

STATISTICAL MODELLING AND PREDICTION OF BEACH PROFILE CHANGE : A CASE OF COROMANDAL COAST OF TAMIL NADU, INDIA

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ABSTRACT - Modelling and prediction of beach profile change is attempted for Coromandal coast of Tamil Nadu using principle component and multiple regression analysis. The first component explains 39 percent of variance and positively loaded with water depth. The second component explains 23 per cent of variance and positively loaded with grain size and wave angle during north-east monsoon. Based on positive and negative component scores the influencing factors in beach profile change were identified for each location. On the basis of the regression analysis, a predicting equation is proposed.

INTRODUCTION

Statistical techniques and models have had wide application in several fields of geology, geography and oceanography. The theoretical and mathematical development of the field is covered in depth by Miller and Kahn (1962). Statistical models and matrix techniques were introduced by Krumbein and Graybill (1965). The predicted and operational aspects of data analysis as applied to earth sciences were explained by Davis (1973). Dolan et al (1977) applied eigen vector analysis to topographic profiles from the sub-aerial portions of barrier islands on the east Gulf coasts. Many of the statistical methods developed for geology as a whole can be used in the coastal regions. Multiple regression, trend surface and factor analysis have been applied to the coastal zone (Fox, 1985). One such study has been attempted in the Coromandal coast of Tamil Nadu, India using multiple regression and principle component analysis using slope, grain size, wave period, wave height, water depth, wave

angle during south-west and north-east monsoon as variables to find out the causes for the beach profile change and to predict the oscillations.

STUDY AREA AND THE NATURE OF THE PROBLEM

The Precambrian group of metamorphics which regionally exhibit a north-east-south-west trend, the sediments of Gondwana, cretaceous and tertiary group of rocks consist of fluvial and marine landforms are the main geologic formations lying adjacent to the Coromandal coast in the west. Fluvial landforms are dominated by a network of deltas such as those of Proto-Cauvery, Palar, Ponnaiyar, Kallar, Vellar, Manimuttat, Vagai and Tamiravaruni rivers (Aruchamy et al. 1992). The marine landforms developed in the area are the beach ridges, swales, backwaters, baymouth bars and off-shore bars and spits.

Coastal erosion and deposition are due to the interaction between the winds, waves, currents, tides, sediment size and supply in the near

shore zone. The movement of sediments often called littoral transport, is of two types: one, the longshore (parallel to the shore) and the other onshore-off shore (perpendicular to the shore). Erosion along the Coromandal coast of Tamil Nadu is due to the longshore transport, unlike the cyclonic erosion, which is bi-directional in nature. Longshore transport results from the shoring up of sediments by the breaking waves and movement of the sediments in a longshore direction by the longshore current generated by the breaking wave. The direction of the longshore transport is directly related to the direction of wave approach. Thus, due to the variability of the wave approach, longshore transport direction may vary from season to season. The study area experiences a bi-directional longshore littoral transport due to the change in the direction of littoral current towards north from January to September and towards south from October to December (Sambasiva Rao, 1987; Aruchamy et al, 1992). As reversals in transport directions occur, two aspects of longshore transport rate become important. The first is the net rate, which is the net amount of materials passing a particular point in the predominant direction during an average year. The other aspect is the gross rate, the total of all materials moving past at a given point in a year despite the direction.

Tamil Nadu has lost many villages and towns in the past due to the ravages of the sea. Therefore a coastline behaviour study has been initiated by the Institute of Hydraulics and Hydrology, Poondi, Tamil Nadu by monitoring 30 observation sites with 229 reference pillars in various places covering a length of 75 km, from 1978 to 1988. Table 1 shows the accretion and erosion details for 15 observation sites (Kaliasundaram et al, 1990; Anti-erosion Cell, 1992). Of which eight stations have recorded erosions while the rest recorded deposition.

