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Geomorphological studies of netravathy and gurpur river estuary in the west coast of India using remote sensing data

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Abstract
The West flowing rivers originating in the mountainous region of Western Ghats, climb down to the narrow coastal alluvium and flows parallel to the sea coast to a considerable distance before joining the sea. In the process, the river carries large quantity of sediment down the hill all along the river course. A unique feature of these rivers is that, two or three rivers with independent catchments join together at the estuary before joining the sea. Due to the dynamic nature of rivers as well as the ocean, changes in the estuary and also along the river course are very common. Most of the rivers in the coastal region overflow to the adjoining land, invariably submerging the agricultural fields during peak monsoon. These rivers being seasonal, large amount of sediment is deposited in the coastal plains giving rise to sand dunes and shoals in the river estuaries as well as in the river coarse. Netravathi and Gurpur rivers are one such combinations of West-flowing rivers joining together on the Western side of the city of Mangalore before joining the Arabian Sea. The river estuary on the sea-side is quite unstable giving rise to sea erosion on either side of the estuary. The sediment deposition all along the rivers with varying sizes of sand dunes and shoals are observed in the river course. The industrial development activities on the bank of Gurpur river has changed the land cover on the river bank to a great extent. Multi-temporal remote sensing data are used to study both long term and short term changes both in the river estuary and along the river upstream. The visual interpretation techniques are used to analyse the changes in the river course and also in the estuary. The results are compared with both field observation and ground truth data. Both qualitative and quantitative analyses are carried out. Frequent changes on the sea-side of the estuarine are established. However, the riverbanks seem to be almost stable over the years. The possible reasons for undisturbed river course are established. The changes in the size and shape of the sand dunes as well as those of shoals are quantified.

INTRODUCTION

The West-flowing rivers in Karnataka originate in the mountainous region of Western Ghat. The rivers flow down to the foothills of the Ghat section, pass through the lateritic plateau in the middle and flat coastal alluvium towards its mouth, before flowing into the Arabian sea. The river cuts across the highly undulated terrain through deep and relatively narrow valleys on the eastern part of the basin, while broad and shallow valleys towards the western part of the basin. Many a times, the rivers change their direction, flowing parallel to sea to a considerable distance before joining the sea. Also it is very common to see that two or three rivers join together at the estuary before they flow to the sea. Netravathy - Gurpur, Pavanje - Shambhavi are a couple of such rivers.

Due to the dynamic nature of the rivers as well as the ocean, changes and modifications in the estuaries and river mouth, from time to time are very common. The various geo-

morphic processes like erosion and accretion along the river at the river mouth and along the shoreline, flooding and water logging of alluvial plains, widening and reduction of the river width are the usual phenomenon that need more attention and preventive measures.

The flat terrain of the coastal plains, relatively large width of the rivers nearer the estuaries, the rough behaviour of the sea during the monsoon period and the tidal influence are the main reasons for the presence of large number of sand shoals in the estuaries as well as to a considerable length in the river. The changes in the areal extent, length and width of the sand shoal, their shift towards the bank are very common. The rivers being shallow, there is frequent flooding of the adjoining lands.

OBJECTIVE

In the present study, an attempt is made to identify the major sandbars in the Gurpur and Netravathy river estuaries as well as along the river upstream to a length of about 5 km. Their size, orientation and changes in the areal extent are quantified. The changes in the estuary are also studied. The effect of changed land use on the banks of Gurpur and Netravathy river is also studied. It is also intended to make a comparative study of the changes in Northern and Southern sand spits at the estuary and to establish possible reasons for the frequent changes that are taking place both on the seaside and on the riverside.

STUDY AREA

The study area lies between 13015'-13030' N latitude and 74040'-74045'E longitude comprising of Gurpur - Netravathy estuary on the West coast of India. The river Netravathy is located on the South of Mangalore city, while Gurpur river is on the Northern side. The New Mangalore Port is located adjacent to Gurpur river on its Northern bank. The new Industrial Area of the Mangalore city is also located on the Northern bank of Gurpur river. The two rivers originally flowing towards the West, change their direction and flow parallel to the sea up to the confluence, which is on the western side of the city. The average annual rainfall in the area is about 3500mm to 4000mm. The monsoon rainfall is normally extended over a period of 100 to 120 days starting from second week of June. The temperature ranges from 17°c to 32°c.

