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# Impact of Rainfall Intensity and Water Management System on Flood Risk in West Java

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## ABSTRACT

This study investigates the impact of rainfall intensity and water management systems on flood risk in West Java, Indonesia. Employing a quantitative approach, data were collected from 125 respondents residing in flood-prone areas through a structured Likert-scale questionnaire. Statistical analysis using SPSS version 25, including descriptive, correlation, and multiple regression tests, was conducted to evaluate the relationship between climatic and infrastructural factors affecting flood risk. The results indicate that rainfall intensity has a significant positive effect on flood risk, implying that higher rainfall intensity directly increases the probability and severity of flooding. Conversely, water management systems demonstrate a significant negative effect, showing that well-maintained drainage networks and effective community-based water governance substantially mitigate flood occurrences. The regression model revealed that both variables jointly explain 53.4% of the variance in flood risk levels, emphasizing the combined importance of climatic adaptation and infrastructural improvement. The study concludes that effective water management systems can serve as a critical resilience mechanism to counter the adverse impacts of increasing rainfall intensity. These findings provide empirical insights for policymakers, planners, and local authorities to design integrated, sustainable flood mitigation strategies tailored to West Java's urban and environmental contexts.



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## 1. INTRODUCTION

Flooding remains one of the most frequent and devastating natural disasters affecting Indonesia, particularly in the province of West Java. The region's complex topography, rapid urbanization, and inadequate drainage infrastructure have made it highly vulnerable to both pluvial and fluvial flooding events. According to the Indonesian National Board for Disaster Management (BNPB), West Java consistently records one of the highest annual flood frequencies in the country, causing significant disruptions to livelihoods, property, and local economies. The intensification of rainfall patterns—attributed to climate variability and the increasing unpredictability of monsoon cycles—further amplifies this risk [1]. Flood events in major cities such as Bandung, Bekasi, and Karawang illustrate how rainfall intensity, coupled with insufficient water management, can lead to large-scale inundation and economic loss [2].

In recent years, rainfall intensity has become a central factor in understanding flood dynamics, as extreme precipitation episodes have increased in both frequency and duration due to global climate change. Studies have shown that higher rainfall intensity tends to overwhelm urban drainage systems, resulting in rapid surface runoff and flash floods [3], [4]. However, rainfall alone does not fully explain the occurrence of flooding; the capacity and effectiveness of water management systems—such as drainage networks, retention ponds, river normalization programs, and flood control infrastructure—play a crucial moderating role. Inadequate planning, poor maintenance, and encroachment on riverbanks exacerbate the problem, transforming natural hydrological processes into social and infrastructural crises.

Effective water management systems are therefore a fundamental component of flood risk mitigation. The ability of local governments to design and maintain sustainable systems of water control directly influences the region's resilience to heavy rainfall events. Water management not only includes physical infrastructure but also involves governance mechanisms, such as early warning systems, public awareness campaigns, and institutional coordination among agencies [3], [5]. Despite various initiatives by the West Java provincial government, many urban and semi-urban areas continue to experience recurrent flooding, indicating gaps in policy implementation, community participation, and technical maintenance.

From a socio-environmental perspective, flood risk is shaped by both natural and anthropogenic factors. The interaction between rainfall intensity and human intervention in land and water systems determines the scale and frequency of flood events. As urbanization continues to expand, the conversion of permeable land surfaces into impervious structures such as roads and buildings significantly reduces water absorption capacity, thereby heightening the vulnerability of urban drainage systems. Understanding how rainfall intensity interacts with water management systems to influence flood risk can thus provide valuable insights for evidence-based planning and sustainable disaster management strategies.

This study aims to quantitatively analyze the impact of rainfall intensity and water management systems on flood risk in West Java. Using data collected from 125 respondents across flood-prone areas, the research applies a Likert-scale survey and statistical analysis through SPSS version 25 to examine both direct and combined effects of these variables. The results are expected to contribute to the formulation of integrated flood management strategies by highlighting the extent to which technical infrastructure and environmental factors jointly determine flood vulnerability. Moreover, the findings will inform local policymakers, urban planners, and environmental agencies in designing adaptive water governance frameworks capable of mitigating the growing threat of flooding in West Java.

