# Climate Risk and Impact Assessment of Pekalongan, Indonesia

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Mercy Corps Indonesia

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**In partnership with**

# Executive Summary

Indonesia ranks fifth in the world in terms of population inhabiting lower elevation coastal zones vulnerable to sea level rise, with 60 percent of the population living along the 100,000 kilometers of coastline. Over 4.2 million people are likely to be exposed to permanent flooding by 2070–2100 without adaptation[1]. The Greater Pekalongan Area on the north coast of Java, comprised of Pekalongan City and Regency, is frequently affected by severe coastal and tidal flooding causing loss of income, assets, and productive land for the 1.2 million residents.

Mercy Corps Indonesia, Diponegoro University, and Bogor Agricultural Institute, as part of the Zurich Flood Resilience Alliance program, conducted a climate risk and impact assessment of the Kupang River watershed and coastal areas of Pekalongan City and Pekalongan Regency, with the aim to support local governments to understand the underlying drivers, risks, and impacts of flooding; and inform policy development. The assessment consists of a hazard, vulnerability, and risk analysis; and an economic and non-economic impact analysis of coastal and tidal flood events.

The decadal climate prediction indicates an increase in the frequency and intensity of extreme rainfall in the upstream areas of the Kupang watershed. The combination of sea level rise (projected to be around 0.81 cm/year) and land subsidence (between 0-34.5 cm/year) is expected to increase tidal flooding in Pekalongan, in addition to climate-induced coastal flooding. The percentage of villages/kelurahans categorized as having a very high hazard index is estimated to rise from the current 10 percent, to nearly 40 percent by 2035.

Poor land use management has led to around 22 percent of the Kupang watershed, the primary water source of Pekalongan, to experience ecosystem degradation and surface runoff. Lack of alternative water sources has led to excessive groundwater extraction and caused significant land subsidence. The rate of land subsidence is alarming, ranging from 0 – 34.5 centimeters (median 16.5) per year, with coastal and downstream areas experiencing the highest rates. The rapid and high rate of land subsidence has led to permanent inundation of villages in coastal areas, and driven some parts of the community to relocate from their ancestral lands. Residents who have opted to stay in permanently inundated areas due to their socio-economic status, are faced with the difficult task of transforming their livelihoods to withstand these climate impacts.

Spatial inundation modelling results predict permanent inundation to increase four times from the current 1,478 Ha to 5,721 Ha by 2035 - 90 percent of Pekalongan City and a major portion of Pekalongan Regency's coastal area will be under water. The majority of this land is currently utilized for agriculture, aquaculture, and residential settlements. The percentage of residential areas impacted by flooding in Pekalongan City is estimated to increase 100 times, from 0.5 percent in 2020 to 51 percent in 2035.

An impact analysis on 41 villages identified as having the highest risk revealed the total annual impact of flooding to be around 474.4 million annually in 2020. This figure is twice the total annual budget of Pekalongan City and Regency. Losses are predicted to increase almost five-fold to USD 2.15 billion per year by 2035 due to increasing flood risks.

The adaptive capacity of communities is predicted to largely remain at a low to moderate level, with slight increases due to flood mitigation infrastructure development and the implementation of a planned health insurance program which is expected to decrease the impact of water-borne

[1] : Climate Risk Profile: Indonesia (2021): The World Bank Group and Asian Development Bank, <https://www.adb.org/publications/climate-risk-country-profile-indonesia > [accessed 1 July 2021].

diseases in flood events. The poor socio-economic conditions of communities, and lack of knowledge and skills on adaptation and disaster risk management, hinder the adoption of adaptive and resilient livelihood practices, and accelerate loss of livelihood productivity and assets. Such conditions have been exacerbated by the COVID-19 pandemic, which has had significant socio-economic and health impacts to communities. The pandemic has affected the resilience of communities to withstand shocks and stresses such as flooding in both the short-term and long-term.

The evidence generated from risk and impact assessments are informing policy development of the Pekalongan City and Regency governments. Policy recommendations are currently being developed around four clusters: zoning and regional adaptation; flood management infrastructure; water resource management through infrastructure and conservation; and human resource and institutional capacity development on disaster risk reduction.

## Background

Indonesia ranks fifth in the world in terms of population inhabiting lower elevation coastal zones, which are vulnerable to sea level rise, with 60 percent of the population living along the 100,000 kilometer coastline. Approximately 3,000 villages located along the coast experienced flooding between 2016-2018. A country abundant with marine resources, 22 percent of the population of coastal villages rely on the fisheries sector for their livelihood (BPS, 2018). Indonesia also ranks in the top-third of countries for climate risk, with high exposure to flooding and extreme heat. Over 4.2 million people are likely to be exposed to permanent flooding by 2070–2100 without adaptation (ADB, 2021). Climate vulnerability, especially for coastal areas in the country, impacts peoples' lives and livelihoods.

The Greater Pekalongan Area on the north coast of Java, comprised of Pekalongan City and Regency and home to 1.2 million, is frequently affected by severe coastal and tidal and sea tides (Pasaribu et al. 2013). Historically, the Pekalongan coastal area has experienced sea level rise of 5 mm per year, which is higher than that of the Java Sea, which is generally 3.9 mm per year (Kismawardhani et al. 2018). The rapid rate of land subsidence in Pekalongan, estimated to be 10-17cm per year (2012-2018), combined with rising sea levels, make the area especially vulnerable to flooding (Tempo, 2019).

The recurring floods have caused losses in assets, productive lands, and infrastructure, as well as disruption in public services. Moreover, the disasters have decreased the communities' income due to significant costs for preparedness, response, and recovery. The local government's fiscal capacity has also been impacted by having to continuously support flood risk reduction and response measures.

The severe impacts and climate vulnerabilities of Pekalongan drove Mercy Corps Indonesia, Diponegoro University, and Bogor Agricultural Institute, to undertake a climate risk and impact assessment as part of the Zurich Flood Resilience Alliance program, with the aim to support the Pekalongan City and Regency governments to understand the underlying drivers, risks, and impacts of flooding; provide evidence for decision making on interventions; and inform policy development.

## Methodology

The climate risk and impact assessment consists of a hazard, vulnerability, and risk analysis; and an economic and non-economic impact analysis of the causal impacts of flooding on peoples' lives (Figure 1). The study area involved two interconnected landscapes: the Kupang River watershed and the transboundary coastal area of Pekalongan City and Pekalongan Regency. The areas were selected for their strategic role in regional water supply heavily influenced by environmental degradation.