DATA USED

The IRS LISSII data of the following dates are used in the present study. 12-Nov-1988 (FCC), 21-Nov-1989 (FCC), 10-Nov-1994 (FCC) and 10-Feb-1998 (Geo-coded product). The other baseline informations are extracted from SOI toposheets on 1: 50000 scale along with the groundtruth informations.

METHODOLOGY

The basemap of the study area is prepared using SOI toposheets on 1: 50000 scale. The multi-date imageries used in the present study are enlarged to 1:50,000 scale using Pro-

com II. Geocoded product of Feb. 1998 is traced using light table for the purpose of superposition on the base map. The visual analysis is carried out by superimposing the multi-date imageries on the base map. The major sand bars, shoals in the estuary as well as along the river course are identified. The location, orientation with respect to the banks, the average length and width of these sand bars along with areal extent are measured. The changes occurred in the Northern and Southern sand spit of the estuary are analysed. The river mouth width on the sea-side as well as on the river-side and also the least width are analysed. The erosion and accretion process at the estuary are also studied. Digital planimeter is used to measure the changes in areal extent of important features of estuary.

RESULTS AND DISCUSSIONS

In the present study, it is attempted to establish the short term changes as well as long term changes in the Netravathy-Gurpur estuary. For the short term changes, the imagery of Nov. 1994 and Feb. 1998 are compared while to analyse the long term changes imageries of Nov. 1988 and Feb. 1998 are compared. The results presented here confine to (i) the river mouth changes, (ii) Southern sand spit and beach around, (iii) Northern sand spit and beach around, (iv) Sand bars and islands in the estuary and along river course.

The river mouth opening

The tidal river mouth at the confluence of the Netravathy-Gurpur rivers is subjected to frequent changes. This can be attributed mainly to the dynamic nature of both the river and the sea. The river mouth opening both on the sea-side and on the river-side along with the minimum width of the opening are given in Table 1.

Table 1. Details of river mouth width.

Opening in m.	12-Nov-1988	21-Nov-1989	10-Nov 1994	10-Feb-1998
Least	240	165	335	430
Facing sea	875	1030	425	660
Facing river	460	690	725	780

It can be observed that the river mouth dimensions on the sea-side is changing more alarmingly than that on the river-side. Fig.1 compares the estuarine details during the years 1988 and 1998.

It has been concluded by the earlier investigators (A. Vittal Hegde and A. Ravindra (1998)), that the construction of breakwater on the Northern side of the estuary during the year 1988 has almost stopped the migration of the river mouth. But the study of these satellite data clearly establishes that the breakwater on the Northern side has not effected the changing nature of the estuary. However, it can be seen that the changes in the river mouth dimensions is mainly due to the changes taking place on the Southern sand spit of the estuary. The sea-side opening is more dynamic compared to the river-side.

At the same time, it is interesting to note that the river mouth width on the riverside has an increasing trend during the study period. The unstable nature of the Southern sand spit

is the result of more dynamic nature of Netravathy river. Relatively straight joining of the river with sea may also be an acceptable cause for this. The least width of the river mouth also shows an increasing trend. Once again, these changes are mainly attributed to the changing nature of the Southern sand spit.

