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The Shifting “Charlands” of the Godavari at Rajahmundry

Priyank Pravin Patel

Having traversed through the Eastern Ghats in a narrow, confined channel till just upstream of Rajahmundry town in Andhra Pradesh, the Godavari becomes a much wider and braided stream here, before splitting into its two main distributaries at the Dowleswaram Barrage, downstream of the town. The numerous channel deposits of the Godavari River consisting mostly of point and mid-channel bars and islands, termed “charlands”, that occupy and comprise the braided reach of the river from upstream of Rajahmundry to the barrage, have been delineated from different geospatial data products such as LANDSAT, IRS & Google Earth images using image processing software. The plan-form changes in the position of the channel deposits were then ascertained on a temporal scale by mapping their distance and direction of shift via digitization of individual deposits from different images and overlaying of the extracted layers using GIS. Digitization also enabled computation of surface area changes of channel deposits over time. Relative heights of the channel deposits and of the embankment at Rajahmundry were extracted from S.O.I. topographical maps for a short segment of the study reach and a three dimensional surface was created to better visualize and decipher the various micro-terrain attributes existent at that time. Precipitation data for the Rajahmundry area and the Godavari’s discharges here have been correlated to understand the river’s regime and how it affects the charlands. Incorporation of the river-borne sediment data into the above showcases the river’s carrying capacity during varying discharges. A field visit enabled ground-truthing of satellite images, collection of sediment samples from the mid-channel islands for analysis and extraction of surface profiles through clinometric survey. An understanding of the socio-economic condition of the small island communities that dwell on these shifting charlands and whose life and livelihood are most affected by the shifting nature of these channel deposits have been gleaned through questionnaire survey. The land use characteristics of the charland surface mapped from satellite images reveal the prevalent practices.

Introduction

People seldom live in isolation. Most reside in settlements, which vary. The town of Rajahmundry (16°58′60″N, 81°46′60″E) in the East Godavari District of Andhra Pradesh is located on the left bank of the River Godavari at the head of its delta, at an average elevation of 14 metres above sea level. Asia’s largest rail-cum-road bridge on the river Godavari linking Kovvur on the right bank with Rajahmundry is considered to be an engineering feat. The Dowleswaram Bridge and barrage across the Godavari is 7 kms. south of Rajahmundry. The Godavari here is a broad, braided river with numerous channel deposits. The channel deposits, some of which are quite large mid-channel islands having sparse vegetal cover (grasses and mangroves), frequently shift their positions relative to each other, evident especially so after the receding of monsoon waters. This causes a lot of distress to the fishermen communities inhabiting these islands. The above channel deposits are the focus of the study, especially their changing positions caused by erosion on their upstream sections and deposition in their lee areas, resulting in a predominant downstream shifting of the channel bars over time.

Study Area

Having traversed through the final vestiges of the Eastern Ghats about 100 Kms. upstream of Rajahmundry town (during which it receives its last major tributary, the Sabari from Orissa), the Godavari initially occupies a wide meandering channel having alternate point bar deposits and then turns into a braided river having numerous islands. The reach of the Godavari from Polavaram (17°14′45″N, 81°39′35″E) about 20 kms. upstream of Rajahmundry till the Dowleswaram Barrage (16°55′N, 81°45′E), 7 kms. downstream of Rajahmundry, is the focus of this study. Since the Godavari occupies a single channel till Polavaram, downstream of which, it splits up into multiple channels as a result of in-channel deposition, the precipitation and discharge data used are of this station’s.

Objectives

The specific objectives of the present study are:

- To delineate the various channel deposits of the study reach from satellite images and construct a 3-D model of a segment of the reach using local elevation data
- Examination of the precipitation received over the study reach, the flow regime of the Godavari River herein and the sediment load borne by it to derive any existent correlations between the above
- Comparison of channel deposits over time to detect any changes in their position and determine the amount of shift
- Examination of a typical charland environment, the prevalent land cover and the land use characteristics as practiced by the resident fishermen communities
- Evaluation of the socio-economic condition of the above mentioned fishermen communities and how the shifting charland environment affects their life and livelihood

Methodology

The flow chart of the above study has been structured as follows:

Delineation of the channel deposits of the study reach from the following satellite images (Plate I)

A. LANDSAT Orthorectified Images to examine long term changes in relative positions:
   i. LANDSAT 2 MSS (WRS-I, Path 153, Row 48) Scene imaged 08/01/1977
   ii. LANDSAT 5 TM (WRS-II, Path 142, Row 48) Scene imaged 10/11/1990
   iii. LANDSAT 7 ETM+ (WRS-II, Path 142, Row 48) Scene imaged 28/10/2000

   For LANDSAT 2 (spatial resolution 79 metres) and 5 (spatial resolution 30 m) data, images of Bands 1, 2, 3, 4 have been stacked to create the required FCC image, which was subsequently used to delineate and demarcate the in-channel deposits. For the LANDSAT 7 ETM+ sensor, only Band 8 PAN Image has been used since it offers a significantly higher spatial resolution (15 m) than the other bands (30 m) facilitating charland demarcation.

B. From the following IRS P6 (RESOURCESAT-I) LISS-IV MX Images to examine short term (successive year-wise) changes in relative positions:
   i. Orbit: 1649 Segment: 1 Strip: 1 Scene:114 Date: 10-FEB-2004 and Orbit: 1649 Segment: 1 Strip: 1 Scene:115 Date: 10-FEB-2004
   ii. Orbit: 10856 Segment: 1 Strip: 2 Scene:094 Date: 19-NOV-2005 and Orbit: 10856 Segment: 1 Strip: 2 Scene:095 Date: 19-NOV-2005
   iii. Orbit: 15701 Segment: 1 Strip: 1 Scene:119 Date: 26-OCT-2006 and Orbit: 15701 Segment: 1 Strip: 1 Scene:120 Date: 26-OCT-2006
   iv. Orbit: 19040 Segment: 1 Strip: 2 Scene:094 Date: 18-JUN-2007 and Orbit: 19040 Segment: 1 Strip: 2 Scene:095 Date: 18-JUN-2007

C. Collaged higher resolution Google Earth Images (Digital Globe, October, 2007) comprising the study reach
   - Geo-referencing of the above images and digitization of the in-channel deposits from each image
   - Overlaying of channel deposit layers derived from above Landsat images to determine amount and nature of charland shift and associated changes and determination of common ground between successive image derived layers
   - Overlaying of channel deposit layers derived from above IRS images to determine amount of shift for one particular sampled bar in successive years
   - Deriving local elevation data (using relative heights of the mid-channel islands and riverbank embankments) from Survey of India Topographical Sheet No. 65G/16 and using the above to create a digital elevation model for a segment of the study reach
   - Correlating precipitation received at Polaravam and discharge and sediment borne data for the Godavari River as measured at Polavaram
   - Evaluation of the socio-economic conditions of the fishermen communities on sampled islands through questionnaire survey
   - Mapping the land cover and land use facets on a sampled island from collaged