BEACH PROFILE CHANGE

Often beach profile modelling requires voluminous data regarding the slope, grain size, wave period, wave height, wave angles and so on for a particular site. Once the data is collected the seasonal changes and their causes can be modeled. One such change in beach profile along the California coast has been successfully modeled using empirical eigen functions (Winant et al 1975; Aubrey et al 1980). The empirical eigen function study has used twenty years of data. However, in the present study the data for 15 observation sites were only available randomly on the long term basis and spread over large area. The modelling is attempted for the entire coast to understand the phenomena of the beach profile change through an eigen function model.

DATA

Data regarding wave height, wave period, wave length, grain size and slope were collected from Anti-erosion Cell for a period of 11 year, and tabulated in Table 1. The following facts were observed from the table: They are : slope is very steep in Kovalam (1/8m) Mahabalipuram (1/8m), Uvari and Kanniyakumari (1/9m). Very gentle slope is observed in Pondicherry, Cuddalore, Poompuhar, Tharangambadi and Nagapattinam (1/22.5m). The slope is moderate in all other places, The grain size is 0.4 mm in Kovalam and Mahabalipuram, which is the smallest in size in the study area. Whereas, Uvari recorded 0.67 mm. Above 0.5mm sizes were measured at kanniyakumari, Manapad, Tiruchendur, Ammapattinam, Pondicherry and Cuddalore. The maximum wave period is observed in Pondicherry, Cuddalore, Poompuhar and Tharangambadi (12.5 seconds). The minimum wave period is measured at Nagapattinam (4.5 seconds) Wave

Table 1.**Slope, grain size, Wave, erosion and accretion details**

Name of station	Slope (m)	Grain size (mm)	Wave period (s)	Wave height (m)	Water depth (m)	Area (acre)	Type	Rate	SW wave approach (Degree)	NE wave approach (Degree)
Kovalam	1/8	0.4	10	1.5	10	63	E	0.81	20	40
Mahabalipuram	1/8	0.4	10	1.5	10	3.4	A	0.25	10	65
Pondichery	1/22.5	0.5	12.5	1.5	10	0.45	E	0.15	8	60
Cuddalore	1/22.5	0.5	12.5	1.5	10	34.8	A	10.98	15	60
Poompuhar	1/22.5	0.495	12.5	1.5	10	3.05	E	0.65	45	50
Tharangambadi	1/22.5	0.495	12.5	1.5	10	3.40	E	1.80	30	50
Nagapattinam	1/22.5	0.47	4.5	1.5	10	1.19	A	0.11	30	50
Point Calimere	1/15	0.5	8	1.5	10	8.19	E	3.40	40	50
Ammapatnam	1/12.5	0.55	8	1.5	5	6.36	A	0.72	30	80
Rameshwaram	1/12.5	0.42	8.5	1.5	5	3.66	A	0.29	10	70
Killakarai	1/11.5	0.42	8	1.5	5	1.35	E	0.25	0	70
Tiruchendur	1/12.5	0.54	10	0.8	10	0.50	A	0.06	40	50
Manapad	1/12.5	0.57	10	0.8	10	1.25	A	0.33	30	70
Uvari	1/9	0.67	10	0.8	10	4.4	E	1.10	0	70
Kanniyakumari	1/9	0.55	10	0.8	10	5.52	E	0.86	30	70

E: Erosion

A: Accretion

Source: Comiled by the authors from various sources

period of 10 seconds is observed in Kovalam, Mahabalipuram, Tiruchendur, Manapad, Uvari and Kanniyakumari. Other stations recorded between 8 seconds and 8.5 seconds of wave period. Wave height is almost the same in all places except in Tiruchendur, Manapad, Uvari and Kanniyakumari recorded 0.8 m wave height. In all other stations the wave height is 1.5m. Water depth is 0.5m in Ammapatinam, Rameshwaram and Killakarai. Whereas, in all other places it is 10m. Kovalam, Pondicherry, Poompuhar, Tjarangambadi, Nagapattinam, Point Calimere, Killakarai, Uvari and Kanniyakumari is eroding in

nature. All other stations the deposition takes place.

