Mainstreaming adaptation strategy for flood risk due to climate change impact on Jakabaring, Palembang, Indonesia

Y Hamdani¹,², R S Ilmiaty², D Noviarti¹, A Hidayat¹

¹ Department of Civil Engineering, Tamansiswa University Palembang, Jl. Tamansiswa 261, Palembang, 30139, Indonesia
² Department of Civil Engineering, Sriwijaya University, Jl. Raya Palembang – Prabumulih KM 32 Indralaya, Ogan Ilir, Sumatera Selatan, 30662, Indonesia
³ Corresponding author: yunanhamdani@ymail.com

Abstract. Jakabaring and its surrounding which is part of Palembang are also experienced a high level exposure to hazard of inundation, where the area is heavily affected by tides which are mostly swamps, consisting of reclamation and protection swamps that are vulnerable to the effects of climate change. This study aims to determine the level of risk due to inundation hazards that occur in current conditions and projected conditions through risk assessment with spatial approaches and adaptation strategies needed. The vulnerability parameters that used are exposure (topography, land use, infrastructure), adaptation capacity (drainage), sensitivity (population density, education level, age, gender and poverty). In the baseline condition, Jakabaring and its surrounding areas is on moderate level of risk. Meanwhile in the projection condition (2030), Jakabaring and its surrounding areas is on high level of risk. The adaptation strategies due to climate change impact that can be carried out are river normalization, drainage normalization, infiltration measure, pumping, green open space, canalization, bio-pore, water retention ponds, multiplying gardens in residential area, roads enhancement, pavement enhancement, polders along rivers, and supervision of swamp regulations.

1. Introduction
Jakabaring and its surrounding areas, which is one of the strategic areas in Palembang where the offices, sports and residential center are concentrated. Administratively, based on Detail Spatial Plan of Jakabaring Development Area consists of 7 sub districts (sub districts 8 Ulu, 15 Ulu, 16 Ulu, Plaju Darat, Sentosa, Silaberanti and Tuan Kentang) covered in three sub districts, Seberang Ulu I, Seberang Ulu II, and Plaju Palembang. It directly adjacent to Banyuasin and Ogan Ilir districts. Topographically, Jakabaring area is a lowland swamp with 6 - 7 m height above sea level. Based on current conditions most of Jakabaring area is still covered by rice field and swamp. With lowland topographical conditions and anthropogenic climate change, Jakabaring and its infrastructures are vulnerable to climate change. Infrastructure is one of the sectors that receive direct impacts from flood hazards. Flood hazards nowadays are one of the main issues of climate change impacts such as extreme events, the change of rain patterns, and sea level rise, Floods are thought to cause damage to all infrastructure sectors, exacerbating or destroying critical components of infrastructure [1].

Based on Palembang City Spatial Plan, Jakabaring area is included in I B Regional Service Center which is a new national and international infrastructure development center located in Seberang Ulu region. Jakabaring area is located in Seberang Ulu I Sub district which is an area of choice as area of government, entrepreneur, community and also as well as city expansion area this is also a buffer area of strategic location from downtown. Jakabaring area of Palembang City is adjacent to Banyuasin
Regency in Rambutan Sub district, Ogan Ilir Regency in District Pemulutan. Jakabaring as a new development and development center is a swamp area, so in the acceleration process of development is experiencing a massive reclamation. The condition above makes Jakabaring area very vulnerable to flood hazard, either because of extreme rain or Musi River tidal influence due to the sea water tidal influence. Jakabaring and surrounding area which is one part of the Palembang City area also experienced a high level of exposure to the danger of inundation, floods surrounded the residential area in Jakabaring Palembang. Some of the housing areas in Jakabaring Palembang area affected by floods are located in Ogan Permata Indah housing, the height of the existing flood is about 10 - 30 cm. At the beginning of development around 1999, this area has not yet experienced flooding, but around 2004 this area began to experience flood caused by the new housing built especially in the rainy season due to increased extreme rainfall. As the topography and function of Jakabaring area are very vital for Palembang City and this town is 16th ranked of the most vulnerable places to climate change in Southeast Asia [2] it is necessary to learn about the vulnerability and risk to climate change.