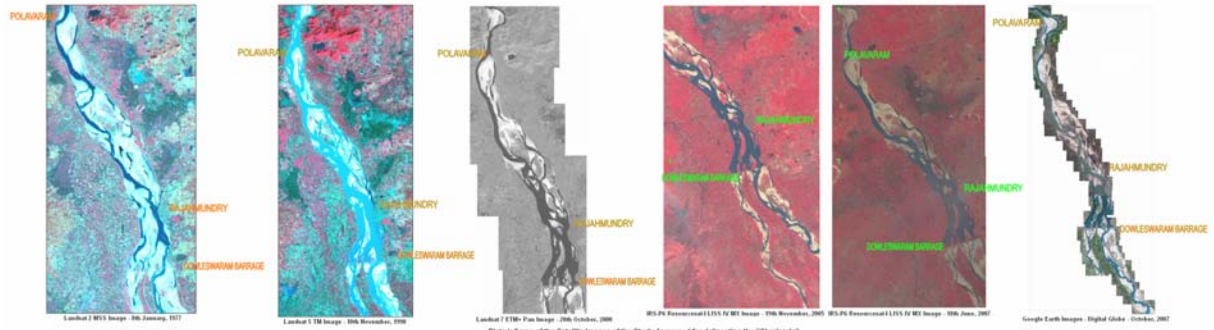

Plate I: Some of the Satellite Images of the Study Area used for delineating the "Charlands"

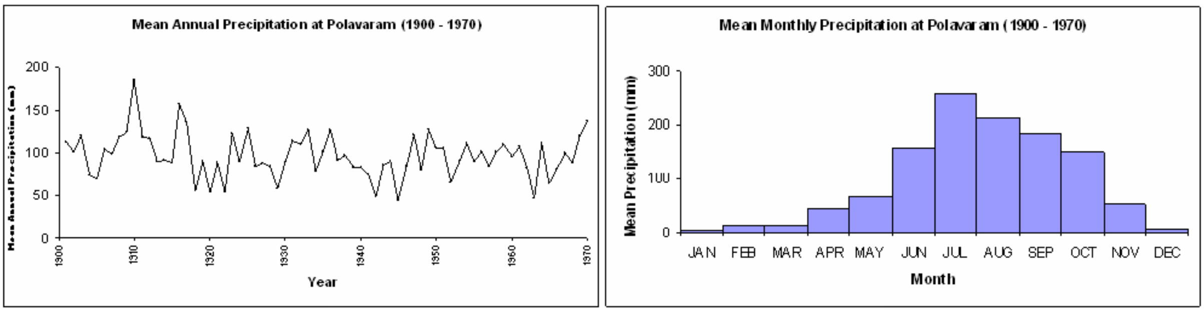

Fig 1(a) & (b): Annual Precipitation & Mean Monthly Precipitation received at Polavaram (1900 - 1970)

high resolution Google Earth images and its slope segments through clinometric survey

The River Godavari at Polavaram

The River Godavari, the largest of the peninsular rivers, and third largest in India, drains about 10% of India's total geographical area. The catchment area of the river is 312,812 sq.km. and is spread in the States of Maharashtra (48.6%), Andhra Pradesh (23.4%), Madhya Pradesh (10.0%), Chhatisgarh (10.9%), Orissa (5.7%) and Karnataka (1.4%) The basin lies in the Deccan Plateau and is situated between latitude 16°16´N to 22°43´N and longitude 73°26´E to 83°07´E.

Rainfall and Discharge

The average annual runoff of the Godavari at Polavaram (1996 to 2000) is 88,728 MCM from a catchment area of 3, 07,800 sq.km. above this station. The maximum water level observed at this station was 28.017 m with a discharge of 87250 cumec on 16.08.1986 while the minimum water level observed was 12.077 metres accompanied with a discharge of 48.40 cumec on 18.05.1973. The rainfall received is characteristic of the southwest monsoon with most of the precipitation in the months of June to September [Fig 1(a) & (b)] with some rain, a fraction of the above, being received in the winter months probably due to the northeast monsoon and cyclonic rain. A

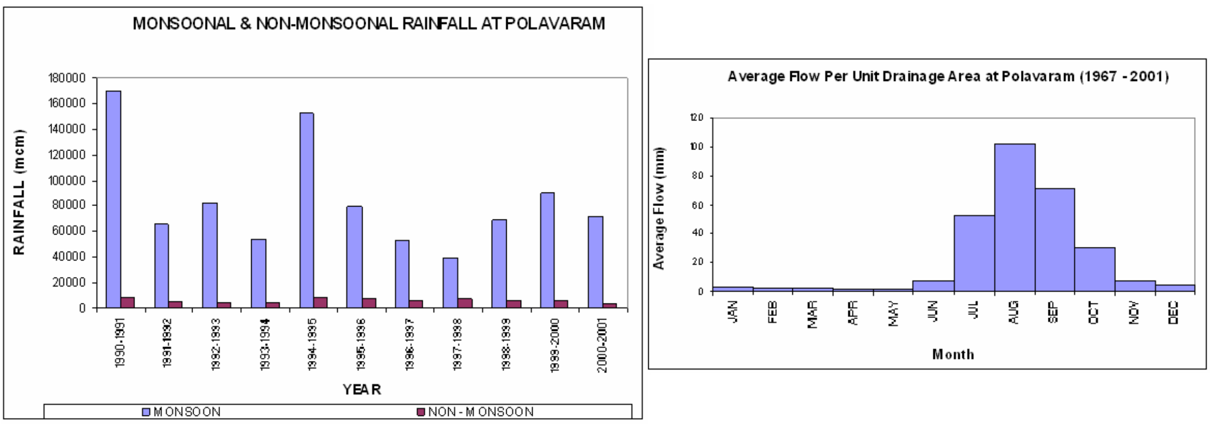

Fig 2 (a) & (b): Monsoonal & Non-monsoonal Rainfall Comparisons and Monthwise Drainage Area Changes at Polavaram

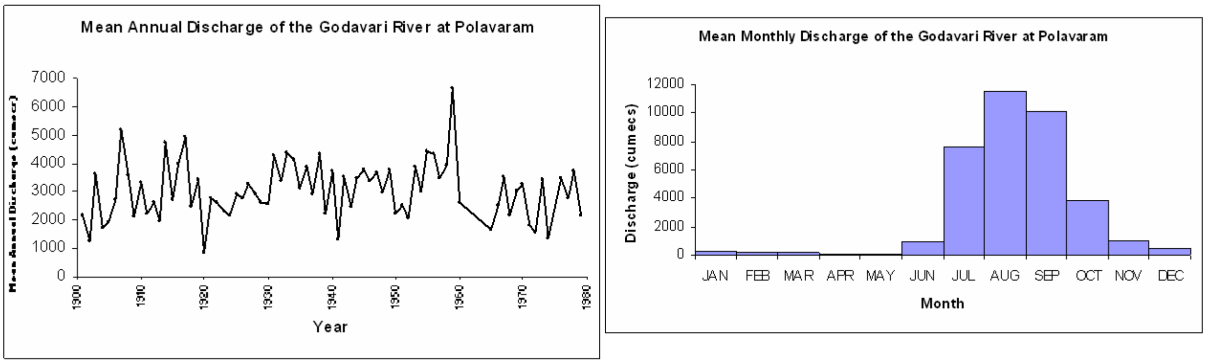

Fig 3 (a) & (b): Annual and Monthly Discharge Variations of the Godavari at Polavaram

