Multidisciplinary Informatics Journal
Vol. 2, No. 1, June 2019, Pg. 91 – 97

COMPARATIVE STUDY OF REGULARIZED AND TENSION SPLINE INTERPOLATION METHOD TO MAP SURFACE-WATER SALINITY OF PULAU TUBA, LANGKAWI, KEDAH

Sharir Aizat Kamaruddin[1], Shaidatul Najwa Zainolabdin[2], Khairul Naim Abdul Aziz[3] and Muhammad Akmal Roslani[3]

[1]Faculty of Applied Sciences, Universiti Teknologi MARA,
40450 Shah Alam, Selangor, Malaysia
[2]Faculty of Applied Sciences, Universiti Teknologi MARA Cawangan Perlis,
02600 Arau, Perlis, Malaysia
[3]Marine Research and Excellent Center, Faculty of Applied Sciences,
Universiti Teknologi MARA Cawangan Perlis, 02600 Arau, Perlis, Malaysia.
Author Correspondence, e-mail: shariraizat@perlis.uitm.edu.my

Received: 10 April 2019 / Accepted: 15 May 2019 / Published online: 15 June 2019

ABSTRACT

Spatial models developed using deterministic interpolation techniques have been popularly used to predict the distribution of water quality parameters. A study was carried out to compare the performance of regularized spline and tension spline methods to estimate the surface-water salinity of Pulau Tuba, Kedah. 20 sampling points have been randomly set up to measure the level of surface-water salinity using YSI 650 Multiparameter Display System (MDS) during the period of September to November 2016. The data from half of randomly selected sampling points have been used to calibrate the model while the remaining was used to validate the model. Regularized and tension spline methods were used in this research. Based on the correlation and error analysis, the research found that the tension spline method performed better than the regularized spline method. The spatial models were then transformed into map. Based on the map accuracy assessment, the developed map of salinity produced an accuracy of 90%. The developed map using tension spline method can be used by government and private sector for future and sustainable development of Pulau Tuba, Langkawi.

Keywords: Spline; Interpolation; Salinity; Pulau Tuba; Spatial.

1. INTRODUCTION

Conventional way of assessing water quality status of study areas are time consuming, expensive and requires a lot of efforts [1]. Alternatively, assessment of water quality can be done using spatial interpolation methods [2]. Spatial interpolation methods used points with known values to estimate the unknown values within the study area [3]. However, there is lack of information on the application of spatial interpolation methods regarding water quality data such as sea surface salinity.

There are two classes of spatial interpolation methods namely deterministic and stochastic interpolation methods [4]. Many research have been carried out on the application of stochastic interpolation technique due to its capability to assess the spatial autocorrelation [5]. The stochastic approach also involved extensive mathematical model to estimate point of unknown locations [6]. On the other hand, less study is been carried out on investigating the potential applicability of spline interpolation methods. Spline interpolation method estimates the value to produce smooth surface that pass exactly through the input points [7]. The smooth surface is a result of applying mathematical function that minimized the overall surface curvature [8].

The aim of this research is to map the sea surface salinity of Pulau Tuba, Langkawi using spline interpolation methods. In order to achieve the aim of this research, several specific objectives are outlined, (1) to develop spatial model of sea-surface salinity using tension and regularize spline methods and (2) to compare the accuracy of spatial model developed using tension and regularize spline methods.

2. METHODOLOGY

Sampling activities were carried out during the period of September to November 2016 during high tide at noon to show the maximum reading of water quality. Twenty sampling points were set up and their locations were recorded using Global Positioning Systems (GPS). These sampling points were randomy selected and based on potential antropogenic activities occur in the sampling area. YSI Multiprobe was calibrated carefully prior the sampling activities. The probe was lowered to a depth of 1 meter to sample the salinity level. Then, the raw data were downloaded into excel sheets and post processing of raw data was carried out later. In this research 10 sampling points were randomly chosen to be used in developing the spatial model while the remaining were use to validate the developed model. Two type of mathematical spline methdos namely tension and regularize spline were used in this research. Correlation analysis was carried out to investigate the strength and magnitude of association between the two variables (predicted and measure values of the salinity) [9]. An error analysis using Mean Absoulte Error (MAE) and Root Mean Squared Error (RMSE) has also been used to investigate the total residuals produced by the developed spatial model. The best interpolation method should yield positive and high correlation [10]. Thus, the developed model should generate less mean square error or residuals. The best spatial model was then transformed into a map. Common map elements such as north arrow, title, scale, legend and frame were inserted for better presentation and visualization [11].

