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# Cost Analysis of Additional Rainfall Station In The Kayan River Area, North Kalimantan Province

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**ABSTRACT**

With a total area of the Kayan River Basin (WS) reaching 3,178,215.72 hectares, when compared to other river basins in Kalimantan, the Kayan WS only has seven rain gauge stations, of which six are in good condition and one is damaged or inactive. Therefore, it is important to determine the appropriate rationalization method to obtain the appropriate number and distribution of rain gauge stations that can represent the characteristics of the area in the Kayan River Basin. The methods used to analyze the rationalization of these rain gauge stations include determining the maximum need, minimum need, and the Kagan-Rodda method. After evaluating several methods, the most suitable method for rationalizing rain stations in the Kayan WS is the Kagan-Rodda method. The results of the evaluation of the need for rain stations in the Kayan River Basin are 33 (thirty-three) stations; the existing rain stations number 6 (six) stations, requiring the addition of 27 (twenty-seven) new rain stations.

**Keywords:** Rationalization; Kagan-Rodda; Gark SK;1982.

## INTRODUCTION

Hydrological analysis is one of the most fundamental stages in water resources management. All planning and design activities for water structures—such as dams, reservoirs, irrigation channels, and flood control systems—rely heavily on the availability and reliability of hydrological data, particularly rainfall data (Bagheri-Gavkosh et al., 2025; Huo et al., 2020; Ngoepe et al., 2025; Ramirez et al., 2023; Shin et al., 2024). Rainfall data serves as the primary input for calculating design discharge, analyzing water availability, and estimating surface runoff (Goshime et al., 2019; Naidu & Chandniha, 2025). Hydrological analysis is crucial for the design of hydraulic structures, which rely heavily on rainfall data.

However, the number of rainfall stations and their distribution patterns must be considered when determining rainfall volume in a watershed unit (Ayu et al., 2019; Haromain et al., 2022; Widyawati et al., 2021). Therefore, enough and well-distributed rainfall stations are crucial to ensure that the data obtained accurately and representatively reflect rainfall characteristics throughout the river basin. Measurement errors often occur, leading to inaccurate data that can result in ineffective and inefficient data processing. The number and distribution of rainfall stations significantly influence measurement errors (Azhari et al., 2022b, 2022a; Fadilah & Retnowati, 2025; Megantara et al., 2022). Estimating the number and location of rain gauge stations is essential to provide adequate information about rainfall in a catchment area (Renaldhy et al., 2021).

The Kayan River Basin (WS) is one of many National Strategic River Basins in North Kalimantan Province. Based on the Regulation of the Minister of Public Works and Public

Housing (*Permen PUPR*) Number 4/PRT/M/2015 concerning the Criteria and Determination of River Basins, the *Kayan WS* is designated as a cross-district river basin within one province. This area encompasses two main regencies: Bulungan Regency, which covers the downstream and middle reaches of the Kayan River Basin (where the Kayan River flows into the Sulawesi Sea) and serves as the main location for economic activity, government, and urban infrastructure; and Malinau Regency, which covers the upstream part of the Kayan WS and is characterized by mountainous topography, high rainfall, and dense forest vegetation.

The total area of the Kayan River Basin reaches 3,178,215.72 hectares (equivalent to ±31,782 km²). Compared to other river basins in Kalimantan, the Kayan River Basin is considered very extensive, with complex physiographic variations ranging from densely forested mountainous areas in the upper reaches to lowlands in the lower reaches. This highly varied topography results in heterogeneous rainfall patterns, both in intensity and spatial distribution. For example, annual rainfall in the upper reaches of Malinau can be twice that of the coastal area of Bulungan.

Water resources management is one of the most critical challenges faced by many countries worldwide, especially in regions with unpredictable rainfall patterns and extensive watersheds. Proper data collection through rain gauge stations is essential for understanding hydrological behavior and making informed decisions about water management. Without accurate and representative rainfall data, efforts in flood control, irrigation management, and water resource planning could be ineffective, leading to adverse impacts on the environment and society.

