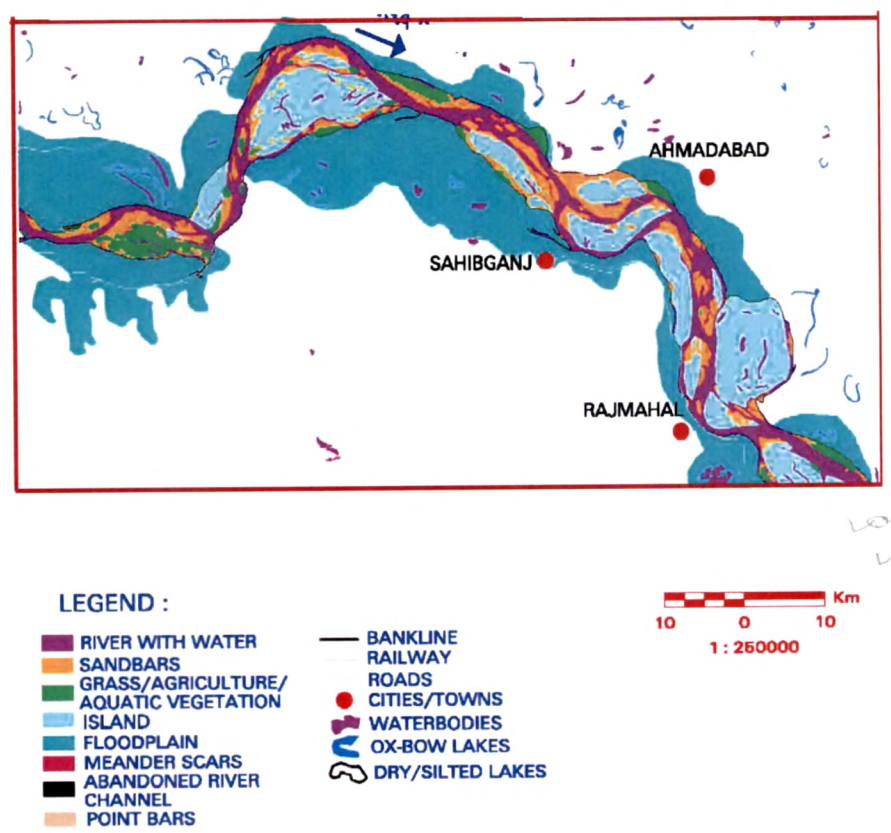



**Fig 5.66: Fluvio-geomorphology of the Ganga river near Sahibganj on 1:250,000 scale from IRS P6 post-monsoon data-2004**

