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Research Article

Development of A Gis-Based Rainfall Mapping System Using Isohyet and Interpolation for Flood Control in the Babak Watershed

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ABSTRACT

Accurate and spatially distributed rainfall data are crucial for effective water resource management, particularly in flood control and infrastructure planning. This study develops a GIS-based rainfall mapping system for the Babak Watershed by integrating Isohyet mapping with spatial interpolation techniques—specifically Inverse Distance Weighting (IDW) and Spline methods—to address the limitations in rainfall data coverage due to the sparse distribution of Automatic Rainfall Recorder (ARR) stations. Secondary rainfall data from 17 Automatic Rainfall Recording (ARR) stations in the Lombok River Basin were analyzed alongside observed values from two Manual Rain Gauge (MRG) stations: MRG Bendung Babak and MRG Bendung Batu Riti. Using ArcGIS 10.2, rainfall distributions were estimated and visualized within a spatial decision-support system.

Results show rainfall estimates at MRG Bendung Babak of 2013 mm/year (IDW), 2210 mm/year (Spline), and 3098 mm/year (Observed); and at MRG Bendung Batu Riti of 1691 mm/year (IDW), 1402 mm/year (Spline), and 1446 mm/year (Observed). Error analysis indicates that Spline had a slightly lower error at Bendung Babak (34%) compared to IDW (37%), while IDW showed superior performance at Bendung Batu Riti (206% vs. 212%). Correlation coefficients further validate IDW's accuracy, with values of 68% and 81% at the two respective sites.

This study demonstrates that integrating Isohyet and interpolation methods within a GIS environment enhances the reliability of regional rainfall estimation. The GIS-based system developed offers a practical tool for hydrological analysis, flood risk assessment, and strategic planning of water infrastructure, particularly in data-scarce regions. To the best of our knowledge, this is the first application of such integrated techniques for rainfall mapping in the Babak Watershed.

Keywords: GIS, Isohyet, IDW, Interpolation, Flood

INTRODUCTION

The Lombok River Basin is a National Strategic Area comprising 197 sub-watersheds, with 52 utilized as water sources. The Babak Watershed is among the most influential and water-surplus sub-watersheds in the region. Water availability is highly influenced by rainfall, which determines infiltration rates and runoff into rivers, ultimately leading to the sea. Reliable rainfall data are crucial for water resource planning, yet the limited number of Automatic Rainfall Recorder (ARR) stations in the Lombok River Basin (17 stations for 4,560 km²) impedes comprehensive spatial analysis.

To address this limitation, rainfall modeling approaches such as Isohyet, Thiessen Polygon, and average methods are commonly applied. These models are calibrated using data from Manual Rain Gauge (MRG) stations to identify the most suitable method for regional rainfall estimation. This study aims to analyze regional rainfall in the Babak Watershed using Isohyet mapping with IDW and Spline interpolation, validated against MRG observations, to support flood control and water infrastructure management.

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While previous research has applied various interpolation methods separately, few have systematically compared IDW and Spline within the Isohyet framework and validated them using manual gauge data in a tropical watershed setting. This research addresses this gap and offers a novel approach for rainfall estimation and hydrological planning in data-limited environments.

1.1. Problem Formulation

- How can a GIS-based rainfall mapping system—using the Isohyet method combined with IDW and Spline interpolation—be effectively implemented to estimate regional rainfall distribution in the Babak Watershed?
- What is the accuracy level of rainfall estimations produced by IDW and Spline methods, based on Volume Error (VE) and correlation coefficients, compared to manual observations at MRG stations?
- In what ways can the results of GIS-based rainfall mapping support data-driven decision-making for flood control planning and water infrastructure management in the Babak Watershed?

1.2. Research Objectives

- To develop a GIS-based rainfall mapping system by applying the Isohyet method in combination with IDW and Spline interpolation techniques for estimating regional rainfall distribution in the Babak Watershed.
- To evaluate the accuracy of rainfall estimations by calculating Volume Error (VE) and analyzing correlation coefficients between interpolated results and observed rainfall data at MRG Bendung Babak and MRG Bendung Batu Riti.
- To examine the practical applications of spatial rainfall mapping in supporting flood control planning and water infrastructure management in data-scarce regions like the Babak Watershed.

2. METHODOLOGY

Secondary data were collected from **17 Automatic Rainfall Recorder (ARR)** stations located within the **Lombok River Basin**, supplemented by **observed data** from **two Manual Rain Gauge (MRG)** stations: **MRG Bendung Babak** and **MRG Bendung Batu Riti**. Spatial data included **geographic coordinates** and **administrative boundaries** of each rainfall station, which were integrated into the **GIS-based rainfall mapping system** for visualization, interpolation, and analysis using **ArcGIS 10.2**.

1.1.1. Rainfall

Rainfall (mm) is the height of rainwater collected in a rain gauge on a flat, non-absorbent, non-penetrating, and non-flowing surface (BMKG, 2016). According to Triatmodjo (2008), a rain gauge station only provides the depth of rain at the point where the station is located, so that rain in an area must be estimated from the measurement point. If in an area there are more than one measurement stations placed scattered, the rain recorded at each station may not be the same.

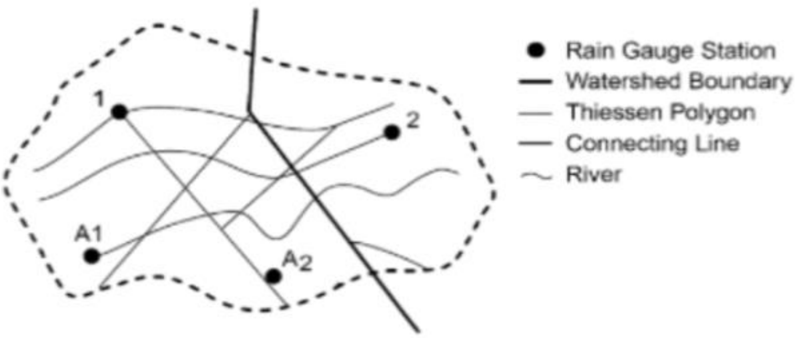

Figure 2.1. Illustration of the Thiessen Polygon Method where there are 4 rain gauge stations (ARR)

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Rainfall Estimation Methods:

- Thiessen Polygon: Calculates area-weighted average rainfall using the following formula: P = (A1P1 + A2P2 + ... + AnPn) / (A1 + A2 + ... + An)

This method takes into account the weight of each station that represents the surrounding area. In an area within the watershed, it is assumed that the rainfall is the same as that at the nearest station, so that the rainfall recorded at a station represents the area. This method is used if the distribution of rainfall stations in the area being reviewed is uneven. The calculation of the Thiessen Polygon is as in the following equation.

