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FLOOD PLAIN MAPPING OF RIVER MAHANADI BY REMOTE SENSING APPLICATION

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ABSTRACT

Man has had to live with floods since the very inception of his existance. The impact of floods has been accentuated by ever-increasing activities of man in flood-plains of rivers to meet his requirements of food and fibre. Destruction of property and loss of life from floods continue to increase despite substantial investments on flood protection works. These protection works, mainly structural in nature have failed to keep pace with continued development in flood plains. Therefore, a preferred method of flood damage reduction would be to adjust use and occupancy of flood-plains through management and regulation of uses rather than solely by structural works.

The first step in this effort is to map the flood-plain boundaries and other associated features of major rivers which are subjected to frequent flooding. Such a mapping by conventional method is a time consuming and expensive procedure. Remote sensing techniques especially after the advent of satellites have shown great promise to delineate flood-plain features and inundated areas in a time and cost effective manner.

This report describes procedures and results of flood-plain delineation in Mahanadi river basin using Landsat data. The area of study extends from downstream of Hirakud dam to the point river meets Bay of Bengal. Flood-plain boundary and other features such as streams, river levees, abandoned channels, sediment deposite etc. were delineated and depicted on a 1:250,000 scale base map.

1.0 INTRODUCTION

Floods are a fact of life. Man has had to live with floods since the very inception of his existance on the earth. The impact of floods was not perhaps felt to the same extent in the past as is felt now, due to the much smaller number of people inhabiting the land and lesser pressure of industrial activities and other developmental works in the flood plains. Indiscriminate encroachment of floodplains by man has further accentuated the problem and many new areas have been exposed to the risk of flood. The traditional approach to reduce flood losses has been rather structural in nature i.e. by constructing flood protection works, flood control reservoirs, levees, dikes etc. But these structural measures have failed to keep pace with continued developments in flood plains. Flood losses continue to rise despite heavy investments in the construction of protection works. The another approach to the management of flood hazards is to take up measures that would reduce the susceptibility to flood damage by integrating land management techniques, such as restricted occupancy of flood plains, with the traditional tools and strategies, such as civil works. This would, however, require detailed information about extent of floodplains and other associated features.

1.1 Floodplain

In a classical concept a river system is said to have three stages of maturity. The young stage of the river occurs in the beginning of the river system where smaller streams and tributaries join the river. In this stage, erosional activities are predominant. The mature stage of the river is characterised by the formation of the flood plain and sediment deposites. The old stage of a river occurs in the coastal region. Here, flood-plains meet together and become delta plains.

The flood plain is an area adjoining a river, stream or other water course which gets flooded during periods of high water when stream flow exceeds the carrying capacity to normal channel. It results from the deposition of sediments transported by the stream during the process of river bed deformation.

Natural floodplains provide a temporary storage for attenuting floods significantly. They generally provide excellent areas for aquacultural, agricultural and forestry production, are pleasing settings for homes, and provide excellent transportation corridors that make them attractive for intense human activities. Due to the encroachments, capacity of flood plains to store water temporarily gets reduced which results in increased flood peaks downstream necessitating expenditures for protection works.

1.2 Flood Plain Features

Mapping of flood plains of a river system is based on the identification of various features connected with floodplains. These features are: river course, drainage pattern, alluvial fans, oxbow lakes, marsh areas and back swamps, point bar deposites, river levees and flood plain deposites.

deposites.

1.2.1 River course

Three distint patterns of river course are identified viz; (i) braided stream (ii) straight stream and (iii) meandring stream. A braided stream can be defined as one which flows in two or more channels around alluvial islands. Braided pattern develops after local deposition of coarser material which can not be transported under local conditions existing in the reach. Straight reach is rarely found in streams over large lengths. Rivers flowing through alluvial material follow a zigzag path. This phenomenon is known as meandring. These streams follow a more or less sinusoidal path.

1.2.2 Drainage pattern

The pattern may be defined as the arrangement of surface drainage ways and shallow subsurface drainage ways covering an area, in the complete details of their density, orientation, uniformity and plan etc. the surface drainage pattern is probably the most consistantly reliable indicator of ground conditions available.

1.2.3 Alluvial fans

When there is a reduction either in the discharge or in the slope of an equilibrium stream, the stream can not transport the material carried by it and the excess materials will be deposited. These deposits depending upon the mode of deposition are called as alluvial fans.

1.2.4 Oxbow lakes

As meanders grow, 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 cut off are then likely to be chocked with sediments. Water from the main stream seeps into this meander and forms what is commonly knowns as Oxbow lake.

1.2.5 Marsh areas and backswamps

Low lying areas that get in-undated during floods turn into marshes when floods recede. Sediments of marshes consists of organic clays. Burrows and plains roots are the more features. Backwamps are developed behind the levees when these are overtopped by flood waters.

1.2.6 Poin bar deposits

Bed forms having lengths of the same order as the channel width or greater and heights comparable to the mean depth of flow are known as bars. A bar occuring on the inside of the bed in an alluvial channel is called a point bar.

1.2.7 Floodplain deposites

During the floods, river water rises above the banks and as it moves away from the main current, its velocity is reduced. As a result a large part of the sediment load of the stream gets deposited as the bank line is passed. These deposites are called flood plain deposites.

1.2.8 River levees

River levees are formed by deposition of sediments when flood waters overtop the river bank. The velocity is reduced causing deposition of much of the suspended sediment near the channel. The maximum height of a levee indicates the water level reached during the heighest flood.

1.3 Techniques of Floodplain Mapping

A variety of techniques is available for mapping of floodplains. The appropriateness of a particular technique can be presumably be judged by the extent to which the floodplain information satisfies the objective of the user. Methods of mapping areas subjected to flood can be grouped into six general categories: physiography, pedology, vegetation, occasional flood, regional flood of selected frequency and flood profile and back water curves.

1.3.1 Physiography

The concept of physiographic mapping of areas subject to flood is based on the correlation of specific topographic features with flood discharges of known frequency. Thus the floodplain, often the lowest topographic bench near a river, has been found to lie at an elevation that is overtopped on the order of once every 1 to 2 years. Where successive levels of stepped topography exist, these river terraces or deposits on them may be correlated with particular flood events. Once such a correlation is established large areas of a valley may be mapped with the knowledge that specific topographic levels can be associated with floods of known frequency and elevation. The method will not of course permit distinction of local variations of topography due to scour and erosion.

1.3.2 Soils

Mapping of flood areas by correlation of soil type, stratification of deposites, or drainage characteristics with known flood levels requires the same kind of established relationships as those required for flood zone mapping based on topographic form. In the field, soil characteristics are often associated with topographic features, and hence one might be used to strengthen the other.

1.3.3 Vegetation

Many observers have noted an association of vegetation with presumed flood levels. Specific assemblages of plants may sometimes be correlated with specific water levels. Studies have established a relationship between susceptibility of species of damage and flood deposition and duration of inundation. Such physiological evidence and the distinct age differences in the flood-plain trees produced by destructive floods suggest the possibility of designating maximum flood heights or minimum land elevations subject to flood from associations between flooding and vegetation.

1.3.4 Occasional flood

The designation occasional flood has been given to the establishment of flood lines based on aerial photographs taken during flood events, evidence of floods from historic records, and generalizations of flood heights based on records of observations at a number of locations in a given region. Recent technological advances in the use of remote sensors such as infrared photography, radar, and others are also increasing the possibility of obtaining wide coverage of areas inundated by floods during flood events. Whereas poor weather may inhibit such efforts, carefully laid emergency plans may permit the occasional flood to be mapped over broad areas of both large and small river floodplains.

Maping the occasional flood in the manner described is dependent on the existence of photographs, historical records, and some gauging station records. The accuracy of the mapping is limited not only by the availability of such information but by the accuracy of the maps on which the data are presented. Nevertheless, the method is rapid, and its adoption is evidence of the recognition of the need to accelerate the presentation of available even though fragmentary information.

1.3.5 Regional flood

Experience has shown that in a given physiographic or hydrologic region, flood heights of chosen frequencies may be mapped on a regional basis from records at selected localities. The method is based on observations at stations in the region of the heights above the channel bed attained by floods of different magnitudes. By relating flood heights of different return periods to parameters such as drainage area and mean annual flood discharge, curves can be drawn that permit flood heights to be determined at ungaged sites of known drainage area within the region.

1.3.6 Flood Profile and back-water curve

In this method flood lines are delineated by defining flood profile from high water marks or detailed hydraulic computations. To achieve a high degree of accuracy detailed topographic information is required for the purpose which may be obtained either by engineering ground surveys or by aerial photography combined with ground control.

Table 1 shows a comparison of principles involved, limitations of these methods.

1.4. Remote Sensing Application to Floodplain Mapping

In hydrology,the dynamic processes associated with river flood-plains include the regime of flooding and receding and the boundaries of floods of different magnitudes. Such information is used for the evaluation of damages of properties situated on floodplains. To obtain this information using surface means is both uneconomical and time consuming. Remote sensing can be used with advantage over conventional methods because of its capability to provide broad synoptic and repetitive coverage of the area in multispectral mode. Floodplain mapping methods as described earlier can be improved significantly if one makes use of remotely sensed data. Table 2 shows some of these capabilities for some of the important methods of floodplains mapping.

Table 1 - Technique of Mapping Areas Subject to Flood

Method	Principles	Principal Methodological Drawbacks
Physiographic	Topographic feature correlation flood levels the flood-plain;return period, 1-2 years	Inadequate correlation
		Topographic form and flooding
	Terraces;stepped topography	Omission of backwater effect
Pedologic	Soil development stratification	Distingushing colluvial & alluvial soils;
	Drainage	Terrace soil similarities
		Indistinct association soil and flooding
Vegetaion	Distinctive vegetation assemblages	Inadequate correlation
	Vegetaion form related to high water	Assemblages or species with flooding
	Microvegetaion related to high water	Soil moisture and flood effects undifferentiated
		Plant deformation not co-rrelated with specific flood height
Occasional flood	Aerial photos, remote sensing of floods	Records unavialable
Highest of record	Historic records,recorded flood profiles	Errors in spatial transposition
Major	Regional stage frequency relations	
Recent major	Topography from stereo-scopic air photos	Subtle topographic variation
Regional flood of selected frequency	Regional stage frequency relations	Errors in spatial transposition
	Regional physiographic relations and generalized hydraulic computations	Variability of hydraulic conditions
Flood profile and back water curve	Definition of flood pro-file from high-water marks or detailed hydraulic computations	Detailed topographic in-formation required

Table 2 - Improvements by Remote Sensing Techniques in Some Important Floodplain Mapping Methods

Sl.No.	Method	Possible use of remote sensing techniques
1.	Physiographic	Precise delineation of the occasional flood on imagery may allow a better correlation of physiographic features and flooding. Stereoscopic imagery could be used for extrapolating to other portions of the basin. Imagery of actual inundated area will show the boundaries of back water effect.
2.	Pedologic	Precise delineation of the occasional flood on imagery can provide a better correlation of particular soil series with flood inundation than other methods. Generally, the same soil series will appear in many floodplains in a geographic region allowing extrapolation of data to other river basins. Imagery of actual inundated area will show the boundaries of backwater effect.
3.	Occasional flood	Infrared sensitive sensors provides much better discrimination of inundation, and allows the inundated area to be mapped after recession of flood water. Provides a map view of entire flooded area - not just point data. Imagery shows backwater effect.
4.	Flood profile and backwater curve	Imagery can provide more accurate delineation of the flooded area. Careful planning of the scale of stereoscopic imagery may allow the imagery to be used for engineering data, topographic mapping.