## 2. LITERATURE REVIEW

### *2.1* Flood Risk and Its Determinants

Flood risk is commonly understood as a function of hazard, exposure, and vulnerability (UNISDR, 2015). Hazard refers to the likelihood of flood occurrence due to meteorological and hydrological conditions, while exposure and vulnerability relate to the degree to which people, infrastructure, and ecosystems are affected by such events. Flood risk is not merely a product of natural phenomena but also of anthropogenic activities that alter the natural water cycle. In the context of West Java, the rapid expansion of urban areas, inadequate drainage networks, and insufficient flood control infrastructure have intensified the impact of rainfall-induced flooding [3], [5]. According to [5], flood risk management requires a comprehensive understanding of both natural processes and human systems, emphasizing that effective mitigation involves not only technical measures but also social and institutional responses.

### 2.2 *Rainfall Intensity and Climate Variability*

Rainfall intensity is one of the primary drivers of flooding, particularly in tropical regions like Indonesia, where monsoon patterns dominate seasonal precipitation. The concept of rainfall intensity encompasses the rate at which rain falls within a given period, typically expressed in millimeters per hour (mm/hr). High-intensity rainfall leads to surface runoff that often exceeds the infiltration capacity of the soil, resulting in flash floods or prolonged inundations [5], [6]. Studies have shown that changes in global climate systems, such as El Niño–Southern Oscillation (ENSO), have significantly altered rainfall distribution patterns in Indonesia [7].

### 2.3 *Water Management Systems and Flood Mitigation*

Water management systems play a pivotal role in controlling flood occurrences and mitigating their impacts. Broadly defined, water management encompasses all measures designed to control the flow, storage, and use of water within a specific catchment area [8], [9]. This includes structural interventions such as drainage channels, dikes, retention basins, and river normalization, as well as non-structural measures like community education, zoning regulations, and disaster preparedness programs. In Indonesia, the government's water management strategy is guided by Law No. 17 of 2019 on Water Resources, which emphasizes sustainability and public participation in flood mitigation.

Effective water management requires both technical and institutional coordination. Research by [10] demonstrates that decentralized management through community-based water governance significantly enhances system resilience by promoting local accountability. However, in many urban areas of West Java, maintenance and monitoring of water infrastructure remain inconsistent. The World Bank (2021) highlighted that 60% of urban drainage systems in Indonesia operate below design capacity due to clogging, sediment buildup, and insufficient maintenance budgets. Consequently, the quality of water management systems directly influences the region's flood risk profile.

### 2.4 *Conceptual Framework*

Based on previous literature, this study proposes that rainfall intensity ($X_1$) and water management systems ($X_2$) significantly influence flood risk (Y). Rainfall intensity is hypothesized to have a positive relationship with flood risk—

higher rainfall intensity leads to higher flood likelihood—whereas water management systems are hypothesized to have a negative relationship with flood risk, meaning that better water management reduces the probability and impact of floods. This conceptual model aligns with the framework of integrated flood management (IFM), which combines hydrological, infrastructural, and social dimensions to achieve sustainable flood resilience (WMO, 2009). From the theoretical and empirical review above, the following hypotheses are formulated:

H1: Rainfall intensity has a significant positive effect on flood risk in West Java.

H2: Water management systems have a significant negative effect on flood risk in West Java.

H3: Rainfall intensity and water management systems jointly influence flood risk in West Java.

## 3. METHODS

### 3.1 Research Design

This study employs a quantitative research design to analyze the impact of rainfall intensity and water management systems on flood risk in West Java. The quantitative approach is appropriate for examining causal relationships among measurable variables using statistical techniques. A descriptive and explanatory design was applied to identify the strength and direction of influence between independent variables (rainfall intensity and water management systems) and the dependent variable (flood risk). Data were collected through a structured survey instrument and analyzed using Statistical Package for the Social Sciences (SPSS) version 25, which provided the tools for descriptive, correlation, and multiple regression analyses.

