ISSN: 3108-267X (P)
ISSN: 3139-6402 (O)

Humanity and Nature
A Multidisciplinary Journal
Vol. No. - 02, Issue No. - 02
July - December, 2026
RESEARCH ARTICLE

Received on
07 August, 2026

Revised on
18 August, 2026

Accepted on
21 August, 2026

Published online
24 August, 2026

Development and Future of the Chilika Lagoon

Sk Majharul Islam [a †]

[a] Department of Geography, Bangabasi College, Kolkata - 700009, West Bengal, India

[†] Corresponding Author:

skmajharulislam@gmail.com (S. M. Islam)

DOI: https://doi.org/10.5281/zenodo.22091695

ABSTRACT

Chilika Lagoon is the largest brackish-water lagoon on the eastern coast of India. It holds considerable ecological and economic significance and serves as an important source of livelihood for communities in its catchment area in Odisha. However, the lagoon has been experiencing degradation due to anthropogenic activities. According to various studies, the lagoon developed over the last 8,000–10,000 years and attained its present form approximately 3,500 years before present (YBP). This study analyses the past processes of lagoon formation, evaluates the present condition of the lagoon using satellite image interpretation, remote sensing techniques, contour analysis of Survey of India topographical sheets, and digital elevation models (DEMs), and assesses its potential future condition based on the hydro-ecological and geomorphological characteristics of the lagoon and its fringe areas. The study also examines the future evolution of Chilika Lagoon and evaluates its likely condition in the near future in response to ongoing physical processes and anthropogenic influences.

KEYWORDS: Chilika lake; Lagoon; Remote sensing; Sedimentation; Spit geomorphology.

1. INTRODUCTION

Chilika is the largest brackish-water lagoon in India and has a significant influence on the ecology and ecosystem of the surrounding area. The lagoon serves as an important source of livelihood for approximately five lakh people living in its catchment area and islands. The aquatic resources of the lagoon also have considerable economic importance to the state of Odisha.

The water spread of Chilika Lagoon covers approx. 1,309.63 sq. km during the monsoon month of September, while it decreases to approx. 797.76 sq. km during April, the non-monsoon period. The pear-shaped lagoon is approx. 66 km long and has a maximum width of about 29 km. The average water depth of Chilika Lagoon is approx. 1.5 m and increases to about 3 m at the southern tip of the lagoon. The water level rises during the monsoon months. The lagoon has evolved over the last 8,000–10,000 years, and its spit system plays an important role in controlling the overall lagoon environment (Rao et al., 1990). Longshore currents and episodic cyclonic events also regularly modify morphology of the lagoon.

The river systems along the lagoon's fringes regularly transport and deposit sediments into the lagoon. This sediment input is influenced by increasing pressure on land resources within the lagoon basin, partly resulting from population growth and intensified human activities. Anthropogenic activities have also altered the biotic components of the lagoon ecosystem. These changes, along with increased sediment input, contribute to ongoing sedimentation and environmental transformation within the lagoon.

2. STUDY AREA

Chilika Lagoon is the largest brackish-water lagoon with estuarine characteristics along the eastern coast of the Indian subcontinent,