The aims of study to determine the level of risk in Jakabaring area at baseline condition and projection condition and this result is used to reduce flood hazards and adaptation strategies that will be used to. Knowledge of these hazards and vulnerability is a very important to determine the level of risk to climate change at this time and its projections in 2030 by Jakabaring residents who live there.

2. Research method
The choice of adaptation is determined based on the risk assessment result due to flood hazards, since the adaptation options for climate change are very influential on the development planning in Jakabaring and its surrounding area. Risks are defined as overlays or magnification hazards of climate change and vulnerability to these hazards, where risk as a function of hazard and vulnerability [3]. The hazards component in this research is flood hazards due to sea level rise into Musi river and extreme rainfall. The indicator of vulnerability are exposure (topography, land use, infrastructure), sensitivity (population/ social density (education level, age, gender and poverty)), as well as the adaptive capacity (drainage). The value of vulnerability is determined based on an index of vulnerability resulting from the indicators that are owned by the elements that have the strong risk to the impacts of climate change [4].

This research is a field survey analysis. Surveying and marking has already done to see drainage system because inundation is also caused by the closure of drainage channels in residential areas, changes in land cover in Jakabaring a map of the area based on existing land cover and the condition of land cover region at projected condition and using GPS (Global Positioning System) to determine measurement locations and altitude. The survey was conducted in the form of a discussion and interview with the community around the location of the house in Jakabaring by filling out a questionnaire to identify conditions in the field, indicators of social parameters are sex, age, occupation, and poverty level. Secondary data needed in the form of population, population growth rate, topography, administrative boundary map, existing land use map and land use planning map and supporting data related this research.

The study focused on assessing the physical vulnerability to climate change and land use change in the Jakabaring area that will be visualized into the Jakabaring risk map. These results are used to determine the level of risks to flood hazards and adaptation strategies that will be used in the face of flood hazards. A physical vulnerability assessment will analyze the vulnerability of infrastructure and settlements in the Jakabaring area to potential hazards due to climate change such as floods, and extreme events based on vulnerability parameters or indicators using a micro scale to analyze the risk Jakabaring and surrounding area.

2.1. Research location.
The location of research is in Jakabaring area, which is one of the strategic areas in Palembang is the area where the center of office, sports and settlement is concentrated. Administratively, Jakabaring area is located in 3 subdistricts of Seberang Ulu I, Seberang Ulu II, and Plaju Palembang and directly adjacent
to Banyuasin and Ogan Ilir districts. Topography Jakabaring area is a lowland swamp with a height of 6-7 m above sea level.

Figure 1. Map location research

Figure 2. Jakabaring administration map
2.2. Framework of adaptation strategy

Adaptation efforts can reduce damage and avoid impacts that can exacerbate natural disasters. Therefore, the need for adaptation measures at the national and local levels. Adaptation issues are rapidly emerging as a central issue in the policy debate on climate change. Climate change adaptation can be classified into three levels [5]:

a. strategy level, focused on the development and implementation of regulations aimed at changing attitudes of populations and individuals towards climate change.

b. population level, adaptation can serve two purposes: protecting from resistance or preventing impact and facilitating adaptation by individuals.

c. individual level, adaptation is focused on behaviour adjustment aimed at limiting hazard exposure.

The appropriate adaptation for Jakabaring and surrounding areas is adaptation strategy level and individual / community level grouped in 2 classes namely adaptation in a short time (soon) and adaptation for a long period of time to support development planning.

