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The Shrinking Island: Analyzing the Yearly Decline Rate and Its Implications

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Abstract

This study examines the gradual reduction in the area of Ghoramara island over several years, driven by global warming and rising sea levels. By calculating the yearly decline rates (velocity) of the island's area, this paper highlights a gradual decrease in the rate of area loss, followed by a sharp acceleration in recent years. While the negative velocities indicate continuous shrinking, the slowing rate at the beginning and the sharp decline later suggest a potential environmental tipping point.This analysis provides insights into the island's future submersion and underscores the need for adaptive measures to address ongoing climate change impacts.

KEYWORDS: Ghoramara, Global warming, Sea level, Climate change, Velocity, Area loss.

INTRODUCTION

The climate change andglobal warming have caused significant environmental impacts, one of which is the loss of land due to rising sea levels and increased coastal erosion. Islands, particularly low-lying ones, are among the most vulnerable to such changes. The gradual reduction in island area due to these factors has profound implications for biodiversity, human settlements, and the broader ecological balance.This study seeks to quantify the yearly decline in the area of a particular island by calculating its yearly decline rate or velocity, which represents the rate at which the island's area decreases over time. While the island's area has been shrinking consistently, the rate of change has not been constant. This paper aims to explore these variations, particularly focusing on the shift from a gradual decline in the early years to a sharp increase in the decline rate in later years.Through an analysis of the data, we hope to understand whether the island's decline is likely to accelerate further, potentially reaching a tipping point where the island could be entirely submerged.

LITERATURE REVIEW

In India, the Sundarban Islands have undergone major coastal changes in recent decades. The coastal islands have experienced significant morphological changes and erosion caused by natural processes and human activities. A study conducted by Jana et al., (2012) on Ghoramara Island in India shows that over the past 40 years, land area has decreased by 50 per cent, with large-scale erosion on the northwestern coast and minor erosion on the southeast side. The study of Bandopadhyay et al., (2023) highlighted the fact that during the last century, the decline rate of Sundarban region in India and Bangladesh is 4.46 square kilometers per year in island area. Similarly, between 1980 and 2014, the study of A. Emran (2016) discussed that theSandwip Island in Bangladesh lost 38.84 squarekilometres mainly due to erosion along its western, southwestern and southern shores. Using remote sensing data and GIS technique,Kundu and Halder (2018) showed that, during 43 years between 1975 and 2018, the Sundarban island's area decreased by an average of 1.59 square kilometers every year. From 2001 to 2009, in Indian Sundarbans, the rate of coastline erosion has been estimated to be roughly 5.60 square kilometers per year (Hazra and Samanta, 2016). Between 1996 and 1999, the islands of Sagar faced critical erosion areas and reduced the spread of paddy fields, beaches and vegetation (K. Jayappa, 2006). The island has experienced 14 per cent of its total area loss over the past six decades, with human factors such as reservoir construction and sand mining contributing to environmental degradation and land erosion (M. Rafeeque et al., 2023). These studies highlight the vulnerability of coastal islands to natural and human changes.Major portion of the inhabited land and agricultural land have been lost during last three decades. Thousands of people of the island have become environmental refugees. Ghosh et al., (2003) discussed how to protect Ghoramara island located in the Bay of Bengal from coastal erosion and areal reduction by using 'bio engineering' technic. Sarmah et al., (2022) worked on Majuli island using multi-temporal satellite data. Majuli is the world's biggest populatedriver island located on thebanks of Brahmaputra. According to the author, there is an average 3.07 square kilometre land loss per year during 1975 to 2021 due to bank line shifting and erosion. In 2014, A. Sarma also studied on Majuli island's areal degradation due to flood and erosion by Brahmaputra River. The data analysis shows that between 1914 to 1949 the island has lost on an average 0.71 square kilometre land area per year. Halder et al., (2022) studied the impact of climate change on Ghoramara island. Land degraded and shoreline changed due to sea level rise. The study reveals that about 39% of the total land area of the island has degraded because of it.Sipra Biswas et al., (2024); S. Thakur et al., (2020); S. Das et al., (2021) studied on erosion and accretion patterns across various islands using satellite images and GIS techniques. According

to their studiesfew islands have lost a significant amount of land where as others have gained land. All sites of Sundarban are not equally erosion prone such as eastern parts of Sundarbans are generally more susceptible to erosion than the western parts of Sundarbans. This phenomenon impacted directly to the mangrove ecosystem. Thakur et al., (2020) highlights the fact that how the erosion causing the loss of mangroves in some areas of Sundarban. Some factors are influential for the coastal changes. Biswas et al., (2024) shows that thefactors those influence coastal erosion include natural processes such as tidal action and sea level rise as well as human activities. For example, Jambudwip Island observed erosion and accretion.Das et al., (2021) observed that the westernmost part of the island was more erosion and the easternmost part accretion.The study of Sahana and Sajjad, (2019) recommend that the size of Sundarban Biosphere Reserve has decreased by 5.98 square kilometers annually as a result of accretion and erosion processes.

