Journal of Mechanical, Civil and Industrial Engineering
ISSN: 2709-0809
DOI: 10.32996/jmcie
Journal Homepage: www.al-kindipublisher.com/index.php/jmcie

JMCIE
AL-KINDI CENTER FOR RESEARCH AND DEVELOPMENT

| RESEARCH ARTICLE

Analysis of Hydrological Station Rationalization in Dompu Regency

Yayak Fitra Dikatanaya[1]✉, Heri Sulistiyono[2], and I. Wayan Yasa[3]
[1]*Postgraduate student in the Civil Engineering Department, University of Mataram, Mataram, Indonesia.*
[2]*Professor, Civil Engineering Post Graduate Study, University of Mataram, Mataram, Indonesia.*
[3]*Associate Professor, Civil Engineering Post Graduate Study, University of Mataram, Mataram, Indonesia.*
Corresponding Author: Yayak Fitra Dikatanaya, **E-mail**: yayakfdikatanayaeducation@gmail.com

| ABSTRACT
This study aims to rationalize the hydrological station network in Dompu Regency to establish an efficient, effective, and regionally representative hydrological monitoring system for the watershed. The analysis was carried out using the Kagan–Rodda Method, the Stepwise Method, and the World Meteorological Organization (WMO) Density Standard. The dataset consists of rainfall observations, river discharge data, and climatological variables sourced from the Nusa Tenggara I River Basin Authority I, the Indonesian Agency for Meteorology, Climatology, and Geophysics, and the Agency for Food and Horticultural Crop Protection. The results show that the existing hydrological station network does not meet the minimum World Meteorological Organization standards for station density and spatial distribution. Based on the Kagan Method, the ideal number of rainfall stations in Dompu Regency is 19, with an interpolation error of 1.01%. Meanwhile, the Stepwise Method indicates that the correlation between rainfall stations and water level gauging station remains low. According to WMO guidelines, Dompu Regency requires at least 93 rainfall stations, 8 water level gauging stations, and 8 climate stations to meet the representativeness standards for small mountainous island regions. Therefore, additional stations are needed along with the revitalization of hydrological equipment to improve data accuracy and the operational efficiency of the network.

| KEYWORDS

Rationalization, Hydrological Stations, Network Efficiency

| ARTICLE INFORMATION

ACCEPTED: 01 December 2025 **PUBLISHED:** 15 December 2025 **DOI:** 10.32996/jmcie.2025.6.5.1

1. Introduction

In hydrological analysis for water resources development, hydrological data—comprising rainfall data, discharge data, climatic data, and other related variables—are essential. These fundamental datasets serve as crucial inputs for generating ready-to-use information needed for the development, research, and management of water resources. Such information includes data on water availability, design floods, low flows, and sedimentation. Errors in monitoring basic hydrological data within a river basin results in inaccurate ready-to- use information, which in turn leads to inefficient and ineffective planning, research, and water resources management. In other words, when poor-quality data are collected, the outputs will likewise be of poor quality (Garbage In–Garbage Out). Conversely, when the data are properly monitored and supported by appropriate methods and competent human resources, effective and efficient planning, research, and water resources management can be achieved.

The quality of the basic data used in any analysis strongly depends on how well the existing hydrological stations can monitor the characteristics of the river basin, or in other words, how many hydrological stations are required in a basin to accurately and reliably observe its hydrological behavior. The issue, therefore, is whether the current number and distribution of stations within a river basin are adequate for monitoring its hydrological characteristics. It is neither feasible nor economically justified to install an excessively large hydrological network, as this will require substantial costs. When too many stations exist, additional

problems may also arise during hydrological analysis—for instance, determining which stations should be used, whether all or only a portion of them, and which ones are most dominant.
To optimize both cost and time, it is necessary to design a hydrological station network that is efficient from economic and management perspectives, yet still capable of producing information with the required level of accuracy for analytical purposes.
Considering the increasing annual costs of operating and maintaining hydrological stations— largely due to the aging of monitoring equipment—a study is needed to determine an effective and efficient network. Such a study enables the early identification of stations that are highly dominant and capable of representing the characteristics of the river basin, as well as stations that are less dominant and may be considered for relocation. Through this study, it is expected that the quantity and quality of data produced by the dominant stations can be maintained, the quality of equipment at these stations can be improved, and less dominant stations can be reallocated accordingly. Other institutions that also manage hydrological stations—particularly rainfall and climatological observation stations—include Indonesia Agency for Meteorology, Climatology, and Geophysics, the agriculture sector, the forestry sector, the Indonesian State Electricity Company (PLN), plantation companies, sugar mills, and irrigation projects, among others. Meanwhile, water level gauging stationare also operated by PLN and irrigation projects.

