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REMOTE SENSING STUDIES ON GANGA RIVER CHARACTERISTICS BETWEEN ALLAHABAD AND BUXAR THROUGH SATELLITE DATA

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PREFACE

River characteristics are concerned with the structure and form of rivers. These are effected by flooding of river which is a regular feature of Indian rivers. For the study of river channel characteristics, detailed map depicting extent of flood plains and other features are required. Such studies help in detecting the change in the terrain condition, land cover etc. due to various developmental activities. The conventional approach to collect such informations, which are dynamic in nature, have been ground based measurements and they are both uneconomical and time consuming. Remotely sensed data provide an unique advantage in synoptic view and study of the dynamics of the river because of the repetitive nature of satellite coverage.

The present report describes characteristics of river Ganga between Allahabad and Buxar using remotely sensed data. The area of study lies between east longitudes 81°45' to 84° and north latitude 25° to 26° and is covered in four frames of Landsat imageries.

The National Institute of Hydrology, Roorkee engages studies and research in the area of hydrology. In order to obtain reliable upto date land and water information in space and time, the Remote Sensing Applications Division has taken up this study. Sh. S.K. Jain, Scientist 'B' and Sh. Tanveer Ahmad, RA were associated with this study.

SATISH CHANDRA
DIRECTOR

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ABSTRACT

River characteristics are concerned with the structure and form of rivers, including channel configuration, channel geometry (cross sectional shape), bed form and profile characteristics. Channel morphology changes with time and is affected by water discharge, including velocities, sediment load, quantity and sediment characteristics; the composition of bed and bank material and other factors. Prediction of when and where future erosion will occur and the extent of such erosion is very uncertain because of the many interacting factor involved.

For study of dynamic behaviour of a river, measurements taken with conventional ground based instruments is a time consuming and expensive procedure. Their main disadvantage however is that they provide only a point measurement which is unlikely to be representative of the whole. Whilest Remote Sensing techniques are unlikely to ever match the accuracy of ground based measurements they are capable of providing a measure of surface variability which can never be appreciated from the ground. Because of the repetitive nature of satellite coverage, space borne observations are particularly suited for monitoring dynamic changes in surface parameters in remote areas or areas that - are difficult to access.

This report describes characteristics of river Ganga using remotely sensed data. The area of study lies between east longitude 81°45' to 84° and north latitude 25° to 26°. The area is covered under four frames of Landsat imagery. The feature such as streams, sediment deposit etc. were delineted and the depited on a 1:250,000 scale base map.

In the present study visual interpretation technique is applied for the characteristics of river. The shifts of river banks were measured with respect to topographical map. The areal extent of various flood plain features

were also determined. For measuring salt affected areas and water logged area, interpretation of TM imagery of year 1987 was carried out.

1.0 INTRODUCTION

1.1 General

Flow in streams and rivers has been nature's way of conveying water on the surface of the Earth since the begining of time. A river is a definite channel developed over the ages draining its basin of precipitation and snow-melt. An alluvial stream is in a state of equilibrium if the discharge, sediment load, sediment size and slopes are delicately balanced as to result in a condition of change in bed elevation in a given reach over a long period of time. A change in any of these controlling variables or the imposition of an artificial change by the construction of structures along or across the stream will disturb its equilibrium and the stream then aggredes or degrades. This process of aggredation or degradation may continue for a long time till a new equilibrium is established. In their natural condition rivers seledom reach a state of equilibrium, even over short reaches. Each river is different and each reach of a stream is different from almost all other reaches of the same stream.

1.2 The Floods

A flood is a natural phenomena occuring since the birth of civilization. A river is said to be in flood when the flow exceeds the capacity within the banks. The magnitude of the floods depends upon the intensity of rainfall, its duration and also the ground conditions when the heavy spell of rainfall occurs. In India, floods are also due to denundation of land and deforestation flooding also occurs at confluences of streams when the main river is in high stage and backs up into the tributaries and areas there out. The flood plain is an area adjoining a river or stream which gets flooded during periods of high water when stream flow exceeds the carrying capacity of normal channel. It results from the deposition of sediments transports by the stream during the process of river bed formation.

1.3 Characteristics of Stream

The various properties of an alluvial stream include: Meandering, braiding and straight river reache, the sinuosity, the channel width, the bank height, oxbow lakes, natural levees, and pattern of vegetation etc. some of these properties may, of course, change with time.

1.3.1 Meandering

A menadering river has more or less regular inflections that are sinuous in plan. It consists of a series of bends connected by crossings. Meandering is one of the means through which rivers tend towards the so called dynamic or quasi-equilibrium state. Meandering increases stream length and decreases slopes.

1.3.2 Braiding

A braided stream can be defined as one which flows in two or more channels around alluvial islands. If the bank material is easily eroded, if the sediment load is composed in large part of sand and gravels moving as bed load, the stream will almost certainly be braided.

1.3.3 Sinuosity

The Sinuosity of a stream is expressed as the ratio of length along the centre line of the stream to the length along the valley.

1.3.4 Channel width

Channel width is a function of bankfull discharge, resistance of the bank and bed material. Bank material changes with distance along a stream. In the upper reaches stream banks may consisted rock or large boulders, and as the river progresses downstream through widening valleys, the bank material changes to gravels, sands, silts and clays. Stream banks may generally be classified as cohesive, non-cohesive and stratified. Stream banks of cohesive materials are more resistant to surface erosion cohesion than those of non-cohesive or stratified materials. Cohesive banks also have low permeability that reduces the erosion effects of seepage, piping and frost action.

The stream boundary in a given river reach is constantly changing with such interacting flow variables as velocity, depth, slope, density and vescoisty of water-sediment mixture, concentration of suspended load discharge, and characteristics of the bed material. Stream bank stability depends upon these inter related stream variables as well as on channel geometry. Stream bank erosion is accompanied by deposition.

1.3.5 Bank Height

The bank height is expressed as the height of the bank measured upward from a normal stage to the surface of the lowest flood plain. High banks may suggest that the river is actively degrading its channel, and high banks are commonly associated with frequent bankful flows. Thus, moderate or high banks usually accompany the uniform sinuous channels.

1.3.6 Oxbow lake

As menders grown, a narrow neck of land is often cut through from two sides, thus causing the stream to straighten its course. The ends of the meander that have been cutoff are then likely to be choked with sediments. Water from the main stream seeps into this meander and forms Oxbow lakes.

1.3.7 Alluvial fans

Alluvial fans are deposits of sediments with. surface resembling a segment of a cone, fan shaped in plan, and having a relatively uniform slope from apex to toe. They occur at the point where a stream emerges from a confined valley and can spread latterly or where the slope abruptly flatters.

1.3.8 Natural levees

River levees are formed by deposition of sediments when flood water overtop the river bank. Natural levees can be identified by examining a cross-section of a flood plain extending beyond the river bank. Well-developed natural levees tend to restrict the gradual lateral shift of the channel, but sudden relocations of levee bounded channels do occur when flood discharges break through the natural levees. So, it can be said that the levee-bound channels carry a relatively high percentage of wash load, suspended load, and frequent bankful flows, and the vegetation on both banks may be favourable to the formation of natural levees.

1.3.9 Pattern of Vegetation:

Vegetal growth in a river basin is one of the most important indicator of the river bank's resistance to flow. Vegetal growth is an important consideration in evaluating morphological properties. Vegetal growth depends upon the amount of rainfall, the climate, and the soil characteristics of the basin. The amount of vegetal growth, the kind of vegetation, and the pattern of growth are important factors in evaluating the overall effect of vegetation on water shed and river behaviour. The pattern of vegetal growth also indicates the past behaviour of the river. A growth of vegetation may serve to confine the stream between otherwise erodible banks.