The Kayan River Basin (WS) in North Kalimantan Province, Indonesia, covers an area of approximately 3.17 million hectares, with significant physiographic variations from mountainous areas to lowlands. Despite its size, the basin has only seven rainfall stations, which is insufficient for accurate hydrological analysis. Of these, one station is damaged, and the remaining six are not optimally distributed to represent the rainfall characteristics of the entire basin. This lack of adequate stations results in significant gaps in data accuracy, hindering effective water resources management.

This study is increasingly urgent given the importance of hydrological data in managing water resources, especially in areas prone to extreme weather events like floods and droughts. The Kayan River Basin's vast size and diverse topography require a more precise and rationalized network of rainfall stations. Without addressing this issue, future planning for infrastructure like dams, reservoirs, and flood control systems could suffer from unreliable data, leading to costly and ineffective interventions.

Several studies have explored the importance of rainfall station networks for hydrological analysis, but few have focused on the specific rationalization of rain stations in the context of the Kayan River Basin. Most previous research has either used generalized methods without considering the basin's unique geographical and topographical conditions or has concentrated on smaller, less complex watersheds. There is a clear gap in studies that integrate regional characteristics with rainfall station distribution to determine the optimal number and placement of stations.

This research introduces a novel approach by applying the Kagan-Rodda method to rationalize the rainfall station network in the Kayan River Basin, considering its unique topography and climatic variations. By integrating the Kagan-Rodda method with cluster analysis and Thiessen polygon analysis, the study aims to provide a more accurate assessment of the basin's rainfall patterns. This will be the first study to propose an optimized and tailored rain station network for this specific region.

The primary objective of this study is to determine the optimal number and distribution of rainfall stations in the Kayan River Basin using rationalization methods. The study seeks to address existing gaps in hydrological data by identifying areas where additional rainfall stations are needed, ensuring more representative data for water resource planning and management. By the end of this study, recommendations for new station placements will be provided to improve data coverage.

The findings of this study are crucial for local government agencies, environmental planners, and water resource managers. By optimizing the rainfall station network, the study will enhance the accuracy of rainfall data, directly contributing to better flood control measures, irrigation planning, and water resource management strategies. This research is vital not only for North Kalimantan but also serves as a model for other large river basins in similar geographical settings.

This research has broader implications for water resource management in Indonesia and beyond. A well-structured rainfall station network will enable more precise hydrological modeling, which is essential for addressing the challenges posed by climate change. With accurate rainfall data, it will be possible to predict water availability more reliably, aiding in the development of infrastructure that is resilient to both floods and droughts, ultimately contributing to sustainable development goals related to water access.

## METHOD

The object taken in this study is the rain station in the Kayan River Basin of North Kalimantan Province, Kayan WS has a total area of 3,178,215.72 Ha which covers 2 regencies in 1 province. The study period was carried out for 3 (three) months, namely from October 2025 to December 2025, which included primary and secondary data collection, data processing and analysis as well as thesis writing. The data analysis techniques used in this study were carried out in several stages of analysis, namely: Cluster Analysis Unit Analysis (CAU), Thiessen Polygon Analysis, Kagan-Rodda Method.

## RESULTS AND DISCUSSION

### Cluster Analysis Unit Analysis (CAU)

To facilitate data analysis, it is necessary to divide the analysis cluster units as a basis for calculating rainfall post requirements. In this case, the division of analysis clusters is adjusted to the existing watershed divisions in accordance with PUPR Ministerial Regulation No. 4/PRT/M/2015, as can be seen in the figure.

