# Journal of Advanced Zoology

***ISSN: 0253-7214***
*Volume **44** Issue **S-2 Year 2023** Page **2615:2621***


# Geostatistical Interpolation Model Selection Using ArcGIS and Analysis of Submerged Land Surface


**Dr.T. Sasilatha[1], Mr.M.Ashok Kumar[2], Dr.T.Baldwin Immanuel[3], Mr.G.Mohendran [4]**

[1]Dean, AMET Deemed to be University, Chennai
[2,4,5] Research Scholar, AMET Deemed to be University, Chennai
[3] Associate Professor, AMET Deemed to be University, Chennai
[1]deaneeem@ametuniv.ac.in, [2]ashokeee@ametuniv.ac.in, [3]bimmanuelt@ametuniv.ac.in,
[4]mohendran.dpp@ametuniv.ac.in



***Article History***

Received: 26 March 2023 Revised: 12 July 2023 Accepted:29 July 2023



***Abstract***

*Geostatistical interpolation is a method of estimating the values of a spatially continuous bathymetry or depth of a submerged coastline, based on a limited number of sample data measured. The bathymetric analysis of the submerged region surrounding the historic port of Poompuhar includes a variety of operations conducted in phases. The survey was conducted using an integrated measuring system by the National Institute of Technology, Chennai which consisted of different 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 are frequently gathered independently for different objectives, were incorporated into the spatial data utilized for elevation surface modeling. Data are captured in different formats with various resolutions and accuracies; thus, a uniform surface model that will allow for easy and accurate analysis is currently lacking. The primary goal of this research was to develop a high-accuracy model of the surface of a coastal area utilizing input data from multiple sources. ArcGIS is a common software platform for analyzing and visualizing geographic data, and it includes various tools for geostatistical interpolation. The study includes the erosion of the coastline and the increase in the water level. The research revealed fresh scientific and methodological data on Poompuhar's bathymetric characteristics and submerged surface area.*



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




## 1. BACKGROUND

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 the 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.

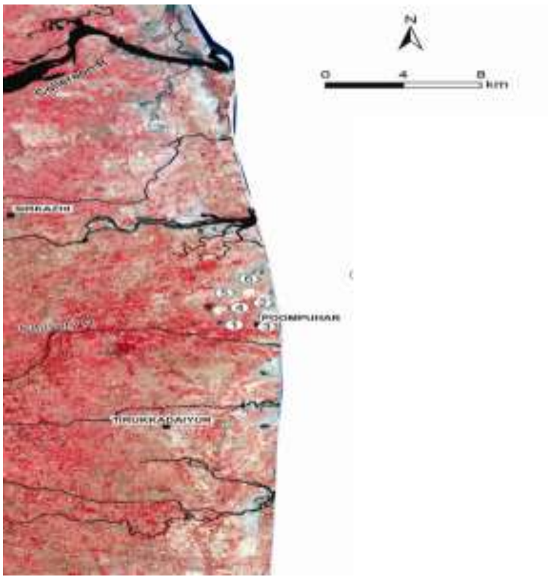


Fig 1: Diagram showing the sites selected for underwater explorations in Poompuhar

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 in the sea (Rao, S.R. 1988).DST has proposed a large investment to rebuild the famous ancient port.

Table 1: Location details of the study area

| **Name** | **Location** | **Length of Coast** |
|---|---|---|
| Poompuhar | 79°51'29.417"E<br>11°5'31.301"N<br>79°51'27.332"E<br>11°9'19.252"N | 10 Km |

**3. RESEARCH MATERIALS AND METHODS**

**A. Equipment used**

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

**B. Processing the Bathymetric data**

Bathymetric data obtained from multibeam echo sounders is one of the fundamental data types used in seafloor system modelling (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.