1.4 Remote Sensing Techniques

For the study of river channel characteristics detailed maps depicting extent of flood plains and water features are required. Such studies help in detecting the change in the terrain condition, land cover etc. due to various developmental activities. The conventional approach to collect such informations has been ground based surveys which is both uneconomical and time consuming.

Remotely sensed data from aircraft platform or space orbital altitude provide an unique advantage in synoptic view and study of the dynamics of the river. Aerial photography for studying river characteristics has certain limitations. Aerial photography is expensive, since the required repetitive information is much more costilier and also poor weather conditions limit the effectiveness of this approach.

Remote sensing technique through satellite has an edge over other techniques. This technique has shown great promise to delineate river characteristics in a time and cost effective manner. One of the great advantages of the satellite image is that it widely covers a synoptic view (e.g. Landsat covers 185 x 185 Kms, IRS-1A covers 148.48 x 148.48 Kms and SPOT covers 60 x 60 Kms. in one frame) and presents an excellent opportunity for the study of terrestrial features on a regional scale. The continuity of such study is possible for the adjacent areas or of the same area on different dates because the successive imagery of the same region have been taken under similiar conditions.

In Remote Sensing Satellite imagery cloud cover can completely mask the terrestrial features. During the monsoon season from June to September most of the area of the Gangetic basin is covered with clouds during above mentioned season. Thus the identification of the flood plain features will almost be impossible. This puts limit to the utilization of the Remote Sensing Satellite imagery for the flood period. Therefore, in general, the available imagery partains to preflood and post flood period. The flooding leaves a mark on the land and certain flood features can be identified in the post-flood period. Hence the study of Remote Sensing Satellite imagery taken in the post flood period can lead to the identification of the inundated areas and other features of flood plain.

2.0 REVIEW

Two basic approaches to flood plain delineation have been described by sollers et al (1978). In the dynamic approach, historical evidence of flooding is used to delineate the extent of inundation. It takes advantage of the fact that visible evidence of inundation in the near infrared region of the spectrum remains for upto some time after the flood. The distinctive changes induced by additional water in an area include increased soil moisture, moisture stressed vegetation, and standing water etc. The dynamic approach to flood plain delineation does have a very significant drawback, however. If the flood events of interest have not occured during the period of study, there will be no information. In the static approach to flood plain delineation, indicators of flood susceptibility are used. Delineation of flood plains using the static approach and remotely sensed data is based on the identification of indicators through their multispectral response and the spatial pattern of these responses. The indicators that can be defined using landsat data are seen in Table 1 (Landsat flood plain indicators by Range and Andesson, 1974).

TABLE : 1

Flood Plain Indicators

a. Upland physiograph

b. Watershed Characteristics such as shape, dranage density etc.

c. Degree of abandonment of natural levees

d. Occurence of Stabilized sand curves on river terraces

e. Channel configuration and fluvial geomorphic characteristics

f. Back swamp areas

g. Soil moisture availability

h. Soil differences

i. Vegetation differences

j. Land use boundaries

k. Agricultural development

l. Flood alleviation measures on the flood plain

Aerial photography is especially useful when it is possible to obtain a series of successive photographs during the flooding and recesion period (Usachev, 1972). The main difficulty in using aerial photographs for the estimation of flood plain inundation is the determination on water boundaries in places covered by bushes and forest. In most cases the colour (tone) of the photograph indicates the direction of water movement over the flood plain (usachev, 1983).

The flood plain delineation was improved using air craft multi-spectral data and using natural indicators such as vegetation types, soil types, moisture differences and geologic variation. Remote Sensing delineations flood plains using aircraft data have proven successful because of capability of detection of various natural artificial indicators - (Bugress, 1967).

Air borne multispectral data has also been used for flood plain mapping by many researchers. It has been reported that a continuous flood plain boundary could not be delineated on the basis of computer analysis of the airborne MSS data. However, the computer anlysis indicates a break between flood plain and non-flood plain within small areas (Sollers, et al., 1978).

Flood assessment on small watershed must generally be done using high resolution, colour infrared photographs such as available from U-2. Such imagery provide the needed resolution for mapping inundated areas (Hasker, 1974).

A number of studies have been made in India as well. Usually, aerial photographs of 1:30,000 to 1:60,000 are used. Bhattacharya and Mankhaned (1979) have delineated geomorphic units in the flood plains of Ganga-Gomti in Azamrgarh and Ghazipur districts in Uttar Pradesh. Chopra (1980) had delineated an abandoned meander belt close to the Ranga river in district Lakhimpur, Assam.

Sollers et al. (1978) used both aircraft and Landsat multispectral data to delineate the flood plain for a watershed in Penusylvania. They found that it was easier to use the Landsat data because of the problems of data reduction involved with the aircraft data, the best indicator was the flood plain soils.

Rango and Anderson (1974) examined the potential of landsat imagery for flood plain delineation by using images of an areas of the Mississippi River obtained before flooding that occured in 1977. They used 1:1000,000 scale images, and successfully delineated the boundaries of the area's artificial levee systems, soil differences, agricultural and vegetation patterns, upland boundaries and special flood alleviation measures in urban areas.

The flood in the Indus Valley of Pakistan in Aug.-Sept. 1973 has been one of the largest flood on record. Landsat data made it possible to easily measure the extent of flooding. Encouraging results of this flood mapping endeavour resulted experimentation in the development of rapid, accurate and inexpensive optical techniques of flood mapping by satellite in 1973 for the Mississippi floods (Deusch and Ruggles, 1978).

Kurus et. al. (1979) illustrated various techniques that could be used to obtain information related to floods from satellite imagery. Multistage sampling uses landsat images and aerial photography at various scales to outline flood damage, from regional scale to single field. Multispectral composites may be made to enhance features such as standing water or flood plain indicators for measurement.

Remotely sensed data for flood plain mapping have been used in India by various investigators. Dhanju (1970) made visual interpretation of Kosi river flood plain with Landsat imagery. In 1979 Dhanju delineated flood plain features of the Ganga Basin by visual interpretation of Landsat imagery.

Multistage remote sensing data has been used to study the flooded coastal areas of Andhra Pradesh during November, 1977 by Narain and Patil (1980). Diazo colour composite and black and white paper prints were used for delineations employing visual interpretations. Chaturvedi (1983) delineated the flood inundated areas in parts of southern and eastern Uttar Pradesh during the peak floods of September, 1982 on the basis of sharp tonal contrast between the water spread and the adjacent areas. It has been possible to delineated areas from where the water had just receded.

Sharma et al. (1985) visually analysed the band-7(IR) of Landsat for mapping flood plains and allied features in the Ganges river between Allahabad (UP) to Chapra (Bihar). The features were identified in the 1:250,000 scale enlargement of band-7 imagery.

3.0 STATEMENT OF THE PROBLEM

The Ganga, snow fed Himalayan river and heavily laden with detritus, flows slugishly west to east. The average gradient is 9.5 cm per km in the region, slowing down to 6 cm in Bihar. The Ganga banks are infested with stable and high levees interplaced with Kankar, gravel and other resistant rock reefs as at the site of Mir zapur and Varanasi. As such, the Southern bank is relatively more permanent than the Northern one.