The maximum change is observed in Cuddalore (34.8 acre). the lowest change is observed in Pondicherry (0.45 acre). Apart from this, the table 1 also shows the change in the coastline configuration and rate of change for all stations. The wave approach during south-west monsoon period is 45° in Poompuhar. The same is 30° in Kanniyakumari, Manapad, Ammapatinam, Nagapattinam and Tharangambadi. In all other stations it is less than 30°. The wave approach during north-east monsoon is 50° in all stations

except in Kovalam it is 40° Ammapatinam records the maximum angle of 80°.

DATA ANALYSIS

In the first step of analysis the data has been standardised. This is necessary since the first step in the principle component analysis is the computation of correlation matrix, which requires normal distributions of all variables. Entries in the correlation matrix enable the component analysis to compare and cluster the variables according to their linear correlation coefficients. As a second stage the data were subjected to principle component transformation of 'm' original variables in the 'm' dimensional measurement space to 'm' statistically independent variables or principle components where each variable is a linear combination of the old. After this step, the choice of the number of components to be extracted is dependent on eigen value. In the present study this is considered as recommended by Davis (1973). The final step is the extraction of the component scores. In the present study two components were extracted. Based on the scores (0.3 and above) the influencing variables in each component were identified. In the multiple regression analysis, matrix of sum of squares and cross products of 'x' were computed followed by the vector of sum of y and sums of cross products of and 'x' s. The next step is the estimation of dependent variable and the residuals were computed. Finally the partial regression coefficients, estimated covariance matrix of the partial regression coefficients, goodness of fit and correlation coefficient were computed.

RESULTS AND DISCUSSION

Intercorrelations and Beach Profile Change

The intercorrelation shows the following significant relationship :

Slope is positively correlated with the wave period (0.474), wave height (0.435), wave angle during north-east monsoon (0.281) and negatively correlated with wave angle during south-west monsoon (-0.37) and water depth (-0.266).

Grain size is positively correlated with wave angle (0.431) and negatively correlated with wave height (-0.735).

Wave period is negatively correlated with water depth (-0.621) and wave angle during south-west monsoon (-0.322).

DETERMINISTIC MODELLING

Component I: Slope and Wave Characteristics

Based on the eigen values two principle components accepted as significant. They cumulatively explain 62 per cent of the total variance. The first component explains 39 per cent of variance with the eigen value of 2.7. Slope (0.418), wave period (0.414), and wave heights (0.371) are positively loaded in the first component. Water depth (-0.413) and wave angle during the south-west monsoon (-0.413) are negatively loaded on this component. The component scores reveal that erosion is mainly controlled by slope, wave period and wave height in Kovalam (0.564), Pondicherry (0.331), Poompuhar (1.631), Tharangambadi (1.127) and Nagapattinam (3.87). Simultaneously, the deposition is controlled by slope, wave period and wave height in Cuddalore (0.457) and Point Calmère (1.727). Negative loadings reveal that the deposition is controlled by water depth (-0.433) and wave angle during south-west monsoon period (-0.606) in Tiruchendur (-0.502) and Manapad (-1.562), while erosion is controlled by water depth and wave angle during south-west monsoon in Killakarai (-0.857), Uvari (-2.746) and Kaniyakumari (-1.730).

Table 2.

Factors determining the beach profile change

Station	Type of Change	Factor determining beach profif change
Kovalam	E	Slope, wave period and wave height
Mahabalipuram	A	Grain size, wave angle (SW)
Pondicherry	E	Slope, Wave period and wave height
Cuddalore	A	Slope, wave period and wave height
Poompuhar	E	Slope, wave period and wave height
Tharangambadi	E	Slope, wave period and wave height
Nagapattinam	A	Slope, wave period and wave hight, grain size and wave angle
Point Calimere	E	Slope, wave period and wave heighr, grain size and wave angle
Ammapatinam	A	Water depth, wave angle (NE, SW) and garin size
Rameshwaram	A	Water depth and wave angle (NE)
Killakarai	E	Water depth and wave angle (NE)
Tiruchendur	A	Water depth, wave angle (NE, SW) and grain size
Manapad	A	Water depth, wave angle (NE, SW) and grain size
Uvari	E	Water depth, wave angle (NE,SW) and grain size
Kanniyakumari	E	Water depth, wave angle (NE,SW) and grain size