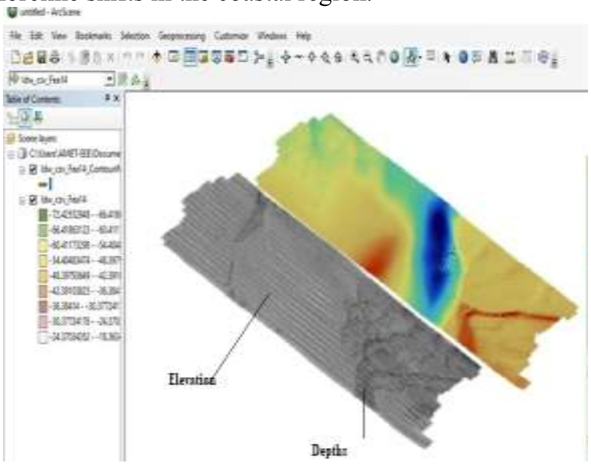


Fig 2: Bathymetry and reflectivity of a multibeam echo sounder

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.

**C. 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, for finding the new data point from the know 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.

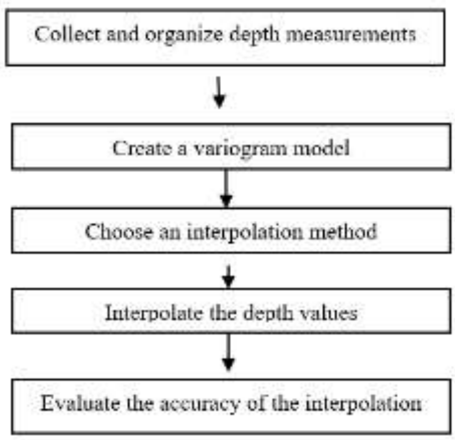


Fig 3: Flow Geostatistical interpolation using ArcGIS

**D. 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, 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 Study Area

The basic equation for kriging is:
$Z^*(s) = \Sigma \lambda_i Z_i$
where $Z^*(s)$ is the estimated value of the variable at location s, $\Sigma \lambda_i Z_i$ is the weighted sum of the sample measurements, and $\lambda_i$ is the weight assigned to the i th sample measurement.
The weights $\lambda_i$ 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:
$\min Var[Z(s) - Z^*(s)]$ subject to $\Sigma \lambda_i = 1$
The weights $\lambda_i$ 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 $\lambda$ is the vector of weights.

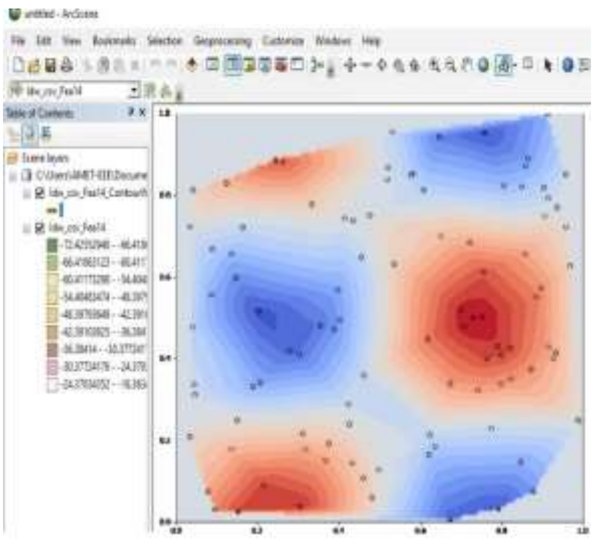

Fig 4: Kriging structural map of input values

The kriging system of equations can be solved to obtain the weights $\lambda_i$, 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 due to the fact that 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 on the study area with respect to 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 with several structural remnants, including fallen walls, scattered dressed stone blocks, shipwrecks, etc. inside the submerged area.