Ganga basin from Allahabad to Buxar has been chosen for the study of characteristics of river Ganga using remotely sensed data. The objective of the study is to prepare a detailed map at 1:250,000 showing changes in river course with time. The visual interpretation of landsat imagery is potentially the most useful remote sensing tool for the study of channel migration and water logging conditions at different time spans. Using visual interpretation the shift in river course is to be carried out with respect to topographical map. Also this study has been undertaken to map various flood plain features. An attempt to map water logged area and salt affeçted area is made in this study.

4.0 DESCRIPTION OF STUDY AREA

4.1 LOCATION AND EXTENT

Ganga river reach between Allahabad (UP) and Buxar (Bihar) taken up for study lies in middle Gangetic is the plain and extending between east longitudes 81°45' to 84° and north Latitudes 25° to 26°.

Ganga river system consists of the river Ganga & its numerous tributaries. In its initial stage, upto Devaprayag, the river is known as Bhagirathi. At Devaparyag, another hilly stream the Alaknanda joins it, from this point. the combined stream is known as Ganga. Beyond Haridwar, the river flows over the fertile plains of Uttar Pradesh and receives the Ramganga before touching Allahabad. At Allahabad, it is joined by the river Yamuna on its right bank. After Allahabad, the river sweeps for another 245 Km to Varanasi, it receives the Tons from the South. The Gomti joins it immediately below Varanasi. The Ganga enters Bihar in the middle region 155 km from Varanasi.

4.2 Geology

Structurally the region is a segment of the great Indo-Ganga trough. An almost imperceptible change in elevation and uniform surface materials are the two note-worthy features in the physiognomy of the region. Alluviam is compared to unconsolidated beds of clay, sand, gravel and their mixure in varying portion.

4.3 Physiography

It is difficult to divide the region into physical subunits on any prominant foundation of relief, except through the help of the river systems which generally curve out somewhat interdistinguishable relief and slope.

The micro level topographic facts and their regional characteristics render possible the delineation of following physiographic units ie (i) the Ganga Ghaghara Doab region (ii) Ganga-Yamuna Doab and (iii) the Yamuna par in the ravine tract.

4.4 Drainage

The region in general is a part of the well integrated drainage system of the Ganga. The extremely gentle gradient almost all over the region, restricts the degradational activities with their master streams at most levels. The Ganga and its major tributaries the Yamuna, and the Ghaghara are the only Himalayan rivers which carry sufficient water all the year round. Wide flood plains and high banks are the common features in the course of the Ganga and Yamuna along with silt and clay deposits.

The drainage pattern is dendritic in general, and the general characteristic feature available throughout the plains is that the rivers meet at acute angles, and several tributaries form parallel or subparallel lines to the main streams.

4.5 Agriculture and Natural Vegetation:

Originally this region was covered with thick forest with a moderate rainfall and fertile soil the region is a natural habitat of a dense forest cover of soil and other species Shisham, Jamun, ber, babul, semal, khair etc. The forests can be grouped as tropical moist deciduous, tropical wet and subtropical dry. Tropical moist decidous forests are confined to the Tarai areas.

The regional economy is dominated by agriculture which together with the allied activities forms the most important source of employment & revenue. This region is one of the highly irrigated agricultural regions of India and irrigation has played a dominant role in boosting its agriculture properity. In general, the proportion of the net sown area to the total area is about 65-70%, with the increasing use of the high yielding varieties of seeds and modern techniques of production and growing facilities for irrigation etc. intensive cropping is being increasingly adopted in the area. The main crops being adopted in the area are wheat, rice, mai æ, cotton, sugarcane barley etc.

4.6 Climate

The average weather conditions emerging out of the combined affect of the various elements lead to the recognition of four well marked seasons i.e. the hot summer, the wet summer, the pre-winter transition and the winter. The gradual rise in temperature which starts from February, becomes more rapid incrasing by 5°C by March and Continues till May/June (Max. temp. over 40°C). The scorching effects of 100 are aggrevated due to the lower relative humidity (below 40%).

The principal rainy season for the area is from June to September which accounts from 80 to 95% of the annual rainfall. July & August are the rainiest months of the year and generally responsible for flood in the area during the S-W monsoon. The normal monthly and annual rainfall is presented in Fig. 1.

During the monsoon season from June to Sept. most of the area of the Gangetic basin is covered with clouds almost all time and so identification of the flood plain features will almost be impossible. If the clud coverage is more than 30% the imagery may not be of practical use at all. The flooding leaves a marks on the Land and certain flood related features can be identified in the post-flood period. In the present case, imageries of December month are taken for analysis.

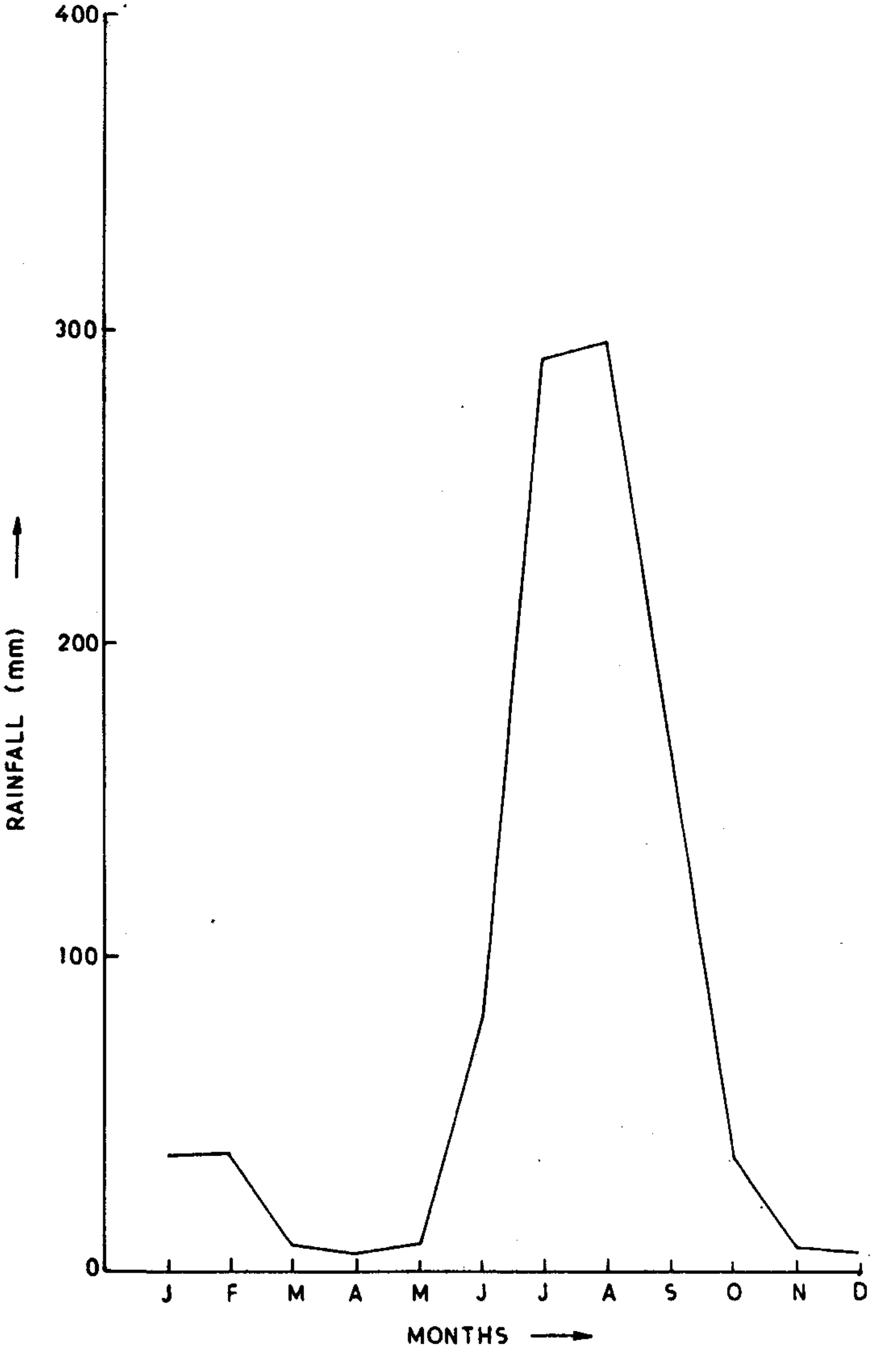

FIG. 1- NORMAL MONTHLY AND ANNUAL RAINFALL

5.0 DATA USED

In the present study landsat MSS imagery together with survey of India toposheets were used. Other reference material on the subject has also been used.