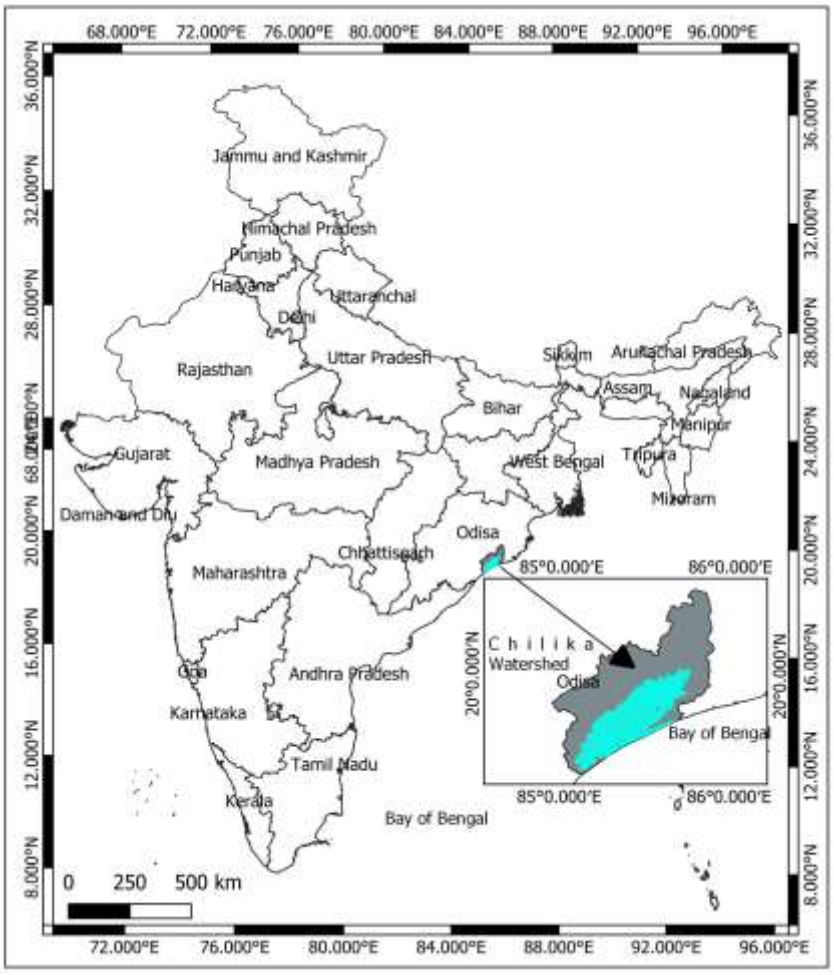

Fig. 1. Location map of Chilika Lagoon; zoomed-in view of lagoon (blue) and its watershed area (gray).

particularly in the coastal region of Odisha. The Chilika Basin covers an area of approximately 3,500 sq. km and extends across parts of the Khurda, Puri, and Ganjam districts of Odisha (Fig. 1). The lagoon is bounded by the Bay of Bengal to the south and southeast, while Puri lies to the east, Bhubaneswar to the northeast, and Ganjam to the west. Chilika Lagoon experiences a tropical monsoon climate, and 52 rivers and rivulets, including the Daya and Bhargavi, drain into the lagoon.

3. LITERATURE REVIEW

Considerable literature is available on the formation and development of Chilika Lagoon. Detailed studies have been conducted by Rao and Sadakata (1996), Rao et al. (1990), and Murray and Mohanty (2006), among others, over the past five decades. Rao et al. (1990) provided a detailed analysis of the sediments and stratigraphy of the lagoon bed and islands. According to Subrahmanyam et al. (2006), spit development in the lagoon began approximately 3,750 years ago. Following the narrowing and partial choking of the lagoon inlet during the 1990s due to spit development in the outer channel region, the lagoon environment became increasingly stressed, with significant implications for its biotic components (Mishra et al., 2022). The effects of inlet opening and increased tidal flux on the hydrology and biotic components of the lagoon have been studied by Rajawat et al. (2007) and Panda et al. (2013).

Although there have been a number of studies on the current status of Chilika Lagoon, especially its degradation, water quality, ecological changes, and land-use/land-cover change over time (Mishra et al., 2022; Rajawat et al., 2007), very few have addressed issues pertaining to its genesis and long-term geomorphologic evolution. Similarly, very few studies have assessed the future geomorphological evolution of the lagoon. This requires an integrated assessment of past evolution, present geomorphological state and future scenarios associated with any given adaptation strategy for the lagoon as a whole. Accordingly, the present study attempts to bridge this research gap by

