The Impact of Flooding on Settlement Along the Jangkok River Mataram, Indonesia

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Abstract. Floods are natural disasters that have harmed populations in several places in the world. Flooding in urban areas can be caused by coastal floods or river floods. One of the flood-prone areas in Lombok is the Jangkok River, the largest rivers that cross the city of Mataram. Floods have consequences that impact the social and economic activities. Direct impacts of flooding can include damage to property and infrastructure, especially in the settlement area. The purposes of this research are to analyze the flood-prone areas and to build a flood modeling of the Jangkok River. The data used for the analysis combined a topographic map scale 1:5.000, DEM LiDAR, land system, and rainfall data from the Tropical Rainfall Measuring Mission. The result shows that along the Jangkok River at a distance of 100 m estimated as the flood-prone areas. River flood modeling shows settlements have very high potential affected by floods caused by overflowing water from the Jangkok River. Modeling of flood inundation for the return period of 10 years, 50 years, and 100 years shows that the area of inundated settlements periodically expands the flooded area of 70.95 ha, 97.17 ha, and 108.41 ha. This study is expected to be an input to improve the preparation of disaster mitigation-based spatial planning in many coastal cities in Indonesia.

1. Introduction
Floods caused by hydro-meteorological events have become the center of attention in many countries globally. Based on the data compiled by the National Disaster Management Authority, the type of disaster that often occurs in Indonesia is floods, accounting for 38% of all disaster occurrences [1]; [http://bnpb.cloud/dibi]. The definition of a flood is a temporary pooling of water in flatlands that are not normally covered by water [2]. Periodic flooding occurs in many rivers, creating what is called a floodplain in the area around it. The cause of floods is predominantly natural conditions and human activities. The natural factors that affect flooding are, among others, high precipitation rates, runoff from rivers, tsunamis, high tides, damaged dams, or other water reservoir constructions [3]. The population activities that affect flooding are the development of settlements or the construction of other buildings in the floodplains, the filling in of marshes or lakes, and the narrowing of the river basin due to the settlements along the river course [4]. Changes in land use concerning urban development influences flooding in multiple ways [5]. A study of the Mulde sub-watershed in Germany showed that the main driver of flood risks changed in land use [6]. Another study in the Netherlands about flood exposure development revealed that socio-economic changes and the development of urban areas in flood-prone
zones caused an exponential increase in the potential flood-related damage in the twentieth century [7]. Climate change may also increase the risk of flooding in addition to the rapid development of settlement [8].

Floods influence both humans and the environment in terms of the economy, damage to settlements, and the deterioration of environmental quality [3]. The steps that could be taken to prevent and reduce the impact of floods include urban planning based on disaster mitigation [9], developing an early-warning system [10], and improving the population’s capacity in disaster-mitigation. The people must adapt to flooding, especially if it is caused by natural factors [11, 12].

Mitigation of the negative impacts caused by floods can be done through both structural and non-structural approaches [13]. The structural approach includes the construction of flood-protection buildings such as levees, check dams, and repairing channels [14]. Also, there could be physical improvements or modifications to the buildings such as elevating house floors and the construction of two-story houses [15]. The non-structural approach includes flood evaluation and mapping for more effective and more efficient flood mitigation [14]. In addition, non-structural mitigation in the form of knowledge improvement, building public awareness, training, and education, especially in terms of policies and laws [16]. According to Masood and Takeuchi [17], the structural mitigation approach alone is not adequate in handling floods. Therefore, mapping of the flood dangers needs to be done as the basis for disaster mitigation to protect both the people and the infrastructure [18].

Hydrodynamic models have often been used to analyze present and future flood risks. Simulations are done using 2D hydrodynamic models to discover the size of the inundated area and the depth of the flood in the immediate future and certain periodic occurrences [9]. One of the coastal cities that is prone to flooding is the City of Mataram. Based on the history of the disasters between 2000-2012, this city has six types of disaster potentials, namely flooding, extreme weather, disease outbreaks, extreme waves and abrasion, earthquakes, and social conflicts [19]. Flooding in this city ranks as the third greatest disaster [http://inarisk.bnpb.go.id/irbi].

Geographically, Mataram city is traversed by several large rivers such as the Meninting River, Jangkok River, Midang River, Ancar River, Baren yok River, Unus River, and Babak River. Most of Mataram City is plains with a slope of <2%. This flat land carries a risk of becoming flooded by both river floods and coastal floods. The flood locations are scattered throughout six sub-districts with a potential risk of up to 75.36% of the total area of Mataram City [19]. The worst flooding occurred in 2012 along the Jangkok River. Besides along Jangkok River, river floods also often occur along the Ancar River and Unus River. This study focused on the Jangkok River as the largest river in Mataram City. The purpose of this study was to map the river flood-prone areas and to create a model of river flood inundations to discover the size of the settlements that were affected in several return periods.