5.1 Landsat Imagery

Imagery of 1981-82 were used at IIRS Dehradun, while that of year 1987 available at the Institute were used for interpretation. An Index for landsat coverage is presented in Figure 2. A brief description of Landsat data products used is given in table 2.

Table 2 : Description of Landsat Data

Sl.No.	Path & Row No.	Date	Satellite	Sensor	Data-type
1.	152 - 042	31.12.81	L3	MSS	Band 7
2.	153 - 043	6.2.82	L3	MSS	RCC 1,2,4
3.	142 - 042	20.12.87	L5	TM	FCC 2,3,4
4.	142 - 043	20.12.87	L5	TM	FCC 2,3,4
5.	143 - 042	27.12.87	L5	TM	FCC 2,3,4
6.	143 - 043	27.12.87	L5	TM	FCC 2,3,4

5.2 Toposheets

For the present study three topographical maps at the scale of 1:250,000 have been used. A suitable base map of the study area was prepared from the toposheets. The specification of the used topographical maps are given below, while their topographical layout is shown in fig. 3.

Table 3 : Description of Topographic Maps

Sheet No.	Edition and Year	Last Survey Year
636	Second, 1977	1972 - 74
63K	Second, 1976	1970 - 73
630	Second, 1978	1963-64, 1968-70 1972-74, 1975-76

