Jakarta's 2020 New Year Flood Assessment by Rainfall-Runoff-Inundation (RRI) Model

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† Presented at the title, place, and date.

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INTRODUCTION

JAKARTA FLOOD JANUARY 2020

Indonesia – Jakarta Floods Leave 47 Dead

3 JANUARY, 2020 BY FLOODLIST NEWS IN ASIA, NEWS

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Flash Floods in Indonesia Leave Hundreds of Thousands Homeless

At least 43 people have been killed in the most intense rains to strike Jakarta, the country's capital, since record keeping began.

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Thousands caught in floods in Jakarta, Indonesia's sinking capital

Niniek Karmini Associated Press

Published 6:54 a.m. ET Feb. 25, 2020 | Updated 9:20 a.m. ET Feb. 25, 2020

Widespread flooding in Jakarta, Indonesia causes chaos

Residents of Jakarta, Indonesia, waded through flooded streets after heavy rain soaked the city on Feb. 25. *Accuweather*

CILIWUNG CISADANE RIVER BASIN AREA

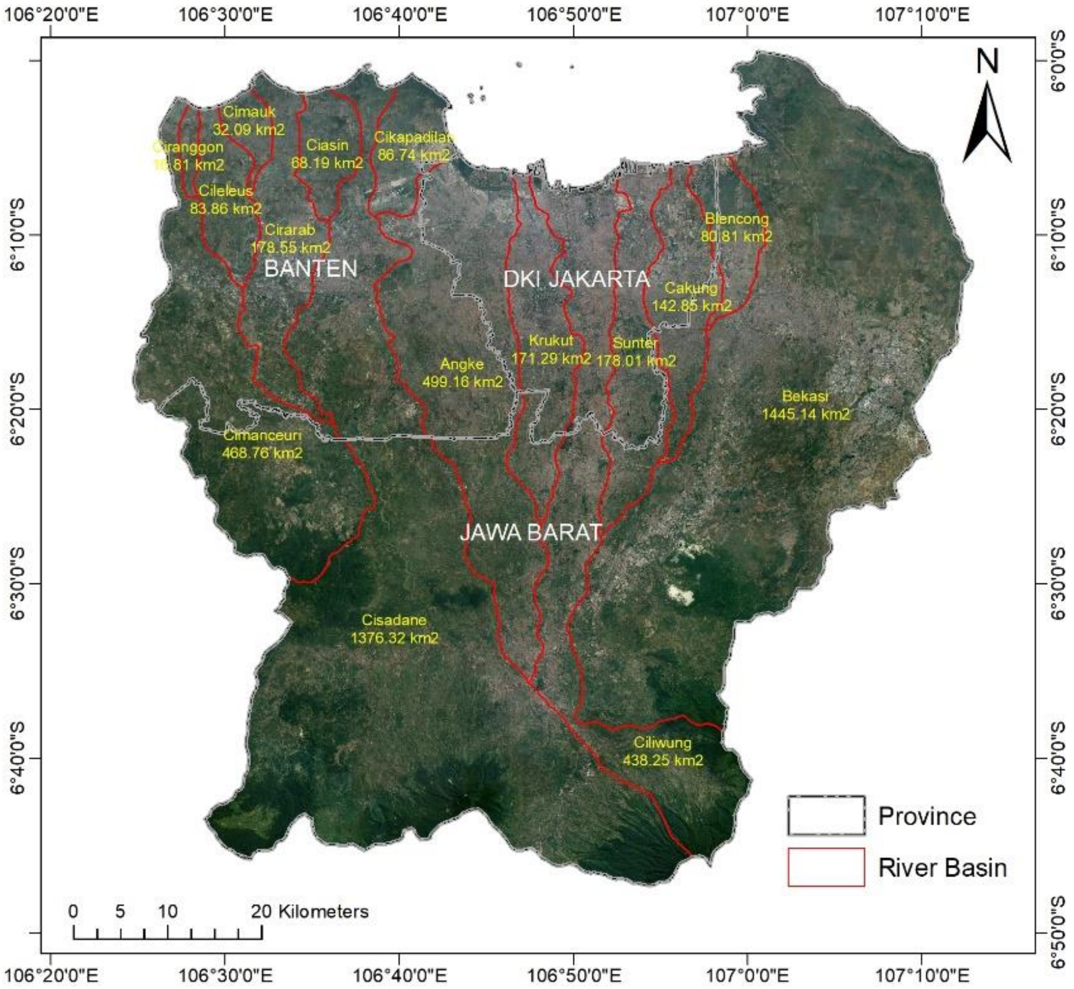

Figure 1 Study Area

Ciliwung-Cisadane River Basin

River Basin:	15 river basins
Total Area:	5269.84 km^2
Administrative area:	3 Provinces, 9 cities/municipalities as follow Province of DKI Jakarta (5 cities), Bogor, Depok, Bekasi, and Tangerang.