2.0 REVIEW

Two basic approach to floodplain delineation by remotely sensed data are available. The dynamic method records floods as they actually occur or soon after the high waters have receded. It takes advantage of the fact that visible evidence of inundation in the near-infrared region of the spectrum remains for up to two or more weeks after the flood. This significantly reduced near-infrared reflectivity in the flooded areas caused by the presence of increased surface soil moisture, moisture stressed vegetation and isolated pockets of standing water. The second method, referred to as the static approach, utilizes the fact that floodplains can be recognized with remote sensing because of permanent or long-term features caused by historical floods (Sollers et al., 1978). These indicators (Table 3 have been enumerated by Rango and Anderson (1974).

Aerial photography is found to give satisfactory results, especially when it is possible to obtain a series of successive photographs during the flooding and recession period. However, the interpretation becomes difficult in the areas where bodies are covered by bushes and forest. Within wide, poorly forested, floodplain water edges can be easiluy identified. Stereoscopic viewing is helpful in areas in which interpretation based on tonal variations is difficult (Usachev, 1983).

Black-and-white infrared film is superior to the black-and-white panchromatic film. the addition of colour

Table 3 - Landsat Floodplain Indicators

Sl.No.	Description
1.	Upland physiograph
2.	Watershed characteristics such as shape, drainage density etc.
3.	Degree of abandonment of natural levees
4.	Occurrence of stabilized sand dunes on river terraces
5.	Channel configuration and fluvial geomorphic characteristics.
6.	Backswamp areas
7.	Soil-moisture availability
8.	Soil differences
9.	Vegetation differences
10.	Landuse boundaries
11.	Agricultural development
12.	Flood alleviation measures on the floodplain.

aids interpretation in both the visual and near-infrared wave lengths. Where heavy vegetation is encountered colour infrared film appears to be the best available film for inundation mapping (Hoyer et al, 1973).

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

Airborne surveying of floodplains requires the favourable coincidence of the inundation level needed for flooding and suitable weather for taking photographs. These difficulties considerably limit the use of aerial photographs for studying floodplain inundation over long river reaches. The use of satellite survey and observations is encouraging because of its advantages of continous tracking of land surface, broad coverage and quick receipt of information. The high degree of generalization of details in the case of satellite surveys favoures regional investigations and allows the monitoring of most characteristic processes of flooding along the shole river from its head to its mouth.

Polar arbiting satellites like NOAA can be used to identify areas of flooding in the case of large floods. Weisnet et al. (1974) in a study of the 1973 Mississippi river flood concluded that NOAA VHRR/IR can be used to prepare flood maps for river having floodplains not less than 3 km in width. Further, in 1979 Berg et al. reported that computer enhanced NOAA VHRR/IR data can be successfully used for floodplain mapping on small rivers that have wide flood plains. It was also deomonstrated that thermal bond of VHRR is well suited for mapping of floods during spring season which are mainly due to excessive snow melt.

The capability of Landsat series of satellites to assess flooding was indicated by Rango and Anderson (1974) and Deutsch et al. (1974). Analysis of data collected during flood periods compared with periods of any or normal conditions makes possible assessment of a variety of hydrological features, including areas of flood damage. Temporal composites may be used to show the changes in the flooded area between two dates of image acquision. Deutsch and Reuggles (1978) has reported that temporal composite produced by projecting preflood and flood image in band 7 through red and green filters respectively, depicts the flooded areas clearly. The areas which were under water in both dry and flood scence appear as black, where there was no water in the dry scene but water during flood appear red in colour. Similar observations were made by Kruus et al. (1979) while carrying out studies on floods, of the Susquehanna River in October 1975 and the Red River in July 1975.

Remotely sensed data for flood plain mapping have been used in India by various investigators. Using satellite data (Landsat 1 and 2) taken during 1972 and 1975, Dhanju

(1976) studied the shifting, meandering and flooding of Kosi river. From the imagery taken in flooding period he was able to map the indundated areas, flood boundaries and other associated features. Chakraborty (1979) has observed that courses of interlacing channels of the river can be easily delineated through band 7 imagery alone. Band 5, however, provides the best information on flood-plain features Analysis of airborne multispectral scanner data was found to be useful in obtaining detailed information regarding flood protection works. Further applications of remote sensing methods on Ganga flood plain mapping indicate the usefulness of satellite data for delineation of the features like inundated areas, backswamps, oxbow lakes, river levees etc. (Dhanju, 1979 ; Sharma et al. 1985).

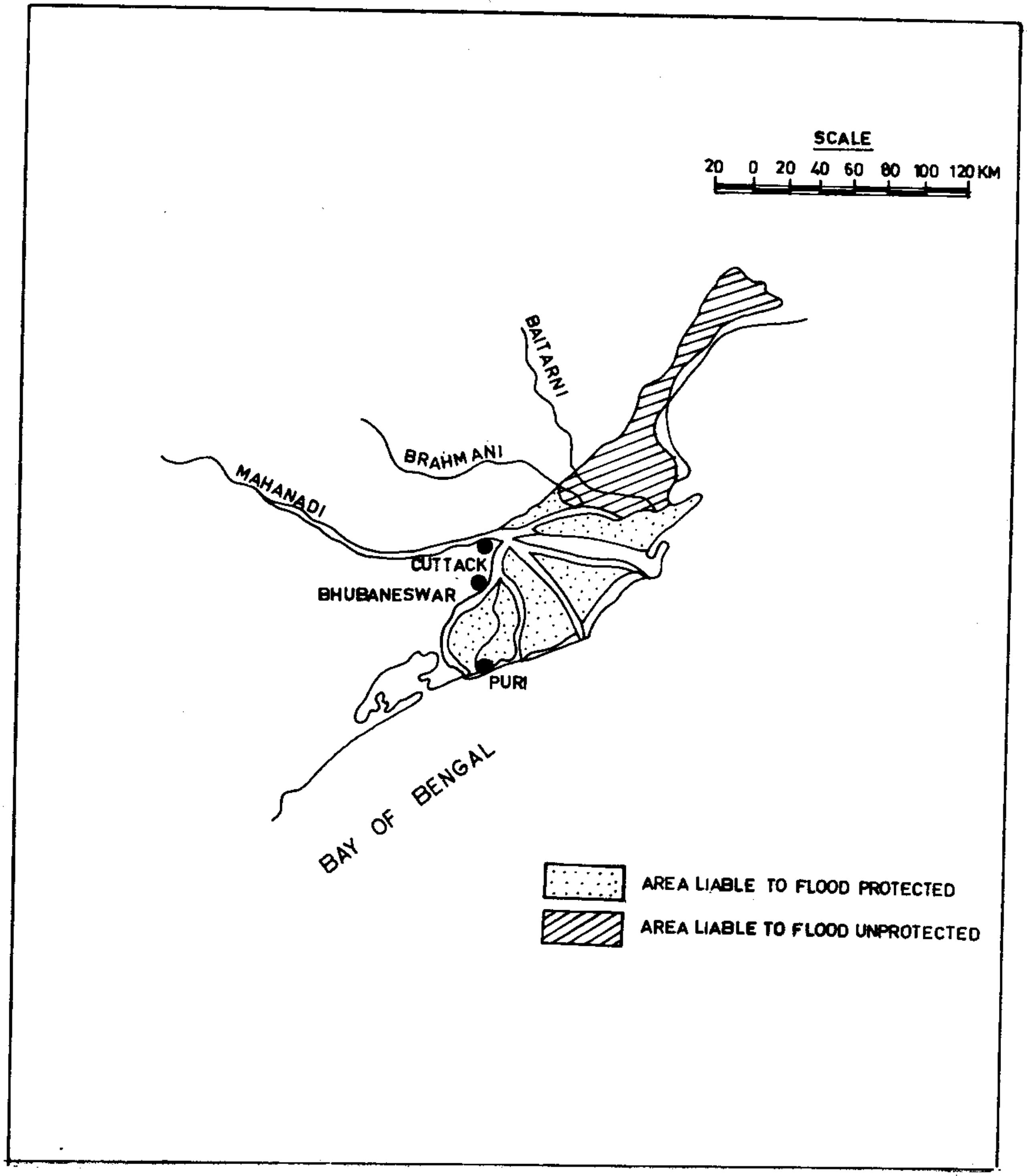


FIG. 1 : FLOODPRONE AREAS IN MAHANADI RIVER BASIN

3.0 STATEMENT OF THE PROBLEM

The flood problems of the Mahanadi are mainly confined to its lower reaches in Orrissa. The main rivers of Orrissa, namely, the Mahanadi, the Brahmani and the Baitarni are inter-connected in the delta. The worst floods in the delta area occur when there is a heavy down pour simulteneously in the catchment areas of more than one of these rivers. The spill from one river flows into the other leading to flooding of most of the delta area. In the the upper reaches of the river occasional flood takes place due to high intensity storms. Due to flooding in delta region vast agricultural land gets submerged and drainage of the area gets affected. These conditions result in the formation of small lagoons and swamps in the doabs towards the sea coast. Figure 1 shows the flood prone areas in Mahanadi river basin.

Mahanadi basin downstream of Hirakud Dam has been chosen for study of flood prone areas using remotely sensed data. The objective of the study is to prepare a detailed map at 1:250,000 showing flood-plain boundaries and various floodplain features such as river course, river levees, inundated areas, abandoned channels, sediment deposites etc.

