SUDEIJ
Sustainable Urban Development and Environmental Impact Journal
SUDEIJ 3(2): 121–136
ISSN 3062-8997

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

Physical flood risk analysis using the climate and financial risk approach

Velia Primadhani Amanda[1,*]
[1] *Department of Environmental Science, Graduate School of Sustainable Development, Universitas Indonesia, Central Jakarta, Special Capital Region of Jakarta 10430, Indonesia.*
*Correspondence: primadhanivelia@gmail.com

Received Date: June 8, 2026 Revised Date: July 27, 2026 Accepted Date: August 29, 2026

ABSTRACT

Background: Demak Regency is one of the areas on the north coast of Java that consistently faces a high flood risk threat based on the Indonesian Disaster Risk Index from 2020 to 2024. This region faces two flood threats: fluvial flooding due to river overflows and tidal flooding due to sea level rise exacerbated by land subsidence. This paper aims to identify and quantify the physical risk of flooding in Demak Regency using a climate financial risk approach based on the Financial Services Authority (*Otoritas Jasa Keuangan*/OJK) framework. **Methods:** The analysis is carried out through four stages: risk identification, exposure mapping, risk quantification through scenario analysis, sensitivity analysis, and stress testing, as well as risk management using a 5x5 matrix. The data used are sourced from the Indonesian Disaster Risk Index, Indonesian Disaster Risk 2023, the Demak Regency Disaster Risk Study, and the Demak Regency Central Statistics Agency. **Findings:** The analysis results show that the flood risk profile of Demak Regency has consistently been in the high category for the past five years. Based on a scenario analysis with a time series assumption of 0.04% per year of the total flood hazard area of 92,656.92 hectares, the baseline potential economic loss is estimated to reach IDR 2.25 trillion (USD 125.5 million) for the medium category and IDR 17.81 trillion (USD 993 million) for the high category. **Conclusion:** Stress testing results with a threshold of IDR 2 trillion (USD 111.5 million) indicate that the high category losses in all scenarios exceed the threshold, so the Demak Regency flood is categorized as an extreme risk that has the potential to trigger credit, market, liquidity, and operational risks in the financial sector. **Novelty/Originality of this article:** Recommended mitigation includes strengthening infrastructure, early warning systems, and integrating flood physical risk into bank credit assessments.

KEYWORDS: climate financial risk; Demak; flood; physical risk; scenario analysis

1. Introduction

Climate change has become one of the greatest threats to human life and has significant impacts on various aspects, including global economic stability (Boros, 2020). In recent decades, the intensity and frequency of disasters such as floods, storms, and heat waves have continued to increase significantly as a direct impact of global warming. The World Economic Forum (WEF), in its Global Risks Report 2024, ranked extreme weather events as the number one risk most likely to occur in the next ten years, surpassing geopolitical, technological, and economic risks. This situation has prompted various countries and international financial institutions to begin integrating climate risk into their risk management frameworks, not only as a purely environmental issue but also as a real threat to global financial stability (WEF, 2024). The economic value associated with climate change has the potential for high losses, due to the increasing frequency and severity of natural

Cite This Article:
Amanda, V. P. (2026). Physical flood risk analysis using the climate and financial risk approach. *Sustainable Urban Development and Environmental Impact Journal, 3*(2), 121-136. https://doi.org/10.61511/sudeij.v3i2.2026.4061

Copyright: © 2026 by the author. This article is distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

disasters and sea level rise (Tol, 2002). Indonesia is one of the countries with the highest levels of vulnerability to hydrometeorological disasters in the world. Nearly all regions in Indonesia are at risk of disasters caused by geological, geographical, climatic, and other influences. One example is rising sea levels, which causes flooding in various regions (Amin, 2024). Floods are the most frequent type of disaster and cause significant losses, accounting for the majority of disasters in Indonesia. The northern coast of Java experiences more complex problems than other regions due to uncontrolled exploitation of coastal natural resources, including excessive groundwater use, contributing to land subsidence, which poses a risk of tidal flooding (Rahman et al., 2021). In 2018, there were 173 floods in Central Java, with 72% of them occurring in the coastal areas *pantai utara* (Pantura), making this region the epicenter of flooding in the province. This situation is exacerbated by inadequate infrastructure to withstand the increasing pressures of climate change, making the coastal areas one of the highest disaster-risk areas in Indonesia (Rahman et al., 2021).

Flooding in the northern coast of Java (Pantura) has unique characteristics because it consists of two interrelated types: fluvial flooding, which occurs due to heavy rainfall and the inability of river embankments to withstand high water discharge, especially during the rainy season (Putri et al., 2024). The combination of these two types of flooding makes the Pantura region double-exposed to physical risks: the threat from extreme rainfall and the threat from rising sea levels (Rahman et al., 2021). The numerous disaster threats in Indonesia require the public to be more prepared to deal with them if they occur. Therefore, it is also crucial for policymakers to assess the natural phenomena that occur (Refnitasari et al., 2022). Demak Regency is one of the regencies in the Pantura region of Central Java that consistently experiences a high risk of flooding. Geographically, this region has a relatively low topography and is traversed by several large rivers, such as the Wulan River and the Tuntang River, which are prone to overflowing during the rainy season. Demak Regency has a population of 1.25 million, with a Gross Regional Domestic Product (GRDP) of IDR 35.46 trillion (USD 1.95 billion) in 2024. Demak's economic growth reached 5.06 percent, but the regency still faces significant poverty challenges. The majority of Demak residents' livelihoods depend on the agricultural sector, with rice fields covering 4,312 hectares, according to 2018 Statistics Indonesia/*Badan Pusat Statistik* (BPS) data. This reliance on the agricultural sector makes Demak's economy highly vulnerable to the impacts of flooding, as each flood event has the potential to cause crop failure and significant economic losses for the community (BPS Demak, 2018; BPS Demak, 2025).