3. RESULTS AND DISCUSSION

The spatial model of salinity was successfully developed using tension and regularized spline methods. In the analysis of Pearson correlation coefficient shows that the tension spline produced a coefficient of 0.860 while the regularized spline generates a coefficient of 0.792. Both models exhibited positive and strong correlation between predicted and observed values of salinity level. It is also found that the coefficient of determination recorded by tension spline is more than the coefficients of determination recorded by regularized spline. 62.78% of the variance was explained by the regularized model compared to 73.94% of the variance explained by tension spline model. The linear equation for regularized and tension is $y = 0.8538x + 4.3837$ and $y = 1.057x + 2.3856$ respectively. When predicting unknown values, tension spline tends to produce high R^2 compared to regularized spline [12].

The standard deviation calculated for the regularized and tension spline is 4.230 and 4.558 respectively. The research found that tension spline had less amount of variation or deviation from the mean compare to regularize spline. Furthermore, this research found that regularized spline method overestimated the level of salinity at ST005, ST007, ST008, ST009, and ST010 and underestimated the level of salinity at ST001, ST002, ST003, ST004, and ST006. Conversely, for tension spline type, the model overestimated the level of salinity at ST0.002, ST005, ST007, ST8, ST009, and ST010 while the model underestimated the level of salinity at ST001, ST003, ST004, and ST006. Table 1 show the measured and predicted value generated using regularized and tension spline method.

In the error analysis, the MAE and RMSE value for regularized spline method was determined at 2.274 and 2.705. In contrast, the MAE and RMSE value for the tension spline method was calculated at 1.912 and 2.297 respectively. This research shows that tension spline method produced less error in predicting salinity compared to regularized spline method. Tension spline generates less error in in estimating unknown values compared to regularized spline [12].

Table 1. Comparison between Measured and predicted reading of salinity (ppt)

Station	Measured	Predicted	
		Regularized	Tension
ST001	33.41	33.09	33.31
ST002	32.17	34.16	33.54
ST003	33.45	28.67	30.62
ST004	32.98	30.94	32.04
ST005	18.41	20.04	21.36
ST006	33.49	29.87	30.81
ST007	29.37	33.19	33.27
ST008	30.57	33.85	33.76
ST009	30.48	30.78	30.92
ST010	32.72	33.68	33.44
Mean (μ)	30.705	30.827	31.307
Standard Deviation (Std.)	4.558	4.230	3.708
Variance (Var.)	20.779	17.893	13.752

The RMSE and MAE were also found to be less than half of the standard deviation of the observed value of salinity which indicates better model performance. Based on the table 1, the research found that tension spline methods produced less variance in comparison to regularized spline method and the measured level of salinity.

Next, the spatial model using tension spline type was transformed into a map. Legend, map title, scales and north arrow were inserted into the map of salinity for better communication and visualization [13]. Only three data classifications were chosen for the map of salinity (<15 ppt, 15-30 ppt and >30 ppt). Figure 1 shows the completed map of surface-water salinity of Pulau Tuba, Kedah. Based on the map, the sea-surface salinity is observed to be in the range of more than 30 ppt. The mean and standard deviation for level of sea surface salinity is calculated at 30.71 ppt and 4.558 ppt respectively.

The accuracy of the developed map was calculated at 90% of accuracy for salinity. One station which was ST007 did not achieve correct. The reason for incorrect occurrence for these stations was due to overestimating of predicted salinity by tension spline method. Table 2 The accuracy of the developed map of surface-water salinity (ppt).