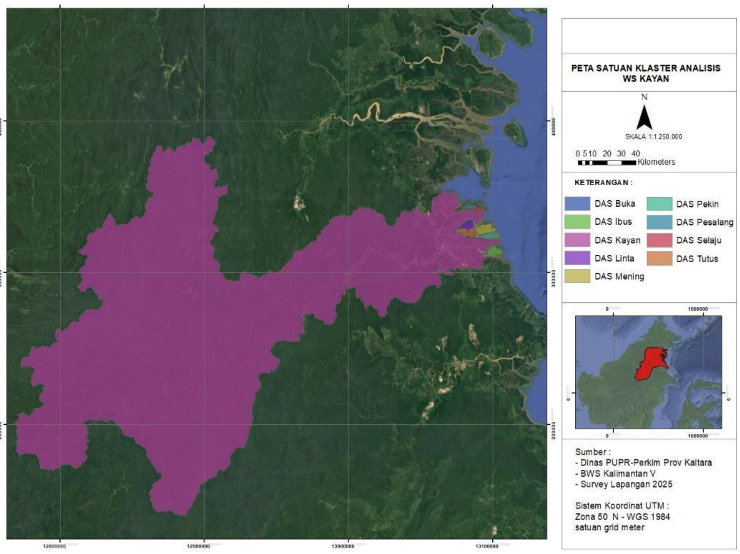


**Figure 1.** Division of Analysis Cluster Units According to the Number of Watersheds
Source: Analysis Results, 2025

**Thiessen Polygon Analysis**

**Table 1. Area of Influence of Thiessen Polygon in Kayan Watershed**

| No | Station Name | Speed Km$^2$ |
|---|---|---|
| 1 | CH. Hang out with Aru | 2.8642,41 |
| 2 | CH. Antutan I | 330,36 |
| 3 | CH. Antutan II | 799,76 |
| 4 | CH. Kulteka | 1.109,50 |
| 5 | CH. Public Works Office | 425,98 |
| 6 | CH. Tanjung Harapan | 184,38 |

Source: Analysis Results, 2025

**Determination of Optimum Requirements (GARG SK, 1982)**

Number of rain stations:

$$N = (\frac{28{,}79}{10})^2$$

Coefficient of variation of rainfall:

$$C_{in} = \frac{100x740{,}43}{2.571{,}75}$$

Standard Deviation:

$$\sigma = \left[\frac{6}{6-1}\{\{7.070761{,}26 - (2.571{,}75)^2\}\right]^{½}$$

Average Rainfall from n stations:

$$\underline{p} = \frac{15.430{,}5}{6}$$

with:

N : number of rainfall stations
Cv : the coefficient of variation of rainfall is based on the existing rainfall stations
AND : percentage of permissible error
p : average annual rainfall
$\underline{p}$ : average rainfall from n stations
n : number of existing rain stations

s : standard deviation

Based on the calculation results using the formula presented by Garg SK (1982), the overall optimum requirement for rainfall stations in the Kayan River Basin is 9. From all the watershed analysis cluster units, it can be seen that in the Kayan River Basin, namely the Kayan River Basin, there are additional rainfall stations. In detail, the Kayan River Basin requires the addition of 3 rainfall stations, while for the other 8 watersheds this cannot be done because there is no rainfall data that can be analyzed to calculate the optimum rainfall station requirement.

**Table 2. Optimal Rainfall Station Requirements Per Analysis Cluster Unit/DAS**

| No | THE | Area (Ha) | Number of Existing Posts | | | | Needs Plan | Adding New Posts |
|---|---|---|---|---|---|---|---|---|
| | | | Existing Amount | Active/Functional | Needs Improvement | Not active | | |
| 1 | DAS Equipment | 3.149.239,3 | 7 | 6 | 0 | 1 | 9 | 3 |
| 2 | Pesalang Watershed | 2.981,74 | 0 | 0 | 0 | 0 | 0 | 1 |
| 3 | Open Watershed | 1.208,41 | 0 | 0 | 0 | 0 | 0 | 1 |
| 4 | DAS Selaju | 2.214,06 | 0 | 0 | 0 | 0 | 0 | 1 |
| 5 | DAS Linta | 4.685,37 | 0 | 0 | 0 | 0 | 0 | 1 |
| 6 | THE Tutu | 4.050,21 | 0 | 0 | 0 | 0 | 0 | 1 |
| 7 | Mening Watershed | 6.693,95 | 0 | 0 | 0 | 0 | 0 | 1 |
| 8 | Pekin Watershed | 3.232,28 | 0 | 0 | 0 | 0 | 0 | 1 |
| 9 | DAS Ibus | 3.910,4 | 0 | 0 | 0 | 0 | 0 | 1 |
| **Total Area of WS** | | **3.178.215,72** | **7** | **6** | **0** | **1** | **9** | **11** |