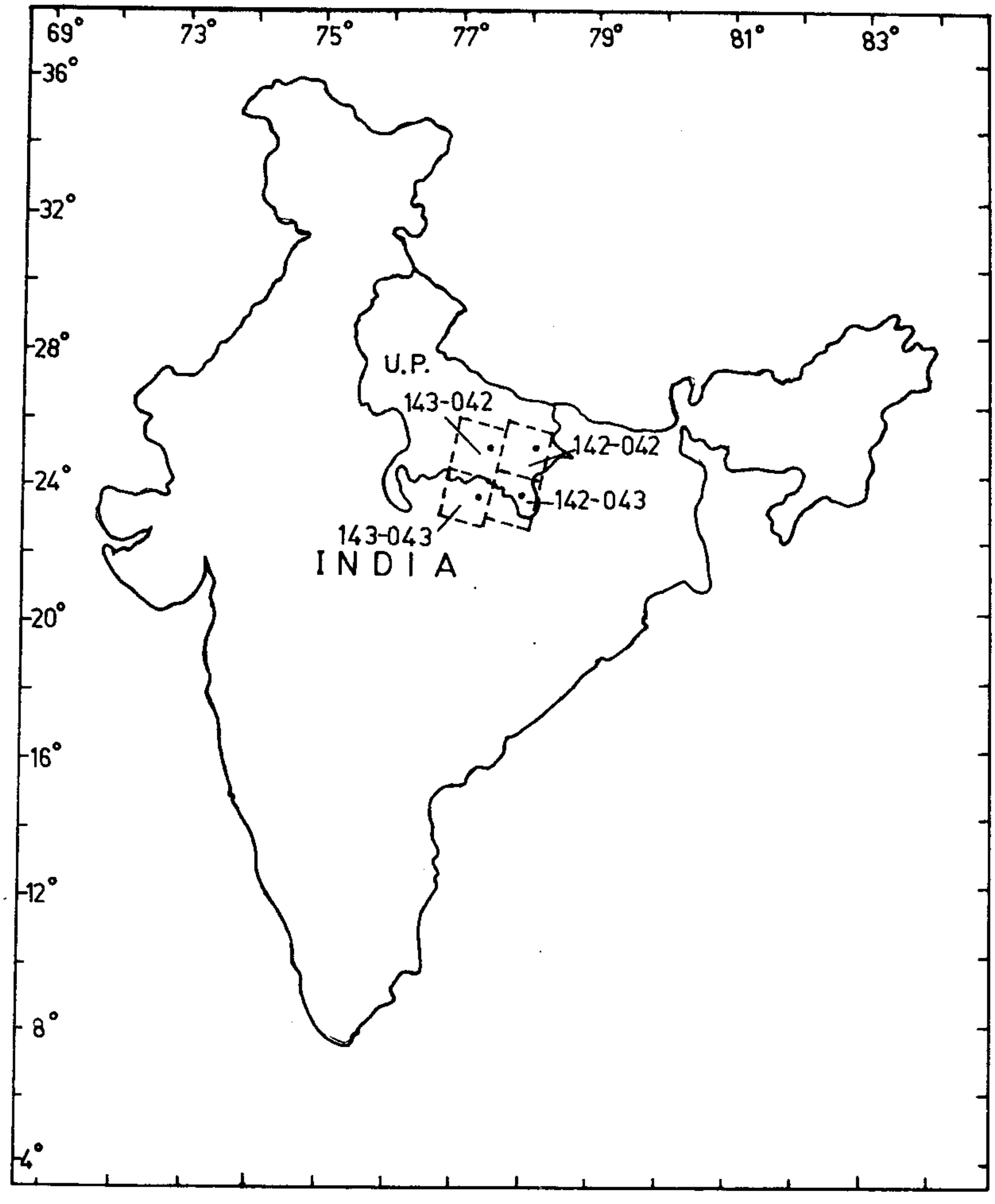

FIG. 2 IMAGE INDEX OF LANDSAT 5

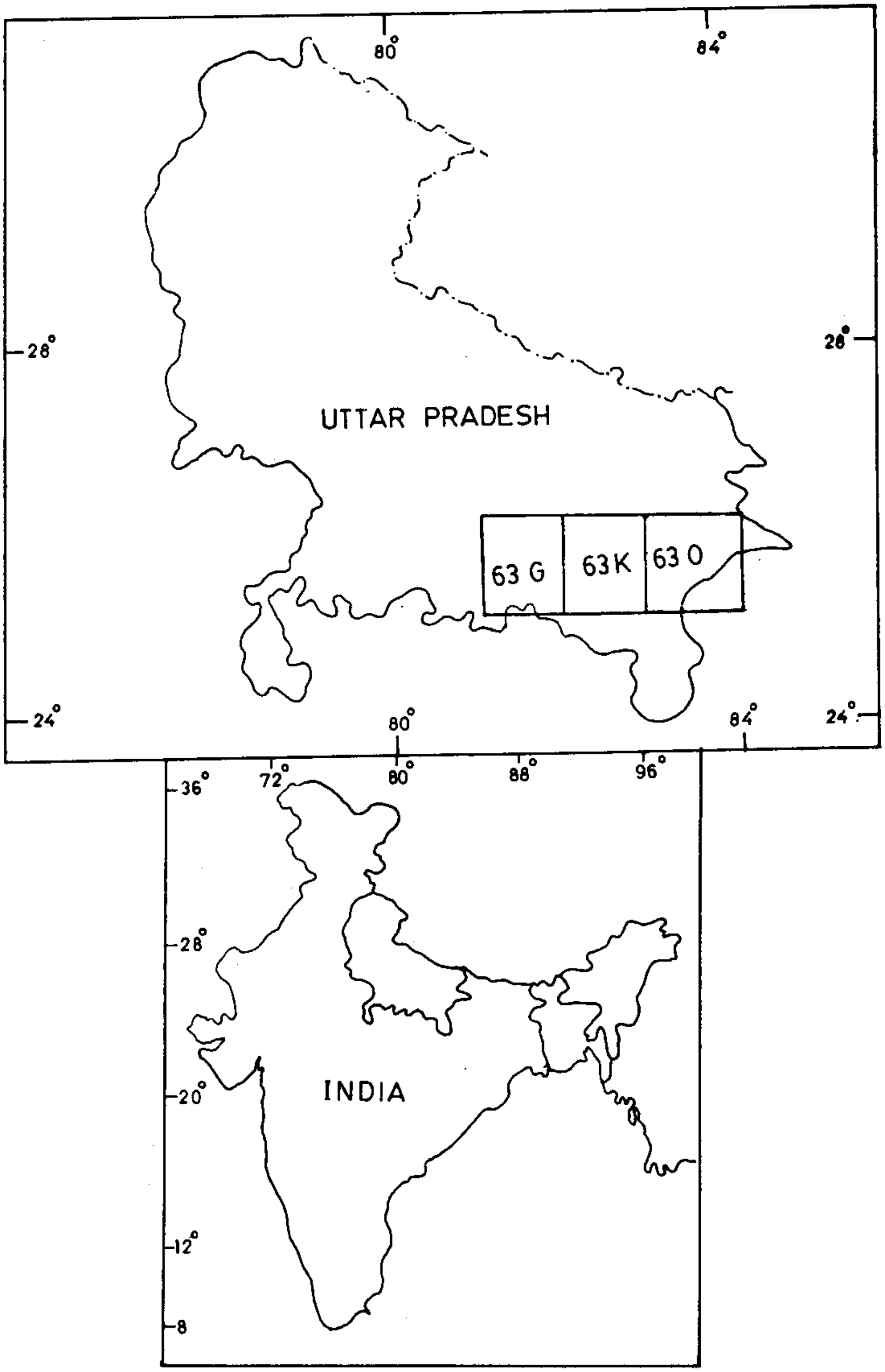

FIG.3 TOPOSHEET INDEX

6.0 METHODOLOGY

For the present study visual interpretation technique was employed to delineate various characteristics of river Ganga. In visual interpretation tone texture variation forms the basis of identification. For each of feature described, various parameters are described by which it can be identified in Landsat imagery. The interpretation key used for identification of various features is given in table 4.

Three topographical map sheets at a scale of 1:250,000 were compiled into one map. The base map was compiled taking in view the main objectives:

(i) To determine the shifting of the river channel.

(ii) To determine the areal shift of the channel.

(iii) To plot the logitudinal profile of the Ganga river.

The details shown on the base map (fig. 4) were rivers, streams, water bodies, sandy areas, railway lines & roadways.

The maps for year 1981-82 and 1987 were studied for detecting any change during the study period. A change in river course was measured from offsets from a line parallel to line joining Allahabad and Buxar.

Table 4 : Interpretation Key for Identification of Flood-plain Features

Item	Description
Stream/Water bodies	Dark blue with smooth texture and strectching continuity
Sandy areas	White
Barren/Salt-affected areas	White to greyish white
Waterlogged area	Dark tone smooth or coarse texture, shape and si æ generally irregular and patchy

Table 4 Contd....

Low lying areas	Areas with dark tone indicating high moisture content in soil
Oxbow Lake	Dark tone, smooth texture blow type shape

7.0 ANALYSIS AND RESULTS:

The maps showing different riverine features have been prepared on the basis of visual interpretation of Landsat MSS imageries of year 1981-82 and Landsat TM imageries of 1987. A base map is prepared using Survey of India Toposheets (fig. 4). The map prepared from imageries of year 1981-82 is presented in fig. 5 while map prepared from imageries of year 1987 is shown in fig. 6. These maps prepared from landsat imageries and toposheets were superimposed to measure the lateral changes in river course. To study the changes in flow pattern of main channel of river Ganga, a reference line was drawn on both the topographical map and the maps prepared from landsat imageries.

Offsets at fixed interval of both the river banks were measured on the topographical maps as well as on the maps prepared from landsat imageries. From these measurements, the respective shifts of both the left and the right banks were computed. Assuming that the mid channel lies at the mean position of both the banks. The shift of mid channel was computed by taking the mean of shifts of both the banks. The shift of banks and the mid channel is given in table 5. The plus sign indicates the displacement towards north. The shifting in left bank and right bank is pictorically represented in fig. 7 and fig. 8 respectively. The shifting in mid channels is shown in fig.9.

It is observed that max. shifting in mid channel is 4.55 km. whereas max. left and right bank shiftings are 4.6 km. and 4.8 km. respectively. The areal extent of various flood plain features was also determined. On the basis of interpretation of TM imagery of year 1987, the salt affected areas computed is 382.82 sq. kms. while water logged area computed is 162.25 sq. kms.

