THE HAZARD BEHIND MINING:

THE FLOOD RISK & SOCIO-ECONOMIC IMPACT OF NICKEL MINING IN WEDA BAY CENTRAL HALMAHERA

FWi
Good Forest Governance Needs Good Forest Information

THE HAZARD BEHIND MINING:

FLOOD RISK AND THE SOCIO-ECONOMIC IMPACT OF NICKEL MINING IN WEDA BAY CENTRAL HALMAHERA

FWI

Good Forest Governance Needs Good Forest Information

THE HAZARD BEHIND MINING:
FLOOD RISK AND THE SOCIO-ECONOMIC IMPACT OF NICKEL MINING IN WEDA BAY, CENTRAL HALMAHERA

Writers:
Aziz Fardhani Jaya
Eryana Nurwenda Az-Zahra
Rosima Wati Dewi

Data Analyst & Map Presenter:
Ogy Dwi Aulia
Eryana Nurwenda Az-Zahra
Rosima Wati Dewi
Andi Juanda

Layout & Design:
S Utamidata

Oktober 2024

Published by:
Forest Watch Indonesia
Jl. Sempur Kaler No 62 Bogor Indonesia
Telp. 0251 8333308
Twitter: @fwindonesia
Facebook : Pemantau Hutan
Instagram : @fwi.or.id
Youtube : Forest Watch Indonesia
website : www.fwi.or.id

CONTENT

Aerial view of the IWIP Industrial Area © FWI 2023

A BRIEF SUMMARY

This paper aims to examine the impact of flood hazards and mining activities on the socio-economic conditions of the community in Weda Bay, Central Halmahera. The frequent flooding in this region is triggered by deforestation and mining activity, which should be a serious concern. From 2019 to 2024, there were 19 floods recorded in the region, with one of the worst occurring in July 2024, when the Kobe River overflowed, causing the water level to rise to two meters in villages like Luko Lamo and Lelilef.

Hydrometeorology hazards, particularly floods, are closely related to high rainfall and anthropogenic activities such as deforestation, resulting in reduced land cover and increased surface runoff. This study shows a correlation between the reduction of forest coverage and the increasing risk of flood. Nickel mining activities driven by the rise of global demand for electric vehicle (EV) batteries, have changed the landscape of Weda Bay significantly. The expansion of Indonesia Weda Bay Industrial Park (IWIP), the center of the nickel refinement process, is the leading cause of deforestation and environmental deterioration. The forest cover in this region decreased from 109.000 hectares in 2016 to 102.000 hectares in 2024, while the open terrain doubled due to industrial and mining activities.

This study analyzed five watersheds in the Weda Bay area using spatial-temporal modeling. The result shows that the areas with significant land cover loss, especially around the mining operation fields, has a higher potential of flooding. The socio-economic impact of these floods is quite notable, with around 10.449 people and 7.129 households falling into the high-risk areas for flooding. In addition to that, the floods also threaten around 777 hectares of agricultural land and 32 km of road infrastructure. The estimated economic loss from this disaster reaches Rp 371,3 billion, with the most significant impact felt by households.

In the last five years, Central Halmahera has frequently experienced flooding. Based on a compilation data from media and the Central Statistics Agency (BPS), there has been approximately 19 floods recorded in Weda Bay of Central Halmahera from 2019 to July 2024.

A worker from PT. IWIP and his wife wading through the flood in Lokulamo Village, Central Halmahera
© Mas Agung Wilis Yudha Baskoro

INTRODUCTION

In the last five years, Central Halmahera has frequently experienced flooding. Based on a compilation data from media and the Central Statistics Agency (BPS), there has been approximately 19 floods recorded in Weda Bay of Central Halmahera from 2019 to July 2024. Most recently, on 28th July 2024, floods struck several villages in Central Weda District after heavy rain for two days. Kobe River overflowed, flooding residential area in some villages. The worst conditions of this flood occured in Luko Lamo and Lelilef Village, with water level reaching almost two meters. Strong currents severed the main road of Trans Weda – Waleh, paralyzing residents of the two villages completely.

The heavy rainfall often becomes the scapegoat for the occurrence of flooding. However, floods are a part of hydrometeorology disasters that are correlated with the weather conditions such as temperature, wind, moisture, and hydrology cycle. Additionally, anthropogenic activities have a significant influence on intensity and frequency of hydrometeorology disasters. Deforestation or forest cover loss also contribute to the rise of local temperatures and water vapor concentration in the atmosphere. The loss of vegetation also heightens the chance of erosion and water runoff, as the land loses it’s capacity for absorption, elevating the of flooding and landslides.

A study from Forest Watch Indonesia (FWI) shows that the decrease in forest cover is directly associated with the increased flood risk[1]. An analysis that compares forest cover ratio data with flood risk from the National Disaster Management Agency (BNPB) indicate a clear trend of correlation: areas with low forest cover have higher probability of flood, whilst areas with higher forest cover have lower probability. This finding is supported by a study that conducted by Bradshaw (2007), which found a positive relation between deforestation and the frequency of global floods during the period from 1990 to 2000.

1 State of Indonesia’s Forest 2013-2017. Forest Watch Indonesia

The Weda Bay area in Central Halmahera has undergone significant changes in the past five years. Expansion of the nickel downstream industrial zone has accelerated due to the policy banning the export of low-grade nickel through the Minister of Energy and Mineral Resources Regulation No. 11 of 2019 and Presidential Regulation No. 55 of 2019. The Indonesia Weda Bay Industrial Park (IWIP), an integrated industrial zone for nickel processing and electric vehicle (EV) battery component production, has now become a National Strategic Project (PSN) officially launched by President Joko Widodo through Presidential Regulation No. 109 of 2020. At this moment, the operational area of IWIP has reached 4.000 hectares.