In anticipation of future challenges—particularly the increasing costs of operation and maintenance due to aging equipment—it has become difficult to continuously secure sufficient funding. Therefore, it is necessary to design an effective and efficient hydrological monitoring network. To streamline and facilitate the rationalization process, supporting software is required, including database systems, information systems, and modeling tools that aid in network rationalization, along with hardware such as computers, scanners, printers, and related equipment. An effective and efficient hydrological station network is expected to be achieved through the support of fast, accessible, accurate, and up-to-date information, which can then be used to meet the objectives of planning, research, and management activities. The rationalization itself involves a series of tasks, including surveys, identification and inventory of hydrological stations, and analytical assessments using various methods and approaches to determine the ideal and effective number of stations within a given region. The issue currently faced in Dompu Regency is the insufficient number of hydrological stations capable of representing the area in a statistically reliable manner, resulting in non-compliance with WMO (World Meteorological Organization) standards.

2. Literatur Review

Previous studies on hydrological-station rationalization are reviewed as follows. Arifah et al. (2018) conducted a study on the rationalization of the rainfall-station network in the Kemuning Watershed, Sampang Regency (area of 344.33 km²), East Java, Indonesia. The study applied the WMO, Kagan–Rodda, and Kriging methods to evaluate six existing rainfall stations. The WMO method, based on the analysis of influence areas using Thiessen polygons, indicated that none of the existing stations met the minimum WMO criteria, which recommend one station representing an area of 100–250 km². Theoretically, the Kemuning Watershed should be served by a maximum of three stations; however, their effectiveness required verification using other rationalization methods. The Kagan–Rodda method selected four stations to be retained based on rainfall correlation coefficients; however, relocation was required due to a high average Relative Error (KR) of 70.81%. In contrast, the Kriging method identified Recommendation II, which retained four stations and produced the smallest error (KR = 5.98%), along with the best statistical performance (R^2 = 0.492; R = 0.701). Consequently, the Kriging method was considered the most effective approach for determining the optimal number and spatial distribution of rainfall stations in the Kemuning Watershed.

Anggun Setyaningrum et al. (2022) investigated the rationalization of rainfall and water-level stations in the Bango Sub-Watershed, Brantas River Basin, East Java (area of 244.9 km²), using the WMO and Stepwise methods applied to seven rainfall stations and one water-level station. The WMO method, based on Thiessen polygon analysis, showed that none of the existing rainfall stations met the minimum WMO criteria, indicating that the sub-watershed should ideally be served by a maximum of two rainfall stations, although further evaluation was required. The Stepwise method, which assessed the influence of rainfall stations on discharge at the water-level station, identified only two rainfall stations with significant influence, yielding a correlation coefficient of R = 0.66.

Firyal Sekar Kafidani (2023) conducted a study on the rationalization of the hydrological-station network in the Rejoso Watershed, Pasuruan Regency, East Java, Indonesia (area of 206.567 km²), using rainfall-station data, water-level station data, and CHIRPS satellite rainfall data. The study applied the WMO and Stepwise methods to evaluate eight existing rainfall stations and one water-level station. The WMO analysis, based on Thiessen polygon influence areas, showed that none of the existing rainfall stations met the minimum WMO criteria, indicating that the watershed should ideally be served by a maximum of two rainfall stations, although further verification using other rationalization methods was required. The Stepwise method, which examined the influence of rainfall stations on discharge at the Winongan water-level station, identified two rainfall stations with strong correlations (R = 0.849 and 0.890) and satisfactory classical assumption test results. The rainfall data from the selected stations were further validated through comparison with CHIRPS satellite rainfall data, yielding acceptable performance (0.50 <

NSE ≤ 0.65; R > 0.8), indicating that the ground-based rainfall data adequately represented the rainfall characteristics of the study area.