The areal degradation of Ghoramara islands is occurring in a rapid way but it is importantto know the intensity of degradation and rate of reduction. Our study is an attempt to this direction and we classified the rate of areal degradation into two phase namely early phase and late phase. In each phase we tried to measure the decline rate in a mathematical point of view.

METHODOLOGY

The data used in this study was collected from an Excel dataset containing two key columns: 'Year' and 'Area'. The area data represents the island's size at the corresponding years, while the Year column denotes the time points over which the measurements were recorded. The data also contains some missing years. Using pythons 'pandas' library the data set is loaded and the library 'matplotlib' is utilized for graphical visualization after considering 'Year' as x-axis and 'Area' as y-axis.

Data Source

Data is collected from the West Bengal Pollution Control Board 2021 & published paper of Jana et al. 2012, Ghosh et al. 2014, Bikash Mondal, 2015, Shiladitya Purakayastha, 2020.

Data Preprocessing

- The data was first sorted chronologically to ensure that the years were in order.
- A yearly decline rate was calculated by taking the difference in area between two consecutive years and dividing it by the difference in time (which, in this case, is always one year, simplifying the calculation).

- The decline rate values were plotted against the midpoints of the years to visualize the rate of shrinkage.

Calculation of Decline Rates

The decline rate was calculated using the formula:

$$\text{Decline Rate} = \frac{\text{Area in Year}_{i+1} - \text{Area in Year}_i}{\text{Year}_{i+1} - \text{Year}_i}$$

where i represents each year in the dataset. This calculation was repeated for each consecutive pair of years, providing an array of yearly decline rates (velocity) that represent the rate at which the island's area is shrinking each year.

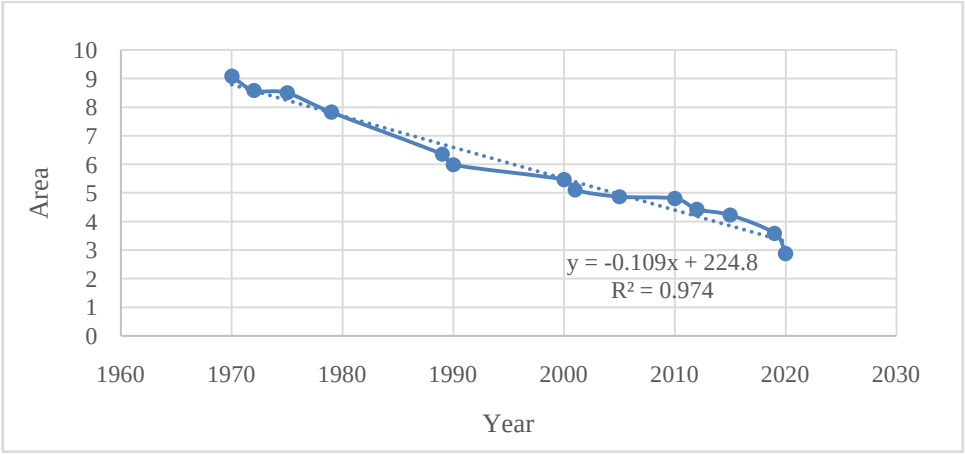

Fig. 1: Scatterplot of area data points

Statistical Analysis

The mean and standard deviation of the decline rates were computed to assess the overall shrinkage and the variability in the rates over time. The trend in the decline rates was visually assessed by plotting the decline rates on a graph, which revealed two distinct phases in the island's shrinking pattern.

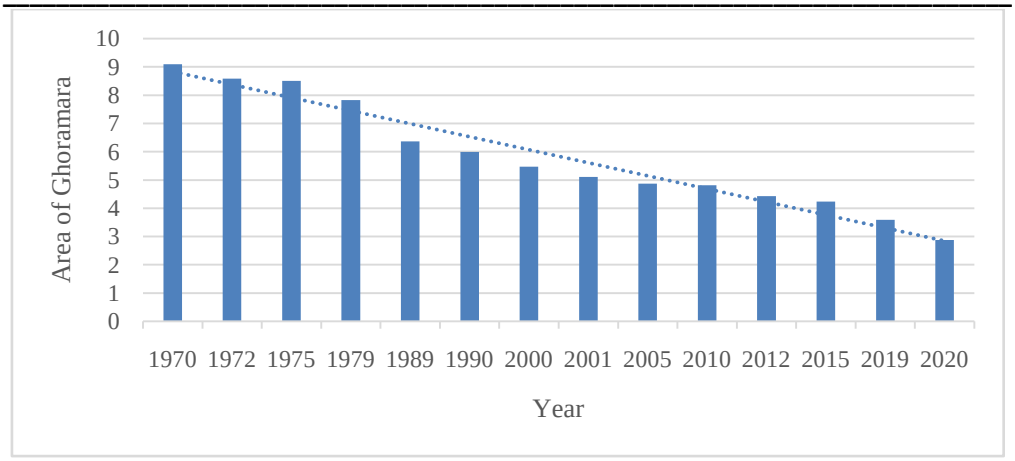

Fig. 2: Bar diagram of decreasing island's area over time

RESULTS

The plot of the decline rates against the midpoint of the years shows a clear, oscillatory pattern. Initially, the decline rates fluctuated between 0 and -0.4, indicating that the island was shrinking, but at a relatively mild and steady pace. Over time, however, the decline rates began to sharply drop, eventually crossing -0.7, suggesting a more rapid loss of area.