Source: Saravanakumar, (1995)

Component II : Grain Size and Wave Angle

Second component explains 23 per cent of the total variance and has an eigen value of 1.61. Grain size (0.599) and wave angle during north-east monsoon (0.434) load significantly on the second component. Erosion is controlled by grain size and wave angle during north-east monsoon in Nagapattinam (1.402,) Uvari (1.345) and Kaniyakumari (1.27) Deposition is controlled by grain size and wave angle during the north-east monsoon in Point Calemere (0.874), Ammapatinam (0.002), Tiruchendur Tiruchendur (1.614) and Manapad (1.467).

Table 2 shows that the beach profile change in southern part of Coromandal coast of Tamil Nadu (south of Point Calemere) is influenced by water depth, wave angle during north-east and south-west monsoon and grain size, except Rameshwaram and Killakarai where it is influenced by water depth and wave angle. Whereas, the beach profile change in northern

part of Coromandal coast of Tamil Nadu is influenced by slope, wave period and wave height except Mahabalipuram where, it is influenced by the grain size and wave angle during south-west monsoon. At Nagapattinam and Point Calemere the beach profile change is influenced by grain size and wave angled during north-east monsoon apart from the slope, wave period and wave height. Littoral current plays a vital role in beach profile change in the southern Coromandal coast of Tamil Nadu, whereas in northern part of Coromandal coast of Tamil Nadu its role is insignificant. This fact is also inferred from the disposition of spits in the southern Tamil Nadu (Manapa, Tuticorin and Muthuranganathapuram -all trending towards north, Aruchamy et al 1992).

PREDICTION OF BEACH PROFILE CHANGE

In many coastal problems, the objective is to predict the response of one element to other