3. Methodology

3. a. Materials and Methods

The study area is located in Dompu Regency. Astronomically, Dompu Regency lies between 117°42'–118°30' East Longitude and 5°54'–8°04' South Latitude. Geographically, the boundaries of Dompu Regency are as follows: to the north, the Flores Sea and Bima Regency; to the south, the Indonesian Sea; to the west, Sumbawa Regency; and to the east, Bima Regency. The total area of Dompu Regency is 2,324.55 km², with elevations in the urban area ranging from 15 to 62 meters above sea level.

The data used in this study include monthly rainfall data, the coordinates of rainfall stations, the coordinates of hydraulic structures (such as dams, reservoirs, and weirs), and maps of Dompu Regency. The rainfall data were obtained from the Dompu 1, Kadindi, and Dompu BWS rainfall stations, each with a record length of 10 years. The discharge data were sourced from the Matua and Raba Laju water-level stations, also with a 10-year data record.

The objective of the rationalization is to establish a hydrological network that is efficient, effective, and capable of representing the present and future hydrological conditions of the region, thereby minimizing the operational and maintenance costs of hydrological stations. The rationalization methods employed in this study include the Kagan–Rodda Method, the Stepwise Method, and the WMO Density Method.

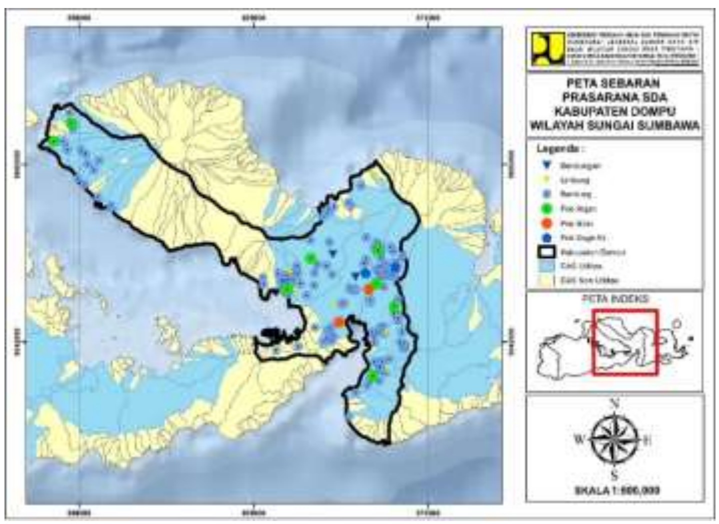

Figure 1. Water Resources Infrastructure Distribution Map of Dompu Regency.

3. b. Rationalization of Rainfall Stations Using the Kagan Method

Among the various approaches for determining rainfall station networks, the Kagan Method is relatively simple, both in concept and in its computational procedure. In addition to providing the required number of stations with a specified level of accuracy, the Kagan Method also offers a clear pattern for the spatial placement of rainfall stations (Harifa et al., 2020).

Fundamentally, this method applies statistical analysis by examining the relationship among rainfall-station network density, interpolation error, and smoothing error. From this analysis, a relationship is derived between the spacing of stations and the magnitude of smoothing or interpolation error, allowing the determination of an optimal station spacing corresponding to an acceptable level of error. Based on this optimal spacing, an equilateral-triangle network is constructed, in which the vertices represent the theoretical ideal locations for rainfall stations. The correlation function can be expressed as shown in the following equation (Rodhita, Limantara, and Dermawan 2012):

$$R_{(d)} = R_{(o)}\, e^{-d/d_{(o)}} \quad (1)$$

$$Z_1 = Cv \sqrt{\left[1 - r_{(o)} + \left(0{,}23\sqrt{A}\right) / d_{(o)}\sqrt{n}\right] / n} \quad (2)$$

$$Z_3 = Cv \sqrt{\left(1 - r_{(o)}\right) / 3 + 0{,}52\, r_{(o)} / d_{(o)} \sqrt{A/n}} \quad (3)$$

$$L = 1{,}07 \sqrt{A/n} \quad (4)$$

Notes : $R_{(d)}$ = correlation coefficient for distance d (km), $R_{(o)}$ = extrapolated correlation coefficient between stations, Cv = coefficient of variation, d = distance between stations (km), $d_{(o)}$ = correlation radius, A = watershed area (km^2), n = number of stations, Z_1 = interpolation error (%), Z_3 = smoothing error (%), and L = spacing between stations (km).

