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Lake Water Quality Assessment Through GIS based Interpolation Method: A Case Study of Beris Dam, Kedah, Malaysia

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Abstract

Preliminary research on physicochemical and water quality in the Beris dam shows that the water catchment area has the best standards and quality during the observation of the wet season and dry season mainly in the northern states of peninsular Malaysia. The analysis of water quality assessment using the DOE-WQI and Carlson Trophic State Index (CTSI) resulted that during the dry season (February), the average DOE-WQI reading is 88 or Class II; while during the wet season, the average DOE-WQI reading recorded 87.1 (October). Although the CTSI score was 34.2 - 27.0 during wet season and dry season, both seasons were classified as oligotrophic conditions. Some physicochemical parameters also show a high correlation between them and indicates minor water quality issues. The use of more efficient interpolation techniques in water quality studies also reinforces the evaluation of water quality. As a reference point for future water research, GIS interpolation application methods can be more effectively and efficiently used with Inverse Distance Weighted (IDW), Ordinary Kriging and Spline techniques.

Keywords: Physicochemical, Water quality index, Carlson trophic state index (CTSI), Interpolation, IDW, Kriging, Spline, Correlation

Introduction

Literature review

Over the past decades, lakes around the world have been the focus of environmental research because of their wide variety in terms of origin, geographical distribution, hydrological regimes and substrate variables. Water quality includes a range of abiotic and biotic variables associated with the environment [1]. Abiotic variables are often the controlling forces of the environment, influencing organism well-being, distribution, and ecosystem functioning. [2]. Water quality is affected by changes in urbanization, industrialization and agriculture. The physicochemical characteristics of water and biological variety are essential to the maintenance of a healthy environment. [3]. Physical properties of lake water such as temperature, light intensity, transparency, pressure, conductivity, and water current, as well as chemical properties such as levels of carbon dioxide, dissolved oxygen, pH, hardness, alkalinity, phosphate, nitrate levels and highly govern aquatic life determines the trophic status of the water body.

Land-use activities surrounding the lake boundaries resulted in the lake's water quality deterioration. Many organic and inorganic pollutants cause eutrophication in lakes and streams, harming the biological system and contributing to the deteriorate of water quality. Such scenario offers significant health risk impact on humans [4]. Analysis of water quality parameters is essential for frequent monitoring and understanding of the environmental condition of water resources [5]. In Malaysia, the National Water Quality Standard (NWQS) is proposed as the water quality baseline for preserving and managing surface water, particularly rivers and lakes. The river and lakes' Water Quality Index (WQI) was derived by integrating 6 water quality parameters, namely dissolved oxygen (DO), biological oxygen demand (BOD), total suspended solids (TSS), pH, chemical oxygen demand (COD) and ammoniacal nitrogen (AN)as suggested by [6].

Carlson's Trophic Status Index (CTSI) is a commonly used method for evaluating the trophic condition or overall health of a lake. This procedure utilizes Secchi's disc transparency, chlorophyll-a, and phosphorus measurements. The whole weight of the biomass of a body of water at a particular place and time is called the tragic state [7,8]. Previous scholars who studied on some analytical analysis such as

Principal Component Analysis (PCM) and a regression model is widely used to determine physicochemical and heavy metal in water quality assessment [9,10].

Meanwhile, GIS does provide possible solutions to environmental issues, such as water quality assessment and indexing. Interpolation methods in GIS enables to predict (z-values) or attributes at sampling stations at the point of location (x and y values) by using a Geostatistical Analysis Approach [11]. Within GIS software, interpolation methods such as Inverse Distance Weighting (IDW), Kriging and Spline are frequently used to estimate and forecast values when a variable is distributed over space or time. Interpolation techniques offer ease on sample data implementation by regions and fits on the spatial trends. IDW is widely used for surface interpolation analysis, especially for water quality analysis [12,13]. However, the nature of IDW, Kriging and Spline methods offer various calculation methods to define "average" values by depending on the nearest neighbor values. It is necessary for scholars to verify the influences of different interpolation techniques to determine accurate trophic condition of a lake.

This paper discusses the significance of studying lakes for environmental research due to their diverse characteristics and the influence of abiotic variables on the ecosystem. It highlights the impact of human activities, such as urbanization and industrialization, on the water quality of Beris Dam, Kedah. The National Water Quality Standard (NWQS) in Malaysia is proposed as a baseline for managing surface water quality. The Carlson Trophic Status Index (CTSI) and water quality parameters like dissolved oxygen and pH are used to evaluate lake health. Analytical methods such as correlation are employed for water quality assessment. GIS based interpolation methods of IDW, Kriging and Spline were utilized to predict variation of spatial trends in water quality.

Materials and methods

Study area

Beris Dam (Figure 1) is a water reservoir located in the Sik District of Kedah, Malaysia. The dam is a rockfill dam with a concrete face located in a small valley along the Beris River, 1.6 km upstream from the river's confluence with the Muda River. Beris dam is fed by 2 major rivers, Sungai Beris and Sungai Batang, which provide an average of 114 million m^3 of water to the dam site annually. This lake is located 24 km from Pekan Sik, 90 km distance from Alor Setar. Sungai Beris originated from Batu Seketol and Kampung Paya, whereas Sungai Batang originates from Sungai Batang.

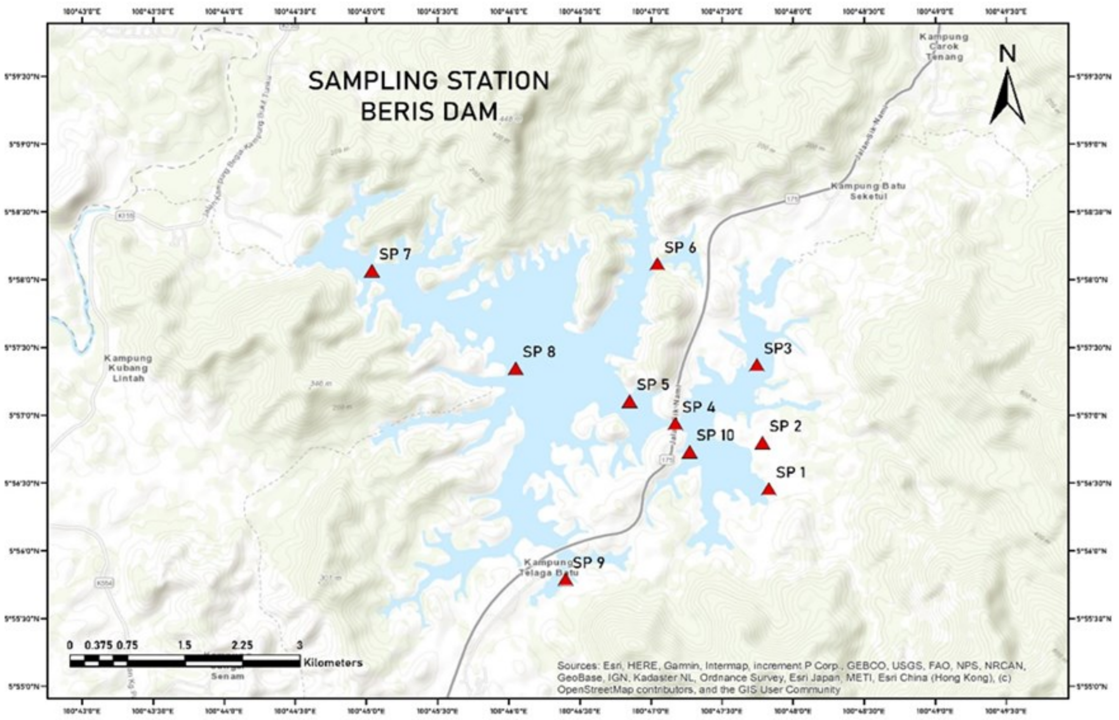

Figure 1 Sampling station at Beris Dam.