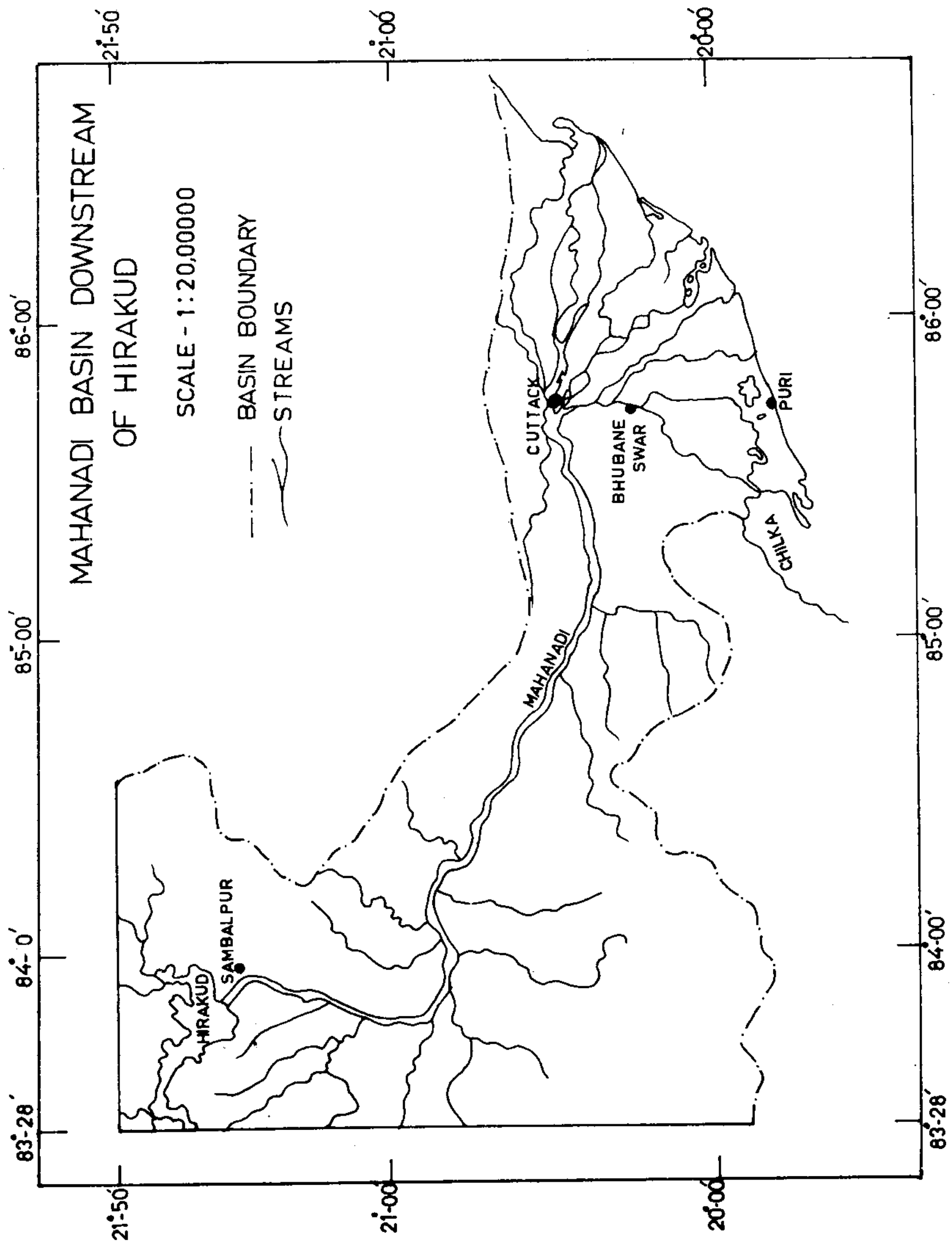


FIG.2 : MAHANADI RIVER BASIN DOWNSTREAM OF HIRAKUD

4.0 DESCRIPTION OF STUDY AREA

The area of study extends from downstream of Hirakud Dam to the Bay of Bengal. It lies in Orrissa state between latitudes 19°21' N and 21°50' N and longitudes 83°28' and 86°57'E (figure 2). The total geographical area of the basin under consideration is about 35473 sq.km.

Hirakud dam is situated on the river Mahanadi near Sambalpur. From Hirakud dam the river flows in southerly direction up to Sonepur where it receives the river Ong. Thereafter, the river flows in a south-easterly direction and the Tel joins it. After passing through Satkosia and Kaimundi gorges it emerges into the deltaic plain near Naraj and splits into the Katjuri and the Birupa. These two branches rejoin after flowing for about 64 km. Several other branches take-off and rejoin the river in the delta. The river falls in Bay of Bengal throwing off numerous branches.

4.1 Physiography

There are four well defined physiographic regions in the basin namely (i) the northen plateau (ii) the eastern ghats (iii) the coastal plains and (iv) the erosional plains of the central table land. The northern plateau and the eastern ghats are well forested hilly regions. The coastal plain stretching over the districts of Cuttack and Puri cover the large delta formed by the Mahanadi and is a fertile area well suited for intensive cultivation. The erosional plains of the central table land are traversed by Mahanadi and its tributaries.

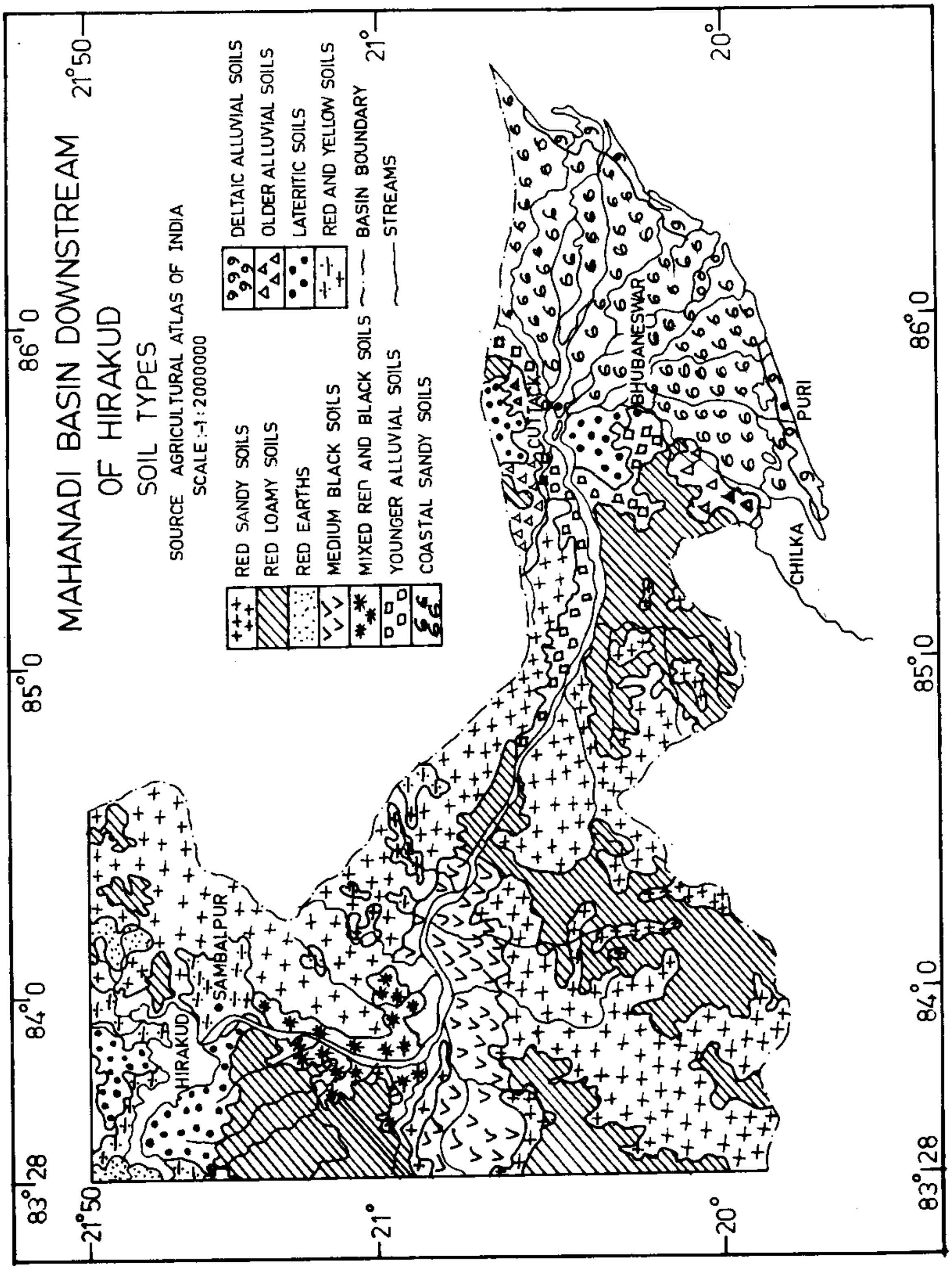


FIG. 3 : MAHANADI RIVER BASIN DOWNSTREAM OF HIRAKUD: SOIL TYPES

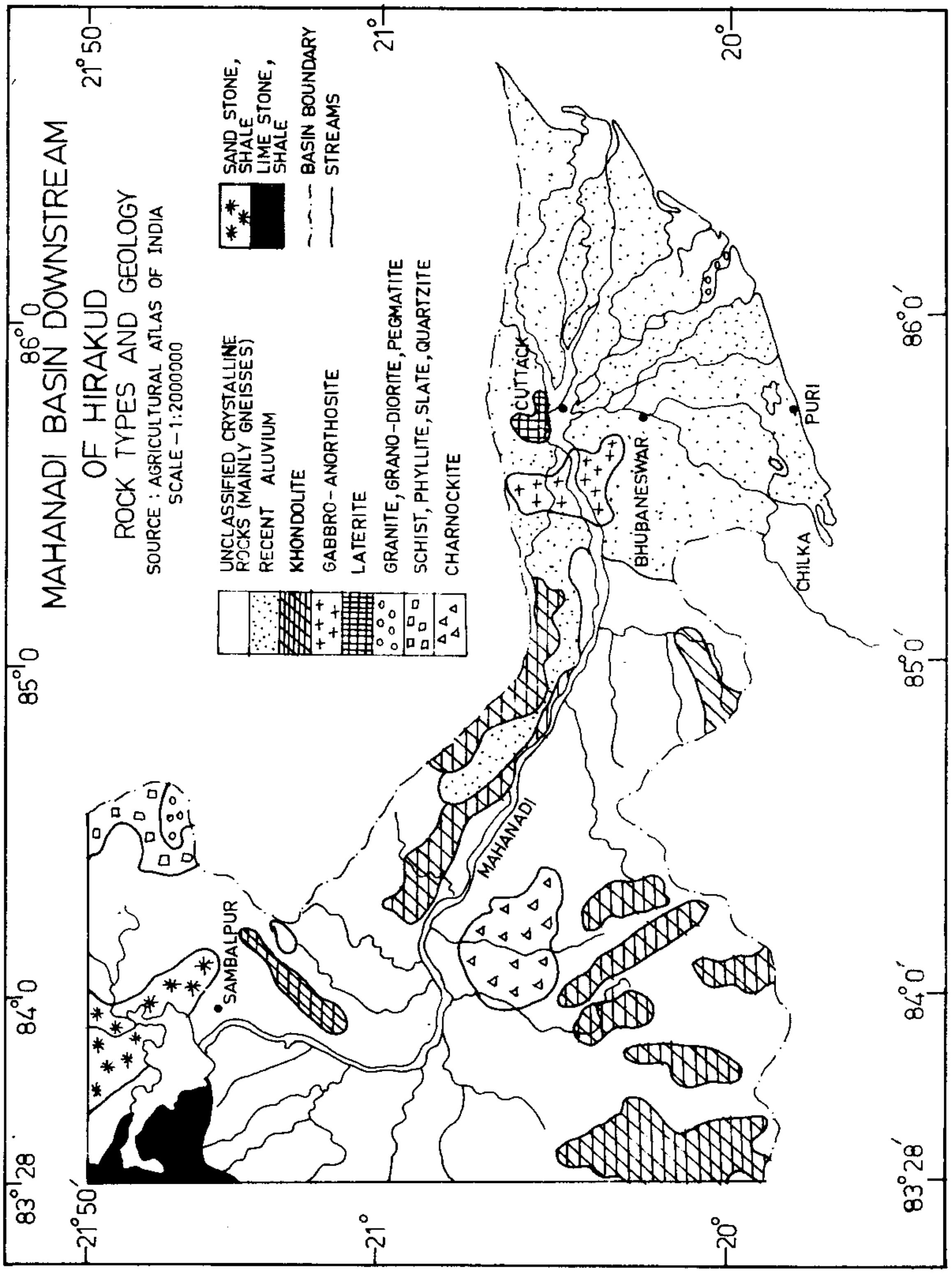


FIG.4:MAHANADI RIVER BASIN DOWNSTREAM OF HIRAKUD:ROCK TYPES & GEOLOGY

4.2 Soils and Geology

The general information about soils of India indicate that the Mahanadi basin consists of mainly of red and yellow soils. Mixed red and black soils occur in parts of Bolangir Patna, Sambalpur and Sundargarh district of Orrissa. Laterite soild is found in the lower part of the basin lying in the Cuttack and Puri district of Orrissa. The coastal plains of the Mahanadi basin are composed of saline and deltaic soils. A regional soils map of the study area is reproduced in figure 3 from Agricultural atlas of India.

The general geologic sequences responsible for the present topography of the high land area are from the Archoean era to the Pleistocene age. The unclassified crystallines which include granite, geneisses and other magmatic rocks are found in Sambalpur, Bolangir, Baudh-Khondmals, Dhenkanel and Ganjam districts of the region. Rock of Gondwana system consisting of shales, sand stones and gret are found in Dhenkanal and Sambalpur district in a narrow and elongated form. Laterites of Pleistocene origin are found in the eastern most part of the Dhenkanal district.