2. Material dan Method

2.1. Location

Jangkok River is one of the largest rivers passing through Mataram City, West Nusa Tenggara (Figure 1). Geographically, the Jangkok Watershed is located between -08°24’28” and -08°35’14” LS and between 122°04’16” and 122°23’40” BT. The source of Jangkok River is Punikan Mountain and flows west then empties into the Lombok Strait (20).

The Jangkok Watershed covers an area of 203.71 Km² with the main river extending from the source to estuary for 47.68 Km. The number of order one rivers in the Jangkok Watershed is 109 rivers and the total number of all orders 217 rivers. The Jangkok Watershed has a drainage density of 1.49 Km/Km² with the main river slope of 0.06.

In the present study, the location is focused on the downstream part of the Jangkok River which traverses Mataram City at a length of 7.52 Km. The land use around the river is dominated by developed areas such as settlements and public facilities.
2.2. Method

The data used in the present study are a topographical map at a scale of 1:5,000, DEM LiDAR, land system map, watershed data, digital soil map, and precipitation data from the Tropical Rainfall Measuring Mission (TRMM). The maximum daily precipitation data were obtained by extracting TRMM images recorded between 01 January 2009 and 31 December 2018. In-depth interviews with respondents were conducted to discover flood occurrences, locations, adaptations, and responses.

The flood-prone analysis was conducted using the landscape approach. River floods occurred in the river channel that included the fluvial landforms in the form of alluvial plains, floodplains, natural embankments, back swamps, river terraces, and river bars [21]. Based on the land system data, most of Mataram City is on alluvial plains. The river flood-prone analysis limit is based on the distance from the river.

The scoring method in the GIS application was conducted to determine the river-flood prone areas according to the parameters in Table 1. In this method, each parameter was calculated using different weights. The parameters and weight used were modifications of [21] and [5]. Based on [21] the river flood-prone analysis used three parameters, i.e. slope, land use, and average precipitation rate. This study used 4 parameters, i.e. slope, land use, average precipitation rate, and distance from the river. The addition of the distance from the river parameter was based on reference [5] and results from the field survey of the flood locations.

Table 1. The river flood-prone analysis parameters ([21];[5])

| Parameter     | Weight | Low Score | Low Score | Moderate Score | High Score | High Score |
|---------------|--------|-----------|-----------|----------------|------------|------------|
| Slope         | 30     | > 4%      | 3         | 2 – 4%         | 2          | 0 – 2%     |
| Land use      | 30     | Forest/rice field | 3          | Bushes/agriculture | 2          | Settlements |
| Rainfall      | 20     | < 50 mm   | 3         | 50 - 200 mm     | 2          | > 200 mm   |
| Distance      | 20     | 0 – 25m   | 3         | 25 – 100m       | 2          | 100 - 250m |

The flood inundation modeling is generally classified into 3 categories, 1D, 2D, and 3D models. The 1D model is the model that is most suitable for application in planning, management, and flood control.
mitigation for areas with large water catchment areas. The Hydrologic engineering Center-River Analysis System (HEC-RAS) is one of the software packages developed by the US military’s Hydrologic Engineering Center (HEC). This software can present a 1D hydraulic flood model simulation for steady and unsteady flows, both for single and multiple channels [22].

The flood inundation model using geometric data in the HEC-RAS 2D was used to design the maximum flood discharge return period. The design flood discharge data for each return period according to the HSS Gama calculation was input data for the flood inundation model in each return period [23]. The DEM 1-m data was used as the terrain in the HEC-RAS 2D model. The land use map which was taken from the digital topographical data was used for calculating the Manning coefficient (n) the 2D flow area. The grid spacing used in the flood inundation simulation was 5 meters.

The parameters required for the modeling using HEC-RAS included channel geometric data, land use, and flow discharge data. The flood inundation modeling results were flood inundation maps for return periods of 10 years, 50 years, and 100 years.

3. Results and Discussion
The river flood-prone analysis was conducted using 4 parameters, namely the slope, land use, precipitation rate, and distance from the river. The results for the analysis along the Jangkok River course at a distance of 0-100m it is classified as highly prone. The intermediate class is located at a distance between 100 and 250 m and there was no low flood-prone class is found (Figure 2). The area along Jangkok River has a flat topography with land covers in the form of settlements, bushes, and rain-fed agricultural fields. Highly flood-prone settlements covered an area of 57.53 ha and the intermediate prone area was 73.81 ha.

Figure 2. The Jangkok River flood-prone map

The flood modeling was conducted using the HEC-RAS 2D analysis of the downstream part of the Jangkok River at a length of 7.52 Km. The 1-meter resolution DTM data was used for geometric analysis consisting of the centerline, cross-section cut lines, main channel banks, flow path centerlines, reach lengths, and Manning coefficient roughness.