ISSN: 3108-267X (P)
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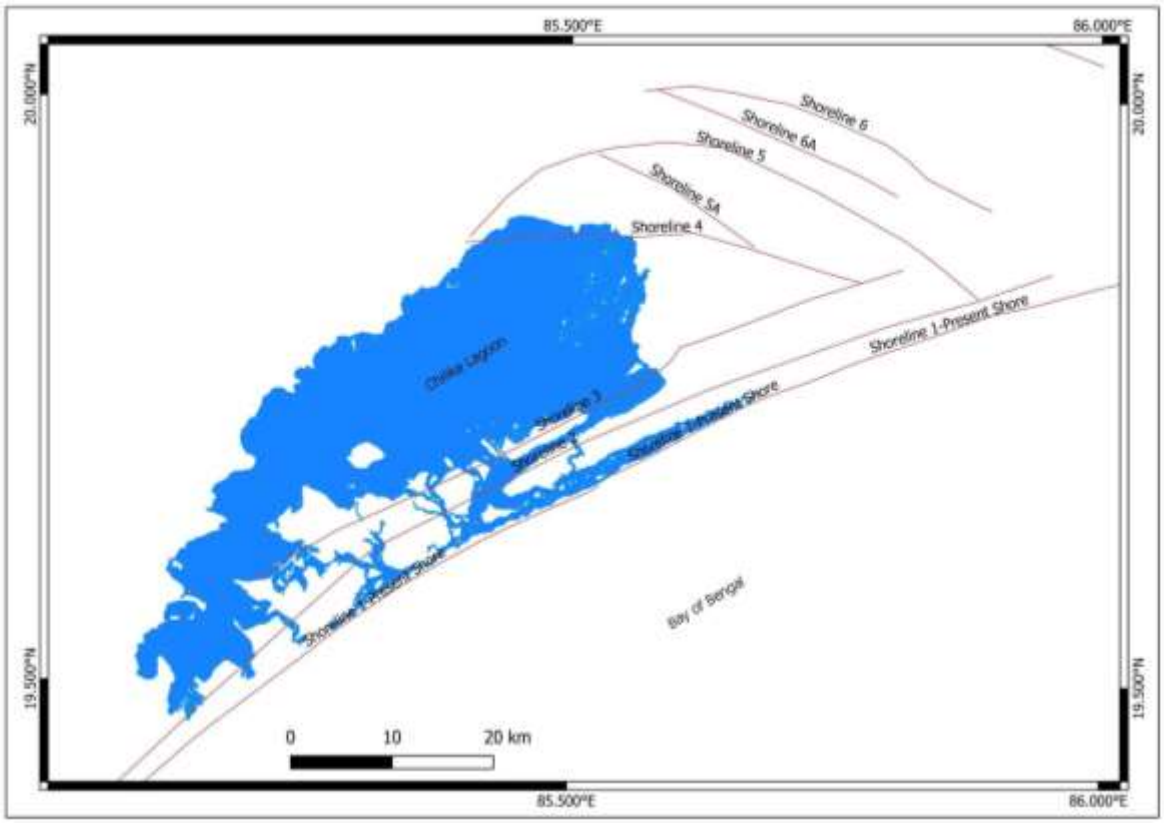

Fig. 2. Paleo and present shoreline and lagoon boundary.