*Source: Author's processing, 2025*

The Kayan River Basin, with an area of approximately 31,782 km², has six rainfall stations. The distances between the surrounding stations and the correlation between the available data were then calculated. Table 3 shows the distances between stations whose locations have been confirmed. Analysis of the distribution of rainfall stations using the Kagan-Rodda method revealed 27 additional rainfall stations in the Kayan River Basin.

**Table 3. Distance between rainwater posts in the Kayan watershed**

| Jarak (km) | CH. Hang out with Aru | CH. Antutan I | CH. Antutan II | CH. Kulteka | CH. Public Works Office | CH. Tanjung Harapan |
|---|---|---|---|---|---|---|
| CH. Hang out with Aru | - | 13,0 | 140,8 | 14,0 | 101,2 | 118,2 |
| CH. Antutan I | 13,0 | - | 131,4 | 26,6 | 100,3 | 108,4 |
| CH. Antutan II | 140,8 | 131,4 | - | 153,8 | 91,2 | 23,7 |

| Jarak (km) | CH. Hang out with Aru | CH. Antutan I | CH. Antutan II | CH. Kulteka | CH. Public Works Office | CH. Tanjung Harapan |
|---|---|---|---|---|---|---|
| CH. Kulteka | 14,0 | 26,6 | 153,8 | - | 108,1 | 131,4 |
| CH. Public Works Office | 101,2 | 100,3 | 91,2 | 108,1 | - | 82,7 |
| CH. Tanjung Harapan | 118,2 | 108,4 | 23,7 | 131,4 | 82,7 | - |

*Source: Author's processing, 2025*

The initial step before conducting a correlation study between rainfall stations is to find out the data conditions of each rainfall station, in the form of an annual rainfall data series.

$$r_{(d)} = r_{(0)} and^{\frac{-d}{d_{(0)}}}$$

$$Z1 = Cv\sqrt{\frac{1-r_{(0)}+0,23\frac{\sqrt{A}}{d_{(0)}\sqrt{n}}}{n}}$$

$$Z2 = Cv\sqrt{\frac{1}{3}}\left(1 - r_{(0)}\right) + 0,52\frac{r_{(0)}}{d(0)}\sqrt{\frac{A}{n}}$$

Kayan Watershed Network $L = 1,07\sqrt{\frac{A}{n}}$

$$L = 1,07\sqrt{\frac{31.782}{33}}$$

$$L = 1,07\, x\sqrt{5.297}$$

$$L = 33.21\ km$$

Where:

$r_{(d)}$ : correlation coefficient of station distance d
$r_{(0)}$ : short station distance correlation coefficient
d : distance between rainfall stations (km)
$d_{(0)}$ : correlation radius
Cv : coefficient of variation
A : watershed area ($km^2$)
n : number of stations
Z1, Z2 : alignment error (%)
THE : interpolation error (%)
L : distance between stations (km)

Based on the calculation results in determining the kagan wheel nets, the calculation for the side length of the kagan wheel nets in the Kayan watershed is 33.21 km. After knowing several calculations of hydrological post requirements, the next step will be to choose the most appropriate method for the Kayan WS based on several considerations, namely the Kagan-Rodda method.

## CONCLUSION

The analysis of rationalizing hydrological posts in the Kayan River Basin successfully addresses the four existing problem formulations, concluding that 13 rain stations are needed to meet standards—requiring relocation of 2 existing stations and addition of 6 new ones. Among the methods evaluated, the Kagan-Rodda method proved most appropriate for this basin. For future research, investigators could validate these recommendations through long-term field implementation and monitoring of the optimized network's impact on hydrological modeling accuracy, potentially integrating advanced geospatial technologies like remote sensing or machine learning for dynamic adjustments amid climate change.

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