The development of this industrial zone aligns with the increasing global demand for nickel. Currently, the major of nickel is used in the stainless steel industry (approximately 74%) and 5-8% are for batteries. Nonetheless, the demand for nickel in batteries is expected to continue rising as the EV market grows. The International Energy Agency projects that annual demands of grade 1 nickel could reach 925 kilotons per year by 2030 under the stated policies scenario, and up to 1.900 kilotons per year under the sustainable development scenario. Indonesia itself has the largest nickel resources in the world, totalling 72 million tons or 525 of global nickel stock. In 2022, Indonesia's nickel ore production reached 1,6 million tons, the highest in the world, surpassing Philippines, which produced arround 330.000 tons.

According to data from the Ministry of Energy and Mineral Resources up to 2023, there are 13 mining business licenses (IUP) covering a total concession area of 59,678.04 hectares in Central Halmahera[2], predominantly for nickel, and most are already begun operating. However, nickel mining operations and processing have caused environmental damage that adversely affects local communities. The impacts include deforestation, river and ocean pollution, and the destruction of residents' living spaces. One example is the pollution of the Sagea River in the villages of Sagea and Kiya, North Weda District, since 2023. Mining activities upstream are believed to be causing the water to turn brownish-yellow, with thick sediment, forcing communities to bear the consequences.

Based on these conditions, FWI conducted a study to identify the environmental impacts of mining activities and nickel downstream industrialization in Central Halmahera. The study includes an analysis of the increased flood potential caused by land cover changes, as well as projections of its impacts on the socio-economic conditions of the community. The results of this study are expected to provide policy recommendations and mitigation measures to minimize the negative impacts of mining activities and nickel downstream industrialization.

---

2 Minerba One Map Indonesia, Kementerian ESDM

Nickel mining exploration camp in PT HSM's concession © FWI 2023

METHODOLOGY

This study uses a spatial-temporal modeling approach, which combines spatial and temporal data to analyze flood potential related to land clearing due to mining activities. The scope of the study encompasses five river basin (DAS) in Weda Bay area: Ake Kobe, Ake Sagea, Lelilef, Ake Gemaf, and Ake Waleh, covering a total area of 129.970, 54 hectares. In most of these river basin, companies have obtained active mining business licences (IUP) that have already started operating (Figure 1).

Flood Risk Analysis

This flood potential analysis is conducted using the Flood Hazard Index (FHI) method. FHI is a multi-parameter model based on Geographic Information System (GIS) used to identify areas at risk of flooding on a regional scale (Kazakiz et al., 2015). The analyzed data includes the years 2016, 2019, and 2024. The year 2016 represents the condition before massive mining activities, 2019 reflects the period during the development of the IWIP industrial area, and 2024 indicates the time when industrial and mining activities are operating at high intensity.

The FHI value is calculated based on the weights of each flood-causing factor, which include rainfall, land cover, flow accumulation, land slope, topography, river buffer, and geology. Five of these seven parameters are fixed, while the other two, land cover and rainfall anomalies, are dynamic.

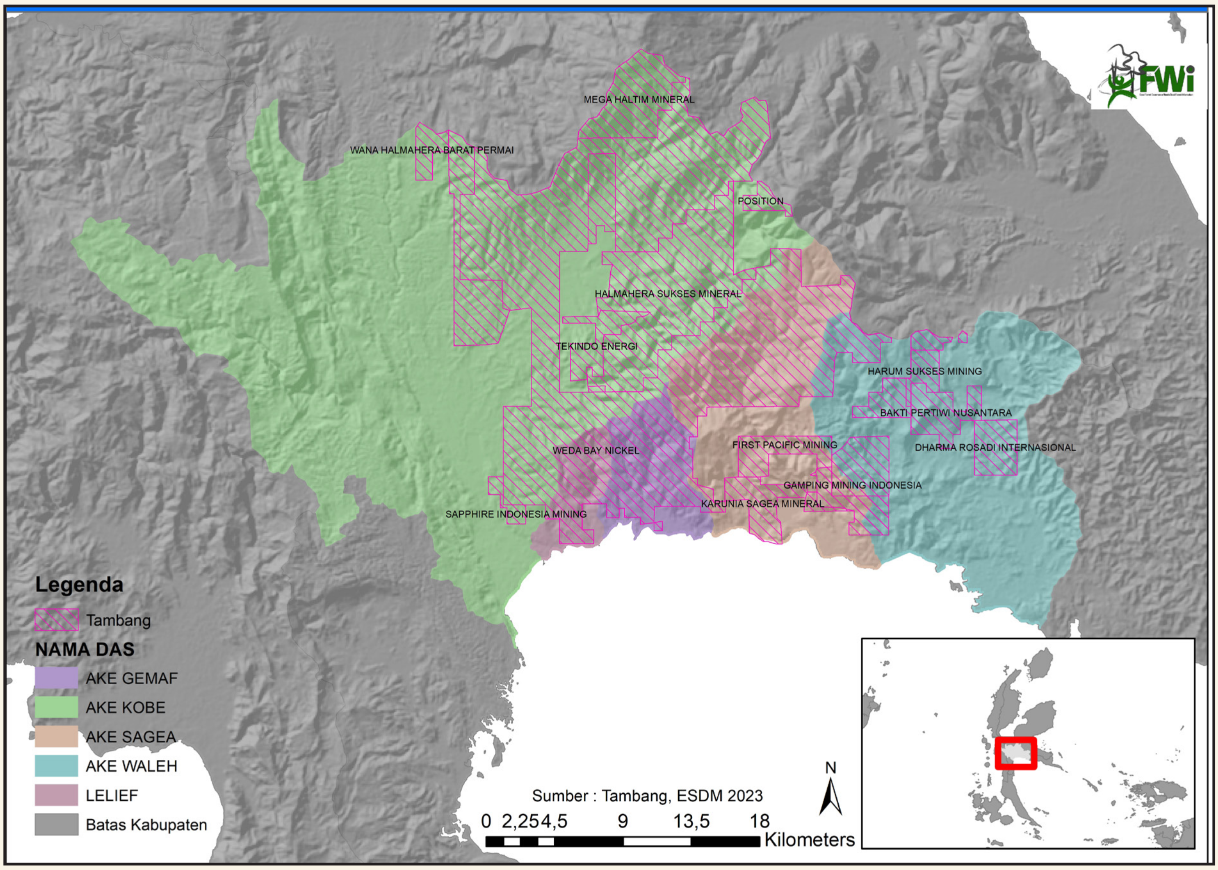


Figure 1 Map of Mining Business Permit in 5 River Basin around Weda Bay, Central Halmahera

Rainfall anomalies are analyzed using the Fournier Index (MFI), which indicates the variability and aggressiveness of rainfall and its impact on soil erosion (Munka et al., 2007). A higher MFI value indicates a greater level of rainfall aggressiveness. The data used in the MFI analysis comes from CHIRPS V.2 (Climate Hazards InfraRed Precipitation with Station data Version 2.0) for the years 2016, 2019, and 2024 (up to July).