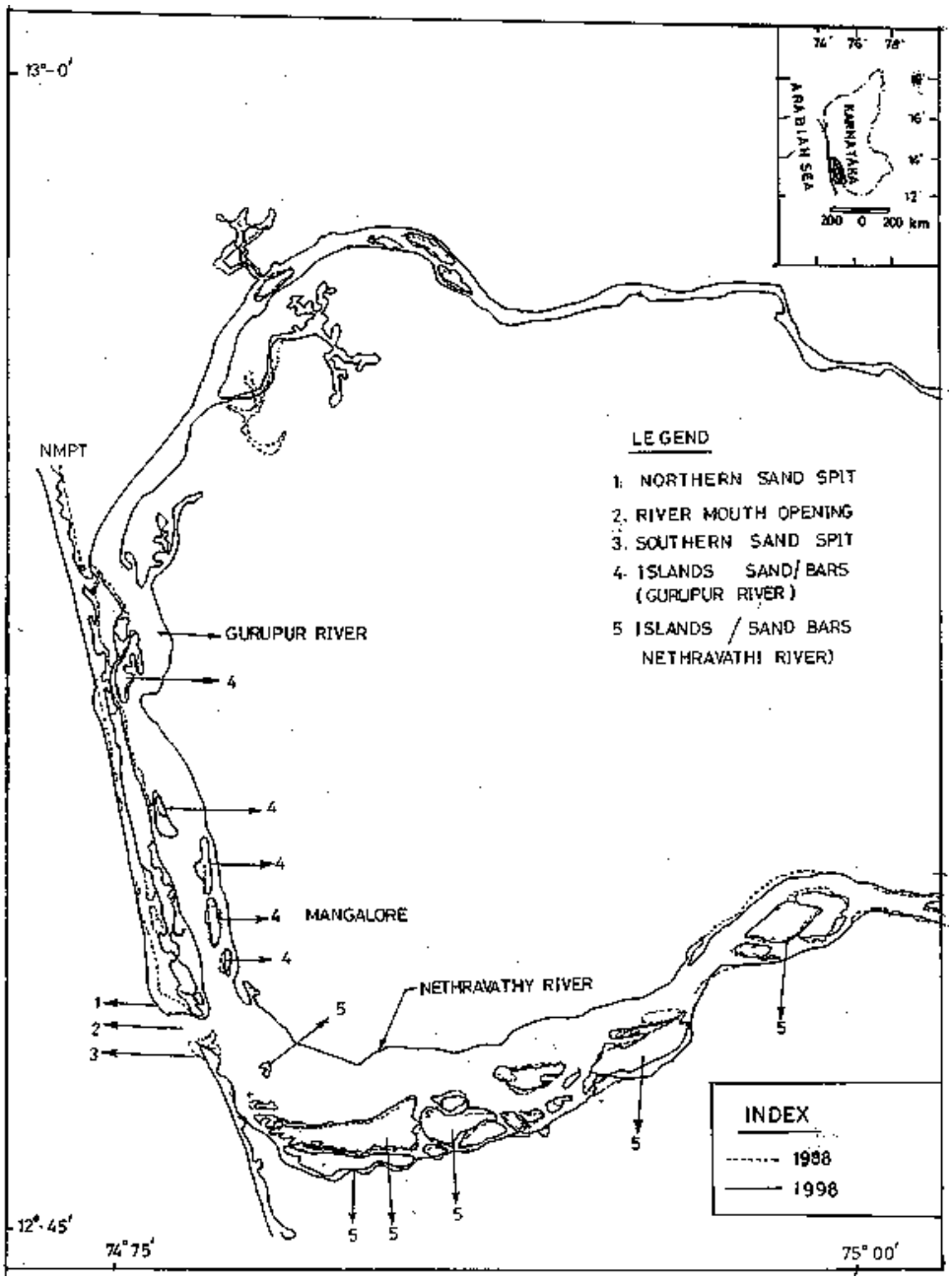

Figure 1. Comparison of imegeries for the years 1988 and 1998.