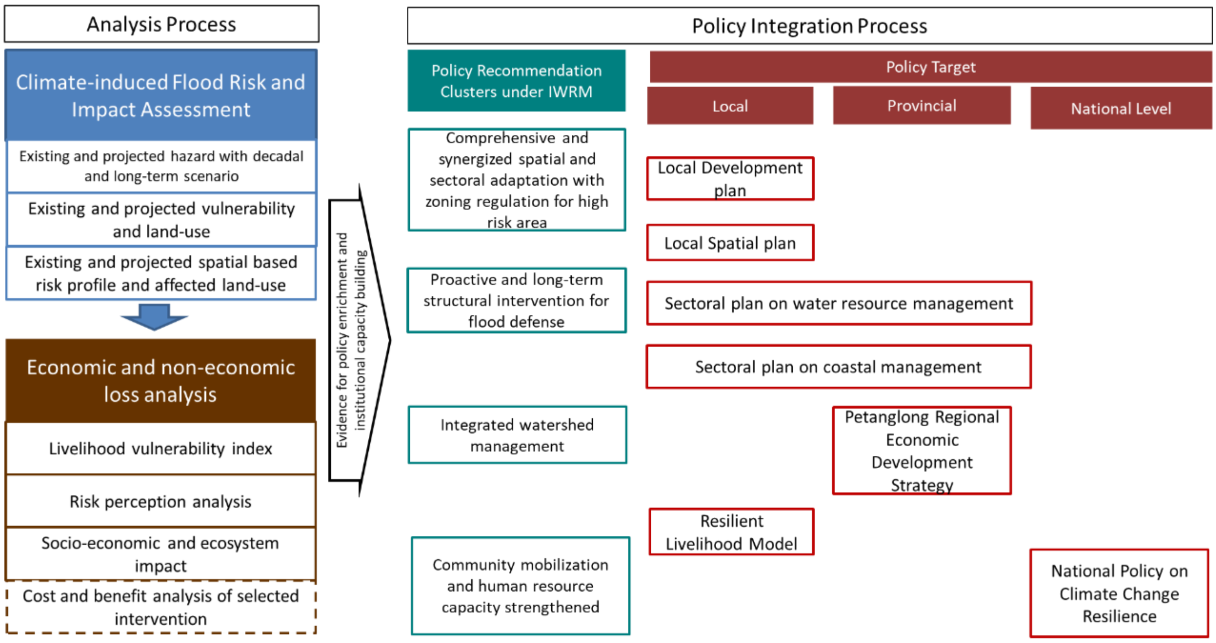


Figure 1: Climate risk and impact assessment and policy integration process.

## Hazard analysis methodology

The hazard analysis entailed climate modelling (climate change projection), sea level rise projection, flood spatial model simulation, and hazard modelling. Considering the rapid physical changes taking place in the studied coastal area and the urgent need for short-term recommendations for policy development, the climate modelling was done for both the near-term (decadal projections) and the long-term (RCP 4.5 and RCP 8.5 predictions).

The hazard analysis process was conducted for the current baseline (2020), 5-yearly projections until 2035 for decadal projections, and 25-yearly projections until 2095 for long-term projections. A flood hazard index for each projection period was determined based on the inundation level and land level from the agent-based model simulation results with 30x30 meter spatial resolution.

| Category | Inundation level (cm) | Index value |
|---|---|---|
| Not affected | 0 | 0 |
| Very light | 0.01-4.2 | 0.2 |
| Light | 4.2-31.7 | 0.4 |
| Moderate | 31.7-77.83 | 0.6 |
| High | 77.83-192.74 | 0.8 |
| Very high | >192.74 | 1 |

Table 1: Flood hazard categorization developed by authors.

## Vulnerability analysis methodology

The vulnerability analysis is comprised of a sensitivity analysis, exposure analysis, and adaptive capacity analysis. The analysis process was conducted for the current baseline condition and 5-yearly projections until 2035. Vulnerability was measured from a function of sensitivity, exposure, and adaptive capacity (vulnerability = [sensitivity*exposure] / adaptive capacity). The results of the vulnerability model were classified into five vulnerability index classes, from very low to very high. Data was obtained from primary and secondary data collection, both spatial and non-spatial, including geospatial data analysis, questionnaires (targeting communities, regency/city governments, and villages/kelurahans), and statistical data at the village/kelurahan level. An analysis on land use change and land subsidence was also conducted to further understand the vulnerability of the study area.

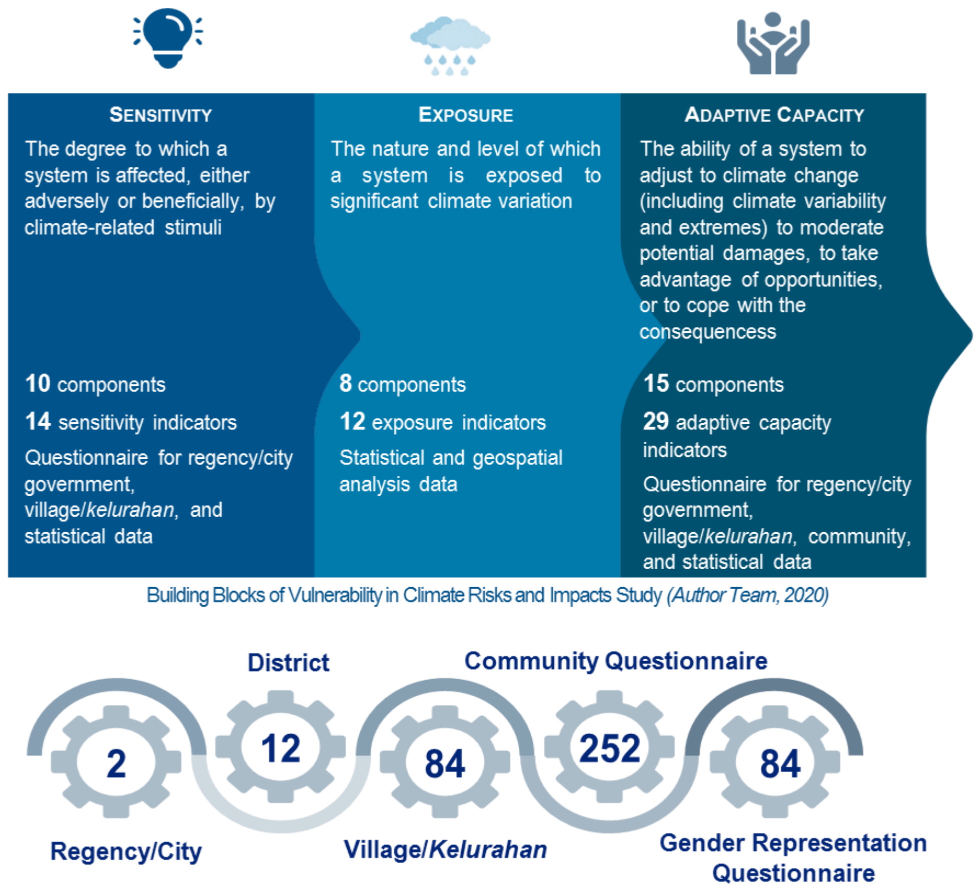


Figure 2: Vulnerability analysis components and indicators.

## Risk analysis methodology

Risk is considered as a function of hazard and vulnerability (risk = hazard * vulnerability).  A risk map was produced with a grid-scale analysis unit, overlaid with village administrative boundaries. The risk analysis additionally examined the potential impact of inundation from a spatial perspective. The results of the risk analysis were classified into five levels of an index, ranging from very low to very high. The classification is done by proportionally dividing the risk value (0 - 1) into the five classes. The risk level is categorized as very-high if the index value is above 0.8 to 1, and categorized as very-low if the value is between 0 to 0.2.

### Loss and damage assessment with economic and non-economic impact valuation methodology

Loss and damage calculation was conducted in 41 villages/kelurahans predicted to be most impacted by inundation. This was assessed across four categories: material loss (costs for adaptation and repair, medical costs, additional cost of clean water needs, additional food cost, and additional energy cost); non-material loss (psychological impacts and household social disruptions such as domestic violence); land productivity loss; and ecosystem service loss (tourism service). The calculation basis utilized are as follows:

- Future loss and damage value is calculated based on the time value of money;
- Future value is calculated by using the discount rate of 4.44% per annum. The respective discount rate is based on the average annual inflation rate in Pekalongan in the last seven years (year 2013-2019);
- Projection of impacted population is calculated exponentially by using the average annual population growth rate;
- Projection of spatial distribution of the flooded area in each period is based on GIS simulations that consider the percentage of flooded areas, percentage of flooded village/ward areas, and data on agriculture and fishpond areas.