The steps for determining the density of a rainfall-station network using the Kagan Method are as follows (R.L. Kagan 1966; World Meteorological Organization 1972):

- Calculate the coefficient of variation (Cv) based on rainfall data from the available stations, using either daily or monthly data as required ;
- Establish the relationship between station spacing and the correlation coefficient, for both daily and monthly rainfall ;
- Develop the relationship between station spacing and correlation in the form of an exponential curve following the correlation-function equation. From this curve, the values of $R_{(o)}$ and $d_{(o)}$ are obtained by fitting the data to the equation ;
- Calculate the parameters Z_1 and Z_3 after determining the desired level of accuracy ;
- After determining the required number of stations in the study area, identify their placement by calculating the spacing between stations. Next, construct a network of equilateral triangles with side length equal to L, as illustrated in Figure 2.

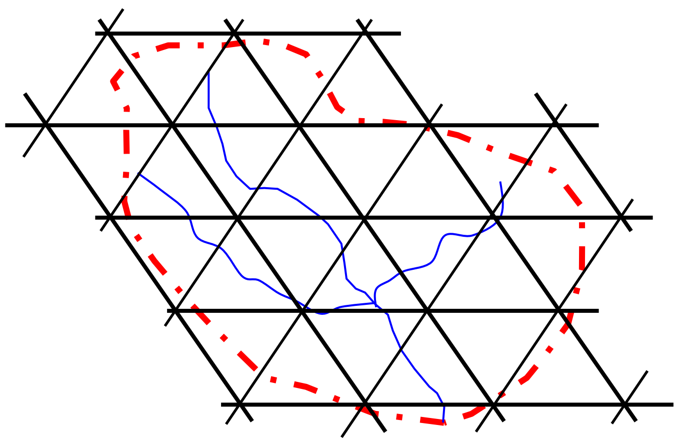

Figure 2. Equilateral triangle of the Kagan method.

3.c. Minimum Density Standards of the World Meteorological Organization (WMO)

The World Meteorological Organization (WMO) provides guidelines on the minimum network density for various regions, as shown in Tables 1 through 3 (Shaw, 1988). Network density refers to the number of stations per unit area within a given region. However, these guidelines serve only as general recommendations; the greater the variability of rainfall, the larger the number of stations required.

Table 1. Minimum Density of Climatological Station Networks

Types of Regional Descriptions	Minimum Network Density (km^2/ station)
Lowland areas : tropical mediterranean and temperate.	1.0 – 2.500 (600 – 900)

Mountainous areas: tropical mediterranean and temperate.	300 – 2.500 (100 – 250)
Small mountainous island regions with variable rainfall	140 – 300
Arid and polar regions	5.000 – 20.000 (1.500 – 10.000)

Table 2. Minimum Density of Rainfall Station Networks and Minimum Density of Water Level Stations

Types of Regional Descriptions	Minimum Network Density of Rainfall Station Networks (km^2/station)	Minimum Network Density of Water Level Stations (km^2/station)
Plains in temperate, mediterranean or tropical zone.	600 - 900	1000 - 2500
Mountainous areas in temperate, Mediterranean, or tropical zones.	100 - 250	300 - 1000
Small mountainous islands with uneven rainfall distribution and very dense river drainage patterns.	25	140 - 300
Arid and polar regions An area is classified as arid when annual rainfall is less than 300 mm/year.	1.500- 10.000	5000- 20.000

3.d. Stepwise Method

The fundamental concept of the Stepwise method is multiple correlation. This method correlates a dependent variable with several independent variables. It was applied to monthly rainfall data as independent variables and monthly river discharge data as the dependent variable within a watershed (WS/DAS/Sub-DAS). The elaboration of the Stepwise model is as follows: For instance, if a watershed had five rainfall stations (A, B, C, D, and E) and one discharge station (F), as shown in Figure 5, the model would determine the correlations between:

- A to B, A to C, A to D, A to E, and A to F ;
- B to C, B to D, B to d E, and B to F ;
- C to D, C to E, and C to F ;
- D to E, and D to F ;
- E to F.