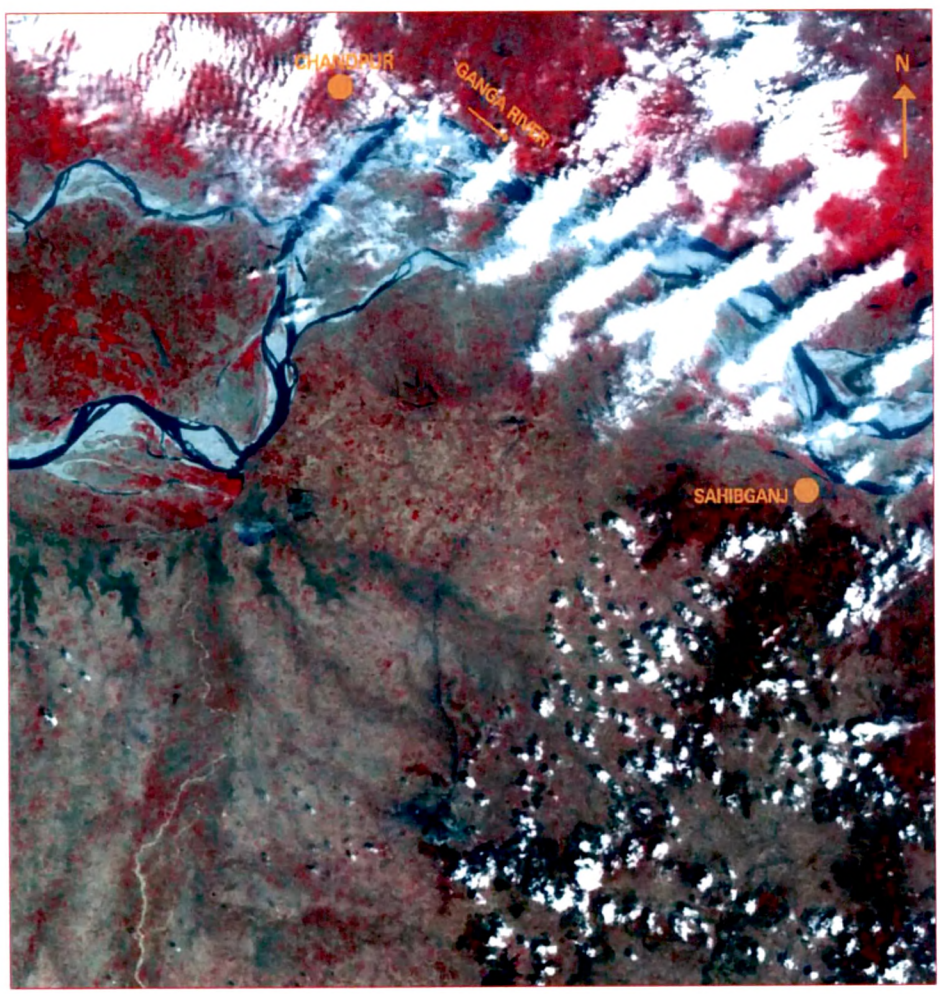



**Fig 5.67: Pre-monsoon satellite image showing Ganga river course near Sahibganj in 2006**

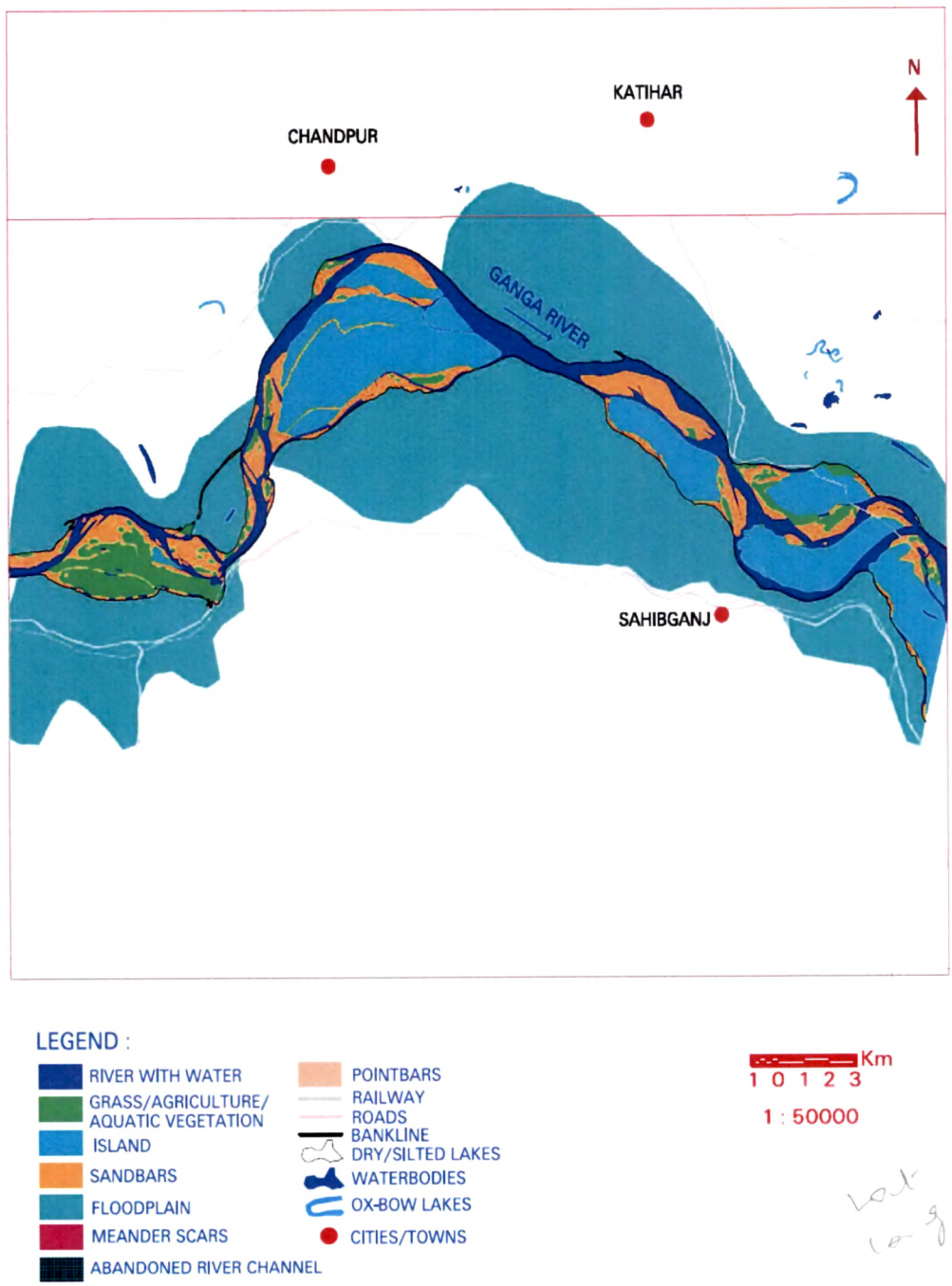



**Fig 5.68: Fluvio-geomorphology of the Ganga river near Sahibganj from IRS P6 pre-monsoon data of 