The impact of flooding is not only felt physically but also has a direct impact on financial stability. Within the climate-related financial risk framework, flooding is categorized as an acute physical risk driver that can trigger various financial risks simultaneously through transmission channels at the micro and macroeconomic levels (The Basel Committee on Banking Supervision (BCBS), 2023). Impacted market risks include credit risk, market risk, liquidity risk, and operational risk, which threaten the stability of financial institutions. The magnitude of this threat prompted the Financial Services Authority/*Otoritas Jasa Keuangan* (OJK) to issue climate risk management and scenario analysis guidelines in 2024, which require all banks in Indonesia to fully implement a climate risk management framework by 2026 (OJK, 2024). Demak Regency provides a concrete illustration of how these four types of financial risks can occur and influence each other. Credit risk arises when floods hit rice fields, potentially impacting farmers with loans from financial institutions and the loss of their primary source of income, which impacts their ability to repay loans (Sugiarto et al., 2023). Market risk occurs when agricultural land is repeatedly inundated by floodwaters, leading to a systematic decline in value as potential buyers and investors consider the potential long-term losses they will incur (Xue et al., 2026). This situation worsens when major flooding occurs and causes many agricultural debtors to default simultaneously, which can undermine the ability of regional banks to meet their customer obligations. This is known as liquidity risk (Conlon et al., 2024). Meanwhile, physical damage to organizations, particularly bank branches and financial service facilities, if inundated by floodwaters will disrupt operations in the affected areas, precisely when people need access

to financial services. This situation requires adequate financial capacity and human resources from organizations to mitigate risks (Wardhana, 2025).

Many previous studies have examined the physical, social, economic, and environmental vulnerabilities caused by flooding in the northern coast of Java, including in Demak Regency (Amin, 2024; Rahman et al., 2021; Refnitasari et al., 2022). However, most studies have focused on qualitative or spatial analysis and have not integrated flood impacts into a quantitative risk analysis framework. The climate financial risk approach developed by the The Basel Committee on Banking Supervision (BCBS) and OJK offers a more comprehensive framework by directly linking the physical risks of flooding to their impact on the financial sector (BCBS, 2022; Financial Services Authority, 2024). This analysis is crucial, especially at the regency level, given that lending decisions by banks and regional financial institutions rely heavily on an understanding of climate risk in their operational areas (Suciati, 2025). Based on the above description, this paper aims to analyze the physical flood risk profile in Demak Regency from 2020 to 2024 using a climate-financial risk approach based on the OJK (2024) framework. Specifically, this paper will map the extent of flood risk in the region, calculate potential economic losses through scenario analysis and sensitivity analysis, identify critical risk points through stress testing, and formulate mitigation recommendations that can be used as a reference by various stakeholders (local governments, financial institutions, and risk managers) in Demak Regency (BCBS, 2023; OJK, 2024).

2. Methods

2.1 Research type

This research is a quantitative descriptive study using the climate financial risk approach (BCBS, 2023) and the Climate Risk Management and Scenario Analysis guidelines (OJK, 2024). This approach was chosen because it provides a framework for quantitatively analyzing the impact of physical flood risk on the financial sector. The data used are sourced from the Indonesian Disaster Risk Index, Indonesian Disaster Risk 2023, the Demak Regency Disaster Risk Study, and the Demak Regency Central Statistics Agency. Overall, the analysis starts by identifying and mapping flood risk in Demak Regency. The potential financial losses are then estimated under different flood scenarios and tested for their sensitivity. The results are finally used to prioritize risk management measures.

2.2 Location and analysis period

The selected research location is Demak Regency, Central Java Province, located on the north coast of Java and experiencing the highest flood risk. The analysis period covers 2020 to 2024, with a high flood risk category based on Indonesian National Board for Disaster Management *Indeks Risiko Bencana Indonesia* (IRBI) data from the National Disaster Management Agency/*Badan Nasional Penanggulangan Bencana* (BNPB). The double exposure of fluvial flooding from river overflows and tidal flooding due to sea level rise makes Demak Regency representative for climate financial risk analysis (Haq et al., 2025).

2.3 Data and data sources

This research uses secondary data sourced from various official government institutions. Primarily the Regional Disaster Management Plans of BNPB (2023-2027) and Demak Regency (2016-2020). The dataset covers flood hazard area (92,656.92 ha), historical flood events (25 incidents) and land damage (7,432 ha) recorded over 200 years, along with estimated economic losses under moderate (IDR 545.28 billion (USD 30.06 million)) and high (IDR4.32 trillion (USD 238.15 million)) flood scenarios and the proportion of environmental damage. In addition, the Flood Disaster Risk Index (IRBI) of

Demak Regency for 2020-2024, which consistently falls in the high category, was used for exposure mapping, as summarized in Table 1.

Table 1. Research data and data sources

No	Data Type	Value	Source	Description
1	Flood Hazard Area	92,656.92 ha	BNPB's Regional Disaster Management Plan 2023-2027	Basis for High Flood Hazard Area
2	Total Land Damage	7,432 ha	Demak Regional Disaster Management Plan 2016-2020	Total land damage due to flooding over 200 years (1815-2015)
3	Number of Historical Flood Events	25 incidents	Demak Regional Disaster Management Plan 2016-2020, Table 3	Total recorded flood events over 200 years
4	Average Area per Event	297.28 ha/incident	Derived	Basis for calculating the average area affected per event
5	Moderate Flood Economic Loss	IDR545.278 billion (USD30.06 million)	(7,432 ÷ 25)	Potential economic losses from flooding in Demak Regency are moderate
6	High Flood Economic Loss	IDR4.324 trillion (USD 238.35 million)	BNPB's Regional Disaster Management Plan 2023	Potential economic losses from flooding in Demak Regency are high
7	Moderate Environmental Damage	5 ha (55.56%)	BNPB's Regional Disaster Management Plan 2023	Proportion: 5 hectares ÷ 9 hectares total = 55.56%
8	High Environmental Damage	4 ha (44.44%)	BNPB's Regional Disaster Management Plan 2023	Proportion: 4 hectares ÷ 9 hectares total = 44.44%
9	Demak Regency Flood IRBI 2020-2024	27.10/20.37/19.76/ 16.34/15.27	BNPB's Regional Disaster Management Plan 2023	All periods in the HIGH category, used for exposure mapping