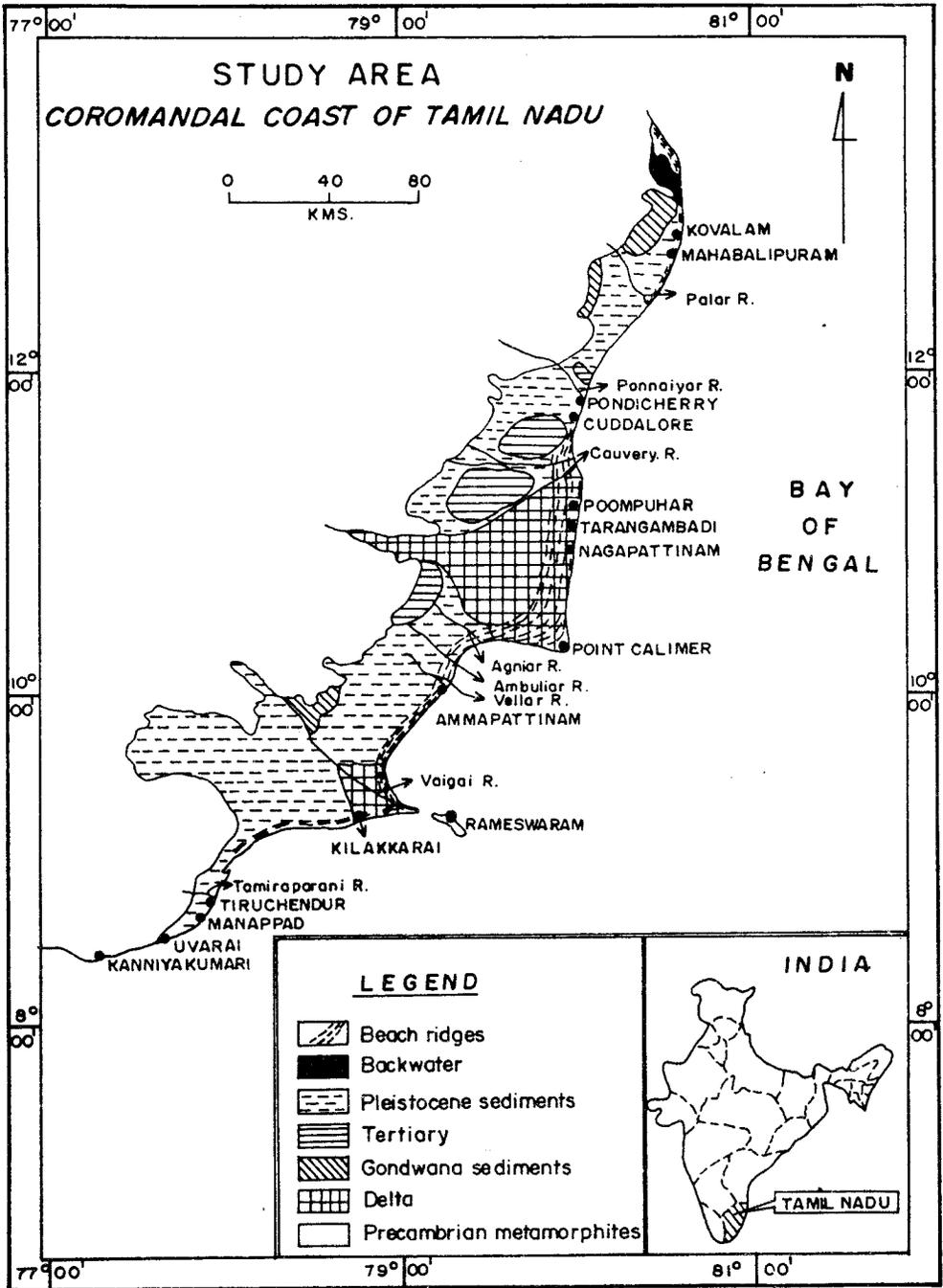


Figure.1

elements of the environment, In a study conducted by Harrison and Krumbein (1964) on the beach at Virginia Island, an attempt was made to predict the beach slope based on the wave energy and mean grain size. Nearshore bottom slope in the shoaling waves were measured at low tide and used as dependent variable. Four independent variables were measured, including wave height, wave period and wave angle and still water depth (Krumbein and Graybill, 1965). According to Fox (1985), stepwise analysis provides method for determining the contribution that each independent variable has on the prediction equation.

In the present study, multiple partial regression analysis was attempted to predict the beach profile change. The assumption here is that oscillations (beach profile change) are influenced by slope, grain size, wave period, wave length, water depth and wave angle during south-west and north-east monsoon (Saravanakumar, 1995). Keeping oscillations as the dependent variable, the analysis was carried out.

The result shows that the beach profile change (oscillations) = 32.97 (constant) + 2.62790 (slope) + 69.42358 (grain size) + 0.76662 (wave period) - 12.02629 (wave height) - 3.14501 (water depth) - 0.74177 (wave angle during north-east monsoon) - 0.98250 (wave angle during south-west monsoon). Where, 32.97 is the constant. The goodness of fit for the analysis is 0.4155 and the correlation coefficient is 0.6446. Once the measurements regarding slope, grain size, wave period, wave height, water depth and wave angles during north-east and south-west monsoon are known, the beach profile change can be predicted using the above said equation, However, this prediction can be useful for long term only (about 10 years or more).

LIMITATIONS OF MODELLING AND PREDICTION

The following are the main limitations of the study :

The Wave angles are calculated from the fact that in east coast of India, the dominant waves are from N60 E during the north-east monsoon and S45E during the south-west monsoon. The original angles give more appropriate empirical solutions.

This model determines the order of influencing factors only, but not the exact numerical values (ie exact percentage is influenced by the particular variables).

No storms and cyclones are taken into considerations.

No tectonic features are included in this model.

CONCLUSIONS

The northern part of Coromandal coast of Tamil Nadu beach profiles are mainly influenced by the slope, wave period and wave height except at Mahabalipuram where the change is controlled by the grain size and wave angle during south-west monsoon. The southern part of Coromandal coast of Tamil Nadu beach profile changes are mainly influenced by the water depth, wave angle during north-east and south-west monsoon and grain size except Rameshwaram and Killakarai where fit is controlled by water depth and wave angle during north-east monsoon. So, any remedial measures should be based on the above said parameters.

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