Archaeological Exploration, Excavation, and Analysis for a Richer Interpretation of the Past Chola Heritage City- Poompuhar

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Abstract -The article deals with the process of collecting underwater data from the historical area in South India and explicitly showcasing its ancient civilization. Various methods are used to investigate the environmental and structural variables that regulate the coastal structures. Geostatistical interpolation is a technique to predict the values of a spatially continuous bathymetry or depth of a submerged shoreline from a few sample data measurements. The bathymetric investigation of the submerged region surrounding the ancient port of Poompuhar consists of numerous processes conducted in stages. The survey was carried out with the use of an integrated measuring system developed by the National Institute of Technology, Chennai, which included various levels of Multi Beam Echo Sounder (MBES), GPS, sonar, and ROV. To discover continuous surfaces required for analyzing the morphology of the bottom of submerged Poompuhar, a suitable interpolation technique must be used to get estimated values in regions that were not physically surveyed.

Bathymetric and topographic data, which typically are gathered independently for various purposes, were included in the spatial data used for elevation surface modeling. Data is gathered in multiple forms with varying resolutions and accuracy; as a result, a standard surface model that will allow for quick and accurate analysis is currently lacking. The major purpose of this study was to create a high-accuracy model of a coastal area's surface using input data from numerous sources. ArcGIS is a popular software platform for analyzing and visualizing geographic data, and it contains several geostatistical interpolation techniques. The research involves the erosion of the shoreline as well as the rise in water level. The study uncovered new scientific and methodological information on Poompuhar's bathymetric properties and submerged surface.

Keywords: Geostatistical Interpolation, bathymetric survey, submerged surface, ArcGIS, Poompuhar

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1 Introduction

One of the richest ancient literature in Tamil Nadu, known as Sangam literature, provides extensive historical records on Poompuhar. Kaveripoompattinam or Poompuhar or Puhar (11°08'33"N; 79°1'31"E), an ancient Tamil port, was important in India's maritime history. The Tamil epics Silappathikaram and Manimekhalai, as well as Sangam period literature like Pattinappalai and Ahananaur, mention Poompuhar as the early Cholas capital port city, occupying an area of roughly 76.8 square kilometers. It stretched west to the existing villages of Karuvindanathapuram and Kadarankondan, south to Thirukadavur, north to Kalikamur, and east to the Sea of Bengal (Rao 1991). The disappearance or submerging of several port cities and coastal regions is mostly due to coastal erosion, changes in sea level, neotectonic activity, and other causes, including tsunamis. Marine archaeological investigations have been carried out around the

Poompuhar region and observations made on the coastal landmarks and other discoveries. Excavations on the site of two Warves (Rao, 1987; Athiyaman, 1999) found two structures on an old Kaveri waterway. The results of offshore exploration, at least 8 meters of water depth, indicate that a portion of habitation has been submerged in the sea. The ancient shoreline of Poompuhar may be shifted some distance offshore (Sundaresh et al. al. 1997), as it was expected to be between 8 and 10 meters above sea level during the Sangam period.

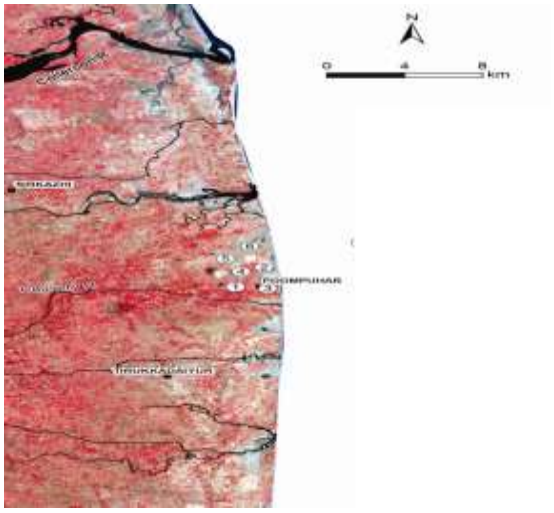

Fig 1: Diagram showing the sites selected for underwater explorations in Poompuhar

Spatial interpolation, which comprises geostatistical and deterministic interpolation, is a technique for estimating data in contiguous areas and predicting information that is unknown or cannot be obtained using current observable data. (Chai et al. 2011; Losser et al. 2014).

