# Predicting Coastal Erosion Rates At Menamkulam Beach Using Artificial Intelligence Techniques

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*Abstract:* In nations with coastal zones—India having the longest—coastal erosion is a serious issue. Rather than soil particles, it impacts slope stability. High waves and early monsoon onslaughts cause 370 kilometres of erosion along Kerala's coast. Twenty-three percent of Trivandrum's coastline was impacted in 2021. Additionally vulnerable to erosion are the coastal regions of Thiruvananthapuram district, such as Menamkulam, Puthenthope, Veli, Adimalathura, and Valiathura. Using INCOIS data, this study intends to examine these susceptible coastal areas, where profound studies are done for menamkulam beach in this paper, and the effects of erosion brought on by wave action and beach slopes. To forecast complete erosion or accretion on these locations, a code utilising cutting-edge AI technology is created.

*Index Terms* - **Soil erosion, Wave action, beach slopes, AI codes**

## I. INTRODUCTION

Accurate data on coastal erosion based on past and present shoreline changes is essential to addressing the increasing hazard to life and property in coastal zones. Waves, currents, tides, winds, and human activity can all cause this, and it can be seasonal, episodic, long-term, or short-term. One consistent indicator of erosion is the retreat of the coastline. Baseline, area-based, dynamic segmentation, buffering, and nonlinear least squares estimation are methods used to measure coastal retreat. Researchers have used Survey of India toposheets, satellite data, and aerial photos to examine coastal erosion near Thiruvananthapuram, on the southwest coast of India. When examining shoreline change, the distinctive morphologies along this high-energy coast are taken into account. Thiruvananthapuram is the area along the Kerala coast where erosion happens most often.

## II COASTAL EROSION

Coastal zones are dynamic environments influenced by geological, physical, biological, and human factors. Understanding coastal erosion is essential to address the growing threat to life and property in these areas. Changes in the coastline can occur over long or short periods, seasonally, or episodically, leading to either erosion or accretion. Factors such as waves, tides, currents, winds, and human activities all contribute to coastal erosion. The specific shape of the coastline, including beaches, barrier beaches, tidal flats, and coastal plains, affects how the shoreline changes. Climate change is also accelerating coastal erosion. One key indicator of erosion is coastline retreat. Various methods, such as the baseline

approach, dynamic segmentation, area-based approach, buffering, and nonlinear least squares estimation, are used to measure this retreat.

A recent study by the National Centre for Sustainable Coastal Management identified areas of erosion along the Kerala coast, with the highest erosion zones found around Thiruvananthapuram. The study used field mapping and geospatial techniques to analyze long-term and short-term shoreline changes. It revealed that 33.6% of India's coastline is vulnerable to erosion, 26.9% is experiencing accretion, and 39.6% remains stable. In Odisha, of the 550 km of coastline, 28% is eroding, 21% is stable, and 51% is accreting. Coastal erosion control is a critical area of focus aimed at managing the ongoing loss of coastal land due to natural processes.

## III LITERATURE REVIEW

Thiruvananthapuram district of Kerala, along the southwest coast of India, is a densely populated coastline and is sensitive to sea surge and severe coastal erosion. Sensitivity of the coast if considered in conjunction with other social factors may be an input into broader assessments of the overall vulnerability of coasts and their communities [1].

A recent study made by researchers uses data from satellite pictures and the 1968 SOI topographic chart to investigate long-term coastline changes along the southwest coast of India from 1968 to 2014. The USGS DSAS programme was utilised to calculate the rate of changes. The study discovered that man-made activities including building dams, hard structure development, and mining sand from beaches and rivers had drastically altered the whole width of the Kerala coast. The paper makes the argument that since shoreline features are constantly changing as a result of both natural and human activity, forecasting future trends may not be feasible. [2]

Several studies highlight the advantages of machine learning (ML) over traditional regression techniques in coastal and ocean engineering. Many research on forecasting coastal engineering characteristics like waves, wave breaking, hydraulic properties, and beach profile changes have been made. The study focuses on regression analysis using continuous variables in supervised machine learning models, excluding categorical variable classification. It provides a comprehensive review of technological advancements and application examples of ML models in coastal engineering [3].