Land cover analysis is conducted using a machine learning algorithm called random forest, utilizing a combination of Sentinel 2-A satellite imagery and Planet Basemaps with a final resolution of 5 meters. Land cover data is analyzed for the years 2016, 2019, and 2024, and this process is performed using a cloud computing platform (Aulia et al., 2022).

Analysis of Flood Impact Projections on the Socio-economic Conditions of Communities

The results of the flood hazard potential analysis are used to project the possible impacts of flooding. This projection includes social, economic, and infrastructure impacts. Social impacts are analyzed based on the number of people and households living in high-risk areas. Economic impacts are calculated using agricultural land cover data from the Ministry of Environment and Forestry in 2022. Meanwhile, the impact on infrastructure is analyzed by mapping road data from the RBI (Base Map) of the Geospatial Information Agency overlaid with flood risk areas.

Economic loss estimation is conducted using the ECLAC (DaLA) method, which is generally used in Latin America and the Caribbean but can also be applied to flood disasters in Asia (Jayantara, 2020). This calculation involves multiplying the affected area or the number of impacted units by the replacement unit value, then multiplying by a damage factor assumed to be 1 in this study.

Table 1. Replacement Unit Value (UCBFM, 2010)

Sector	Replacement Unit Value (Rupiah)
Agriculture	9.295.500/Ha
Small Scale Industry	44.300.000/Unit
Medium Scale Industry	1.170.000.000/Unit
Large Scale Industry	2.600.000.000/Unit
Main Roads	1.480.000/Meter
Local Roads	740.000/Meter
Households	47.700.000/Unit

Nickel mining exploration camp in PT HSM’s concession © FWI 2023

The nickel industrial zone, **Indonesia Weda Bay Industrial Park (IWIP)**, has undergone massive expansion since 2019. This project has exacerbated environmental damage, including river and ocean pollution, as well as significant deforestation

Aerial view of IWIP (Indonesia Weda Bay Industrial Park) © FWI 2023

Open-pit nickel mine in PT HSM's concession © FWI 2023

RESULT OF THE STUDY

Dynamics of Land Cover Change

The land cover classification results indicate that significant changes occurred between 2016 and 2024, particularly in built-up areas, open land, and natural forests. The area of built-up land increased from 229 hectares in 2016 to 1,056 hectares in 2024. Meanwhile, the area of open land also saw a significant rise, growing from 8,017 hectares in 2016 to 16,015 hectares in 2024.

The increase in built-up land indicates the development of the nickel downstream industrial zone in Weda Bay. The addition of open land, on the other hand, reflects increasingly intensive mining activities. The concentration of open land is evident in mining concession areas. Furthermore, natural forest cover has also declined, from approximately 109,000 hectares in 2016 to 102,000 hectares in 2024.

Table 2. Dynamics of land cover change in 5 river basin around Weda Bay

Land Cover	Year		
	2016	2019	2024
Water	1.234,78	1.329,73	1.346,10
Built Area	229,25	376,18	1.057,98
Open Area	8.017,39	10.677,12	16.015,66
Natural Forest	109.777,53	108.712,44	102.452,44
Shrubs Area	10.788,30	8.951,31	9.174,59
Total	**130.047,25**	**130.046,77**	**130.046,77**

The development of the IWIP began in 2016, with the goal of becoming the largest nickel processing central in Indonesia. Infrastructure development, including roads, ports, airports, and other supporting facilities, commenced. By 2019, after the completion of basic infrastructure, intensive nickel mining and processing activities began. Nickel extracted from Weda Bay is then processed at the smelter that has been constructed. As industrial activities increased, thousands of workers started arriving, leading to a rise in the number of settlements around Weda Bay area.

The global demand for nickel, particularly for the electric vehicle industry, has also driven the increase in production at IWIP. By 2020, the smelter's capacity reached over 100,000 tons of nickel per year, making this area one of the largest nickel producers in the world. In 2023, expansion continued with the construction of additional smelters, projected to reach a total of 10 smelters with a combined production capacity of 300,000 tons per year. This increase in nickel production undoubtedly accelerates the extensification of mining activities, which ultimately triggers massive land clearing and deforestation.