### 3.2 Population and Sample

The population of this study consists of residents living in flood-prone areas in West Java, including several regencies and cities such as Bandung, Bekasi, Karawang, and Cirebon. These locations were selected due to their historical exposure to seasonal flooding and diverse characteristics in terms of topography and water infrastructure. The sampling technique used in this research is purposive sampling, which allows the selection of respondents who have experienced flood events or possess sufficient awareness of local rainfall and drainage conditions.

A total of 125 respondents were surveyed, representing individuals from various demographic groups such as community members, local business owners, and residents who have faced flood events within the past five years. The sample size meets the minimum requirement for regression analysis, as suggested by Hair et al. (2019), who recommend at least 100 samples for models with two or more predictors. This ensures that the data are statistically reliable for inferential analysis.

### 3.3 Data Collection Techniques

Primary data were collected using a structured questionnaire distributed both online and in-person. The questionnaire consisted of closed-ended questions measured using a five-point Likert scale, where responses ranged from 1 (“strongly disagree”) to 5 (“strongly agree”). The instrument was designed to capture perceptions related to rainfall intensity ($X_1$), which was measured through indicators such as the frequency of heavy rain, duration of rainfall, and perceived changes in rainfall patterns; water management systems ($X_2$), which included indicators such as drainage quality, river maintenance, flood control infrastructure, and community-based water initiatives; and flood risk (Y), which was measured through indicators including the frequency of flooding, depth of inundation, duration, and perceived damage to property and infrastructure. The questionnaire was pre-tested with 20 respondents to ensure clarity, reliability, and validity before final distribution, and feedback from the pilot test led to minor revisions in wording and sequencing of questions to improve respondent understanding.

### 3.4 Data Analysis Techniques

The collected data were analyzed using SPSS version 25 through several statistical procedures to ensure the validity and reliability of the findings. First, a descriptive analysis was performed to summarize respondents' characteristics such as gender, age, education level, and location, as well as to examine measures of central tendency (mean), dispersion (standard deviation), and frequency distribution for each variable. This stage provided an overview of how respondents perceived rainfall intensity, water management performance, and flood risk in their respective areas. Next, validity and reliability tests were conducted to ensure the quality of the measurement instruments; validity was assessed using Pearson's Product Moment Correlation, where items with correlation coefficients (r) above 0.30 were deemed valid (Sugiyono, 2019), while reliability was tested using Cronbach's Alpha, with values exceeding 0.70 indicating acceptable internal consistency (Sekaran & Bougie, 2016). Subsequently, a correlation analysis was carried out to determine the strength and direction of relationships between variables, identifying whether rainfall intensity and water management systems were significantly related to flood risk. Finally, multiple linear regression analysis was employed to test the research hypotheses using the equation model $Y=\beta0+\beta1X1+\beta2X2+\varepsilon$, where a 5% significance level ($\alpha = 0.05$) was applied to assess the statistical significance of each independent variable's effect on flood risk. The coefficient of determination ($R^2$) was also analyzed to measure the extent to which variations in flood risk could be jointly explained by rainfall intensity and water management systems.

## 4. RESULTS AND DISCUSSION

### 4.1 Respondent Profile

A total of 125 respondents participated in this study, representing residents from flood-prone areas across Bandung, Bekasi, Karawang, Cirebon, and Bogor in West Java. The demographic profile shows that 54.4% of respondents were male and 45.6% female, with the majority aged between 30–49 years (58.4%). Most respondents (62.4%) had lived in their area for more than ten years, which indicates sufficient experience in observing flood occurrences and local water management efforts. In terms of education, 46.4% held a bachelor's degree, while 33.6% had completed senior high school. This demographic distribution supports the reliability of responses regarding environmental and infrastructural conditions affecting flood risk.