2 Study area

Poompuhar, a port city, was established at the mouth of the Cauvery River. The Poompuhar port was selected for the study area. The port runs for up to 8 kilometers into the Bay of Bengal Sea and for around 20 kilometers along the shore (Table 1). Marine archaeology research at Poompuhar has uncovered terracotta ring wells, brick houses, intertidal storage containers, brick structures, stone structures, and ceramics from offshore projects that strongly suggest habitation. Excavation both on land and sea was required to reconstruct Poompuhar's early history and the people's social, economic, and religious lives, as well as their role in the cultural development of India in Southeast Asia. The major goal of the survey was to conduct a bathymetric investigation and locate wrecks or structural remains using side scan sonar, echo sounders, and magnetometers. The exploration area spread from Vanagiri to Nayakkankuppam, approximately 20 kilometers along the coast and approximately 8 kilometers from the sea (Rao, S.R. 1988).DST has proposed a large investment to rebuild the famous ancient port.

Name	Location	Length of Coast
Poompuhar	79°51'29.417"E 11°5'31.301"N 79°51'27.332"E 11°9'19.252"N	10 Km

Table 1: Location details of the study area

3 Research materials and methods

3.1 Equipment used

The depth of the seabed at sea level is most commonly referred to as bathymetry. Using multibeam echo sounder equipment, the archaeology department provided unique data. The National Institute of Ocean Technology created high-resolution geophysical devices to collect data. An incorporated measuring system was used to take the bathymetric measurements. The shape of the seafloor makes it undesirable to use installed equipment like a multi-beam echo sonar or a laser sonar for measuring.

3.2 Processing the Bathymetric data

Bathymetric data obtained from multibeam echo sounders is one of the fundamental data types used in seafloor system modeling (Fig 2). The collected MBES data, along with previous

and current satellite images, are used in geospatial analysis of shoreline changes in the Poompuhar port area. This study used topographic maps and satellite images to identify shoreline shifts in the coastal region.

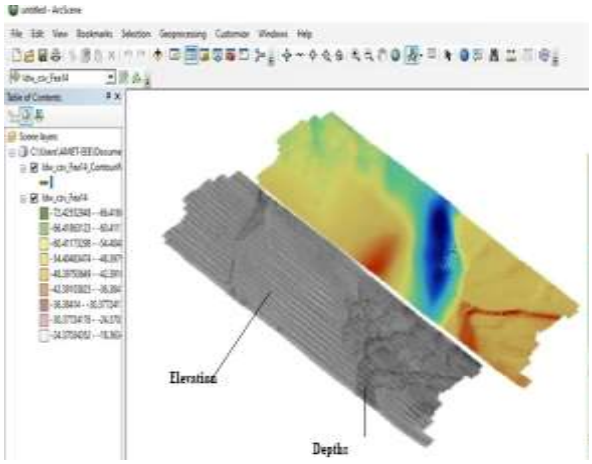

Fig 2: Bathymetry and reflectivity of a multibeam echo sounder

The resultant maps and charts give vital information on the shape, features, and properties of the ocean bottom, which is important for finding the submerged land portions, scattered old structures, and civilization of the ancient period.

3.3 Geostatistical Interpolation

Interpolation is the technique of calculating a value at an unknown place from the values in the grid data set. Interpolation methods predict a value at a given position by taking a weighted average of the known values in the point's surroundings. Many researchers have used spatial interpolation methods to find new data points from the known data procured. (Zhou et al., 2007). Several authors (Heritage et al., 2009; Guarneri and Weih Jr., 2012; Tan and Xiao, 2014) examined the performance of spatial interpolation methods in extensive published research. According to certain research, geostatistical interpolation approaches outperform other interpolation techniques (Li and Heap, 2008). Numerous studies have been done to determine the accuracy of interpolation techniques used in the development of the Digital Elevation Model (DEM).

Geostatistical interpolation can be used to estimate the depth of a submerged coastline based on a limited number of depth measurements. The most appropriate methods have been chosen, based on minimum value, maximum value, range, sum value, mean value, variance, and standard deviation.

