CHAPTER - III

CHAPTER THREE

APPROACH AND DATA USED

The basis of entire study is to find changes in fluvio-geomorphological features from time-different data. SOI maps and recent satellite data has been used for mapping long term as well as short term changes. In the following sections remote sensing methods of extraction of features, vectorization of features and method of change detection have been discussed.

3. Basis of Remote Sensing

This study has been carried out on the basis of interpretation from the remote sensing data or in other words from the images acquired from the orbiting satellites. Remote sensing provides wide application in the field of geomorphology due to three main reasons. Firstly, remote sensing data gives direct information about the landscape i.e. information on various earth surface features because of which the investigations and interpretation become much easier and faster. Secondly, the synoptic view provided by the remote sensing techniques helps in studying the landforms on a regional scale whereas instead if we study the same thing by field data it becomes far more difficult and thirdly, the stereoscopic ability helps in evaluating the slopes, relief and forms etc.

The fluvial landscape mainly comprises of drainage networks, different types of drainage patterns, channel ways, valleys etc. Different patterns indicate a specific geological setting of the area and each pattern has its own geometry, shape, structure etc. Remote sensing techniques facilitate the identification of specific terrain feature or drainage type from which much valuable information about the region can be extracted and inferred. Sometimes the region may be controlled by certain basement structure

which also becomes very easy to study with the aid of remote sensing which infact may not be that easy by field works. Different fluvial landforms depending on their dimensions can be easily identified through aerial and satellite remote sensing data. An important application of repetitive remote sensing data is the study of dynamic features, such as river channel changes, its migration pattern, changes in the planform and delineation of palaeochannels and palaeohydrology (Gupta, 2003)[33].

Remote sensing is the science of acquiring information about an object, area or phenomenon without physically coming in contact with these entities. The data or the information is mainly taken from an aircraft, satellite, ship etc. and is most often used to collect information about the earth's surface and atmosphere (Levin, 1999)[46], (Lillesand and Kiefer, 2000)[48], (Jong and Meer, 2004)[39], (Joseph, 2005)[40], (Elachi and Zyl, 2006)[25], (Campbell, 2007)[16] and (Liaghat and Balasundram, 2010)[47]. The principle source of remote sensing data is the electro magnetic radiation (EMR) which is reflected or emitted as it strikes an object. It is made up of electric and magnetic fields and spans a large spectrum of wavelengths from very short gamma rays to long radio waves. EMR is basically a dynamic form of energy which propagates as a wave motion at a velocity of $c = 3 \times 10^{10}$ cm/sec. the parameters characterizing a wave motion are wavelength (λ), frequency (v) and velocity of light (c) and the relationship is given as, $c = v \lambda$ (Drury, 2001)[24].

However, the human eyes are limited only to a small portion of the total electro magnetic spectrum (EMS) (plate 3.1) i.e. approximately up to 400 to 700 nm only whereas through remote sensing techniques it is possible to use tools which go much beyond these ranges especially the near infrared (NIR), middle infrared (MIR), thermal infrared (TIR) and microwaves. Here, the sensor and the object which is sensed or to be sensed are located quite afar, distance may be in the order of several km or

several hundred km. The intervening space is filled with air (aerial platform) or even partly by vacuum (space platform) and only the electromagnetic waves are able to serve as an efficient link between the sensor and the object. If the observation is made based on the electro magnetic radiation from the sun or self emitted radiance, it is called **passive remote sensing.** It is also possible to produce electro magnetic radiation of a specific wavelength or band of wavelengths to illuminate the object or terrain, and then the interaction of this radiation can be studied by sensing the radiance from the target and this is called **active remote sensing** (Jong and Meer, 2004)[39], (Joseph, 2005)[40], (Schowengerdt, 2007)[78] and (Barrett and Curtis 1999)[7].

The basic principle involved in remote sensing techniques is that in different wavelength ranges of the electro magnetic spectrum, each type of object reflects or emits a certain definite intensity of light which is dependant on the physical and the chemical properties i.e. the composition of that particular object. Various features appear different in different spectral bands and by making use of this information from one or more wavelength ranges it becomes possible to differentiate between various object such as dry soil, wet soil, sand, water, vegetation, man-made structures etc. thus when electromagnetic radiation is incident on a surface it either gets reflected, absorbed, re-radiated or transmitted depending on the properties of that particular object and the wavelength of the incident radiation (Gupta, 2003)[33].