### 4.2 Descriptive Statistical Analysis

Descriptive statistics were used to assess the overall tendency of each variable. Each construct was measured using several items on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).

Table 1. Descriptive Statistics

| Variable | N | Mean | Std. Deviation | Interpretation |
|---|---|---|---|---|
| Rainfall Intensity ($X_1$) | 125 | 4.02 | 0.63 | High |
| Water Management Systems ($X_2$) | 125 | 3.48 | 0.71 | Moderate |
| Flood Risk (Y) | 125 | 3.87 | 0.68 | High |

The results presented in Table 1 show the descriptive statistical analysis of the three main research variables: rainfall intensity ($X_1$), water management systems ($X_2$), and flood risk (Y). The mean score for rainfall intensity is 4.02 with a standard deviation of 0.63, which falls into the high category. This indicates that respondents consistently perceive rainfall in West Java as frequent and intense, reflecting the actual climatic conditions characterized by short-duration but heavy rainfall episodes. Such high rainfall intensity is consistent with recent climate variability trends that have increased the frequency of extreme precipitation events in the region. Meanwhile, the mean score for water management systems is 3.48 with a standard deviation of 0.71, interpreted as moderate. This suggests that while basic water infrastructure—such as drainage systems, flood channels, and retention ponds—exists, its effectiveness remains suboptimal. Respondents' moderate ratings likely reflect issues such as inadequate maintenance, sediment buildup in drainage networks, and insufficient coordination among local authorities. These findings highlight that the existing flood control mechanisms function only partially and may not yet meet the growing demands caused by intensified rainfall events.

The flood risk variable records a mean of 3.87 and a standard deviation of 0.68, categorized as high, indicating that respondents experience flooding relatively frequently, with considerable depth and duration. The high perception of flood risk corresponds with the combination of intense rainfall and only moderately effective water management systems, reinforcing the hypothesis that weak infrastructure and governance exacerbate the effects of natural climatic conditions. Overall, the descriptive statistics reveal a clear pattern: high rainfall intensity combined with moderate water management capacity leads to high flood risk in West Java. This pattern provides preliminary evidence for the hypothesized relationships in this study—rainfall intensity showing a positive correlation with flood risk, and water management systems demonstrating a negative one. These descriptive findings form the foundation for subsequent inferential analyses, including correlation and regression tests, to determine the magnitude and statistical significance of these interactions.

### 4.3 Validity and Reliability Testing

The validity test using Pearson's correlation indicated that all questionnaire items achieved correlation coefficients (r-count) greater than the critical value of 0.176 at a significance level of $\alpha = 0.05$ with $n = 125$, thereby confirming that each item was valid and capable of accurately measuring its respective construct. This result demonstrates that the indicators used for rainfall intensity, water management systems, and flood risk effectively captured respondents' perceptions and aligned well with the intended dimensions of the study variables. The high correlation values also reflect the coherence of the questionnaire items and the appropriateness of the measurement model employed in this research.

The reliability test, conducted using Cronbach's Alpha, produced coefficients of 0.811 for rainfall intensity ($X_1$), 0.874 for water management systems ($X_2$), and 0.862 for flood risk (Y). Since all variables surpassed the commonly accepted reliability threshold of 0.70, the results confirm that the instrument demonstrated strong internal consistency. These values indicate that the items within each variable were stable, consistent, and measured the same underlying construct. Thus, the overall reliability and validity results affirm that the research instrument was statistically sound and suitable for subsequent inferential analyses using SPSS.

