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RESEARCH ARTICLE

MORPHODYNAMICS OF CHILIKA MOUTH- STUDY ON SHIFTING OF TIDAL INLETS AND ASSESSMENT OF SHORELINE CHANGE ALONG EASTERN COASTAL INDIA, USING GEOSPATIAL TECHNIQUES AND DSAS EXTENSION

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Abstract

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This study is focused on the spatio-temporal change in shoreline along Chilika coast and migration of tidal inlet of Chilika lagoon using multi temporal satellite images from the year 1972-2019. This study is carried out over decadal analysis with utilization of EPR and LRR system of DSAS model. For this change analysis studies the Landsat satellite images and IRS-P6 LISS-III images has been used. From the study it reveals that there is one new mouth opening in 2019 after occurrence of cyclone Fani. Based on calculations, the mouth of Chilika mostly has shifted in northward direction. It may due to frequently occurrences of cyclonic storm surges, which usually associated with winds and tidal actions over the coast. This study shows the high erosion trend along 8.3 km in northern part of shoreline. The accretion found along 6.5km in central part of shoreline. The coastal region is now more vulnerable to natural disaster as well as manmade disaster. Most of the areas are prone to floods. This problem may become very serious due to rapid increase in population. Every year the eastern coastal region is destroyed by cyclone and floods.

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Introduction:-

A shoreline represents the boundary between ocean and land. The identification of shoreline change carries a vital role in environmental monitoring assessment. The movement of shoreline could be due to a single factor or a combination of many factors. It depends on various natural coastal processes like waves, tides, winds, periodic storms, sea-level change and interruption of human activities. At coast the mouth has been changed periodically in its shape and size due to formation of sandbars which is produced by deposition of river sediment materials. The formation of sand bar depends on intensity of fresh water & sea water interaction process at river mouth and the flow action of sea water.

The historical analysis as well as present position of shoreline including erosion and accretion rates is very important to make better decisions for developmental activities. The Remote Sensing data has the ability to provide synoptic views of large area at regular time interval, which is useful in monitoring coastal erosion and mouth shifting by integrating with Geographical Information System (GIS).

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In the present study, IRS P6 LISS-III and Landsat multispectral images has been used for identification of shoreline change along Chilika coast in temporal scale of 60 years interval. The spatio-temporal change in Shoreline were analysed using Remote Sensing and GIS.

Study Area

The study area ranges from 19°28’ and 19°54’ N latitude to 85°05’ and 85°38’ E longitude in state of Odisha, one of the eastern coastal state of India. Chilika Lake is the largest brackish water lagoon in eastern Coastal India which spreads over Khurda, Puri and Ganjam districts. It covers an area almost 1165 sq.km.in summer and 906 sq.km. in winter at the mouth of DayaNadi and flowing towards Bay of Bengal. It receives the fresh water from various rivers like Daya, Bhargavi, Malaguni, Nuna and other distributaries of Mahanadi River and saline water from Bay of Bengal.

Geomorphic Evolution Of Chilika

Chilika lagoon is the largest brackish water body in east coast of India. From the history of Orissa the ports located around Chilika lagoon had an important role in expanding the Indian culture to other countries. Hydrologically, it has been observed that three subsystems have an influence on Chilika. Those are the Mahanadi river system, rivers flowing from the western catchment in to the lagoon, and the Bay of Bengal. The lagoon receives freshwater from a series of 52 channels. The lake is about 64 km long. It extends from the southeast corner of the Khurda district into the adjoining district of Ganjam. However, the formation of sand bars, spits are due to changes in the hydrodynamic regime.

From history over 4th century AD, Chilika was appeared due to the sudden inflow of water into the sea. Most commonly Chilika lagoon hasexperienced both coastal submergence and emergence. According to (Gazetteer 1908) the Chilika lagoon was formed as the sea receded for a couple of miles and at the same time flooded over a greater part of Puri district.

According to a school of researchers Chilika lagoon may have been formed towards the end of Pleistocene period. Post, Pleistocene period the coastline might have receded due to marine and fluvial activities. This geomorphological activity in the Bay of Bengal might have created a shallow, brackish-water inshore lake connected to the Bay of Bengal through a narrow mouth. According to B. N. Sinha the evolution of Chilika is parallel with the origin of Eastern Ghats. Through the researches of geologists, can be said that when Gondwana land started to move in north eastern direction, the Tethys Ocean got folded up into present Himalayas during Tertiary period. The peninsular India was formed when the land drift stabilized upon touching the Tibetan plate. Simultaneously, the Western Ghats was formed through a massive N-S fault which when stabilized & subsided balanced with a tilt to the eastern side. This resulted in the rivers flowing from west to east.

During the same stage the Deccan land plate drifted from East coast of Mozambique towards the Indian land mass. While through the creation of Western Ghats the volcanic lava in the Deccan flowing to the eastern coast of India. The rivers now started flowing from the higher altitudes of Western Ghats giving rise to numerous gorges along the Eastern Ghats, during its formative time. Hence, evolution of Eastern Ghats is a very important landmark in the history of Peninsular India.

As Rambha spur in Eastern Ghats, the Gondwana strike line changed its direction towards and entered into Bay of Bengal. This spur gave rise to the present day Palur hills, which may be attributed of having given birth to Chilika. Evidence show that the river Mahanadi was draining into the Bay of Naraj and not into Bay of Bengal. The Mahandi delta was formed much later forming the NE of the present Chilka. The SE frontier of the Chilka is attributable to the advancing of the delta formed by Daya, Luna and Bhargavi, distributaries of Mahandi.