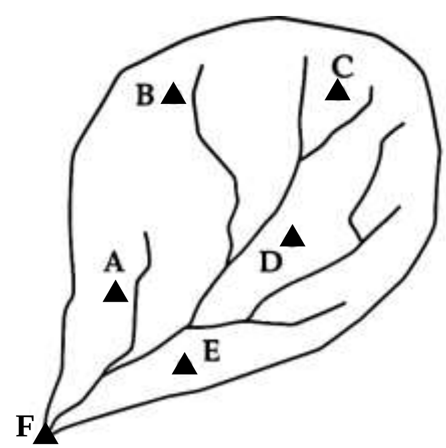

Figure 3. Illustration of the Hydrological Station Network.

The model calculated the correlation coefficient, standard deviation, standard error of estimate, multiple correlation coefficient, goodness of fit, t-value, beta coefficient, and its constant. The Stepwise method was used to rationalize the rainfall station network. The advantage of this model was that it identified the most dominant rainfall stations with the strongest correlation to the water level gauging station. Additionally, the number of rainfall stations that significantly influenced the discharge data could be determined by evaluating the improvement in the multiple correlation coefficient value. If the increase became insignificant compared to the previous multiple correlation coefficient value, the required number of stations could be determined.

The relationship between the number of rainfall stations exhibiting the best correlation with the discharge station and their correlation coefficients is illustrated in Figure 3. Monthly mean rainfall from several stations and their correlation coefficients with river discharge at a specific observation point The curve indicates that increasing the number of rainfall stations beyond a certain threshold does not significantly improve the multiple correlation coefficient. Therefore, the number of rainfall stations to be selected depends on the desired accuracy level. The basic concept of the Stepwise method is multiple correlation:

$$Y = aX1 + bX2 + cX3 + dX4 + \ldots \quad + n\,XZ \tag{5}$$

Notes : $X1$: Independent variables (rainfall). Y : Dependent variable (discharge). a,b,c……n = Coefficients.

The principle of this method was to determine the correlation between stations both individually and collectively (multiple regression – Stepwise). This method consisted of one dependent variable and some independent variables. The dependent variable was the observed monthly discharge, while the independent variables were the observed monthly rainfall data from stations within the studied watershed. This method also calculated the correlation coefficients among independent variables (rainfall stations data) and determined which independent variable (rainfall station) had the strongest correlation with the dependent variable (discharge station data). In addition to calculating correlation coefficients, the method also measured the standard deviation, standard error of estimate, multiple correlation coefficient, goodness of fit, t-value, beta coefficient, and the constant term of the multiple correlation equation.

The selection process was carried out step by step between the dependent variable (water level gauging station data) and the independent variables (rainfall station data). This process allowed the influence of correlation coefficient changes to be evaluated when a watershed contained multiple independent variables. In other words, this method could identify which independent variables (rainfall stations) had the strongest correlation with the dependent variable (water level gauging station). For example, if Station B yielded a multiple correlation coefficient of X_1, the model would then search for the next alternative by adding another rainfall station, for instance Stations B and D, resulting in a coefficient X_2 ($X_2 > X_1$). This process continued, producing values such as ($X_5 > X_4 > X_3 > X_2 > X_1$). In such a condition, the decision-maker determined whether it was appropriate to use two, three, or all five rainfall stations.

To evaluate the number of required rainfall stations, the improvement in the multiple correlation coefficient was considered. Dominant stations in a watershed could be identified, while less influential stations might be relocated. The relocation decision was left to the hydrology management authority. New station locations should ideally refer to monthly Isohyet maps and/or topographic data, as these reveal areas needing rainfall stations to represent watershed conditions properly.

4. Result

4.a. Kagan-Rodda Method Analysis

The first step in the Kagan Method is determining the distance and correlation among reference stations. The distance calculation results are shown in Table 2.