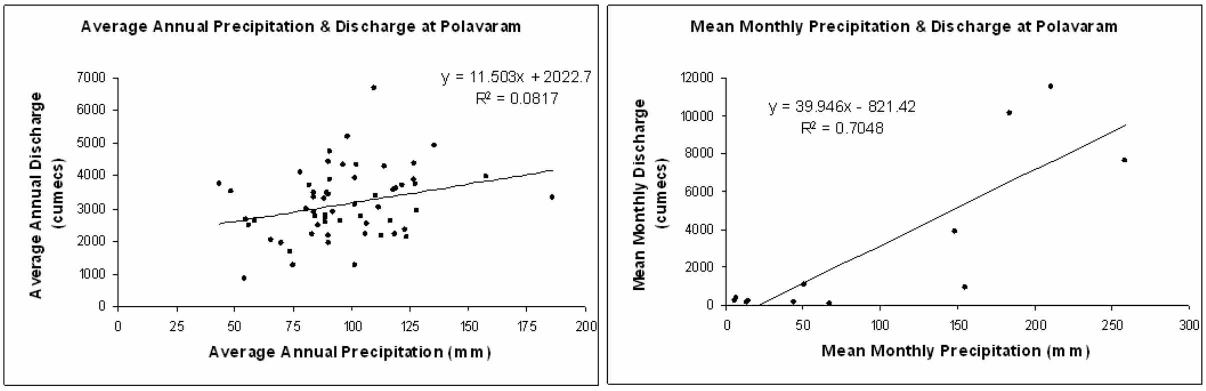

Fig 4 (a) & (b): Precipitation & Discharge Correlations for the Godavari at Polavaram

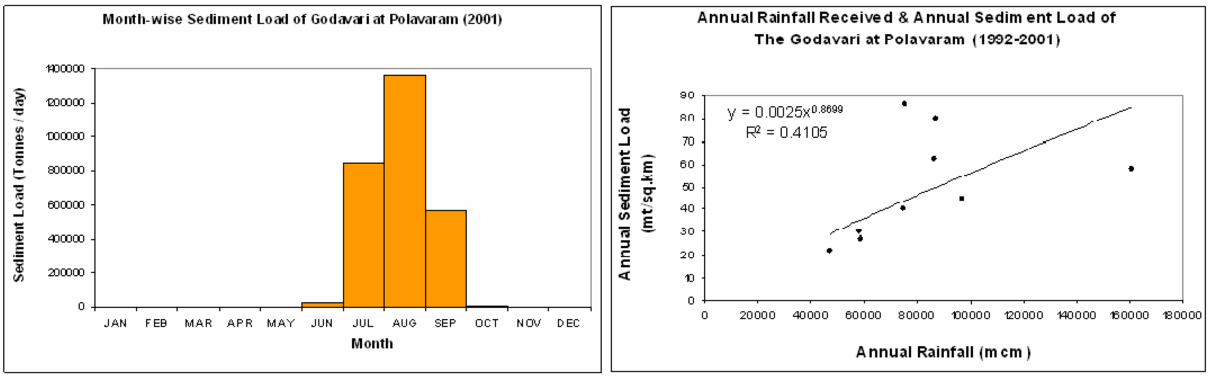

Fig 5 (a) & (b): Monthwise Sediment Load Variations and
Rainfall - Sediment Load Correlation for the Godavari at Polavaram

comparison of the monsoonal and non-monsoonal rainfall for the period 1990-1991 to 2000-2001 at Polavaram further exemplifies this view with the monsoonal rainfall amount being at times more than ten times the non-monsoonal rainfall amount [Fig. 2(a) & (b)].

Consequently, the average flow per unit drainage area too shows a sharp spurt in the monsoonal months due to the heavy runoff and subsequent inflow into the channel from the surrounding areas, headwater reaches and tributaries. Such concentrated rainfall results in a much elevated run-off and high discharge for a short duration [Fig 3 (a) & (b)] with rainfall and discharge being strongly correlated [Fig 4 (a) & (b)] – a condition ideal for forming braided reaches.

Sediment Borne

The sediment system in a river is a continuum of sediment supply, transport and storage operating at a range of scales in space and time and incorporating the terrestrial and aquatic components of the river catchment. The catchment is perhaps the largest scale at which this system operates, whilst particles can be supplied, transported and stored within the river channel over areas of a few square meters.

The Godavari's seasonality ensures that maximum sediment is borne by the river during the monsoonal months, with the amount of sediment being transported by it during the rest of the year being almost negligible to the load borne between July and September at Polavaram [Fig. 5(a) & (b)]. A sediment-wave thus passes through the study reach. This augments mid-channel bar deposition and braided reach formation. Both precipitation and discharge are thus well correlated with the borne sediment load.

Braiding and Charland Formation

River channels form the main conduits for the transfer of water, sediment, nutrients and organic matter. They comprise the river network and they provide particular suites of physical habitat. The river channel may be divided into reaches that have been defined as "a length of river in which channel dimensions and features relate characteristically to identifiable sediment sources and sinks" (Newson, 2002). Rivers with different calibre bed material require different discharges for sediment transport and bank erosion. The dimensions and planform of a river channel must therefore depend locally on the materials into which it is cut and the legacy of past processes and management.

Channel planform

One of the most important features of a river channel is the planform. The planform controls the local stream gradient, affects the 3-dimensional structure of the flow within the channel banks and through these influences the range of depositional and erosional features and sediments that make the physical habitat. The planform is diagnostic of the type of channel processes present in the river system at that point; for example, a braided channel is indicative of high rates of sediment transport and local storage in the river channel. The channel planform can be inherited from past processes and undergo further modification as a result of river management efforts. The Godavari, like many rivers exhibit a tightly meandering planform set within broad floodplains. These rivers have low stream energy relative to the strength of the river bank and bed material. They can be thought of as "naturally canalised". Therefore modifications to the planform in these river systems tend to be permanent. (Sear, et. al., 2003)

Braiding

The following conditions lead to river braiding:

- Braiding occurs when the transport capacity of a river is exceeded by the sediment supply, or when transport rates are typically very high.
- The response of the river channel is to deposit sediment in bars (shoals) that are inundated by higher discharges and subjected to sediment transport.
- During higher flows, channels may be cut across shoals or blocked by aggrading sediment, leading to a planform that is characterised by a dynamic network of channels and bars. Braided channels are typified by relatively high bank-full channel width, and low bank-full depth.
- Braided rivers occur across a range of valley slopes, depending on the grain size of the bed material in transport with lower gradient braided rivers which tends to form in sand sized bed material.
- Vegetation of bar surfaces is one of the main mechanisms by which natural braided rivers become stabilized. This occurs following incision of the river channel into the bed, progressively abandoning the bar surfaces and enabling colonization by plants. In natural braided systems, Large Woody Debris (L.W.D.) too helps to create bars and islands by acting as local sites for sedimentation.