In later years, the silt deposited by the river Salia, Mandakini, Malaguni, Dhanua etc. delivered the western margin of the Lagoon. In the north east from Palur hills there was a formation called bar, which is built by the silt and sand carried by Rushikulya river and wave action during south west monsoons aided by strong current from the Coromondal coast. The sea wind drifted the sand dunes from Bay of Bengal coast to Chilika, forming numerous islands due to this Aeolian action. This bay bar and islands developed through stages and not continuously, but continually. This phenomenon is evident through the presence of the ten mouths as identified in the satellite imageries. Thus mouth of Chilika was open from Palur hills to Arkhakuda. After the formation of Malud Island there was a constricted opening and the free flow of salt water from the Bay of Bengal was obstructed and thus Chilika started to deteriorate in its ecosystem.

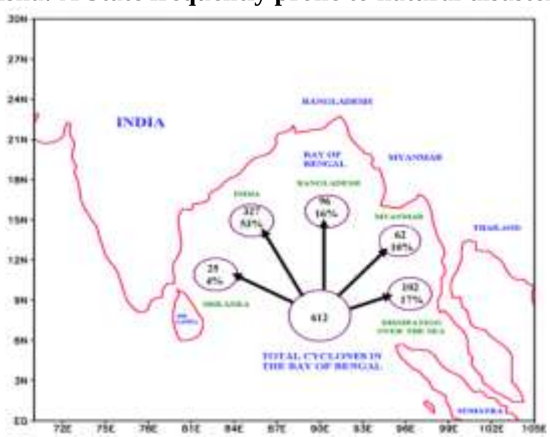
The presence of the headland and bay topography, the sea cliffs and sea stacks along the western and southern margins of Chilka indicates that it was exposed to open wave action during the geologic past, there by shifting the coast line. The erosional features evident in the periphery of the Lake are presumed to have resulted towards the end of Pleistocene or latest, during the time of the maximum Holocene transgression, before the beach ridge on the eastern side of the lake. A possible neotectonic activity might have resulted in the prominent lineament trending in NE- SW direction parallel to the long axis of the lake, as interpreted through the satellite imagery.

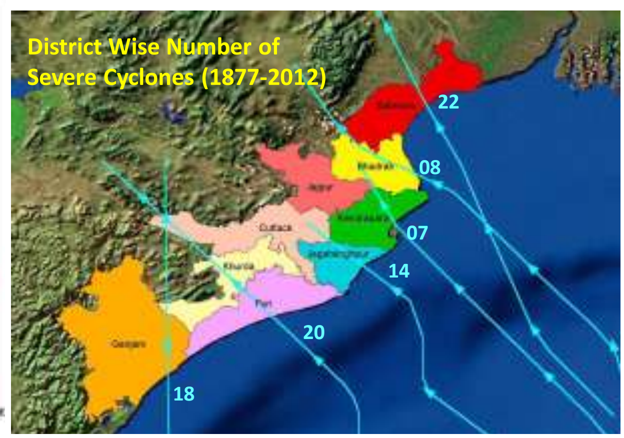
The deposition of the bidge ridges and the spit which enclosed a body of sea water resulting in the formation of lagoon Chilika took place during later part of the Holocene.

From historical data collected from India Meteorological Department (IMD), it has been reviewed that 48.19% of the total number of cyclones (i.e. 387 out of the 803 cyclones that hit the eastern coastal states) occurred in Odisha during 1891–2007.

Cyclonic Storms (1891-2007)	**Thunderstorms**
Depression and Deep Depression: 280	Tornado (1975-1996): 54
Cyclonic storms: 72	Hail Storm (1975-1996): 55
Severe Cyclonic Storms, Very Severe Cyclonic Storms/ Super cyclone: 20	Gale (1975-1996): 24 Squall (1975-1996): 15

Odisha: A State frequently prone to natural disasters





Number of Tropical cyclones crossing different Countries surrounding Bay of Bengal: (1890 – 2012)

Detailed Decade-wise frequency of cyclones in Odisha during 1971-2019.

Year	**Location**	**Disaster types**	**Disaster sub-types**
1978	Odisha	Storm	Tropical Cyclone
1978	Odisha	Storm	Tropical Cyclone
1981	Odisha	Storm	Convective Storm
1981	Odisha	Storm	Tropical Cyclone
1982	Odisha	Storm	Tropical Cyclone
1983	Odisha	Storm	Tropical Cyclone
1989	Odisha	Storm	Tropical Cyclone
1995	Odisha	Storm	Tropical Cyclone
18.10.1999	Ganjam,Puri,Gajapati	Storm	Tropical Cyclone
28.10.1999	Kendrapara, Jagatsinghpur, Cuttack,	Storm	Super cyclone (05B),

	Nayagarh, Bhadrak, Keonjhar, Dhenkanal, Balesore, Mayurbhanj, Jajpur.		Tropical Cyclone
2002	Odisha	Storm	Convective Cyclone
2009	Kendrapara,Odisha	Storm	Convective Cyclone
2013	Odisha	Storm	Phailin, Tropical Cyclone
2014	Ganjam,Odisha	Storm	Hudhud, Tropical Cyclone
2018	Gopalpur, Odisha	Storm	Titli, Very severe cyclonic storm
2019	Odisha Coast	Storm	Fani, Very severe cyclonic storm