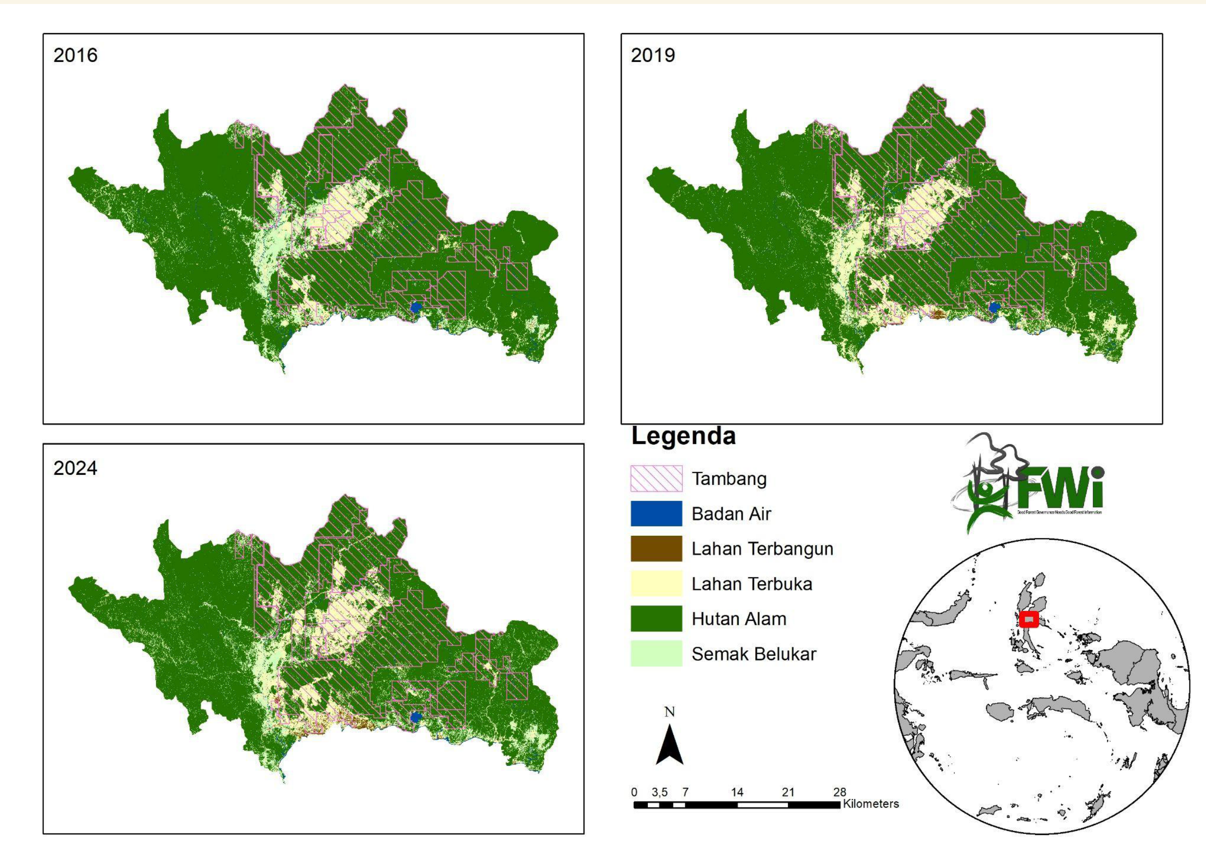


Figure 2. Land cover change dynamics map in 5 river basin around Weda Bay by year 2016, 2019, and 2024.


Hauling road in PT WBN's mining concession © FWI 2023

Rainfall Anomalies

In this study, rainfall was analyzed using the Fournier Index (MFI), which indicates the intensity of annual rainfall. A higher MFI value corresponds to greater intensity and concentration of annual rainfall. MFI calculations were performed for three observation years: 2016, 2019, and 2024. The observation area includes five river basin (DAS) around Weda Bay: DAS Ake Kobe, DAS Ake Sagea, DAS Lelilef, DAS Ake Gemaf, and DAS Ake Waleh. MFI values were classified into five categories: very low, low, moderate, high, and very high.

The MFI analysis results from the five river basin around Weda Bay over the three observation years indicate the presence of rainfall anomalies. In 2019, there was an increase in the area with very high rainfall, reaching 60,275 hectares, which is double the area recorded in 2016. Meanwhile, in 2024, the intensity of rainfall tended to fall within the moderate category, with an MFI value of around 35,637 hectares. For the very high category in 2024, there was a drastic decrease to 10,125 hectares. However, the MFI value for 2024 was only analyzed up to July.

Table 3. Area size based on rainfall class in 5 river basin around Weda Bay

MFI Classification	Year (Ha)		
	2016	2019	2024
1 (Very Low)	21,559.57	25,353.85	22,336.92
2 (Low)	25,005.30	10,070.02	27,227.72
3 (Moderate)	11,222.55	9,199.13	35,637.65
4 (High)	36,052.06	19,577.30	29,147.74
5 (Very High)	30,636.16	60,275.34	10,125.61
Total	**124,475.65**	**124,475.64**	**124,475.64**

From the perspective of area distribution, high rainfall intensity is generally concentrated in the northeastern region, particularly in the Sagea, Waleh, and Gemaf river basin, as well as parts of the northeastern Kobe River basin. A comparison between 2016 and 2019 shows a change in rainfall concentration in the western part of the Kobe River basin, where there was an increase in intensity. By 2024, high rainfall concentration occurred in the Gemaf river basin and parts of the Kobe River basin, which experienced significant land cover changes and deforestation due to mining activities.

Changes in rainfall intensity can be attributed to various factors, one of which is climate change (such as La Niña and El Niño) that affects precipitation patterns worldwide. According to BMKG records, 2019 was the second hottest year after 2016, both globally and in Indonesia. This led to extreme weather events in several regions of Indonesia from late 2019 to early 2020. Based on compiled data, four flood disasters occurred in Central Halmahera during 2019–2020.

Central Halmahera falls under climate type A (very wet) according to the Schmidt-Ferguson climate classification, with average rainfall ranging from 1,695 to 2,570 mm per year. Additionally, this region has a moderate to severe erosion risk. The high rainfall and extensive land cover changes increase the likelihood of disasters such as floods and landslides.