In all remote sensing methods there is to be a basic property on the basis of which identification of an object is done, this property is called **signature** which plays a very important role in remote sensing. They are basically the main characteristics of a feature which directly or indirectly leads to its identification and there are four types of signatures in remote sensing, which are discussed below (Joseph, 2005)[40].

(a) **Spectral signature or spectral variations** are the changes in the reflectance or emittance of an object as a function of wavelength and this signature is the most often used in remote sensing especially in the optical –IR region. Different materials have different spectral reflectance characteristics and this phenomenon is responsible for the color and tone of an image or any object. For e.g. trees appear green in color because they reflect more of green wavelength then any other color wavelength. Spectral reflectance is dependant on wavelength and thus for a given terrain features it will show different spectral values at different wavelengths. The reflectance characteristics of the earth's surface features are expressed by spectral reflectance which is given by the following equation:

$$P(\lambda) = [\, E_R(\lambda) \,/\, E_I(\lambda) \,] \times 100$$

Where,

$P(\lambda)$ = spectral reflectance at a particular wavelength .

$E_R(\lambda)$ = wavelength energy reflected from an object

$E_I(\lambda)$ = wavelength energy incident on an object

Now, if we plot a curve of $P(\lambda)$ and (λ) it is called as a spectral reflectance curve. It will always vary with the variation in the chemical composition and the physical conditions of the feature and thus we will be getting a range of values which means each specific feature will show a specific spectral response pattern which is termed as spectral signature of an object. The spectral reflectance curve for the three basic types of earth's features vegetation, dry bare soil and clear water is shown in (plate 3.2).

The spectral characteristics of these three earth features are briefly described as under:

Vegetation: chlorophyll Present in green vegetation strongly absorbs radiation in the red and blue wavelengths whereas reflects green wavelength. The internal structure of

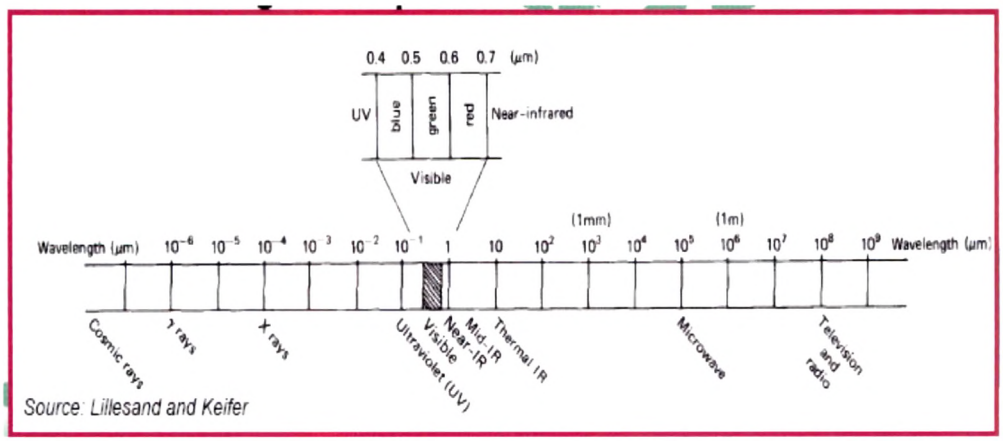

Plate 3.1: Electromagnetic Spectrum (Lillesand and Kiefer, 2000)[48]