Data acquisition and method

A 2-season water sample was collected in October 2020 and February 2021 to reflect a 2-season wet and dry monsoon season in Peninsular Malaysia. The sample for all 10 sampling locations was collected during morning time. It is due to the possible water quality might also deteriorated by temperature to influence results of water parameter analysis such as dissolved oxygen and conductivity [14,15]. The sampling approach employed in this investigation was manually pumping water via a hose with a surface water sample obtained at the range of 20 - 50 cm below the water surface. Water is collected in a polyethylene bottle and maintained at 2 - 4 °C using a cooler and gel packs to maintain water quality. The water is then delivered to the lab within 24 h and is examined by the APHA.

In-situ pH, salinity, temperature, conductivity, turbidity and dissolved oxygen data were measured with a multi-probe AZ Instrument 86031 Water Quality and turbidity meter Sinotester LH-TB01 Turbidity Meter by the APHA Standard shown in **Figure 2**. Water samples were analyzed following APHA 2550 for Temperature, APHA 4500-O OXYGEN (Dissolved oxygen), APHA 4500-H+ for pH Value, APHA 2130 B for Turbidity, APHA 2540 for Total Suspend Solids and Total Dissolve Solids [16,17] .

All lab-need samples were analyzed by MUPA USM and the Department of Chemistry Malaysia. Total phosphorus (TP) was analyzed by methods complying with APHA-4500-P. Chlorophyll-a (CA) were extracted with acetone absorption using UV-Spectrophotometer. For water transparency, for each sample site, a Secchi disc is utilized to recognize the visibility of lake water.

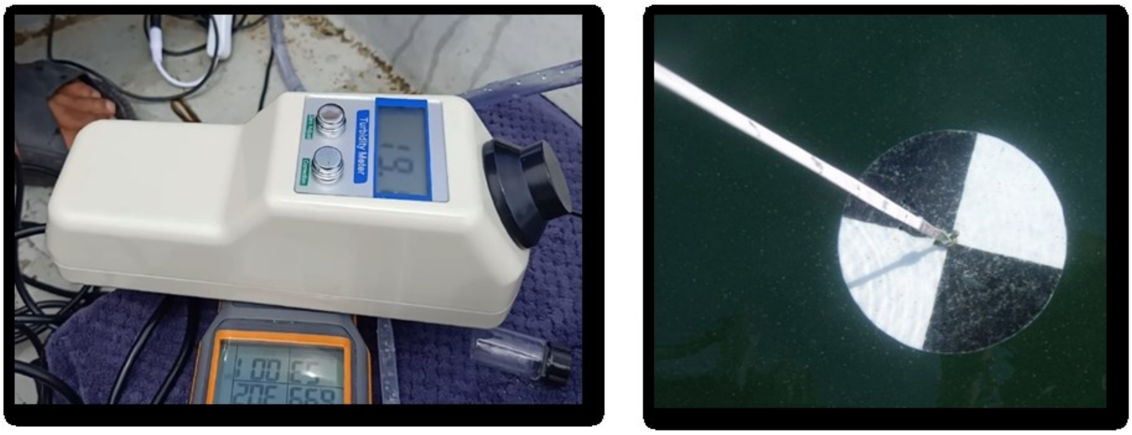

Figure 2 Equipment used in beris dam in-situ observation.

DOE water quality index

The Water Quality Indicator (WQI) is a numerical index based on essential factors such as pH, turbidity, temperature, conductivity, dissolved oxygen, total dissolved solids, total suspended solids and other chemical parameters in water [18-21]. This index is also utilized as a reference guideline in the Ministry of Health Malaysia's National Water Quality Standard (NWQS) and National Drinking Water Standard (NDWQS) [22]. These characteristics were then used to generate the water quality index, which was based on the Eq. (1):

$$\text{DOE-WQI} = (0.22\times SIDO) + (0.19\times SIBOD) + (0.16\times SICOD) + (0.15\times SINH3N) + (0.16\times SITSS) + (0.12\times SIpH) \quad (1)$$

where: WQI: Water Quality Index
SIDO: Sub-Indices Dissolve Oxygen
SIBOD: Sub-Indices Biological Oxygen Demand
SICOD: Sub-Indices Chemical Oxygen Demand
SINH3: Sub-Indices Ammonia Nitrate
SITSS: Sub-Indices Total Suspend Solids
SIpH: Sub-Indices Acidity and Alkalinity

Carlson trophic state index (CTSI)

The Carlson Trophic State Index (CTSI) refers to one numerical index to categorize lake eutrophication. The trophic index was defined as oligotrophic if the values were less than 40 and mesotrophic if the values ranged between 40 to 50. Values of 50 to 70 are considered eutrophic, whereas

70 or more is deemed to be hypereutrophic [24]. This calculation incorporates 3 in-situ and lab-measured data, including chlorophyll-a (CA), total phosphorus (TP) and Secchi disc (SD).

In a water sample, total phosphorus is present as orthophosphate, condensed phosphate, organic phosphate in solid and liquid forms. The SD or Secchi disc employs a black-white circular disc with a 20 cm diameter to evaluate water transparency. When the disc is no longer visible, it is submerged to measure visibility. Next, Chlorophyll-a (CA) is an algae-containing chlorophyll that absorbs sunlight for energy and photosynthesis. The values were derived from equation TSI (SD), TSI (TP), and TSI (CA) [8,25]. Eqs. (2) - (5) are listed below:

TSI for Chlorophyll-a (CA) TSI = 9.81 *Ln* Chlorophyll-a (ug/L) + 30.6 (2)

TSI for Secchi depth (SD) TSI = 60-14.41 *Ln* Secchi depth (Meters) (3)

TSI for Total phosphorus (TP) TSI = 14.42 *Ln* Total phosphorous (ug/L) + 4.15 (4)
Carlson's TSI (CTSI) = [TSI (TP) +TSI (CA) +TSI (SD)]/3 (5)

*BOLD replaces observation data

Spatial interpolation techniques

A wide variety of methods, models and interpolation approaches rely on essential characteristics of the quality of the results. Many of these procedures and strategies have previously been developed and widely utilized to produce satisfactory results [26]. Spatial interpolation methodologies are influenced separately by factors such as sampling or sample density. Interpolation based on sampling of every 10 m is more accurate than a sampling distance of 50 or 100 m which delivers 50 and 70 % fewer sampling units, respectively, and sampling density affects each interpolation methodology differently [27-29]. Given surface heights or (z point) at any given instant (x and y point) are governed by just one variable Eq. (6), and the position is related to the known (z point) value, spatial interpolation considers univariate [30].

$$Z_{x,y} = f(x,y) \tag{6}$$

Point-based and line-based interpolation areas are both used for interpolation of the surface. The difference between them is the character of the results received. Point-based interpolation obtains cover with very different patterns of local parts of the surface. For example, kriging method and spline, IDW more specifically as line-based interpolation techniques [31].