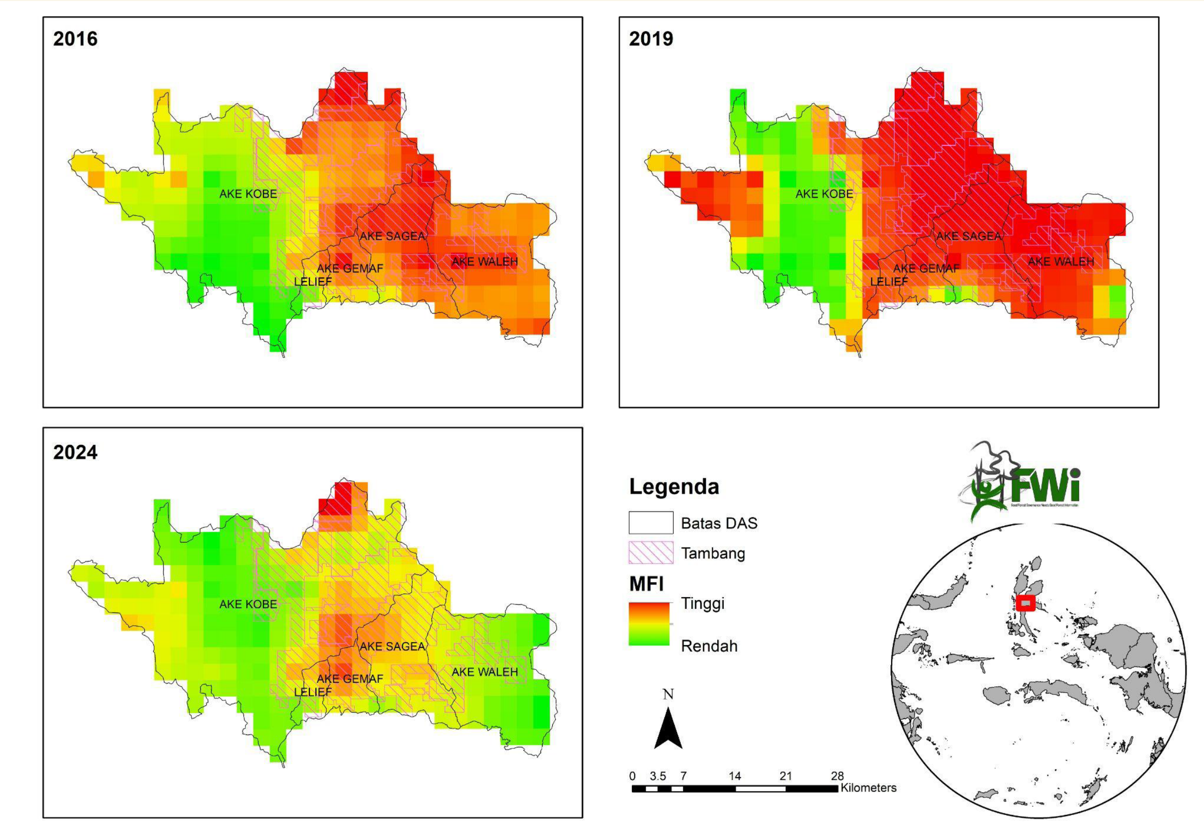


Figure 3. Annual rainfall map in 5 river basin around Weda Bay by years 2016, 2019, and 2024.

Flood Risk Potential

Based on the flood hazard potential analysis from 2016 to 2024, the area around Weda Bay has experienced a significant increase in flood risk. The average index indicates that the five river basin in this region are dominated by areas with moderate to high flood risk potential, covering approximately 40.000 hectares for the moderate category and 32.000 hectares for the high category.

The areas with remarkably high flood risk increased by about 3.080 hectares during this period, rising from 9.082,71 hectares in 2016 to 12.162,97 hectares in 2024. In 2024, the Kobe river basin recorded the largest area with a high to very high flood risk index, approximately 22.487 hectares, followed by the Sagea river basin with 6.719.5 hectares. The Gemaf and Lelilef river basin have around 3.738 hectares and 2.319 hectares, respectively, of high to extremely high-risk areas.

Table 4. Flood risk potential values in 5 river basin around Teluk Weda

Flood Hazard Index (FHI) Category	Area (Ha)		
	2016	2019	2024
Very Low	17.43,09	18.07,85	17.850,55
Low	27.081,91	19.741,29	36.118,46
Moderate	41.707,45	41.658,48	39.383,34
High	34.736,59	39.028,99	24.531,42
Very High	9.082,71	11.545,13	12.162,97

Table 5. Flood risk potential values in 5 river basin around Teluk Weda in 2024

Natural Break Classification Method	Watershed in 2024 (Ha)					Total (Ha)
FHI Category	**AKE GEMAF**	**AKE KOBE**	**AKE SAGEA**	**AKE WALEH**	**AKE LELIEF**	
Very Low	7.83	12,068.21	149.89	5,618.96	5.67	17,850.55
Low	127.65	23,577.66	1,174.08	11,167.85	71.23	36,118.46
Moderate	1,035.83	23,409.14	8,118.30	6,390.25	429.82	39,383.34
High	1,966.76	14,581.01	5,426.84	1,305.92	1,250.89	24,531.42
Very High	1,771.42	7,905.98	1,292.73	154.58	1,038.25	12,162.97
TOTAL	**4,909.49**	**81,542.01**	**16,161.84**	**24,637.56**	**2,795.85**	**130,046.75**