Table 3. Distance between rainfall stations (km)

	Kadindi	Dompu BWS	Dompu
Kadindi	0.0		
Dompu BWS	151.2	0.0	
Dompu	82.4	213.2	0.0

After calculating the distances between the rainfall stations used in this study, the next step was to perform correlation analysis on the rainfall data from each station.

Table 4. Correlation coefficients between rainfall stations

	Kadindi	Dompu BWS	Dompu
Kadindi	1.00		
Dompu BWS	0.72	1.00	
Dompu	0.65	0.75	1.0

Based on the calculated distances and correlation coefficients among rainfall stations, an exponential relationship was illustrated, as shown in Figure 4. The graph indicates an R_0 value of 0.596 and a d_0 value of 0.0011.

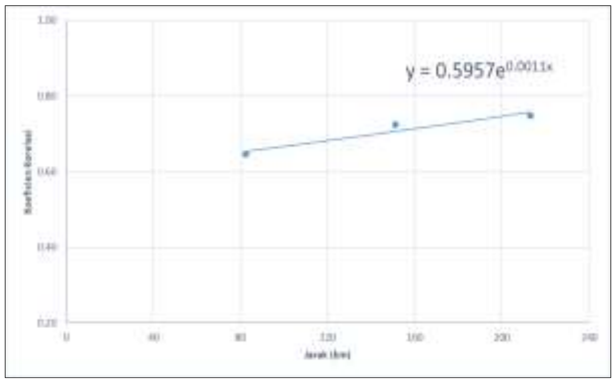

Figure 4. Graph of the Relationship Between the Correlation Coefficient and the Distance Between Rainfall Stations in Dompu Regency.

The obtained values were then substituted into Equations (2) and (3), after determining the required number of stations based on the smoothing error (Z1) and interpolation error (Z3). Subsequently, calculations were performed to determine the side lengths of the Kagan triangle, followed by constructing Kagan triangles with interpolation error levels of 1%, 2%, 3%, 4%, and 5%. The side lengths of the Kagan triangle for each condition are presented in Table 5.

Table 5. Relationship between N, Z1, Z3, and L

N	Z1	Z3	L
1	4.35	2.39	51.59
2	3.09	2.44	36.48
3	2.53	2.46	29.78
4	2.19	2.47	25.79
5	1.96	2.48	23.07
6	1.79	2.48	21.06
7	1.66	2.49	19.50
8	1.55	2.49	18.24
9	1.46	2.50	17.20
10	1.39	2.50	16.31
11	1.33	2.50	15.55
12	1.27	2.50	14.89
13	1.22	2.51	14.31
14	1.18	2.51	13.79
15	1.14	2.51	13.32
16	1.10	2.51	12.90

17	1.07	2.51	12.51
18	1.04	2.51	12.16
19	1.01	2.51	11.84
20	0.98	2.51	11.54

After determining the side lengths, Kagan triangles with interpolation errors of 1%, 2%, 3%, 4%, and 5% were constructed iteratively until the number of existing and additional stations resulting from the rationalization met the WMO requirements. Based on the table above, the number of rainfall stations, error level, and inter-station distances can be identified. An optimal configuration was obtained with L = 11.84 km, a smoothing error of 1.01%, and a total of 19 rainfall stations. The rationalized network layout according to the Kagan–Rodda method for Dompu Regency is shown in Figure 5.

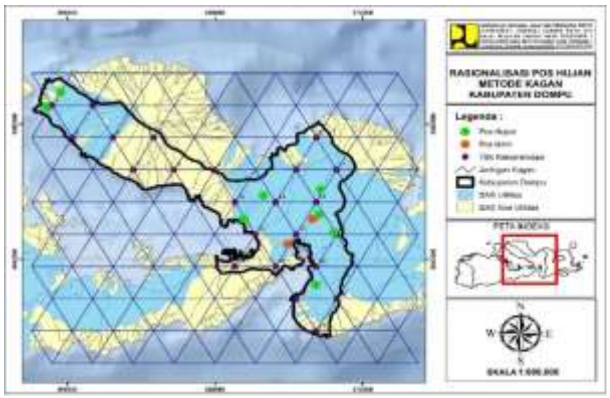

Figure 5. Hydrological Station Rationalization Map
Based on the Kagan Method, Dompu Regency.

