International Journal of Applied and Natural Sciences (IJANS)
ISSN(P): 2319-4014; ISSN(E): 2319-4022;
Vol. 5, Issue 1, Dec – Jan 2016; 1-10

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

CHANGING MORPHOLOGICAL VIEW OF NAYACHARA TAIL USING GEOINFORMATICS

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ABSTRACT

Nayachara, a small island of unconsolidated alluvium, located at the confluence of the Hooghly River and the Haldi River at the northern extent of the Bay of Bengal. The island is prone to tidal effects and cyclonic activities. The complex geomorphological and hydrological study along with remote sensing techniques are applied for understanding the recent morphological changes arising out of rapid growth of small islands just downstream of southern tip of Nayachara Island generally known as Nayachara tail. The present study has analyzed the change in area in and around the Nayachara tail through erosional, depositional and tidal activities during the last four decades using multi-temporal satellite images.

KEYWORDS: Alluvium, Multi-Temporal, Remote Sensing, Tidal

INTRODUCTION

The Hooghly estuary being a highly dynamic zone requires continuous monitoring and updating of information. Conventional means of study is time-taking, labour oriented and expensive. Remote sensing techniques have the ability to monitor this dynamic environment and record changes. The study area is located in West Bengal state covering parts of Purba Medinipur and South 24 Parganas districts. The latitudinal extent of the study area is from $21^{0}42^{'}00^{"}$ North to $21^{0}57^{'}00^{"}$ North and longitudinal extent of the study area is from $87^{0}50^{'}00^{"}$ East to $88^{0}12^{'}00^{"}$ East. It covers the lower part of the Nayachara Island in the Hooghly Estuary.

Previously, several works have been done on this context. Ghosh T. et al., (2001) make an assessed landuse dynamics and shoreline changes of Sagar Island using remote sensing techniques. Gopinath G. and Seralathan P. (2005) estimated erosional action of the Coast of Sagar Island. Melesse AM. (2004) worked on space and time related changes of land surface parameters in the Red River of the North basin. Apart from these, Purkait B. (2008) evaluated coastal erosion due to wave dynamics operative in Sundarban delta. Moreover, Shaikh MG et al., (1989) used Landsat TM data in order to design coastal morphological mapping around the Gulf of Khambhat.

GENERAL DESCRIPTION OF THE STUDY AREA

Nayachara Island virtually divides the Hooghly River into two channels. Till the early eighties, the channel between Nayachara and Haldia (Jellingham-Haldia channel) was navigable up to Kolkata Dock. But because of reduced flow, sediments started getting deposited further up stream instead of compensating erosion in the sea-facing islands. As the riverbed at Balari gradually became more shallow, the main downward flow of the river took the Rangafalla channel on the eastern side of Nayachara, thereby eroding the islands of Lohachara, Bedford and Ghoramara. Bifurcation of flood flow took place near the tail of Nayachara Island (southern end) proved to be the major resistance for flood flow causing change

in flow path. The same resistance attributes for damping effect and gradual cessation of flood flow through Haldia channel. The details regarding the extension of Nayachara Tail (in southern direction), its spatial and vertical growth and erosion are analysed by Image Analysis.