The murky waters of Sagea river due to suspended sediments © SaveSagea 2023

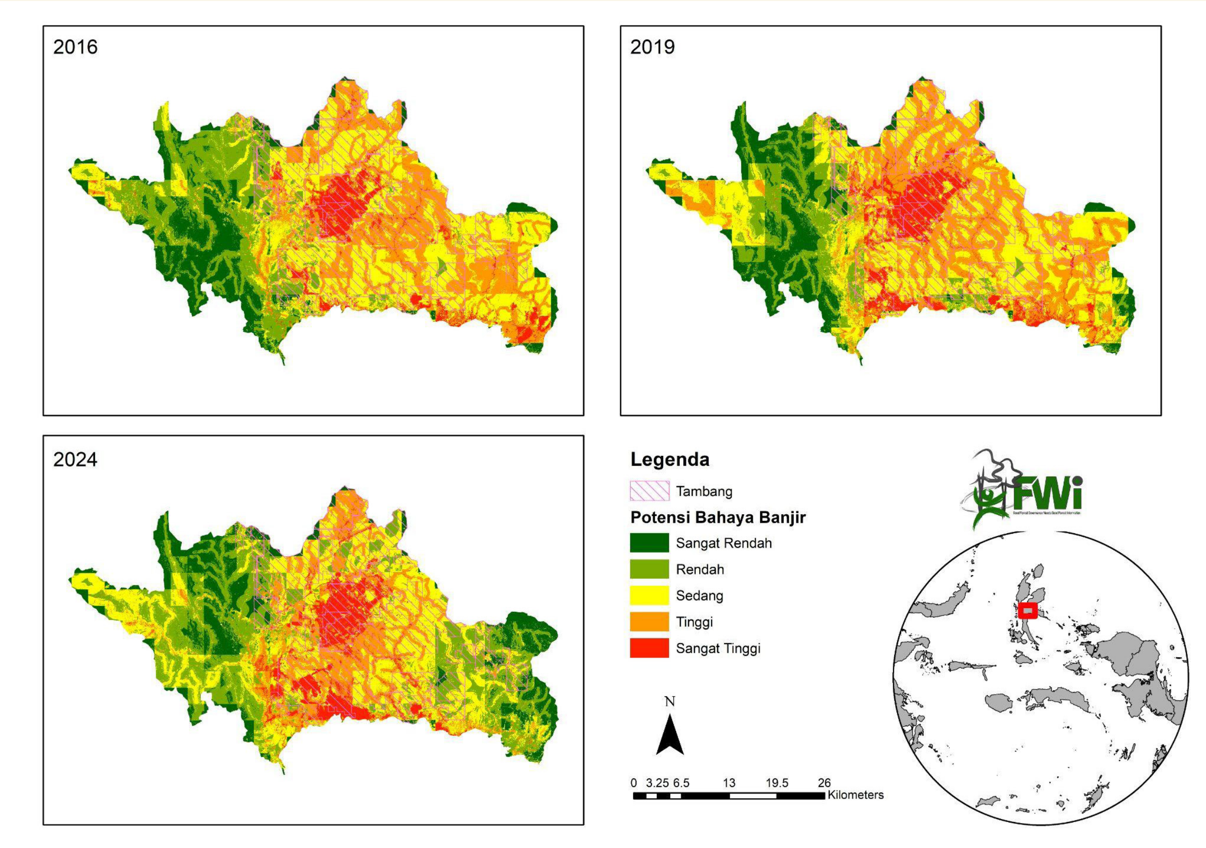


Figure 4. Flood hazard risk potential map in 5 river basin around Teluk Weda by the years 2016, 2019, and 2024.

High flood risk areas are concentrated in open land due to mining activities, near industrial zones, residential areas, and along rivers. Over the past five years, the Kobe river basin and the sub-basin of Ake Lelilef and Ake Gemaf have undergone drastic changes. The development of the IWIP industrial zone downstream of the Kobe river basin and the Lelilef-Gemaf sub-basin, along with mining activities upstream, have resulted in massive deforestation, altering the landscape and land cover.

Land cover changes and deforestation significantly increase the flood risk in the Central Halmahera region. When forest vegetation is lost, the land's ability to absorb water diminishes, leading to increased surface runoff. Additionally, the loss of trees and plants that serve as natural barriers results in faster and stronger water flow, thereby raising the flood risk, especially during the rainy season.

In the past five years, the Weda Bay area in Central Halmahera has experienced a significant increase in flood frequency. Based on the compiled data, approximately 19 floods have occurred since 2019. These floods have inundated villages around the IWIP industrial zone, causing infrastructure damage, transportation disruptions, and economic losses for local residents. The floods have also severed access to the main roads that are connecting the villages.


Flooding submerges Lukolamo village © News.org 2024

Flood Impact Projections on the Communities Socio-Economic Aspects

Floods has a remarkable impact on the socio-economic conditions of communities. Socially, floods lead to many residents losing their homes and an increased health risk due to the spread of diseases. Economically, floods cause substantial losses, ranging from damage to agricultural land affecting crop yields to the destruction of infrastructure such as roads, bridges, and public facilities. These impacts add to the burden on affected communities, particularly those living in high-risk areas.

This study analyzes the impact of flooding on the socio-economic conditions of communities. The analysis focuses on areas with high and very high flood risk. In 2024, the high and very high-risk areas in the five river basin surrounding Weda Bay reached approximately 36,693 hectares. The analysis of social impact projections includes the number of residents and households in high flood risk areas, while the economic impact is measured by the extent of agricultural land and roadways in high-risk areas.

Social Impacts

The analysis of the impact of flood hazards on the population projects that approximately 10,449 individuals are at high risk of being affected by flooding. This population is spread across 12 villages located in two sub-districts, namely Central Weda and North Weda. In Central Weda, the residents of the villages of Lelilef Sawai, Waibulan, and Kulo Jaya are at the highest risk of flood impacts, with populations of approximately 1,861, 1,851, and 906 individuals, respectively. Meanwhile, in North Weda, the villages of Sagea and Waleh are the areas with the largest number of residents at risk of flood hazards, with populations of around 1,207 and 1,021 individuals, respectively.