Inverse distance weighting (IDW)

IDW method is a popular method of interpolation in geographical analysis. This approach uses a set of linear weighted sample points for the calculation of cell values. More weight will be put on the points closest to the target location. The IDW technique can be improved by removing the pre-set size of the "search radius" and focusing on several linked measurement locations [32]. The inverse-distance-weighted approach uses a weighted linear combination of a set of sampled points to calculate values for non-sampled sites [33,34]. The weight is a function of the inverse distance multiplied by any mathematical exponent. The space rises, the weight falls, and the more outstanding exponent's drop becomes more intense [35]. In order to carry out spatial interpolation of water quality, ArcGIS 10.8 software was used to complete all interpolation computations.

Spline

Spline estimates values by minimizing total surface curvature, producing a smooth surface that reliably passes across the input locations. The spline stretching effect helps estimate values below and above the lowest and maximum recorded in the data set. As a result, the Spline interpolation approach is ideal for predicting high and low values not included in the sample data [36]. The Spline surface interpolation formula is employed in the procedure as in Eq. (7) below:

S (*x, y*) = T (*x,y*) l*jR rj* N *j=I* (7)

Description: S: Interpolation point
j: 1, 2, and (n)
N: number of samples

l*j*: Coefficient found in the linear equation system
rj: the distance between (*x,y*) and another *J*T point

T(*x,y*) and R (r) are defined differently depending on the choice. All regions of the output raster are separated into equal size chunks for calculation reasons. The number of features in the x and y axes equals the number of elements in the square form. The component number is derived by dividing the number of issues by the number of points entered. These sections may substantially differ in the number of dots, resulting in approximate values for data with a less uniform distribution.

Kriging

Kriging is a geostatistical interpolation strategy that utilizes the distance and degree of variation between known data points when estimating values in unknown places. A kriging estimate is a weighted linear grouping of known sample values centered on a calculated endpoint. Masses are evaluated for each interpolated point based on the spatial structure of the interpolated position of all sampled points [37,38]. The implications are calculated using the variogram produced on the data's spatial system and applied to the tested spots using Eq. (8) below:

$$\hat{z}(\mathbf{x}_0) = \sum_{i=1}^{N} \lambda_i z(\mathbf{x}_i) \tag{8}$$

where the value of the projected point (z-hat, at location x-naught) equals the total of the importance of the independently sampled point (x, at the position I multiplied by that point's unique weight (lambda, for location, its tries to decrease the error variance and adjust the mean of the prediction errors to zero so that there are no over-or under-estimations [39]. Kriging has various subtypes, such as conventional kriging, universal kriging, block kriging, cokriging, Poisson kriging, spherical kriging, etc.

The Kriging technique may create a semi-variogram of the data to weigh close sample points while interpolating. It also allows users to comprehend and model their data's directional (e.g., north-south, east-west) patterns. Kriging differentiates itself by measuring the error at each interpolated point, providing a measure of confidence in the presented surface [38,40].

Results and discussion

Water quality index (WQI) of beris dam

All sub-index were calculated and determined into WQI per sampling station and season. Wet season sampling in October 2020 represents Northeast Monsoon and dry season sampling in February 2021 represents during Inter-monsoon changes that happens in the north region of West Malaysia [23]. The assessment using the DOE-WQI index is conducted because it is the most suitable index considering the weather and environmental factors in Malaysia, which experiences a hot and humid climate throughout the year. The DOE-WQI assessment is widely used by water suppliers across the country to test the water quality in real-time, ensuring that the water quality remains satisfactory before entering and after treatment in water treatment plants. The WQI index is also continually adjusted by researchers by incorporating new or additional parameters to align with the specific water studies they are conducting.

Tables 1 and **2** shows a DOE-WQI score calculated from the equation for every sampling station in Beris dam during wet and dry season respectively.

Table 1 Physicochemical parameter observed during wet season and WQI calculation.

Physicochemical parameter		SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10
pH	pH	8.6	7.75	7.66	7.68	7.74	7.23	7.72	7.65	7.5	7.51
	SIpH	80.18199	94.22188	95.19662	94.988	94.335	98.50095	94.5577	95.2989	96.6875	96.6034
TSS (mg/L)	TSS	13.4	11.4	10.5	10.9	11.3	12.4	10.2	10.4	9.3	10.3
	SITSS	89.72626	90.83849	91.34435	91.11911	90.8945	90.28033	91.5137	91.4008	92.0241	91.4572
DO	DO (mg/L)	8.4	8.4	7.7	7.4	7.9	5.9	7.2	7.4	7.3	6.3
	SIDO	100	100	100	100	100	85.65788	100	100	100	94.4957

Physicochemical parameter		SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10
DO	DO (%)	108.948	108.948	99.869	95.978	102.463	76.5623	98.64	101.38	100.1	86.31001
NH_3-N	NH_3-N	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	SINH_3-N	98.4	98.4	98.4	98.4	98.4	98.4	98.4	98.4	98.4	98.4
BOD	BOD (mg/L)	12.4	8.5	8.8	9.4	14.3	5.8	7.5	6.6	7.8	7.2
	SIBOD	53.36532	66.81921	65.68182	63.46114	47.7571	79.682	70.7453	74.4633	69.5453	70.9647
COD	COD (mg/L)	24.2	18.3	16.8	17.9	19.7	14.6	16.2	14.6	10.6	15.6
	SICOD	69.47395	74.761	76.756	75.293	72.899	79.682	77.554	79.682	85.002	78.352
Temp	°C	29.8	29.4	29.8	30.1	30.3	29.6	31.1	32	32.3	31.7
WQI		82.0	87.3	87.6	86.8	83.4	87.4	88.6	89.7	89.9	88.0
CLASS		Class II	Class II	Class II	Class II	Class II	Class II	Class II	Class II	Class II	Class II

Table 2 Physicochemical parameter observed during dry season and WQI calculation.