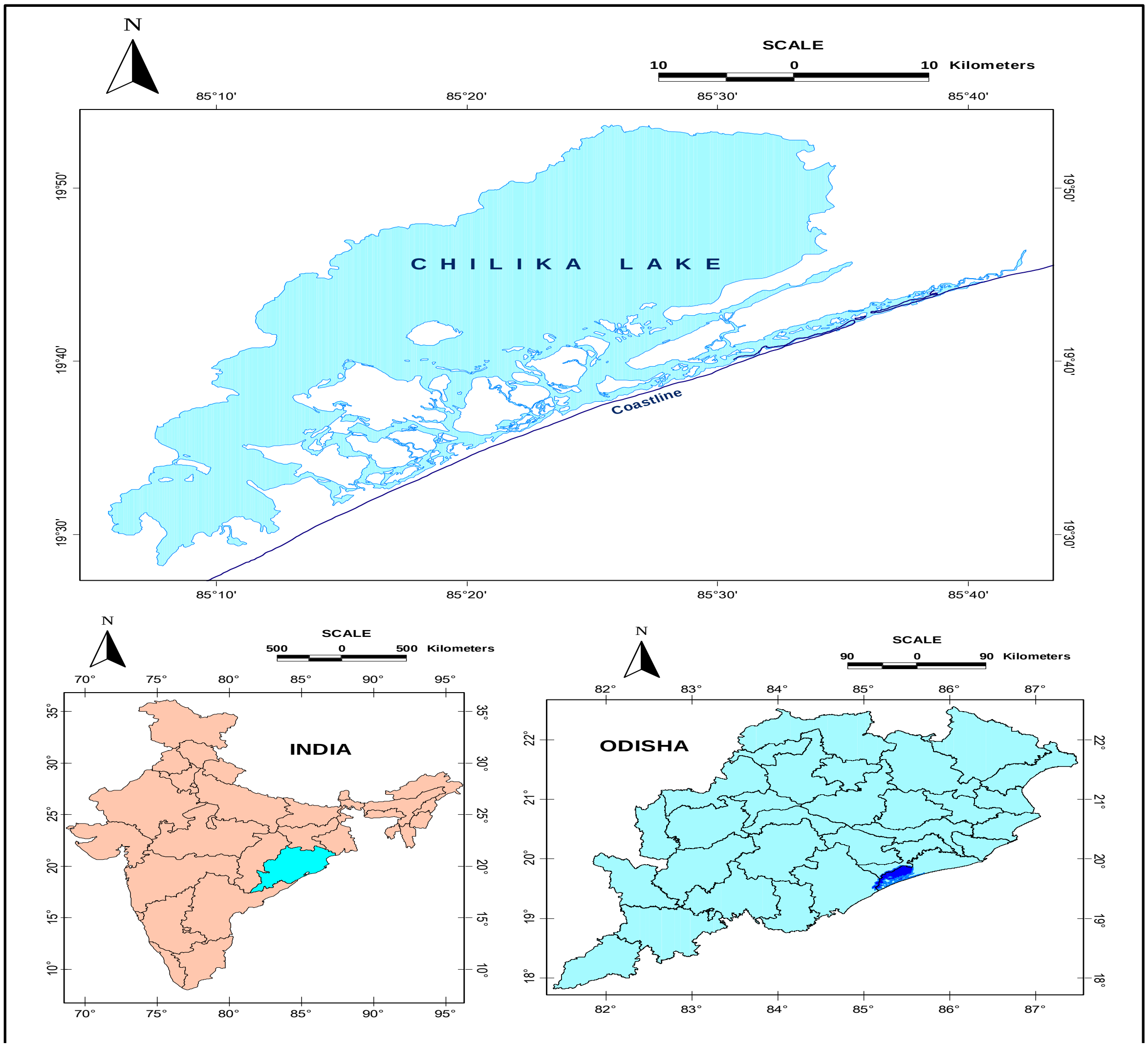


Fig-2:- Study Area Map.

Material and Methodology: -

Data Used

Date and Year	Path/Row	Satellite ID	Sensor	Resolution (m)
07-11-1972	150/046	Landsat 1	MSS	80
18-01-1980	150/046	Landsat 3	MSS	38
13-02-1990	140/046	Landsat 5	TM	30

29-11-1999	140/046	Landsat 7	ETM+	30
12-07-2011	140/046	IRS P6	LISS III	23.5
19-07-2019	140/046	Sentinel	Sentinel	30/ 10

Table 3.1:– Details of satellite image considered in study.

In the present study according to predefine objective, the satellite images for the years of 1970s, 1980s, 1990s, 2000s, 2010s & 2020s has been used for assessing the movement of shoreline. The detail of data used in present study has been mentioned in table 3.1.

In this study the US Toposheet for the year of 1930-35 has been used as primary reference for extract shoreline and the location of mouth along Chilika. Based on that toposheet the change in position of shoreline (erosion/ accretion) and shifting of tidal inlet has been identified.

The LANDSAT satellite images (L1 MSS, L5 TM, and L7 ETM+ & Sentinel) have been downloaded from United States Geological Survey (USGS) and used. The LISS III image has been downloaded fronBhuban, ISRO site and used for preprocessing.

The focus of this study is assessment of historical change of shoreline along Chilika coast form various of year intervals i.e. 1972-1980, 1980-1990, 1990-1999, 1999-2012 and 2012-2020.

All the images have been preprocessed in geo-tiff format, and geo-corrected in the WGS84 datum through Arc GIS 10.1. The visual interpretation and band rationing process has been done. The layer stalk and subset process of images has been made according to study area.

Then need to digitize the shoreline from Landsat satellite images using Arc GIS software in line feature to identify the movement of shoreline.

To quantify the erosion and accretion rate the year wise shoreline has been digitized in line feature from multi temporal satellite imagery.

The overlay analysis for different year of satellite images has been done to delineate differences in year wise increase and decrease of shoreline length.Then the displacement of shoreline has been measured in time series format. The landward movement of shoreline is identified as erosion and seaward movement in shoreline is known as accretion.