(BNPB, 2020, 2021, 2022, 2023a, 2023b, 2024)

2.4 Analysis stages

The analysis was conducted following the four-stage climate change risk framework from the Financial Services Authority (2024) and Wardhana (2025). Risk Identification = Physical risk scenarios, considering flood disasters with a high level of severity and causing damage to physical assets. Exposure mapping referring to the Indonesian Disaster Risk Index (IRBI) and disaster loss data using the Indonesian Disaster Risk Index (RBI). This stage categorizes climate change risks as financial risks. Risk Quantification = Consists of scenario analysis, sensitivity analysis, and stress testing. This section calculates economic losses from flood-affected areas using a time series. Furthermore, sensitivity analysis aims to determine the extent to which the scenario analysis changes if there are changes in key climate change risk variables. Stress testing is used to assess the resilience or limits of an organization's capabilities due to climate change risks, including physical risks. Risk Management Type 1, to assess the risk rating based on risk drivers, physical risks, their probability, and impact. This is done by assessing and visualizing risks using a risk matrix. 5x5, determining mitigation strategies, and calculating residual risk after mitigation.

3. Results and Discussion

3.1 Climate change

Climate change not only poses serious risks to the environment but also to the financial system (Pasha et al., 2025). BCBS (2023) defines climate financial risk as the risk that could negatively impact assets, income, and debt repayment capacity due to climate change. Financial risk essentially assumes that the future will be the same as the past, but with climate change, financial risk must be calculated because it will change over time (Reinders et al., 2025). The economic value associated with climate change has a high potential, due to the high frequency of natural disasters and sea level rise in various parts of the world (Tol, 2002). Bolton et al. (2020) introduced the concept of a green swan as an analogy to a black swan to describe climate risks that have the potential to trigger a financial crisis that conventional risk models cannot anticipate. Unlike a black swan, which is an unexpected event, a green swan is an event that is almost certain to occur, but its certainty, timing, and impact are difficult to predict precisely, requiring a more adaptive risk management approach. Another finding, a systematic review of 174 Scopus publications from 1988 to 2024, found that researcher attention to climate risk and financial stability has increased 500% since the 2015 Paris Agreement, with key findings being a shift toward an integrated risk-based financial framework and increasing concern about climate threats (Suciati, 2025). Climate risks encompass a broad spectrum of threats, ranging from direct physical impacts such as extreme weather events and sea level rise to physical risks related to policy and technology adjustments.

A recent study by Xue et al. (2026) showed that physical climate risks significantly increase bank risk-taking through transmission mechanisms in the form of increased non-performing loans and a decline in the value of collateral assets, with a greater impact on banks operating in areas with a high potential for natural disasters. Climate risk exposure acquired through cross-regional lending not only increases the individual risk of the bank itself but also contributes to broader risks. Banks tend to respond by tightening credit distribution and increasing loss reserves after experiencing unexpected climate problems (Conlon et al., 2024). In addition to physical risks, Indonesian banks also face exposure to transition risks as government policy moves towards a low-carbon economy. Indonesia's commitment through the ratification of the Paris Agreement (Law No. 16 of 2016) targets a 41% reduction in carbon emissions by 2030 and carbon neutrality by 2060, which is expected to have a significant impact on the future direction of the banking industry. The risks arising from climate change pose a challenge for banks, which are increasingly required to adapt by integrating climate risk considerations into decisions, business processes, governance, and risk management frameworks (Financial Services Authority, 2024).

3.2 Physical risk

Physical risk is the risk directly felt by the public as a result of climate change risk (Wardhana, 2025). Physical risk has occurred globally and nationally, thus attracting the attention of many parties, including economic actors who will be directly impacted by physical risk. Physical risk is divided into two main categories: acute risk and chronic risk. Acute physical risks are risks arising from sudden extreme weather events such as floods, storms, and forest fires, while chronic physical risks are risks arising from long-term climate change such as rising average temperatures, sea level rise, and changes in rainfall patterns (BCBS, 2022). Physical risks can directly cause damage to physical assets and accelerate the depreciation of capital assets, for example through a direct relationship with extreme weather events such as floods, storms, or forest fires (Conlon et al., 2024). Forest fires are one phenomenon that causes physical risks, namely posing a direct threat to ecosystems,

causing biodiversity loss, ecosystem damage, and increasing global temperatures that exacerbate climate change (Gajendiran et al., 2024).

Physical risks can erode production capacity. This means that when assets are impacted by disasters, the output produced is reduced. This impacts the return on capital assets and weakens the debtor's ability to repay loans, thus deteriorating credit quality (Conlon et al., 2024). When natural disasters damage assets or disrupt business activities, the impact is not limited to credit risk; market, liquidity, and operational risks are simultaneously triggered and difficult to anticipate (Sugiarto et al., 2023). To address this challenge, Pasha et al. (2025) developed a hazard vulnerability exposure framework that allows for a more structured measurement of physical losses due to flooding, producing two primary values: the loss from a single event and the Expected Annual Damage (EAD), which can be used as a basis for stress testing project cash flows. Organizations exposed to physical risks need to mitigate these risks but must still consider their financial and human resource capacity. The impact of these physical risks needs to be analyzed quantitatively to determine their monetary impact (Wardhana, 2025).

