PACC
Peatland Agriculture and Climate Change Journal
PACC 1(2): 81–88
ISSN 3048-2690

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Risk management of the impacts of climate change floods and water availability on Citarum Riverbanks

Winda Carla Viena[1]*

[1] *Department of Environmental Engineering, President University, Jl. Ki Hajar Dewantara, Kota Jababeka, Cikarang Baru, Bekasi, 17530, Indonesia.*

*Correspondence: winda.viena@student.president.ac.id

Received Date: June 20, 2024 Revised Date: July 27, 2024 Accepted Date: August 31, 2024

ABSTRACT

Background: Water is essential for human life and is required for daily activities. Climate change threatens the availability of water and can lead to potential disasters. Therefore, it is crucial to conduct a risk analysis to minimize the impact of such disasters. The Citarum River Basin is significant due to its ecological, economic, and social potentials in West Java. **Methods:** This study employs risk assessment techniques to evaluate the impacts of climate change, focusing on flood risks and water availability. Data collection involves analyzing historical flood data, ecological assessments, and socioeconomic surveys. **Findings:** The study identifies critical vulnerabilities along the Citarum Riverbanks and suggests that effective risk management strategies can significantly reduce the adverse effects of climate change. **Conclusion:** It is essential to implement comprehensive risk management measures to mitigate the impacts of floods and enhance water resource management in the Citarum River Basin. **Novelty/Originality of this article:** This research presents innovative approaches to risk management specific to the Citarum River, highlighting unique vulnerabilities and proposing tailored strategies that have not been extensively explored in existing literature.

KEYWORDS: river; risk management; flood; Citarum River.

1. Introduction

Life in this world will not escape from a compound called H_2O. In a never-ending cycle, water circulates on Earth, preserving the survival of its inhabitants since millions of years ago. However, climate change is disrupting the balance of this stable system. Additionally, the demand for water is increasing due to the expanding industrial, agricultural, and global population needs, putting this vital resource at risk (DW Documentary, 2022).

Human activities in daily life are inseparably dependent on natural elements, one of which is water. Water is fundamental to human survival, and its benefits are widely recognized across various aspects of life, including daily consumption, transportation, energy production, and agriculture (Detik, 2022). If all water from the oceans, atmosphere, and surface or subsurface of the Earth were drawn into a sphere, it would measure approximately 950 miles (1,500 km) in diameter, whereas the Moon's diameter is 2,160 miles (3,475 km). Only about 3 percent of this water is fresh, and of that, only about two-thirds is in a form or location easily accessible to humans (Woods Hole Oceanographic Institution, 2022). Rivers serve as natural reservoirs, where water from a region collects and flows downstream due to gravity (Yogafanny, 2022). Human activities along rivers

Cite This Article:
Viena, W. C. (2024). Risk management of the impacts of climate change floods and water availability on Citarum Riverbanks. *Peatland Agriculture and Climate Change Journal, 1*(2), 81-88. https://doi.org/10.61511/pacc.v1i2.2024.1283

significantly affect water quality, and Indonesia, as the world's largest archipelagic country, is home to many river systems, including the Citarum River. West Java has 40 watersheds, with the largest being the Citarum watershed. The IKA value of the Citarum River was 50.13 in 2021, up from 40.67 in 2019, while the IKA for West Java Province increased from 42.73 in 2019 to 43.09 in 2021 (Bandung Regency Environment Agency, 2016). The Citarum River holds considerable ecological, economic, and social importance in West Java (West Java Province, 2000).

The West Java Provincial Regulation No. 39/2000 indicates that water quality monitoring results show that the Citarum River's water quality does not meet established drinking water standards, especially during the dry season (West Java Province, 2000). Identifying risks associated with climate change is essential to minimizing losses by avoiding hazards, reducing social and economic vulnerability, and enhancing preparedness for adverse events. The Citarum watershed is particularly crucial in this context, as climate change impacts water availability, and increases the potential for floods and droughts within the watershed. A detailed analysis of these risks is thus necessary to mitigate their effects on the environment and local populations (National Agency for Disaster Countermeasure, 2016).

2. Methods

The research methodology utilized in this study is a literature review. This approach was chosen to gather relevant references and deepen understanding of the subject matter. The study focuses on analyzing existing regulations and their application concerning water resources, particularly in the context of river management and sustainability in West Java. The reviewed literature encompasses a variety of sources, including national and international journals, textbooks, theses, dissertations, project reports, and government regulations. These sources provide a comprehensive foundation for examining water resource issues in light of regulatory frameworks and practical implementation.