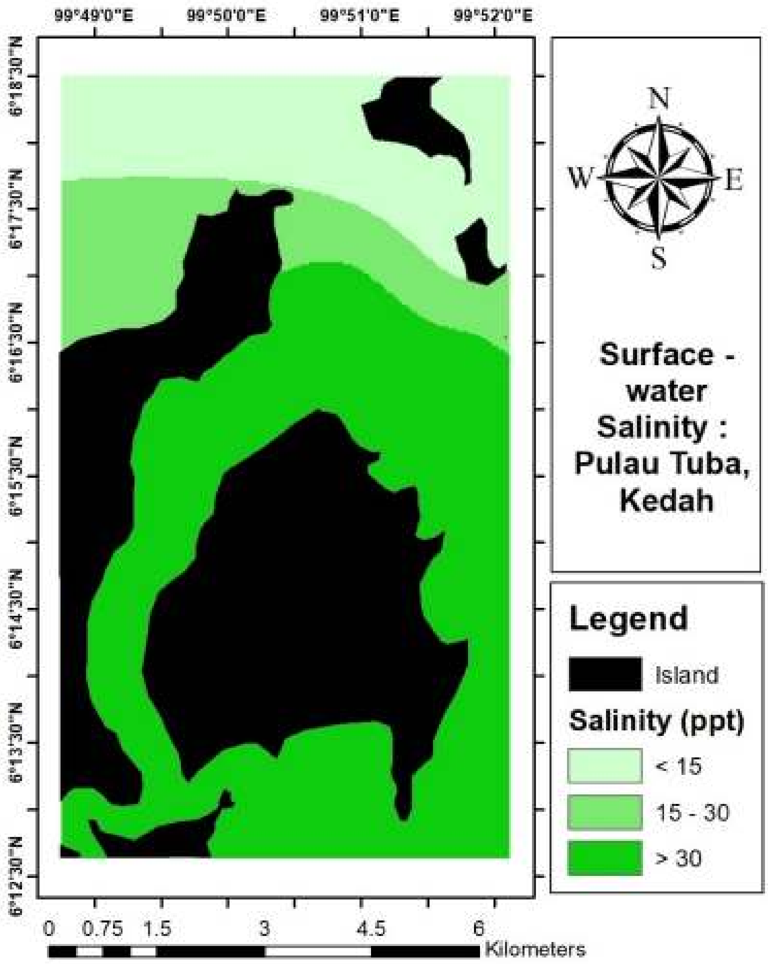

Fig. 1. The map of surface-water salinity of Pulau Tuba, Kedah.

Table 2. The accuracy of the developed map of surface-water salinity (ppt)

Measured	Station	Predicted
>30 ppt	ST001	>30 ppt
>30 ppt	ST002	>30 ppt
>30 ppt	ST003	>30 ppt
>30 ppt	ST004	>30 ppt
15-30	ST005	15-30
>30 ppt	ST006	>30 ppt
15-30	ST007	>30 ppt
>30 ppt	ST008	>30 ppt
>30 ppt	ST009	>30 ppt
>30 ppt	ST010	>30 ppt

4. CONCLUSION

The spatial models of surface water salinity have been successfully developed using spline interpolation technique. The research found that the tension spline method performed better than the regularized spline method to estimate the spatial pattern of sea-surface salinity. The developed model characterized positive correlations and high coefficient of determinations between measured and predicted level of salinity. Furthermore, low MAE and RMSE value indicated that the model has the capability to estimate the salinity. The developed spatial model was successfully transformed into map to test its accuracy. The developed map demonstrated high in overall accuracy. The developed map can be a useful tool for government and private bodies to plan for imminent and sustainable growth of Pulau Tuba, Langkawi, Kedah.

5. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the generous assistance and support from the academic and non-academic staff for their contributions in this research especially to Marine Research Center (MAREC), Universiti Teknologi MARA Cawangan Perlis.

6. REFERENCES

[1] S. Srivastava, S. Vaddadi and S. Sadistap (2018). Smartphone-based System for water quality analysis. *Appl. Water Sci.*, 8:130, 5-13.

[2] R. R. Murphy, F. C. Curriero and W. P. Ball (2010). Comparison of Spatial Interpolation Methods for Water Quality Evaluation in the Chesapeake Bay. *Journal of Environmental Engineering*, 136(2), 160-171.

[3] D. W. Wong, L.Yuan and S. A. Perlin. (2004). Comparison of spatial interpolation methods for the estimation of air quality data. *Journal of Exposure Science & Environmental Epidemiology*, 14(5), 404-415.

[4] P. P. Adhikary and C. J. Dash (2014). Comparison of deterministic and stochastic methods to predict spatial variation of groundwater depth. *Applied Water Science*, *7*(1), 339-348.

[5] M. I. Bakr, C. B. Te Stroet and A. Meijerink (2003). Stochastic groundwater quality management: Role of spatial variability and conditioning. *Water Resources Research*, 39(4). doi: 10.1029/2002WR001745.

[6] E. A. Varouchakis and D. T. Hristopulos (2012). Comparison of stochastic and deterministic methods for mapping groundwater level spatial variability in sparsely monitored basins. *Environmental Monitoring and Assessment*, 185(1), 1-19.

[7] S. M. Robeson (1997). Spherical Methods for Spatial Interpolation: Review and Evaluation. *Cartography and Geographic Information Systems*, 24(1), 3-20.

[8] N. S. Lam (1983). Spatial Interpolation Methods: A Review. *The American Cartographer*, 10(2), 129-150.

[9] B. G. Sari, A. D. Lúcio, C. S. Santana, D. K. Krysczun, A. L. Tischler and L. Drebes (2017). Sample size for estimation of the Pearson correlation coefficient in cherry tomato tests. *Ciência Rural*, 47(10). doi:10.1590/0103-8478cr20170116

[10] A. A. Hassan (2018). Accuracy Assessment of Open Source Digital Elevation Models. *Journal of University of Babylon*, 26(3), 23-33.

[11] C. H. Wood and C. P. Keller (1996). "*Cartographic design: theoretical and practical perspectives*. New Jersey, NJ: John Wiley & Sons.

[12] J. O. Lilly (2016). *A GIS Approach to Modeling Groundwater Levels in the Mississippi River Valley Alluvial Aquifer*. Retrieved from https://pdfs.semanticscholar.org/80d0/2bf3b64518acfe973066926c598d8c442e66.pdf

[13] M. Agrawala (2010). *Cartography and information presentation*. Paper presented in proceedings of the 18th SIGSPATIAL International Conference on Advances in Geographic Information Systems. doi:10.1145/1869790.1869792.