There are many studies that explores the use of machine learning (ML) in coastal morphodynamics and sediment transport research, highlighting the shift from traditional empirical methods to data-driven strategies. It emphasizes the importance of computational methodology, data amount, nonlinearity, and high dimensionality. The study identifies various ML applications in sediment transport, morphologic, and hybrid coastal prediction problems, discusses common concepts, future goals, comparisons with standard approaches, and the selection of relevant ML methods [4].

## IV EXPERIMENTAL PROCEDURE

An experimental setup was prepared to analyse wave action's impact on soils. The setup included a wave tank made of glass walls; a wave generator programmed using Arduino UNO, a laptop and a power supply. Experimental setup is shown in Fig. 4.1.

(a)  Experimental setup                          Experimental modelling

Fig - 4.1:  Erosion degree– 45 degrees experimental analysis

The soil slopes of 45 degrees were modelled in the glass tank. The glass walls were chosen to resist the wave impact as well as to offer easy visual analysis of the experiment. The soil samples were mixed in their initial moisture content, compacted and filled in 5 layers and the slopes were made accordingly. The water level was maintained constant at a height of 10cm throughout the experiment. The wave generator operated in three different velocities i.e., 0.06 m/s, 0.07 m/s, 0.08m/s and 0.09m/s respectively. The experiment was conducted for one hour on the slope and soil sample with varying velocities. The wave height and amplitude were also noted during the experiment. The initial height of the slope was noted and the difference in heights was noted down at 0,5,10,15,30,45 and 60mins respectively. The difference in height of the soil slope was used to find out the change in the slope angle of the soil slope. The initial mass of the soil sample was noted and the eroded mass was also found by calculating the difference between the soil mass retained and the mass initially taken. Erosion degree, De is analysed and found out using the formula, De = $\theta/\theta'$. Erosion degree is unity when the slope is stable. The reduction in De indicates the soil mass being eroded away.
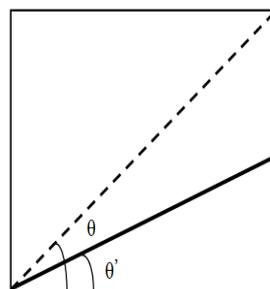


Where,
Original Slope=$\theta$
Modified Slope =$\theta'$

## V   INTRODUCTION OF AI IN EROSION ASSESSMENT

Artificial intelligence has been used as a tool to solve numerically complex problems where a number of variables are involved in the field of wave energy and ocean engineering. In recent years, wave height forecasting has been improved by means of diverse artificial intelligence techniques, such as Genetic programming, Neuro wavelet technique, Sequential learning neural networks, Extreme Learning Machine, Bayesian methods, Artificial neural networks. Artifical neural networks(ANNs) arise as a useful tool as they can deal with non-linear function regression. ANNs can be applied to optimize the coastal protection performance of a wave farm, reducing the computational cost of physically-based numerical models.