The **Digital Shoreline Analysis System (DSAS)** model as an extension of Arc GIS software is applied for the study of coastal behaviour and shoreline change rate.

There are different methods of DSAS system i.e. net shoreline movement (NSM), end point rate (EPR), linear regression rate (LRR) has been used which is helpful in evaluation of historical change in shoreline position.

For this study the transect layer has been created by considering 50 meters of spacing as fixed distance. In this method the uncertainty of results increases by high spacing of transects and massive data values occurs along low distance spacing.

So here by 50mtr spacing has been taken for the study. In the present study to calculate the distance of movement of shorelines from 1972-2019, three statistical methods has been use. Such as – End Point Rate (EPR), Net Shoreline Movement (NSM) and Linear Regression Rate (LRR).

End Point Rate is calculated by dividing the distance of shoreline movement by the time between the oldest and recent shoreline.

EPR (m/yr) = distance/ (time between the oldest and recent shoreli

Net shoreline Movement is used to calculate the distance. It denotes the distance between oldest and recent shoreline.

NSM (m) = distance between the oldest and recent shoreline

Linear Regression Rate is determined by fitting a least squared regression line to all shoreline points for a particular transects. LRR is the slope of line.

Results &Discussion:-

The administrative map of Chilika Lake and movement of Shoreline at Chilika coast in 50 years of duration is shown in map 4.1 & 4.2. The detailed shoreline lengths have been measured and presented in table- 4.

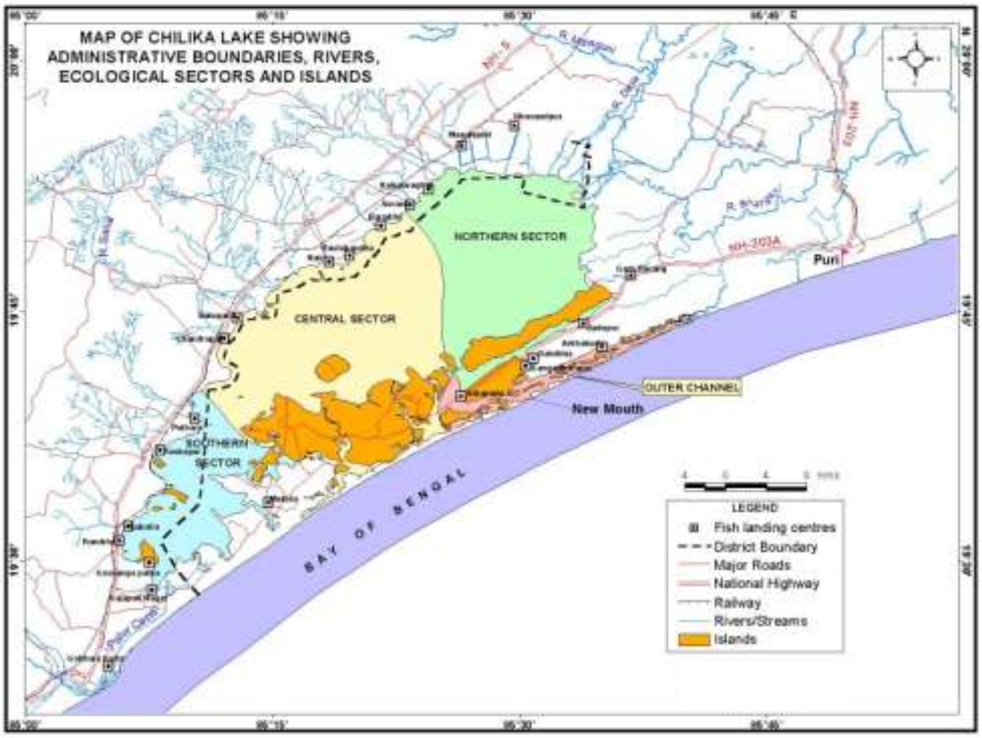


Fig-3:- The administrative map of Chilika location of mouth.

Fig-4:- Map showing shoreline for the year 1972-2019 with primary base shoreline of year 1931, US Toposheet.

Table- 4.1:- Shoreline Length in km measured through DSAS System for different years.

1931	1972	1980	1990	1999	2011	2019
61.96	62.05	62.08	62.12	62.05	62.00	62.07

Periodic River Mouth Dynamics

Identification of shoreline change is due to periodic mouth dynamics and erosion/ accretion along the study area for the period of 50 years interval from 1972 to 2019 using remote sensing and GIS.From past literatures found that many cyclonic storms have been occurred along Chiika coast and shifting of tidal inlet takes place. Here in this study the past cyclonic storms along Chilika have been listed out and the detail shifting of mouth relating to cyclone has been identified.