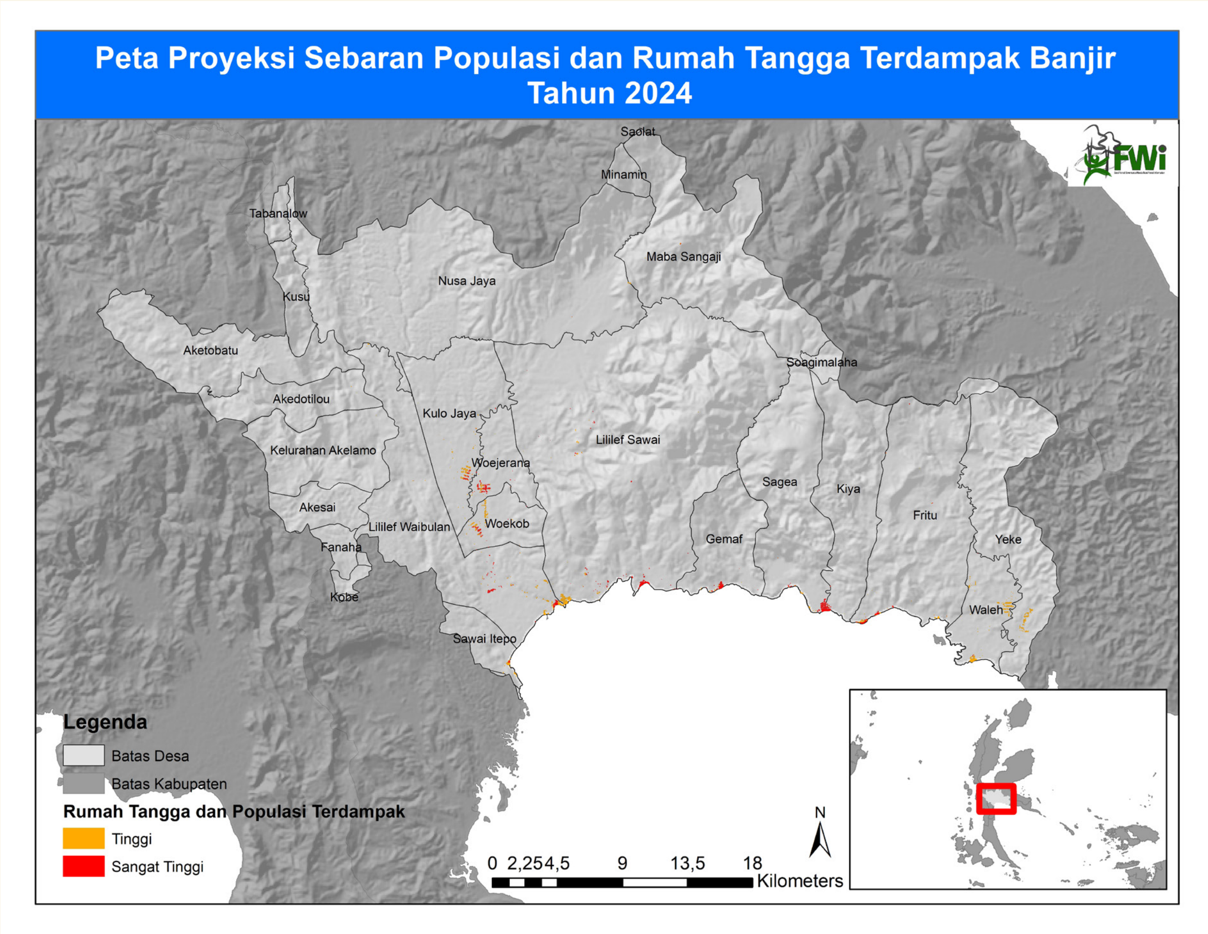
Table 6. Projected flood impact on population in high-risk flood areas

Location		Affected Population		Total
District	Village	High Risk Area	Very High Risk Area	
Central Weda	Kobe	4	0	4
	Kulo Jaya	689	217	906
	Lililef Sawai	1.188	673	1.861
	Lililef Waibulan	1.277	574	1.851
	Sawai Itepo	238	49	287
	Woejerana	247	451	698
	Woekob	435	238	673
North Weda	Sagea	72	1.135	1.207
	Fritu	366	415	781
	Gemaf	60	437	497
	Kiya	5	658	663
	Waleh	1.020	1	1.021
Total		**5.601**	**4.848**	**10.449**

The projections also indicate that there are approximately 7,129 households located in areas with high to very high flood risk. In Central Weda District, the villages of Lelilef Sawai and Lelilef Waibulan have the highest number of at-risk households, with around 1,362 and 1,291 units, respectively. This projection aligns with the flood occurrences in 2024 in several villages in Central and North Weda, including Lelilef Sawai, Lelilef Waibulan, and Sagea. Based on the risk assessment, these villages indeed have a very high level of flood risk.

Table 7. Projected flood impact on household units in high-risk flood areas

Location		Affected Household		Total
District	Village	High Risk Area	Very High Risk Area	
Central Weda	Kobe	1	0	1
	Kulo Jaya	242	114	356
	Lililef Sawai	777	585	1362
	Lililef Waibulan	649	642	1291
	Sawai Itepo	268	81	349
	Woejerana	115	269	384
	Woekob	308	339	647
North Weda	Sagea	24	517	541
	Fritu	246	390	636
	Gemaf	69	488	557
	Kiya	1	358	359
	Waleh	638	8	646
Total		**3.338**	**3.791**	**7.129**



Economic and Infrastructure Impact

The economic impact is measured based on the area of agricultural land located in regions with high to very high flood risk. The agricultural land referred to in this study includes dryland agriculture, mixed shrubland, and rice fields, according to land cover data from the Ministry of Environment and Forestry (KLHK).

The analysis of flood hazard impact estimates that approximately 777.12 hectares of agricultural land are at high risk of being affected by floods. The largest area of at-risk agricultural land is in North Weda District, with about 487.33 hectares, while Central Weda District has around 289.78 hectares of agricultural land at high risk of flooding.

Flooding submerges Lukolamo village and surrounding areas © Subhan 2024

Table 8. Projected flood impact on agricultural land in high-risk flood areas

District	Affected Agricultural Land (Ha)		Total
	High Risk Area	Very High Risk Area	
North Weda	142,32	147,47	289,78
Central Weda	205,06	53,06	258,12
	3,23	138,4	141,63
	43,44	5,99	49,42
	33,95	4,2	38,16
Total	**428,00**	**349,12**	**777,12**

Aside from the area of agricultural land cover analysis, the economic impact analysis is also measured using road infrastructure data. Roads are a primary transportation access point that connects economic activities within a region. Disruptions to road access due to flooding can significantly affect economic activities in the area. The analysis shows that there are approximately 32,580 meters of roads at risk of flood impact, comprising both local roads and footpaths.