$$P = \frac{A1.P1 + A2.P2 + A3.P3 + \cdots + An.Pn}{A1 + A2 + A3 + \cdots . + An} \ldots . . (2.1)$$

With:

P = Average Area Rainfall

P1, P2, P3, Pn = Rain at stations 1,2,3, and n

n = Number of Stations

A1, A2, A3, An = Station Area 1,2, ... N

- IDW Interpolation: Estimates rainfall based on the weighted average of nearby stations, where weights decrease with distance: Zo = (Σ Zi / dik^k) / (Σ 1 / dik^k)

IDW (Inverse Distance Weighted) Interpolation

Inverse Distance Weighted (IDW) interpolation is a simple deterministic method that considers the surrounding points (NCGIA, 1997). This method assumes that the interpolation value will be more similar to the sample data that is closer than the farther one. The weight will change linearly according to the distance to the sample data. This weight will not be affected by the location of the sample data. This method is usually used in the mining industry because it is easy to use. The selection of the power value greatly affects the interpolation results. A high power value will give results like using nearest neighbor interpolation, where the value obtained is the value of the nearest data point. The disadvantage of the IDW method is that the interpolation result is limited to the values in the sample data. The effect of sample data on the interpolation result is called isotropy. In other words, because this method uses the average of the sample data, its value cannot be smaller than the minimum or larger than the sample data. So, the peak of the deepest hill or valley cannot be displayed from the interpolation results of this model (Watson & Philip, 1985). To get good results, the data sample used must be dense in relation to local variations. If the sample is rather sparse and uneven, the results are likely to be less than desired.

The IDW method is a conventional interpolation method that takes distance into account as a weight. The distance referred to here is the (flat) distance from the data point (sample) to the block to be estimated. So the closer the distance between the sample point and the block to be estimated, the greater the weight, and vice versa.

$$Z0 = \frac{\sum_{i=1}^{s} Zi \frac{1}{dik}}{\sum_{i=1}^{s} \frac{1}{dik}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.2)$$

Where:

Zo = Estimated value at point o

Zi = What is the Z value at control point i?

d1 = Distance between point I and point o

k = the larger k, the greater the influence of neighboring points

S = Number of S points used

● Spline Interpolation: Fits a smooth surface that passes through all input points, minimizing overall curvature.

Spline interpolation uses an interpolation method that estimates values using a mathematical function that minimizes the overall curvature of the surface, resulting in a smooth surface that passes exactly through the input points. The basic form of minimum curvature Spline interpolation imposes the following two conditions on the interpolant:

➢ The surface must pass exactly through the data points.

➢ The surface must have minimum curvature - the cumulative sum of the squares of the second derivatives of the surface taken over each point on the surface must be a minimum.

Spline interpolation is used because polynomial interpolation often gives less than optimal results. After all, if the data given is large, the degree of the polynomial formed will be very high, which also makes it difficult to calculate. Polynomials with high degrees will produce very fast data fluctuations. Changes in data at small intervals can cause large changes in the entire interval. So interpolation usually uses low-degree polynomials. By limiting the degree, another alternative can be determined to obtain a smooth curve through several points, namely dividing an interval containing point data into several subintervals and in each subinterval, an interpolation polynomial is constructed. The result is a curve consisting of pieces of polynomial curves of the same degree, this function is called a spline function. A spline function is a function consisting of several parts of a polynomial function that are connected with several smoothness requirements (Sahid, 2005).

$$S(x) = \begin{cases} S_1(x) & \\ S_2(x) & untuk\ x_1 \leq x \leq x_2 \\ . & untuk\ x_2 \leq x \leq x_3 \\ . & \dots . \\ . & untuk\ x_{n-1} \leq x \leq x_n \\ S_{n-1}(x) & \end{cases} \qquad (2.3)$$

$$Sk(x) = a_k X^n + a_{k-1} X^{n-1} + \cdots + a_2 X^2 + a_1 X + a_0 \dots \dots (2.4)$$

where

Sk(X) = The k-th spline function on a specific interval. For example, if there are 4 data points, there will be 3 spline functions (since the number of splines = number of data points – 1).

X = The independent variable (commonly time, distance, etc.).

$a_0, a_1, \dots, a_k$ = The coefficients or constants of the polynomial that need to be determined through calculation (usually by solving a system of linear equations).

n = The degree of the spline polynomial (e.g., for a cubic spline, n = 3).

k = The spline index, ranging from the first spline to the (n–1)-th spline, depending on the number of data points.

Software: ArcGIS 10.2 was used for spatial analysis, Isohyet mapping, and interpolation (IDW and Spline).

ArcGIS is a Geographic Information System (GIS) based software developed by ESRI (Environmental Science & Research Institute). The main product of ArcGIS consists of three main components, namely: ArcView (functions as a comprehensive data manager, mapping, and analysis), ArcEditor (functions as an editor of spatial data) and ArcInfo (is a feature that provides functions in GIS, namely including analysis needs of the Geoprocessing feature).

ArcGIS was first launched to the public as commercial software in 1999 with version (ArcGIS 8.0. With the development and demands for the features needed, ESRI always provides updates to ArcGIS. currently, the latest updated version has been released, namely ArcGIS Pro, which is a development of ArcGIS 10.7.

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In its latest version, ArcGIS Desktop has several features, including:

1. ArcMap which is the main application used in GIS data management. ArcMap has the ability to visualize, edit, create thematic maps, manage tabular data (Excel), select (Query), use Geoprocessing features to analyze and customize data, or output in the form of map displays. Operators can also process data according to their wishes.

2. ArcGlobe is an application that has a display like Google Earth, which functions as a display of the Earth's surface datum using satellite imagery.

3. ArcCatalog, which is an application that has features to create vector data and group it according to the desired function. With the ability of tools to explore information (browsing), organize data (organizing), share data (distribution) and document spatial data or data related to geographic information.

4. ArcScene is an application that has similar features to ArcMap, but its advantage lies in the 3D features used where the worksheet can be processed with X, Y, and Z views.

The following are the tools used to create an Isohyet map using ArcGIS 10.7.