Satellite images showing the dynamics of Chilika mouth

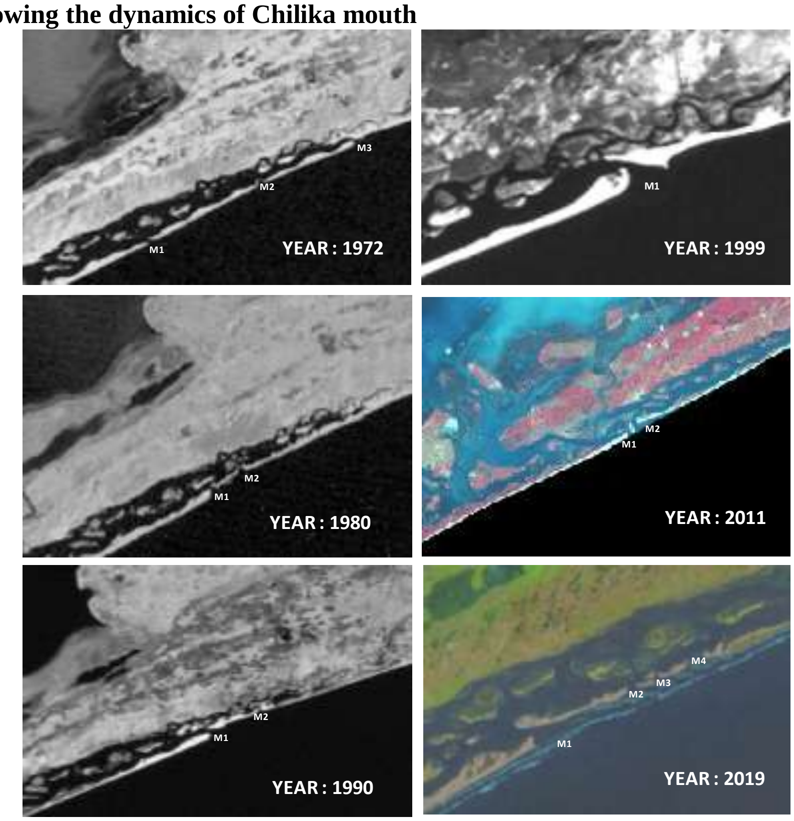


Fig. 5:- Satellite images showing location of mouth of Chilika Lake in Years from 1972 to 2019.

Table 4.2:- Displacement of Chilika mouth in kilometers

sl. no	**year/month**	**no. of mouth**	**lat**	**long**	**width (m)**	**source**	**Direction of movement**	**Distance from primary location (1931)**
1	1930-1935	mouth 1	19.705	85.592	196.35	US topo 1931 by Army Map Services, US department of Defence		
	1930-1935	mouth 2	19.712	85.602	487.23			
	1930-1935	mouth 3	19.714	85.605	82.15			
2	1972 nov _m1	mouth 1	19.697	85.579	245.68	Landsat MSS	southward	1.72 km
	1972 nov_m2	mouth 2	19.723	85.63	269.03		northward	3.33 km
	1972 nov_m3	mouth 3	19.742	85.675	204.44		northward	7.9 km

3	1980 jan_m1	mouth 1	19.709	85.597	208.92		northward	670.60 m
	1980 jan_m2	mouth 2	19.717	85.611	182.07		northward	1.19 km
4	1990 feb_m1	mouth 1	19.72	85.621	225.50		northward	3.39 km
	1990 feb_m2	mouth 2	19.73	85.642	106.55		northward	4.74 km
5	1999 nov_m1	mouth 1	19.737	85.657	119.04		northward	7.7 km
6	2019 jun_m1	mouth 1	19.69	85.552	246.5	Landsat sentinel	southward	4.7km
	2019 jun_m2	mouth 2	19.7	85.574	84.59		southward	3.2km
	2019 jun_m3	mouth 3	19.7	85.576	103.68		southward	3.4km
	2019 jun_m4	mouth 4	19.7	85.582	126.89		southward	new
	2019 jun_m5	mouth 5	19.7	85.585	106.8		southward	new
7	2019 july_m1	mouth 1	19.686	85.555	211.15	Landsat sentinel	southward	4.5 km
	2019 july_m2	mouth 2	19.695	85.571	162.53		southward	3.7 km
	2019 july_m3	mouth 3	19.697	85.577	116.61		southward	3.5 km
	2019 july_m4	mouth 4	19.701	85.584	326.55		southward	

In the present study, the location of mouth demarcated on US Topo by Army Map Services, US department of Defence in the year of 1931 has been taken as standard point and the shifting of mouth along years from 1972-2019 has been measure with respect to that. In the image of 1972 Nov. it has been observed that there are 3 mouths opening to Bay of Bengal and the mouth 1 is found to be shifted 1.72km in southward direction where other 2 mouths are shifted in northward direction. It may occur due to cyclonic storm on Sept, 1972 which touched the land at Gopalpur coast. On Jan, 1980 it is found that there were only 2openings which was displaced by 670.60 m and 1.19 km in northward direction. On Feb, 1990 it is observed that the mouth has shifted around 3-4km in northward direction. On Nov, 1999 it is observed that there is only 1 mouth opening to Bay of Bengal, which has shifted 7.7 km towards north. Again on July, 2019 there is a significant change along coast after occurrence of Cyclone Fani. Ii is found that there is one new mouth opening. Other 3 mouths have shifted by 4.5, 3.7 & 3.5km in southward direction. There also field verification has been done by collecting GCPs and the compilation of remote sensing data has been done. It is observed that there is a deposit of slit, mudflats clay with fine sand along Chilika Coast. This study reveals that the instability motion of sandbar due to water waves is the important element of mouth dynamics. The wind direction along Chilika coast causes wave approach to the shoreline and give rise to shifting in position of mouth

Erosion and Accretion

The present study reveals that the shoreline change has dynamic behaviour which has been influenced by the occurrences of cyclonic storms and wave height. In Chilika coast there is 100 m increase in length of coastline in 50 years of period for the year from 1972-2019. In this work these results have been calculated for 1972- 2019. Coast under study area shows different behaviour under different time scale.

Map depicts that a maximum erosion of 326.9 m and accretion of 60.6 m has been observed at transect id 199 and 91 respectively in the year 1970-1980 at Chilika coast. In the shoreline mapping of year 1980-1990, transect id 207 & 17 shows 439 m & 47m of erosion respectively and at transect id 199 accretion of 417m has been identified. The map of the year 1990-1999 depicts that at transect id 221 there is maximum erosion of 253m and maximum accretion of 345m has been observed at transect id 207. In the map of year 1999-2011, transect id 207 shows maximum erosion of 98.12 m and at transect id 56 accretion of 139 m has been identified. From the shoreline map of year 2011-2019, a maximum erosion of 146.32m has been assessed at transect id 225 and at transect id 206 accretion of 84.69m has been identified.