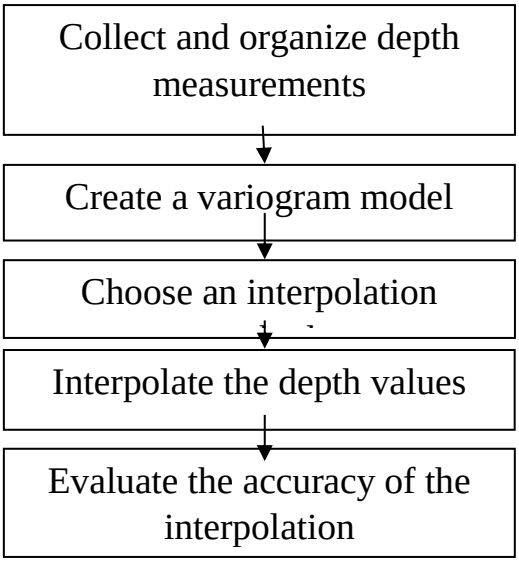

Fig 3: Flow Geostatistical interpolation using ArcGIS

3.4 Kriging Methodology

Kriging is the most often used geostatistical interpolation method. Kriging is a mathematical approach for predicting the value of a phenomenon in unsampled places that takes into account the spatial autocorrelation between sample measurements. Kriging is an advanced geostatistical process that creates an estimated surface from a scattering of z-valued points. Before deciding on the ideal estimation technique for creating the output bathymetry surface, you have to do a detailed analysis of the spatial behavior of the phenomena represented by the x, y, and z-values (Table 1). Kriging is based on the assumption that the spatial correlation structure may be represented by a stationary variogram, which depicts how the spatial correlation between sample values varies with distance.

X	Y	Z
398402.5	1225903	-71.19
398407.5	1225903	-71.43
398412.5	1225903	-71.43
398417.5	1225903	-71.47
398422.5	1225903	-71.29
398427.5	1225903	-71.18
398432.5	1225903	-71.6
398437.5	1225903	-71.97
398442.5	1225903	-71.75

Table 1: Processed data Collected from the Study Area

The basic equation for kriging is:

$Z^*(s) = \Sigma\lambda iZi$

Where $Z^*(s)$ is the estimated value of the variable at location s, $\Sigma\lambda iZi$ is the weighted sum of the sample measurements, and λi is the weight assigned to the ith sample measurement.

The weights λi are determined based on the spatial correlation between the sample measurements and the distance between the unsampled location and the sample locations. The Kriging estimator seeks to minimize the variance of the estimation error, subject to the constraint that the weights sum to one:

$\min \mathrm{Var}[Z(s) - Z^*(s)]$ subject to $\Sigma\lambda i = 1$

The weights λi are typically calculated using the Kriging system of equations, which takes the form:

$K\lambda = b$

Where K is the matrix of spatial covariances between the sample measurements, b is the vector of covariances between the unsampled location and the sample measurements, and λ is the vector of weights.

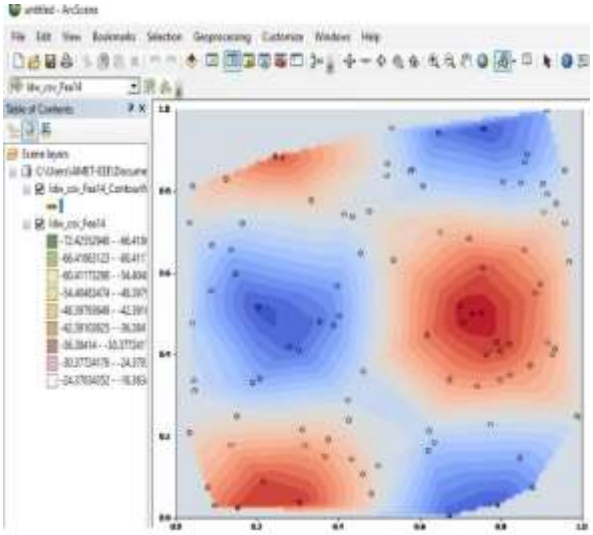

Fig 4: Kriging structural map of input values

The kriging system of equations can be solved to obtain the weights λi, which can then be used to calculate the estimated value $Z^*(s)$ at the unsampled location (Fig 4)

4. Result and Discussion

To construct continuous regions required for the study and comprehension of the Poompuhar submerged land, it was necessary to determine values in places that were not directly sampled. This was accomplished through the use of several interpolation algorithms. The efficiency of interpolation techniques was investigated. During the first step, several locations were utilized to create a bathymetry model and compare interpolation algorithms. The second phase covered the same locations as the first. Interpolation parameters were automatically improved for each interpolation technique using the ArcGIS application within the Geostatistical Analyst tool.

Based on the analysis, kriging interpolation from ArcGIS yielded the best interpolation surface because the Digital Depth Model (DDM) generated was consistent with the slopes and curvatures of the submerged land surface. The 3-D (bathymetric) grid was used to generate bathymetric contour, shaded relief, longitudinal depth profile, and 3-D derivatives for the submerged Poompuhar. Fig 5 is the digital depth model (DDM), while the contour map of the lower depth of the study area is

presented in Fig 6. The DDM (Fig 5) shows the study area relief with different ranges (Itoro Udoh et al. 2022). Each contour line defines the depth of points in the study area concerning the mean water level (Fig 6). The different section ranges are depth, shallow areas are shown. The model also revealed that major parts of the sea bed are not even. It shows several structural remnants, including fallen walls, scattered dressed stone blocks, shipwrecks, etc. inside the submerged area.