So the code is coded for calculating erosion degree as follow:

```python
import numpy as np
import math
def calculate_erosion(initial_slope_degrees, final_slope_degrees, velocity, time_interval):
# Convert slope from degrees to radians
initial_slope = math.radians(initial_slope_degrees)
final_slope = math.radians(final_slope_degrees)
# Calculate erosion degree using the equation: erosion = final_slope / initial_slope
erosion = final_slope / initial_slope
# Calculate reduction percentage
reduction_percentage = ((initial_slope - final_slope) / initial_slope) * 100
return erosion, reduction_percentage
# Example parameters
initial_slope_degrees = 45 # Initial beach slope in degrees
final_slopes_by_velocity = {
0.06: [45.00, 41.05, 38.85, 32.57, 31.43, 27.82, 23.96],
0.07: [45.00, 30.26, 29.05, 28.32, 28.07, 27.07, 23.00]
0.08: [45.00, 23.96, 19.86, 15.52, 14.04, 12.53, 11.00],
0.09: [45.00,21.25, 15.52, 14.93, 12.53, 11.00, 7.91] }
time_intervals_minutes_list = [0, 5, 10, 15, 30, 45, 60]  # Different time intervals in minutes
velocities = [0.06, 0.07, 0.08, 0.09]  # Different velocities in m/s
# Calculate erosion for different velocities, final slopes, and time intervals
erosion_degrees = []
for velocity in velocities:
erosion_degree_for_velocity = []
print(f"Velocity: {velocity} m/s")
print("{:<25} {:<25} {:<20}".format("Time Interval (minutes)", "Final Slope (degrees)", "Erosion Degree"))
for final_slope_degrees, time_interval in zip(final_slopes_by_velocity[velocity], time_intervals_minutes_list):
erosion, _ = calculate_erosion(initial_slope_degrees, final_slope_degrees, velocity, time_interval)
erosion_degree_for_velocity.append(erosion)
print("{:<25} {:<25} {:<20.3f}".format(time_interval, final_slope_degrees, erosion))
erosion_degrees.append(erosion_degree_for_velocity)
print("\n")
# Calculate reduction percentage based on erosion degrees for the first and last velocities
reduction_percentages = []
for i in range(len(time_intervals_minutes_list)):
reduction_percentage = ((erosion_degrees[0][i] - erosion_degrees[-1][i]) / erosion_degrees[0][i] * 100
reduction_percentages.append(reduction_percentage)
# Print reduction percentage table
print("Reduction Percentage:")
print("{:<25} {:<20}".format("Time Interval (minutes)", "Reduction Percentage"))
for time_interval, reduction_percentage in zip(time_intervals_minutes_list, reduction_percentages):
print("{:<25} {:<20.2f}".format(time_interval, reduction_percentage))
```

the above code will provide the output in tabulated form with the erosion degrees and reduction percentage.

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The following code, when included, will provide the output for reduction percentage corresponding to each velocity in graphical data

```
# Plot reduction percentages against time intervals for each velocity
for velocity, erosion_degree_for_velocity in zip(velocities, erosion_degrees):
    plt.plot(time_intervals_minutes_list, erosion_degree_for_velocity, label=f'Velocity: {velocity} m/s')
plt.xlabel('Time Interval (minutes)')
plt.ylabel('Erosion Degree')
plt.title('Erosion Degree vs Time Interval')
plt.legend()
plt.grid(True)
plt.show()
```

For predicting the total erosion or accretion happening at the site define the following as well;

```
import math
def calculate_erosion_accretion(velocity_data, time_interval, relative_density,
original_beach_slope_degrees, erosion_slope_reduction_degrees):
    total_erosion = 0
    total_accretion = 0
    # Calculate sediment density from relative density
    sediment_density = relative_density * 1000  # Density of water is 1000 kg/m^3
    for i in range(len(velocity_data)):
        velocity = velocity_data[i]
        time = time_interval[i]
        erosion_slope_reduction = erosion_slope_reduction_degrees[i]
        # Calculate the slope ratio from the original beach slope in degrees
        original_slope_ratio = math.tan(original_beach_slope_radians)

        # Assuming erosion and accretion are proportional to velocity and adjusted beach slope
        sediment_transport_rate = velocity * reduced_slope_ratio
        # Calculate erosion or accretion for this time interval
        erosion_accretion = sediment_transport_rate * time * sediment_density
        # Update total erosion or accretion
        if erosion_accretion < 0:
            total_erosion += abs(erosion_accretion)
        else:
            total_accretion += erosion_accretion
    return total_erosion, total_accretion
```