3.3 Floods as a physical risk driver

Flooding is one of the most significant physical risk drivers in the context of climate financial risk. Flooding is defined as the submergence of land due to increased water volume due to heavy rainfall, river overflows, or dam ruptures, and can also occur due to sea level rise (Amin, 2024). The physical risk of flooding is assumed to impact the financial system through its macro- and microeconomic impacts, including impacts on corporations, households, governments, and other financial institutions (Sugiarto et al., 2023). At the micro level, flooding directly impacts debtors' physical assets, disrupts their ability to repay loans, reduces asset values, and disrupts business operations. At the macro level, flooding impacts inflation due to supply chain disruptions, decreased purchasing power, and slowed regional economic growth (BCBS, 2022). Flooding in the northern coast of Java has multidimensional impacts that include physical vulnerability in the form of damage to buildings and infrastructure, economic vulnerability in the form of losses to productive land and GRDP, social vulnerability in the form of the number of exposed residents, and environmental vulnerability in the form of damage to coastal ecosystems (Amin, 2024; Refnitasari et al., 2022). Specifically in Demak Regency, spatial analysis using Geographic Information System (GIS) shows that the northern coastal areas, especially Sayung, Bonang, and Mranggen Districts, have a higher level of flood vulnerability than other districts, with the number of villages affected by flooding continuing to increase in the period 2021 to 2024 (Haq et al., 2025). The physical vulnerability in the northern coastal area is exacerbated by the dominance of land use in the form of residential buildings, public facilities, and facilities such as schools and health centers located in flood-prone zones (Refnitasari et al., 2022).

3.4 Stress testing and scenario analysis in climate risk

Stress testing is a technique used to estimate the impact on financial sector variables of adverse conditions that have not yet occurred but may occur (Reinders et al., 2025). Climate Risk Stress Testing (CRST) is a technique designed to measure the vulnerability of a portfolio, financial institution, or even the entire financial system to climate-related shocks and scenarios. What distinguishes CRST from conventional stress testing is its approach, which integrates three layers of modeling: climate, economic, and financial, and classifies various types of climate shocks into six categories and four distinct approaches (Reinders et al., 2025). Scenario analysis for climate change risks, including physical risks, is an assessment of physical risks using assumptions that influence physical risks and that the assumptions used are believed by the organization (Wardhana, 2025). Unlike conventional stress tests, climate risk stress testing considers the unique characteristics of climate

change, including profound uncertainty, non-linear complexity, and long-term impacts manifested over long timescales (Reinders et al., 2025).

Reinders et al. (2025) identified several key limitations in the current CRST approach, including the neglect of certain types of climate shocks, such as green swan and Minsky-type events. This limitation leads to significant underestimation of financial losses. Pasha et al. (2025) offer an alternative approach using a hazard-vulnerability-exposure framework to quantify financial losses from flooding on infrastructure, which generates loss values as the basis for stress testing project cash flows. This approach, however, still suffers from weaknesses related to the coarse resolution of global flood maps and vulnerability functions that have not been calibrated to local conditions. Sensitivity analysis is part of scenario analysis that aims to see how far the results of the scenario analysis can change when key variables shift, while stress testing plays a role in testing the extent to which an organization can withstand the pressures caused by climate change risk (Wardhana, 2025). In practice, the OJK (2024) developed a climate risk framework consisting of four main components: risk identification, exposure mapping, risk quantification, and risk management, which serves as a reference for Indonesian banks in analyzing and managing climate risk in a structured manner.



Fig. 1. Flood analysis framework
(Pasha et al., 2025)

This figure illustrates the flow of physical flood risk analysis from hazard identification to calculating financial losses for Climate Risk Stress Testing purposes. The Financial Services Authority (OJK) (2024) encourages banks to continuously and forward-thinkingly refine their risk management tools through scenario analysis and resilience testing, as well as increasing the availability of supporting data, including the establishment of metrics and targets. Banks also need to take a long-term risk perspective to ensure the sustainability of their business models, including considering setting decarbonization targets that support the transition to a low-carbon economy.

3.5 Previous research

Several studies have examined the relationship between flood disaster risk and its impact on the financial sector and the economy. Bolton et al. (2020) introduced the green swan concept and emphasized that climate risk has the potential to trigger a financial crisis, requiring a proactive response from central banks and financial supervisory institutions. Pasha et al. (2025) conducted a climate risk stress test on infrastructure affected by flooding in Indonesia and found that flooding has the potential to cause significant economic losses for banking infrastructure borrowers. Conlon et al. (2024) examined the impact of climate change on bank credit risk and emphasized the importance of integrating climate risk analysis into the credit granting process. Sugiarto et al. (2023) analyzed the impact of climate change on bank loans in Indonesia and found that rainfall intensity significantly impacted bank credit quality. Xue et al. (2026) examined the impact of physical climate risks on the risk-taking behavior of small and medium-sized banks and found that physical climate risks significantly increased non-performing loans, especially in banks operating in areas with high disaster exposure. Reinders et al. (2025) conducted a critical review of climate risk stress testing methodology and classified various approaches that can be used to assess the vulnerability of the financial system to climate risk. Hu et al. (2022) examined the relationship between flood disaster risk and socioeconomic conditions in the Yellow River Basin, China. They found that areas with higher levels of socioeconomic vulnerability

tended to experience greater losses from flooding, suggesting that community socioeconomic recovery is key to successful long-term disaster risk reduction.

At the local level, Amin (2024) examined the physical, economic, social, and environmental vulnerability to tidal flooding in Demak Regency and found that economic vulnerability was the most dominant dimension. Rahman et al. (2021) identified the factors causing tidal flooding in the north coast of Central Java, including Demak, and emphasized the role of land subsidence due to groundwater exploitation as a factor exacerbating flood risk. (Putri et al., 2024) examined the characteristics of flooding in the north coast area and found double exposure to fluvial flooding and tidal flooding, which increases the risk of damage. From this review of previous research, a research gap was identified: there has been no study that specifically integrates flood risk analysis in Demak Regency into a quantitative climate financial risk framework using scenario analysis, sensitivity analysis, and stress testing approaches in accordance with OJK guidelines (2024).