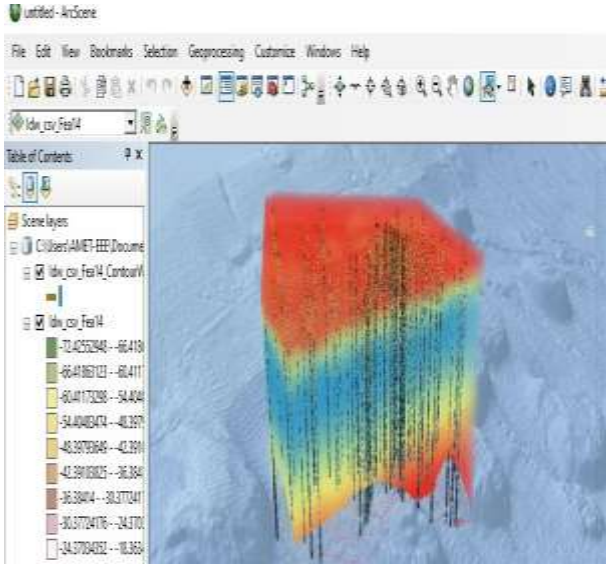

Fig 5: Interpolating submerged levels at Various Depths below the Sea Surface in DDM

The survey was limited to certain areas with a depth of 7–23 meters, and the slope was found to be steeper in the shallow area. The slope changes sharply at a depth of about 17 meters, after which the slope is gentle. Echo images, when correlated with sonography, show that the sea floor is covered with sand. There is no penetration to a depth of 7–8 meters in the coastal region. The presence of acoustically transparent clay elsewhere in the area is indicated by an echo sounder, which shows penetration of 2–3 meters.

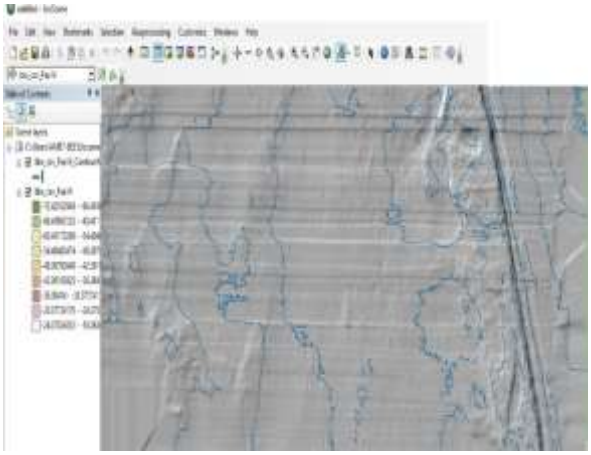

Fig 6: Contour map of the lower depth of the submerged area

5. Conclusion

This study provided an overview of scattered data spatial interpolation algorithms applicable to GIS applications. There has been significant progress over the last decade in terms of accuracy, multivariate frameworks, and robustness. GIS should provide a variety of interpolation algorithms that allow the user to select the most appropriate way to locate submerged particles in Poompuhar.

In this analysis using the geostatistical Interpolation technique, Poompuhar has eroded 129 m in the past 36 years. Our cultural heritage includes submerged sites and sunken shipwrecks. India has a 7516.6 km long coastline (including the islands of Andaman and Nicobar) but only a small portion of it has been explored by Sila Tripati et al. (2003). If any archaeological remains are discovered, they should be reported immediately to the archaeological authorities, since evidence can never be recovered once it's been lost. Even though very few shipwrecks have been discovered in India, the salvage rate is great. This may result in the irreversible destruction of evidence unless it is prevented. Submerged ports and shipwrecks, on the other hand, might be promoted as tourist destinations. Onshore exploration has occurred in a variety of locales, but underwater exploration has occurred in only a handful.

Submerged and buried remains cannot be brought to light unless underwater exploration is carried out in the future, which may reveal some clues about our country's heritage. Further research will provide a clear image of the scarred structures beneath Poompuhar port city using advanced tools such as ROV surveys, underwater profiler surveys, underwater optical and sonar photography, and their processing.

6. Acknowledgment

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The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.