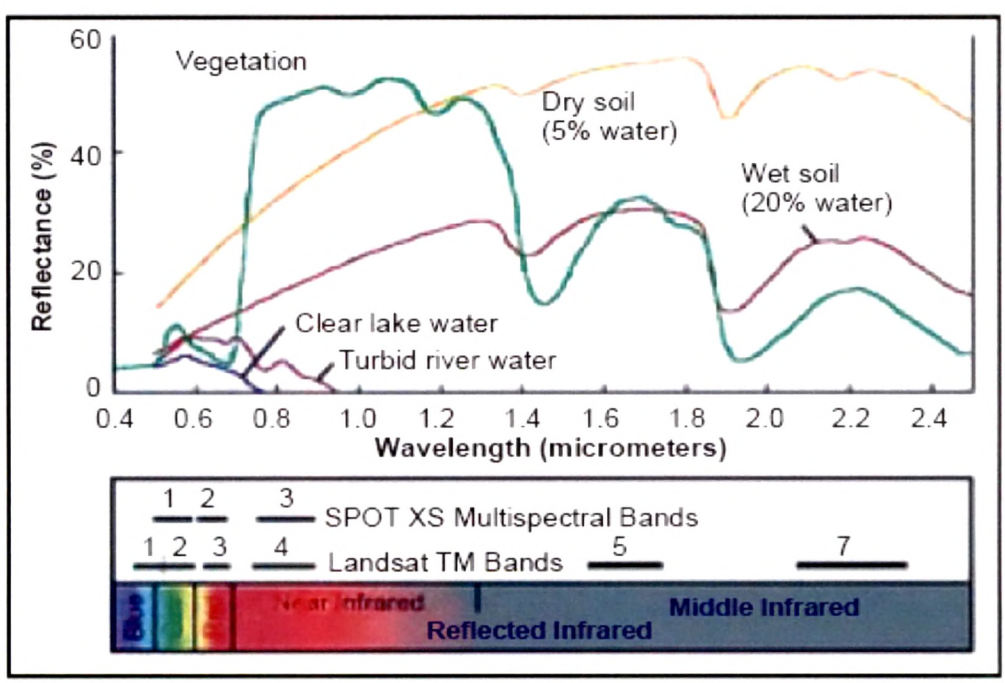

Plate 3.2: Typical spectral reflectance curve for vegetation, soil and water

(Aggarwal, 2003)[2]

healthy vegetation act as diffuse reflector of NIR reflectance from which it becomes possible to assume about the type pf vegetation.

Water: in case of water maximum incident radiation is not reflected back but it is either absorbed or transmitted back. Longer visible and NIR radiation is absorbed more and thus water appears blue or blue-green which means that it is strongly reflected in shorter wavelengths whereas it will appear darker if seen at red or IR wavelengths. Depth of the water, other materials Present in water, and the surface roughness of water are the factors which affect the variability in reflectance of water.

Soil: in case of soil most of the incident radiation on soil is either reflected or absorbed and very less is transmitted back. The amount of soil moisture, its texture, amount of organic matter Present in soil, its structure and the amount of iron-oxide determines the soil reflectance properties. For e.g. the Presence of moisture will Decrease the soil reflectance (Aggarwal, 2003)[2].

(b) Spatial signature or spatial variation provides terrain features attributes such as shape, size and texture of an object.

(c) Temporal signature or the temporal variations are the changes in the reflectivity or the emissivity with respect to time.

(d) Polarization signature or the polarization variation relates to the change in the orientation of the radiation reflected or emitted by any object and the degree of orientation becomes the identifying characteristic (Jong and Meer, 2004)[39], (Joseph, 2005)[40] and (Warner, et al. 2009)[103].

3.1. Importance of Remote Sensing in Geomorphological Studies

The main advantage of digital data acquired from the remote sensing techniques is, that various manipulations can be applied to the data on the basis of various digital image processing techniques.

Geomorphology deals with changes in landforms from the geologic past to the present in varying spatial as well as temporal scales. Climate is also a very important factor playing a major role in shaping and thereafter in modifying the landforms since climatic conditions varies enormously with varying climatic zones (Rao, 2002)[71], (Worcester, 1939)[104] and (Naqi, 2005)[58]. Through multitemporal capability of the sensors we get repetitive coverage, through which it is possible to track any major or minor changes occurring between the two successive visits. This especially becomes useful when dynamic changes brought about by natural disasters such as landslides, cyclones and floods which cause drastic and sudden river fluctuation; bank erosion etc. needs to be studied. Also, because of the specified revisit period changes occurring in all different seasons can be automatically detected. Spectral signature is the most widely used signature, but sometimes identification through a single spectral band becomes difficult and in such cases we need to generate more than single continuous spectra, called as multiple spectra. The multispectral capability of the sensors provides us to get data not only in the visible region but also in the NIR, SWIR and MIR regions through which we can have an advantage of getting combination of bands, thus providing us with better contrast which is helpful in distinguishing certain features for proper image interpretation. This property is very useful in fluvio-geomorphological studies, where sometimes two season data needs to be compared before reaching to a final conclusion in assigning a feature class whereas, multispatial ability helps us to study the data on the required resolution (high or low). By the using the combination of these remote sensing properties it allows us to get a more clear picture as to the basic identification signatures such as relief, slope, color, tone, texture, shape etc. which finally leads to a better understanding as well as image interpretation. Thus, by using various sensors it is possible to get the entire terrain information (Rao, 2002)[71].