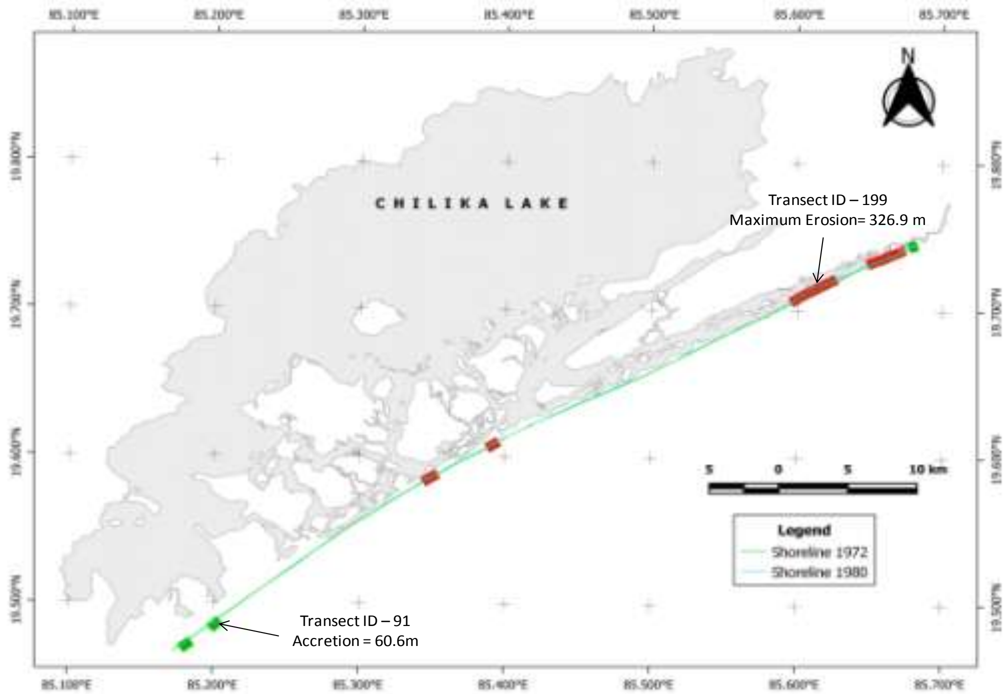


Fig. 6:- Erosion and accretion mapping for Chilika coast for years 1972-1980.