This literature review approach allows the researcher to integrate multiple perspectives and findings on water regulation challenges. For example, literature indicates the increasing urgency of water management due to the growing pressures of climate change and industrial demands (DW Documentary, 2022). Additionally, research underscores the essential role of water in human survival and its extensive applications, such as in agriculture, industry, and energy (detik.com, 2022). With specific focus areas such as the Citarum River watershed, where population activities directly impact water quality (Yogafanny, 2022), this review highlights how local governance and community practices interact to shape the river's ecological health. The significance of monitoring water quality in these settings is amplified by findings that document substantial pollution and threats to water availability and sustainability (BPS West Java, 2020).

Further exploration in this review addresses regulatory insights from the West Java Provincial Regulation on water allocation, examining how local authorities are tasked with implementing these standards to ensure sustainable water use (West Java Province, 2000). This legal perspective is supported by broader risk analysis studies that consider climate-related hazards impacting the river basins, proposing preparedness strategies to mitigate water-related risks. Through this method, the literature review synthesizes these various sources, creating a multifaceted understanding that considers legal, environmental, and societal dimensions of water management in West Java.

3. Results and Discussion

3.1 Hazard analysis

This analysis assesses the impact of climate change on the Citarum River, affecting water availability, flood potential, and drought risks (National Agency for Disaster

Countermeasure, 2016). Additionally, numerous textile industries discharge waste into the river, making it unsuitable for consumption, with nearby residential areas also contributing to hazardous conditions (Imansyah, 2012). High rainfall combined with restricted flows due to settlement structures poses a significant risk.

Table 1. Average rainfall and discharge of Citarum River flow

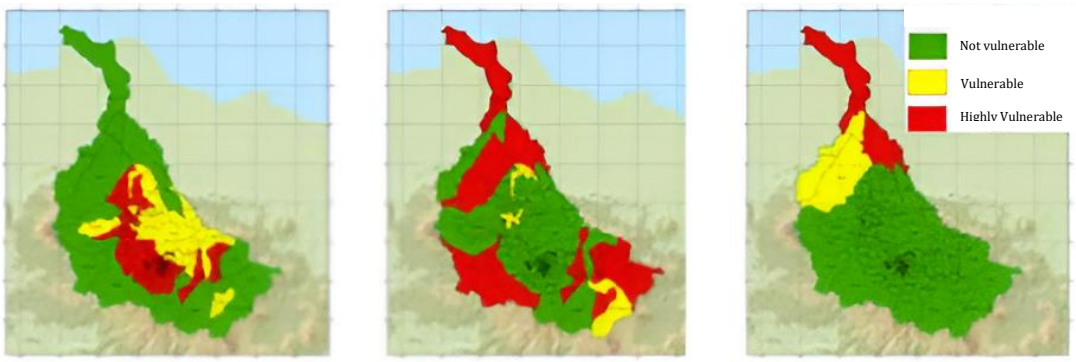
Year	Area	Precipitation (mm)	Rainy Days (days)	Flow Rate (lit/sec/km^2)	Flow Volume (Million m^3)
2015	Bandung	2199.3	177	36.3	1965.6
	Soreang	2199.3	177	45.5	288

(Lestari & Dasanto, 2019)

The Citarum River has a steep slope cross-section (high hydraulic head) compared to its tributaries (low hydraulic head), making these areas prone to runoff (Physical and Spatial Condition, 2022). Table 1 shows that despite having the same rainfall, Bandung and Soreang have significantly different river flows due to the flow patterns from mountain areas to basins. Generally, the annual rainfall in the Citarum watershed averages between 1500–4000 mm, with plains like Bandung receiving 1500–2000 mm and hillier areas experiencing higher precipitation (Directorate General of Water Resources, 2007).

The Cikapundung River, one of the Citarum tributaries, flows through 15.5 km of densely populated Bandung, where it serves as a key waterway. The river measures 22 meters upstream and 26 meters downstream, with a minimum discharge of six cubic meters per second (Sarifuddin et al., 2020). Citarum functions as a critical irrigation source, raw water supplier for Regional Drinking Water Companies (Perusahaan Daerah Air Minum/PDAMs) in multiple cities, a power source for the Jatiluhur Hydroelectric Plant, and serves as a communal resource for riverside communities (Rahayu et al., 2018).