In-channel deposition and depositional features – the charlands

The accumulation of sediment in the river network over time results in a variety of morphological features that are often transient, but may also be apparently permanent. The residence time of sediments within these stores is very variable and depends on:

- The nature of the materials stored (how easily they are transported),
- The degree of storage available at a given site (it is possible for sediment stores to be "over-filled" and to become suppliers of sediment)
- The type of store; either active such as a dune where particles are concentrated but in motion, or passive where sediments are immobile e.g. a floodplain or infrequently inundated bar surface.
- Cover of vegetation
- Distance from channel (as opportunity for subsequent storage is increased)

At the largest scale are zones of sediment accumulation. These comprise reaches of up to several kilometres in length, that are characterised by braided or wandering planforms, high rates of channel movement across the floodplain, and coarse/mixed grain size sediments. Reworking of this sediment, and the accumulation of new sediment stores arriving from upstream maintain the activity of the channel. In some cases, the input of sediment can lead to the formation of a sediment wave. Sediment waves, lead to a progressive downstream adjustment in the river morphology as the wave of sediment passes through.

Within the river channel, there exist in response to sediment transport processes and hydraulic patterns, localised accumulations of sediment that are termed "bars" but may be more commonly referred to as "shoals" – "chars" in the vernacular. Bars typically form in channels that can create flows that are 10 times the depth of the median grain size of the bed sediment (Church, 1992), and that have general movement of the river bed. Bars exhibit a variety of forms depending on the geometry of the channel and the structure of the flow. Free bars such as mid-channel bars and alternate bars often develop after rare large flood flows and produce patterns that can influence subsequent channel adjustment.

In the study reach where the floodplain consist of past river sediments, the channel is able to transport most of the sediment load. Bar forms are organised into relatively well defined features, with typically finer sediments than adjacent parts of the river bed. In straight or gently sinuous channels, asymmetrical cross-sections develop, resulting in side bars or even alternating side bars (alternate bars) in response to the structure of the flow field. Greater meandering results in these side bars becoming point bars from their position on the "point" of the inner bend of the meander. The fine sediment is deposited on the outside of a meander bend, constructing so-called "counter-point bars". All the above bars are seen in the study reach.

The mid-channel bars or charlands have a variety of forms in themselves, depending on the extent to which they have been dissected by subsequent flows following their formation. Mid-channel bars form under three basic mechanisms:

- Deposition on a riffle following high flows and scour of the upstream pool;
- Deposition in an over-wide section due to a rapid reduction in transport capacity
- Erosion of a channel at the back of a point bar, followed by capture of the main channel and diversion through the new channel.

In such lowland channels where a significant fine sediment load exists in the river network, fine sediments can be deposited in sufficient depth to form morphological features and deposition is usually dominated by fine sediments (sand, silt and clay). However in-channel features are often less significant, in terms of the quantity of material deposited, than marginal and over-bank storage, especially at flood levels. Typically, fine sediments accumulate in areas of low velocity, such as the margins of river channels where the frictional resistance of the banks slows the flow, or in dead water areas formed in the lee of bars or where old channels create backwaters. Sediment exchange often takes place through the growth and migration of bends in meandering channels. The configuration of bars and the pattern of planform change through time are related to interactions and changes in coarse supply, local exchange with material derived from lateral shifting, and throughput to downstream (Sear, et. al., 2003). A reach with numerous, large, high relief bars with mixed sediments including fines and limited vegetation colonisation is indicative of a reach that is accumulating and storing sediment – such as the study reach.

Derived Charlands' Attributes

The above charlands have been delineated form the various satellite images (Fig. 6) and their attributes tabulated (Fig. 7). The salient features are:

- The number of mid-channel islands has increased showing a marked increase from 1997 (LANDSAT MSS) to 1990 (LANDSAT TM), more than doubling in number. This may have occurred due to dissection of the former existing bars, further aided by the greater spatial resolution (30 m for LANDSAT TM as compared to 79 m for LANDSAT MSS) available that facilitates demarcation of smaller bars. However the total area of the charlands has decreased significantly (56.0760 Sq.km. as compared to 101.01 Sq.km.). Maximum perimeter and maximum area too show a marked decline. A higher water level in the river may be a possible cause for the above.