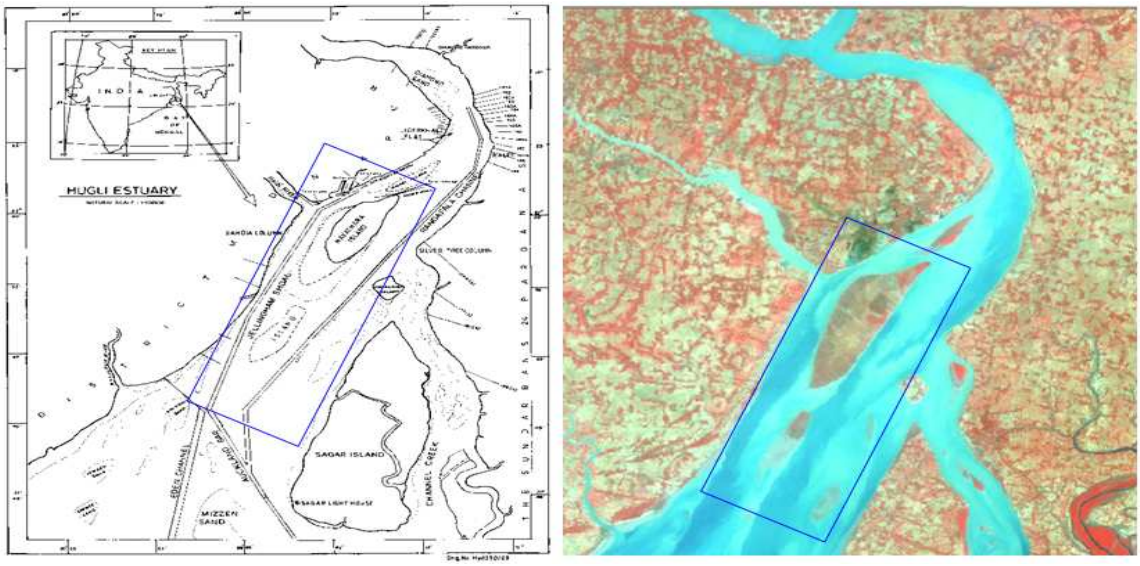

Figure 1: Location of the Study Area

OBJECTIVE OF THE STUDY AREA

The main objective of the present study is to monitor the changes observed in and around Southern tip of Nayachara Island and its extended tail using time series satellite images. Remote Sensing technique (viz. interpretation of satellite data along with synchronous hydrological condition) is applied to the study area over the year 1973-2010. The visual interpretation as well as digital image processing technique is applied for understanding the recent morphological changes arising out for rapid growth of a small island just downstream of southern tip of Nayachara Island locally named Nayahara Tail and presentation of some hydrological parameters adjacent to the study area are also needed for evaluation.

IMAGE INTERPRETATION

The morphological condition of the estuary is overviewed from the images covering the tail of Nayachara Island, Ghoramara Island & western strip of Sagar Island between the periods 1973 to 2010. The images considered for comparison are IRS 1C 16/12/2000, IRS 1C 05/02/2005, IRS 1C 14/02/2008, IRS 1C 15/01/2009 and IRS 1C 10/01/2010 and LandSat TM 1973. Interpreted results are given below:

Table 1: Tidal Information Synchronous With Satellite Passes

Date	Name of the Satellite Product with Details	Time of Pass	Tide in Metre				
			Sagar	Gangra	Haldia	Balari	D.Harbour
16/12/2000	IRS 1C LISS-III	10.30 A.M.	NA	2.3	1.73	1.55	1.45
05/02/2005	IRS 1C LISS-III	10.30 A.M.	2.05	2.4	2.6	2.86	2.95
14/02/2008	IRS 1C LISS-III	10.30 A.M.	2.2	1.45	1.16	1.25	1.25
15/01/2009	IRS 1C LISS-III	10.30 A.M.	3.5	2.75	2.38	1.94	1.25
10/01/2010	IRS 1C LISS-III	10.30 A.M.	2.15	2.3	2.47	2.6	2.75

- The overall health of the estuary was well in 1973.
- The Bedford group of Islands are remarkably reduced in size and some of them are totally disappeared.
- The transverse rotation of the shipping channel from Mud Pt. to Lower Rangafalla channel indicates creation of a slack zone in the tail of Nayachara Island (south eastern part).
- A small tail of Nayachara Island has been seen in the IRS image of Dec. 2000.
- Tail of Nayachara Island has been developed gradually since 2000.
- From 2008 image, it is clear that heavy deposition has been taken place in and around Nayachara tail.
- 2009 image shows some erosion around Nayachara Island compare to 2008 image but this is due to high tidal condition.
- Continuous deposition is vividly clear from 2010 image.
- The southern part of Nayachara Island has been deposited during this period.

NAYACHARA ISLAND DURING 1973 -2010

Table 2: Area of Nayachara Tail in Different Years

Year	Area in sq. km.
1973	------
16/12/2000	4.278
05/02/2005	10.145
14/02/2008	19.187
15/01/2009	8.437
10/01/2010	12.118

From the satellite images the growth or decay of Nayachara Tail has been analysed. In 1973, in the southern tip of Nayachara Island there was no trace of sand bar or land mass. From 2000, a small patch of exposed land had been identified. Continuous deposition had been taken place from 2000 to 2010 (Figure 3). Around 19 sq. km. area had been added in the Nayachara tail during this period. There were also some lenticular strip of small exposed land mass / sand bars have been developed in the down-stream of Nayachara Island and the over-all area of Nayachara tail has been increased throughout this period (Table 2).