For geomorphological studies it is essential to know as to how certain natural as well as man-made processes leads to the formation of a specific type of a landform. For carrying out such studies it is required that we have a thorough knowledge of all major and minor details regarding that particular region such as its topography, sub-surface geology, soil type, water conditions etc. every time it is not possible for a worker to visit the place and collect all the details since it is very difficult to acquire all finer details in a repetitive manner, also sometimes the area may not be that easily accessible politically as well as topographically then in such cases remote sensing provides us with all the required details.

River migration may be triggered due to various reasons such as spinning of the earth, tectonic activities, sea level changes, climatic changes, flash floods, etc. migration patterns can be easily studied through remote sensing methods since the palaeo channels as well as other similar left out trace features of the rivers show certain characteristics such as darker tone along with thick vegetation, or a left out loop, etc which facilitates the identification. Braided pattern may be a result of tectonic upliftment or may indicate a subsurface feature. Remote sensing helps in mapping and monitoring of braided pattern which may be helpful in generating earthquake and subsurface tremor predictive models (Kumanan, and Ramasamy, 2005)[43].

Almost every year we hear about large scale flooding in Bihar which itself is a very big issue leading to many fluvial problems such as erosion, deposition of sediment load which is largely responsible for major riverine changes.. For overcoming such issues the environmental pattern needs to be continuously monitored so that effective measurements can be taken. To deal with such huge morphological changes, the in-situ measurements with GPS or topographic maps become very difficult and sometimes not possible due to inaccessibility of the region. Also such large scale studies requires huge

amount of data which may not be easy and fast to acquire. Here remote sensing techniques have become a very helpful alternative. Remote sensing data contains integrated information regarding the ground, the landform, ecology of the region, sub-surface information, and resources of the area and also the impact of humans on the natural landscape (Gibson and Power, 2000)[27].

Apart from this it has a wide range of application in almost every field of human interest starting from military purposes and other useful application such as:

- In the study if archaeology as well as anthropology
- Agricultural and environmental sciences, civil engineering, geo-technical investigations
- Geological surveys, mineral exploration, investigations of sub-surface folds, faults, lineaments, unconformities, presence of intrusions, lithological studies, and identification of different types of rocks, study related to different landforms such as tectonic, fluvial, aeolian, glacial, volcanic, coastal and deltaic landforms.
- In oceanography and coastal monitoring, meteorological, climatological studies
- Mapping and natural disaster studies and planetary sciences
- In the field of hydrology and water resource management, ground water surveys (Gupta, 2003)[33], (Lillesand and Kiefer 2000)[48], (Levin, 1999)[46] and (Pandey, 1987)[61].

3.2. Data Used

In carrying out the present study on the Ganga river, following data has been used:

A. Remote sensing images

- Multi-date IRS-1D LISS III pre- and post-monsoon data for the year 2000

- Multi-date RESOURCESAT-1 (IRS-P6) LISS-III pre- and post-monsoon data for the year 2004 and
- Multi-date RESOURCESAT-1 (IRS-P6) LISS-III pre- and post-monsoon data for the year 2006

For the specifications of these datasets of the years 2000, 2004 and 2006 (ref table 3.1). For the details of the data used (ref table 3.2 and 3.3). Besides the use of remote sensing data following addition information was also used to complete the study.

B. Collateral data:

Survey of India topographical maps on 1:250,000 and 1:50,000 scale

D. Ancillary data:

Available published reports and maps on rainfall, floods, geomorphology, and geology related to Gangetic plains.

3.3. Feature extraction or the RS techniques used in the present study

3.3.1. Generation of database and feature extraction from SOI maps or base map preparation

The entire study was remote sensing based and was carried out using ERDAS imagine 9.1 software.

1. Fluvio-geomorphological dataset from the SOI topographical maps were created at 1:250,000 scale. This study was carried out for the whole Ganga river stretch falling in Bihar for getting a complete preliminary fluvio-geomprphological status. There were total five maps ranging from 1922-23 onwards up to 1976.

Firstly, all the required maps were geo-registered individually by taking the co-ordinates (latitude and longitude) at corner and mid points of the SOI maps in order to minimize the mapping errors. Then the vectorization of the major linear features such as major roads, railways was done. It was followed by vectorization of permanent

salient features such as main cities/ towns. Three tools were used for vectorization: line tool for linear features, polygon tool for closed form mainly referred as polygon form, and point tool for delineation of cities or towns. The purpose of extracting linear features was that these features are easily identified on the images and cross-section of linear features are useful for GCP identification which is required for precise geo-correction of the satellite images.