Physicochemical parameter		SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SP9	SP10
pH	pH	8.9	7.86	7.33	7.48	7.24	7.65	7.72	7.65	7.5	7.51
	SIpH	69.31961	92.89742	97.93215	96.85208	98.4495	95.29887	94.5577	95.2989	96.6875	96.6034
TSS (mg/L)	TSS	16.5	12.4	11.6	18.5	11.3	13.9	12.4	13.2	10.4	10.4
	SITSS	88.03442	90.28033	90.72652	86.96329	90.8945	89.45077	90.2803	89.8368	91.4008	91.4008
DO	DO (mg/L)	10.4	7.9	7.9	8.9	8.6	8.1	8.4	9.2	8.2	8.3
	SIDO	100	100	100	100	100	100	100	100	100	100
DO	DO (%)	134.888	108.23	108.23	121.93	117.82	105.057	115.08	126.04	112.34	113.71
NH_3-N	NH_3-N	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	SINH_3-N	98.4	98.4	98.4	98.4	98.4	98.4	98.4	98.4	98.4	98.4
BOD	BOD (mg/L)	10.3	6.7	7.8	8.4	9.9	6.6	7.9	7.2	7.8	7.8
	SIBOD	60.26089	74.04129	69.54527	67.20242	61.6642	74.46333	69.1495	71.9647	69.5453	69.5453
COD	COD (mg/L)	22.1	16.2	15.5	16.5	21.2	14.6	16.2	14.6	10.6	10.6
	SICOD	71.91914	77.554	78.485	77.155	72.9911	79.682	77.554	79.682	85.002	85.002
Temp	°C	30.2	31.4	31.3	31.5	31.4	30.9	31.1	32.4	31.9	31.3
WQI		82.1	88.8	88.8	87.4	86.5	89.4	88.1	89.0	89.8	89.8
CLASS		Class II	Class II	Class II	Class II	Class II	Class II	Class II	Class II	Class II	Class II

In-situ data obtained during both the wet and dry seasons, consisting of pH, TSS, DO, NH3-N, BOD, COD, and water temperature, are calculated for their sub-indices using the DOE-WQI formula. During the wet season, pH readings show relatively minor differences compared to the dry season, except at SP1 where higher alkalinity readings are observed compared to other stations.

This factor originates from the nearby inflow of a river tributary from the dam, which has the potential to carry pollutants with a higher alkalinity content than the surrounding area. TSS, BOD, and COD readings also indicate that Station SP1 has a higher range in both seasons, which correlates with the mentioned river tributary's flow. However, the calculation of DOE-WQI indicates that the water quality at all sampling stations falls under Class 2, where the water can be used for recreational purposes, fish farming, agricultural irrigation, and domestic use with minimal treatment for human consumption.

Carlson trophic state index (CTSI) of beris dam

In the case of DOE-WQI index for Beris Dam, CTSI values for dry season and wet season are not significantly different. All sampling stations between 2 seasons scored index values below 40, which shows a trophic class Oligotrophic. As a water dam supply, the Beris Dam is not contaminated by heavy metals, and all physicochemical are still in the permissible range guided by NLWQS [18]. **Table 2** shows CTSI score per sampling station measured during the wet season and dry season in Beris Dam, while **Figure 3** represents the comparison graph of CTSI index for wet and dry season.

Table 3 CTSI index for Wet and Dry Season.

Sampling stations	CTSI index (Wet)	CTSI index (Dry)
SP 1	31.3	34.2
SP 2	26.4	29.4
SP 3	29.3	28.1
SP 4	27.5	29.2
SP 5	28.0	29.4
SP 6	31.6	34.0
SP 7	26.5	27.8
SP 8	28.9	27.2
SP 9	27.3	27.0
SP 10	27.2	29.9

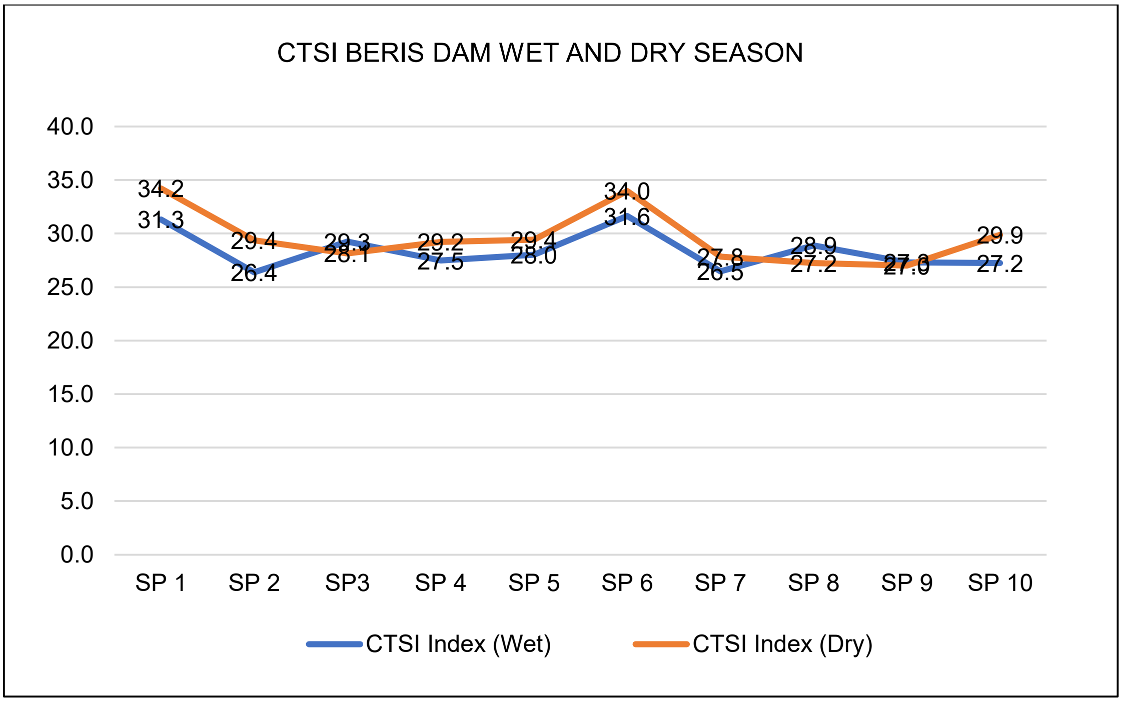

Figure 3 CTSI index for beris dam during wet and dry season.

Correlation matrix physicochemical wet and dry

Pearson's correlation matrix was developed between analyzed physicochemical parameters and presented in wet and dry data as depicted in **Figures 4** and **5**. A highly positive correlation in the wet season ($p < 0.99$) was noticed between Salinity and Total Dissolve Solids (TDS) and Chloride. Total suspended solids (TSS), fluoride and turbidity are also strongly correlated ($p > 0.80$). TSS increases the turbidity of a body of water, which reduces the penetration of light and therefore inhibits the photosynthetic activities of aquatic plants, which may result in oxygen deprivation [41].

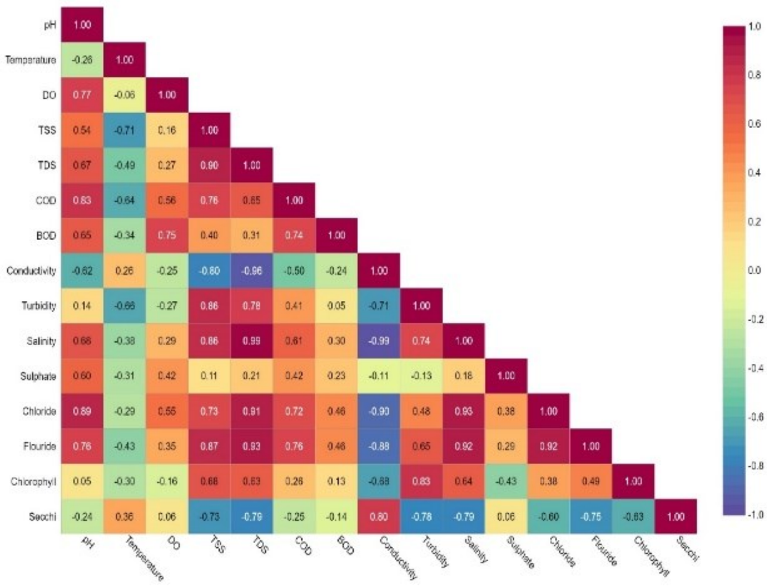

Figure 4 Correlation matrix physicochemical for wet season.