In the coastal plains, a group of lime stones, sand stones and clays occur in the beds of Burabalong river south of Baripada town. Pleistocene alluvium occurs at several places along the coastal tract. Large deposites of laterite occur as capping over Khondolite hills. Such laterite is of insitu origion, while the laterite occuring at lower levels is of detritol origin. A geological map of the basin considered for the study is given in figure 4.

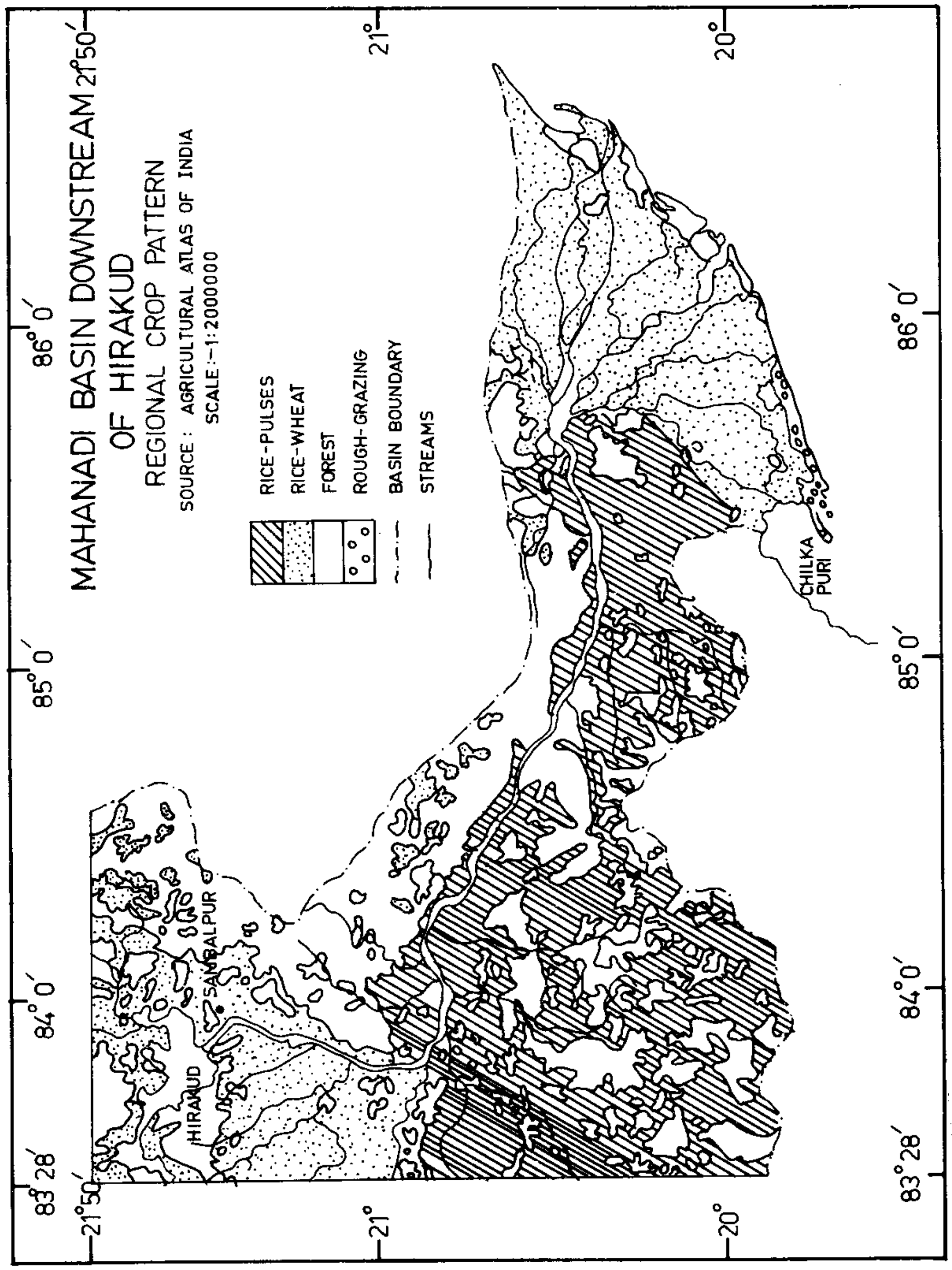


FIG.5:MAHANADI RIVER BASIN DOWNSTREAM OF HIRAKUD:REGION CROP PATTERN.

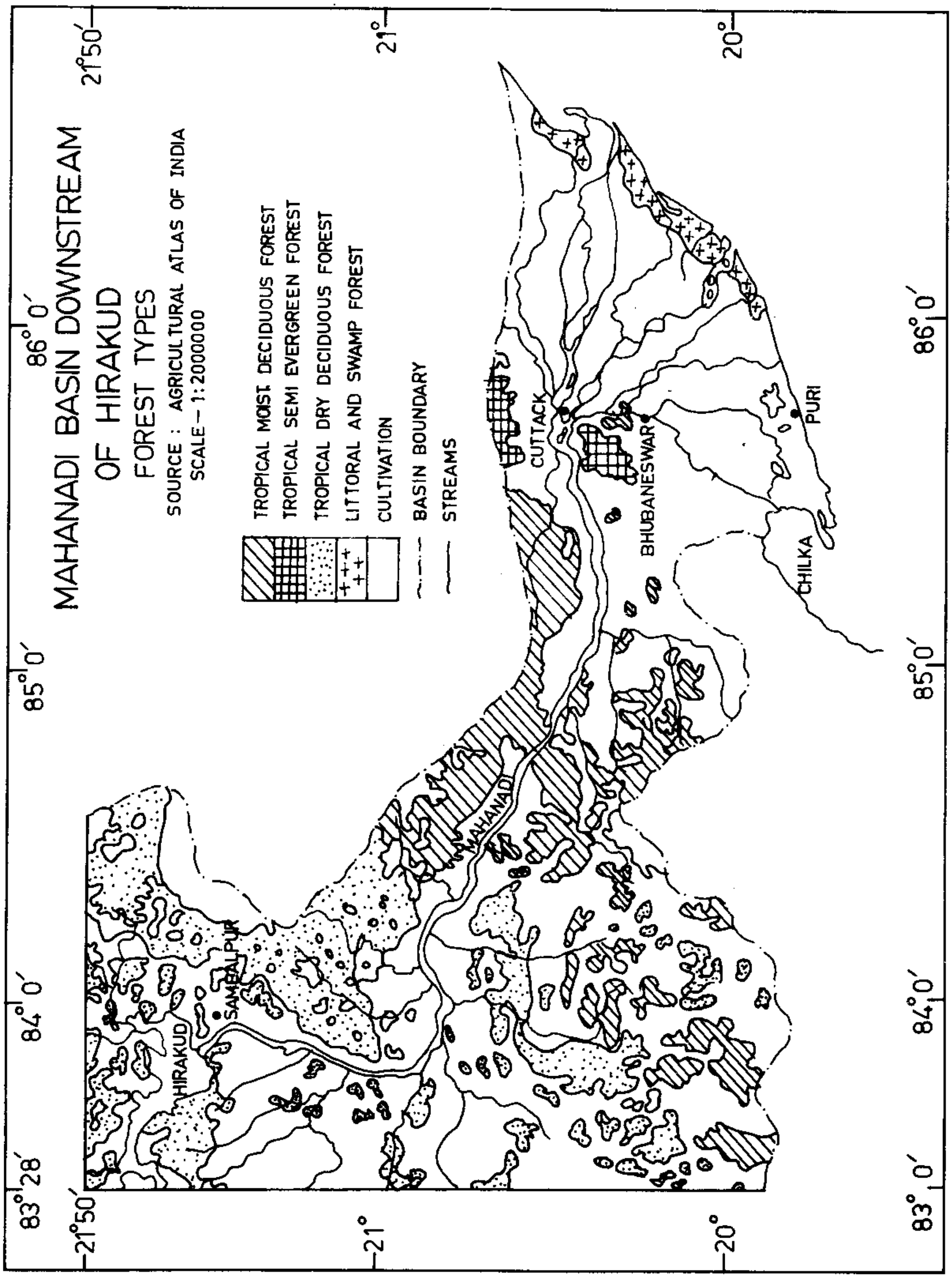


FIG.6:MAHANADI RIVER BASIN DOWNSTREAM OF HIRAKUD:FOREST TYPES

4.3 Agriculture and Natural Vegetation

A large part of the basin is under forest. Agreicul-ture is generally rainfed with relatively low yields. There are mainly two crop seasons, the Rabi and the Kharif. the Kharif crop is mainly paddy which is the major crop of the area. Besides paddy other Kharif crops grown in the area are jowar, bajra, maize, ragi, groundnut and fodder crops. Wheat is sown as major Rabi crop. In some parts barely, gram, linseed, mustered etc. are also grown as Rabi crops. Sugar-cane and cotton are two cash crops of the region. Figure 5, represents regional cropping pattern of the area.

Some Parts of the basin are covered by thick forest. The forested areas can broadly classified as tropical dry deciduous forests, tropical semi-evergreen forests, tropical moist deciduous forests and swamp vegetation (figure 6).

4.4. Climate

The climate in the stdy area ranges from dry sub-humid to moist sub-humid. There are four distnict seasons in the year; (i) the cold weather (ii) the hot weather (iii) the south-west monsoon and (iv) the post monsoon.

The mean minimum temp. ranges between 10 and 13.7^{o}C in inland areas whereas near the cost, it usually does not fall below 15.8^{o}C. The mean maximum temperature ranges from 38^{o}C over the hills to 43^{o}C in the plains. South-west monsoon setting in by the middle of June over the entire basin, continues to be active till and first week of October. During