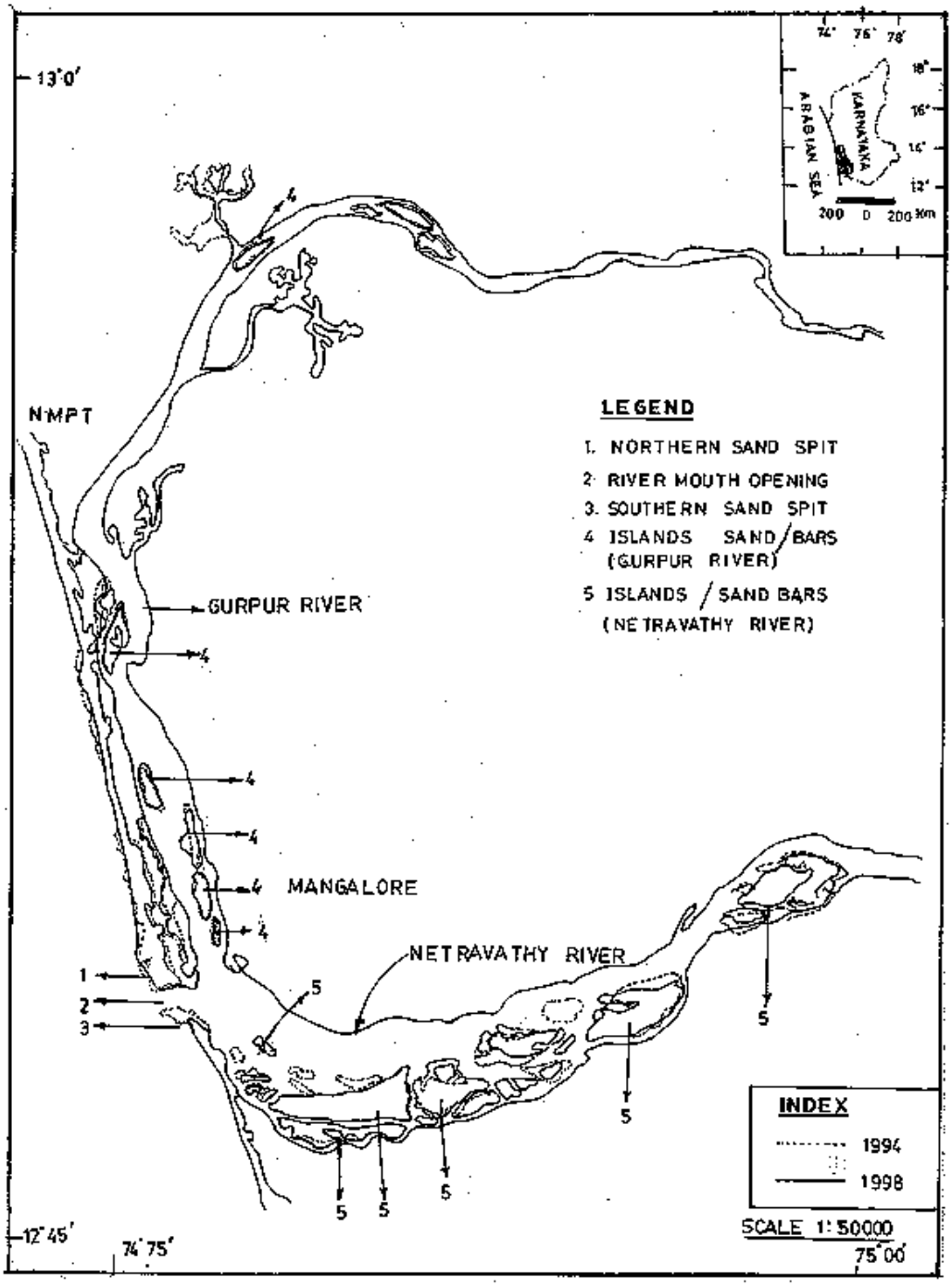

Figure 2. Comparison of imegeries for the years 1994 and 1998.

Southern sand spit and beach around

Analysis of the satellite data of various dates clearly establishes that the Southern sand spit is more vulnerable than Northern sand spit. Table 2. shows the changes in the areal and linear dimensions of Southern sand spit.

Table 2. Details of Southern sand spit.

Description	12-Nov-1988	21-Nov-1989	10-Nov 1994	10-Feb-1998
Area in Sq. km.	2,36,250	2,31,250	2,68,550	1,77,000
Length in m.	1,915	2,200	1,765	1,270

It is observed that there is a decrease in the areal extent of sand spit and also the length on the river-side. However, during 1994, due to the extension of the spit towards West in the form of a lip, there is a temporary increase in the areal extent of the Southern sand spit (Fig. 2). This concurs with the earlier observation of increase in the width of the river mouth on the river-side. The estuary portion on the Netravathy river side adjacent to the Southern spit is relatively more dynamic, causing more frequent changes in the size and shape of the Southern spit as well as that of the shoals and sand bars in the estuary.

Northern end sand spit and beach

The details of land masses and sand beach both on sea-side and river-side are given in Table 3. During 1988 major area was covered by beach sand. However, there were isolated pockets of land masses with human habitat. By studying the imagery of 1989 and 1994, it is evident that the land masses have grown in size, reducing the areal extent of beach sand.