## Hazard Analysis Findings

### Climate scenario

Analysis of the probability of monthly rainfall anomaly, which indicates the deviations of annual rainfall from long-run averages, shows a trend of Above Normal (AN) anomaly. For example, in 2021, AN rainfall is predicted to occur more frequently in the study area, particularly in the upstream and midstream areas of the Kupang River watershed, except for February and December. Meanwhile, downstream and coastal show a Normal (N) rain anomaly. **The trend of increased rainfall in upstream areas is predicted to continue, indicating a likelihood for flash floods to occur and affect the midstream and downstream areas if risk reduction measures are not taken.** The need for a comprehensive watershed management system is evident.

The wet extreme indices analyzed under the decadal climate prediction are comprised of: 1) Rx1day, which is the highest daily rainfall within a year; 2) Rx5day, which is the highest 5-day cumulative rainfall in a year; and 3) R20mm, which is the number of rainy days in a year with daily rainfall value of more than 20 mm. The upstream areas of the Kupang watershed will likely experience an increase in the frequency and intensity of extreme rainfall. The midstream and downstream areas are predicted to experience more frequent but less intense rainfall.

### Long-term climate projection

Long-term climate projection was carried out for two scenarios from 2021-2095, namely 1) RCP 4.5, which represents a moderate condition with a scenario of moderate mitigation measures to maintain radiative forcing level due to greenhouse gas emissions, and 2) RCP 8.5, which represents an extreme condition with a scenario of no measures conducted to limit greenhouse gas emissions. The extreme indices utilized for the projection were Consecutive Dry Days (CDD), Consecutive Wet Days (CWD), R10mm, R20mm, Rx1day, and Rx5day. The Rx1day, Rx5day, and R20mm indices served as a reference for wet extreme conditions that are correlated with flood and landslide events. Meanwhile, Consecutive Dry Days (CDD) indicates the possibility of drought, as the index provides information on the number of consecutive days without rain over a certain period of time.

**The long-term climate projection results predict the Pekalongan will experience wetter conditions. Higher rainfall intensity and frequency will not only affect coastal areas, but also the southern upstream areas.** Spatial analysis shows an increase in the likelihood of intensity and frequency of extreme rainfall events, especially in the coastal area as shown by the increases of percentage changes in the Rx1day, Rx5day, R10mm and R20mm. Moreover, **in a RCP8.5 scenario without any measures for mitigation, the number of Consecutive Wet Days (CWD) is expected to increase 40 percent.** The number of Consecutive Dry Days (CDD) did not show significant change in the future.

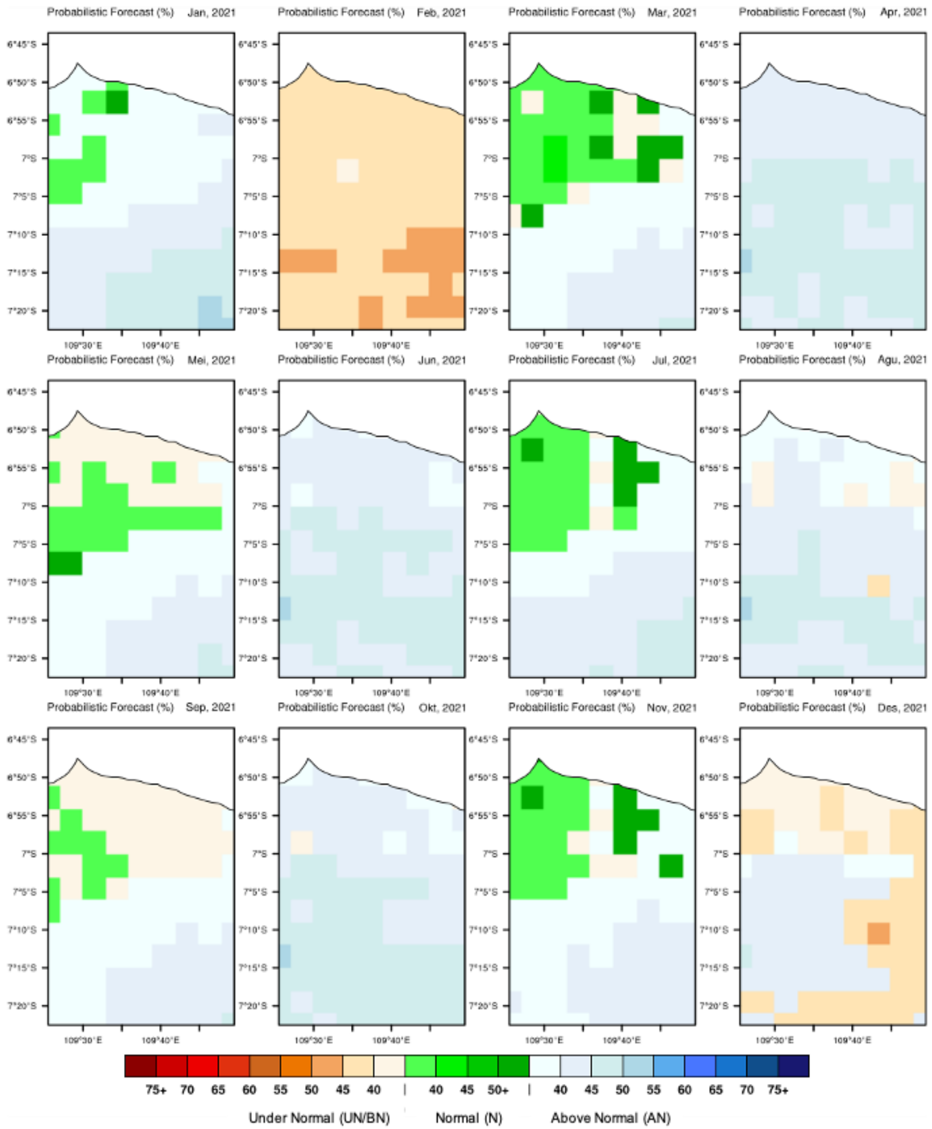


Figure 3.1: Decadal climate prediction - probability of monthly rainfall anomaly for the period of January-December 2021.

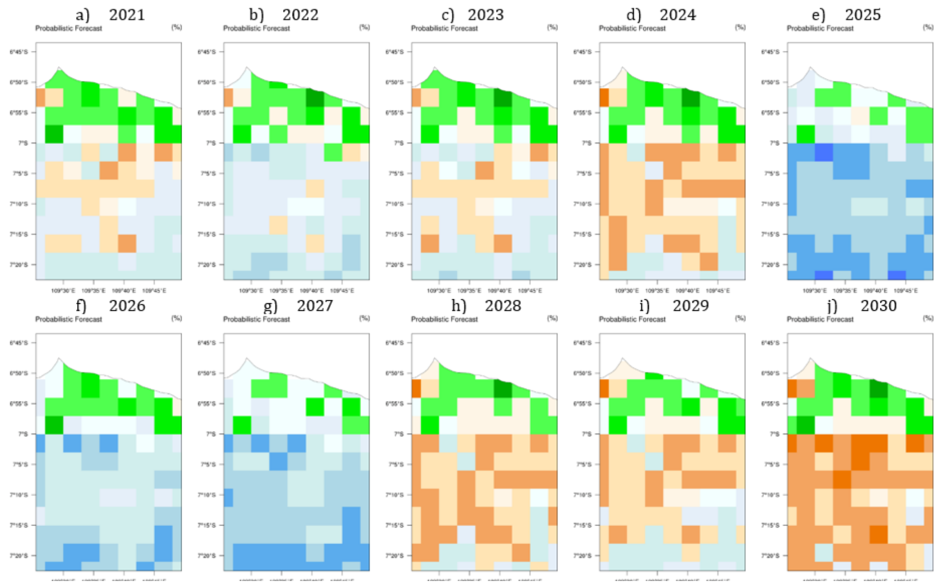


Figure 3.2: Prediction on the possibility of number of days in a year with daily rainfall value of more than 20 mm.