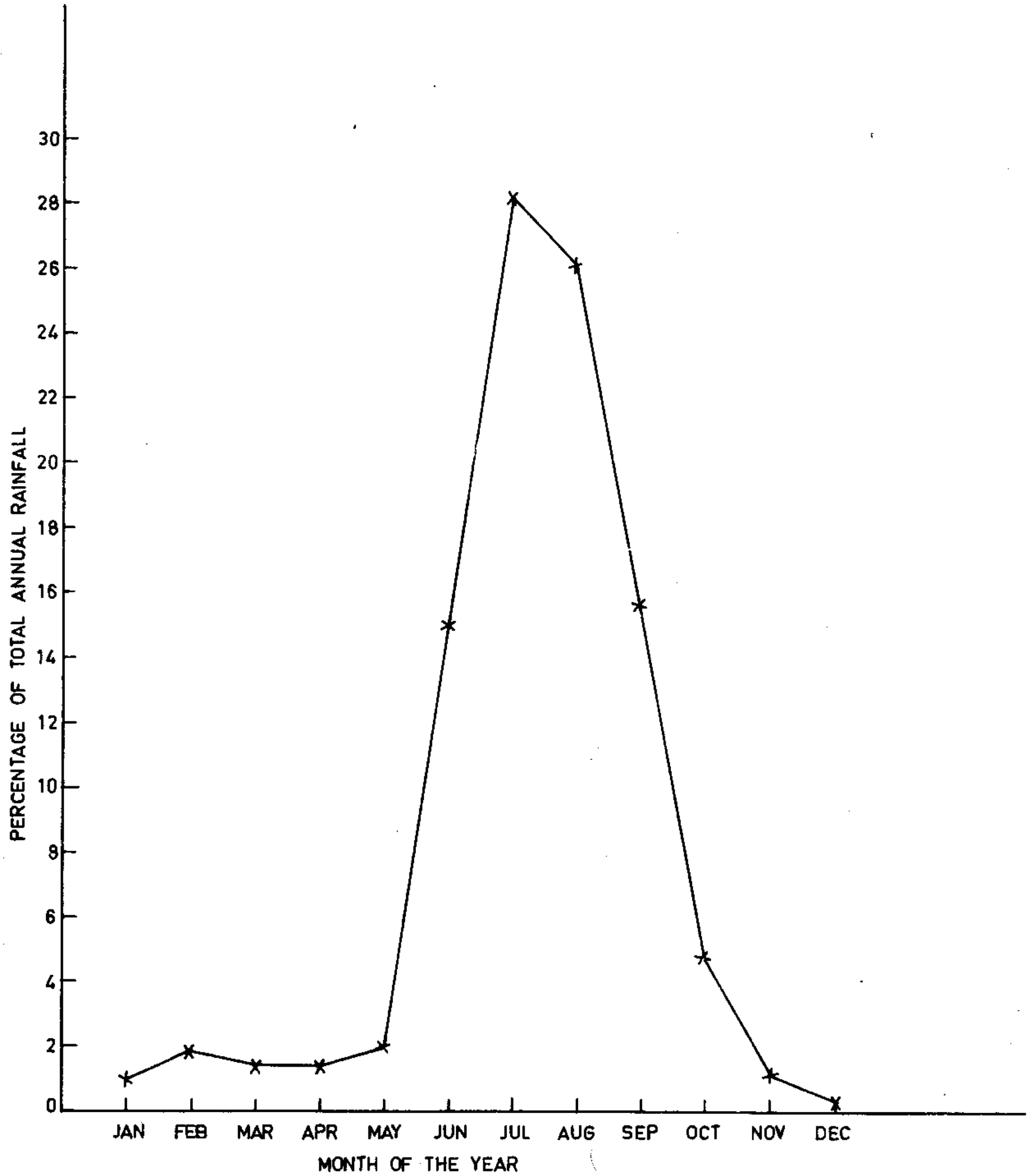


FIG.7:MONTHLY DISTRIBUTION OF ANNUAL RAINFALL IN THE STUDY AREA.

this period the basin receives over 90% of its total annual rainfall (figure 7). After the withdrawal of the south-west monsoon, a few thunder storms continue to occur. The weather clears up by November and it is cool thereafter.

5.0 DATA USED

This study was carried out using Landsat MSS imagery together with conventional data such as Survey of India toposheets and other reference material on the subject.

5.1 Landsat Imagery

The study area is covered in four frames of Landsat imagery. Both preflood and post-flood data 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 4.

Table 4 - Description of Landsat Data

Sl.No.	Path & Row No.	Date	Satellite	Sensor	Data Type	
1.	139-046	5.4.85	L4	MSS	FCC	1,2,4
		20.10.85	L5	MSS	FCC	1,2,4
		23.11.85	L5	TM	Band	4
		15.3.86	L5	TM	Band	4
2.	140-046	12.4.85	L4	MSS	FCC	1,2,4
		22.11.85	L4	MSS	FCC	1,2,4
3.	141--45	27.4.85	L5	MSS	FCC	1,2,4
		28.10.85	L4	MSS	FCC	1,2,4
4.	141-046	27.4.85	L5	MSS	FCC	1,2,4
		29.11.85	L4	MSS	FCC	1,2,4

5.2 Toposheets

The study area is covered in seven Survey of India toposheets at 1:250,000 scale. A suitable base map of the study area was prepared from these toposheets. Index for

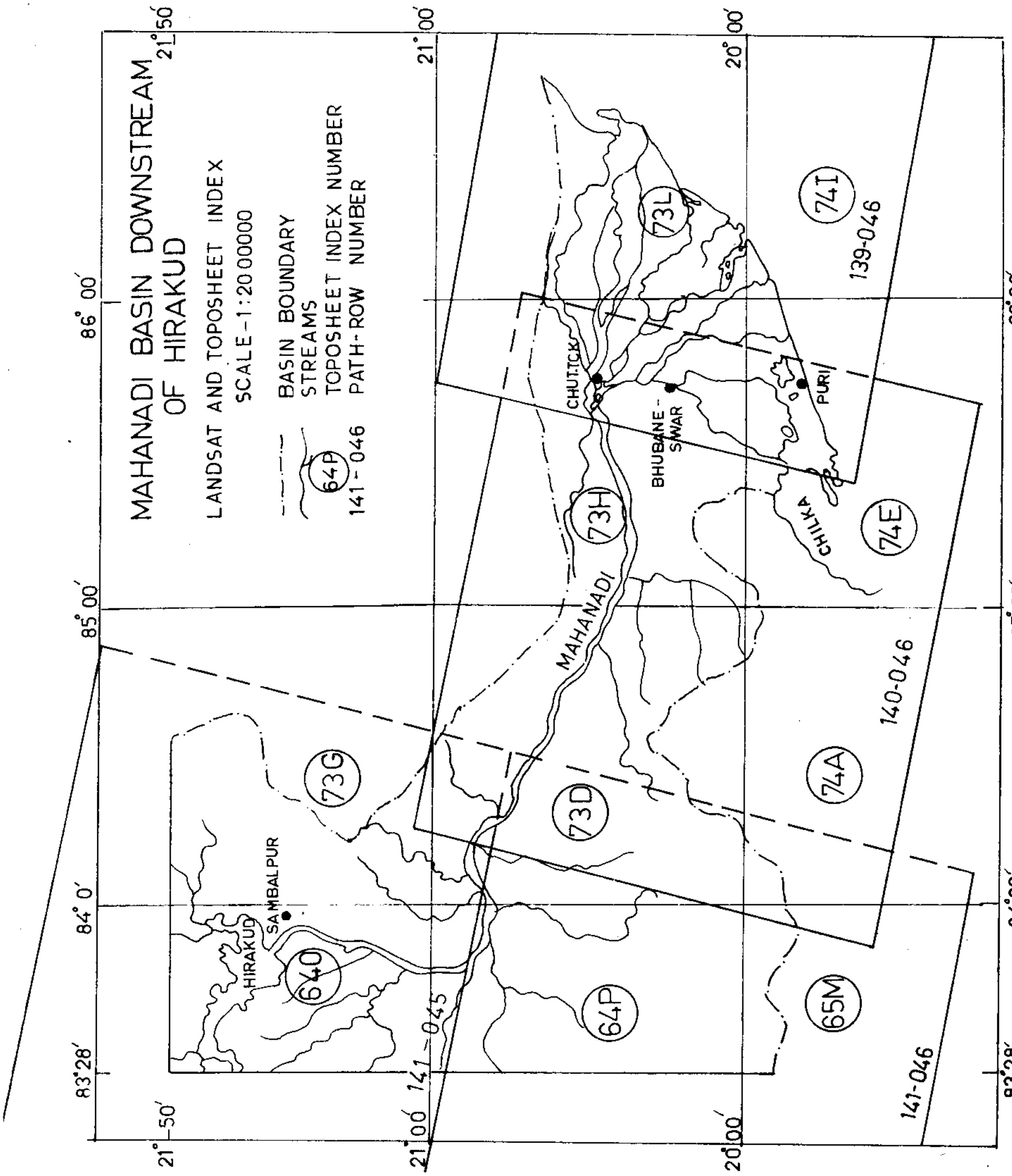


FIG.8:MAHANADI BASIN DOWNSTREAM OF HIRAKUD:LANDSAT & TOPOSHEET INDEX

Photo 1 : Landsat MSS Scene 139-046 dated 20.10.85

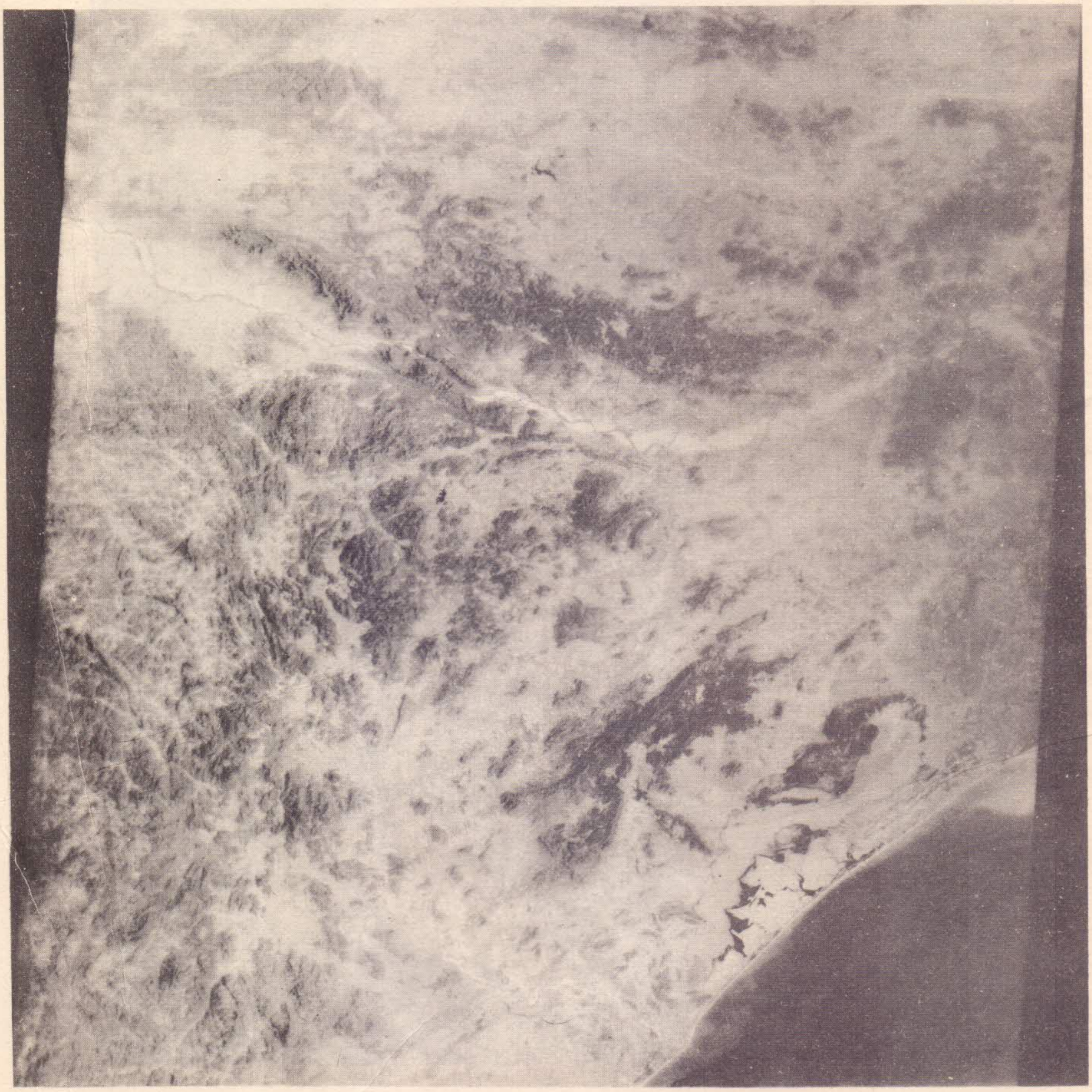


Photo 2 : Landsat MSS Scene 140-046 dated 22.11.85

Photo 3 : Landsat TM Scene 139-046 dated 23.11.85

these toposheet is shown in Fig. 8.

5.3 Other Reference Material

Various types of information such as agriculture and vegetation, forest cover, geology and rocks, soils etc. pertaining to study area has been collected from Agricultural Atlas of India. Climatological information for the area has been obtained from report of the Irrigation Commission.