### 4.4 Correlation Analysis

The Pearson correlation results are presented below:

Table 2. Correlation Analysis

| Variable | Rainfall Intensity ($X_1$) | Water Management ($X_2$) | Flood Risk (Y) |
|---|---|---|---|
| Rainfall Intensity ($X_1$) | 1 | 0.412** | 0.642** |
| Water Management ($X_2$) | 0.412** | 1 | -0.581** |
| Flood Risk (Y) | 0.642** | -0.581** | 1 |

The correlation results presented in Table 2 illustrate the relationships among the three key variables: rainfall intensity ($X_1$), water management systems ($X_2$), and flood risk (Y). The correlation coefficient between rainfall intensity and flood risk is 0.642, significant at the 0.01 level ($p < 0.01$), indicating a strong positive relationship. This means that as rainfall intensity increases, the likelihood and severity of flood events also rise. This finding aligns with hydrological theory and previous research (Pramono et al., 2020), which found that short-duration but high-intensity rainfall in West Java often overwhelms drainage capacity and leads to flash flooding. The correlation between rainfall intensity and water management systems is 0.412, also significant at the 0.01 level, showing a moderate positive relationship. This may suggest that heavy rainfall conditions often trigger responses or improvements in local water management initiatives, although the intensity of rainfall remains a stress factor for existing infrastructure.

Conversely, the correlation between water management systems and flood risk is -0.581, significant at the 0.01 level, indicating a moderate to strong negative relationship. This means that better-performing water management systems—characterized by effective drainage, regular river maintenance, and strong community participation—are associated with lower flood risks. The negative correlation confirms that improvements in water management can mitigate the adverse effects of high rainfall intensity. Overall, the correlation matrix supports the hypothesized relationships in this study: rainfall intensity positively affects flood risk, while water management systems serve as a mitigating factor. These relationships provide the empirical basis for further regression analysis to determine the magnitude and statistical significance of these effects in explaining the variability of flood risk across West Java.

### 4.5 Regression Analysis

To determine the effect of rainfall intensity and water management systems on flood risk, multiple regression analysis was performed.

Table 3. Hypothesis Testing

| Model | Unstandardized Coefficients (B) | Std. Error | t-value | Sig. |
|---|---|---|---|---|
| Constant | 0.742 | 0.291 | 2.55 | 0.012 |
| Rainfall Intensity ($X_1$) | 0.563 | 0.072 | 7.82 | 0.000 |
| Water Management ($X_2$) | -0.417 | 0.069 | -6.04 | 0.000 |

The results of the hypothesis testing presented in Table 3 indicate that the overall regression model is statistically significant ($F = 69.83$, Sig. = 0.000), confirming that rainfall intensity ($X_1$) and water management systems ($X_2$) collectively have a meaningful influence on flood risk (Y). The coefficient of determination ($R^2 = 0.534$) demonstrates that 53.4% of the variation in flood risk can be explained by the two independent variables, while the remaining 46.6% is influenced by other external factors such as urban expansion, land-use changes, and the capacity of existing drainage infrastructure. The correlation coefficient ($R = 0.731$) also reflects a strong overall relationship between the predictors and the dependent variable, suggesting that both rainfall intensity and water management are important determinants of flood risk in West Java.

Individually, the regression coefficients reveal distinct directions and strengths of influence. Rainfall intensity (β = 0.563, t = 7.82, Sig. = 0.000) has a positive and significant effect on flood risk, implying that higher rainfall intensity directly increases the frequency and severity of flooding events. This supports the first hypothesis (H1) and aligns with previous studies emphasizing the role of extreme rainfall in driving hydrological disasters (Suryadi et al., 2022). In contrast, water management systems (β = -0.417, t = -6.04, Sig. = 0.000) exhibit a negative and significant effect on flood risk, confirming that improved water management can effectively reduce flood occurrence and impact. This validates the second hypothesis (H2) and reinforces the view that proactive drainage maintenance, river normalization, and community-based water governance play crucial roles in mitigating flood hazards. The results together support the third hypothesis (H3), which posits that both variables jointly shape flood risk levels in the region. Therefore, this regression analysis not only highlights the quantitative significance of climatic and infrastructural factors but also underscores the need for integrated water governance to enhance flood resilience in West Java.