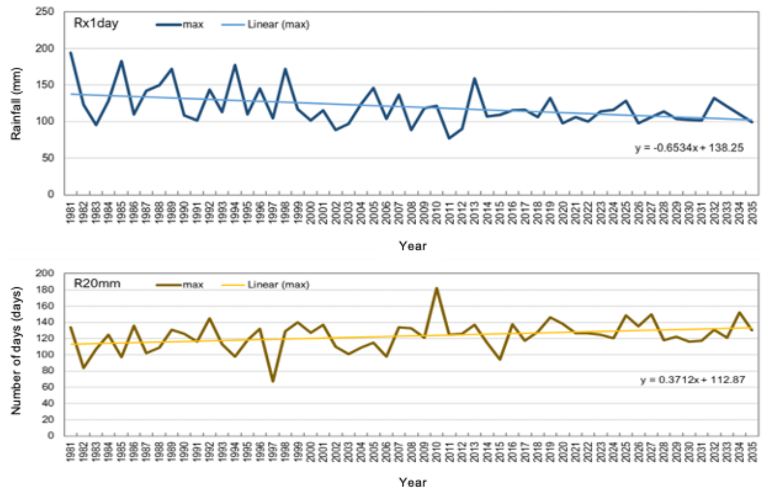


Figure 3.3: Historical trend and decadal prediction of Rx1day Wet Extreme Index (above) and R20 mm (below).

## Inundation Modelling

Inundation modelling was conducted by using the extreme values of inputs such as climate attributes (rainfall, sea level rise, and tidal waves), geological attributes (land topography and subsidence), and hydro-geological attributes (geomorphology of coastal and river areas). The maximum Rx1day data in each grid obtained from the decadal prediction calculation, and the 95th percentile value for RCP4.5 and RCP8.5 scenarios were used to assess runoff. The 90th percentage of tidal water level during the observation period (2020) was used for tidal flood. 2019 data analysis shows a constant rate of land subsidence, and therefore, a constant value was used throughout the projection period.

### Permanent inundation

The significant rate of land subsidence, caused by excessive ground water extraction due to lack of alternative water sources, has led to chronic and irreversible impacts of flooding, such us permanent inundation. **The spatial inundation modelling results show a significant four-fold increase in permanent inundation from the current 1,478 Ha in 2020 to 5,721 Ha by 2035.** The inundation will reach Kelurahan Tirto in the south and some parts of Kelurahan Padukuhan Kraton and Pasir Kraton Kramat in the east by 2025. By 2035, permanent inundation will further expand to the south and reach some parts of Kertijayan and Simbangkulon in Pekalongan Regency, and Kelurahan Kalibaros and Kuripan Yosorejo in Pekalongan City.

The current furthest inundation was observed to be 4.2 km away from the shore. By 2025, this distance is expected to reach around 7.5km, and reach Kelurahan Degayu, Kuripan Yosorejo, Noyontaansari, and Jenggot. **By 2035, the furthest distance of inundation from the shore will increase up to 8.5 km and 9.4 km, for the decadal prediction and RCP 4.5 projection, respectively**; and reach the villages of Simbangwetan and Wonoyoso, as well as Kelurahan Sokoduwet and Kuripan Kertoharjo.

In 2035, inundation in Pekalongan City is projected to reach 674 Ha across 10 kelurahans, and mostly cover settlement areas (248 Ha), green space (104.8 Ha), and aquaculture zone (154 Ha). For Pekalongan Regency, inundation will be experienced by 11 villages with a total affected area of 1,383 Ha, covering aquaculture areas (811 Ha) and urban settlement areas (266 Ha).

**DISAPPEARING VILLAGES FACE DIFFICULT DECISIONS**

Simonet, one hamlet in Semut village in Pekalongan Regency, with a total area of 15 Ha, has almost completely disappeared due to inundation and tidal flooding. Tidal flooding in Simonet is a daily occurrence. The height of floods can reach up to 5 meters, forcing residents to evacuate. The local district government decided to provide one hectare of land for ten families that chose to relocate. Now, the government is preparing to relocate the remaining 67 households (162 people) – however, relocation is a difficult decision since the majority of residents work in the fisheries sector and need to live along the coast to sustain their livelihood.