6.0 METHODOLOGY

In the present study visual interpretation technique was employed to delineate various flood-plain features and inundated areas. A comparison of pre-flood and post-flood data helped in better identification of these features. A low cost diazo colour technique was adopted to produce false colour composite in the Remote Sensing Lab. of the Institute. In this technique yellow, magneta and cyan transparancies are prepared on diazo films for MSS 1,2 and 4 imagery respectively. These transparancies, after proper registration, are projected through a large formate optical enlarger to given four times enlargement. At this scale it is possible to compare imagery with available toposheets at 1:250,000 scale

In addition to MSS imageries a portion of the area was studied using TM band 4 data in B&W mode. A comparison of information extracted from both MSS and TM was also made.

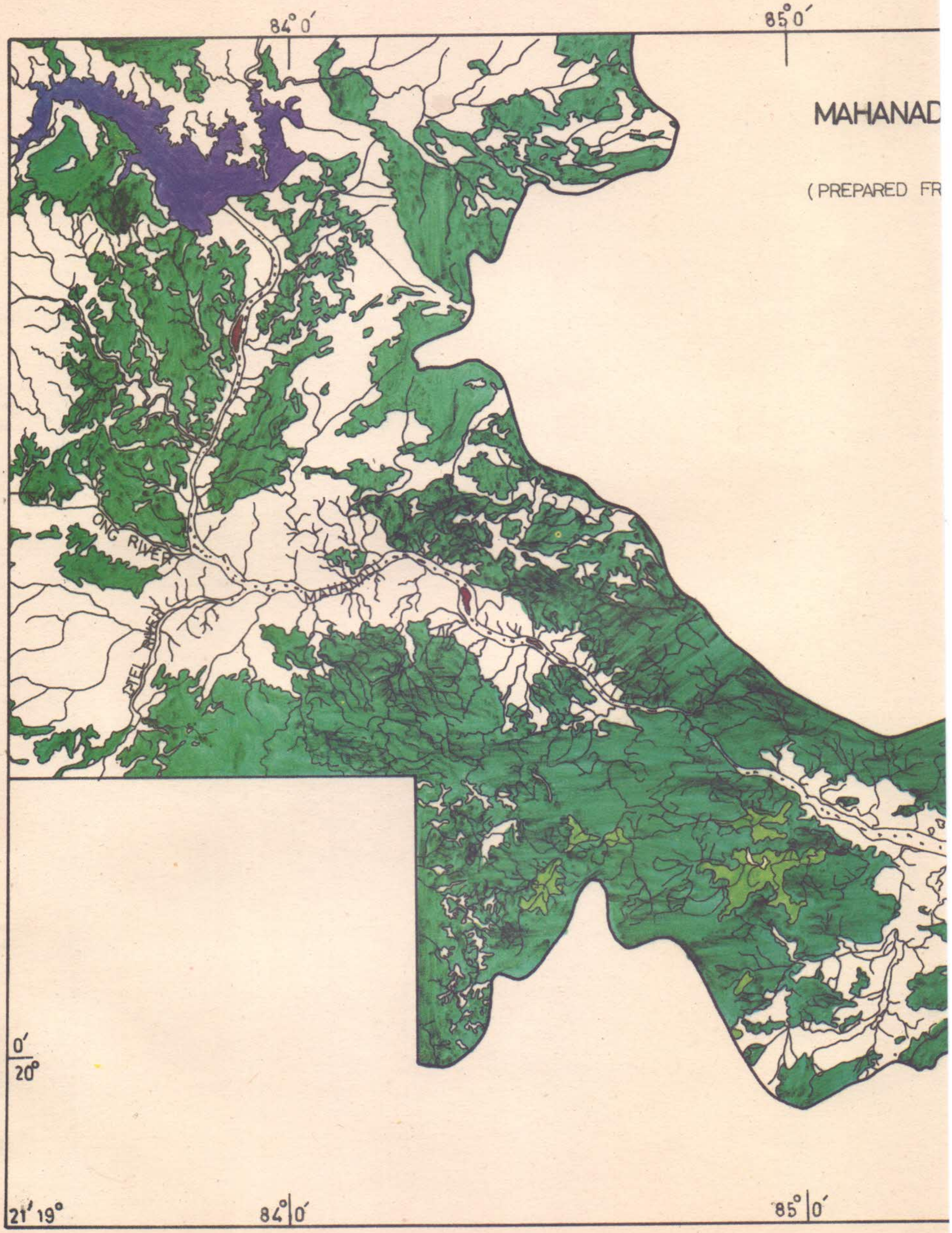
Limited ground truth was obtained by consulting toposheets and other reference material available. A few sites were visited and occurance of features verified where-ever any confusion arrived during interpretation of imageries.

7.0 ANALYSIS AND RESULTS

7.1 Land Use/Land Cover Classification Scheme

The purpose of a land use/land cover classification scheme is to provide a logical frame work for presenting land use/land cover information derived from the interpretation of satellite imagery. Land use/land cover categories to be mapped are selected on the basis of their influence on hydrologic processes, aim of interpretation and other environmental factors. Several inherent characteristics of satellite imagery such as ground resolution, seasonal effects, spectral separability of the features etc. are adequately considered while deciding upon a suitable classification scheme.

The classification scheme developed for the present study is based on USGS land use classification scheme(Anderson, 1971). In this classification scheme two level categorization has been adopted. Six land use categories have been identified at level I. There was no further categorization possible for the first and second category namely, urban or built-up land and agricultural land. Forested land has been subdivided into the level II categories; dense forest and thin forest. Here, the scheme slightly differs from the original USGS classification scheme. The fourth category representing water bodies is subdivided into three level II categories. There are two subcategories in wet land, (i) forested wet land and (ii) non forested wet land. Two level IIcategories are identified in barren land. These are named as sandy areas and transitional areas. Transitional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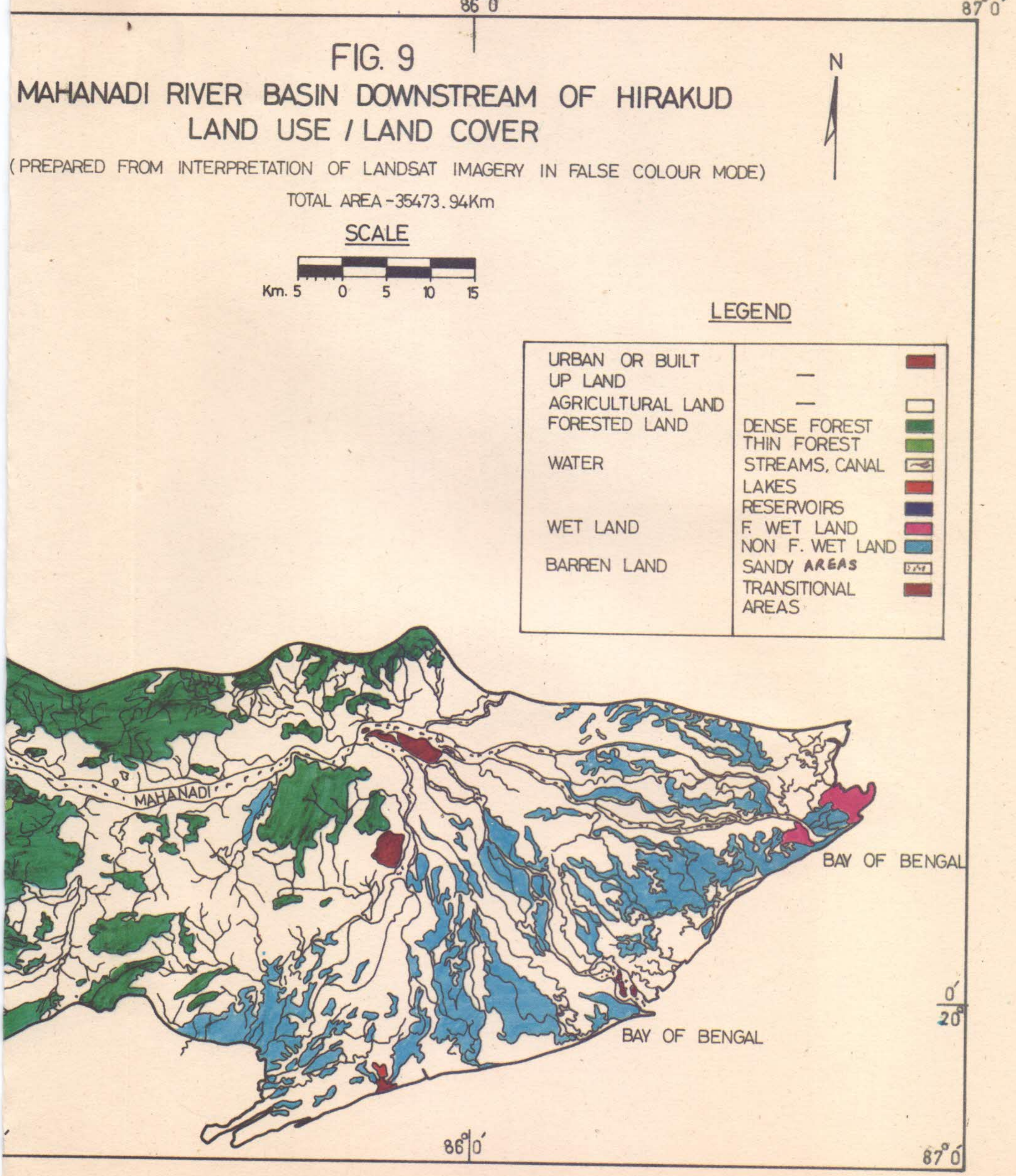
85° 0′

FIG. 9

MAHANADI RIVER BASIN DOWNSTREAM OF HIRAKUD LAND USE / LAND COVER

(PREPARED FROM INTERPRETATION OF LANDSAT IMAGERY IN FALSE COLOUR MODE)

