RISK ATTRIBUTION STUDY FOR FLOODING IN COASTAL URBAN AREA, CASE OF PEKALONGAN, CENTRAL JAVA, INDONESIA

Ali Dastgheib, IHE-Delft, & IMDC, a.dastgheib@un-ihe.org
Roni Prasetia, Central Java Provincial Gov., roniprasetia@gmail.com
Tim Leijnse, Deltares, Tim.Leijnse@deltares.nl
Roel de Goede, Deltares, Roel.deGoede@deltares.nl
Dano Roelvink, IHE-Delft, TUD & Deltares d.roelvink@un-ihe.org

INTRODUCTION

Urban areas in low elevation coastal zones are subjected to flooding, which is increasing due to the climate change. Thus, proper Disaster Risk Reduction (DRR) measures and Climate Change Adaptations (CCA) are necessary to reduce the risk of flooding. However, these measures and adaptions can easily become maladaptation if the source of the risk is not clearly identified. Flood risk in coastal urban areas can be very complicated. Flood hazard can be driven by different sources including climatic impact drivers such as sea level rise, surge driven extreme sea levels, extreme river discharge and rain fall, as well as non-climatic drivers such as land subsidence. Also, vulnerability and exposure in coastal urban areas are rapidly changing due to migration, economic development, change in land use, insurance coverage, city planning etc. In order to design effective and efficient DRR and CCA, a risk attribution study is essential. In this paper a methodology for such a study is discussed by implementing it in the case of Pekalongan, Central Java, Indonesia.

STUDY AREA

Pekalongan Municipality (Figure 1) with a population of about 310,000 is located in the lowland areas of the north coast of Central Java, and the land elevation in the city reaches to a maximum of only 6 m above mean sea level. The population density tends to increase along with the increase in population, with 6786 people in one square kilometer (BPS, 2020). This city suffers from frequent floods due to combination of tides and river flow. The flooding is exacerbated by the high rate of land subsidence with the rate of 4.8 -10.8 cm/year (Sarah and Soebowo, 2017). Four main rivers, namely Sragi Baru, Sengkarang, Loji and Kupang, cross Pekalongan to reach the north coast of Java. In recent years several DRR measures have been carried out by the government, such as the construction of a tidal dike, polder system, and there are plans to build a barrage in the river as well as change the zoning of the city.

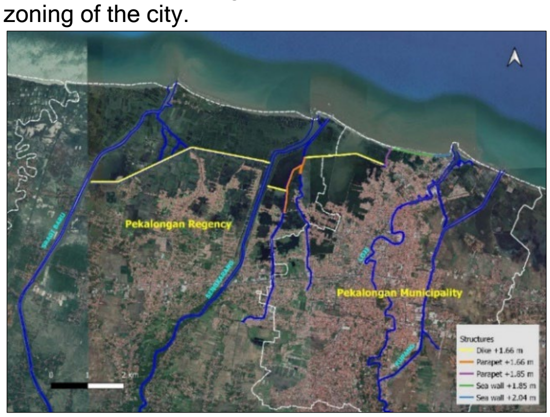

Figure 1. Pekalongan area

METHODOLOGY

For this risk attribution study 4 different risk components are analyzed:

1. Extreme Sea Level;
2. Land subsidence;
3. Extreme River Flow;
4. Land use

Flooding due to different combinations of drivers for different time horizons are simulated using the SFINCS model, a reduced-physics model that efficiently simulates compound flooding in coastal areas (Leijnse, 2021), and the resulting inundation maps are developed. For examples Figure 2 shows the flood inundation depth for coastal flooding due to the extreme sea level in 2100, and compound fluvial and coastal flood at the same time.