Table 3: Spatial Distribution of Land and Water Area for Different Years

Year	Area of Nayachara Tail (sq. km.)	
	Decrease	Increase
1973-2000	—	4.278
2000-2005	—	5.867
2005-2008	—	9.042
2008-2009	10.75	—
2009-2010	—	3.681
1973-2010	—	12.118

Table 4: Decrease/Increase of Nayachara Tail Compare To Different Years

Area in sq. km.			
Year	**Total Land Area**	**Total Water Area**	**Total Study Area**
1973	162.52	420.71	583.23
16/12/2000	181.8	401.43	583.23
05/02/2005	191.62	391.61	583.23
14/02/2008	212.58	370.65	583.23
15/01/2009	180.52	402.71	583.23
10/01/2010	199.92	383.31	583.23

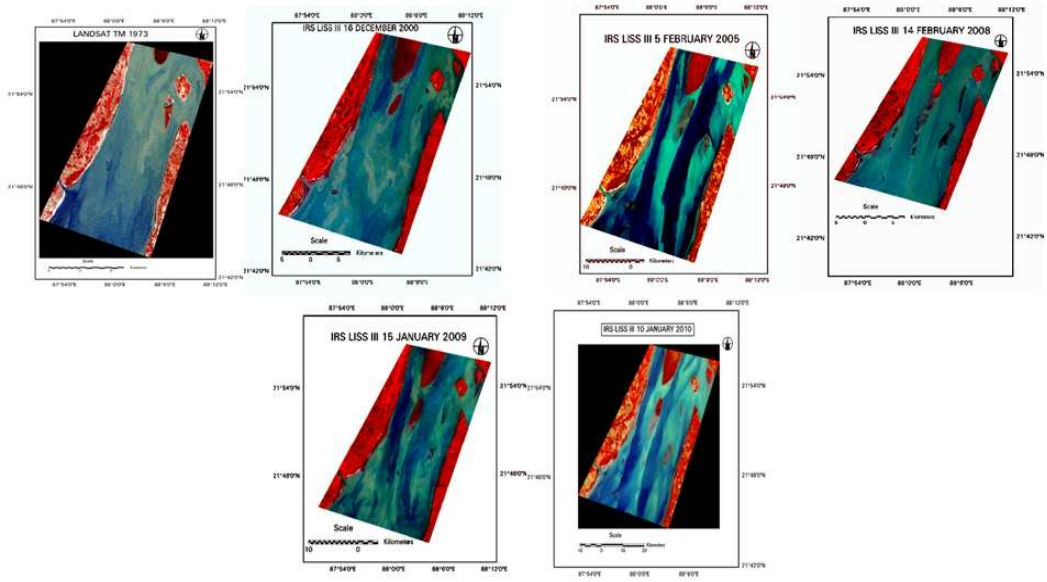

Figure 2: Multi-temporal Satellite Imageries of the Study Area

STUDY RELATED TO HYDROLOGICAL INPUTS

To study the flow characteristics in the vicinity of east-west passage near the southern tip of Nayachara Island different hydrological parameters namely velocity and its direction (both during flood and ebb), the suspended sediment concentration, salinity measured in parts per thousand and average grain size distribution of the bed material have been observed during different time period (2001-2009). The following results are furnished below as a result of those observations:-

Velocity: The maximum velocity observed along the right bank side of Gangra position-A was 2.83 m/sec during flood and 2.03 m/sec during ebb on 21st August, 2001. At Ghoramara Island the maximum velocity 1.66 m/sec was found during flood and 2.43 m/sec during ebb on 17th February, 2003. At southern tail of Nayachara Island the maximum velocity 1.5 m/sec during flood and 2.31 m/sec during ebb was observed on 10th February, 2009 (Table 5).

Current Direction w.r.t. north: The direction during flood was 44 degree on 12th January, 2001 and 217 degree on 21st June, 2005 along the right bank side of Gangra position-A. The direction at Ghoramara Island was recorded as 339 degree during flood and 216 degree during ebb on 8th may, 2008 and 9th May, 2008 respectively. At southern tail of Nayachara Island direction was 118 degree and 284 degree during flood and ebb respectively on 12th February, 2009 (Table 5).