1. *ArcToolbox Spatial Analyst Tools*

This tool functions as an interpolation method from rain points. In this study, two interpolation methods were used, namely IDW (Inverse Distance Weighting) and Spline

2. *ArcToolbox Spatial Analyst Supplemental Tools*

This tool functions as a rain height line former with the same height, where this tool requires the results of the spatial analyst tools that will be used as input. In this study, the Filled Contours tool was used

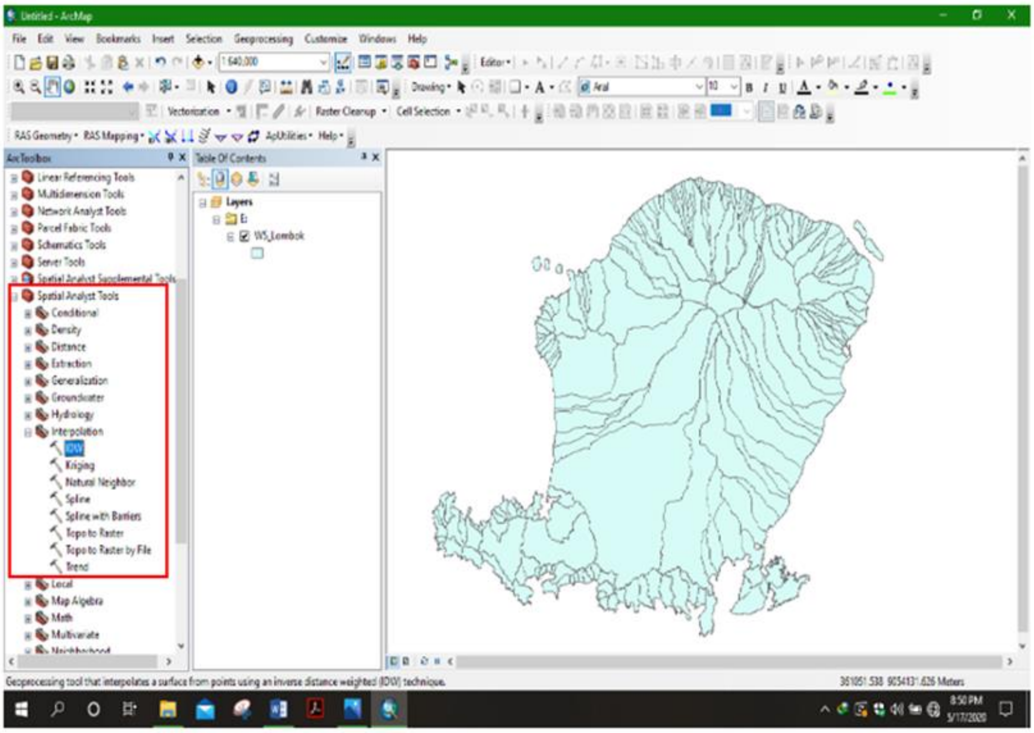

Figure 2.2. ArcToolbox Spatial Supplemental Tools View in ArcGIS

Study Area

The Babak Watershed is located in West Lombok Regency, West Nusa Tenggara Province, Indonesia, and is part of the Lombok River Basin (total area: 4,560.5 km²). The locations of ARR and MRG stations are mapped using ArcGIS.

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The Lombok River Basin (WS) based on the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia No. 04 of 2015, is a National Strategic River Basin with a total of 197 (one hundred and ninety-seven) River Basins (DAS). The total area of the Lombok WS is 4,560.50 km2, with the smallest DAS area variation of 0.47 km2 (Sentelik DAS) and the largest 578.62 km2 (Dodokan DAS). The location of the research study area used is the Babak DAS, located in West Lombok Regency, West Nusa Tenggara Province.

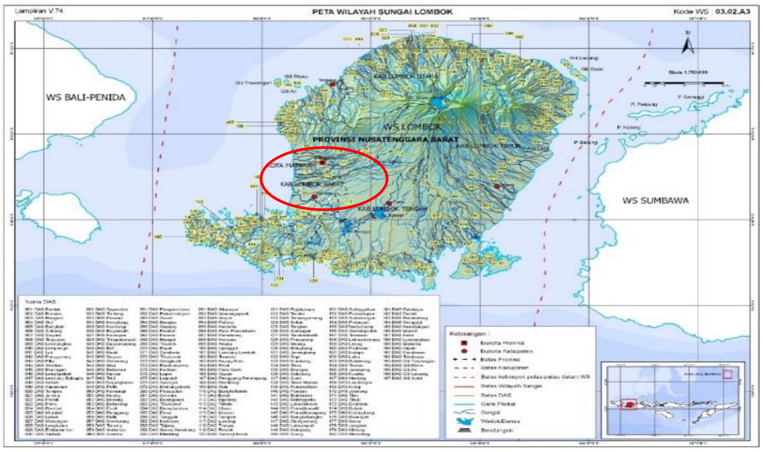

Figure 2.3.WS Lombok Map (Source: BWS NT I, 2020)

RESULTS AND DISCUSSION

1.2. Location of Automatic Rainfall Station (ARR) in the Lombok River Basin (WS)

The rainfall data used for the ARR Station in this study is automatic rainfall data from 17 rainfall stations managed by the River Region Office - Nusa Tenggara I. The following is a list of rainfall stations (ARR/Automatic Rainfall Recorder) presented in Table 3.1 and Table 3.2, as well as in Figure 3.1

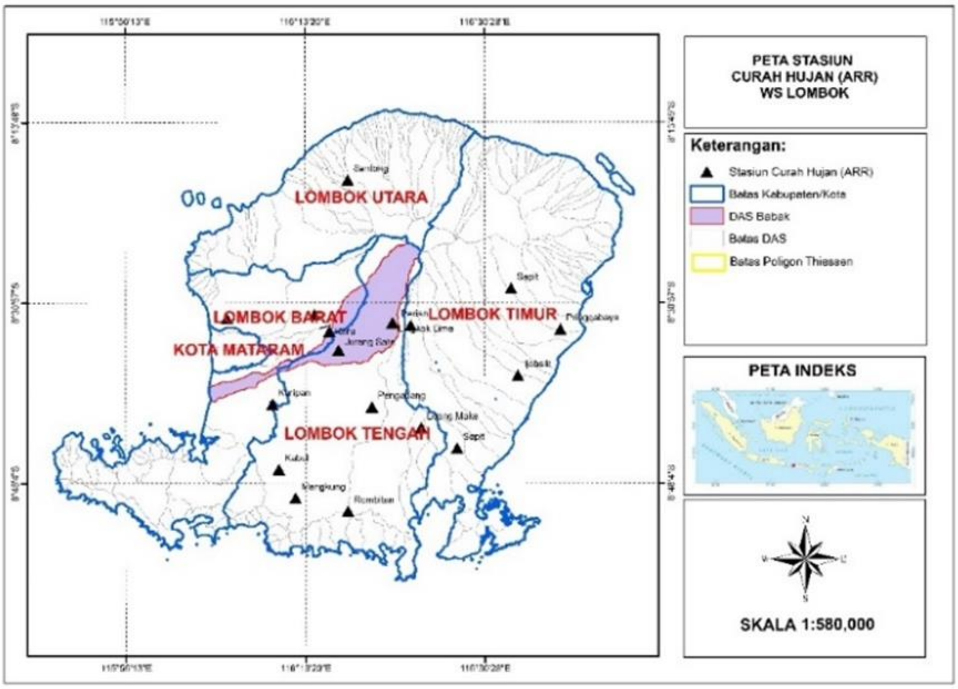

Figure 3.1. Rainfall stations (ARR/Automatic Rainfall Recorder)