TOTAL AREA - 35473.94Km



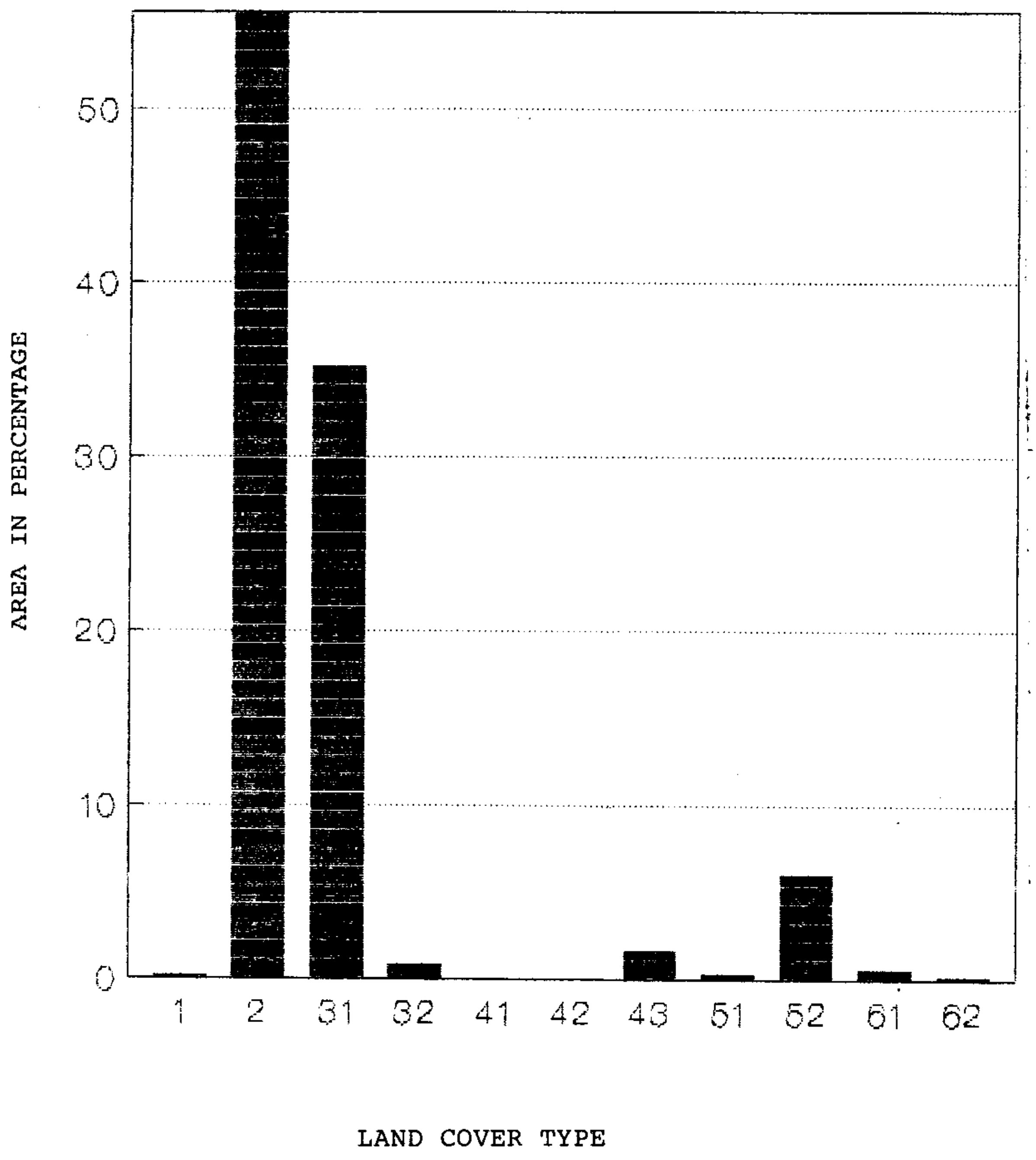


FIG 10 : DISTRIBUTION OF LAND USE/LAND COVER areas are nothing but river islands in this particular case (Table 5).

Table 5 - Land Use/Land Cover Classification Scheme

	LEVEL I	LEVEL II
1.	Urband on built-up land	-
2.	Agricultural land	-
3.	Forest land	31 Dense forest
		32 Thin forest
4.	Water	41 Stream and Canals
		42 Lakes
		43 Reservoirs
5.	Wet land	51 Forested wet land
		52 Non forested wet land
		61 Sandy Areas
6.	Barren land	62. Transitional areas (river islands)

7.2 Land Use/Land Cover Distribution

Areal extent of various land use/land cover categories was measured from the map prepared by interpretation of Landsat MSS imagery at 1:250,000 scale (Fig.9). A 0.25 cm^2 grid was used for measurement of areas under various types of land cover.

Following interpretations can be made from a careful study of land use/land cover map prepared.

1. In upper reaches of the basin forest is the predominent land cover. Tropical deciduous forests cover

almost all the hilly regions of the basin.

2. Downstream of Naraj, where the river enters in plains, basin is intensively cultivated.

3. In the delta area numerous branches take off from the main river and many of them rejoin it after traversing a few kilometers forming a grid. During periods of high flows spilling of water from these streams causes flooding of the region.

4. Dense mangrove growth is found near deltaic region.

5. In the delta many areas are permanently wet, however, their spread increase during flooding season. Since there are no definite flood-plain boundaries in this region, delineation of such wet areas could help in identification of flood prone areas.

Table 6 - Areal Distribution of Various Land Use/Land Cover Features

(based on interpretation of MSS imageries)

Description	Areal extent (Sq.km)	Percentage of total area
1. Urban or built up land	32.81	0.09
2 Agricultural land	19702.18	55.55
31 Dense forest	12475.00	35.17
32 Thin forest	290.63	0.82
41 Streams & Canals	-	-
42 Lakes	9.38	0.03
43 Reservoirs	562.50	1.58
51 Forested wet land	75.00	0.21
52 Non forested wet land	2123.44	5.99
61 Sandy area	178.12	0.50
62 Transitional areas (river islands)	21.88	0.06
Total area = 35473.94 sq.km.		