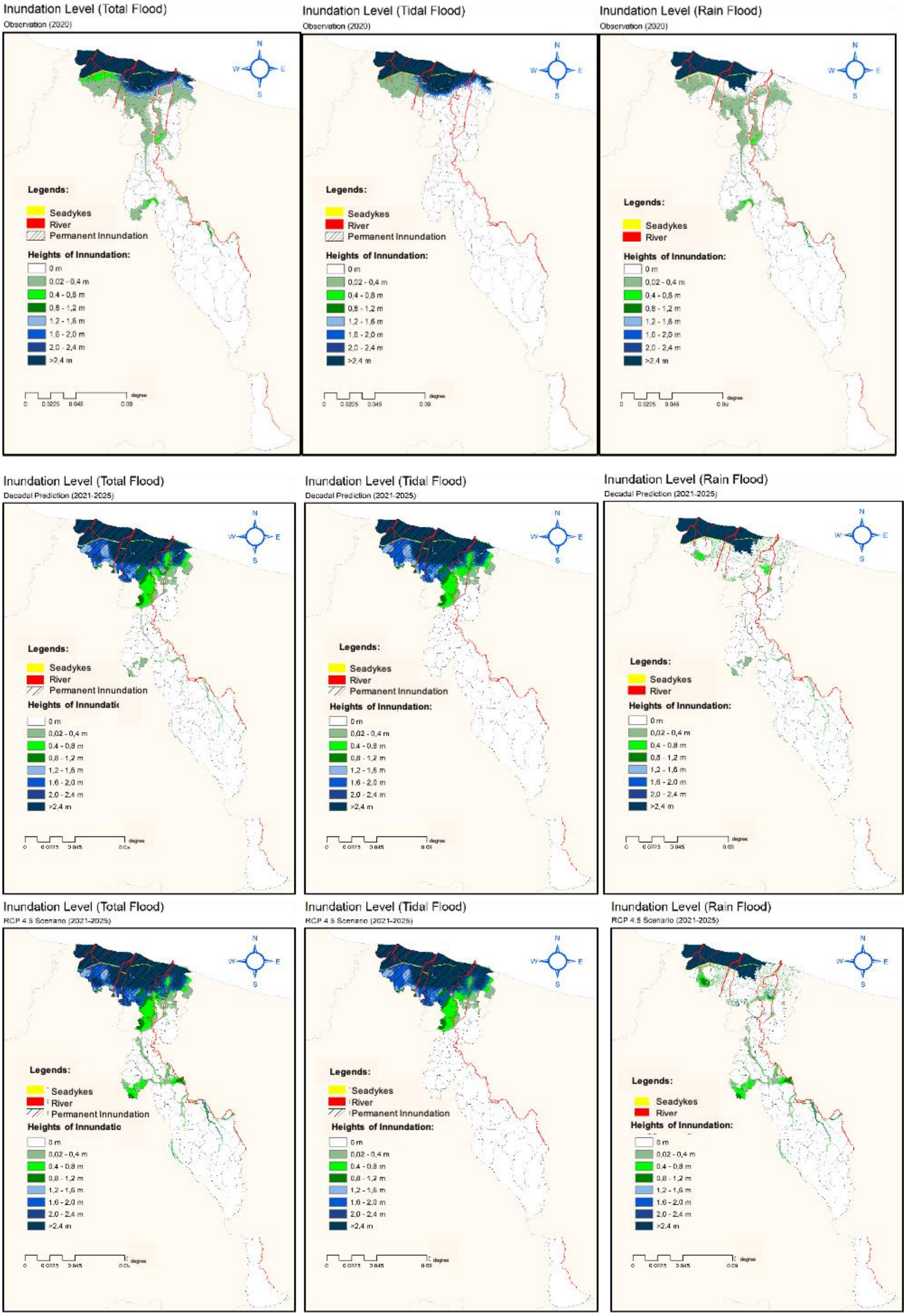


Figure 5: Inundation of current state in 2020 (above), and inundation simulation for the period of 2021-2025 for decadal prediction (middle), and RCP 4.5 scenario (below).

## Hazard Modelling

The hazard level is very high in most of the coastal areas, especially in areas south of the seawall including Wonokerto Kulon, Tratebang, Wonokerto Kulon, Api-Api, Pecakaran, as well as some locations in the midstream area of the Kupang watershed such as Pakisputih, Pejambon, and Kuripan Yosorejo. Moreover, the decadal prediction also indicates the southern and midstream areas of the watershed will experience an increase in hazard levels. For the entire study area, **the number of villages/kelurahans with a very high hazard index is estimated to increase from the current 11 percent to 39 percent by 2035 in the decadal projection. Meanwhile, the RCP4.5 scenario projection suggests an increasing proportion of areas with a high and very-high risk profile – raising from 26 percent to 43 percent between by 2035.** For the period of 2031-2035, the most significant hazard increase will take place in the southern area of Pekalongan City.

The land subsidence rate in the Kupang watershed in 2019 was relatively high, ranging between 0 - 34.5 cm per year. **High land subsidence rates (over 11 cm per year) were found in both the coastal areas and downstream segments of the watershed. Semut, Tratebang, and Pacakaran villages in Pekalongan Regency, and Kelurahan Tirto village in Pekalongan City, have a land subsidence rate up to 34.5 cm per year.** The analysis also showed land subsidence of Pekalongan to be widening south and east, compared to preceding studies which showed subsidence concentration in eastern areas.

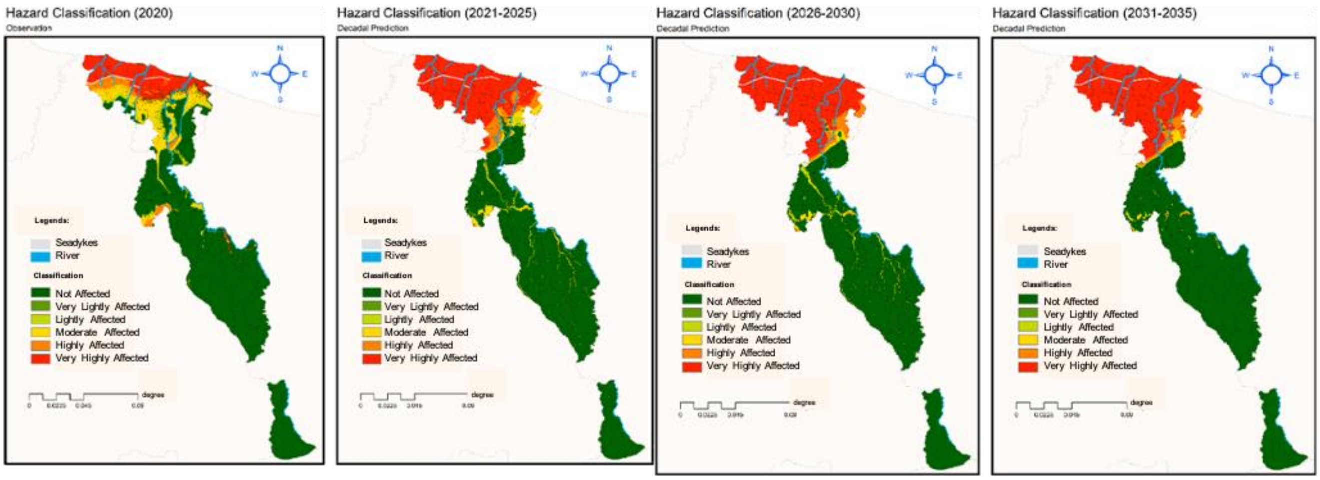


Figure 6: Hazard map of 2020, 2021-2025, 2028-2030, 2031-2035.

# Vulnerability Analysis Findings

Vulnerability was measured from a multiplication function of sensitivity, exposure, and adaptive capacity (vulnerability = [sensitivity*exposure] / adaptive capacity). The sensitivity level generally showed a declining trend due to the positive trend in poverty and per capita income components. There was an increase in exposure level for villages/kelurahans in the study location, particularly in coastal areas and areas near rivers. Projection showed limited changes in adaptive capacity level, with most villages/kelurahans having moderate to low adaptive capacity.

The analysis results also showed **the study location to have moderate to very high vulnerability in the current baseline state, largely influenced by low adaptive capacity and high sensitivity.** Very high vulnerability levels were found in 16 villages in the coastal and midstream areas of Pekalongan Regency – this shows that high vulnerability is not limited to areas directly affected by tidal floods. Approximately 75 percent of the villages/kelurahans with very high vulnerability levels have low adaptive capacity level, and 60% have high sensitivity level.

Projections of vulnerability differ according to the segment of the watershed, and is described below:

- Upstream: Increasing vulnerability in upstream areas is caused by the increase of exposure in the area, with relatively minor changes in sensitivity and adaptive capacity (Talun, Tlogohendro). The increase in exposure is largely influenced by changes in topography and planned settlements.
- Midstream: Decreasing vulnerability in midstream areas is due to a decline in sensitivity and increase in adaptive capacity. The midstream area overall sees an increase in average income and a declining proportion of people living under the poverty line, as well as improved access to health care services due to the planned insurance roll out, which together strengthens communities' capacity to deal with shocks and stresses such as flooding.
- Downstream and coastal area: The decreasing vulnerability level in downstream and coastal areas is influenced by a decline in sensitivity and an increase in adaptive capacity due to infrastructure development which mitigates flood impacts.