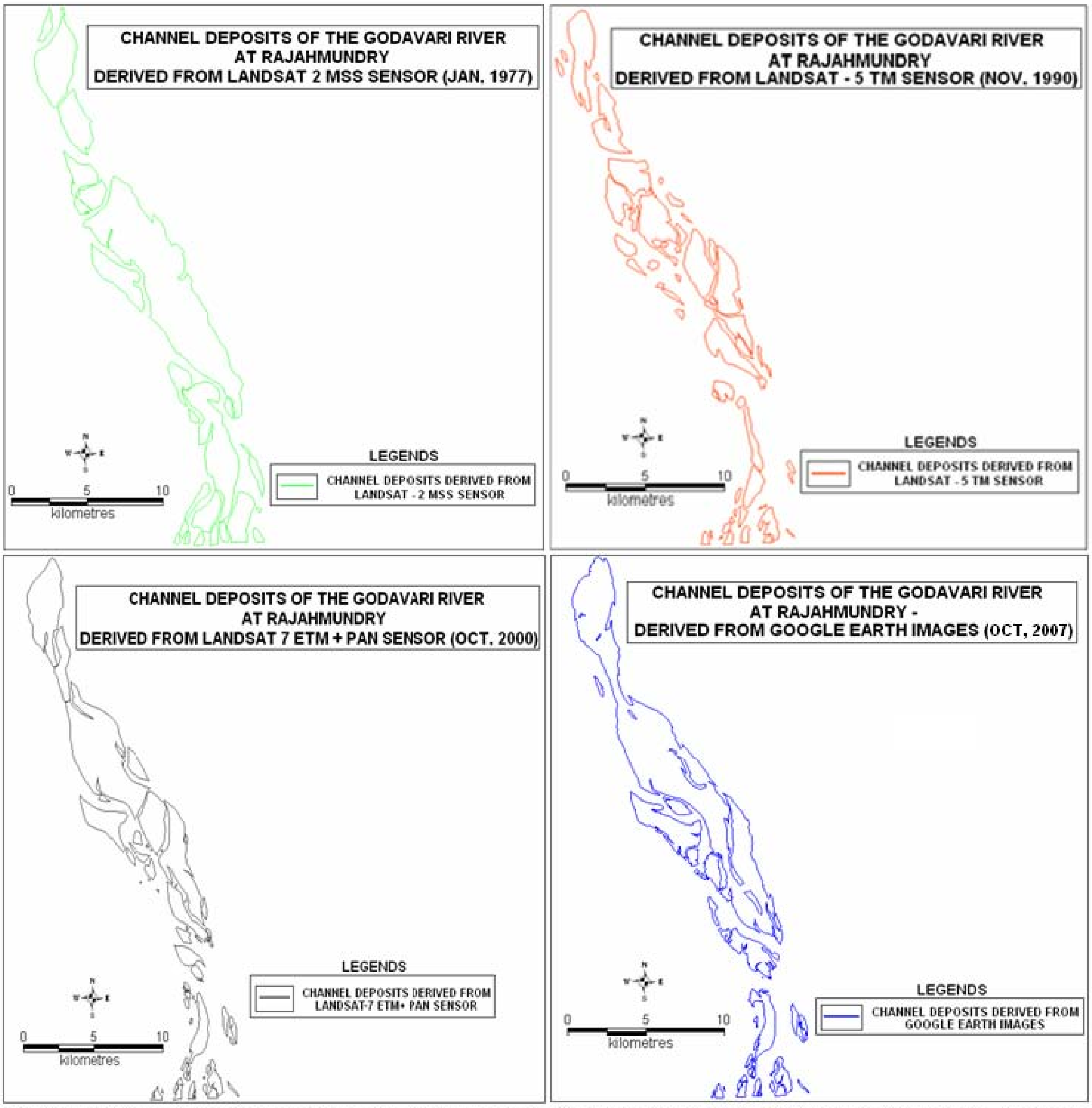

Fig 6 : The Delineated Channel Deposits of the Godavari River at Rajahmundry from various Satellite Images

- The number of mid-channel islands from 1990 to 2006 does not vary widely, though their attributes like total area, maximum area, total perimeter and maximum perimeter do show a marked, steady increase. Sensors of higher resolutions have facilitated better demarcation and more accurate computation of their attributes. A greater number of bars are apparently being formed in this reach as the river dynamics change over time.

A 3-dimensional view of a section of the study reach (Fig. 8) created from local R.L. values help to understand the creation of these bars, especially showing how they rise up from the riverbed due to continued local sedimentation. The derived charland deposits from different sensors have been superimposed (Fig. 9) in order to obtain the common sections of bars across two time periods or from two different sensors. The attributes of these common sections (Fig. 10) indicate the amount of channel deposit shifting and the percentage change that has occurred for that time period and the relative change in bar positions. The above changes have been tabulated (Fig. 11). The salient features are:

- The number of common channel deposit fragments has shown a steady increase, especially among the latter day sensors like TM, ETM+ and Google Earth (GE) having

VARIOUS DIMENSIONS OF DELINEATED *CHARLANDS* AS OBTAINED FROM THE DIFFERENT IMAGES

Sensor	Scene Image Date	No. of Channel Deposits (C.D.)	Total Area (Sq.Km)	Mean Area (Sq.Km)	Min. Area (Sq.Km)	Max. Area (Sq.Km)	Total Perimeter (Km)	Mean Perimeter (Km)	Min. Perimeter (Km)	Max. Perimeter (Km)
LANDSAT 2 MSS	1977	25	101.0100	4.0404	0.0150	45.1940	202.3950	8.0958	0.6910	47.3990
LANDSAT 5 TM	1990	57	56.0760	0.9838	0.0210	6.5590	225.7290	3.9602	0.6750	17.2710
LANDSAT 7 ETM+ PAN	2000	63	70.8230	1.1242	0.0020	21.3900	230.6590	3.6613	0.1890	33.1660
Google Earth	2007	52	79.2758	1.5245	0.0006	56.2005	257.9930	4.9614	0.1180	114.1320