3.6 Risk identification

The assumptions used in this analysis are a physical risk scenario that considers the impact of a flood event with a relatively high level of severity and damage to the debtor's physical assets. Furthermore, this disaster is assumed to reduce the debtor's business productivity (Wardhana, 2025). Flooding is an acute physical risk stemming from risk drivers in the form of increased frequency and intensity of extreme weather events due to climate change. Through transmission channels at the microeconomic level (damage to the debtor's physical assets, decreased repayment capacity, stranded assets, and increased Capital Expenditure (Capex) and Operational Expenditure (Opex)), and macroeconomic levels (inflation and decreased purchasing power), flooding in Demak Regency has the potential to simultaneously trigger credit risk, market risk, liquidity risk, operational risk, and business and reputational risk (BCBS, 2022; OJK, 2022). Based on IRBI BNPB data for the 2020-2024 period, the flood disaster risk index for Demak Regency consistently ranks HIGH. The risk profile, which is entirely in the high category, indicates that the future forecast for the flood risk index in Demak Regency will remain high, unless there is risk mitigation that is believed to be effective.

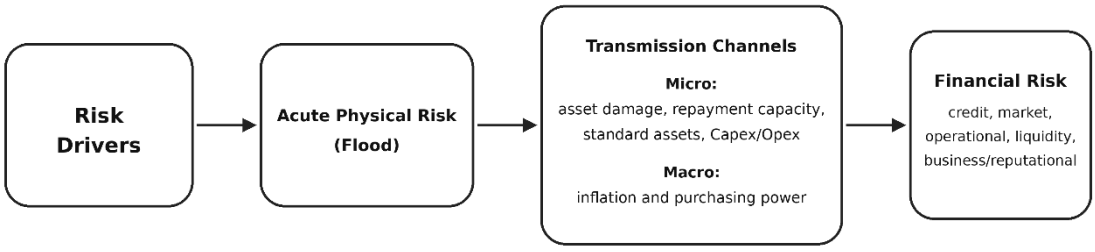

Fig. 2. Transmission channel diagram
(Wardhana, 2025)

3.7 Exposure mapping

The assumption used in exposure mapping is that the physical flood risk category refers to the official Indonesian Disaster Risk Index (IRBI) data published by the National Disaster Management Agency (BNPB). The top-down (regional) method used is because physical flood risk is more easily identified at a regional scale using nationally standardized IRBI data. The data used include: (1) BNPB's IRBI time series for the 2020-2024 period; and (2) disaster loss data using BNPB's RBI for 2023. The risk profile for the past five years has all been categorized as high, indicating that the flood risk index in Demak Regency will remain high even in the future, unless effective risk mitigation is implemented.

Table 2. Flood risk index of Demak Regency 2020-2024

Year	2020	2021	2022	2023	2024
Index	27.1	20.37	19.76	16.34	15.27
Category	High	High	High	High	High

(BNPB, 2020, 2021, 2022, 2023a, 2023b, 2024)

Based on 2023 BNPB RBI data, the economic losses due to flooding in Demak Regency are shown in Table 3. Based on the data, environmental damage due to flooding is categorized as moderate at 55.56% (5 hectares of the total area of 9 hectares) and high at 44.44% (4 hectares of the total area of 9 hectares).

Table 3. Flood losses in Demak Regency 2023

No	Province/Regency/City	Economy		Environmental damage	
		Medium	High	Medium	High
1	Demak Regency	IDR 545.278 billion (USD 30.06 million)	IDR 4.324 trillion (USD 238.35 million)	5 ha	4 ha

(BNPB, 2023a, 2023b)

Flooding in Demak Regency will trigger credit risk, market risk, liquidity risk, and operational risk, as shown in Table 4. Credit risk arises from the potential for default by agricultural debtors due to crop failure. Market risk arises from a decline in debtor asset prices due to the effects of climate change. Liquidity risk arises when portfolios are significantly impacted. Operational risk arises from disruptions to bank operations in affected areas (BCBS, 2022; OJK, 2024).

Table 4. Flood risk classification in Demak Regency

Physical Risk	Credit Risk	Market Risk	Liquidity Risk	Operational Risk
Flooding	Yes	Yes	Yes	Yes

(BCBS, 2022; OJK, 2024)

3.8 Risk quantification

Scenario analysis for climate change risk, including physical risk, is an assessment of physical risk using assumptions that influence physical risk and are believed by the organization (Wardhana, 2025). The flood-prone area of Demak Regency, according to the BNPB's 2023-2027 Flood Risk Assessment/*Kajian Risiko Bencana* (KRB), is 92,656.92 hectares. Based on time series data, flooding inundates 0.04% (37.06 hectares) of the flood-prone area in Demak Regency annually. The time series of 0.04% was obtained from the average area of land damage due to historical flooding in Demak Regency based on the BNPB KRB (2016-2020), namely the total flood damage of 7,432 ha over 200 years (1815-2015) so that an average of 37.16 ha per year was obtained, which was then compared to the total area of flood hazard areas of 92,656.92 ha. Economic losses were calculated proportionally: Medium Loss = IDR 545.278 billion (USD 30.06 million) × (Medium Area ÷ 92,656.92 ha); High Loss = IDR 4.324 trillion (USD 238.35 million) × (High Area ÷ 92,656.92 ha).

Table 5. Flood risk scenario analysis in Demak Regency

Area affected annually (ha)	Economic Loss (IDR)		Information
	Medium	High	

37.06	IDR 2.25 trillion (USD 123.79 million)	IDR 17.81 trillion (USD 981.55 million)	The area used to calculate economic losses based on categories, using the proportion approach of medium (55.56%) and high (44.44%) categories.