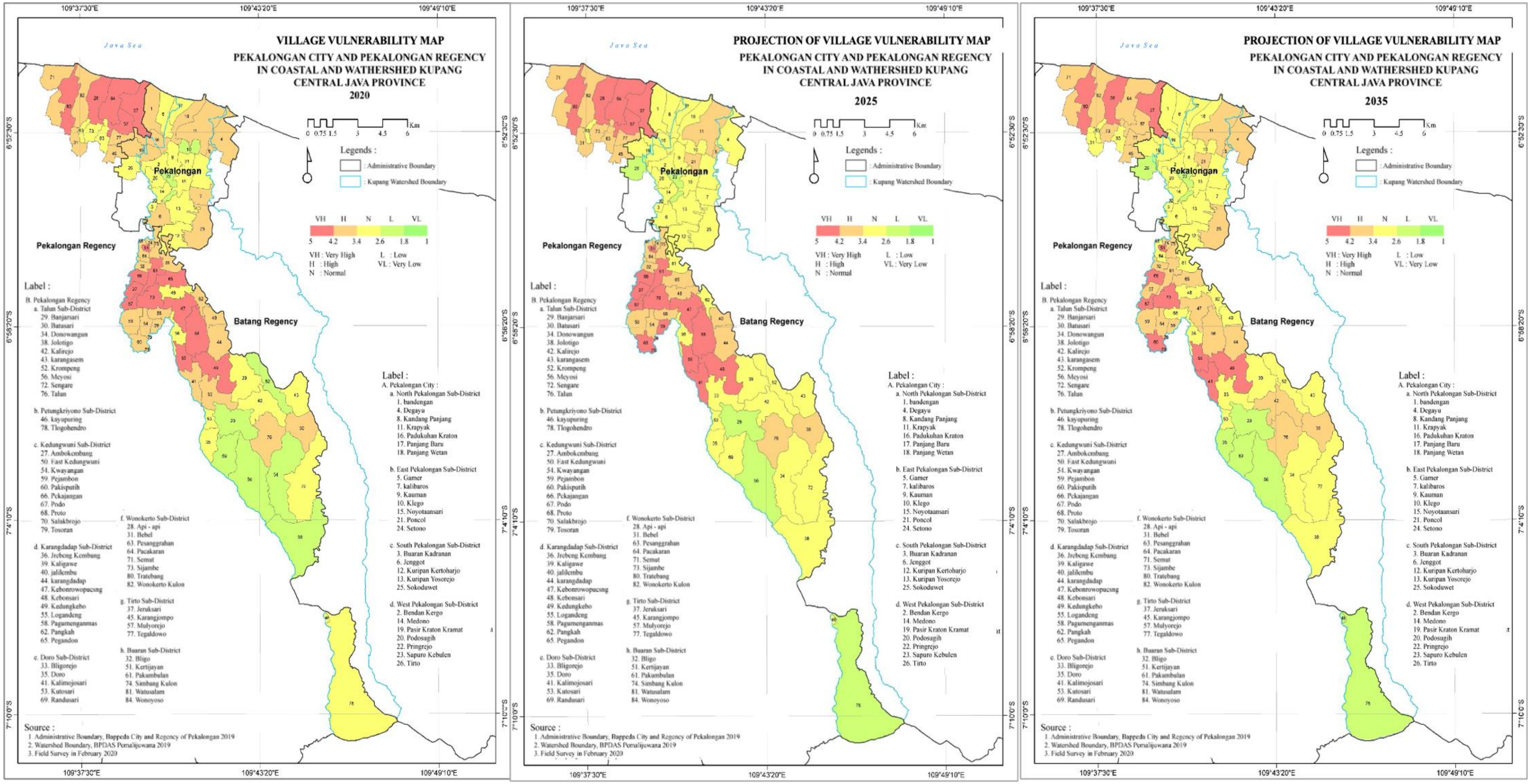


Figure 7: Spatial distribution of vulnerability index at 2020 (left), 2025 (middle), and 2035 (right).

# Risk Analysis Findings

Risk was considered as a function of hazard and vulnerability (risk = hazard * vulnerability) The projection results show an increase of risk level in coastal areas due to increasing hazard levels in most of the villages/kelurahans. **Inundation projections predict an increase in inundation size in coastal areas, which will definitely contribute to an increase in flood risk. Both sea level rise and the high rate of land subsidence will contribute to a rapid increase in permanently inundated land.** Historical data from the Disaster Management Agency show that flood hazards caused by extreme rain affects coastal areas as well as midstream and upstream areas of the Kupang river, and areas with lower elevation.

## Coastal Area

In general, the villages/kelurahans have high to very high risk level, except for Pesanggrahan Village. The high flood risk in the coastal area of Pekalongan Regency is caused by high levels of vulnerability and hazards – the area experiences multiple types of flooding, including coastal flooding, flash floods and localized urban flooding due to poor drainage systems. The kelurahans of Kandang Panjang, Panjang Baru, and Tirto, have a moderate vulnerability level. This vulnerability profile is due to not only the high level of exposure, but also due to the moderate-high sensitivity level.

Exposure is strongly influenced by the potential of hazard events, as well as population density and state of development. The number of critical assets and poor health care system are the dominant factors influencing the sensitivity level. All coastal villages in Pekalongan City and Regency have moderate, high, or very high vulnerability levels. Well-planned adaptation measures are highly needed to increase the communities' adaptive capacity, especially in dealing with the increasing flood hazard.

## Non-Coastal Area

The risk profile of the non-coastal area is generally categorized to be medium to low. Some areas in the Pekalongan Regency (Ambokembang Kebonrowopucang, Kedungkebo, Kertijayan, Logandeng, Pagumenganmas, Pakumbulan, Pegandon, Pekajangan, Podo and Salakbrojo) and a small portion of downstream and midstream areas in Pekalongan City have a high level of risk. The contributing factors of the risk differ according to location. In the downstream area, the relatively flat topography and close distance to the sea or river, lead to high exposure. The insufficient health care system leads to high sensitivity. Meanwhile, in the midstream areas, the low socio-economic status of the communities contributes to a high sensitivity level. Communities in this area also have a low level of adaptive capacity and lack understanding on flood management practices. Strengthening the communities' skills and knowledge to cope with potential hazards is critically important.

## Risk Projection (2021-2035)

In Pekalongan City, the number of kelurahans experiencing a higher risk level will increase consistently, and all of the kelurahans will have a high to very high risk level (both in decadal prediction scenario as well as RCP 4.5 projection) by 2035, compared to only 65 percent having such risk levels in the baseline year of 2020.

For Pekalongan Regency, differences were found between the projection results from the decadal prediction and RCP4.5 projection. In the baseline year of 2020, 36 out of 58 villages had a high-very high risk level. By the end of the 2035, this number shifted to 32 villages and 48 villages for the decadal prediction and RCP 4.5 projection, respectively – there was a decrease in the number of villages for the decadal prediction, whereas the RCP 4.5 projection showed an increase. This difference shows that the change in rainfall intensity (especially maximum daily rainfall) influences the risk level of Pekalongan Regency; the hazard analysis showed a different trend (until year 2035) for maximum daily rainfall under the two scenarios.

The difference of characteristics of vulnerability and hazard levels can be used to determine the most suitable adaptation option, such as one that will focus on the decrease of exposure and sensitivity level, or one that will focus on adaptive capacity, although all components must be considered. In addition, the use of the 30x30m spatial resolution within our analysis will better indicate the most appropriate intervention area for the formulated programs and activities.

## Interlinkage between land use change and inundation

### Trend in Land Use Change

The projection indicates that land use in Pekalongan will still be dominated by settlements, rice fields, and forests in 2035. Agriculture is expected to remain one of the main income sources for communities. An increasing trend can be observed for the settlement size (±1.000 Ha) and tidal flood/inundated land (± 1.400 Ha), while the land size for rice fields and fish ponds show a decline of approximately 1,600 Ha and 1,300 Ha. Such predictions and further analysis show that the expansion of inundated land and settlement areas leads to a decrease in rice fields and fish ponds. Fish ponds become permanently inundated areas in coastal areas, while rice fields are converted to settlements in non-coastal areas.

### Land use affected by inundation

**Over 90 percent of mangroves, bushes, and park land will be permanently inundated by the end of 2035. Further, more than half of settlements, fish ponds, open land, and industrial land will also be permanently inundated.** The increase in affected settlement area will increase gradually from 0.53% in 2020, 21.59% by 2025, 46.9% by 2030, and 50.83% by 2035. Areas currently being developed into settlement areas are located in places vulnerable to permanent inundation.