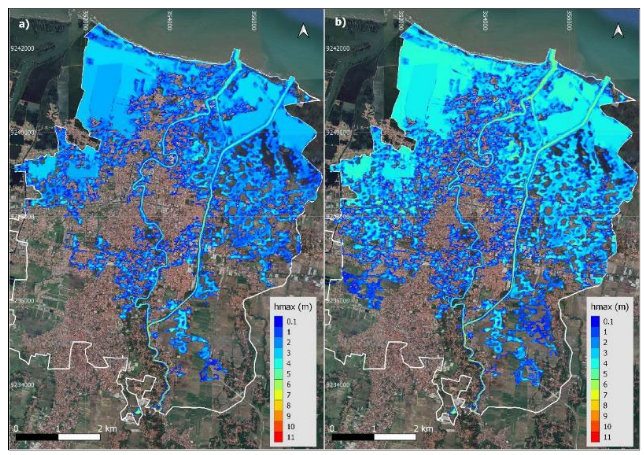

Figure 2. Inundation map for a) coastal flood due to extreme sea level in 2100, b) compound fluvial and coastal flood in 2100.

The inundation maps are translated to risk levels using different land use plans and the transformation matrix shown in Table 1. This transformation matrix is developed based on local and regional depth/damage curves.

Table 1 – Risk levels based on the range of inundation depth and land use

Land Use	Risk levels / rang of inundation depth (m)				
	1	2	3	4	5
Residential buildings	< 0.3	0.3 - 0.7	0.7 - 1.4	1.4 - 2.5	> 2.5
Commercial buildings	< 0.3	0.3 - 0.6	0.6 - 1.3	1.3 - 2.3	> 2.3
Industrial buildings	< 0.4	0.4 - 0.8	0.8 - 1.4	1.4 - 2.6	> 2.6
Transport	< 0.3	0.3 - 0.6	0.6 - 1.1	1.1 - 1.8	> 1.8
Infrastructure - roads	< 0.5	0.5 - 1.1	1.1 - 1.5	1.5 - 2.9	> 2.9
Agriculture	< 0.6	0.6 - 1.1	1.1 - 2.4	2.4 - 3.8	> 3.8
Aquaculture	< 0.4	0.4 - 1	1.0 – 2.3	2.3 – 2.8	> 2.8

For example, the current risk indicator map of current hazard (compound fluvial and coastal flood) and current exposure (existing land use) is compared with the future risk indicator map if the land use remains the same in the future is shown in Figure 3.

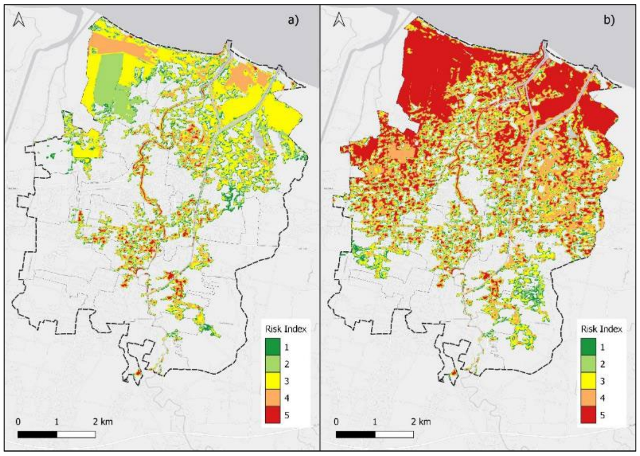

Figure 3. Comparison of current and future risk if the land use does not change in the future.

The sum of the areas falling in each risk level is then compared for different scenarios to determine the relative importance of each risk component. Table 2. Shows these changes for the scenario presented in Figure 3 in which the exposure (land use) is kept constant over time while hazard is changes in the future.

Risk Index	Area [km^2]		Percentage of changes
	Current hazard	Future hazard	
0	32.43	21.97	-32.25%
1	1.06	1.20	13.28%
2	2.99	1.98	-33.65%
3	5.86	4.23	-27.80%
4	2.44	6.17	152.73%
5	0.47	9.69	1979.40%

RESULTS AND CONCLUSIONS

The results of the study show that the area threatened by a risk level of 5 will increase with about 20 times due to the increasing compound hazards by the end of the century, if there is no change in the land use. In comparison, changing the land use in the future can reduce the areas in each risk level for about 15% on average by the end of the century. It is identified that the most important driver of the flood risk is land subsidence and that sea level rise and extreme river flow are relatively less important.

Therefore, it can be concluded that the most effective measures to reduce the risk of flooding in Pekalongan are to limit the land subsidence by reducing groundwater exploitation, and imposing a new zoning for a different land use in the city.

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