(BNPB, 2023a, 2023b)

Within the framework of climate risk analysis, sensitivity analysis serves to assess how far scenario analysis results can change when key variables shift, while stress testing goes further by assessing an organization's resilience to the pressures posed by climate change risk (Wardhana, 2025). The key variable tested is the percentage of flood-affected areas per year, with a range of ±0.02% of the baseline (Table 6). Based on the sensitivity analysis results, the likelihood of flooding in Demak Regency could range from 18.53 to 55.59 hectares per year, with economic losses ranging from IDR 1.12 trillion (USD 61.74 million) (moderate, best effort) to IDR 26.71 trillion (USD 1.47 billion) (high, worst case). Furthermore, banking debtors operating in Demak Regency can conduct stress tests to determine their organization's ability to tolerate flooding and maintain its sustainability.

Table 6. Sensitivity analysis of flood risk in Demak Regency

Sensitivity		Affected Area Each Year (ha)	Economic Loss (IDR)	
Category	Value		Moderate	High
Best Effort (1%)	0.02%	18.53	IDR 1.12 trillion (USD 61.89 million)	IDR 8.90 trillion (USD 490.77 million)
Baseline	0.04%	37.06	IDR 2.25 trillion (USD 123.79 million)	IDR 17.81 trillion (USD 981.55 million)
=Worst case (+1%)	0.06%	55.59	IDR 3.37 trillion (USD 185.68 million)	IDR26.71 trillion (USD 1.47 billion)

(BNPB, 2023a, 2023b)

Stress tests are used to assess the strength, resilience, or critical limits of an organization due to climate change risks, including physical risks (Wardhana, 2025). The threshold of IDR 5 trillion (USD 275.63 million) was set based on the assumption that business organizations in Demak Regency would experience significant disruption to their business continuity if flood losses exceeded that value within one year. Debtors operating in Demak Regency can conduct stress tests using the following three approaches: Organizational sustainability approach: companies or organizations managing agricultural businesses will collapse or go bankrupt if flood losses exceed IDR 5 trillion (USD 275.63 million) per year. Creditability approach: Flood losses exceeding IDR 5 trillion (USD 275.63 million) will result in an organization being unable to repay its loan installments to the bank. Asset value approach: Flooding will reduce the value of assets, thus reducing the ability to obtain credit in the future, maintaining asset value is crucial.

The approaches above can serve as a framework for determining the risk appetite and risk tolerance of banking debtor organizations in Demak Regency (Wardhana, 2025). Based on stress testing results with a threshold of IDR 5 trillion (USD 275.63 million), moderate losses in all scenarios (best effort IDR 1.12 trillion (USD 61.74 million), baseline IDR 2.25 trillion (USD 124.04 million), and worst case IDR 3.37 trillion (USD 185.78 million)) are still below the threshold, allowing the organization to survive moderate flood conditions. However, high losses in all scenarios (best effort IDR 8.90 trillion (USD 490.63 million), baseline IDR 17.81 trillion (USD 981.81 million), and worst case IDR 26.71 trillion (USD 1.47 billion)) exceed the IDR 5 trillion (USD 275.63 million), indicating that if a high-risk flood

occurs, the business sustainability of banking debtors in Demak Regency will be severely threatened.

3.9 Risk management type 1 (using a 5x5 matrix)

Risk Management Type 1 is used to assess an organization's financial capacity using a 5x5 matrix that considers the probability and impact of flood risk in Demak Regency. The probability scale is divided into five levels: almost impossible (1), meaning there is no track record of flooding; small possibility (2), meaning flooding may occur under extreme conditions but not every year; possible (3), meaning flooding occurs once in a 5-year period; possible once (4), meaning flooding occurs three times in a 5-year period; and almost certain (5), meaning flooding occurs annually in a 5-year period. The impact scale is likewise divided into five levels: insignificant (1), with losses below IDR 200 billion (USD 11.03 million); small (2), with losses between IDR 200 billion (USD 11.03 million) and IDR 500 billion (USD 27.56 million); moderate (3), with losses between IDR 500 billion (USD 27.56 million) and IDR 1 trillion (55.13 million); large (4), with losses between IDR 1.01 trillion (USD 55.68 million) and IDR 2 trillion (USD 110.25 million); and severe/significant (5), with losses above IDR 2 trillion (USD 110.25 million).

Table 7. Flood risk assessment of Demak Regency

Risk Driver	Physical Risks	Risk Description	Probability	Impact	Risk Rating
Rising temperatures and extreme weather due to climate change	Flooding and Submerged Land	Flooding occurs in flood-prone areas, resulting in economic, environmental, and social losses.	Almost certain to happen Based on IRBI time series data, floods occurred every year during 2020-2024 with a HIGH category. Based on the forecast for the next 10 years, the frequency of flooding will continue to increase in line with rising temperatures in Demak Regency.	Severe/Significant Losses range from IDR 1.12 trillion (USD 61.74 million) (best effort) to IDR 26.71 trillion (USD 1.47 billion) (worst case) Flooding of agricultural business debtors in Demak Regency has the potential to result in bankruptcy.	EXTREME

(Wardhana, 2025)

To lower the risk rating from Extreme, comprehensive mitigation efforts are required. If risk mitigation is carried out, the potential for flooding every year can be reduced but there is still the potential for it to occur during the extreme rainy season (La Nina) every 2-3 years. The mitigation measures include building adequate irrigation and drainage systems,

strengthening the flood early warning system, and diversifying debtor businesses into more flood-resistant sectors. Table 8 summarizes these measures and the residual flood risk that remains after they are implemented.