4.b. Stepwise Method Analysis

The Stepwise analysis in Dompu Regency was conducted using correlations between the Raba Laju and Matua water level gauging stations and the Dompu and Dompu BWS rainfall stations. The following presents the correlation between rainfall stations and water level gauging stations in Dompu Regency.

Figure 6. Graph of the Relationship Between Correlation Values and
Rainfall Stations Influencing the Raba Laju Water Level Station.

Based on the graph, the Dompu Rainfall Station and the Dompu BWS Rainfall Station demonstrate a very weak influence on the Raba Laju Water Level Station. This is indicated by the very low correlation values = 0.028 for the correlation between the Raba Laju Water Level Station and the Dompu Rainfall Station, and 0.173 for the correlation between the Raba Laju Water Level Station and the Dompu BWS Rainfall Station.

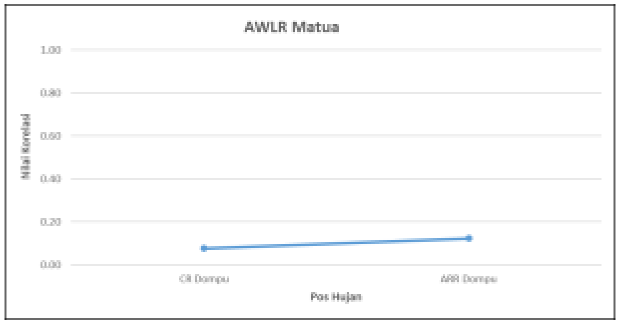

Figure 6. Graph of the Relationship Between Correlation Values and Rainfall Stations Influencing the Matua Water Level Station.

Similarly, both rainfall stations also exhibit a weak influence on the Matua Water Level Station. The correlation values are 0.077 for the relationship between the Matua Water Level Station and the Dompu Rainfall Station and 0.123 for the relationship between the Matua Water Level Station and the Dompu BWS Rainfall Station. Therefore, it can be concluded that the recorded rainfall at these two stations contributes insignificantly to water level fluctuations at both the Raba Laju and Matua Water Level Stations.

4.c. Minimum Station Density Analysis Based on WMO Standards

Based on Tables 1, 2, and 3, Dompu Regency falls under Category 2: small mountainous islands, characterized by uneven rainfall distribution and dense drainage networks, covering an area of 2,324.55 km². The minimum and optimal number of stations required based on WMO standards are as follows.

Table 6. Number of rainfall stations required in Dompu Regency

Number of Existing Stations	Minimum Number of Stations	Optimal Number of stations
8	93	93

Table 7. Number of water level gauging stations required in Dompu Regency

Number of Existing Stations	Minimum Number of Stations	Optimal Number of stations
2	8	17

Table 8. Number of climate stations required in Dompu Regency

Number of Existing Stations	Minimum Number of Stations	Optimal Number of stations
2	8	17

5. Conclusion

- Based on the analysis, to achieve an ideal rainfall station distribution, 21 additional rainfall stations are required in Dompu Regency. These new stations are recommended to be located at water resources infrastructure such as dams, reservoirs, or weirs. Among the existing stations, 6 stations should be retained and 2 stations upgraded ;
- Based on the WMO density method, the minimum required number of water level gauging stations and climate stations is eight units each. In contrast, the existing number of stations currently consists of only two water level gauging stations and two climate stations. Therefore, an additional six stations for each category are required to meet the minimum station density standards prescribed for Dompu Regency ;
- Revitalization is necessary for hydrological stations that have deteriorated either in structure or instrumentation.

Funding: his research did not receive any financial support from other organizations or institutions. All expenses and required resources were provided by the author. No entity was involved in any stage of the research, and it is confirmed that there was no support that could influence the results. This reflects the author's independence.
Conflicts of Interest: Conflict of Interest: The author declares that there are no conflicts of interest in this study. There are no financial or personal relationships that could affect the research. All opinions and conclusions are based on scientific evidence, and this statement contributes to the transparency and ethics of the research.
Acknowledgment: I would like to express my sincere gratitude to Prof. Ir. Heri Sulistiyono, M.Eng., Ph.D. and Dr. Ir. I Wayan Yasa, S.T., M.T., IPM. for their guidance and supervision throughout all stages of the research and writing process, which enabled this manuscript to comply with the standards of academic research and journal publication. I also extend my appreciation to PSDA Team of the Nusa Tenggara I River Basin (Balai Besar Wilayah Sungai Nusa Tenggara I) for providing valuable data and insightful knowledge that supported this study. Finally, I would like to express my deepest gratitude to my father, Drs. Nasrullah, my mother, Sumarni, my two younger siblings, Isabela Amanda Putri Tanaya and M. Arsy Wattatanaya, and Dinda Zuliafitri S. Ars, for their continuous support, encouragement, and understanding throughout the completion of this research.
Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers.