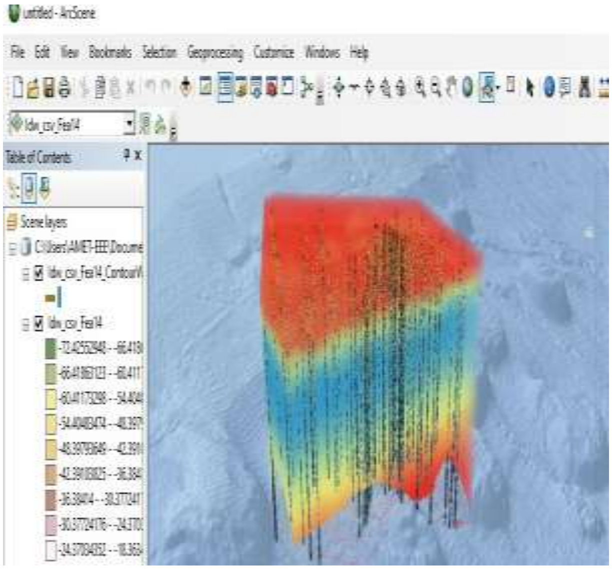


Fig 5: Interpolating submerged levels at Various Depths below the Sea Surface in DDM

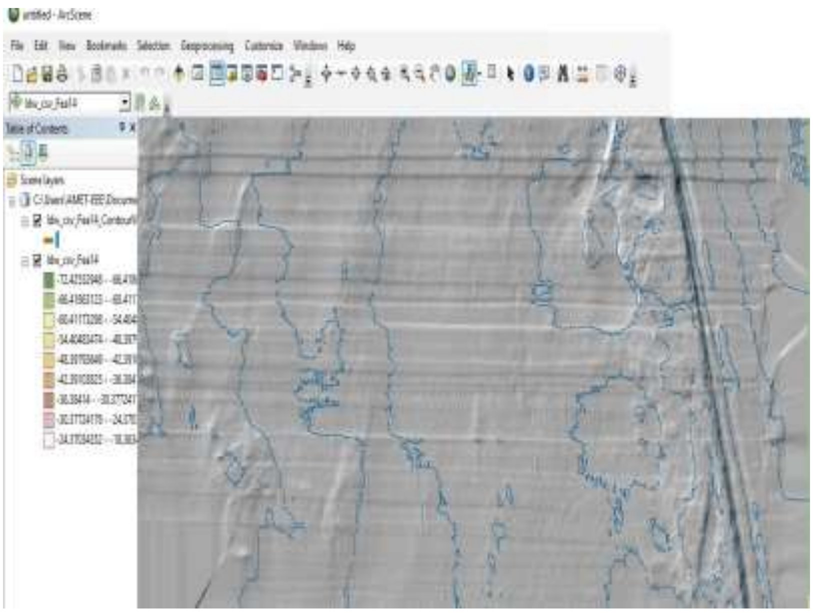


Fig 6: Contour map of the lower depth of the submerged area

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.

**5. CONCLUSION**

This study provided an overview of scattered data spatial interpolation algorithms applicable to GIS applications. It is obvious that 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 for locating 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, 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. Notwithstanding the fact that 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**

The first author Dr. T. Sasilatha Professor and Dean sincerely acknowledge the financial assistance received from the Department of Science and Technology (DST), Government of India, under Underwater Structural Data Acquisition: A case study on Poompuhar heritage underwater site.

**References:**

Rao, S.R. 1991. Underwater Exploration of Submerged Towns near Tranquebar (Tarangambadi) on Tamil Nadu Coast, Recent Advances in Marine Archaeology (S.R. Rao Ed.), pp. 60-64. Goa: Society for Marine Archaeology.

Athiyaman, N. 1999. Two Wharves at Poompuhar: A Technical Study. Paper was presented at Second International Conference on Marine Archaeology, held at Thane, 8-10 January, 1999.

Rao, S.R. 1987. Progress and Prospects of Marine Archaeology in India. National Institute of Oceanography, Goa.