**Discussion**

The findings confirm the dual influence of climatic and managerial factors on flood dynamics in West Java. High rainfall intensity serves as a natural driver of flooding, but its effects are significantly amplified by human-induced vulnerabilities such as poor land-use planning, excessive urbanization, and weak water governance. This relationship supports the Integrated Flood Management (IFM) framework proposed by the World Meteorological Organization (WMO, 2009), which posits that flood risk is the result of interactions between natural hydrological processes and human systems. When rainfall intensity exceeds the carrying capacity of drainage networks, unregulated land conversion and inadequate infrastructure exacerbate the impact, leading to higher flood frequency and severity.

The important role of water management in mitigating flood risk underscores the need for better infrastructure maintenance, cross-agency coordination, and public participation. Although regional initiatives such as the Citarum River normalization and various drainage rehabilitation projects have been implemented, field evidence and community feedback reveal persistent weaknesses—including irregular drainage cleaning, insufficient institutional coordination, and low community awareness. Bridging these gaps requires both technical innovation, such as the use of smart water monitoring systems, and community-based approaches rooted in adaptive governance, as suggested by [3], [11]. Furthermore, the moderate explanatory power of the regression model ($R^2$ = 0.534) indicates that while rainfall and water management are key determinants, other factors—such as land conversion, topographical variation, and socio-economic resilience—also shape flood outcomes. This aligns with [12], [13], who emphasize that sustainable flood mitigation in Indonesia must integrate spatial planning, ecological restoration, and behavioral adaptation within a comprehensive resilience framework.

**Implications of the Study**

The practical implications of this study highlight the need for concrete, multi-level action in flood mitigation planning. Local governments should prioritize strengthening the maintenance of drainage systems, retention ponds, and flood gates to ensure that infrastructure design capacity aligns with current and projected rainfall intensity trends. Equally important is enhancing community participation through public awareness campaigns, education programs, and neighborhood-based water stewardship initiatives to encourage shared responsibility in managing flood risks. Furthermore, urban development policies must integrate climate adaptation mechanisms, particularly in densely populated areas with high surface runoff, to prevent future flooding through sustainable land-use and water management planning.

From a theoretical perspective, the study reinforces the causal relationship model that links climatic hazards and governance structures to environmental risk outcomes. The findings validate the use of quantitative analytical models in explaining the interplay between natural and anthropogenic factors in flood dynamics, thereby providing empirical support for the Integrated Flood Management (IFM) framework within tropical urban contexts. This study contributes to environmental management theory by illustrating how governance effectiveness and adaptive infrastructure collectively mediate the impacts of climate-induced rainfall variability. It thus offers a scientific basis for refining models that address environmental risks through integrated, data-driven approaches in regional and urban planning.

## 5. CONCLUSION

The results of this study demonstrate that both natural and human factors play essential roles in determining the extent of flood risk in West Java. The analysis confirms that rainfall intensity has a significant and positive influence on flood risk, indicating that extreme precipitation events—particularly during monsoon periods—serve as the primary triggers of flooding in the region. Conversely, water management systems exhibit a significant negative influence, emphasizing their crucial role in reducing flood hazards through effective drainage maintenance, river normalization, and community-based water governance. The empirical model reveals that rainfall intensity and water management together explain more than half of the variance in flood risk, underscoring the need for integrated and adaptive management strategies to achieve sustainable flood control. This finding aligns with the Integrated Flood Management (IFM) framework, which advocates balancing natural hydrological processes with human adaptive mechanisms to minimize disaster impacts.

From a practical perspective, the study highlights that local governments must focus on improving drainage system maintenance, enhancing early warning systems, and fostering community participation to strengthen flood resilience. Coordination among regional agencies should be intensified, rainfall and hydrological data must be integrated into spatial planning, and public awareness of water governance should be promoted at the household and community levels. These actions will help reduce vulnerabilities and build long-term adaptive capacity. In conclusion, this research reaffirms the importance of adaptive water management as a central policy direction to confront the escalating flood risks driven by intensified rainfall patterns. By harmonizing technical, institutional, and social dimensions, West Java can progress toward a more resilient and sustainable flood management framework, capable of withstanding the challenges posed by climate variability and rapid urbanization.

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