2006**

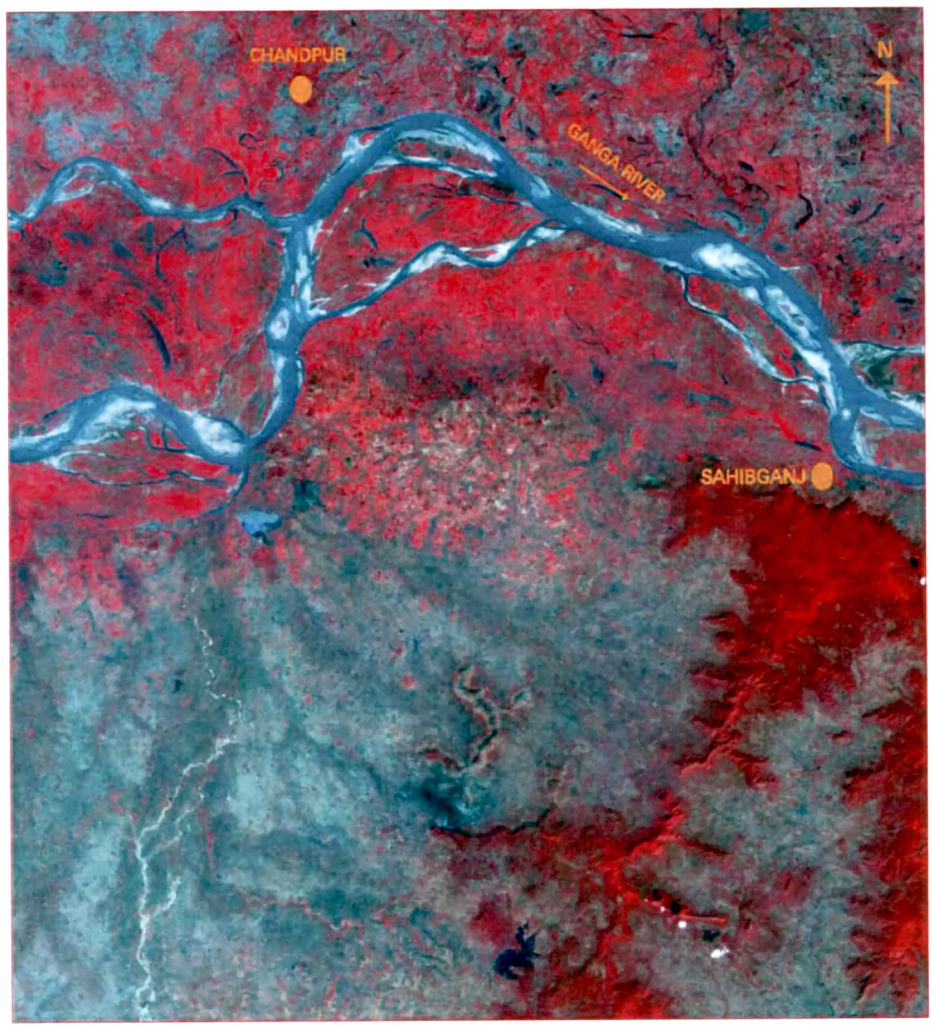



**Fig 5.69: Post-monsoon satellite image showing Ganga river course near Sahibganj in 2006**

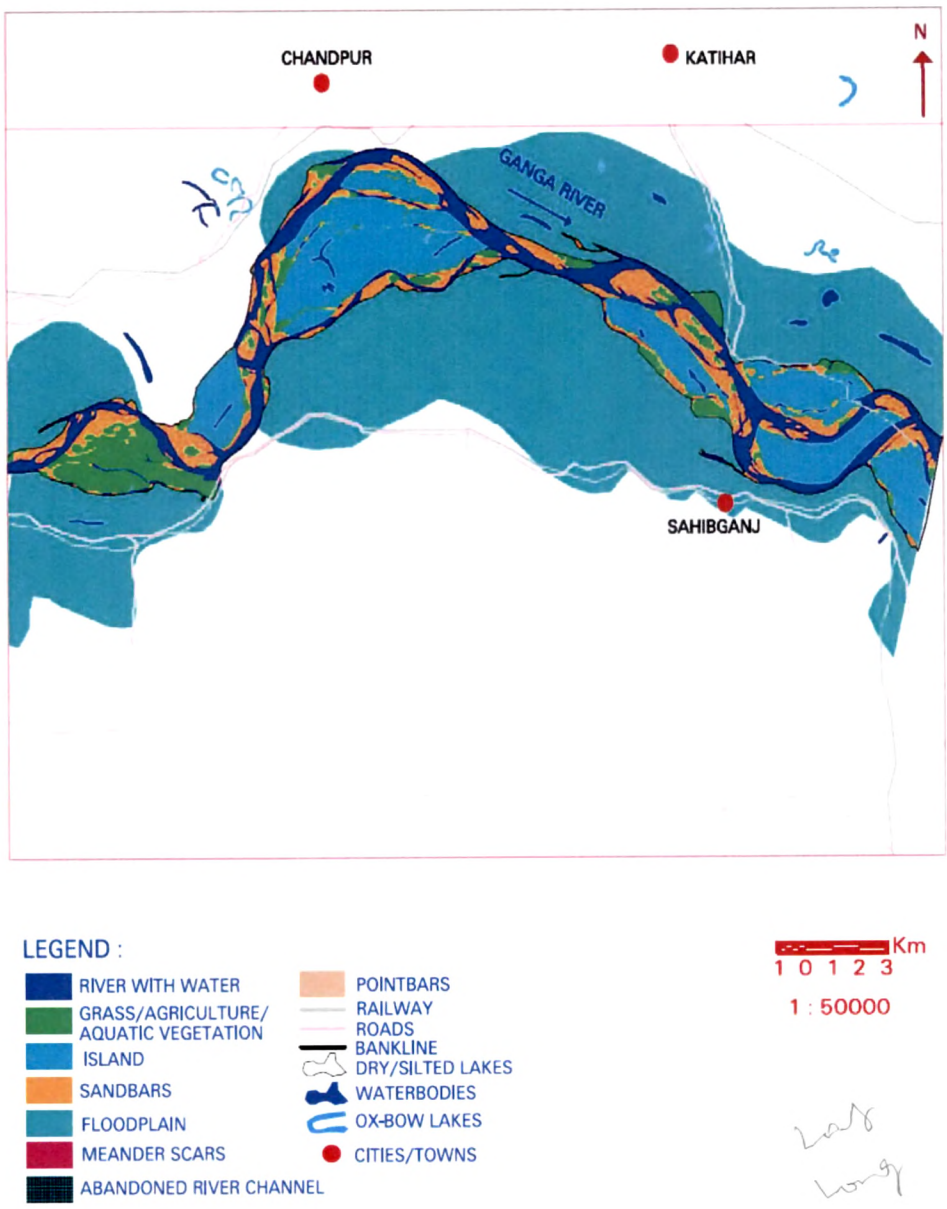



**Fig 5.70: Fluvio-geomorphology of the Ganga river near Sahibganj from IRS P6 post-monsoon data of 2006**

**Table 5.10: Salient features regarding the various fluvio-geomorphological changes using IRS 1D LISS III and IRS-P6 LISS III pre-monsoon and post-monsoon satellite data for the years 2000 and 2004 on 1:250,000 scale covering regions in and around Sahibganj**