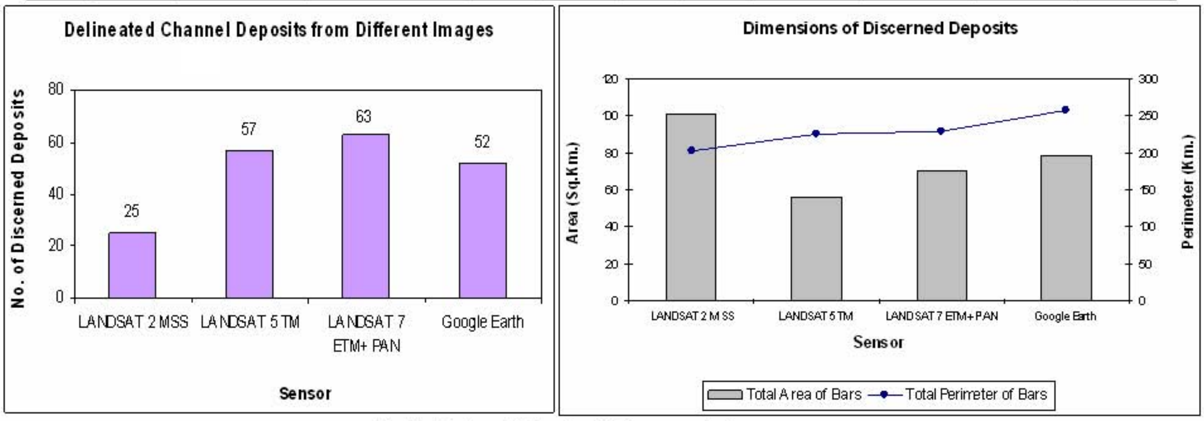

Fig 7 : Derived "Charland" Characteristics

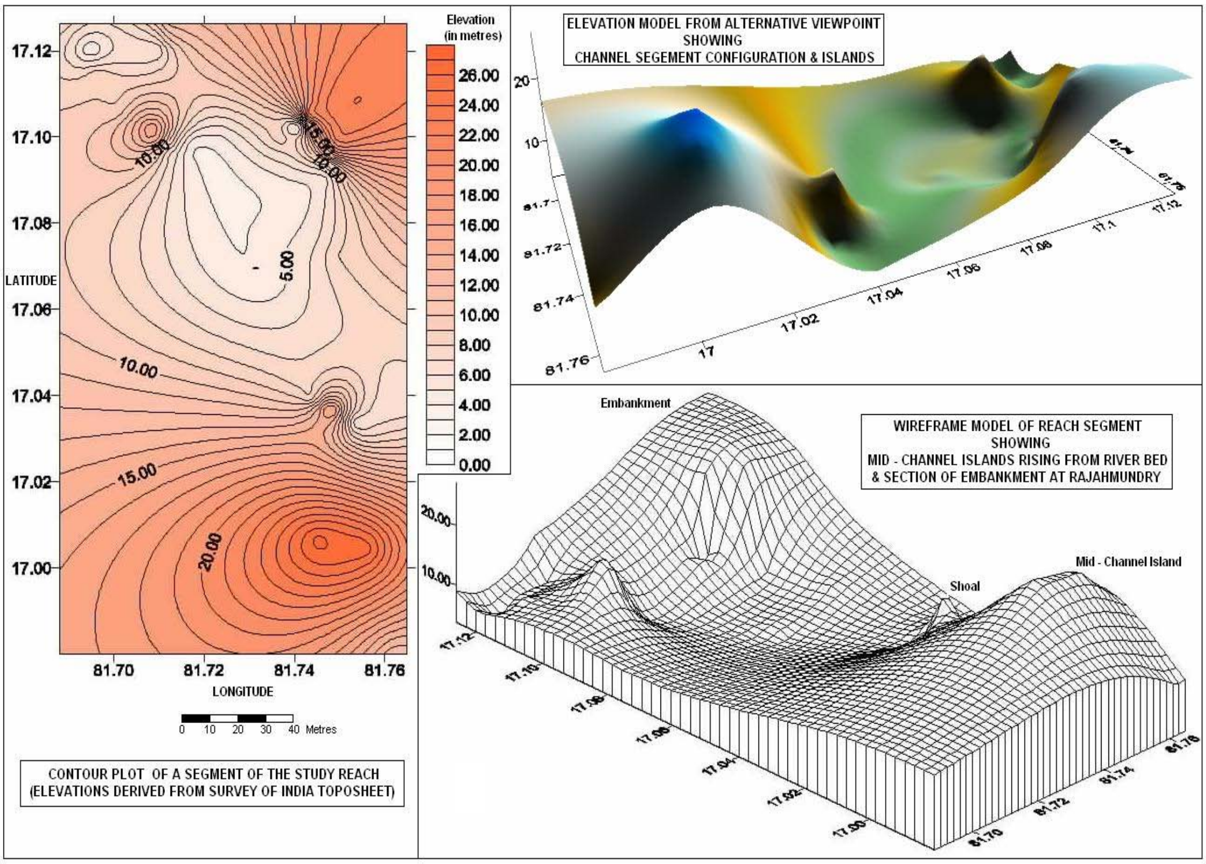

Fig 8 : Morphology of a Section of the Study Reach - 3D Surface generated from local R.L. values

a great many numbers of fragments that are common to both. As such the percentage change in the channel deposit positions is quite low when charlands derived from these sensors are compared with each other. TM – GE and ETM+ - GE comparisons show a change of less than 20%. It indicates that though having experienced much fluctuations in previous