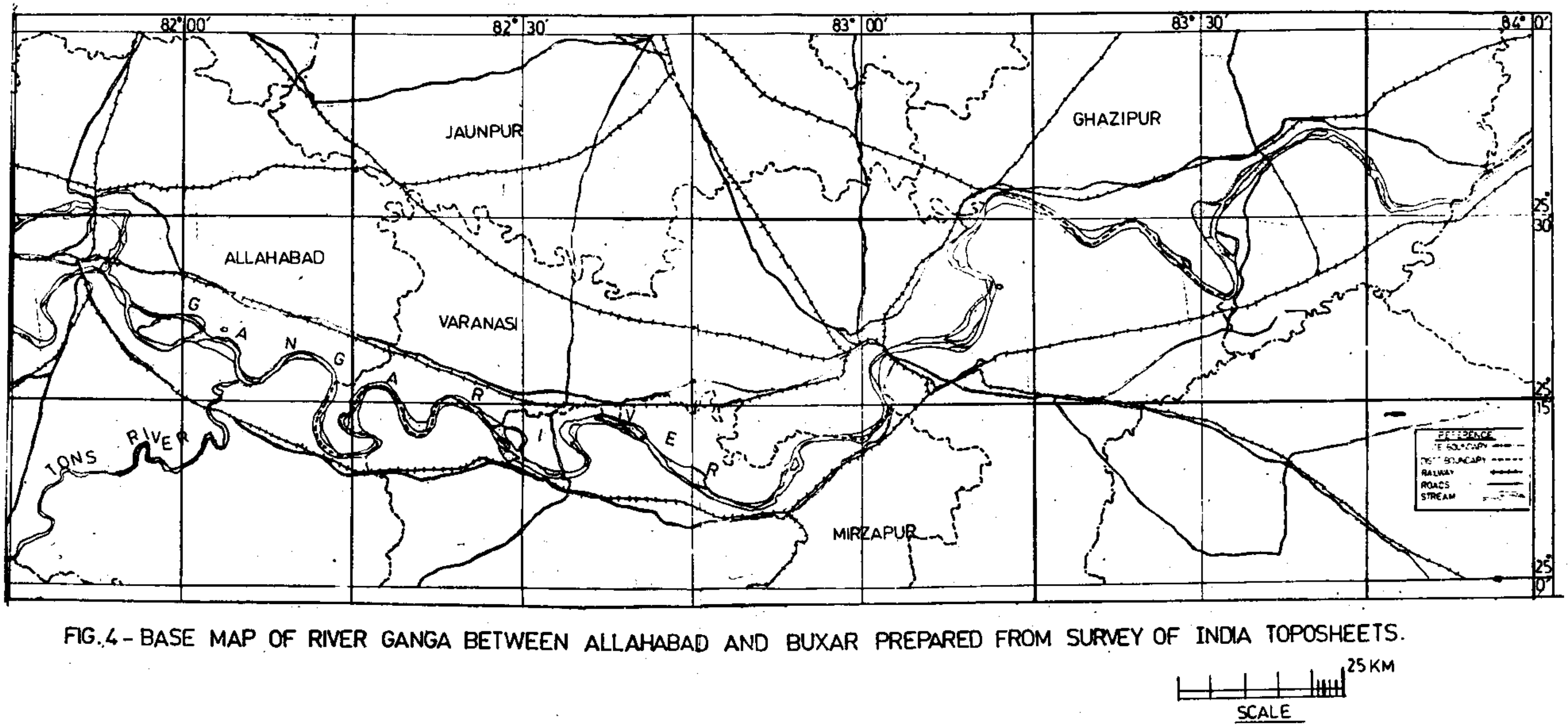

FIG. 4 - BASE MAP OF RIVER GANGA BETWEEN ALLAHABAD AND BUXAR PREPARED FROM SURVEY OF INDIA TOPOSHEETS.