However, future climate projections for 2026–2035 suggest improved conditions, while the 2036–2045 period shows significant vulnerabilities, especially downstream (Taofiqurohman, 2011). Rain distribution from 2006–2015 was mostly normal, then predominantly dry in 2016–2025, followed by wetter conditions in 2026–2035, and much drier weather from 2036–2045. Daily rainfall analysis reveals that rainfall intensity generally increases even as rain days decrease, indicating a higher flood and drought risk due to more intense, sporadic rain events. Projections suggest that drought classifications in the watershed will become vulnerable by 2025, improve by 2035, but reach critical vulnerability levels by 2045.



water avalability potential flood potential drought potential

Fig 1. Potential water availability, floods, and droughts in the Citarum Watershed in 2020

3.2 Insecurity analysis

This analysis consists of two indicators: exposure and sensitivity (Nurlina, 2014). Exposure indicators are calculated based on population density and poverty levels, while

sensitivity indicators are based on water demand and housing density. Riverbank areas are particularly flood-prone due to high population density and inadequate environmental protections for human developments.

3.2.1 Exposure indicators

The exposure indicator is calculated using data on population density and the ratio of the poor population, where population density is weighted (0.6) higher than the proportion of the poor (0.4). Population density data is calculated based on population density data from 2020 onwards, with estimates considering population growth in West Java, which is approximately 1.1% per year (BPS West Java, 2020). In 2016–2035, the population density level is expected to remain unchanged, with only the city of Subang experiencing a rise in vulnerability status to "very vulnerable" by 2045. Information on the poor population ratio is calculated based on data from 2010, 2015, and 2020, with forecasts using the average change in the proportion of poor individuals over three periods. The relationship between the poor in the West Java region between 2010–2020 shows a range of 2.4% to 20.7%, with a negative rate of change, indicating a continuous decrease in the number of poor individuals. Hence, by the projection for 2015–2045, the entire Citarum watershed is not categorized as vulnerable to poverty in this regard.

3.2.2 Index losses

Index losses can be analyzed through economic vulnerability, physical vulnerabilities, and environmental vulnerabilities (Widodo, 2014). Economic vulnerability examines the value of productive land—such as rice fields, plantations, agricultural lands, and ponds—in monetary terms and compares this with the region's gross domestic product (GDP). This data comes from land use maps and district records, which provide productive land areas in rupiah, and sector or district reports for GDP. The Economic Vulnerability Index is formed by weighting the productive land average at 60% and the gross national product at 40%.

Physical vulnerabilities include population density, public building/facility availability, and the presence of critical facilities, encompassing permanent, semi-permanent, and non-permanent structures. House density is calculated by dividing the number of houses by the settlement or village area in hectares, with each parameter adjusted by its unit price. The physical vulnerability index is a weighted average with 40% from population density, 30% from public facility availability, and 30% from critical facility availability.

Environmental vulnerabilities are assessed based on land cover, including protected forests, natural forests, mangrove forests, swamps, and shrub areas. The Environmental Vulnerability Index is calculated by assigning weights to each type, with protected forests and natural forests each contributing 30%, while mangroves, swamps, and shrubs each contribute 10%.

3.2.3 Sensitivity indicators

Sensitivity indicators rely on housing density and water infrastructure locations, such as raw water intake and irrigation points, with both factors weighted equally. Banjar City has the lowest housing density compared to other cities or regions on Java Island, but it also has a high density value of 50,621 houses per hectare, significantly exceeding the non-vulnerable class standard of only 80 houses per acre. Additionally, the projected population density has shown a positive growth index, indicating an increase in housing density across the Citarum watershed from 2015 to 2045, placing the area in a high-risk category. The location data for raw water intake and irrigation infrastructure within the Citarum watershed in 2020 is also used in water infrastructure calculations.

3.3 Risk analysis and adaptation options

For water availability, areas within the Citarum watershed identified as highly vulnerable include the lower Citarum, Cipamingkis, Cisangkuy, and Cirata regions. Flood-prone areas include Cibeet, Cisangkuy, and the downstream Citarum. Drought risks are notably present in the downstream Citarum, Cipamingkis, and Cisangkuy areas (No et al., 2014). Meanwhile, cooperation between the Government of Indonesia and the Asia Development Bank for the "Integrated Citarum Water Resources Management Project" program was agreed upon in 2023 (Directorate General of Water Resources Ministry of Public Works, 2007).