2. In the second step, a detailed database comprising of different fluvial features visible on the SOI maps was prepared. The features considered were within the main river Ganga channel and outside the channel within 5 minute grid. A standard legend of features was created. Thematic layers comprising of different fluvial features such as river water channel i.e. river course comprising of water, both the bank-lines, various depositional and erosional features such as sand-bars, point-bars, river-islands, flood-plains, palaeo features such as meander scars, ox-bow lakes, palaeo-channels as well as all major water bodies of that region were digitally demarcated. After this each feature was given a particular class or attribute or we can in general say 'a name'. For e.g. for a town, city or a village a code was given named cities/towns and so on and maps were prepared. Thus in total five SOI base reference maps on 1:250,000 scale were generated.

3.3.2. Generation of database and feature extraction from satellite images

Based on the remote sensing principles, fluvio-geomorphological features were interpreted and extracted from images. Detailed steps followed are given below:

1) Depending on the path-row specifications of images of the required area, the images were browsed from the NRSC data site and then the required cloud free image covering the river course were procured.

2) In the first stage, the fluvial dataset was prepared on 1:250,000 scale for the year 2000 using IRS 1D LISS III satellite data and 2004 using RESOURCESAT-1 (IRS-P6 LISS III) satellite data both having a spatial resolution of 23.5 mt. For the pre-monsoon and the post-monsoon satellite images of the years 2000 and 2004 (ref plates 3.3 to 3.6) and for specifications and details (ref table 3.1 to 3.3). Two season data i.e. pre as well as post monsoon satellite images was used because sometimes in case of a major flood event few areas might show drastic channel changes which may be due to heavy flooding and not the actual shift/change. In such cases it becomes difficult to decide whether the characteristic feature observed along a river valley are in fact relicts of infrequent floods and not the result of day to day conditions of normal flow (Pitty, 1971)[68]. So in such cases comparison have to be done with the same year data or Pre-monsoon data of the immediate next year.

3) The digital interpretation of the satellite images is done on the basis of color, tone, texture and amount of reflectance for e.g. the sand will give more reflection and thus appears white in color, whereas areas with vegetation cover will generally show red or green color, forest will show a dark red signature, water if shallow will show light blue tone and whereas deep waters will generally show darker tones.

4) In order to minimize the mapping errors, first the satellite data were geo-corrected with reference to the base maps (SOI maps) and then the outer grid was demarcated by taking reference from the SOI grid so that exact area could be outlined.

5) All the major linear features like railways, roads, and cities and the fluvial features such as river water channel i.e. river course comprising of water, both the

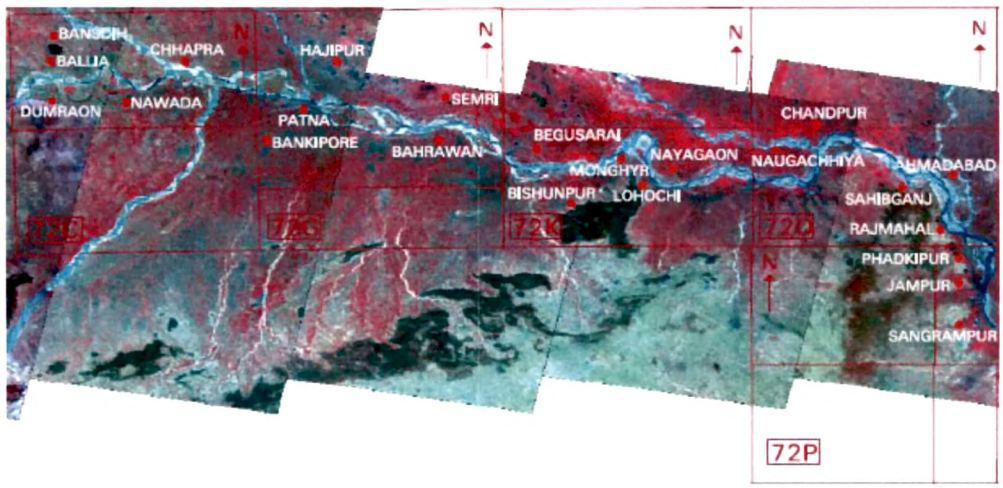

Plate 3.3: Pre-monsoon coverage of the Ganga river course in Bihar on 1:250,000 scale - year 2000