Table 9. Projected flood impact on road infrastructure in high-risk flood areas

District	Local Roads (m)		Footpaths (m)		Total (m)
	High Risk Area	Very High Risk Area	High Risk Area	Very High Risk Area	
Central Weda	12.270	8.630	2.740	3.700	27.340
North Weda	-	-	4.520	720	5.240
Total	**12.270**	**8.630**	**7.260**	**4.420**	**32.580**

Based on the distribution of the area, the roads in Central Weda District are the most affected, with a length of approximately 27,340 meters. In North Weda District, there are about 5,240 meters of roads at high risk of flood impact. This situation highlights the significant economic impact that flooding can have on infrastructure and accessibility, which in turn will affect economic activities and the welfare of the communities in the region.

Calculating Estimation of Economic Loss from Flood

The estimated economic loss calculated in this study represents direct losses. Direct losses are those incurred due to direct physical contact with flood disasters, such as buildings and areas submerged by water. In this study, the estimation of economic losses includes the value of losses in household units, agricultural land, and road infrastructure.

The results of the economic loss estimation projected for the flood disaster in the river basins around Weda Bay are approximately IDR 371 Billion. This loss includes agricultural land valued at IDR 7,22 Billion, local road infrastructure at IDR 24,1 Billion, and the largest loss in household units, amounting to IDR 340 Billion.

Table 10. Estimated economic loss impact of floods in high-risk flood areas

Sector	Impacted Area	Total Replacement Cost (Rupiah)
Agriculture (hectare)	777,12	Rp 7.223.718.960,00
Local Roads (meter)	32.580	Rp 24.109.200.000,00
Household (unit)	7.128	Rp 340.005.600.000,00
	Total	**Rp 371.338.518.960,00**

In addition to the calculated material losses, flood disasters also have long-term impacts on the social and economic conditions of the community. The loss of homes and agricultural land directly affects the livelihoods and economic stability of the residents. Damaged infrastructure complicates transportation access and the distribution of goods, ultimately hindering economic and social activities in the affected areas. Post-disaster recovery efforts require significant time and resources, exacerbating the burden on the impacted communities and reducing their quality of life.

The murky flow of Sagea river due to suspended sediments © SaveSagea 2023

CONCLUSION

All in all, this study emphasizes that nickel mining activities in Weda Bay significantly worsen the risk of hydrometeorological disasters, particularly flooding. The increased flood risk indirectly heightens the community's vulnerability to serious social and economic impacts. Several key points noted in this study include:

1. **Expansion of Nickel Mining and Its Impact on Land Cover Change and Deforestation**
   The nickel industrial zone, Indonesia Weda Bay Industrial Park (IWIP), has undergone massive expansion since 2019. This project has exacerbated environmental damage, including river and ocean pollution, as well as significant deforestation. Changes in land cover are evident from the increase in built-up areas, which rose from 229 hectares in 2016 to 1,056 hectares in 2024, while open land doubled in size. Conversely, the area of natural forest decreased from 109,777 hectares to 102,452 hectares during the same period.

2. **Increased in Disasters and Flood Risk**
   Since 2019, Weda Bay has seen a significant rise in flood frequency, with a total of 19 events. From 2016 to 2024, the area around Weda Bay experienced an increased flood risk, with high-risk zones reaching 36,693 hectares by 2024. Villages such as Lelilef, Waibulan, and Sagea are among the most vulnerable. Changes in land cover and deforestation have significantly contributed to the heightened flood risk in this region. High-risk flood areas are concentrated in open land due to mining activities, near industrial zones, settlements, and along riverbanks.

3. **Potential Socio-Economic Impacts and Estimated Losses**
   Approximately 10,449 individuals and 7,129 households in the area around Teluk Weda are at risk of flooding. The economic impacts include damage to infrastructure, agricultural land totaling 777.12 hectares, and the disruption of road segments totaling 32,580 meters. The total estimated economic losses due to flooding reach Rp 371.3 billion, with the largest losses incurred by households, amounting to Rp 340 billion, followed by losses in infrastructure and agricultural land.

REFERENCES

Bradshaw, C. J. A., Sodhi, N. S., Peh, K. S.-H., & Brook, B. W. (2007). Global evidence that deforestation amplifies flood risk and severity in the developing world. Global Change Biology, 13(11), 2379–2395. https://doi.org/10.1111/j.1365-2486.2007.01446.x

Harsányi, E., Bashir, B., Alsilibe, F., Moazzam, M. F. U., Ratonyi, T., Alsalman, A., Széles, A., Nyeki, A., Takács, I., & Mohammed, S. (2022). Predicting modified fournier index by using artificial neural network in Central Europe. International Journal of Environmental Research and Public Health, 19(17), 10653. https://doi.org/10.3390/ijerph191710653

Jayantara, I. G. N. Y. (2020). Implementasi QGIS untuk Mengestimasi Kerugian Ekonomi Akibat Banjir di Kabupaten Bandung. Jurnal Pendidikan Teknologi dan Kejuruan, 18(2), 231-242. P-ISSN: 0216-3241, E-ISSN: 2541-0652.

Kailola, J., Purwanto, R., Sumardi, S., & Faida, L. R. W. (2023). Anthropogenic damage, land cover change and mitigation of Mount Hamiding Protected forest area in North Halmahera District, North Maluku Province-Wallace Zone, Indonesia. MDPI AG. http://dx.doi.org/10.20944/preprints202305.1624.v2.

Lessy, M. R., Wahiddin, N., & Nagu, N. (2018). Flood risk assessment and its vulnerability in coastal villages, central halmahera district – north maluku. Proceedings of the International Conference on Science and Technology (ICST 2018). http://dx.doi.org/10.2991/icst-18.2018.79

Nyarko, B. K. (2002). Application of a rational model in GIS for flood risk assessment in Accra, Ghana. Journal of Spatial Hydrology, 2(1), 1-14.

Patrikaki, O., Kazakis, N., Kougias, I., Patsialis, T., Theodossiou, N., & Voudouris, K. (2018). Assessing flood hazard at river basin scale with an index-based approach: The case of Mouriki, Greece. Geosciences, 8(2), 50. https://doi.org/10.3390/geosciences8020050

Good Forest Governance
Needs Good Forest Information
www.fwi.or.id