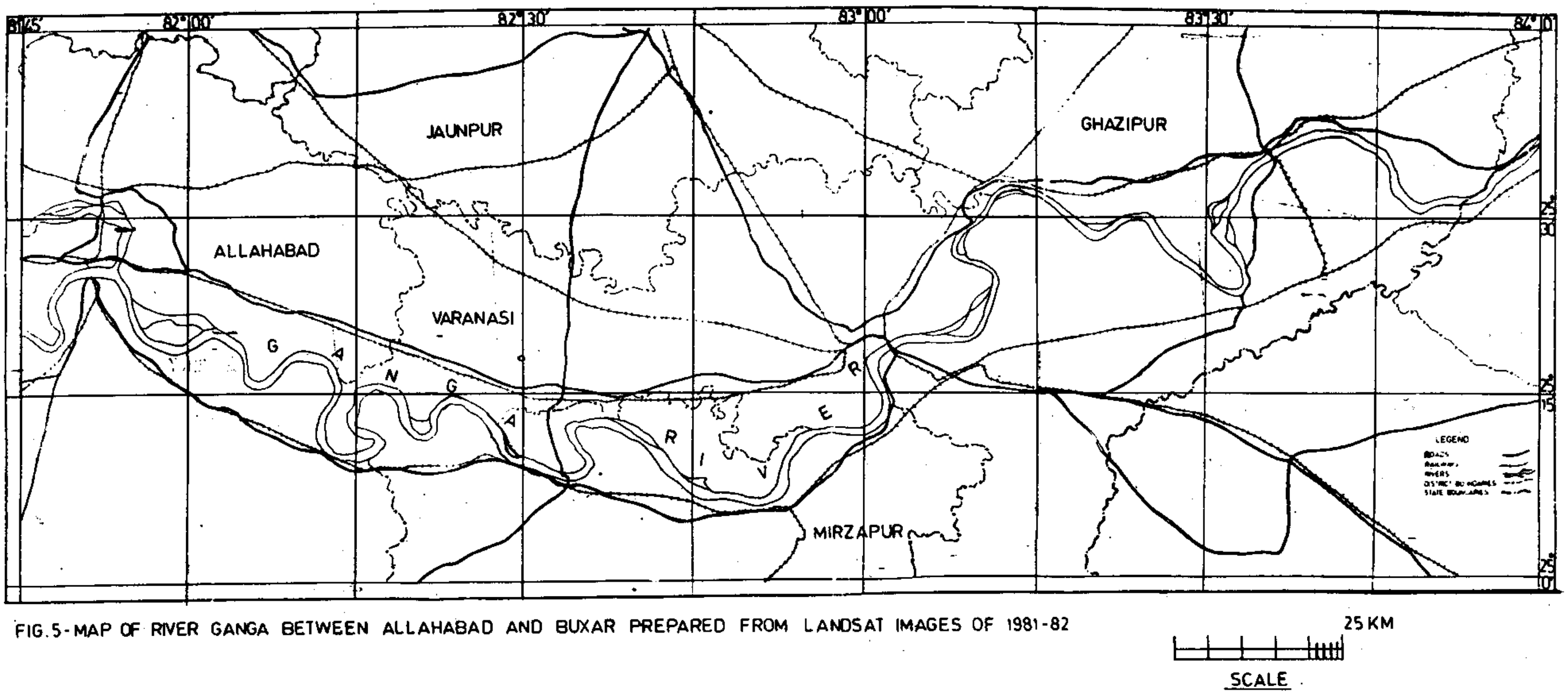

FIG.5-MAP OF RIVER GANGA BETWEEN ALLAHABAD AND BUXAR PREPARED FROM LANDSAT IMAGES OF 1981-82

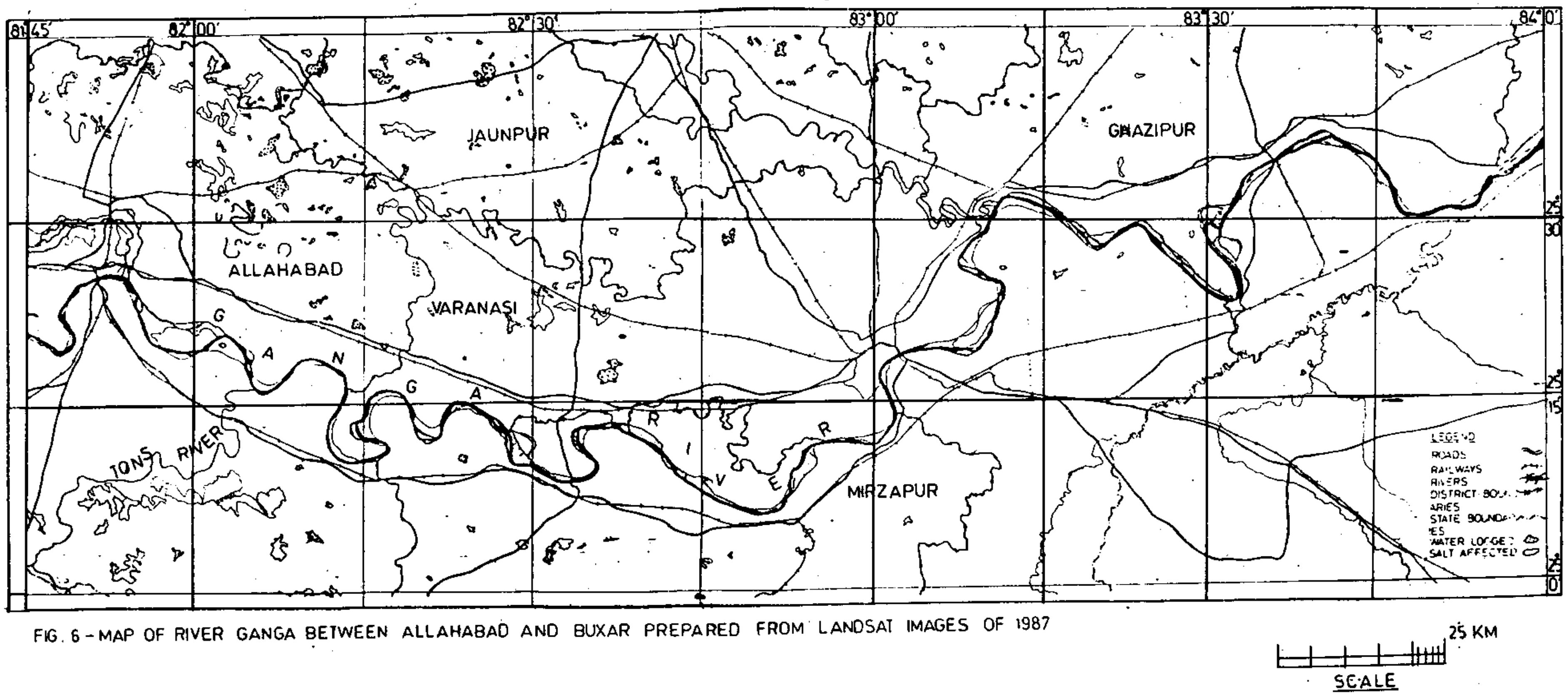

FIG. 6 - MAP OF RIVER GANGA BETWEEN ALLAHABAD AND BUXAR PREPARED FROM LANDSAT IMAGES OF 1987

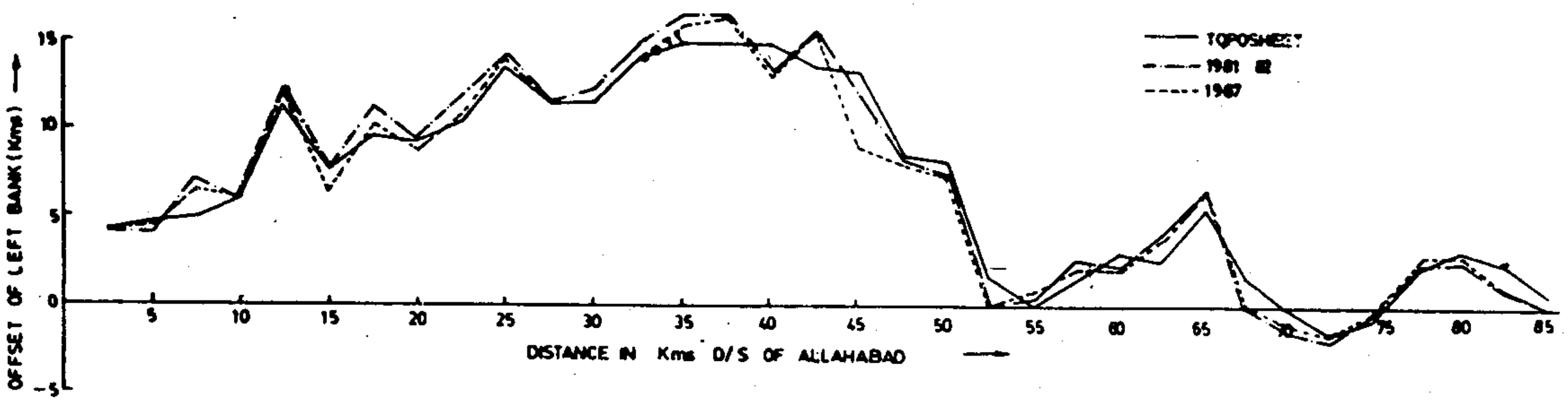

FIG. 7 - SHIFTING OF LEFT BANK

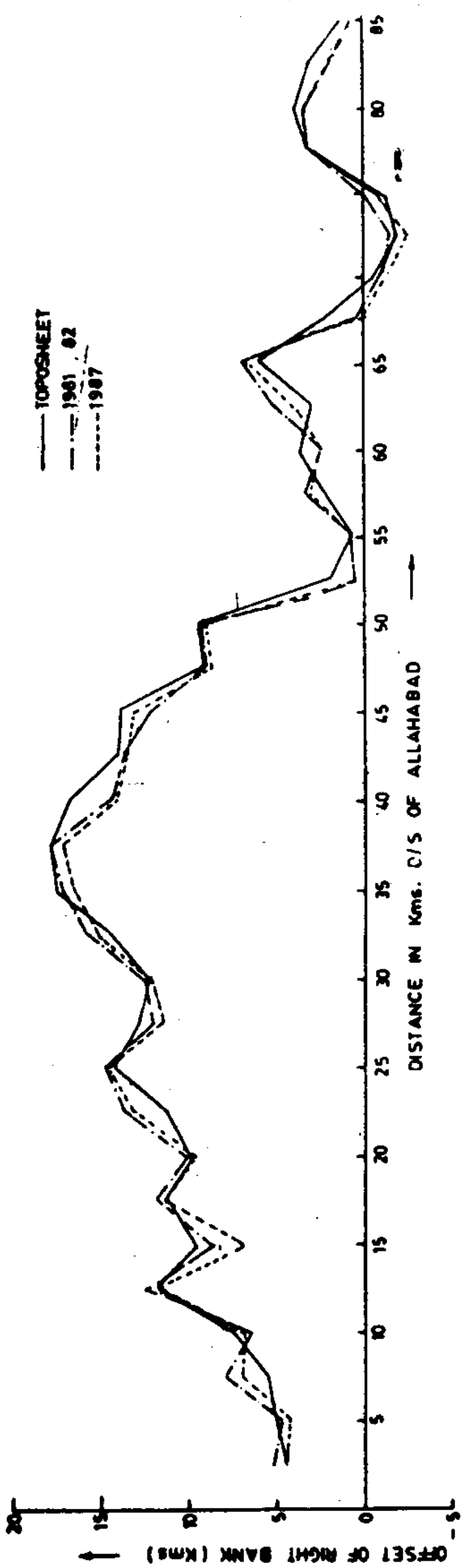

FIG. 8 - SHIFTING OF RIGHT BANK

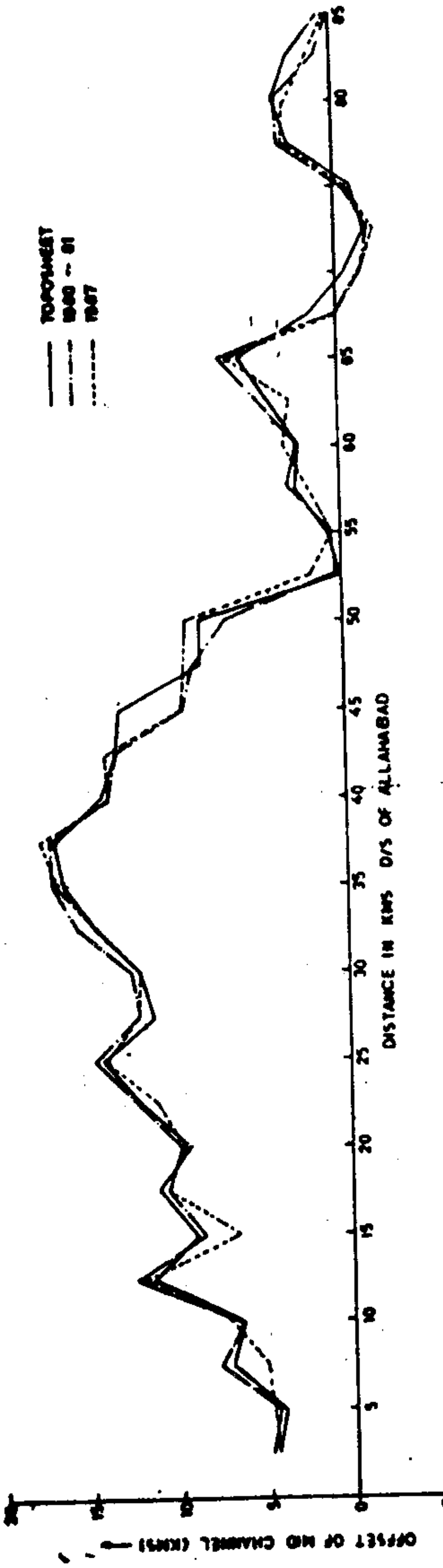

FIG. 9 - SHIFTING OF MID CHANNEL

TABLE - 5

SHIFTING IN RIVER BETWEEN ALLAHABAD AND BUXAR

istance rom Allahabad in (Km.)	Offset to left bank from reference line: Topesheet	1981-82	1987	Offset to right bank from reference line: Topesheet	1981-82	1987	Offset to mid channel from reference line: Toposheet	1981-82	1987	Shifting with respect to Toposheet 1981-82: LB	RB	Mc	1987: LB	RB	Mc
2.5	4.3	4.5	4.3	4.7	5.2	4.7	4.50	4.85	4.5	0.2	.5	.35	0.0	0.0	0.0
5.0	4.5	4.1	4.2	5.0	4.9	4.6	4.80	4.5	4.4	-0.4	-.1	-.3	-0.3	-0.4	0.45
7.5	4.9	7.1	6.5	5.3	7.9	7.50	5.1	7.50	7.0	2.2	2.5	2.4	1.6	2.2	-1.9
10.0	6.6	6.1	6.0	7.4	6.6	6.90	7.0	6.35	6.2	-.50	-.80	-.65	-0.6	-0.5	1.0
12.50	11.3	12.1	11.8	11.8	12.50	12.1	11.55	12.3	11.95	.8	.7	.75	+.5	0.3	+.40
15.00	8.4	8.2	6.4	9.50	8.6	6.80	8.95	8.4	6.6	-.2	-.9	-.55	-2.0	-2.7	-2.35
17.50	9.6	11.4	10.8	11.3	11.8	11.4	10.45	11.6	10.90	1.8	-5	-1.15	+1.2	0.10	-0.45
20.00	9.3	9.4	9.1	9.9	10.0	9.6	9.6	9.7	9.35	.1	.1	.1	-.2	-0.30	0.25
22.50	10.6	11.9	11.00	11.3	13.50	13.0	10.85	12.70	12.0	1.3	2.2	1.55	.4	1.70	-1.15
25.00	13.6	14.1	14.1	14.2	14.6	14.45	13.90	14.35	14.27	.5	+.4	.45	.5	.25	-.37
27.50	11.4	11.5	11.0	13.0	12.0	11.50	12.20	11.75	11.25	.1	-1.0	-.45	+.4	-1.5	0.95
30.00	11.6	12.4	11.4	12.2	12.80	12.20	11.90	12.6	11.80	.8	.6	.7	-.2	0	0.1
32.50	14.0	15.0	14.2	14.8	15.8	14.80	14.40	15.4	14.50	1.0	+1.0	1.0	.2	0	-0.1
35.00	15.2	16.5	16.2	17.6	16.9	16.5	16.40	16.70	16.35	1.3	-.4	.3	1.00	-1.1	.05
37.50	17.4	16.5	16.7	18.0	17.5	17.10	17.70	17.00	16.90	-.9	-.5	-.70	-.70	-0.9	.8
40.00	15.1	13.4	13.4	16.7	14.2	13.80	15.90	13.80	13.6	-1.7	-2.5	-2.1	-1.7	-2.9	1.8
42.50	13.6	13.3	13.1	14.0	13.7	13.50	13.80	13.50	13.3	-.3	-.3	-.3	-0.5	-0.5	0.6
45.00	13.3	9.0	8.8	14.0	9.4	9.2	13.65	9.2	9.1	-4.3	-4.6	-4.25	-4.5	-4.8	-4.55
47.50	8.6	8.2	8.0	9.2	8.70	8.4	8.90	8.45	8.2	-.4	-.50	-.45	-0.6	-.80	0.7
50.00	8.4	8.6	7.30	9.5	8.90	9.0	8.95	8.75	8.15	.2	-.6	-.20	-1.1	.5	0.8