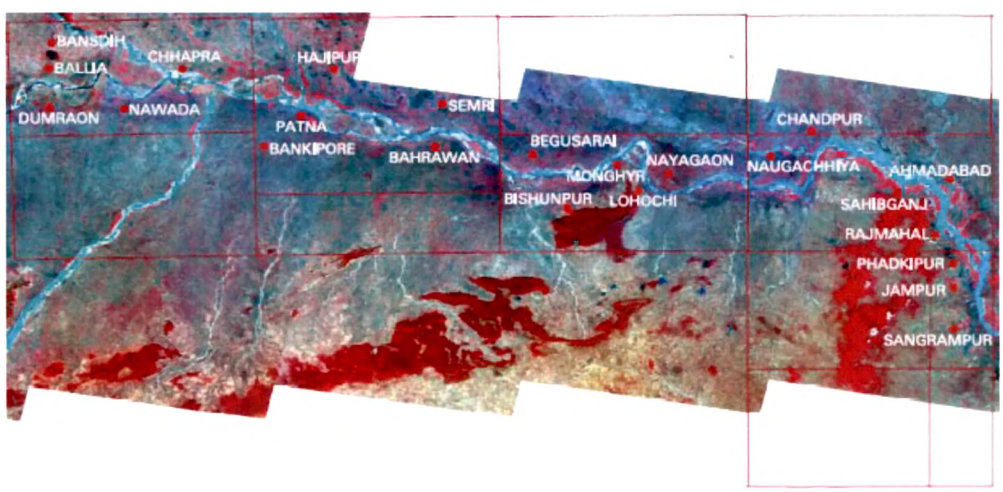

Plate 3.4: Post-monsoon coverage of the Ganga river course in Bihar on 1:250,000 scale – year 2000

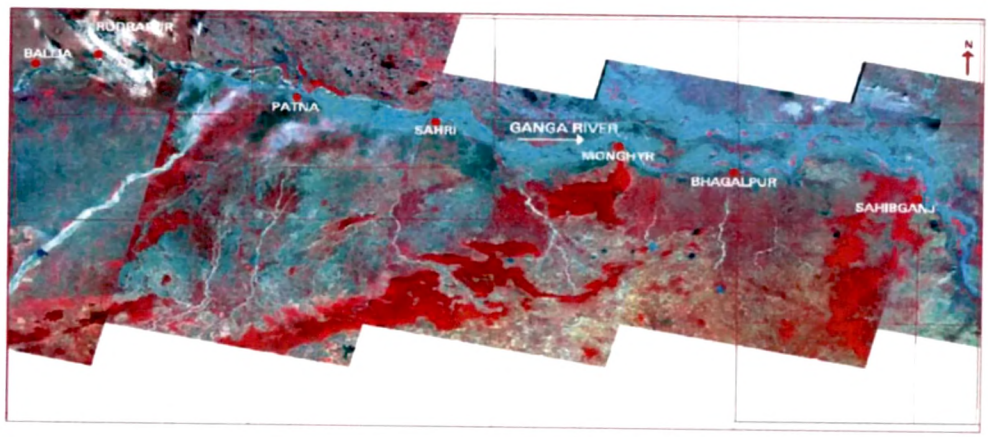

Plate 3.5: Pre-monsoon coverage of the Ganga river course in Bihar on 1:250,000 scale - year 2004

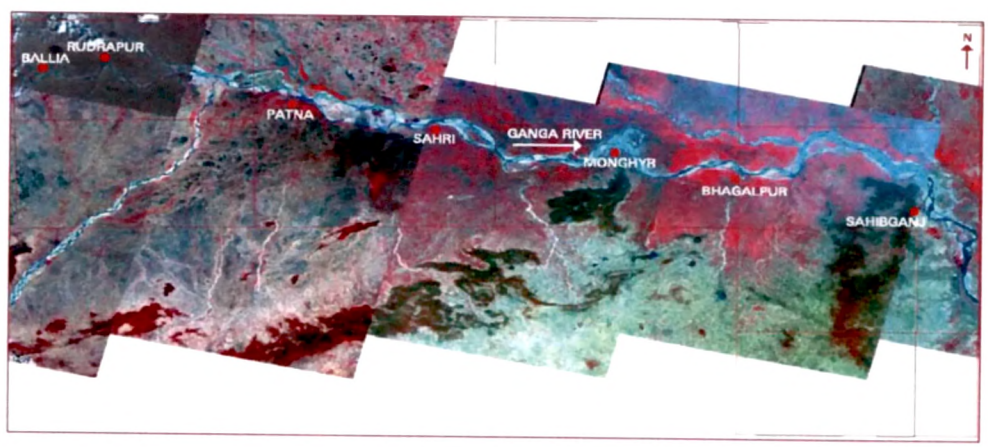

Plate 3.6: Post-monsoon coverage of the Ganga river course in Bihar on 1:250,000 scale - year 2004