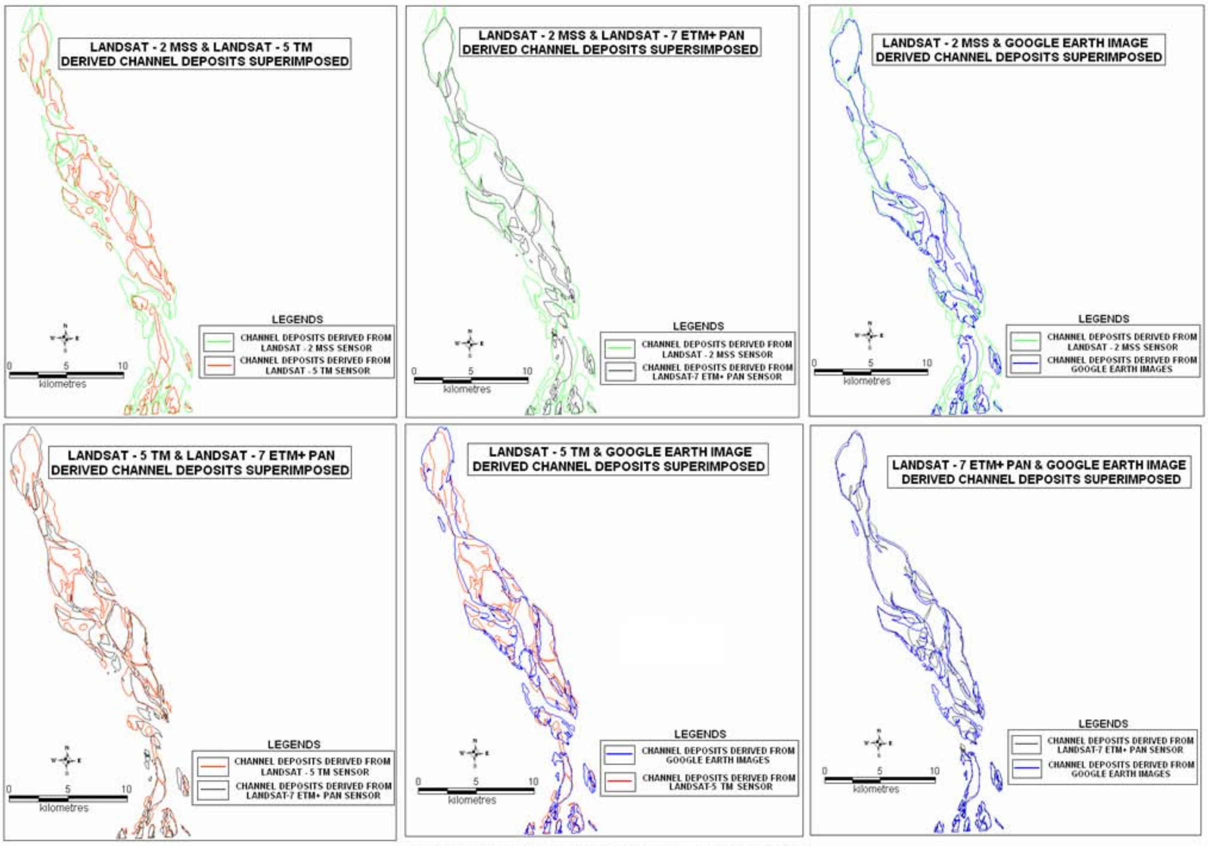

Fig 9 : Superimposed "Charland" Deposits

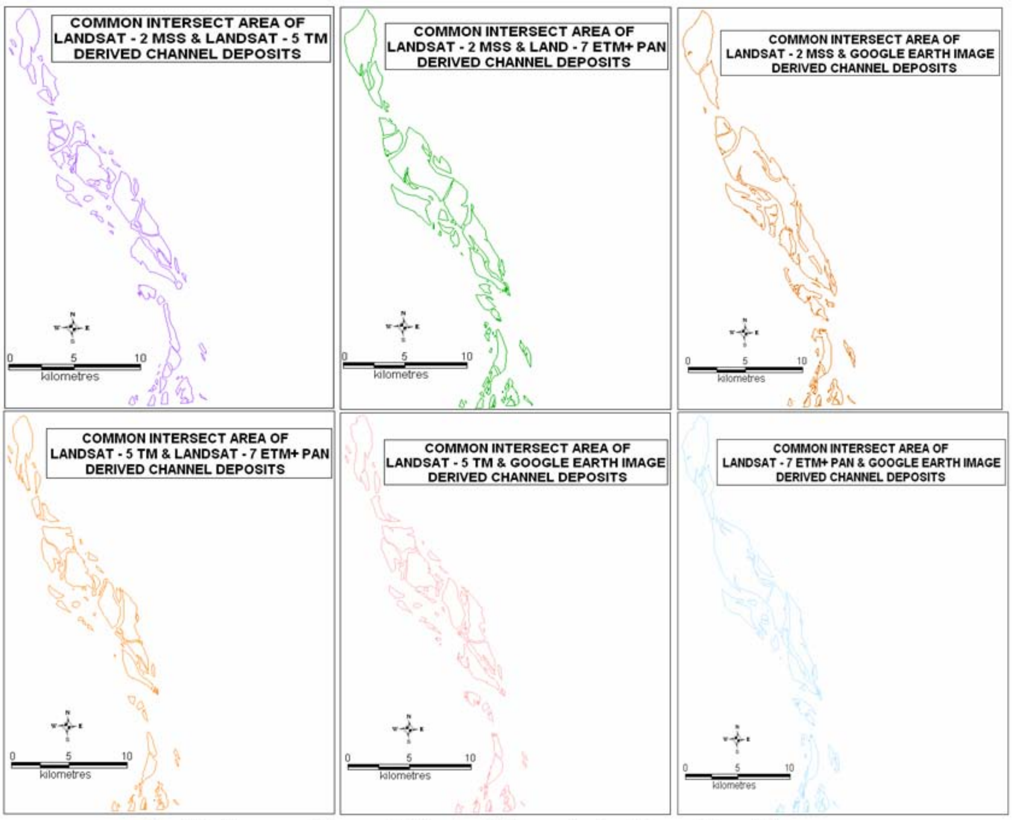

Fig. 10 : Common Intersect "Charland" Areas derived from different Sensors

CHARLANDS DATA DERIVED FROM INTERSECTION OF IMAGE LAYERS

Intersect Layers	Time Range	No. of Common Channel Deposit Fragments	Total Common Area (Sq.Km)	% Change
MSS & TM	1977 - 1990	67	46.3281	54.14
MSS& ETM+	1977 - 2000	68	58.6877	41.89
MSS & GE	1977 - 2007	72	70.4768	30.23
TM & ETM+	1990 - 2000	77	43.7772	21.93
TM & GE	1990 - 2007	97	45.1328	19.51
ETM+ & GE	2000 - 2007	97	61.6960	12.89

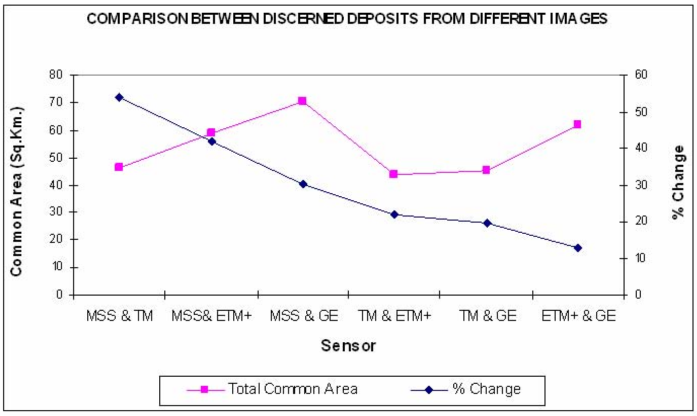

Fig 11 : Comparison and Changes between different Sensor derived "Charlands"

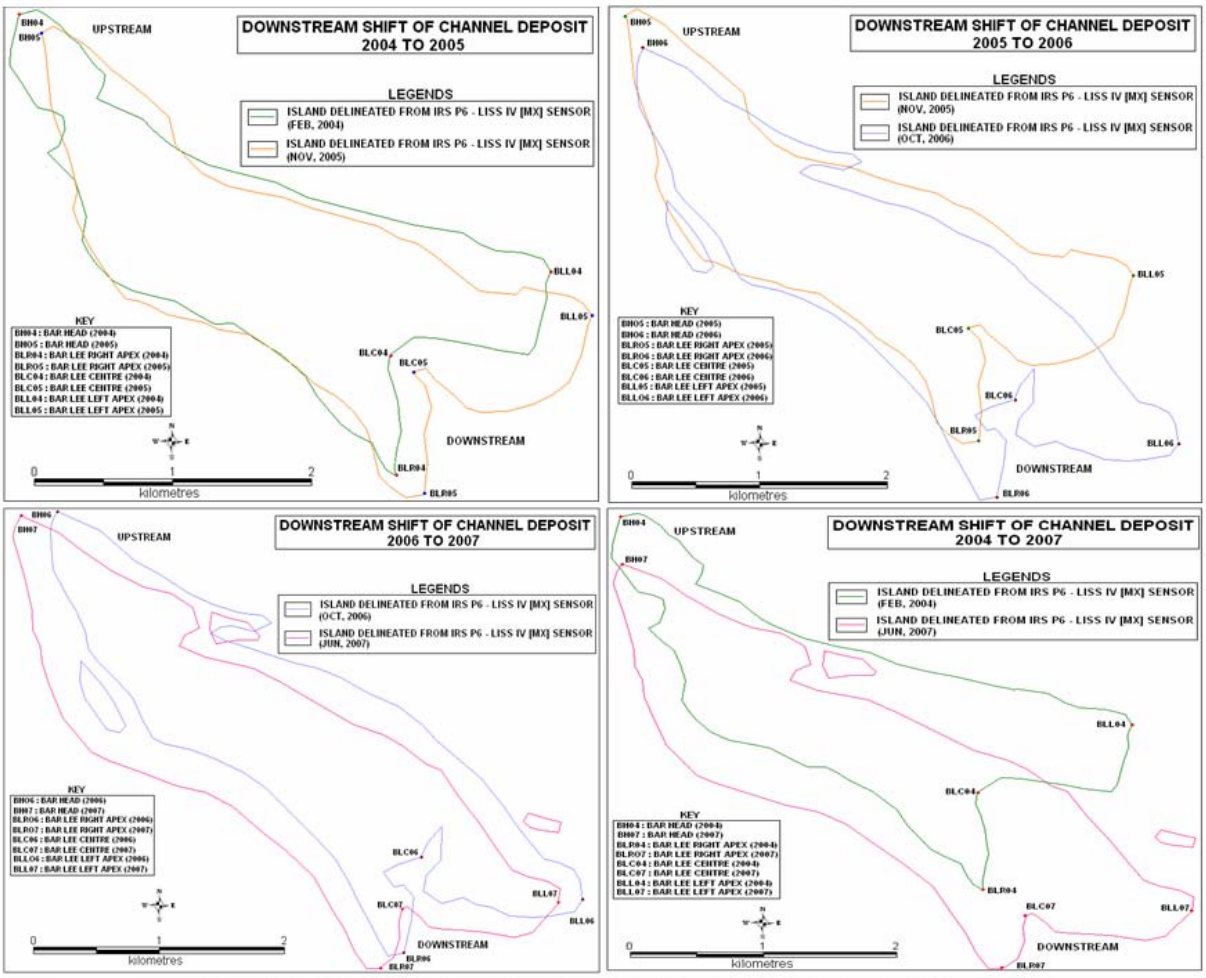

Fig 12 : Positional Shifts of a Single "Charland" in Successive Years and Overall Shift decades, of late, the study reach has stabilized to a greater degree, till possibly the next high-intensity but low-frequency occurrence, for example a sudden massive deluge and/or associated great flood.

- The greatest change is seen when channel deposits derived from MSS & TM sensors are compared. With the least number of common fragments between them (67) a change of 54.14% occurs between the deposits of these two eras, possibly due to a sudden change in the river regime and dynamics during that period.
- Across the largest timescale (1977 to 2007), there are 72 common channel deposit fragments between the MSS & GE sensors with a change of 30.23%.