References

[1] Arifah, S., Suhartanto, E., & Chandrasasi, D. (2018). Rationalization of rainfall station networks in the Kemuning Watershed, Sampang Regency, using the Kagan–Rodda method. Jurnal Mahasiswa Jurusan Teknik Pengairan, 1(2), 15–22. https://repository.ub.ac.id/11485/2/JURNAL.pdf
[2] Bakhtiari, B., Nekooamal Kermani, M., & Bordbar, M. H. (2013). Rain gauge station network design for Hormozgan Province, Iran. Journal of Water Resource and Protection, 18, 45–52.
[3] Harifa, A. C., Charits, M., Setiono, J., & Khamim, M. (2020). Evaluation of rainfall station networks in the Dumoga–Sangkub River Basin. Jurnal Teknik Pengairan, 5(1), 37–50.
[4] Hartono, R. (2016). Identification of soil erosion forms through Google Earth image interpretation in the Sumber Brantas area, Batu City. Jurnal Pendidikan Geografi, 21(1), 30–43.
[5] Junaidi, R. (2015). Rationalization study of rainfall station networks in the Parigi–Poso River Basin, Central Sulawesi, using the Kagan–Rodda and kriging methods. Jurnal Ilmu-Ilmu Teknik – Sistem, 11(1), 22–31.
[6] Kafidani, F. S., Suhartanto, E., & Wahyuni, S. (2023). Rationalization of hydrological station networks using rainfall station data, CHIRPS satellite rainfall data, and water-level station data with the stepwise method in the Rejoso Watershed. Jurnal Teknologi dan Rekayasa Sumber Daya Air (JTRESDa), 4(1), 1–14. https://jtresda.ub.ac.id/index.php/jtresda/article/view/638
[7] Kagan, R. L. (1966). An evaluation of the representativeness of precipitation data. Works of the Main Geophysical Observatory USSR, 191.
[8] Krisnayanti, D. S. (2007). Evaluation of rainfall station network density on the accuracy of design rainfall estimation in the Noelmina River Basin, Timor Island. Jurnal Teknik Sipil FST Undana, 57–71.
[9] Ministry of Public Works and Housing of the Republic of Indonesia. (2015). Regulation of the Minister of Public Works and Housing No. 04/PRT/M/2015 on criteria and designation of river basins.
[10] Ministry of Public Works and Housing of the Republic of Indonesia. (2017). Water resources management plan for the Sumbawa River Basin.
[11] Mulya, H. (2015). Rationalization study of the hydrological network on Seram Island, Maluku Province. Media Komunikasi Teknik Sipil, 20(1), 71–82.
[12] PT Virama Karya & Associates. (2010). Hydrology management training module I.
[13] Rodhita, M., Limantara, L. M., & Dermawan, V. (2012). Rationalization of rainfall gauge networks in the Kedungsoko Watershed, Nganjuk Regency. Jurnal Pengairan, 3, 185. https://jurnalpengairan.ub.ac.id/index.php/jtp/article/view/163
[14] Setyaningrum, A., Suhartanto, E., & Wahyuni, S. (2022). Rationalization of rainfall and water-level station networks using the stepwise method and WMO standards in the Bango Sub-Watershed. Jurnal Teknologi dan Rekayasa Sumber Daya Air (JTRESDa), 3(2), 153–162. https://jtresda.ub.ac.id/index.php/jtresda/article/view/464
[15] World Meteorological Organization. (1972). Precipitation: Statistical principles. In Casebook on hydrological network design practice (No. 324). World Meteorological Organization.