In the Dry season, Chlorophyll-a shows a high correlation between Total Dissolve Solids (TDS), Turbidity, and Chloride ($p > 0.80$). The similarity between dry and wet seasons, turbidity also has a high correlation between Total Dissolve Solids (TDS) and Chloride ($p > 0.80$). For lake water, all results are not significantly different between seasons because a lake is not the same as a river in which the river also constantly changes and flows out to the other source [42].

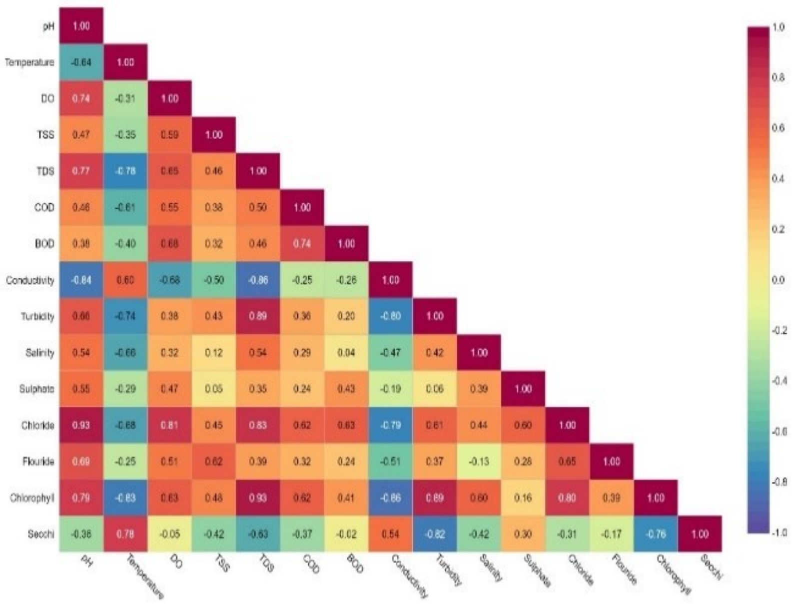

Figure 5 Correlation matrix physicochemical for dry season.

IDW vs Kriging vs Spline

Figures 6 - 17 displays index data from DOE-WQI, CTSI and 2 physicochemical datasets from dry seasons. The dry season data sets sample were selected, tested and elaborated to visualize differentiation of interpolation map representation using IDW, Kriging and Spline approach. The interpolation map was generated and processed using ArcGIS 10.8 software. The minimum, maximum, mean, and standard deviation values were derived using the spatial analyst tool in ArcGIS 10.8 as stated in **Table 4**. This analysis compares the 3 interpolation methods using the same index data and selected physicochemical data to assess their suitability for water quality assessment.

Table 4 Statistical comparison of interpolation analysis using different IDW, Kriging and Spline methods.

Method/Figure	Min	Max	Mean	S.D
DOE-WQI Dry Point Data	82.12	89.8	87.98	2.31
Figure 6: IDW WQI Dry	82.1	89.80	88.24	0.95
Figure 7: Ordinary Kriging WQI Dry	87.97	87.97	87.97	0
Figure 8: Spline WQI Dry	74.46	105.27	88.68	*2.49
CTSI Dry Point Data	27.0	34.2	29.6	2.55
Figure 9: IDW CTSI Dry	27	34.2	29.18	1.4
Figure 10: Ordinary Kriging CTSI Dry	27.02	34.15	29.23	1.41
Figure 11: Spline CTSI Dry	18	40.46	28.84	*3.63
Physicochemical (pH) Dry Point Data	7.24	8.9	7.684	0.464
Figure 12: IDW pH Dry	7.24	8.9	7.68	0.2
Figure 13: Ordinary Kriging pH Dry	7.25	8.87	7.68	0.14
Figure 14: Spline pH Dry	6.96	9.97	7.68	*0.37
Physicochemical (Water Temp) Dry Point Data	30.2	32.4	31.34	0.579
Figure 15: IDW Water Temp Dry	30.20	32.40	31.47	0.35
Figure 16: Kriging Water Temp Dry	30.28	32.36	31.50	0.36
Figure 17: Spline Water Temp Dry	28.48	33.58	31.62	*0.87

Using a 3-interpolation approach, we can demonstrate that Spline interpolation is suitable for predicting high and low-value data not included in the sample data. For DOE-WQI index data and CTSI, with slight differences between the minimum and maximum value, IDW is the most accurate method to interpolate all point data, resulting in a small standard deviation value. For example, the IDW interpolation techniques for DOE-WQI Dry index is s = 0.95 compared to the Spline method's s = 2.49.

A similar pattern is observed for CTSI Dry Index, where the IDW method shows standard deviation values of s = 1.4, whereas the Spline method shows s = 3.63. However, for Ordinary Kriging (OK), the standard deviation values are s = 0.00 for DOE-WQI Dry index and s = 1.41 for CTSI wet index. When assessing interpolation techniques based on their standard deviation score indicates the best technique for presenting data.

For the selected physicochemical data, such as pH and water temperature, the Spline method showed the highest standard deviation score among all methods. The standard deviations were s = 0.37 when compared with IDW and OK for the Dry pH season. This clearly indicates that the Spline method is weak when dealing with small range data and fewer sampling points. It is suitable for determining both physicochemical data and any water quality index data.

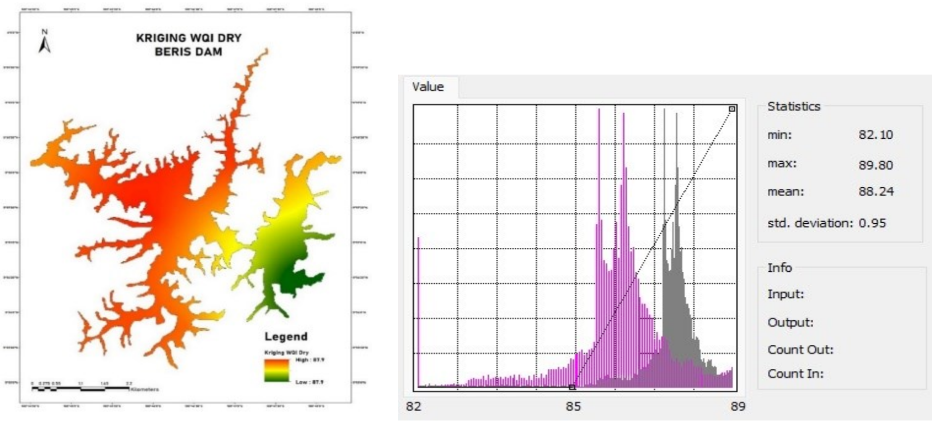

Figure 6 IDW WQI dry.