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Table 3.1 Coordinates of Automatic Rainfall Recorder (ARR) Locations in the Lombok River Basin (WS)

No	ARR Name	Post Type (Water Estimate/Rainfall/Climatology)	UTM (X)	UTM (Y)	LS	BT
1	Mount Sari	Rainfall	400707	9055857	8°32'25"	116°05'52"
2	Ijobalit	Rainfall	451589	9045903	8°38'24"	116°35'25"
3	Satay Abyss	Rainfall	420223	9050308	8°35'27"	116°16'30"
4	Granted	Rainfall	409814	9029403	8°46'47"	116°10'48"
5	Keru	Rainfall	418627	9053561	8°33'41"	116°15'38"
6	Copy	Rainfall	408689	9040825	8°40'21"	116°07'04"
7	Lime Circle	Rainfall	429660	9055116	8°32'51"	116°21'39"
8	Make a Loan	Rainfall	434672	9036728	8°42'50"	116°24'22"
9	Bowl	Rainfall	412727	9024403	8°49'30"	116°12'23"
10	Barrier	Rainfall	426079	9040368	8°40'51"	116°19'41"
11	Perian	Rainfall	432840	9054661	8°33'06"	116°23'23"
12	The Great	Rainfall	459008	9053988	8°33'29"	116°37'39"
13	Rembitan	Rainfall	421896	9022118	8°50'45"	116°17'23"
14	Santong	Rainfall	421819	9080071	8°19'18"	116°17'24"
15	Cow	Rainfall	450380	9061165	8°29'35"	116°32'57"
16	Tongs	Rainfall	440971	9033175	8°44'46"	116°27'48"
17	One day	Rainfall	415992	9056473	8°32'06"	116°14'12"

Table 3.2 Location of Automatic Rainfall Recorder (ARR) Station Areas in the Lombok River Basin (WS)

No	ARR Name	River Basin Area (DAS)	Village	Subdistrict	Regency
1	Mount Sari	Inking	Mount Sari	Mount Sari	West Lombok
2	Ijobalit	Star fruit	Tempasan	Thank you	East Lombok
3	Satay Abyss	Half	Satay Abyss	The Great	Central Lombok
4	Granted	The Dodokan	Granted	Southwest Praya	Central Lombok
5	Keru	Half	The Destroyer	Narmada	West Lombok
6	Copy	The Dodokan	Copy	Copy	West Lombok
7	Lime Circle	Half	Lime Circle	The Coop	Central Lombok
8	Make a Loan	Pare Ganti	Make a Loan	Janapria	Central Lombok
9	Bowl	The Dodokan	Bowl	West Praya	Central Lombok
10	Barrier	The Dodokan	Barrier	Central Praya	Central Lombok

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11	Perian	Trough	Betok	Terra	East Lombok
12	The Great	Village	The Great	The Great	East Lombok
13	Rembitan	The Renggan of the Village	Rembitan	The Poppy	Central Lombok
14	Santong	The following	Santong	Heaven	North Lombok
15	Cow	Village	Cow	Suela	East Lombok
16	Tongs	The Rebels	Tongs	Crackers	East Lombok
17	One day	Jangkok	Aiknyet	Narmada	West Lombok

The distance between rainfall stations (ARR) is presented in Appendix 1.

1.3. Location of Manual Rainfall Station (MRG) DAS Babak WS Lombok

To analyze rainfall stations in the Babak River Basin (DAS), a manual rainfall station (MRG) overlay was performed in the Babak DAS. The MRG station overlay is presented in Figure 3.2. below.

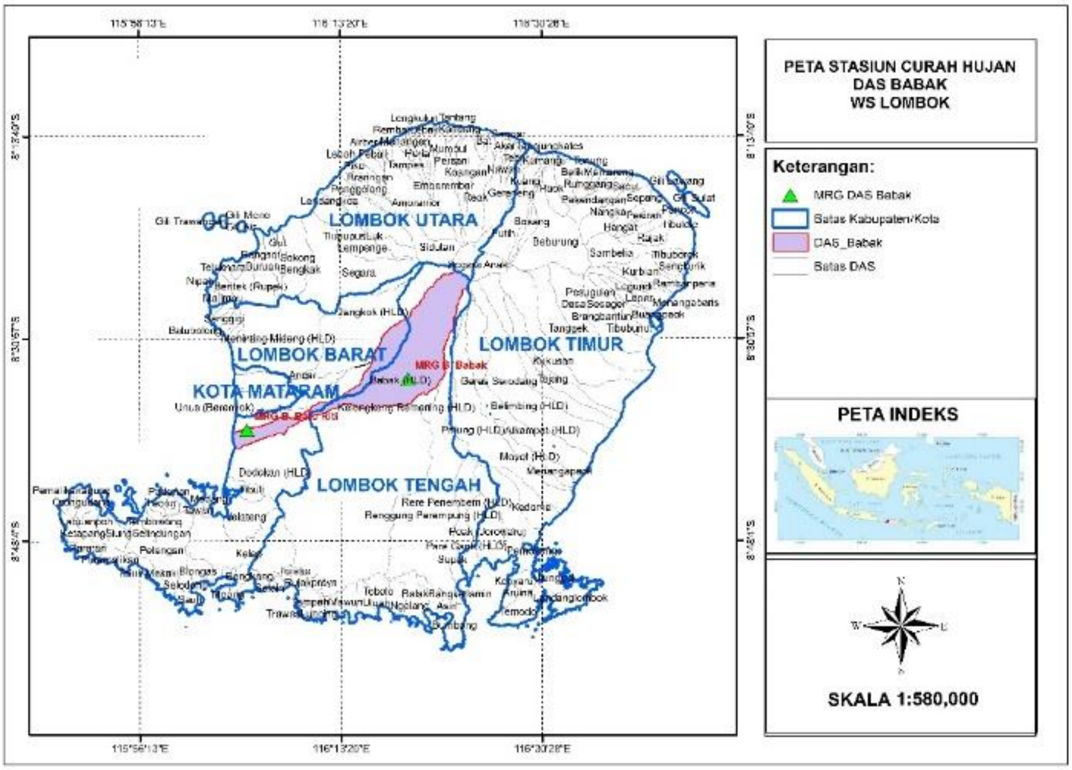

Figure 3.2. Overlay Analysis of MRG Stations in the Babak WS Lombok Watershed

1.4. Automatic Rainfall Data (ARR) in the Lombok River Basin (WS)

The data used is the Average Automatic Rainfall Data (ARR) at each Rainfall Station obtained from the River Region Office - Nusa Tenggara I. Rainfall data is presented in Table 3.3 as follows:

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Table 3.3 Average Rainfall Data at 17 ARR Stations in the Lombok River Basin (WS)

No	Stasiun ARR	Jan			Feb			Mar			Apr			Mei			Jun			Jul			Agt			Sep			Okt			Nov			Des		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	Gunung Sari	64	62	84	71	68	65	57	47	62	66	37	39	40	47	46	18	28	21	28	15	23	8	7	13	15	36	30	54	44	69	76	85	72	91	86	67
2	Ijobalit	55	41	53	61	36	39	60	40	29	27	21	18	13	10	12	2	8	14	9	9	4	3	1	5	5	7	8	15	12	10	17	27	45	36	41	46
3	Jurang Sate	95	78	97	110	73	63	78	84	90	75	51	44	34	56	55	18	29	26	20	19	13	4	3	21	21	33	42	41	41	36	75	89	85	105	94	93
4	Kabul	61	83	86	94	72	65	57	55	59	60	44	38	19	22	23	37	15	15	20	6	5	2	3	7	10	17	20	31	16	42	37	51	64	57	67	69
5	Keru	88	79	83	72	68	56	65	71	94	50	62	43	31	30	58	22	28	22	16	14	11	4	3	13	21	23	29	40	39	40	77	94	80	82	85	75
6	Kuripan	72	50	72	70	49	48	54	39	61	54	58	36	33	27	44	23	17	13	30	17	17	6	4	9	4	43	47	25	23	61	61	63	77	73	80	74
7	Lingkok Lime	106	89	143	122	78	76	92	93	118	97	72	60	33	48	51	22	24	42	28	33	12	14	7	13	12	13	50	41	59	74	90	119	131	138	99	104
8	Loang Make	92	68	76	73	52	44	55	41	45	40	34	26	12	21	19	35	13	11	8	14	4	3	4	8	7	20	15	11	13	18	24	46	62	65	93	62
9	Mangkung	82	66	86	86	90	69	75	51	52	45	33	20	17	17	14	23	18	11	11	8	10	4	13	15	7	11	29	11	23	41	25	52	61	63	69	75
10	Pengadang	83	69	94	94	73	58	66	76	79	75	51	34	34	33	28	16	16	10	21	9	4	6	4	4	9	22	30	21	11	29	53	90	94	77	93	78
11	Perian	109	92	102	99	85	69	88	88	104	89	61	61	24	34	29	22	17	38	25	22	10	8	5	27	23	22	35	61	45	72	90	98	109	118	91	79
12	Pringgabaya	59	59	57	57	48	37	50	32	20	30	15	14	12	7	10	16	13	20	10	13	5	9	5	4	10	6	19	2	9	7	23	21	36	33	38	55
13	Rembitan	84	73	100	107	74	53	67	53	60	55	51	35	11	26	27	8	19	9	17	5	11	5	5	7	12	23	30	13	17	25	53	69	60	83	86	88
14	Santong	58	106	136	117	142	94	120	111	92	74	64	40	47	29	28	16	14	16	19	17	11	5	4	5	6	8	13	21	21	18	39	46	80	61	110	93
15	Sapit	61	84	104	105	68	68	88	82	54	61	48	30	18	15	25	14	12	21	22	20	5	23	5	15	10	23	20	30	30	23	48	61	66	70	80	84
16	Sepit	84	72	84	68	57	49	57	51	35	39	36	19	12	20	12	8	5	7	11	8	5	7	3	2	16	6	15	20	10	21	30	56	37	56	79	56
17	Sesaot	131	96	113	124	88	67	61	86	92	99	80	50	44	37	64	24	41	39	22	22	12	6	2	12	20	29	49	41	52	61	104	134	101	118	71	93

*Satuan Curah Hujan dalam mm

1.5. Manual Rainfall Data (MRG) of Babak Watershed, Lombok WS

The data used is the Average Manual Rainfall Data (MRG) at each Rainfall Station obtained from the River Region Office - Nusa Tenggara I. Rainfall data is presented in Table 3.4 as follows:

Table 3.4 Rainfall Data at MRG Babak and MRG Batu Riti Stations in the Babak Watershed in the Lombok River Basin (WS)

No	Stasiun Hujan	Tahun	Jan			Feb			Mar			Apr			Mei			Jun			Jul			Agt			Sep			Okt			Nov			Des		
			I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	MRG B. Babak	2016	25	27	160	163	135	100	86	149	195	88	37	77	155	105	120	27	40	64	16	128	22	31	15	13	15	36										
		2017	60	251	97	101	71	111	58	192	104	20	98	0	259	160	185	128	180	70	89	143	52	0	0	0	268	525	100	240	154	356	140	17	247	165		
		2018	240	171	158	120	89	53	116	212	26	11	24	0	0	27	88	0	26	37	1	2	1	1	22	29	25	0	27	0	0	0	154	162	158	128	5	89
		2019	146	122	104	32	91	132	104	85	123	101	242	144	152	0	0	0	19	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	116	134	228	174
		Rerata	**118**	**143**	**130**	**104**	**97**	**99**	**91**	**159**	**112**	**55**	**100**	**55**	**142**	**73**	**98**	**39**	**66**	**43**	**27**	**71**	**19**	**8**	**9**	**11**	**77**	**140**	**42**	**80**	**51**	**119**	**98**	**60**	**174**	**142**	**116**	**131**
2	MRG B. Batu Riti	2016	45	34	88	58	37	75	25	7	87	78	15	21	41	47	156	4	74	17	5	17	9	0	15	10	0	19	23	42	62	50	31	120	173	85	174	24
		2017	25	54	153	262	45	0	33	27	46	103	39	9	25	0	57	0	183	5	20	0	0	3	0	0	0	0	4	31	0	94	90	24	67	20	63	142
		2018	71	139	271	62	67	84	10	75	7	11	75	2	0	0	11	0	27	0	0	0	0	0	0	0	8	0	0	30	0	0	161	38	36	83	2	26
		2019	28	35	137	52	13	16	93	117	135	27	22	41	1	0	0	0	6	0	5	2	0	0	0	0	0	0	0	0	0	0	0	27	127	75	39	103
		Rerata	**42**	**66**	**162**	**108**	**40**	**44**	**40**	**56**	**69**	**55**	**38**	**18**	**17**	**12**	**56**	**1**	**73**	**5**	**7**	**5**	**2**	**1**	**4**	**2**	**2**	**5**	**7**	**26**	**16**	**36**	**70**	**52**	**101**	**66**	**70**	**74**

1.6. Distance Between Rainfall Stations in the Lombok River Basin (WS)

In the Isohyet method, the distance between Automatic Rainfall (ARR) stations determines the isohyet results, where the isohyet is a line formed based on a certain rainfall height influenced by the distance between rainfall stations. The following table of the distance between automatic rainfall (ARR) stations is presented in Table 4.5 then the table of the distance between automatic rainfall (ARR) stations and manual rainfall (MRG) stations is presented in Table 3.5.