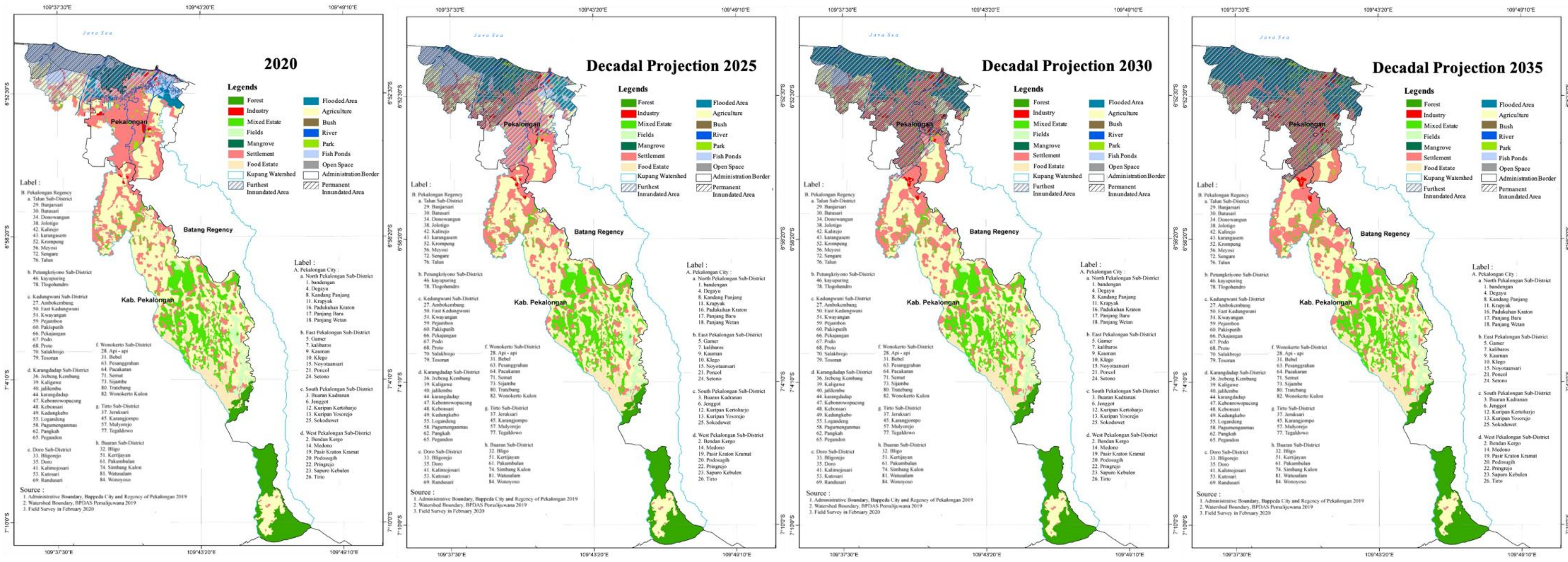


Figure 8.1: Potential impacts of permanent inundation and furthest inundation in the decadal prediction model.

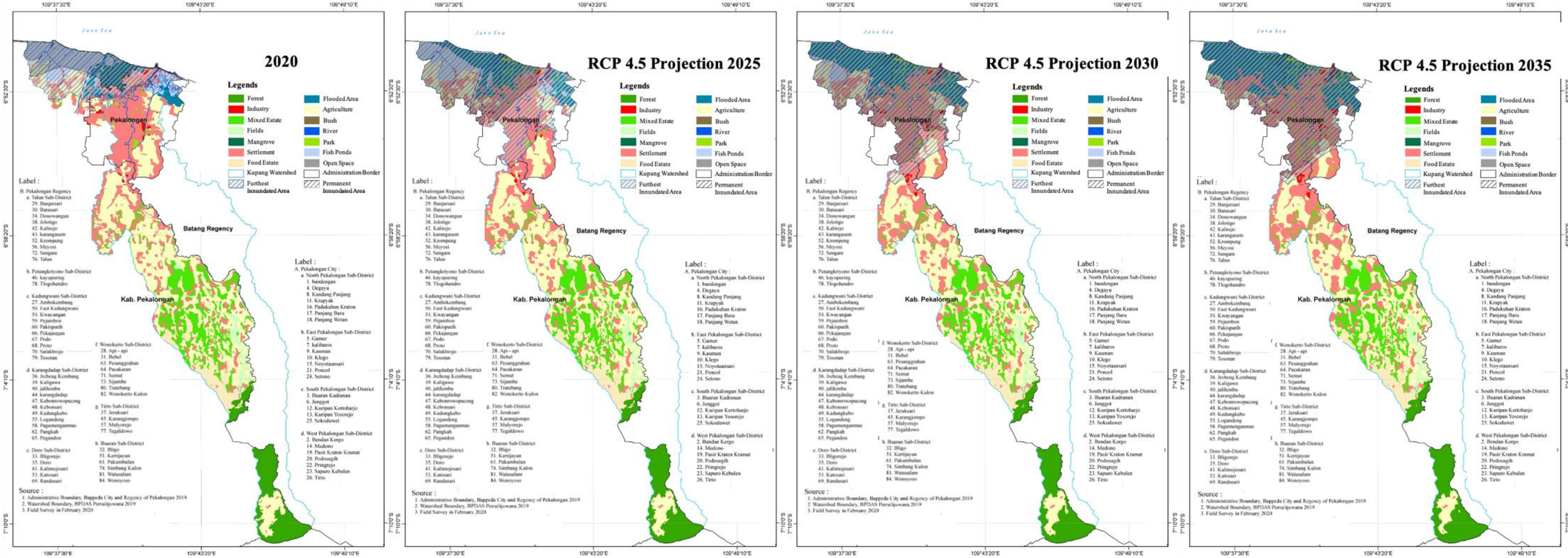


Figure 8.2: Potential impacts of permanent inundation in the RCP 4.5 projection model.

# Loss and damage predictions from floods by 2035

## Baseline Profile (2020)

**Flood damage values in 2020 was estimated at USD 474.4 million, with Pekalongan City at USD 287.4 million and Pekalongan Regency at USD 187 million**. This is a significant figure, as the total annual budget for Pekalongan City and Regency for 2020 was around 206 million USD. **The annual impact of flooding is more than twice the local annual budget.** Material loss is the main contributor, with USD 162 million and USD 114 million for the city and regency, respectively. The highest costs of material loss are adaptation costs, asset repairment costs, and income loss.

## Loss and Damage Projection (2021-2035)

Flooding is predicted to severely affect 41 villages/kelurahan (24 kelurahans in Pekalongan City and 17 villages/kelurahans in Pekalongan Regency) by 2035[2]. **Flood impacts are predicted to reach USD 2.1 billion per year by 2035 from USD 474.4 million in 2020**, with USD 1.17 billion in material losses, USD 806 million in non-material losses, USD 5 million in land productivity; and over USD 174 million in ecosystem services loss.

Economic and non-economic adaptation costs and impacts to households are significant with income loss, additional costs for livelihood activities, and reduction of land productivity**. Loss of income due to tidal flooding in the 41 affected villages is predicted to reach USD 171 million annually. The three livelihood sectors of trade and service, aquaculture, and farming will especially be affected** due to market and material distribution disruption, inundation, and flood defence measures that will affect the hydrological environment.