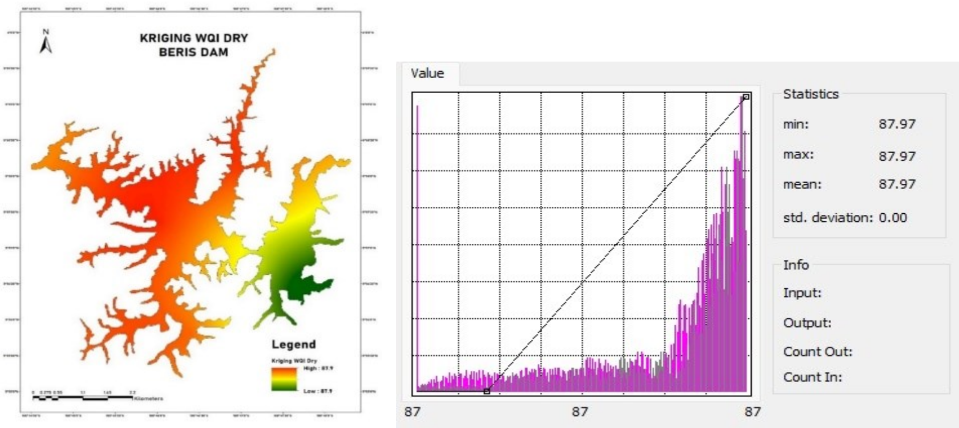

Figure 7 Ordinary Kriging WQI dry.

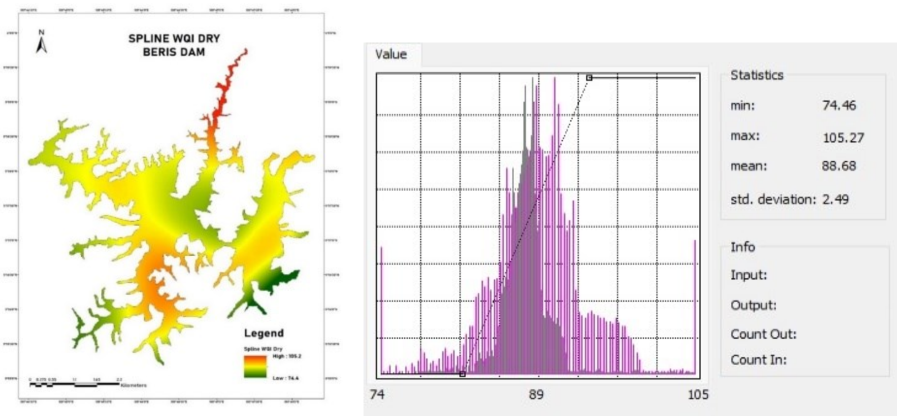

Figure 8 Spline WQI dry.

Using the DOE-WQI index data, testing was conducted only on the dry season data. Interpolation testing was performed using the IDW method, Kriging method, and Spline method, which are the most popular approaches in spatial interpolation. Based on the data, the DOE-WQI values range from 0 to 100. The Spline method in **Figure 8** shows that the predicted data fall outside the established range of the DOE-WQI, reaching the highest value of 105.2. However, for the IDW and Kriging methods, the respective index scores still fall within the index range even after the data has undergone interpolation processes.

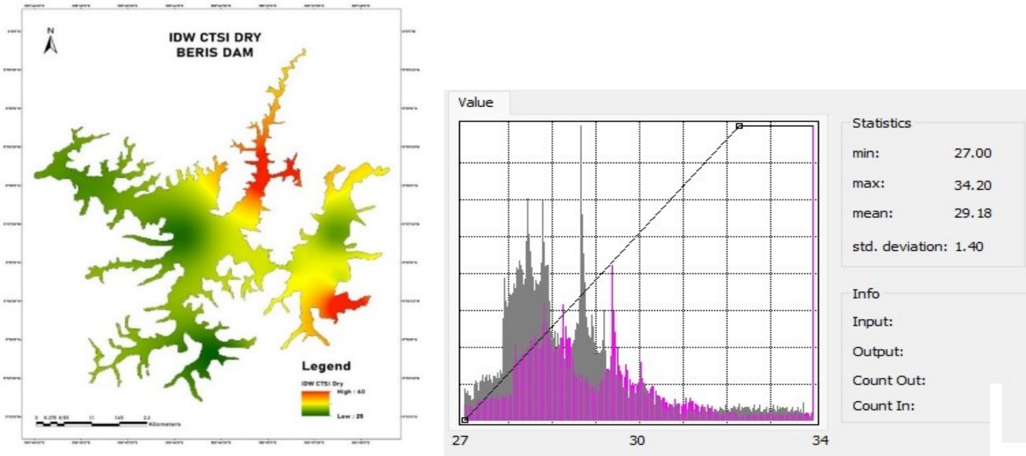

Figure 9 IDW CTSI dry.

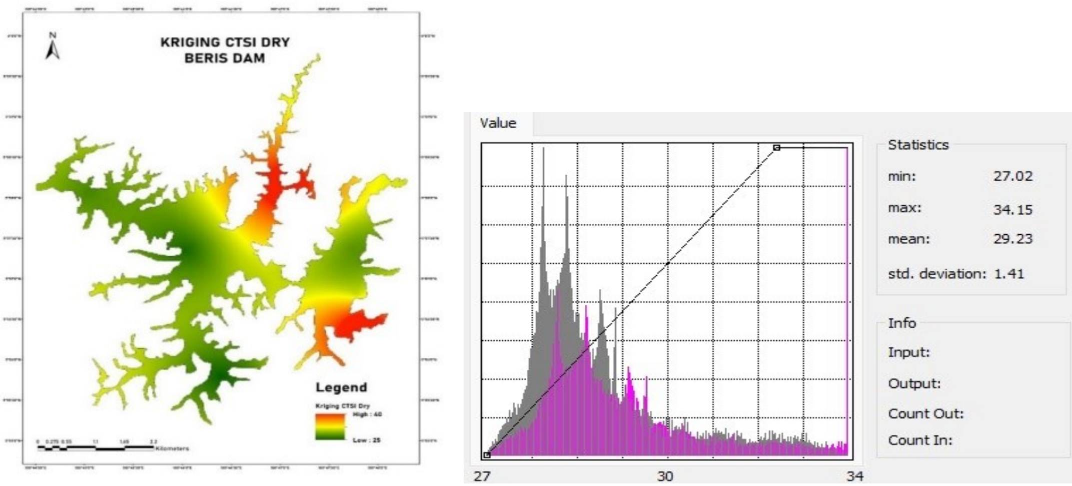

Figure 10 Ordinary Kriging CTSI dry.