Table 3.5 Distance Between Automatic Rainfall Stations (ARR) in the Lombok River Basin (WS)

No	Stasiun Hujan (ARR)	Jarak ke (km)																
		Gunung Sari	Ijobalit	Jurang Sate	Kabul	Keru	Kuripan	Lingkok Lime	Loang Make	Mangkung	Pengadang	Perian	Pringgabaya	Rembitan	Santong	Sapit	Sepit	Sesaot
1	Gunung Sari		51.85	20.29	27.98	18.07	17.02	28.96	38.98	33.67	29.73	32.16	58.33	39.84	32.13	49.96	46.21	15.30
2	Ijobalit	51.85		31.67	44.92	33.84	43.20	23.79	19.25	44.41	26.10	20.69	10.97	38.05	45.32	15.31	16.58	37.13
3	Jurang Sate	20.29	31.67		23.35	3.62	14.93	10.59	19.83	26.97	11.54	13.35	38.96	28.24	29.81	32.05	26.91	7.48
4	Kabul	27.98	44.92	23.35		25.72	11.48	32.48	25.91	5.79	19.62	34.18	55.00	14.11	52.07	51.52	31.39	27.77
5	Keru	18.07	33.84	3.62	25.72		16.15	11.14	23.25	29.75	15.15	14.26	40.38	31.61	26.70	32.65	30.25	3.93
6	Kuripan	17.02	43.20	14.93	11.48	16.15		25.38	26.30	16.91	17.40	27.83	52.01	22.90	41.38	46.39	33.18	17.27
7	Lingkok Lime	28.96	23.79	10.59	32.48	11.14	25.38		19.06	35.07	15.18	3.21	29.37	33.90	26.16	21.58	24.69	13.74
8	Loang Make	38.98	19.25	19.83	25.91	23.25	26.30	19.06		25.17	9.33	18.03	29.84	19.41	45.21	29.05	7.23	27.18
9	Mangkung	33.67	44.41	26.97	5.79	29.75	16.91	35.07	25.17		20.81	36.33	54.93	9.45	56.41	52.62	29.58	32.24
10	Pengadang	29.73	26.10	11.54	19.62	15.15	17.40	15.18	9.33	20.81		15.81	35.63	18.72	39.93	31.98	16.54	19.00
11	Perian	32.16	20.69	13.35	34.18	14.26	27.83	3.21	18.03	36.33	15.81		26.18	34.33	27.70	18.71	22.97	16.95
12	Pringgabaya	58.33	10.97	38.96	55.00	40.38	52.01	29.37	29.84	54.93	35.63	26.18		48.92	45.42	11.22	27.54	43.09
13	Rembitan	39.84	38.05	28.24	14.11	31.61	22.90	33.90	19.41	9.45	18.72	34.33	48.92		57.95	48.33	22.05	34.86
14	Santong	32.13	45.32	29.81	52.07	26.70	41.38	26.16	45.21	56.41	39.93	27.70	45.42	57.95		34.25	50.66	24.31
15	Sapit	49.96	15.31	32.05	51.52	32.65	46.39	21.58	29.05	52.62	31.98	18.71	11.22	48.33	34.25		29.53	34.71
16	Sesaot	46.21	16.58	26.91	31.39	30.25	33.18	24.69	7.23	29.58	16.54	22.97	27.54	22.05	50.66	29.53		34.16
17	Sesaot	15.30	37.13	7.48	27.77	3.93	17.27	13.74	27.18	32.24	19.00	16.95	43.09	34.86	24.31	34.71	34.16	

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Table 4.6 Distance between Automatic Rainfall Station (ARR) and Manual Rainfall Station (MRG) in the Lombok River Basin (WS) Distance from Rainfall Stations (ARR) to MRG Babak and MRG Batu Riti

No.	Rainfall Station (ARR)	Distance to (km) MRG Babak
1	Gunung Sari	24.48
2	Ijobalit	27.41
3	Jurang Sate	5.09
4	Kabul	27.41
5	Keru	6.43
6	Kuripan	19.86
7	Lingkok Lime	5.52
8	Loang Make	18.35
9	Mangkuk	30.42
10	Pengadang	11.96
11	Perian	8.27
12	Pinggabaya	34.13
13	Rembitan	30.30
14	Santong	27.97
15	Sapit	26.96
16	Sesaot	24.94
17	Sesaot	9.87

Note:
The distance between MRG Babak and MRG Batu Riti is 26.34 km.

1.7. Regional Rainfall Analysis Using the Isohyet Method with Inverse Distance Weighting (IDW) and Spline Interpolation.

Analysis of regional rainfall at the ARR station to determine the High Rainfall in MRG Babak and MRG Batu Riti based on ARR Data. The results of the IDW and Spline Interpolation Isohyets are as follows.

Spatial Distribution of Rainfall Stations: 17 ARR stations are distributed across the Lombok River Basin. Two MRG stations (Bendung Babak and Bendung Batu Riti) are selected for validation.

Rainfall Estimation Results: At MRG Bendung Babak: IDW = 2013 mm/year, Spline = 2210 mm/year, Observed = 3098 mm/year. At MRG Bendung Batu Riti: IDW = 1691 mm/year, Spline = 1402 mm/year, Observed = 1446 mm/year.