Risk maps are obtained from overlayed vulnerability maps and hazard maps, vulnerability maps consist of exposure (E), sensitivity (S), and adaptive capacity (AC) [6] that are composed of topographic maps, infrastructure, land use as exposure, population /social density (education level, age, gender and poverty) as sensitivity, drainage system as adaptive capacity and hazards component (flood hazards and extreme rainfall ). To get risk map in the existing conditions (baseline) and the projection condition in year 2030 [7]. The level of risk is classified into six classes o which are no risk, very low risk, low risk, moderate risk, high risk, and very high risk. The map of risk analysis will determine the accuracy of the resulting level of risk of the region and adaptation strategies to be formulated later. Risk assessment can be written as in the following formula:

\[ R = H \times V \{ (E \times S) / AC \} \] ........................................ (1)

Where
- \( R \) = risk
- \( H \) = hazards
- \( V \) = vulnerability
- \( E \) = exposure
- \( S \) = sensitivity
- \( AC \) = adaptive capacity
The framework of adaptation strategy can be seen below.

![Diagram of adaptation strategy](image)

**Figure 4.** Framework of adaptation strategy

### 3. Results and discussion

Jakabaring risk assessment refers to the risk modeling result of the South Sumatra Climate Change Adaptation Risk Assessment document. South Sumatra Province area is mostly lowland which has an impact on the high level of exposure to climate change, especially coastal flooding hazard caused by the combination of sea level rise, storm surge and La-Nina phenomenon when maximum tidal occurs. While in the reports it is known that the highest level of risk is located in Seberang Ulu I, Plaju, and Kalidoni subdistricts. The meso level risk assessment shows that 41.72% of the Palembang City area is at high risk for the climate change impact [8]. From this micro level study, it is known that Jakabaring area is one of the areas (Seberang Ulu I) which has high risk to climate change impact. At the baseline condition, the area which has risk to climate change in Jakabaring and surrounding areas is 2303.81 ha or 72.3% of the total Jakabaring and surrounding areas. While in the projection condition, the risk area in Jakabaring and its surrounding is 2333.54 ha (73.28%) of the total area. Based on the risk analysis result in Jakabaring and its surrounding areas, it is known that high and very high risk is a residential area and housing.

![Risk map](image)

**Figure 5.** Risk map at (a) baseline condition and (b) projection condition
Table 1. Area of climate change risk at baseline and projection conditions

| Risk Level      | Baseline (Ha) | Projection (Ha) |
|-----------------|---------------|-----------------|
| No risk         | 882.56        | 850.89          |
| Very low risk   | 660.49        | 7.41            |
| Low risk        | 1231.48       | 1207.14         |
| Moderate risk   | 315.05        | 458.32          |
| High risk       | 92.57         | 302.73          |
| Very high risk  | 4.23          | 339.89          |

According to table 1, at baseline condition, area which has high risk to climate change in Jakabaring and surrounding areas is 92.57 ha of the total Jakabaring and surrounding areas. While in the projection condition increased to 302.73 ha and very high risk level at baseline condition is 4.23 ha. While in the projection condition increased to 339.89 ha. According to report of climate risk adaptation assessment in the South Sumatra Province [9] The flood risk assessment also will be analyzed by province scale, In the baseline condition, based on percentage coverage of flood risk area is 14.55 % and projection condition is 17.39 %. In extreme event which is influenced strongly by tidal and sea level rise, the highest potential inundation risk area at baseline condition is 59.36 % and projection condition is 60.57 %.

Climate change adaptation is a process through which societies make themselves better able to cope with negative impact of climate change, or it also can be infer as the means to reduce the risk of losses. Adapting to climate change entails taking the right measures to reduce the negative effects of climate change (or exploit the positive ones) by making the appropriate adjustments and changes [10]. The adaptation choices to climate change in Jakabaring and its surrounding areas are two choices (Table 2):

- Short term adaptation. Adaptation actions under these conditions are focused and prioritized for areas with high and very high risk under baseline conditions.
- Long term adaptation. Long term adaptation actions in development planning and adaptation support that are devoted to very low, low, and moderate risk levels under baseline conditions.