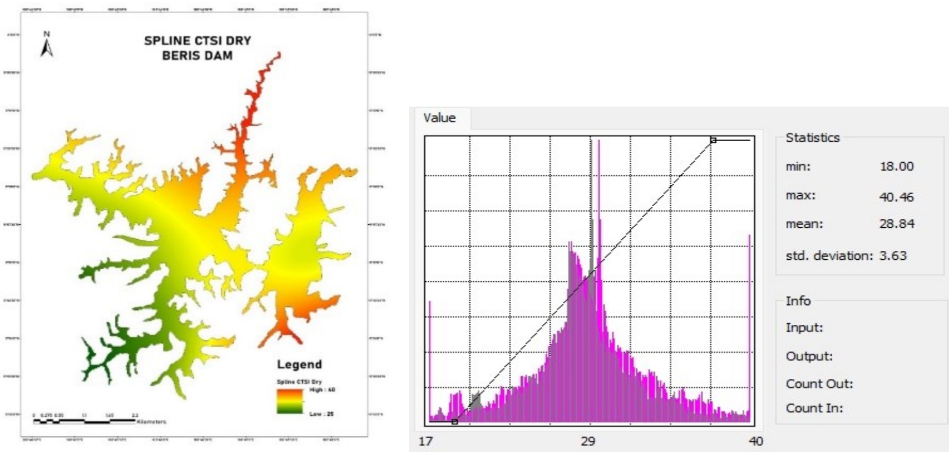

Figure 11 Spline CTSI dry.

This also applies to the dry season CTSI data, where the Spline on **Figure 11** method demonstrates less satisfactory interpolation performance. Due to the CTSI data for the 10 sampling stations hovering only between 27 and 34, it cannot establish a broader range on the map legend. Consequently, the interpolation map will appear to have more uniform contouring compared to using a larger data range.

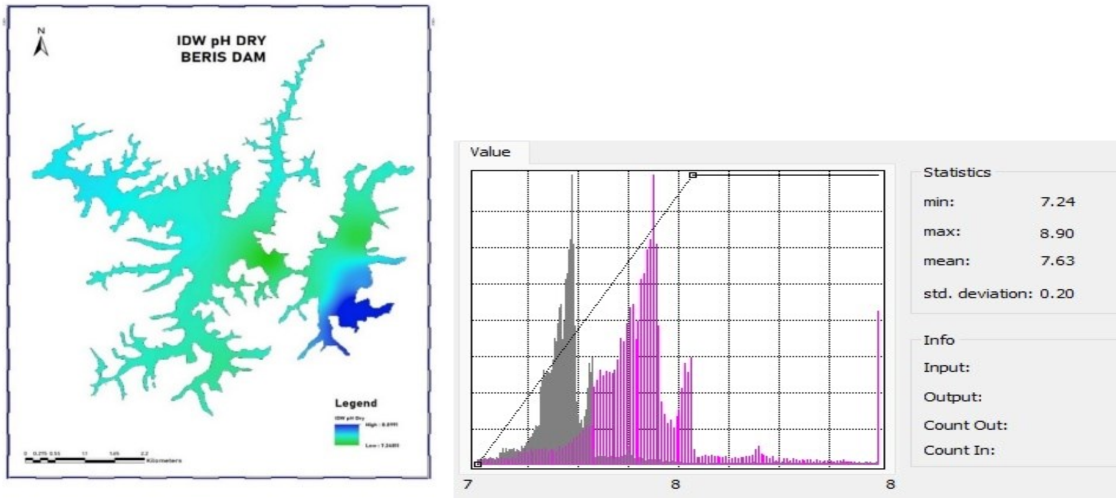

Figure 12 IDW pH dry.

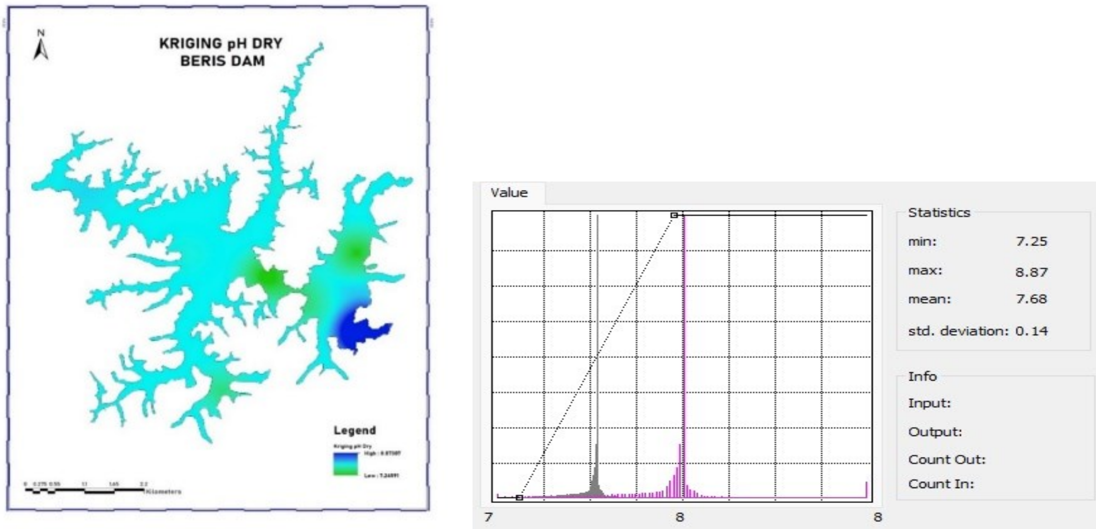

Figure 13 Ordinary Kriging pH dry.

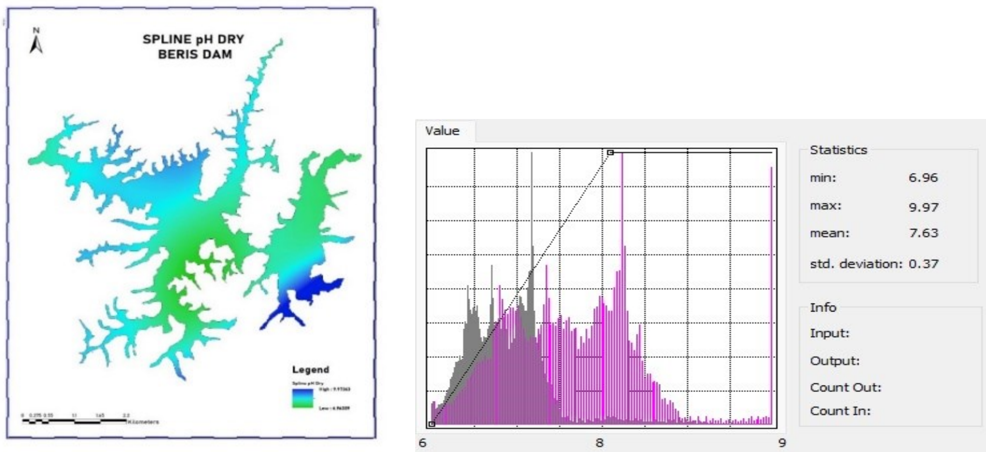

Figure 14 Spline pH dry.