Sediment Concentration: The maximum concentration was found as 4.7 Gms/lit on 18th February, 2010 along the right bank side of Gangra position-A. At Gangra position-D maximum concentration 1.77 Gms/lit was observed on 8th February, 2005. At Ghoramara Island maximum concentration 1.24 Gms/lit observed on 8th may, 2008. Maximum concentration at the southern tail of Nayachara Island was observed as 2.23 Gms/lit on 12th February, 2009 (Table 6).

Salinity: Along the right bank side of Gangra position-A the maximum salinity was recorded as 13.39 parts per thousand (ppt) on 21st June, 2005. A maximum measured salinity of 21.50 ppt was found at Gangra position-D on 28th February, 2009. At Ghoramara Island and at southern tail of Nayachara Island the maximum salinity was recorded as 19.8 ppt and 15.1 ppt on 8th May, 2008 and 12th February, 2009 respectively (Table 6).

Average grain size: The Avg. grain size along the right side bank of Gangra position-A and Gangra position-D was measured as 0.110 m and 0.096 m on 9th February, 2008 and 28th February, 2009 respectively. At Ghoramara Island avg. grain size was 0.099 m on 30th July, 2009 while it was 0.150 m on 10th February, 2009 at southern tail of Nayachara Island (Table 6).

Table 5: Velocity Observation near Nayachara Tail

Place	Maximum Velocity and Direction				Date
	Flood		Ebb		
	Velocity in m/sec	Direction in Degree	Velocity in m/sec	Direction in Degree	
Gangra Position-A					
Right Bank Side	1.88	44	1.46	140	12/1/2001
Right Bank Side	2.83	14	2.03	188	21/8/2001
Right Bank Side	1.29	38	1.1	140	30/8/2001
Right Bank Side	—	—	—	—	1/2/2002
Right Bank Side	—	—	—	—	20/2/2003
Right Bank Side	1.55	21	1.75	217	21/6/2005
Right Bank Side	—	—	—	—	9/2/2008
Right Bank Side	—	—	—	—	18/2/2010
Ghoramara Island	1.41	35	1.73	174	28/12/2002
Ghoramara Island	1.66	5	1.34	155	2/1/2003
Ghoramara Island	1.66	44	2.43	156	17/2/2003
Position-D, c/s-181 (s)	—	—	—	—	8/2/2005
Ghoramara Island	1.62	339	0.78	127	8/5/2008
Ghoramara Island	1.22	48	1.75	216	9/5/2008
Ghoramara Island	—	—	—	—	5/9/2008
Position-D, c/s-181 (s)	—	—	—	—	28/2/2009
Ghoramara Island	—	—	—	—	30/7/2009
Southern Tail of Nayachara	1.5	44	2.31	213	10/2/2009
Southern Tail of	—	—	—	—	10/2/2009

Nayachara					
Southern Tail of Nayachara	1.06	118	0.51	256	12/2/2009
Southern Tail of Nayachara	0.58	62	0.92	284	12/2/2009

Table 6: Suspended Sediment Concentration, Salinity and Average Grain Size near Nayachara Tail

Location	Date	Suspended Sediment Concentration in gms/lit	Salinity in ppt.	Average Grain Size of Bed Material (D_{50} in m)
Gangra Position-A				
Right Bank Side	12/1/2001	2.3	7.92	0.084
Right Bank Side	21/8/2001	1.3	5.22	0.092
Right Bank Side	30/8/2001	0.32	4.32	0.107
Right Bank Side	1/2/2002	0.49	8.1	0.106
Right Bank Side	20/2/2003	1.17	8.28	0.13
Right Bank Side	21/6/2005	2.15	13.39	0.169
Right Bank Side	9/2/2008	0.5	5.85	0.11
Right Bank Side	18/2/2010	4.7	9.36	0.074
Ghoramara Island	28/12/2002	0.5	5.76	0.14
Ghoramara Island	2/1/2003	0.68	3.6	—
Ghoramara Island	17/2/2003	1.07	6.84	0.114
Position-D, c/s-181 (s)	8/2/2005	1.77	10.86	—
Ghoramara Island	8/5/2008	1.24	19.8	0.113
Ghoramara Island	9/5/2008	0.97	16.74	0.101
Ghoramara Island	5/9/2008	0.29	—	0.078
Position-D, c/s-181 (s)	28/2/2009	1.2	21.5	0.096
Ghoramara Island	30/7/2009	0.09	7.57	0.099
Southern Tail of Nayachara	10/2/2009	1.28	14.89	0.15
Southern Tail of Nayachara	10/2/2009	1.73	13.84	—
Southern Tail of Nayachara	12/2/2009	1.79	14.73	0.1
Southern Tail of Nayachara	12/2/2009	2.23	15.1	0.094