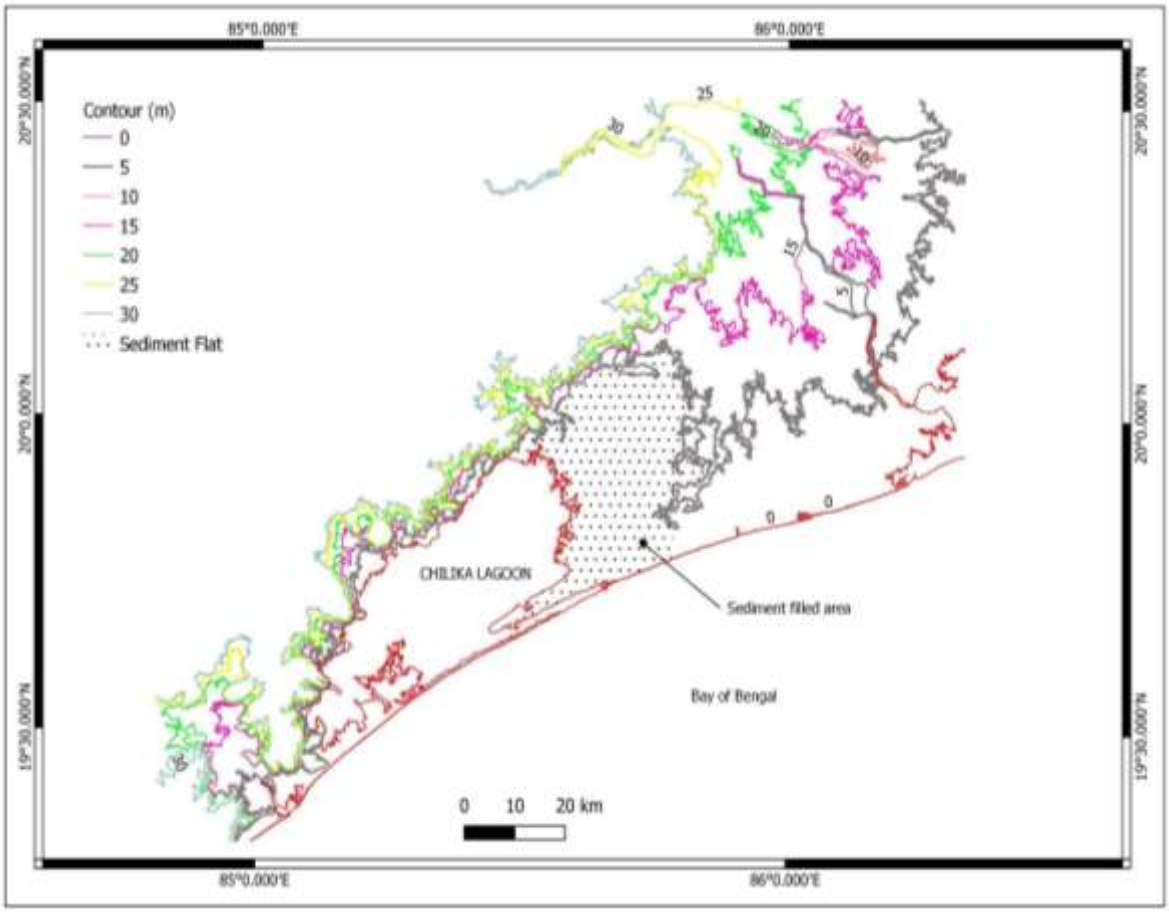

Fig. 3. Contours around Chilika Lagoon.

synthesizing information from previous studies with satellites images, DEMs (digital elevation models), Survey of India (SOI) topographical sheets, geological surveys and sediment analysis to obtain a holistic view of past, present and prospective geomorphological evolution of Chilika Lagoon.

4. MATERIALS AND METHODS

This study utilizes contour data from SOI topographical sheets as well as SRTM (Shuttle Radar Topography Mission) DEM data and satellite images over a time-period of 1970 to 2025. This study incorporates portions of ongoing sediment and stratigraphic analysis, topographic assessment, water-quality analysis, and field survey data collected in the lagoon and its vicinity between 2008 and 2025.

Composite analysis of DEMs, standard false-colour composites from numerous satellite datasets, SOI topographical sheets, Total Station surveys and sediment analysis has also revealed high strandlines and paleo-shorelines (Panda et al., 2013; Mishra et al., 2022). In this integrated analysis, we have identified seven main paleo-shorelines from Shoreline 1 to Shoreline 7 (Fig. 2).

An extensive review of existing literature was also conducted to understand geological, geomorphological, sedimentological and environmental evolution of Chilika Lagoon. Similarities and differences in findings and interpretations of previous researchers, including geologists and geomorphologists, were compared and integrated with results of the present study. This will provide a comprehensive overview of past change, present situation, and details on potential future geomorphological evolution for the lagoon.

5. RESULTS AND DISCUSSION

The study and analysis of high strandlines and paleo-coastlines at different locations within the study area, together with interpretation of contour patterns from SOI topographical sheets at 20 m intervals and the 5 m and 1 m contours generated from the DEM, illustrates the pattern of lagoon development (Figs. 2 & 3).

According to present geomorphological study, the dotted areas between the 0 m and 5 m contours in Figure 3 indicate the former extent of the lagoon in the recent past. According to various studies, the coastline was located near the 25 m contour line approximately 8,400 years ago during the Early Holocene (Dey et al., 2025).