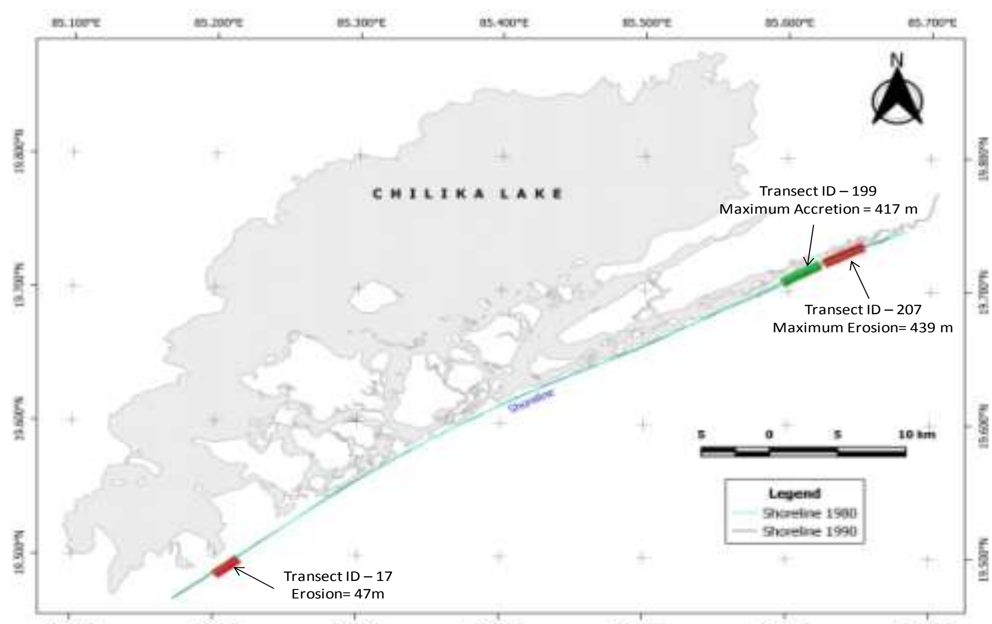


Fig. 7:- Erosion and accretion mapping for Chilika coast for years 1980-1990

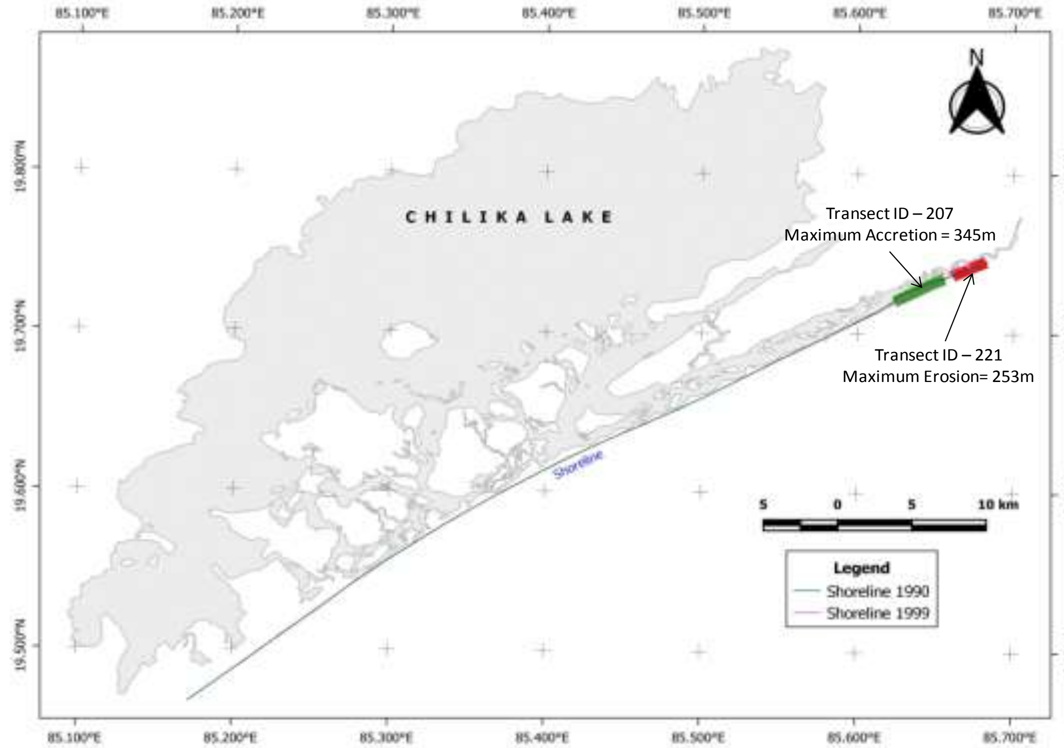


Fig. 8:-Erosion and accretion mapping for Chilika coast for years 1990-1999.

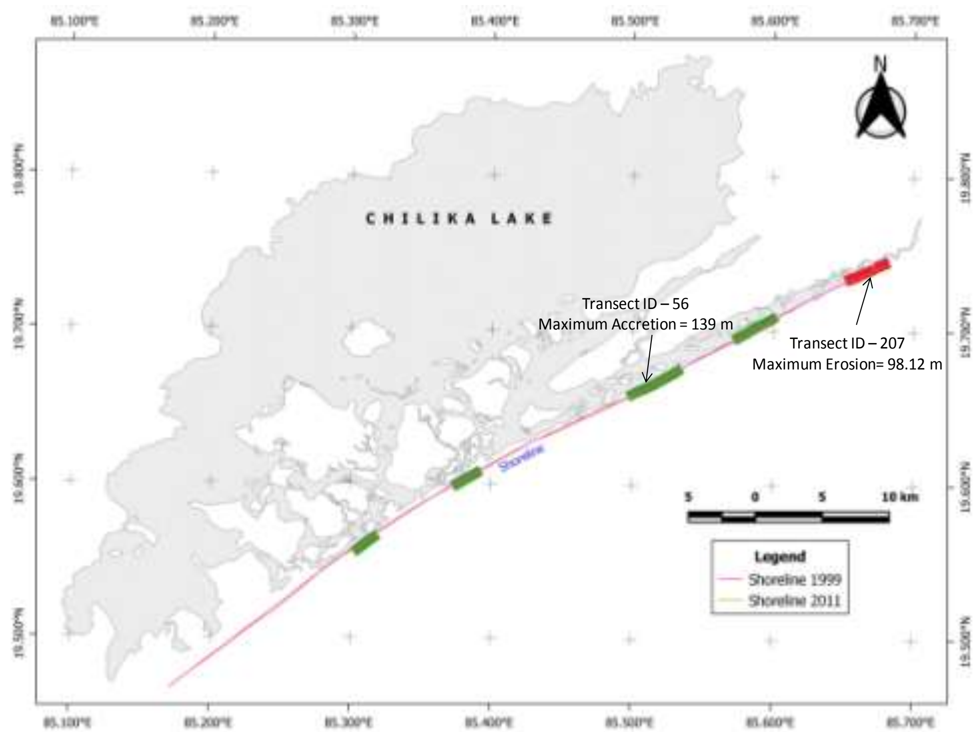


Fig. 9:- Erosion and accretion mapping for Chilika coast for years 1999-2012.

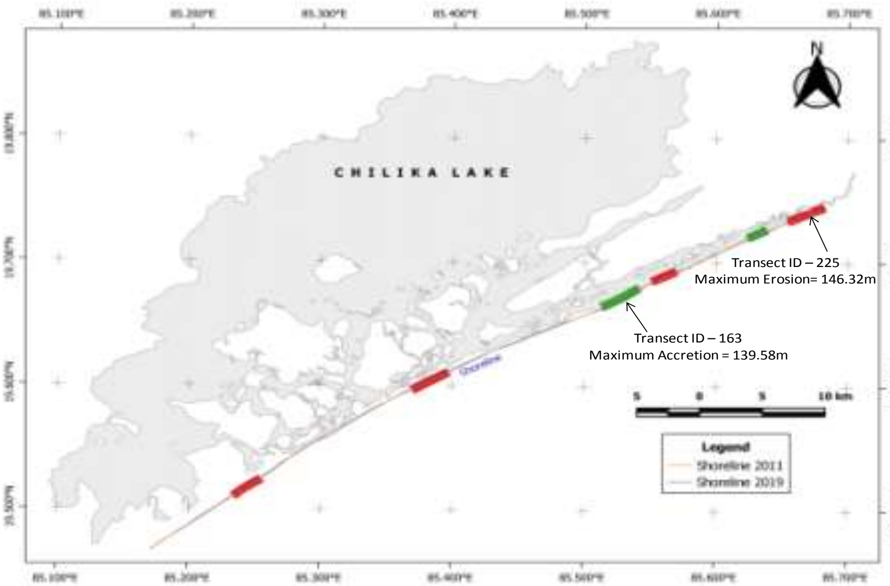


Fig. 10:- Erosion and accretion mapping for Chilika coast for years 2012-2019.