Sundaresh, Gaur, A.S. and Nair, R.R. 1997. Our Threatened Archaeological Heritage: A Case Studyfrom Tamilnadu Coast. Current Science 73 (7) : 593-98

Chai H, Cheng W, Zhou C, Chen X, Ma X, Zhao S (2011) Analysis and comparison of spatial interpolation methods for temperature data in Xinjiang Uygur Autonomous Region, China. Nat Sci 3(12):999–1010

Losser T, Li L, Piltner RA (2014) Spatiotemporal interpolation method using radial basis functions for geospatiotemporal big data. In: IEEE fifth international conference on computing for geospatial research and application (COM. Geo), pp 17–24

Rao, S.R. 1988 (cd.) Marine Archaeology of Indian Ocean Countries. Goa.

Zhou, F., Guo, H. C., Ho, Y.-S., and Wu, C. Z.: Scientometric analysis of geostatistics using multivariate methods, Scientometrics, 73, 265–279, 2007.

Heritage, G. L., Milan, D. J., Large, A. R. G., and Fuller, I. C.:Influence of survey strategy and interpolation model on DEM quality, Geomorphology, 112, 334–344, 2009.

Guarneri, J. C. and Weih Jr., R. C.: Comparing Methods for Interpolation to Improve Raster Digital Elevation Models, Journal of the Arkansas Academy of Science, 66, 77–81, 2012.

Tan, Q. and Xu, X.: Comparative Analysis of Spatial Interpolation Methods: an Experimental Study, Sensors & Transducers, 165,155–163, 2014.

Li, J. and Heap, A. D.: A Review of Spatial Interpolation Methods for Environmental Scientists, Geoscience Australia, Record2008/23, Canberra, 2008

Sila Tripati, G. Parthiban, K. H. Vora, Sundaresh, S. N. Bandodker National Institute of Oceanography, Dona Paula, Goa, India The International Journal of Nautical Archaeology (2003). Lead ingots from a shipwreck off Poompuhar, Tamil Nadu, East Coast of India: evidence for overseas trade and their significance.

Gaur A, Marine Archaeological Investigations along the Tamil Nadu Coast and their Implications for Understanding Cultural Expansion to Southeast Asian Countries. Early Interactions between South and Southeast Asia: Reflections on Cross-cultural Exchange, 2011. 2:221.

S.M.Ramasamy, J.Saravanavel, K. Palinivel, CJ Kumanan and D Rajasekar Detection of the submerged harbour using GEBCO and MBES data, in the offshore region of ancient port city Poompuhar, south India, Published Aug 2020.

S.Sankar, Vijaya Ravichandran, D.Venkatarao & S.Badrinarayanan, Mapping of spatial and temporal variation of shoreline in Poompuhar using comprehensive approach, Indian Journal of Marine Sciences, Vol. 43(7), July 2014, pp.

Sundaresh, Jayakumar.S,Gaur.A.S, Chandramohan.P, and Jena.B.K.S., Submergence of Poompuhar study based on underwater explorations and coastal processes, in Indian National Conference on Harbour & Ocean Engineering. 2004: NIO, Goa,.7-9.

Krishnakumar, K., Lakshumanan, C., Viveganandan, S., Jonathan, M. P., & Muthukumar, S. (2011). Change detection studies in coastal Zone features of Nagapattinam, Tamilnadu by Remote Sensing and Geographical Information System. International Journal of Environmental Science,2(1),201–209

Schmidt, B., Borchert, R., Gundlach, B. (2021): Bathymetry Model Generation and 3D Visualization Based on Multibeam Echo sounder Measurements, report on current research activities, Bochum University of Applied Sciences, Bochum

Borchert, R., Gundlich, B., Schmidt, B. (2020): Echosouunder measurements of the subsurface on smaller bodies of the water, internal R&D report, Department of Geodesy at the Bochum University of Applied Sciences, Bochum

R. Gradka, and A. Kwinta, “A Short Review of Interpolation Methods Used for Terrain Modeling,” Geomatics, Land Management and Landscape, vol. 4, pp. 29–47, 2018.

Itoro Udoh, Akwaowo Ekpa, James Mbat, “Optimizing Single Beam Data for Bathymetric Analysis” SSRG International Journal of Geo-informatics and Geological Science, Volume 9 Issue 3, 10-24, Sep-Dec 2022