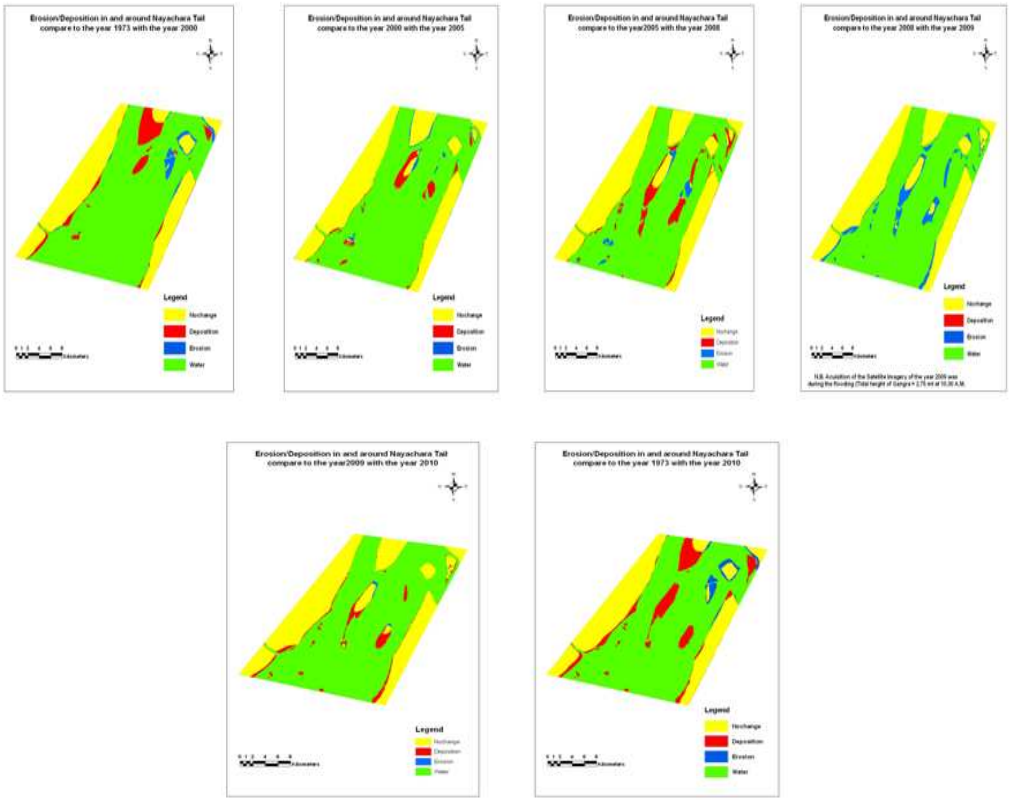

Figure 3: Erosion/Deposition in and Around Nayachara Tail Compare to the Different Years