As a result of the present study, at Chilika coast an average erosion of 32.6 m/year from 1972 to 1980 has been observed which has again increased in next during 1980-1990 i.e. 41.7 m/year, then in the year of 1990-1999 average erosion decreased to 25.3 m/year and in decade 1999-2012 the average erosion is decreased and is about 9.8 m/year and in last decade it has been found that 14.6 m/year.

From the shoreline map of year 1970-2019, a maximum erosion of 169.5 m has been assessed at transect id 224 & at transect id 53 the erosion is found to 73.4m in northern part and at transect id 206 accretion of 84.69 m has been identified in central part.

The coast may be affected due to storm surge generated by the cyclones and the wave height ad wind pressure in the Bay of Bengal.

Here maximum erosion occurred at northern part of Chilika coast. Somehow central part of the Chilika coast is accreted and erosion is mostly observed in northern and southern part.

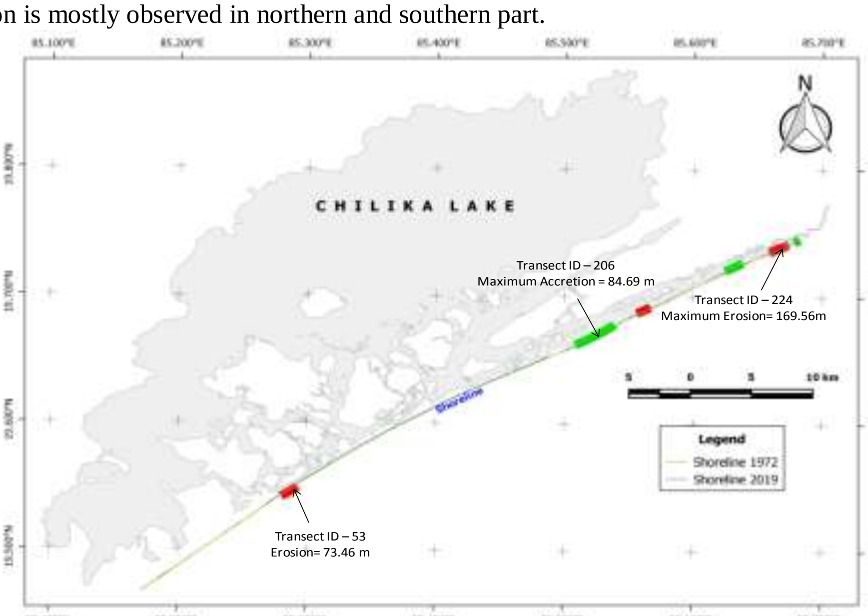


Fig. 11:- Erosion and accretion mapping for Chilika coast for years 1972-2019.

Conclusion:-
From this study it concludes that, application of remote sensing and GIS is very helpful in monitoring periodically shoreline change with high accuracy. The state Odisha is considered as highly vulnerable state in eastern coastal India. Odisha has been facing cyclonic hits more frequently now days. This causes increase in coastal erosion in recent years. The deficiency in forest and vegetation cover may aggravate the vulnerability of coast. As a result, the cyclonic winds may affect the land without any restriction. The coastal areas are highly populated and that may cause more vulnerable to infrastructure and human health. Chilika coast has undergone accretion in central part and erosion is in northern direction, which seems the ocean current and wind direction is northward flowing. A GPS survey with geo tagging application may be carried out for accurate shoreline change detection and morphological assessment.

Further scope of study

The more specific micro level study including land form change and characteristics of agricultural and aquaculture activities can be taken for consideration. Studies of sediment dynamics from land into oceans by rivers in this region may be suggested for future study.Further, the impact of wave energy and other meteorological factors on the erosion and accretion process were also measured.

References:-

1. Bagdanaviciute I, Kelpsaite L, Daunys D (2012) Assessment of shoreline changes along the Lithuanian Baltic Sea coast during the period 1947–2010. Baltica 25(2):171–184
2. Bedini E (2007). Use of GIS and remote sensing to detect change along the coastline segment between Shkumbini and Semani rivers, central Albania. Bulletin of the Geological Society of Greece vol. XXXVII, Proceedings of the 11th International Congress, Athens
3. Khalid M. Dewidar and Omran E. Frihy (2010). Automated techniques for quantification of beach change rates using Landsat series along the North-eastern Nile Delta, Egypt. Journal of Oceanography and Marine Science, Vol. 1(2) pp. 028-039, February 2010.
4. Kumar A, Jayappa KS (2009) Long and short-term shoreline changes along Mangalore coast, India. Int J Environ Res 3(2):177–188
5. Kuleli T (2010) Quantitative analysis of shoreline changes at the Mediterranean Coast in Turkey. Environ Monit Assess 167:387–397
6. Mujabar PS, Chandrasekar N (2011) Shoreline change analysis along the coast between Kanyakumari and Tuticorin of India using remote sensing and GIS. Arab J Geosci 4:394
7. Murali RM, Shrivastava D, Vethamony P (2009) monitoring shoreline environment of Paradip, east coast of India using remote sensing. CurrSci India 97:79–84
8. PINTO, P., CABRAL, P., CAETANO, M. and ALVE, M.F., 2009. Urban growth on coastal erosion vulnerable stretches. Journal of Coastal Research, SI 56 (Proceedings of the 10th International Coastal Symposium), Lisbon, Portugal.