The flood inundation modeling results for the Jangkok River downstream part with a flood discharge scenario for the 10-year, 50-year, and 100-year return period are presented in Figure 3. The flood inundation is mainly concentrated at the downstream of the river. The flood inundation in settlements covered an area of 70.95 ha in the 10-year return period, 97.17 ha in the 50-year return period, and 108.41 ha in the 100-year return period.
Figure 3. The (A) 10-year, (B) 50 year, and (C) 100-year simulation results

Flood simulations are a good method of identifying and preparing for flood occurrences [24]. The main purpose of the simulation was so that the information could be processed into a policy for future flood mitigation management. Study results in France showed that strategies to reduce the vulnerability of settlements were relocation, home architectural adaptations, protection, and preventive warning. Relocation is the most efficient strategy; however, this is costly [25].

The Jangkok River Watershed, especially the downstream, is a densely populated slum area with an area of 73.21 Ha or 24.12% of the Mataram City slum area [19]. Based on data, the population around the downstream area of the Jangkok River Watershed is 75,370 in the Selaparang Sub-district with a
density of 6,998/km² and 92,714 in the Ampenan Sub-district with a density of 9,801/km² [26]. The issues often faced by the Jangkok River are the clogging/narrowing of the downstream river/estuary capacity, damage to river infrastructure, a decline in water quality due to pollution by industrial and household waste, decrease in the riparian zone, and the utilization of the river floating net cages. River pollution is mostly caused by people using the river for bathing, washing, and as a public toilet and as a place to dispose of waste materials, both domestic and industrial waste. These activities cause a reduction of the river depth due to the piling of sediments and trash, leading to the inability to accommodate the volume of water from upstream. This is unfortunate as Jangkok River is the source of raw water for fulfilling the domestic, agricultural, and industrial needs in Mataram City.

This is what then caused flooding the areas surrounding the Jangkok River. Floods experienced by the people around the riparian zone disrupt community activities, interrupting both social and economic activities. Besides inundating settlements, floods also inundate the people’s main roads. The overflow from the Jangkok River may pose a threat to the people’s health and to the environment since the water is fairly polluted. The river water quality decreased further because the content of chemicals and harmful bacteria have exceeded the standards. According to data, the total Coliform exceeds the threshold, signifying the river as polluted by coliform bacteria [20].

When there are heavy rains, the people living in the riparian zone prepare for floods. To prevent flood inundation from entering their houses, the people usually create a temporary (emergency) levee from sandbags. When it floods, most people opt to stay at home and look after their belongings, and some choose to evacuate to their relative’s house in a safer location. The people who often experience floods have also modified their homes such as by building cement barriers in front of doors, placing their valuables and electronics in areas that are safe from flood inundation, and renovating to elevate the position of the house.

Flood disaster management policy is very important and has been regulated in the Law of the Republic of Indonesia No. 24 of 2007 concerning disaster management. As stated in the law, the responsibilities of local governments in implementing disaster management include: (a) guarantee the fulfillment of the rights of the community and evacuees affected by the disaster following the minimum service standards; (b) protection of the community from disaster impacts; (c) disaster risk reduction and integration of disaster risk reduction with development programs; and (d) allocation of adequate disaster management funds in the regional expenditure budget. The Mataram City government has made several efforts to reduce the flood hazards from the Jangkok River such as the construction of a floodwall and artificial levee, the expansion of the drainage system, and cleaning the river from garbage and other pollutants. Moreover, other efforts that can be made in flood prevention is the construction of a reservoir/basin. Based on research from [27] proved that a reservoir in a watershed can be used as a place to hold sediment in the upstream area so that it can reduce the magnitude of massive flood hydrographs. [28] also states that developing upstream reservoirs have helped to reduce the flood peak discharge in downstream areas and improved the function of existing river training schemes. Also, it is necessary to develop an early warning system for flood disaster mitigation by using information technology, for example through short messages disseminated for potentially affected communities.

In flood disaster management, aside from the need for increasing the planning and technical fields in the physical or infrastructure sector, it also needs for strengthening in its social aspects. There are some Risk Response Strategies based on the research of [29] that can be implement for people affected by flooding, such as, disseminating and guiding the community around the river to increase awareness to not litter the river. It is also important to build community empowerment related to waste, especially green waste, for example counseling on waste sorting and composting as well as working with farmers to utilize the products produced as organic fertilizer. Furthermore, promote the importance of watershed conservation to local communities. This is a major challenge in motivating people to be more aware of the potential risk of river flooding that threatens them. Currently the local government and several community groups along the Jangkok River have begun a campaign to stop the people from disposing the garbage into the river; some local events have also been organized to build the people’s awareness in keeping the river clean such as cooperation to clean the river. Alternative policies for the development
of settlement areas in flood-prone areas include disaster education, increasing socialization in flood-prone areas, and disaster mitigation-based spatial planning. The local government needs to be firm and consistent in spatial planning [30].

4. Conclusion
The research indicated that the area along the Jangkok river is highly prone to flooding. The results of the flooding simulation showed that the inundated settlement area constantly increases. As the inundated settlement area continues to grow, there needs to be appropriate management. Prevention of flood dangers can be done by educating the people living along the river to improve the awareness of flood dangers. The local government needs to find long term solutions to overcome the flooding issues. The recommendation for further studies is developing a model of the effects of settlement land-use change and the population on river floods.

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