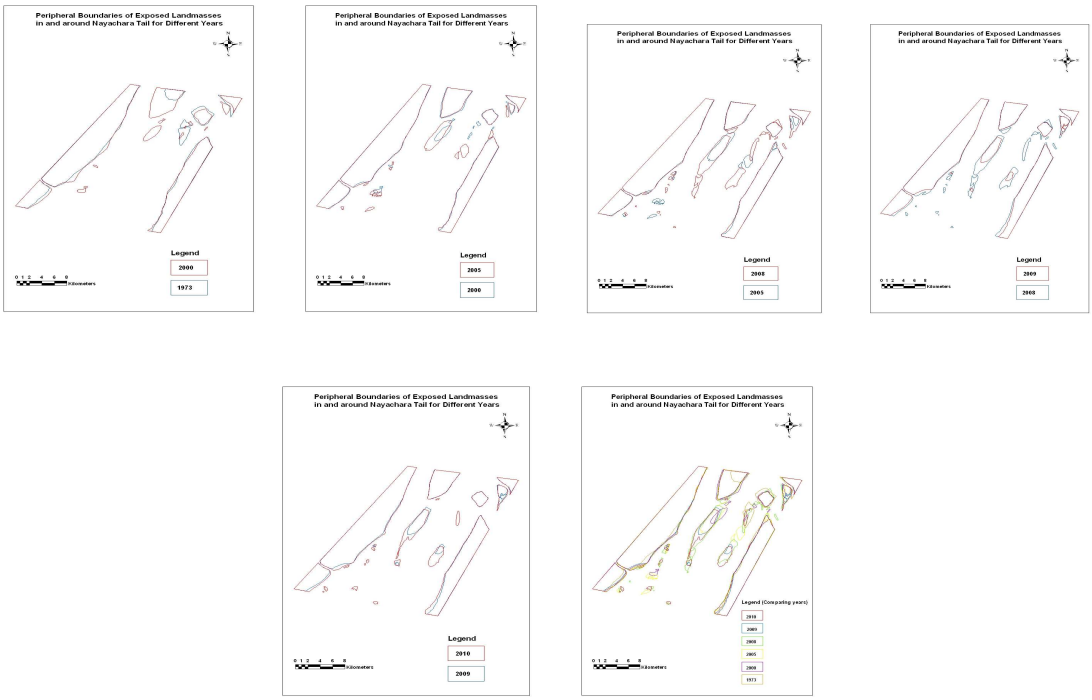

Figure 4: Spatial Shifting of Peripheral Boundaries of Exposed Land Masses in and around Nayachara Tail for Different Years

RESULTS AND DISCUSSIONS

Remotely sensed data of different years are examined and interpreted through logical process of defect, identify, measure and evaluate the significance of environmental and cultural objects, pattern and spatial relationship.

The satellite synchronous tidal information is recorded in Table 1. Sagar, Gangra, Haldia, Balari and Diamond Harbour are the five tidal stations.

Table 3 gives the idea about the total study area over the year (1973 to 2010). During this period total land area has been increased from 162.52 sq. km. to 199.92 sq. km which is the indication of heavy deposition in this area.

Table 2 shows the change in land area in and around Nayachara tail from 1973 to 2010. In 1973 there was no evidence of an island. But, in 2000 an island of an area of 4.278 sq km was found along the southern tip of Nayachara Island. The Nayachara tail has been increased in area from 4.278 sq km to 10.145 sq km in 2005 and 19.187 sq km in 2008. Due to high tide the observed area was decreased at 8.437 sq km in 2009. Again in 2010, the area of the tail is 12.118 sq km.

Table 4 shows the erosional and acrretional area in and around Nayachara during the period from 1973 to 2010.

While suming up the activities of last 5 years, it is observed from image analyses that the peripheral growth of Nayachara tail between 2005 and 2010 has played a crucial role in deflecting and/or ceassation of ebb flow through Lower Rangafalla Crossing. This growth alongwith the emergence of a sub-merged shoal has straightened the ebb flow through Bedford channel. As a result the bifurcation of flow leading from Sagarface to Bedford and Jellingham channel occurs at a Point much below the tail of Nayachara Island thus the proposed guidewall with its present alignment has little to do with the deflection of flood flow.

It appears that during post dredging scenario (IMD) the area around Nayachara tail in absence of any river regulative measure, have undergone fast changes due to the imbalance created by the stressed flow and the system as a reaction developed resistive forces enabling the morphological changes occurring in those areas.

The above interpretations, analyses and inferences are drawn on the basis of satellite data interpretation. Apart from detailed Numerical and Hydraulic Model studies, hydrological analyses with detailed hydrographic survey will be required for the formulation of the comprehensive river training scheme.

CONCLUDING REMARKS

Nayachara tail is a newly formed geomorphological feature in Hooghly estuary and also a very significant evidence to determine the complex morphological and tidal nature of the area. It is a dynamic mixing zone of fresh water and saline water. The Nayachara tail is gradually developed due to high rate of deposition. Due to the extension of the Nayachara tail in the south Haldia channel is deteriorating at fast rate.

ACKNOWLEDGEMENTS

The authors, thankfully acknowledges the Global Land Cover Facility (GLCF) centre for providing quality satellite image without which the study would have not been possible. We are also very much thankful to the Survey of India, Dehradun, India for procuring topographical maps which have been used as the reference maps in the study.

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