52.50	1.5	0.00	0.00	2.1	0.40	0.0	1.80	0.20	0.0	-1.5	-1.7	-1.6	-1.50	-2.1	.8
55.00	0.0	0.50	0.60	0.7	0.90	1.1	0.35	0.70	0.85	.5	.2	.35	.60	.4	-.50
57.50	1.5	2.6	2.1	2.2	3.3	3.1	1.85	2.95	2.6	1.1	1.1	1.10	.6	.9	-.75
60.00	3.0	2.2	2.2	3.6	2.6	2.6	3.30	2.4	2.40	-.8	-1.0	-.7	-0.8	-1.0	0.9
62.50	2.4	4.2	3.5	3.0	5.0	4.2	2.70	4.6	3.85	-1.8	2.0	-1.9	1.1	1.2	-1.15
65.00	5.5	6.8	6.40	6.0	7.0	6.90	5.75	6.90	6.65	1.3	1.0	1.15	0.9	0.9	-0.9
67.50	1.5	-0.2	0.00	2.2	0.30	0.0	1.85	0.05	0.0	-1.7	-1.9	-1.8	-1.5	-2.2	1.85
70.00	-0.2	-1.6	-1.0	-0.7	-0.90	-1.40	-.45	-1.25	-1.20	-1.4	-0.2	-.80	-0.8	-.7	0.75
72.50	-1.5	-2.0	-1.6	-2.0	-1.6	-2.60	-1.75	-1.8	-2.1	-.5	.4	-.05	-.1	-0.6	0.35
75.00	-0.7	-0.6	-0.1	-1.5	0.0	-1.1	-1.1	-0.3	-0.6	.1	1.5	-.8	0.6	0.4	-0.5
77.50	2.00	2.70	3.0	3.20	3.0	3.20	2.6	2.85	3.1	.7	-.2	-.25	1.0	0	-0.5
80.00	3.20	2.60	2.9	3.70	3.0	3.30	3.25	2.80	3.1	-.6	-.7	-.45	-.30	-.04	0.35
82.50	2.60	1.00	1.30	3.00	1.70	1.80	2.75	1.35	1.55	-1.5	-1.3	-1.4	-1.20	-1.2	.2
85.00	0.3	0.00	0.0	1.1	0.00	0.60	0.7	0.00	0.30	-.30	-1.1	-.7	-.30	-.5	0.7

8.0 CONCLUSION

Remote sensing technique for the characteristics of river Ganga was applied, using MSS and TM Landsat data. On the basis of study it is concluded that temporal imagery could provide the information about the change occured during the period. It is also obvious that flood related interpretation could be improved by taking both preflood and post flood data.

In the study area large meandering of river is clearly seen. There is sudden change in flow direction from West-East to nearly South-North upto Varanasi. Corresponding to those, the shifts in the banks are not much. Reason for, this situation may be that the terrain is hilly on the right bank restricting expansion of flood plain on the right side. The shifts of river banks were measured with respect to topographical map. Maximum channel shifting with respect to topographical map for 1981-82 imagery was about 4.6 kms while for 1987 imagery was about 4.8 kms. It is difficult to calculated the annual shift as the topographical maps taken for analysis are of different survey year. On the basis of interpretation of TM imagery of year 1987, the salt affected areas computed is 382,82 sq. kms. while water loddged area computed is 16.2.36 sq.kms.

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