| Sr no | Features (Regions covering Sahibganj) | Observations from pre-monsoon satellite data | | Observations from post-monsoon satellite data | |
|---|---|---|---|---|---|
| | | 2000 pre-monsoon data | 2000 post-monsoon data | 2004 pre-monsoon data | 2004 post-monsoon data |
| 1 | Geomorphological features | River with water, sandbars, island, agriculture, water bodies, flood plain, ox-bow lakes | | River with water, sandbars, island, agriculture, water bodies, flood plain, ox-bow lakes | |
| 2 | River pattern | Braided and complex asymmetrical meandering, meandering pattern likely to be controlled by some basement structure | | Braided and complex asymmetrical meandering, meandering pattern likely to be controlled by some basement structure | |
| 3 | Shifting of the river channel | Shift of around 1-4 km but not very distinct. | | Shift of around 2-5 km but not very distinct. | |
| 4 | Length of the river bank | 160.5 | | | |
| 5 | Surface water area of the river | 271.00 sq km | 350.00 sq km | 242.00 sq km | 300.00 sq km |
| 6 | Area of the sandbars | 280.00 sq km | 175.00 sq km | 242.00 sq km | 134.00 sq km |
| 7 | Area of the flood plain | 590.00 sq km | 719.00 sq km | 868.00 sq km | 900.00 sq km |
| 8 | Width of the river | From 1.00 km to 10.00 km | From 1.5.00 km to 11.00 km | From 1.00 km to 13.3 km | From 1.0 km to 15.2 km |
| 9 | Area of the island | 240.00 sq km | 258.00 sq km | 179. 00 sq km | 335.00 sq km |

**Table 5.11: Salient features regarding the various fluvio-geomorphological changes using IRS P6 LISS III pre-monsoon and post-monsoon satellite data for the year 2006 on 1: 50,000 scale covering regions in and around Sahibganj**

| Sr. No. | Features (regions around Sahibganj) | Observations near Sahibganj from 2006 pre-monsoon satellite data | Observations near Sahibganj from 2006 post-monsoon satellite data |
|---|---|---|---|
| 1 | Geomorphological features | River with water, sandbars, island, grass/agriculture, water-bodies, floodplain, ox-bow lakes | River with water, sandbars, island, grass/agriculture, water-bodies, floodplain, ox-bow lakes |
| 2 | River pattern | Complex, asymmetrical and Meandering pattern controlled by basement structure | Typical complex asymmetrical meandering. Meandering pattern controlled by basement structure |
| 3 | Shifting of the river channel | Shift 1 to 5 km | Shift 0.8 to 6.2 |
| 4 | Length of the river bank | 112.5 km | 119 km |
| 5 | Surface water area of the river | 135.00 sq km | 149.00 sq km |
| 6 | Area of the sandbars | 105.00 sq km | 104.00 sq km |
| 7 | Area of the floodplain | 942.00. sq km | 931.00. sq km |
| 8 | Width of the river | From 0.9 km to 11.5 km | From 1.00 km to 12.00 km |
| 9 | Area of the island | 209.00 sq km | 209.00 sq km |

**Table 5.12: Overview of the bank-line shifting in different regions from SOI to 2000, 2004 and 2006**

| REGION | YEAR | | |
|---|---|---|---|
| | From SOI - 2000 | From SOI - 2004 | From SOI - 2006 |
| BALLIA | Upto 2 km | Upto 2.5 km | Upto 3 km |
| RUDRAPUR | Upto 3 km | Upto 4 km | Upto 5 km |
| PATNA | Upto 8 km | Upto 9.5 km | Upto 10 km |
| SAHRI | Upto 3 km | Upto 3.8 km | Upto 4 km |
| MONGHYR | Upto 7.5 km | Upto 9 km | Upto 9.7 km |
| BHAGALPUR | Upto 5.9 | Upto -6 km | Upto 6.5 km |
| SAHIBGANJ | Upto 4 km | Upto 5 km | Upto 6.2 km |