From analysis of satellite imagery, seven paleo-shorelines are identified surrounding the Chilika Lagoon which can be broadly classified into two opposing sets based on their orientation and spatial distribution (Fig. 2). The initial group contains three paleo-shorelines (Shoreline 1–3), which are roughly parallel to the present-day coastline of the Bay of Bengal and their related paleo-dune systems. These shorelines can be regional in extent, usually oriented NNE–SSW parallel to the modern coastal margin. Second is a series of four paleo-shorelines (Shorelines 4–7), principally located to the NE, inland from the present lagoon. Their evolution is explained in terms of continued retreat of deltaic depositional surfaces into the former lagoonal basin, mainly corresponding to sediment contributed from Daya and Bhargavi river system. Continuous sediment deposition gradually filled the northern end of the lagoon, forming linear deposits that represent successive former shorelines.

These paleo-shorelines trends ESE–WNW to E–W across the lagoonal basin. Shoreline 7, one of the shorelines in this sub-group is the most landward paleo-shoreline and also extends far beyond the present lagoon water body indicating a former basin that is many times larger than at present. Its location and position may represent the maximum landward shoreline advance during the Holocene climatic optimum. This was followed by the further offshore development of Shorelines 6, 5 and 4, representing ongoing sediment accumulation and deltaic progradation with the gradual infilling of lagoonal water bodies behind the coastal spit system. The successive shinking and geomorphological evolution of Chilika Lagoon in response to sediment deposition, along with shoreline migration and coastal processes is thus recorded by the spatio-temporal distribution of paleo-shorelines (Fig. 2).

The continuous reshaping of the Mahanadi Basin through Holocene transgression and the development of the Mahanadi fan contributed to the formation and evolution of the lagoon. Another important factor was spit development associated with longshore sediment transport. Various studies have reported changes in the direction of longshore drift during different periods.

A pronounced increase in marine influence resulted in the deposition of shore-parallel sand bodies through the onshore transport of sediments from shallow-shelf submarine sand ridges. The formation of older spits was influenced by the northeast monsoon current, which generated strong longshore drift from northeast to strong longshore drift from northeast to southwest. In