Table 2. Integrated Citarum water resources management project

No	Project title	Description
1	System service improvement WTC	Rehabilitation of West Tarum Canal and associated structures, and institutional strengthening for effective management
2	System service improvement ETC	Rehabilitation of East Tarum Canal and associated structures, and institutional strengthening for effective management
3	System service improvement NTC	Rehabilitation of North Tarum Canal and associated structures, and institutional strengthening for effective management
4	Irrigation modernization WTC	Improvement of water supplies to irrigators in the WTC irrigation area by rehabilitation of secondary and tertiary canals and water control structures and development of a real-time irrigation management system
5	Irrigation modernization ETC	Improvement of water supplies to irrigators in the ETC irrigation area by rehabilitation of secondary and tertiary canals and water control structures and development of a real-time irrigation management system
6	Irrigation modernization NTC	Improvement of water supplies to irrigators in the NTC irrigation area by rehabilitation of secondary and tertiary canals and water control structures and development of a real-time irrigation management system
7	Productive Reforestation	Reforestation of degraded catchments by planting productive trees in the Upper Citarum, Upper Cipamingkis, and Upper Bekasi sub-basins
8	Integrated Management of Disaster	Disaster mitigation in the Bandung lowlands, Upper Bekasi, Lower Citarum, Lower Cibeet, Lower Ciheran, Lower Cilamaya, and Lower Cipunegara areas through river improvement works, development of a disaster forecasting and warning system, and improving disaster preparedness
9	Upgrading of Water Source - Upper Cipunegara	Construction of a dam and inter-basin diversion to provide increased water supplies in the Cipunegara River, and improved watershed management in the catchments
10	Upgrading of Water Source - Cipancuh	Upgrading of Cipancuh Dam and associated works
11	Upgrading of Water Source - Ciherang	Construction of Ciherang Dam and associated works
12	Upgrading of Water Source - Ciputarua	Construction of Ciputarua Dam and associated works
13	Enhancement of System Reliability	Increasing reliability of supply to Jakarta through a new conveyance system, and institutional strengthening for better management of the system
14	Integrated Erosion Management	Provision of structural erosion control works and a forecasting and warning system for mud flows and

		landslides in the Upper Citarum, Upper Bekasi, and Upper Cipunegara areas
15	Management of Domestic Effluent	Construction of new sewerage systems to service domestic users in Bandung City, Bekasi City, Municipalities of Cikarang and Karawang, and implementation of new tariff arrangements
16	Management of Industrial Effluent	Construction of new sewerage systems to service domestic users in Bandung City, Bekasi City, Municipalities of Cikao and Cilamaya, and along with WTC and implementation of new tariff arrangements
17	Solid Waste Management	Implementation of structural and non-structural measures for improved solid waste management in Bandung City and Bekasi City, and along WTC
18	Water Supply System	Construction of improved water offtake and reticulation systems for water supply to Bandung (City and District), Municipalities of Puruwakarta, Karawang and Sumedang

4. Conclusions

To effectively mitigate the impacts of climate change on critical water-related risks, such as flooding, drought, and clean water availability, a comprehensive analysis is necessary to identify appropriate and sustainable interventions. This process should involve continuous assessment to establish benchmarks for improvement. Recommended strategies include building essential infrastructure, enhancing irrigation system services, and upgrading irrigation canals in areas particularly vulnerable to drought and flooding. These solutions are aligned with government initiatives and partnerships, such as those with the Asia Development Bank, aimed at addressing these pressing challenges through collaborative development efforts.

In addressing the specific challenges of the Cisangkuy watershed, building a reservoir is a crucial step to manage water supply effectively and reduce flood risks. The region is prone to extreme climate events, making water storage infrastructure vital for maintaining water availability during dry seasons. Additionally, improving the irrigation canals within the Cisangkuy River Basin will enhance the efficiency of water distribution, ensuring agricultural areas receive adequate irrigation. Modernizing the irrigation system along the East Canal will further bolster the area's resilience to drought and ensure a sustainable water supply through improved management practices.

Acknowledgement

The author would like to thank God Almighty for His blessings and gifts so that I can complete my final Environmental Law and Risk Management assignment. Thank you also to parents, siblings, and friends in arms.

Author Contribution

The author is responsible for the conception and design of the research, including literature review, data collection, analysis, and methodology development. She drafted and revised the manuscript, ensuring clarity and coherence throughout the study..

Funding

This research received no external funding.

Ethical Review Board Statement

Not available.

Informed Consent Statement

Not available.

Data Availability Statement
Not available.

Conflicts of Interest
The author declare no conflict of interest.

Open Access

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Biographies of Author

Winda Carla Viena, Department of Environmental Engineering, President University, Jl. Ki Hajar Dewantara, Kota Jababeka, Cikarang Baru, Bekasi, Indonesia.

- Email: winda.viena@student.president.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A