The rainfall value at MRG in the Babak Watershed, based on the Isohyet method with IDW and Spline Analysis at the ARR Station in the Babak Watershed, Lombok River Region (WS), is as follows:

Table 3.7 Comparison Results of Rainfall (mm) Observations at MRG and IDW, and Spline Analysis at ARR Stations at MRG B. Babak DAS Babak WS Lombok

No	Stasiun MRG	Analisis	Jan I	Jan II	Jan III	Feb I	Feb II	Feb III	Mar I	Mar II	Mar III	Apr I	Apr II	Apr III
1	MRG B. Babak	Observasi	118	143	130	104	97	99	91	159	112	55	100	55
1	MRG B. Babak	IDW	98	82	105	103	75	65	77	81	94	76	60	48
1	MRG B. Babak	Spline	98	83	125	117	74	70	86	89	108	84	62	51

No	Stasiun MRG	Analisis	Mei I	Mei II	Mei III	Jun I	Jun II	Jun III	Jul I	Jul II	Jul III	Agt I	Agt II	Agt III
1	MRG B. Babak	Observasi	142	73	98	39	66	43	27	71	19	8	9	11
1	MRG B. Babak	IDW	32	42	48	21	26	29	22	21	12	8	5	16
1	MRG B. Babak	Spline	35	54	56	20	27	34	24	27	12	10	6	14

No	Stasiun MRG	Analisis	Sep I	Sep II	Sep III	Okt I	Okt II	Okt III	Nov I	Nov II	Nov III	Des I	Des II	Des III
1	MRG B. Babak	Observasi	77	140	42	80	51	119	98	60	174	142	116	131
1	MRG B. Babak	IDW	17	24	39	40	42	51	78	97	96	105	90	88
1	MRG B. Babak	Spline	15	20	46	38	51	53	80	107	112	122	99	101

Curah Hujan Total (mm)			
1	MRG B. Babak	Observasi	3098
1	MRG B. Babak	IDW	2013
1	MRG B. Babak	Spline	2210

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Table 3.8 Comparison Results of Rainfall (mm) Observations at MRG and IDW, and Spline Analysis at ARR Station at MRG Batu Riti DAS Babak WS Lombok

No	Stasiun MRG	Analisis	Jan I	Jan II	Jan III	Feb I	Feb II	Feb III	Mar I	Mar II	Mar III	Apr I	Apr II	Apr III
1	MRG B. Batu Riti	Observasi	42	66	162	108	40	44	40	56	69	55	38	18
2	MRG B. Batu Riti	IDW	79	68	87	84	67	59	63	57	69	63	52	39
3	MRG B. Batu Riti	Spline	49	49	66	52	50	54	52	30	54	45	41	35

No	Stasiun MRG	Analisis	Mei I	Mei II	Mei III	Jun I	Jun II	Jun III	Jul I	Jul II	Jul III	Agt I	Agt II	Agt III
1	MRG B. Batu Riti	Observasi	17	12	56	1	73	5	7	5	2	1	4	2
2	MRG B. Batu Riti	IDW	32	33	41	22	22	19	24	16	15	7	5	12
3	MRG B. Batu Riti	Spline	33	32	40	24	17	12	30	14	21	7	6	10

No	Stasiun MRG	Analisis	Sep I	Sep II	Sep III	Okt I	Okt II	Okt III	Nov I	Nov II	Nov III	Des I	Des II	Des III
1	MRG B. Batu Riti	Observasi	2	5	7	26	16	36	70	52	101	66	70	74
2	MRG B. Batu Riti	IDW	12	31	36	34	31	53	64	77	78	82	82	76
3	MRG B. Batu Riti	Spline	8	39	33	40	28	67	56	54	64	66	62	62

Curah Hujan Total (mm)			
1	MRG B. Babak	Observasi	1446
2	MRG B. Babak	IDW	1691
3	MRG B. Babak	Spline	1402

Error Analysis: Volume Error (VE) at Bendung Babak: Spline = 34%, IDW = 37%. At Bendung Batu Riti: IDW = 206%, Spline = 212%. Lower errors at Bendung Babak are attributed to its proximity to ARR stations, while higher errors at Batu Riti are due to greater distances from ARR stations.

The Volume Error (VE) value for MRG in the Babak Watershed based on the Isohyet method with IDW Analysis at the Lombok River Basin (WS) ARR Station is as follows:

Table 3.9 Volume Error (VE) Results for IDW and Spline Analysis at ARR Station against observations at MRG B. Babak Station in Lombok WS

No	Stasiun MRG	Analisis	Jan I	Jan II	Jan III	Feb I	Feb II	Feb III	Mar I	Mar II	Mar III	Apr I	Apr II	Apr III
1	MRG B. Babak	IDW	17%	43%	19%	1%	22%	34%	15%	49%	16%	38%	40%	13%
2	MRG B. Babak	Spline	17%	42%	4%	13%	23%	29%	5%	44%	4%	53%	38%	8%

No	Stasiun MRG	Analisis	Mei I	Mei II	Mei III	Jun I	Jun II	Jun III	Jul I	Jul II	Jul III	Agt I	Agt II	Agt III
1	MRG B. Babak	IDW	77%	43%	51%	46%	61%	32%	17%	70%	36%	2%	45%	51%
2	MRG B. Babak	Spline	75%	26%	43%	48%	59%	21%	9%	62%	36%	27%	34%	32%

No	Stasiun MRG	Analisis	Sep I	Sep II	Sep III	Okt I	Okt II	Okt III	Nov I	Nov II	Nov III	Des I	Des II	Des III
1	MRG B. Babak	IDW	78%	83%	8%	50%	18%	57%	20%	63%	45%	26%	23%	33%
2	MRG B. Babak	Spline	81%	86%	9%	53%	1%	55%	18%	80%	35%	14%	15%	23%

Volume Error Rerata			
1	MRG B. Babak	IDW	37%
2	MRG B. Babak	Spline	34%

Table 3.10 Volume Error (VE) Results for IDW and Spline Analysis at ARR Station against observations at MRG B. Batu Riti Station in Lombok WS

No	Stasiun MRG	Analisis	Jan I	Jan II	Jan III	Feb I	Feb II	Feb III	Mar I	Mar II	Mar III	Apr I	Apr II	Apr III
1	MRG B. Batu Riti	IDW	87%	4%	46%	22%	67%	35%	57%	1%	0%	15%	37%	112%
2	MRG B. Batu Riti	Spline	16%	25%	59%	52%	24%	24%	30%	47%	21%	18%	8%	90%

No	Stasiun MRG	Analisis	Mei I	Mei II	Mei III	Jun I	Jun II	Jun III	Jul I	Jul II	Jul III	Agt I	Agt II	Agt III
1	MRG B. Batu Riti	IDW	89%	183%	27%	2216%	70%	258%	225%	244%	598%	775%	35%	390%
2	MRG B. Batu Riti	Spline	95%	174%	29%	2426%	77%	126%	307%	201%	877%	775%	62%	308%