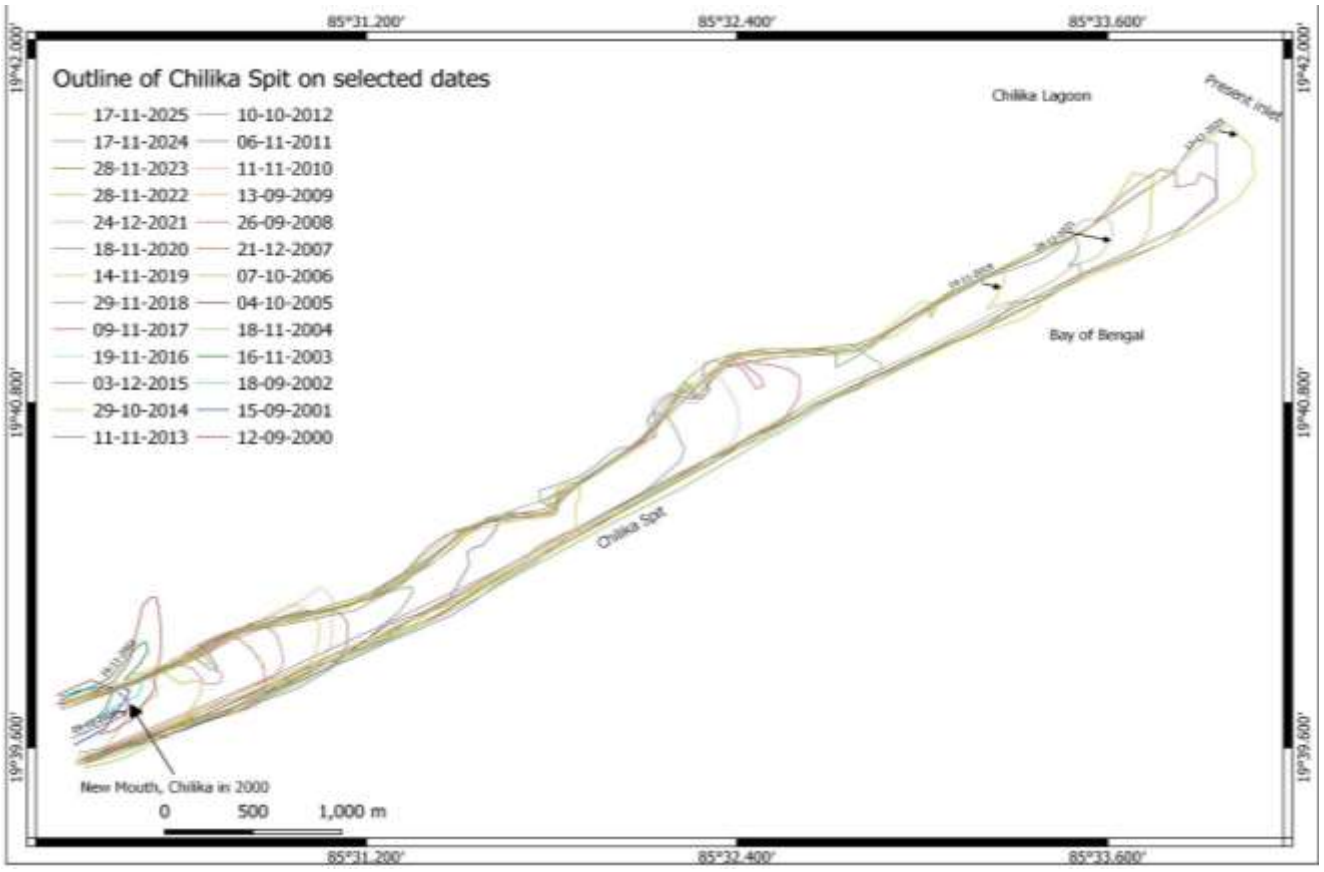

Fig. 4. Changes of Chilika spit during 2000-2025.

recent times, longshore drift during the monsoon months has generally occurred from southwest to northeast (Fig. 4). According to recent studies, there is a positive relationship between the opening of the lagoon inlet and subsequent tidal mixing, which enhances the hydrological and biological conditions of the lagoon (Rajawat et al., 2007; Panda et al., 2013).

6. CONCLUSIONS

The lagoon began to develop approximately 8,000–10,000 years ago and attained its present lagoonal form approximately 3,500 years ago. The progressive narrowing of the lagoon inlet due to spit development, reduced seawater influx, accumulation of biogenic sediments, and increased sedimentation by rivers indicate that, in the future, the lagoon may gradually transform into a flat plain, similar to other coastal lagoons that disappeared during the historical period (Kjerfve, 1994).

Field surveys and previous studies indicate that tidal flux through the lagoon inlet plays an important role in maintaining the ecological condition of Chilika Lagoon. Continuous tidal exchange helps to renew the lagoonal water and supports its biological components. Proper basin management and effective regulation of the over-exploitation of aquatic resources are essential for maintaining the present ecological condition of the lagoon and reducing the adverse effects of sedimentation. Hence, the dynamics of opening and closure of the lagoon inlet including development and migration of coastal spit can be viewed as critical geomorphological processes that determine the long-term sustainability of Chilika Lagoon.

ACKNOWLEDGEMENTS

The author SMI would like to thank Principal of the Bangabasi College, West Bengal, India for his support and encouragement.

FUNDING

The authors did not receive support from any organization for the submitted work.

CONFLICTS OF INTEREST/COMPETING INTERESTS

The authors have no relevant financial or non-financial interests or conflict of interest to disclose.

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HOW TO CITE THIS ARTICLE:

Islam, S. M. (2026). Development and Future of the Chilika Lagoon. *Humanity and Nature: A Multidisciplinary Journal*, *2*(2), 94 - 99. **https://doi.org/10.5281/zenodo.22091695**

DR. SK MAJHARUL ISLAM is an Assistant Professor in the Department of Geography at Bangabasi College, affiliated with the University of Calcutta. He joined Bangabasi College in August 2017 and has teaching and research experience in Geography. He holds a Ph.D. in Remote Sensing and GIS from Vidyasagar University and an M.Sc. in Geography with specialization in Remote Sensing and GIS Applications. His research interests include remote sensing, GIS, coastal and lagoon environments, land-use/land-cover analysis, and environmental studies. He has published research papers on Chilika Lagoon and other geographical and environmental issues.