Table 8. Risk mitigation and residual risk of flooding in Demak Regency

Risk Mitigation	Probability	Impact	Risk Rating
The government and debtors are building adequate irrigation and drainage systems to reduce the impact of flooding in agricultural areas. Strengthening the flood early warning system and diversifying debtor businesses into more flood-resistant sectors.	Possible (3) If risk mitigation is carried out, the potential for flooding every year can be reduced but there is still the potential for it to occur during the extreme rainy season (La Nina) every 2-3 years.	Medium (3) If risk mitigation is carried out, the impact of flood risk can be reduced to below IDR 20 billion (USD 1.10 million) per year.	MEDIUM

(Wardhana, 2025)

The 5x5 matrix is used to determine the flood risk level in Demak Regency by combining the probability of flooding with its impact. Each risk is placed at the intersection of the probability scale (1 to 5) and the impact scale (1 to 5), which then corresponds to a risk level ranging from Low to Extreme. As shown in Table 9, the flood risk before mitigation lies in the highest probability and severe impact position, which falls in the Extreme category. After mitigation is carried out, the risk moves to a lower position in the matrix, which shows that the mitigation measures can reduce the risk level.

Table 9. 5x5 matrix

Impact Insignificant (1)	Small Impact (2)	Moderate Impact (3)	Major Impact (4)	Severe Impact (5)
Probability Almost Certain (5)				1
Probability Maybe Once (4)				
Probability Maybe (3)		RA 1	RT	
Probability Small Possibility (2)				
Probability Almost Impossible (1)				
Risk Level Description	Low	Medium	High	Extreme

4. Conclusions

Based on the analysis of physical flood risks in Demak Regency using a climate-financial risk approach, the following conclusions can be drawn: Demak Regency's flood risk profile for the 2020-2024 period consistently ranked in the HIGH category according to the BNPB's IRBI (National Disaster Mitigation Agency) with the index showing a downward trend from 27.10 (2020) to 15.27 (2024), but has not yet moved out of the high category. This indicates that Demak Regency remains one of the areas with the highest flood risk in Indonesia. Exposure mapping results indicate that the total flood hazard area in Demak Regency is 92,656.92 hectares (BNPB's KRB 2023-2027), with an estimated baseline impact area of 37.06 hectares per year (time series 0.04%). Baseline economic losses are estimated at IDR 2.25 trillion (USD 124.04 million) for the moderate category and IDR 17.81 trillion (USD 981.81 million) for the high category. Sensitivity analysis results indicate a loss range of IDR 1.12 trillion (USD 61.74 million) to IDR 26.71 trillion (USD 1.47 billion). Stress testing results with a threshold of IDR 5 trillion indicate that only the moderate losses in the best-effort scenario (IDR 1.12 trillion (USD 61.74 million)) remain below the threshold (safe),

while the moderate losses in the baseline and worst-case scenarios, as well as all high-case scenarios, exceed the threshold, indicating a very significant risk to the business sustainability of banking debtors in Demak Regency. Based on risk management type 1 using a 5x5 matrix, the flood risk in Demak Regency is rated EXTREME (probability 5 x impact 5). After comprehensive risk mitigation, the residual risk can be reduced to MEDIUM (probability 3 x impact 3).

Based on the above conclusions, the following recommendations can be made: Financial and banking institutions operating in a Demak Regency need to immediately integrate climate risk management into their credit granting processes, particularly for debtors in the agricultural sector, in accordance with OJK guidelines (2024). Agricultural debtors need to be encouraged to diversify their businesses and access agricultural insurance products to reduce their exposure to credit risk due to flooding, thereby maintaining their ability to repay loans despite flooding. The Financial Services Authority (OJK) needs to encourage regional banks to conduct regular climate risk stress testing in accordance with OJK guidelines (2024), and to increase human resource capacity in understanding and managing climate-related financial risks. The Demak Regency Government needs to accelerate the implementation of structural mitigation measures, including the construction and strengthening of embankments, improvements to drainage systems, and the development of a flood early warning system that reaches all levels of society.

Acknowledgement

The author would like to thank all parties who contributed to the completion of this research, particularly those who provided valuable support, feedback, and assistance during the research and manuscript preparation process.

Author Contribution

V.P.A.: Conceptualization; Methodology; Investigation; Data curation; Formal analysis; Writing – original draft; Writing – review & editing; Visualization; Project administration.

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 authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the authors used Grammarly to assist in improving grammar, clarity, and academic tone of the manuscript. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

Open Access

©2026. The author. This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction

in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third-party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit: http://creativecommons.org/licenses/by/4.0/

References

Amin, M. (2024). Kajian perbandingan mitigasi kerentanan fisik, ekonomi, sosial dan lingkungan akibat banjir rob di Demak. *Journal of Economic Resilience and Sustainable Development*, *1*(1),47-63 https://doi.org/10.61511/ersud.v1i1.2024.640

BCBS. (2022). *Basel committee on banking supervision principles for the effective management and supervision of climate-related financial risks*. The Basel Committee on Banking Supervision. https://www.bis.org/publications/202206-guidelines-principles-effective-management-and-supervision-climate-related-financial-risks

BCBS. (2023). *Basel committee on banking supervision consultative document*. The Basel Committee on Banking Supervision. www.bis.org

BNPB. (2015). *Kajian risiko bencana Kabupaten Demak Jawa Tengah 2016-2020*. Deputi Bidang

BNPB. (2020). *Indeks risiko bencana Indonesia tahun 2020*. Badan Nasional Penanggulangan Bencana. https://inarisk.bnpb.go.id

BNPB. (2021). *Indeks risiko bencana Indonesia tahun 2021*. Badan Nasional Penanggulangan Bencana. https://inarisk.bnpb.go.id

BNPB. (2022). *Indeks risiko bencana Indonesia tahun 2022*. Badan Nasional Penanggulangan Bencana. https://inarisk.bnpb.go.id

BNPB. (2023a). *Indeks risiko bencana Indonesia tahun 2023*. Badan Nasional Penanggulangan Bencana. https://inarisk.bnpb.go.id

BNPB. (2023b). *Risiko bencana Indonesia*. Badan Nasional Penanggulangan Bencana. https://rbi.bnpb.go.id

BNPB. (2024). *Indeks risiko bencana Indonesia tahun 2024*. Badan Nasional Penanggulangan Bencana. https://inarisk.bnpb.go.id