The monitoring of pH data in **Figures 12 - 14** using all 3 interpolation methods also shows that low-range pH data exhibit small standard deviation values when interpolation analysis is performed. This is because the maximum displayed pH data is 8 and the minimum is 7, making the data harder to interpolate and the values involved are assessed to a smaller decimal. This also indicates that all 3 interpolation methods are not suitable for use when the data has a very small range gap.

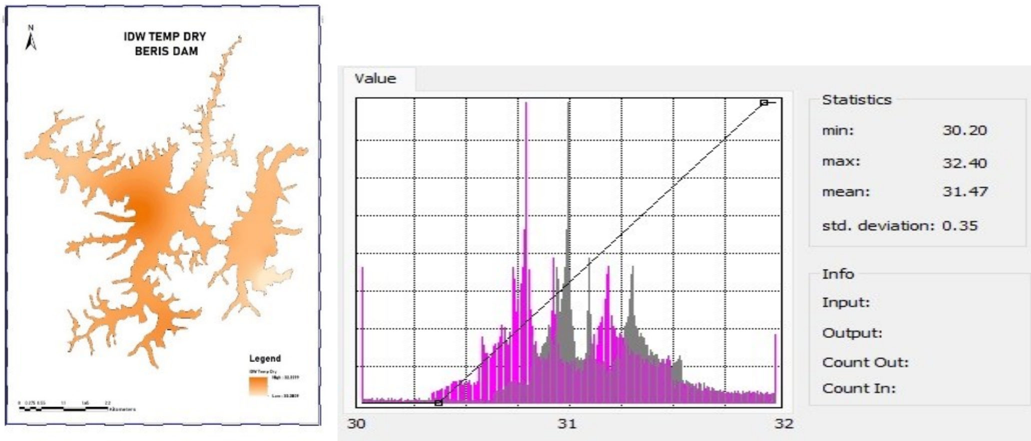

Figure 15 IDW water temp dry.

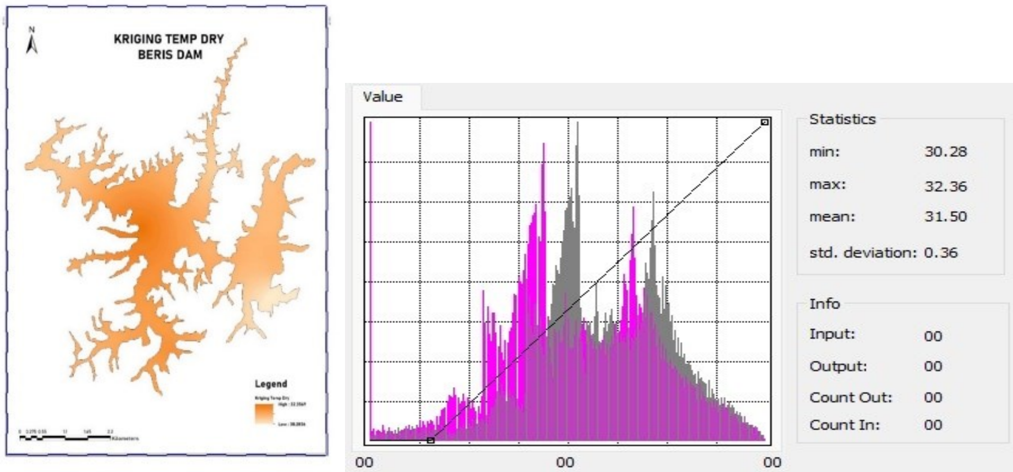

Figure 16 Ordinary Kriging water temp dry.

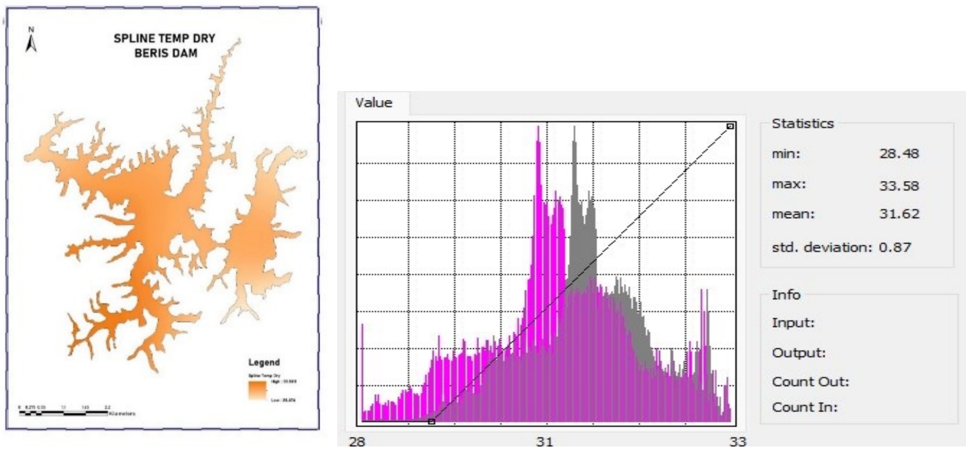

Figure 17 Spline water temp dry.

For interpolation methods on temperature data, the performance of the IDW and kriging methods shows that the range of temperature observations for the dry season is still within the range of variation. However, the spline method still exhibits characteristics of being ‘out of range’, where 32.4 degrees Celsius is the highest temperature recorded at SP8, and the lowest is 30.2 degrees Celsius, while the spline method provides a maximum interpolation range reading of 33.58 degrees Celsius, differing by 1.18 degrees Celsius from the maximum temperature value in that dry season.

Conclusions

Beris dam, in terms of DOE-WQI, exhibits the best water quality in both seasons, with an index score of more than 80 to 100 for all sampling points. This categorizes the water as Class II, requiring conventional treatment only for daily use. The Carlson Trophic State Index (CTSI) also indicates that the water is in an oligotrophic status, with a CTSI score ranging from 27 to 35. Meeting all criteria as fresh water suitable for human activity, thus indicates better water quality without any issues. For correlation assessment, it is evident that the levels of suspended solids and dissolved solids play a significant role in the presence of fluoride and the increase in turbidity levels due to their high correlation values, in addition to the presence of chlorophyll-a in the water. Each of these physicochemical parameters is often closely linked to pollution and the decomposition of organic materials in the water.

The study compares 3 methods of spatial interpolation. Among them, IDW stands out as the best interpolation technique for analyzing water quality assessment and numerous other indexes and physicochemical data, regardless of whether the observation data is on a small or large scale. IDW’s linear-weighted ability, along with the capacity to eliminate the “search radius,” effectively reduces most errors and enhances its ability to relate to the nearest point. However, the spline method seems unsuitable in this case because it provides interpolation values that fall outside the range of the original data. This may be due to the characteristics of splines, which attempt to generate piecewise functions that can result in significant gaps between known data points. This might not be suitable for temperature data, which should ideally fall within a specific range. The Spline method requires a larger number of sampling data points and an extensive range of data reading to provide a satisfactory and appealing result for interpolation analysis. Both ordinary and universal kriging also benefit from having more sampling points, as it helps reduce interpolation errors and improves the accuracy of zero values interpolation points. This research also highlights that spatial interpolation is the optimal analysis method that should be employed to visualize water quality assessment. It is also the easiest method for researchers and water management planners to understand.

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