Table 3. Details of Northern sand spit.

Area in Sq. km.	12-Nov-1988	21-Nov-1989	10-Nov 1994	10-Feb-1998
Sand bank facing river & sea	7,27,750	7,18,750	5,26,000	6,91,250
Sand bank facing river only	4,17,500	3,02,750	2,68,750	3,22,500
Land masses	23,500	1,68,250	2,08,500	Extending in the form of a strip
	1,41,000		Extending in the form of a strip	
	1,23,500	1,71,500		

Analysis of the imagery of 1998 shows very clearly the further growth of the land mass in the form of a strip from the Southern end of spit (near the confluence of rivers) towards the mainland on the Northern side extending towards the harbour area. The width of this land between the Gurpur river and the sea has substantially increased from 1988 to 1998. The gain on the beach sand on the sea-side is relatively more. The accretion on the river-side is observed after 1994. It would be very interesting to note that the northern spit is more stable over the years compared to the Southern spit, with substantial gain in the land area. This may be attributed mainly due to two reasons,

The construction of breakwater on the Northern side of the Northern spit (near the harbour).

The Gurpur river taking a gradual 900 bend, flows parallel to the sea for a considerable distance before reaching the confluence of Netravathy, causing less danger to the Northern spit.

Sand bars and islands

Both Netravathy and Gurpur rivers consist of several sandbars and islands of varying sizes along the river for a considerable distance upstream. Some of them are islands with vegetation and human activities. A few among these are also surrounded by river sand. The islands of larger size are found more in Netravathy river than in Gurpur river.

These islands/sand bars are generally elliptical in shape with converging downstream end. These islands and sand bars keep changing both in their size and shape. There is a lateral shift in these sand bars or islands towards the outer bank. However, the depth of water near sand bars are relatively shallow, mainly due to deposition of river sand.

One of the major problem in the river dynamics is the erosion and sedimentation. Removal of sand from these rivers is a continuous phenomenon and the same is being used as building material in the form of fine aggregate. This removal of sand is observed in both the rivers throughout the year except during monsoon floods. This may be one of the important reasons why the river maintains its normal course. This also reduces the flooding of adjacent lands. There is a natural balance between deposition and erosion in the river bed because of this human activity. Otherwise the sediment carried by the river water from the steep slopes of Western Ghat and from the river bed upstream would have caused a more serious problem of silting of these rivers near the estuary, every year. This phenomenon is observed in almost all the West flowing rivers of the district.

Both the rivers have maintained their width almost constant over the years, except for slight changes in the meandering portions near the Netravathy estuary. The natural disilting because of the removal of the river sand virtually throughout the year might be an advantageous phenomenon to maintain the river course and the width. However, it can be observed that Gurpur river is relatively more stable compared to Netravathy river. This may be attributed to the fact that the confluence of the river is near the straight portion of Netravathy river. The effect of this is more realised in the sandbars and islands in the Netravathy river as well as Southern sand spits, as they are subjected to more frequent changes in shape and size.

The effect of Gurpur estuary, being parallel to the sea coast has resulted in more stable Northern spit. However, the Southern spit caused by the Netravathy river is subjected to more frequent changes, as the Netravathy river estuary is more straight to the sea.

CONCLUSIONS

The analysis of the multi date satellite data leads to the following conclusions.

Northern spit formed by the Netravathy-Gurpur river estuary is relatively more stable, mainly due to the parallel flow of Gurpur river near the estuary and also due to the existence of breakwater on the Northern side of the spit.

Southern spit formed on the Netravathy river side is unstable, mainly due to relatively straight joining of the river to the sea.

The removal of the river sand in the region upstream of the estuary by the local people is an advantageous phenomenon as far as the river dynamics are considered.

Netravathy river estuary is more dynamic and its effect is felt on the sand bars and islands found in the estuary as well as on the Southern spit.

One of the remedial measures for stabilising the southern spit on the Netravathy river side may be to construct a breakwater on the Southern side of the Southern spit.

The changes in the river mouth width is mainly due to the changes in the Southern spit and the influence of the Northern spit on this is practically negligible.

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