Bolton, P., Despres, M., Pereira da Silva, L., Awazu, A., & Svartzman, R. (2020). *The green swan : Central banking and financial stability in the age of climate change*. Bank for International Settlements. https://www.bis.org/publ/othp31.pdf

Boros, E. (2020). Risks of climate change and credit institution stress tests. *Financial and Economic Review*, *19*(4), 107–131. https://doi.org/10.33893/fer.19.4.107131

BPBD, n.d. *Pencegahan dan kesiapsiagaan.* Badan Nasional Penanggulangan Bencana. https://bpbd.kotimkab.go.id/pencegahan-dan-kesiapsiagaan/

BPS Demak. (2018). *kabupaten Demak dalam angka 2018*. Badan Pusat Statistik. https://bps.go.id

BPS Demak. (2025). *Demak 2025*. Badan Pusat Statistik. https://bps.go.id

Conlon, T., Ding, R., Huan, X., & Zhang, Z. (2024). Climate risk and financial stability: Evidence from syndicated lending. *European Journal of Finance*, *30*(17), 2001–2031. https://doi.org/10.1080/1351847X.2024.2343111

Gajendiran, K., Kandasamy, S., & Narayanan, M. (2024). Influences of wildfire on the forest ecosystem and climate change: A comprehensive study. In *Environmental Research*, *240*. Academic Press Inc. https://doi.org/10.1016/j.envres.2023.117537

Haq, M. N., Bambang, A. H., & Ahmad, K. A. (2025). Analisis spasial kerawanan banjir di Kabupaten Demak berdasarkan sebaran desa terdampak dan penurunan muka tanah. *Jurnal Multidisiplin Ilmu Akademik*, *3*(1), 493–503. https://doi.org/10.61722/jmia.v3i1.7979

Otoritas Jasa Keuangan. (2022). *Prinsip manajemen yang efektif atas risiko keuangan terkait iklim*. Otoritas Jasa Keuangan https://ojk.go.id/id/kanal/perbankan/implementasi-

basel/Documents/Pages/Consultative-Papers/Consultative%20Paper%20Prinsip%20Manajemen%20Efektif%20Atas%20Risiko%20Keuangan%20terkait%20Iklim.pdf

Otoritas Jasa Keuangan. (2024). *Climate risk management & scenario analysis perbankan 2024*. Otoritas Jasa Keuangan. https://ojk.go.id/id/Publikasi/Roadmap-dan-Pedoman/Perbankan/Pages/Climate-Risk-Management-&-Scenario-Analysis-(CRMS)-2024.aspx

Pasha, M. D. S., Dirgantara, G. G., Wiliandi, S. K., & Budianto, E. T. (2025). Flood damages in an infrastructure climate risk stress test: a case study of a solar power plant project. *Journal of Infrastructure Policy and Management*, *8*(2), 113–126. https://doi.org/10.35166/jipm.v8i2.137

Putri, S. I. P., Syakira, H., Nugroho, E. O., Layaliya, H. N., Soeharno, A. W., Kusuma, M. S. B., Farid, M., Kuntoro, A. A., Sidiq, T., Nurmalia, S. L., Widigdo, C., & Sadat, S. H. (2024). An overview of flood risk components: The Land subsidence case of Pekalongan City. *E3S Web of Conferences*, *513*. https://doi.org/10.1051/e3sconf/202451301001

Rahman, B., Karmilah, M., Kautsary, J., & Ridlo, M. A. (2021). The tidal flooding causes in the north coast of Central Java: A systematic literature review. *Journal of Southwest Jiaotong University*, *56*(6), 184–194. https://doi.org/10.35741/issn.0258-2724.56.6.15

Refnitasari, L., Cahyaka, H. W., Handayani, K. D., & Amudi, A. (2022). Analisis kerentanan fisik wilayah pesisir utara kota Surabaya terhadap bencana banjir rob. *Tata Kota dan Daerah*, *14*(2). https://doi.org/10.21776/ub.takoda.2022.014.02.2

Reinders, H. J., Schoenmaker, D., & van Dijk, M. (2025). Climate risk stress testing: A critical survey and classification. *Journal of Climate Finance*, *10*. https://doi.org/10.1016/j.jclimf.2025.100061

Suciati, R. (2025). The role of financial stability in mitigating climate risk: A bibliometric and literature analysis. In *Journal of Risk and Financial Management*, *18*(8), 428. https://doi.org/10.3390/jrfm18080428

Sugiarto, A., Puspani, N. N., & Trisilia, M. S. (2023). The shocks of climate change on bank loans. *International Journal of Energy Economics and Policy*, *13*(5), 493–514. https://doi.org/10.32479/ijeep.14773

Tol, R. S. (2002). Estimates of the damage costs of climate change. Part 1: Benchmark estimates. *Environmental and resource Economics*, *21*(1), 47-73. https://doi.org/10.1023/A:1014500930521

Wardhana, Y. M. A. (2025). *Manajemen risiko lingkungan seri-climate change risks*. UI Publishing. https://fliphtml5.com/zpkfi/udcf/Manajemen_Risiko_Lingkungan%3A_Seri_-_Climate_Change_Risks/

World Economic Forum (WEF). (2024). *The Global Risks Report 2024 (19th ed.)*. World Economic Forum. https://www.weforum.org/publications/global-risks-report-2024/

Xue, Z., Zhu, S., & Fu, H. (2026). The impact of climate physical risks on risk-taking of Chinese small and medium-sized banks: Transmission mechanism and heterogeneity. *International Review of Economics and Finance*, *107*. https://doi.org/10.1016/j.iref.2026.105126

Biography of Author

Velia Primadhani Amanda, Department of Environmental Science, Graduate School of Sustainable Development, Universitas Indonesia, Central Jakarta, Special Capital Region of Jakarta 10430, Indonesia.

- Email: primadhanivelia@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A