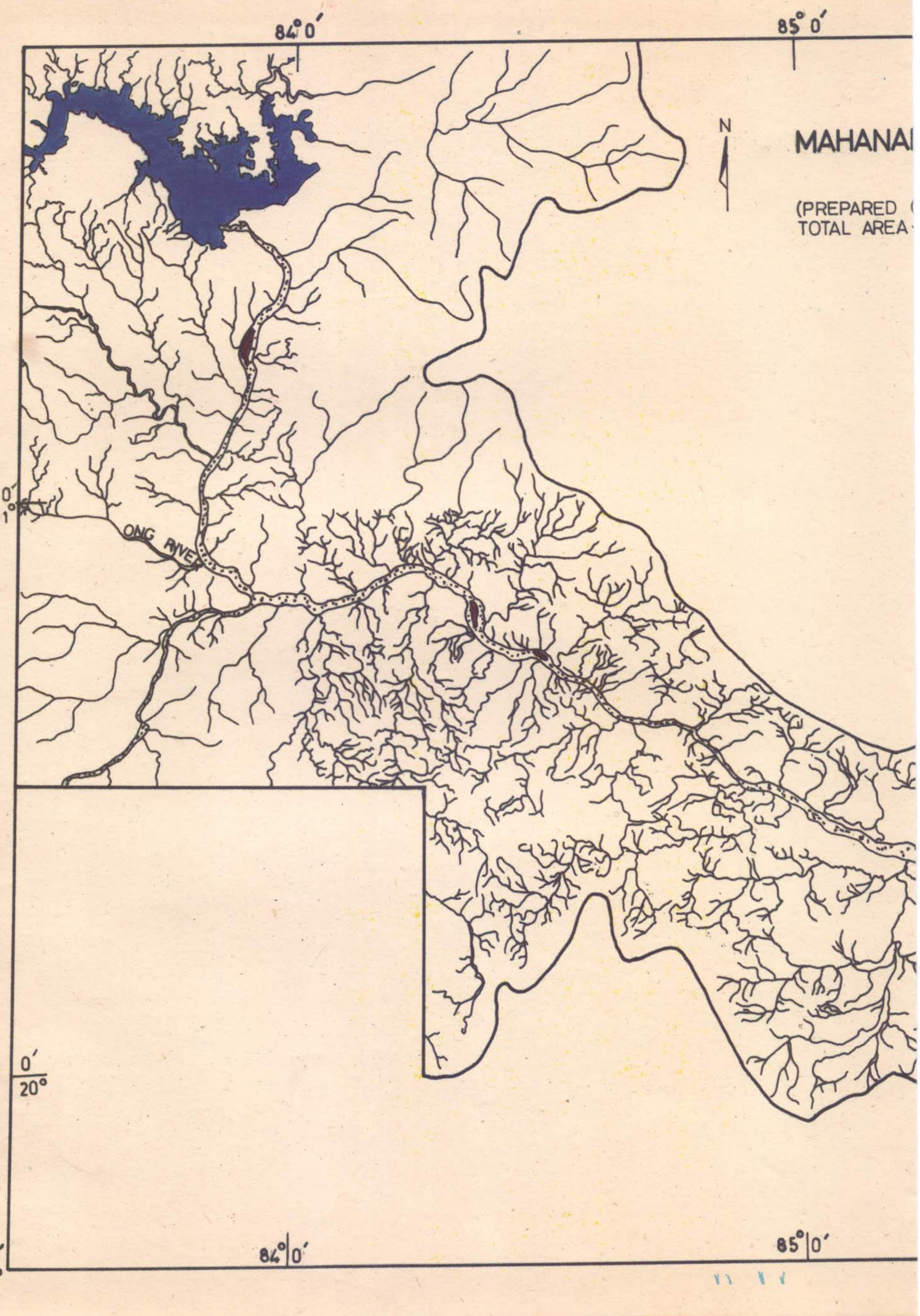

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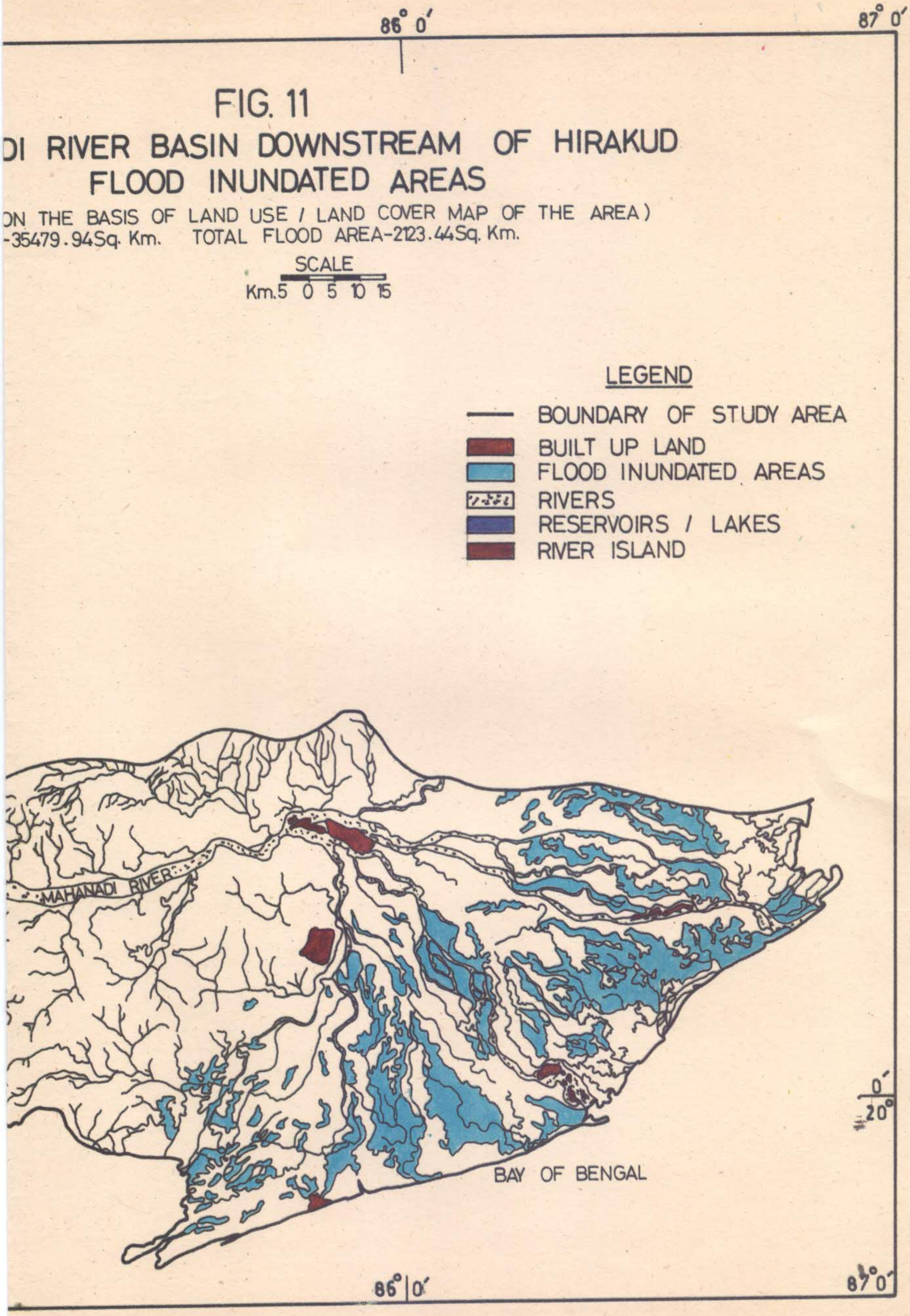
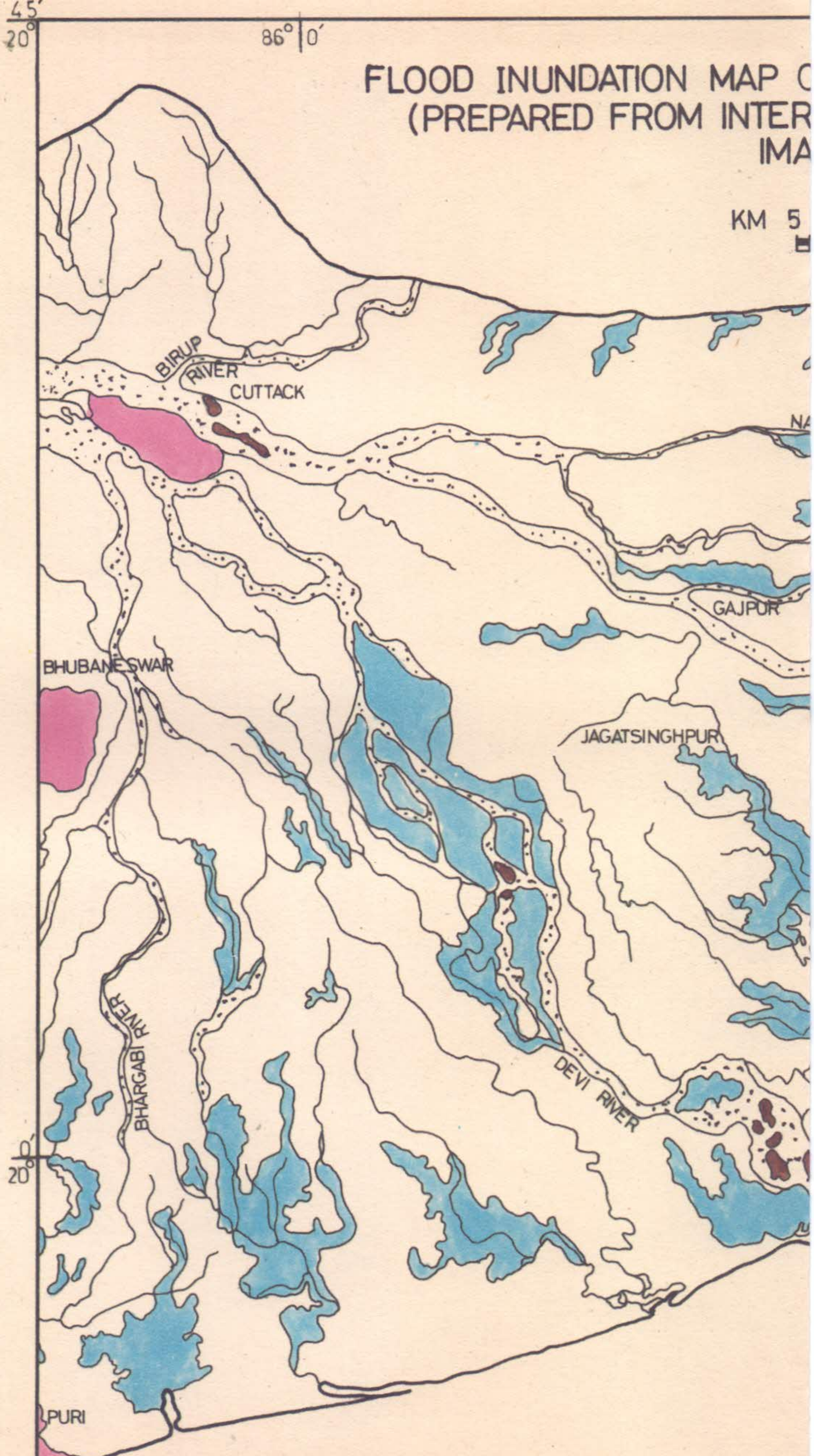
FIG. 11

DI RIVER BASIN DOWNSTREAM OF HIRAKUD
FLOOD INUNDATED AREAS

(ON THE BASIS OF LAND USE / LAND COVER MAP OF THE AREA)
-35479.94Sq. Km. TOTAL FLOOD AREA-2123.44Sq. Km.

SCALE
Km.5 0 5 10 15




FLOOD INUNDATION MAP C
(PREPARED FROM INTER
IMA
KM 5
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20°
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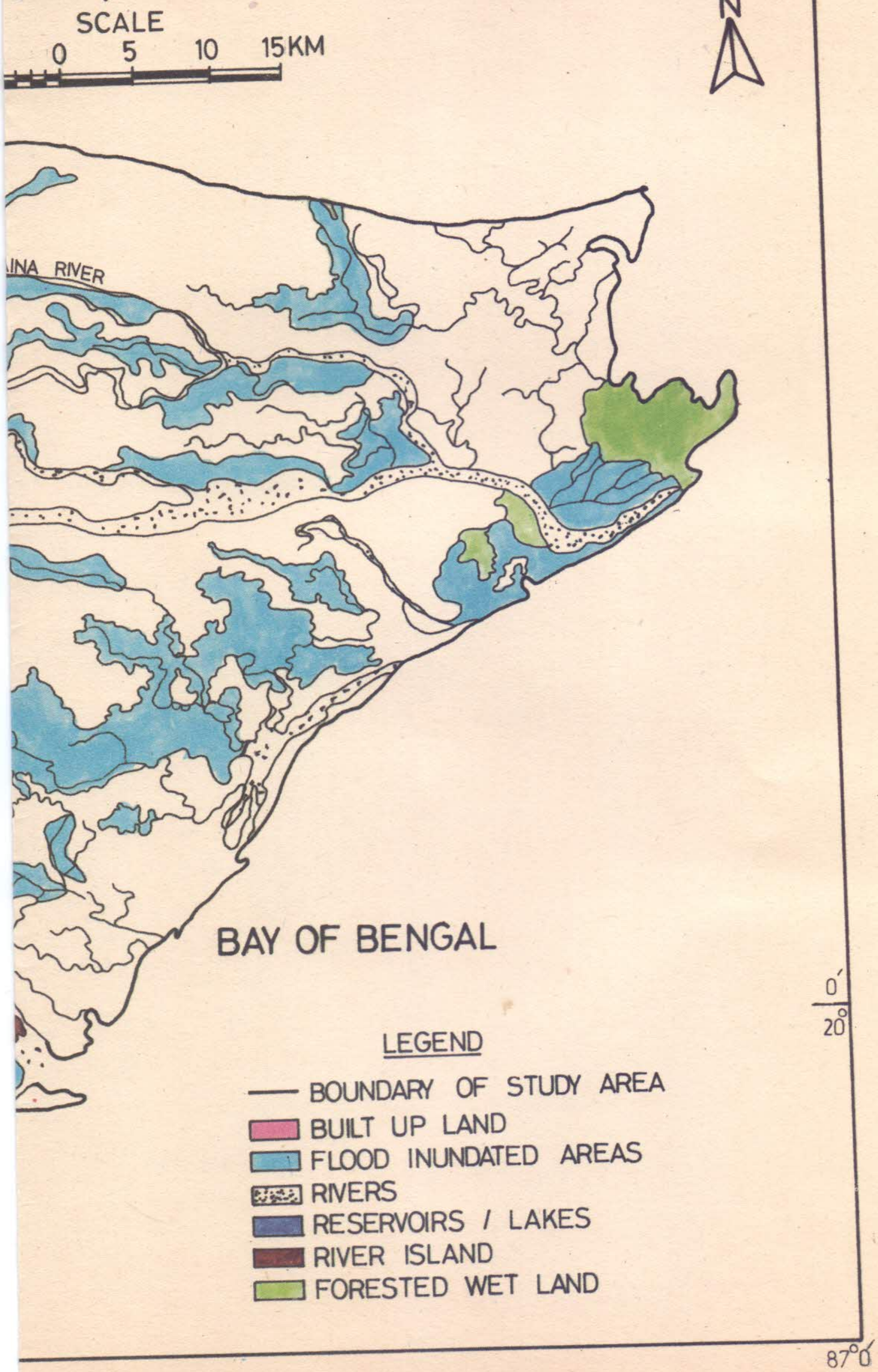
BIRUP RIVER
CUTTACK
NA
GAJPUR
BHUBANESWAR
JAGATSINGHPUR
BHARGABI RIVER
DEVI RIVER
0'
20°
PURI
20'
19°
86°|0'

FIG. 12

)F A PART OF MAHANADI RIVER BASIN
PRETATION OF LANDSAT TM BAND 4
GERY)



7.3 Floodprone Areas

In Deltaic regions, like Mahanadi delta, clear flood plain boundaries are not seen on imagery because of intermingling of river channels, overflowing of flood waters from one basin to another and presence of coastal vegetation and marshy areas. A comparison of preflood and post flood scenes could further improve the interpretation.

In this study also, similar approach has been adopted to delineate flood inundated areas. A flood inundated map of the area is shown in figure 11 which is based on MSS imageries. A small portion of the area lying mostly in delta region was also analysed on landsat TM band 4 imagery (Fig.12). Since, this TM imagery is of Nov. 1987 whereas MSS imagery for the same area is of Oct. 85. Hence extent of flood affected areas is slightly less in the map prepared from TM imagery. This may be attributed to reduction in surface soil moisture.

7.4 Ground Truth

Field visits were made to verify the flood inundated map. Since, the field visits were conducted in the period Jan-Feb. 1988, ground truth data collection was mostly based on local enquiries, study of general topography.

It was found during ground visits that presence of embankments on southern bank of river Mahanadi near Gajpur was the reason of flooding on northen side only (plate no.4) Flooding is caused near Mallipadar, Tulsipur and Raghunathpur due to spilling of flood water over the embankments. This spilled water gets accumulated in low lying areas and remains there far quite a long time. Because of this reason flooded areas are seen a little distance away from Rana river (Plate no. 5).

Photo 4 : Southern Bank of River Mahanadi near Gajpur

Photo 5 : Water Accumulation in Low Lying Areas

8.0 CONCLUSIONS

At present remote sensing applications to flood plain mapping is categorised as an operational technique. In India, several projects dealing with flood problems of Indo-Gangetic plains have been successfully completed. While carrying out these studies researchers have concluded that band 7 alone is sufficient for delineation of flood plain boundaries and other flood plain features. However, it was felt during this study that this alone could not be used for identification of features like mangrove areas which are better identified on false colour composites. But the presence of numerous colours and hues on false colour composite creates some confusion in the mind of interpreter. It was also realised that interpretation could be improved by using both pre-flood and post-flood data.

With particular reference to study area it was felt that interlacing of numerous river channels poses a serious problem in delineation of a clear flood plain boundaries. Because of this difficulty an indirect method of identification of wet areas and then marking flood prone areas had to be adopted.

Flood problem in the delta area has not be effectively managed with existing flood protection structures, specially the events occuring due to simultaheous heavy downpour in catchment areas and high tides in the sea water. Thus, it is suggested that a fresh review of existing flood protection schemes be taken up and suitable measures be adopted. It is also suggested to make use of some of the non-conventional techniques such as flood plain management instead of constructing flood protection structures alone.

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