By their very nature, and influenced by the river dynamics, charlands shift downstream. To further elucidate this, a single bar's position has been mapped over the years 2004 to 2007 and the total shift documented. Furthermore, the rates of movement differ at different point along a bar's periphery. It does not move bodily or en masse, rather it is more of a piece-meal shift, with a portion being eroded and detached from the upstream section and continued deposition in the lee or downstream section of the bar. Four stations are thus taken along the selected bar's perimeter, the Bar Head (BH) on the upstream apex point of the selected bar, the area which first feels the force of the Godavari's considerable flow velocity. The Bar Lee Left (BLL), Bar Lee Centre (BLC) and Bar Lee Right (BLR) are three stations along the transverse lee portion of the above bar. The shifting of these four stations across the selected timescale reveals the differential movement occurring along the bar edges (Fig. 12). The overall shift amount of the bar and the above individual stations are computed (Fig. 13). The salient features are:

- A comparison of the shifting across consecutive years reveals that the greatest overall shifting has taken place in the time period 2005 to 2006, where the amount of shift of each individual station was nearly or more than double that of the previous (2004 to 2005) or even the ensuing year (2006 to 2007). An event of large magnitude could have been possible for this. The time periods 2004 to 2005 and 2006 to 2007 show almost similar amount of shifting for every station.

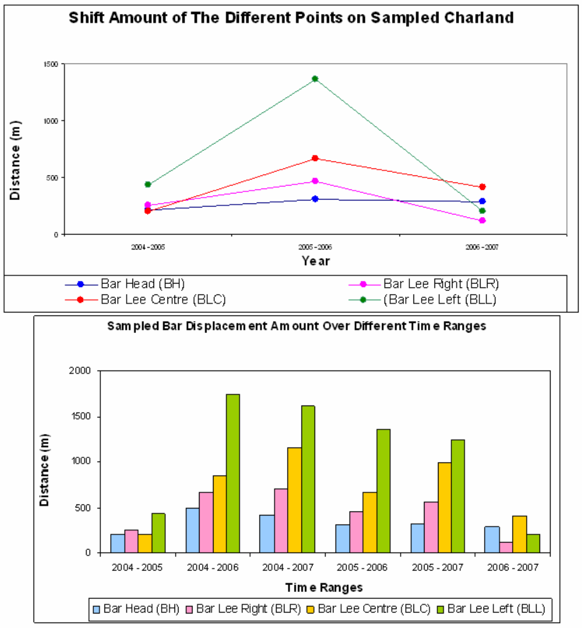

Fig 13 : Successive Year-wise and Overall Shift of the Demarcated Four Stations on the Sampled Bar

- The station that has shifted the most in a downstream direction is the Bar Lee Left (BLL) station, moving the most during the time period 2005 to 2006 and having an overall shift of more than 1500 m in the time period 2004 to 2007.
- Delineations of the bar's position over the above time periods reveals the piece-meal shifting that takes place. Portions of the bar can be seen to detach and again re-attach as the bar shift downstream.

Socio-Economic Overview of the Charland Dwellers

Sample questionnaire survey conducted on a few of the charlands reveals a few facts about the day-to-day lives of its inhabitants. Ironically, the shifting nature of these islands attract fishermen and other poor people to make their homes there, since no rent can be officially charged for such impermanent surfaces. However their lives are greatly dependent on the Godavari's regime, often having to spend months living on their boats during the flood season. For all necessary goods and services they have to row across to Rajahmundry or Kovvur on either bank.

The number of dwellings per island vary, the larger ones having as many as 25-30 while the smaller shoals being home to 5-10 ramshackle huts with mud walls and thatched roofs on the upper surface (Plate II). A small school has been set up on one of the larger islands by a local missionary, the sole teacher rowing across each day to teach about 30 children. The children suffer the most from having to live in such an environment. Stomach ailments abound due to lack of proper drinking water facilities.

Fishing is obviously the primary form of sustenance with the numerous boats being anchored to the islands when not in use (Plate III). Around 10 kgs. of fish are caught by each boat's crew and sold in Rajahmundry daily, prices ranging between Rs. 30 to Rs. 50 per kg. Some larger islands have developed enough of a soil profile to enable vegetable gardening. This augments the inhabitants' diets and some produce is even sold in Rajahmundry. Every household has its own small plot. The upper surface of the islands, about 7 m above the river level, is where these small patches of cultivable land are, along with the huts. The rest of the islands are usually covered in riverine grasses, some scrub or are just bare sand (Fig. 14).

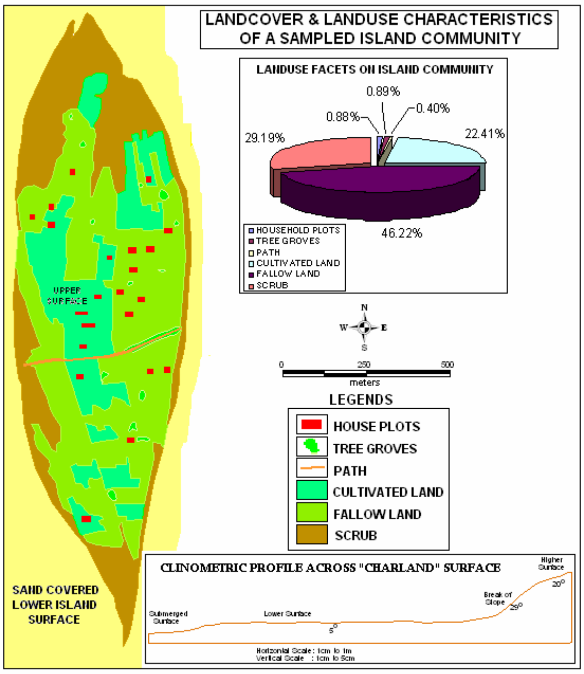

Fig 14 : A Typical "Charland" Community

Conclusion

The river islands or charlands of the Godavari at Rajahmundry are dynamic surfaces, continuously shifting due to the throughput of discharge and sediment load that passes through this reach in a concentrated form during the monsoonal months every year. The above study has revealed the shifting

Low Gradient Charland Surface sloping into the River Godavari

Break-of-Slope on Charland Surface with Vegetated & Inhabited Upper Surface

Vegetated Upper Charland Surface with thin soil cover & Mangrove Vegetation

Multi-layered Charland Surface

Plate II: The Different Types of "Charland" Surfaces

The Fishermen Communities on the "Charlands"

Google Earth Images depict the small Settlements on the "Charland" Upper Surface

Plate III : The "Charland" Fishermen Communities as seen from the ground level and above

nature and rates of these islands and how they often break-up into smaller pieces or unite together again, dependent on the sediment-discharge balance in the reach. The above has only been a planimetric study of this phenomenon, with more detailed studies of river flow patterns required to understand how the river dynamics affects these mobile surfaces.

The stability of these charlands has a huge effect on the life of their inhabitants. To protect these communities, possible conservation efforts must be in place, to retard any active degradation of the islands through anthropogenic misuse. The islands are popular picnic sports for the residents of the surrounding towns and the local government has plans of developing them as theme parks and as real estate. However, detailed studies are required to understand the charlands' behaviour, stability and annual changes that are part of the natural cycle, before these plans are to be pursued rigorously.

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