## VI RESULT AND DISCUSSIONS

### 6.1 FROM EXPERIMENTAL DATA

The result obtained for the experiment is tabulated below

Table 6.1: Erosion degree– 45 degrees

| Time (min) | Θ (degree) | Wave velocity 0.06m/s | | Wave velocity 0.07m/s | | Wave velocity 0.08m/s | | Wave velocity 0.09m/s | | % reduction |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Θ' (degree) | Erosion degree, $D_e = Θ'/Θ$ | Θ' (degree) | Erosion degree, $D_e = Θ'/Θ$ | Θ' (degree) | Erosion degree, $D_e = Θ'/Θ$ | Θ' (degree) | Erosion degree, $D_e = Θ'/Θ$ | |
| 0 | 45 | 45.00 | 1.00 | 45.00 | 1.00 | 45 | 1.00 | 45.00 | 1.00 | 0.00 |
| 5 | 45 | 41.05 | 0.91 | 30.26 | 0.67 | 23.96 | 0.53 | 21.25 | 0.47 | 48.23 |
| 10 | 45 | 38.85 | 0.86 | 29.05 | 0.65 | 19.86 | 0.44 | 15.52 | 0.34 | 60.04 |
| 15 | 45 | 32.57 | 0.72 | 28.32 | 0.63 | 15.52 | 0.34 | 14.93 | 0.33 | 54.16 |
| 30 | 45 | 31.43 | 0.70 | 28.07 | 0.62 | 14.04 | 0.31 | 12.53 | 0.28 | 60.14 |
| 45 | 45 | 27.82 | 0.62 | 27.07 | 0.60 | 12.53 | 0.28 | 11.00 | 0.24 | 60.45 |
| 60 | 45 | 23.96 | 0.53 | 23.00 | 0.51 | 11.00 | 0.24 | 7.91 | 0.18 | 67.00 |

From Table 6.1, the extreme case is observed in velocity 0.09m/s after 60 minutes of wave action where the slope noted was almost 8 degrees. Erosion degree at that point is noted as 0.18. After 60 minutes of experiment, it is observed that the erosion degree is reduced by almost 67%. The variation in Erosion degree of 45-degree slope with respect to variation in time and velocities are plotted in Fig. 6.1.
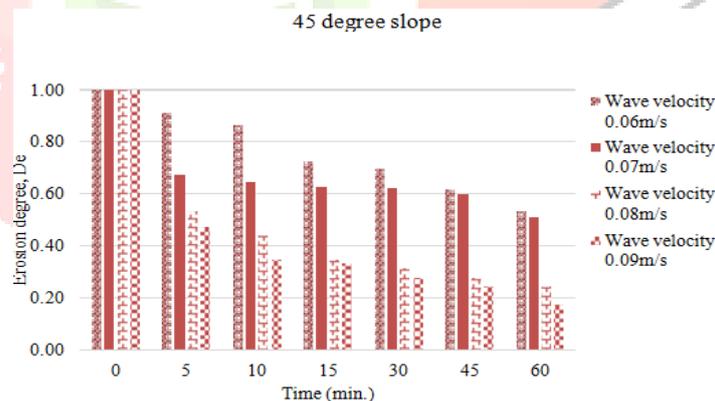


Chart - 6.1:  Erosion degree– 45 degrees

From the graph, it was observed that with the increase in velocity, the erosion degree decreases which represents that the amount of soil being eroded away increases. This increase is due to the increased impact caused by the waves. Also, the variation in erosion degree is found to be more in the initial stages of the experiment Difference in erosion degree among 0.08m/s and 0.09m/s velocities are observed to be minimal. After 30mins, the difference among erosion degrees of 0.06m/s and 0.07m/s are also found to be minimal.. This might be due to the swash and backwash effect of the waves.