Table 3.1: Specifications of the data used IRS-1D LISS-III for the year 2000 and IRS-P6 LISS-III for the year 2004 and 2006

Satellite	Sensor	Resolution	Spectral bands	Type of bands	Revisit period	Swath	Altitude	Orbit type
IRS-1D (year-2000)	LISS-3	23.5 m	Band 2 (green) 0.52 – 0.59 μm	Multi-spectral	25 days	141 km	816-818 km	Sun-synchronous
		23.5 m	Band 3 (red) 0.62 – 0.68 μm					
		23.5 m	Band 4 (NIR) 0.77 – 0.86 μm					
		70 m	Band 5 (SWIR) 1.55 – 1.70 μm			148 km		
RESOURCESAT-1 (IRS-P6) (year - 2004 and 2006)	LISS-3	23.5 m	Band 2 (green) 0.52 – 0.59 μm	Multi-spectral	24 days	141 km	817 km	Sun-synchronous
		23.5 m	Band 3 (red) 0.62 – 0.68 μm					
		23.5 m	Band 4 (NIR) 0.77 – 0.86 μm					
		23.5 m	Band 5 (SWIR) 1.55 – 1.70 μm					

Table 3.2: Details of the data used for the year 2000

Serial No	Satellite	Sensor	Path	Row	Date and year of data acquisition
1	IRS-1D	LISS-III	103	53	21/mar/00 (pre-monsoon) 26/nov/00 (post-monsoon
2	IRS-1D	LISS-III	103	54	15/apr/00 (pre-monsoon) 21/dec/00 (post-monsoon)
3	IRS-1D	LISS-III	104	53	18/mar/00 (pre-monsoon) 18/dec/00 (post-monsoon)
4	IRS-1D	LISS-III	104	54	18/mar/00 (pre-monsoon) 18/dec/00 (post-monsoon)
5	IRS-1D	LISS-III	105	53	15/mar/00 (pre-monsoon) 15/dec/00 (post-monsoon)
6	IRS-1D	LISS-III	105	54	15/mar/00 (pre-monsoon) 15/dec/00 (post-monsoon)
7	IRS-1D	LISS-III	106	53	6/apr/00 (pre-monsoon) 17/nov/00 (post-monsoon)
8	IRS-1D	LISS-III	106	54	12/mar/00 (pre-monsoon) 12/dec/00 (post-monsoon)
9	IRS-1D	LISS-III	107	54	9/mar/00 (pre-monsoon) 14/nov/00 (post-monsoon)
10	IRS-1D	LISS-III	107	55	3/apr/00 (pre-monsoon) 14/nov/00 (post-monsoon)

Table 3.3: Details of the data used for the year 2004 and 2006

Serial No	Satellite	Sensor	Path	Row	Date and year of data acquisition	
					2004	2006
1	RESOURCESAT-1	LISS-III	103	53	22/apr/04 (pre-monsoon) 24/nov/04 (post-monsoon	19/mar/06 (pre-monsoon) 14/nov/06 (post-monsoon)
2	RESOURCESAT-1	LISS-III	103	54		-
3	RESOURCESAT-1	LISS-III	104	53	22/apr/04 (pre-monsoon) 18/dec/04 (post-monsoon	24/mar/06 (pre-monsoon) 13/dec/06 (post-monsoon)
4	RESOURCESAT-1	LISS-III	104	54	27/apr/04 (pre-monsoon) 29/nov/04 (post-monsoon	24/mar/06 (pre-monsoon) 13/dec/06 (post-monsoon)
5	RESOURCESAT-1	LISS-III	105	53	27/apr/04 (pre-monsoon) 05/nov/04 (post-monsoon	-
6	RESOURCESAT-1	LISS-III	105	54	15/mar/04 (pre-monsoon) 10/nov/04 (post-monsoon	29/mar/06 (pre-monsoon) 18/dec/06 (post-monsoon)
7	RESOURCESAT-1	LISS-III	106	53	15/mar/04 (pre-monsoon) 10/nov/04 (post-monsoon	-
8	RESOURCESAT-1	LISS-III	106	54	25/feb/04 (pre-monsoon) 15/nov/04 (post-monsoon	03/apr/06 (pre-monsoon) 23/dec/06 (post-monsoon)
9	RESOURCESAT-1	LISS-III	107	54	25/feb/04 (pre-monsoon) 15/nov/04 (post-monsoon	-
10	RESOURCESAT-1	LISS-III	107	55	25/mar/04 (pre-monsoon) 20/nov/04 (post-monsoon)	-