Table 2. Short term adaptation and long term adaptation to face climate change in Jakabaring and its surrounding areas

| Land cover type               | Short term                      | Long term                                         |
|-------------------------------|--------------------------------|---------------------------------------------------|
| Road                          | Drainage normalization          | Raising road surface                              |
|                               |                                | Raising pavement surface                          |
|                               |                                | Biopore                                           |
| Residential                   | Drainage normalization          | Increasing green space in neighbourhood           |
| Along the river areas         | River normalization             | Polder/ embankment along the river                 |
| Swamp                         | Pumping                        | Swamp regulation supervision                       |
| Industrial, Offices, Trades and Services | Infiltration measure (permeable paving) | Biopore                                           |
| Others land cover type        | Infiltration measure (permeable paving) | Water retention pond                             |
|                               | Drainage normalization          | Canalization                                      |
|                               |                                | Green open space                                  |
3.1. Canalization
Channelling is traditional way of drainage systems. Canalization is done by removing barriers and straightening rivers and smoothing river banks to streamline river transportation. Canalization strategies are highly recommended for lowland areas.

3.2. Polder and embankment
Polders make the river does not overflow by building embankments along the river flow. Inner area required for connection and additional access to distribute local air into the reservoir.

3.3. Infiltration measures
Infiltration measures allow to partially restore natural hydrological catch behaviour. Infiltration actions can be divided into several different categories. Those are trench infiltration, vegetated surfaces, rain gardens, porous or permeable sidewalks. The trench infiltration, which is a very common infiltration device, is a linear excavation dumped with rocks or gravel.

3.4. Drainage normalization
Based on survey results and drainage modelling analysis, it is known that drainage with dimensions of 45 cm x 45 cm and 25 cm x 25 cm cannot accommodate the water flow in case of rain for 6 hours. In order to reduce the impact of rainwater puddles it is recommended to redesign the drainage channel dimension to 45 cm x 60 cm. Adaptation choice is prioritized in residential.

3.5. Water retention pond
Flood reduction is an effective step to distribute discharges over time. The increase in runoff volume, resulting from urbanization, is not reduced, in fact, but the peak of floods is reduced. The damping process works by storing water and controlling outflow with limited discharge structures. Retention Pond can be placed in the Public Park, and or under the ground

4. Conclusion
The results of total risk at the site showed that the trend is increased, at the baseline condition, the area which has risk to climate change in Jakabaring and surrounding areas is 92.57 ha of the total Jakabaring and surrounding areas. While in the projection condition, the risk area in Jakabaring and its surrounding increased to 302.73 ha of the total area. Most of Jakabaring area is lying in lowland area which greatly influenced by sea level rise.

Based on this situation, the adaptation options for this area are canalization, polder and dikes, retention pond, and infiltration measures. Adaptation options are determined by the type of land cover that poses risks to climate change impacts. Adaptation options are grouped into 2 groups: short term adaptation and long-term adaptation. Short term adaptation is focused and prioritized to areas with high and very high-risk levels under baseline conditions whereas long term adaptation is directed to areas with very low to moderate risk levels at baseline and planning areas that have subsequent risks in the future can affect development planning. In general, the adaptation options in Jakabaring and surrounding areas consist of adaptation options, namely river normalization, drainage normalization, infiltration measure, pumping, green open space, canalization, bio-pore, water retention ponds, reproduction of gardens in residential, raising the road surface, raising pavement surface, polder/embankment along the river, and supervision of swamp regulations.

References
[1] Freeman P and Warner K 2001 Vulnerability of infrastructure to climate variability: how does this affect infrastructure lending policies?: report commissioned (Washington: the Disaster Management Facility of The World Bank and the Pro Vention Consortium)
[2] Yusuf A A and Francisco H 2009 Climate Change Vulnerability Mapping for Southeast Asia EEPSEA Special and Technical Paper tp200901s1
Acknowledgments
Author would like to thank the Province Government of South Sumatra and District Government of Palembang for giving the opportunity to involve in this study and use a part of the results to be written for this paper.