The assessment further shows that **tidal floods have caused household conflict, making women particularly vulnerable to domestic violence.** Further, around 14 percent of families in Pekalongan Regency are female-headed, and work in climate-vulnerable sectors such as agroforestry, fishery, and batik sector. As the family head, such women are also responsible for household and caregiving duties, leading to further financial, physical, and psychological pressure during disasters such as flooding. The total projected estimation of economic and non-economic loss for flooding is summarized in the following table.

[2] Loss and damage analysis from 2020-2035 does not include Pringrejo Village due to lack of data.

## Recapitulation of Total Economic and Non-Economic Loss (thousand USD)

| Components | Pekalongan City | | | | Pekalongan Regency | | | |
|---|---|---|---|---|---|---|---|---|
| | 2020 | 2025 | 2030 | 2035 | 2020 | 2025 | 2030 | 2035 |
| **Affected area (kelurahan/villages)** | **11** | **24** | **24** | **24** | **13** | **15** | **17** | **17** |
| **Material loss (economic)** | | | | | | | | |
| Adaptation Cost | 81,345 | 221,729 | 294,539 | 385,157 | 42,838 | 62,744 | 87,201 | 115,141 |
| Asset repairment cost | 16,651 | 51,300 | 67,858 | 89,316 | 24,462 | 33,886 | 45,812 | 59,497 |
| Medical cost | 5,325 | 19,664 | 26,269 | 34,937 | 5,902 | 7,948 | 10,919 | 14,236 |
| Additional cost for water | 13,677 | 38,401 | 50,614 | 67,021 | 7,890 | 10,791 | 15,032 | 19,662 |
| Additional cost for food | 11,176 | 31,430 | 41,659 | 55,257 | 10,943 | 14,554 | 19,745 | 25,698 |
| Additional cost for energy | 7,387 | 25,699 | 34,240 | 45,239 | 7,602 | 10,318 | 14,463 | 18,915 |
| Wastewater treatment | 9,074 | 30,115 | 40,154 | 52,943 | 7,031 | 9,886 | 13,639 | 17,778 |
| Income reduction | 13,243 | 60,498 | 82,016 | 110,072 | 5,020 | 6,801 | 10,147 | 13,153 |
| Increase in business cost | 4,319 | 19,787 | 26,849 | 36,055 | 2,383 | 3,188 | 4,616 | 5,985 |
| **Total material loss** | **162,198** | **498,622** | **664,199** | **875,997** | **114,071** | **160,117** | **221,575** | **290,065** |
| **Non-material loss (non-economic)** | | | | | | | | |
| Mental health | 32,047 | 110,709 | 150,202 | 198,400 | 19,424 | 27,537 | 37,549 | 48,557 |
| Household system disruption | 71,023 | 266,268 | 354,440 | 469,158 | 29,271 | 48,657 | 68,934 | 90,127 |
| **Total non-material loss** | **103,070** | **376,977** | **504,641** | **667,558** | **48,695** | **76,194** | **106,483** | **138,684** |
| **Land productivity loss** | | | | | | | | |
| Farming | 355 | 1,130 | 1,403 | 1,744 | 751 | 1,036 | 1,401 | 1,740 |
| Fish-pond | 267 | 331 | 412 | 511 | 742 | 922 | 1,145 | 1,423 |
| **Total land productivity loss** | **622** | **1,461** | **1,815** | **2,255** | **1,493** | **1,958** | **2,546** | **3,163** |
| **Ecosystem service loss (for tourism)** | **21,522** | **68,288** | **90,207** | **119,319** | **22,741** | **30,028** | **40,970** | **54,936** |
| **Total** | **287,410** | **945,348** | **1,260,862** | **1,665,128** | **187,000** | **268,296** | **371,573** | **486,848** |

Table 2: Projected economic and non-economic loss from flooding in Pekalongan City and Regency for 2020 – 2035.

# Flood risk perceptions of communities in Pekalongan

The risk perception analysis was conducted through a structured interview in 42 villages/kelurahans and used five indicators of knowledge, direct experience, impact, awareness and concern, and personal readiness. The risk perception level in Pekalongan City and Regency showed a score of 9.6 and 10.5 respectively, on a scale of 5-25 – indicating a low risk perception level. Interviewees generally scored high on knowledge and experience of disasters, but scored low on concern and readiness levels.

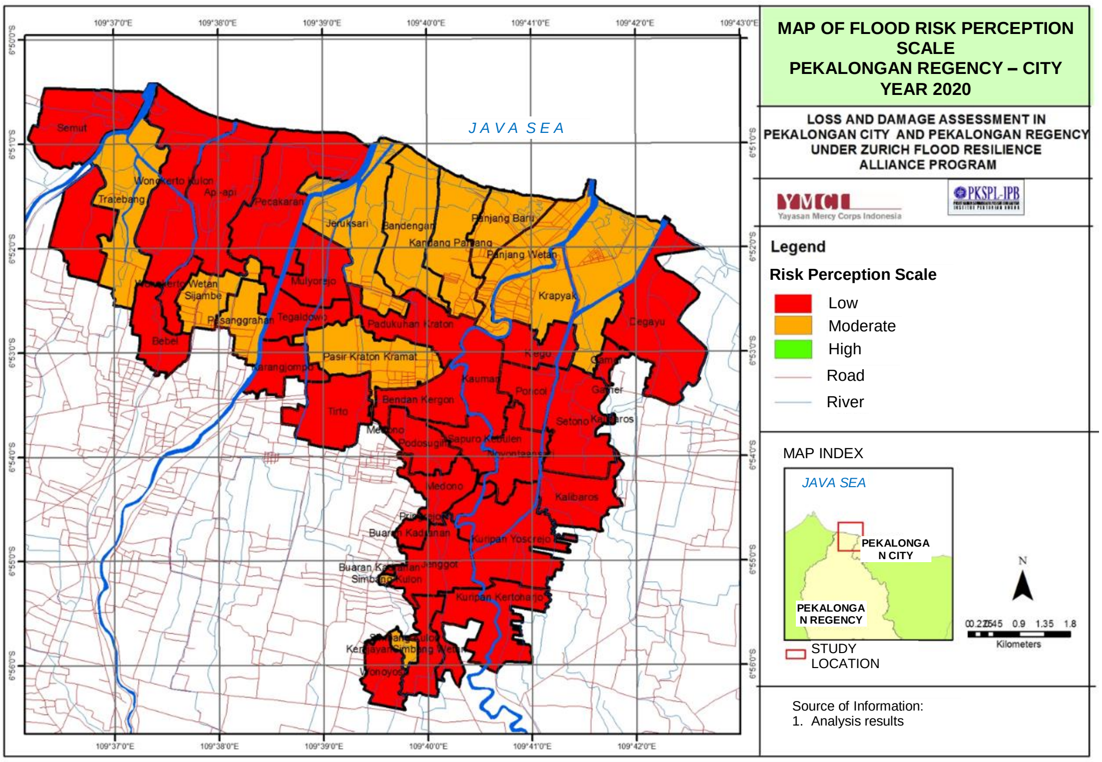


Figure 9: Risk perception scale in 42 high-risk villages/kelurahans in Pekalongan City and Regency.

# Way forward

The findings from the study are currently being utilized to conduct dialogues with the Pekalongan City and Regency governments to identify interventions that can address climate risk and impacts, and inform policy development. Four clusters of actions to contribute to a comprehensive transboundary flood management roadmap in Pekalongan City and Regency have been proposed to date: zoning and regional adaptation; flood management infrastructure; water resource management through infrastructure and conservation; and human resource and institutional capacity strengthening on disaster risk reduction. Mercy Corps Indonesia and research partners will continue to work with governments and key stakeholders to support climate resilient policy making and programming in Pekalogan City and Regency.

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