## 6.2 FROM AI CODE

From the AI Code the output generated is as given below,
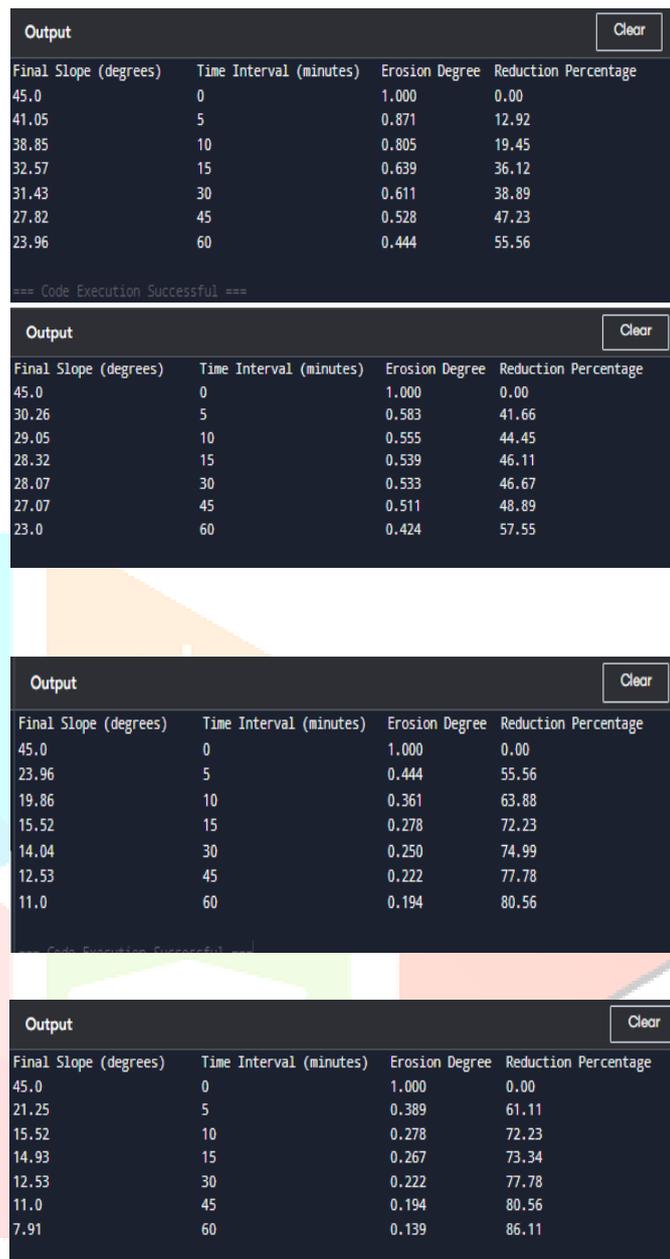
| Final Slope (degrees) | Time Interval (minutes) | Erosion Degree | Reduction Percentage |
|---|---|---|---|
| 45.0 | 0 | 1.000 | 0.00 |
| 41.05 | 5 | 0.871 | 12.92 |
| 38.85 | 10 | 0.805 | 19.45 |
| 32.57 | 15 | 0.639 | 36.12 |
| 31.43 | 30 | 0.611 | 38.89 |
| 27.82 | 45 | 0.528 | 47.23 |
| 23.96 | 60 | 0.444 | 55.56 |

=== Code Execution Successful ===

| Final Slope (degrees) | Time Interval (minutes) | Erosion Degree | Reduction Percentage |
|---|---|---|---|
| 45.0 | 0 | 1.000 | 0.00 |
| 30.26 | 5 | 0.583 | 41.66 |
| 29.05 | 10 | 0.555 | 44.45 |
| 28.32 | 15 | 0.539 | 46.11 |
| 28.07 | 30 | 0.533 | 46.67 |
| 27.07 | 45 | 0.511 | 48.89 |
| 23.0 | 60 | 0.424 | 57.55 |

| Final Slope (degrees) | Time Interval (minutes) | Erosion Degree | Reduction Percentage |
|---|---|---|---|
| 45.0 | 0 | 1.000 | 0.00 |
| 23.96 | 5 | 0.444 | 55.56 |
| 19.86 | 10 | 0.361 | 63.88 |
| 15.52 | 15 | 0.278 | 72.23 |
| 14.04 | 30 | 0.250 | 74.99 |
| 12.53 | 45 | 0.222 | 77.78 |
| 11.0 | 60 | 0.194 | 80.56 |

| Final Slope (degrees) | Time Interval (minutes) | Erosion Degree | Reduction Percentage |
|---|---|---|---|
| 45.0 | 0 | 1.000 | 0.00 |
| 21.25 | 5 | 0.389 | 61.11 |
| 15.52 | 10 | 0.278 | 72.23 |
| 14.93 | 15 | 0.267 | 73.34 |
| 12.53 | 30 | 0.222 | 77.78 |
| 11.0 | 45 | 0.194 | 80.56 |
| 7.91 | 60 | 0.139 | 86.11 |

Fig 6.1: Erosion degree– 45 degrees code output for different velocities and the reduction percentage

## VII  CONCLUSIONS

- The erosion degree of soil slopes made in the apparatus was calculated from the experiment.
- It is found that increase in velocity decreases erosion degree which indicates more amount of soil mass eroded.
- Numerical study was conducted using AI codes and the erosion rates are calculated.
- The values of erosion degree obtained from the experiment is comparable to that of the output obtained from the
    AI code, hence the code is validated.
- Similarly the code can be used to validate the data for different sites

## VIII  REFERENCES

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