No	Stasiun MRG	Analisis	Sep I	Sep II	Sep III	Okt I	Okt II	Okt III	Nov I	Nov II	Nov III	Des I	Des II	Des III
1	MRG B. Batu Riti	IDW	500%	570%	450%	31%	99%	47%	9%	48%	23%	25%	18%	3%
2	MRG B. Batu Riti	Spline	300%	743%	404%	54%	80%	86%	21%	3%	36%	0%	11%	16%

Volume Error Rerata			
1	MRG B. Babak	IDW	206%
2	MRG B. Babak	Spline	212%

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Based on Table 3.9 and Table 3.10 above, it can be seen that the MRG of Babak Dam for the Spline analysis isohyet method has a total error value of 34% and has a better value than the IDW Analysis, which is 37%. While for the MRG of Batu Riti Dam, it has a Total error for IDW Analysis of 206% and is better than the IDW Analysis, which is 212%. The error for the MRG of Babak Dam is better than the error in the MRG of Batu Riti Dam. This is because the location of the MRG of Babak Dam is near the automatic rainfall station (ARR) while for the Batu Riti Dam it is located far from the automatic rainfall station (ARR)

Correlation Analysis: Correlation coefficients at Bendung Babak: IDW = 68%, Spline = 67%. At Bendung Batu Riti: IDW = 81%, Spline = 72%. IDW generally correlates better with observed rainfall data, especially when observation points are close to ARR stations.

The correlation or relationship between the results of the Isohyet method, both IDW analysis and Spline, on observation data at the MRG Station is shown in the following figure:

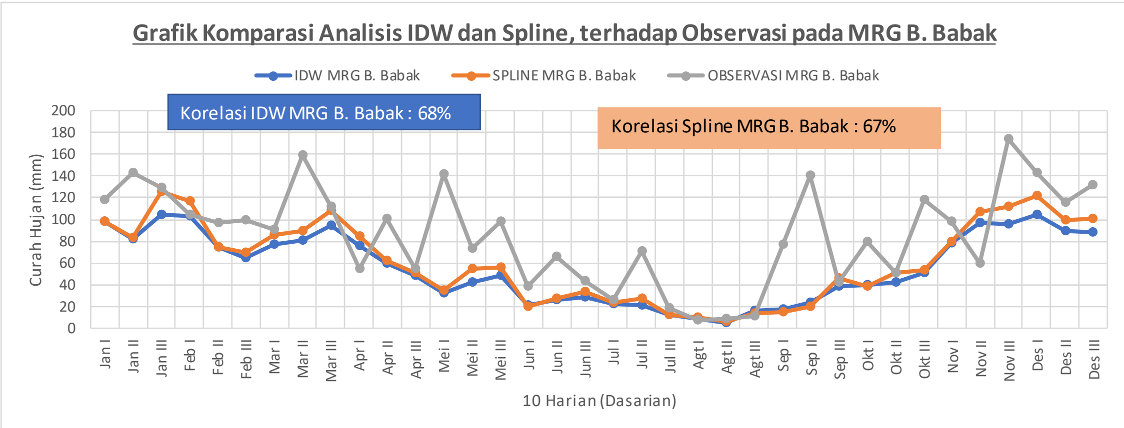

Figure 3.3. IDW and Spline Analysis Graphs of Observations on MRG B. Chapter

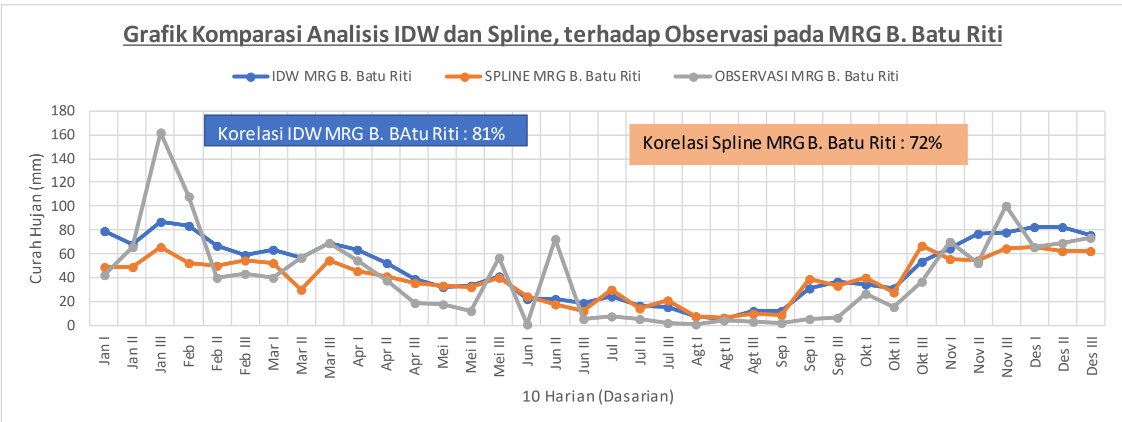

Figure 3.4 IDW and Spline Analysis Graphs of Observations on MRG B. Batu Riti

Based on Figure 3.3 and Figure 3.4, it is found that the Correlation of the Isohyet Method of IDW analysis on MRG Bendung Babak is better, which is 68%, compared to the Spline analysis on MRG Bendung Babak, which is 67%. While the Correlation of the Isohyet Method for IDW analysis on MRG Bendung Batu Riti is 81% better than the Spline analysis on MRG Bendung Batu Riti, which is 72%.

CONCLUSION

Based on the analysis conducted in this study, it can be concluded that the integration of the Isohyet method with IDW interpolation in a GIS-based rainfall mapping system provides more reliable rainfall estimates than the Spline method in the Babak Watershed. IDW interpolation yielded annual rainfall estimates of 2013 mm/year at MRG Bendung Babak and 1691 mm/year at MRG Bendung Batu Riti, while the Spline method produced 2210 mm/year and 1402 mm/year, respectively.

Error analysis indicated that although Spline had a slightly lower error at Bendung Babak (34%) compared to IDW (37%), IDW outperformed Spline at Bendung Batu Riti with a lower error (206% vs. 212%). These differences were primarily attributed to the proximity between observation points and the nearest ARR stations. Furthermore, correlation analysis showed that IDW achieved higher correlation coefficients—68% vs. 67% at Bendung Babak and 81% vs. 72% at Bendung Batu Riti—confirming its relative superiority.

Therefore, the Isohyet method combined with IDW interpolation is more suitable for rainfall estimation and hydrological planning in the Babak Watershed. This approach provides a practical and data-driven foundation for flood control strategies and the planning of water infrastructure projects, particularly in regions with limited rainfall monitoring stations.

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