bank- lines, various depositional and erosional features such as sand-bars, point-bars, river-islands, flood-plains, palaeo features such as meander scars, ox-bow lakes, all major water bodies palaeo-channels, levees, etc were interpreted and digitally delineated. All the features were saved as individual thematic layers and assigned with specific attributes as done for SOI maps.

6) In the next step all the thematic layers were compiled to generate different fluvio-geomorphological maps as under:

- pre-monsoon water course of the Ganga river for the year 2000
- post-monsoon water course of the Ganga river for the year 2000
- post-monsoon shifting of the Ganga river course for SOI to 2000
- pre-monsoon fluvio geomorphology of the Ganga river for the year 2000
- post-monsoon fluvio geomorphology of the Ganga river for the year 2000 and,
- pre-monsoon water course of the Ganga river for the year 2004
- post-monsoon water course of the Ganga river for the year 2004
- post-monsoon shifting of the Ganga river course for SOI to 2004
- pre-monsoon fluvio geomorphology of the Ganga river for the year 2004
- post-monsoon fluvio geomorphology of the Ganga river for the year 2004
- bank-line shifting and erosion/aggradation along both the banklines of the Ganga river from SOI to 2004

7) Based on fluvio-geomorphological maps for both the seasons prepared from satellite image, shifting of the Ganga river course was studied by the comparison of the maps of river water courses derived from SOI maps. In order to calculate the amount of erosion and deposition occurred along both the banks and to study the bank-line changes that have occurred since SOI year till 2004, the thematic layer comprising of the bank-line of SOI was superimposed with that of 2004 and compared. The

comparative study was also carried out between pre-and post-monsoon data of 2000 and 2004 so that we could also get the status regarding the short term changes.

8) From this study various fluvio-geomorphological statistical parameters were also calculated. This included study of the type of the river pattern, shifting of the river channel, length of the river bank, length of the surface water channels, surface water area of the river, area of sand-bars, area of river islands, flood-plain area and width of the river.

9) By this study we could get the complete fluvio-geomorphological status of the Ganga river in Bihar till 2004. It was observed that the changes were not uniform throughout. Certain locations showed very minor change whereas at some points it had shown major changes which varied in dimension as well as direction. So a more detailed study was done for the areas which were under major riverine changes such as drastic changes in the bank-line, large scale changes in the fluvio- geomorphological features as well as in the amount of erosion and deposition occurring there. It was found that there were seven such areas throughout the entire course of the Ganga region, namely Ballia, Rudrapur, Patna, Sahri, Monghyr, Bhagalpur and Sahibganj which had either undergone major change or very minor change compared to the other regions.

10) This study was done on 1:50,000 scale for the year 2006 using RESOURCESAT-1 (IRS-P6 LISS III) satellite data having a spatial resolution of 23.5 mt. The specifications are given in table 3.1 and 3.3. The entire study was similar as done for the years 2000 and 2004. Different thematic layers were prepared for the year 2006 as earlier done for 2000 and 2004 and compiled to form various thematic maps. Comparative study and analysis between 2000, 2004 and 2006 (for selected regions)

with SOI maps was carried out which helped in depicting the major and minor fluvial as well as bankline changes.

Thus, we can say that from the entire study mainly three types of changes were studied

1) Fluvio-geomorphological changes

2) Bank-line changes and the

3) Erosion deposition occurred along both the banks

For the details of statistical results and discussion refer next chapter.

3.4. Ground truth and field data

A detailed ground truth was carried out all along the Ganga river course in Bihar in Pre-monsoon season during March 2008. during the field survey, ground control points (GCP'S) using GPS and field photographs were collected at various places in and around Ballia, Rudrapur, Patna, Sahri, Monghyr, Bhagalpur and Sahibganj which were later on used to compare and verify the fluvial as well as the bank-line changes of the Ganga river. For the field photographs (ref chapter 5).