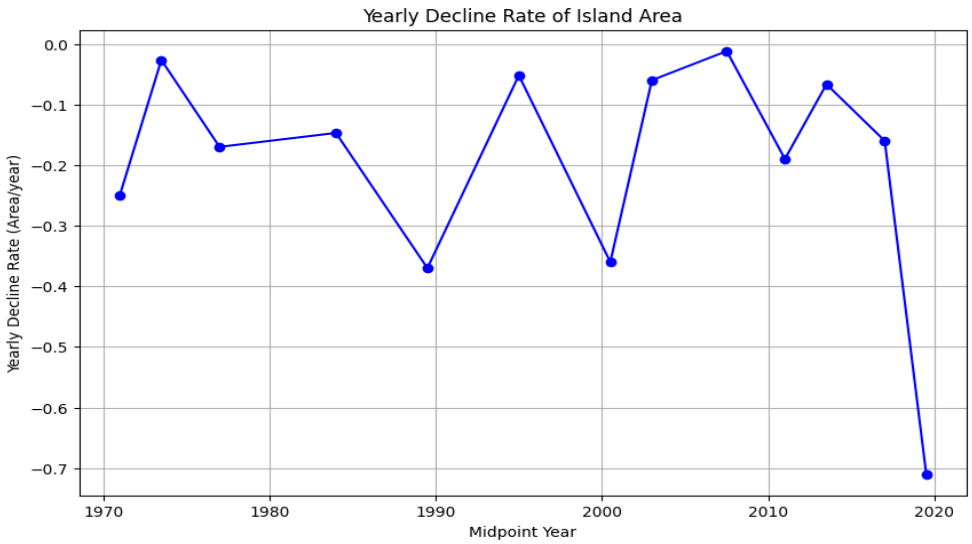

Figure 3: Plot of yearly decline rate of Ghoramaraisland area

Statistical Summary

- **Mean Yearly Decline Rate**: -0.198 (indicating a steady reduction in area of approximately 0.198 units per year).

- **Standard Deviation of Decline Rates**: 0.193 (indicating moderate variability in the yearly rates of change).
- The initial part of the graph lies between 0 and -0.4, showing a slow but consistent shrinkage.
- The later years exhibit a sharp drop, crossing -0.7, indicating a sudden acceleration in the shrinkage rate.

This change in the rate of decline is the key observation of this study, where theisland's shrinking process shifts from a gradual, steady pace to an accelerated one in the final years.

DISCUSSION

The findings indicate that the island has been continuously shrinking, but at varying speeds. The negative velocities show that the area has been consistently decreasing, a pattern driven by global warming and rising sea levels. However, the data reveals two distinct phases:

- **Early Phase (0 to -0.4 decline rate)**: During this phase, the rate of area loss was relatively mild. This could suggest that during this period, environmental factors contributing to the island's shrinkage (such as gradual sea level rise or moderate weather events) were not severe, leading to a slower rate of erosion and area reduction.
- **Late Phase (sharp drop crossing -0.7)**: In the latter part of the data, the decline rate sharply increased, suggesting a significant acceleration in the shrinkage of the island. This could be indicative of more severe environmental changes, such as intensified global warming, increased sea-level rise, or stronger storms. These factors could be causing the island to erode at a much faster rate than before. The sharp decline in the rate of shrinkage might signal that the island is reaching a critical threshold beyond which the shrinkage process could escalate even more rapidly.

The variability observed in the decline rates (with a standard deviation of 0.193) further suggests that environmental conditions are not uniform over time. This variability is likely due to fluctuating climatic factors, such as seasonal variations or occasional extreme weather events.

CONCLUSION

This study shows that theGhoramara island has been shrinking over time, with a gradual decrease in area during the initial period followed by a sharp acceleration in

the rate of shrinkage in recent years. The negative velocities throughout the period indicate a consistent loss of area, but the increasing decline rate suggests that the speed of the island's shrinkage is becoming more pronounced.The findings suggest that the island is approaching a critical tipping point where the rate of area loss could accelerate even more drastically. This acceleration underscores the urgency of addressing climate change and its impacts on vulnerable ecosystems, such as islands. The results also provide valuable insights into the potential future of the Ghoramara island, helping inform environmental policy and conservation strategies aimed at mitigating further loss.Future research should focus on identifying the precise environmental factors responsible for the observed acceleration in the shrinkage rate and whether this trend is reversible or will continue to worsen in the coming decades.

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