DATA

PRECIPITATION DATA

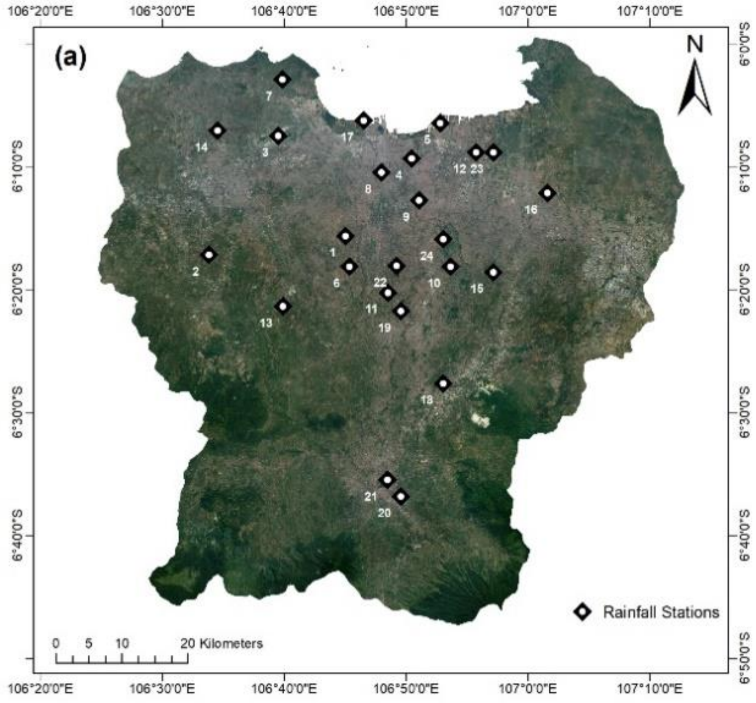

Figure 2 Rainfall datasets in the study area: (a) Rainfall station locations;

The precipitation data were collected from 24 rainfall stations in Ciliwung – Cisadane Watershed during the flood event. All of the rain stations are located around the study area as shown in **Figure 2** (a) and in **Figure 2** (b) presents the rainfall distribution throughout the river area using Inverse Distance Weighted Interpolation (IDW) method.

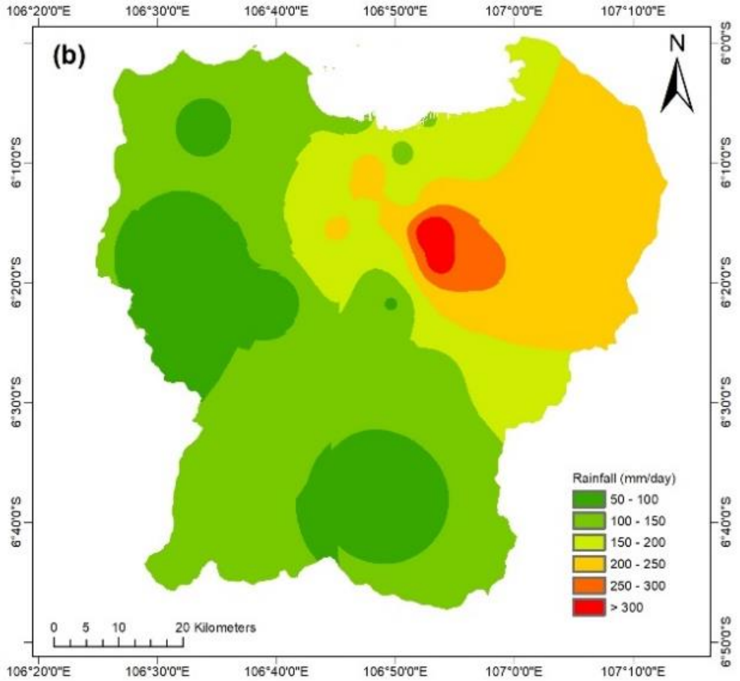

Figure 2 Rainfall datasets in the study area: (b) Rainfall distribution on January 1st, 2020

PRECIPITATION DATA

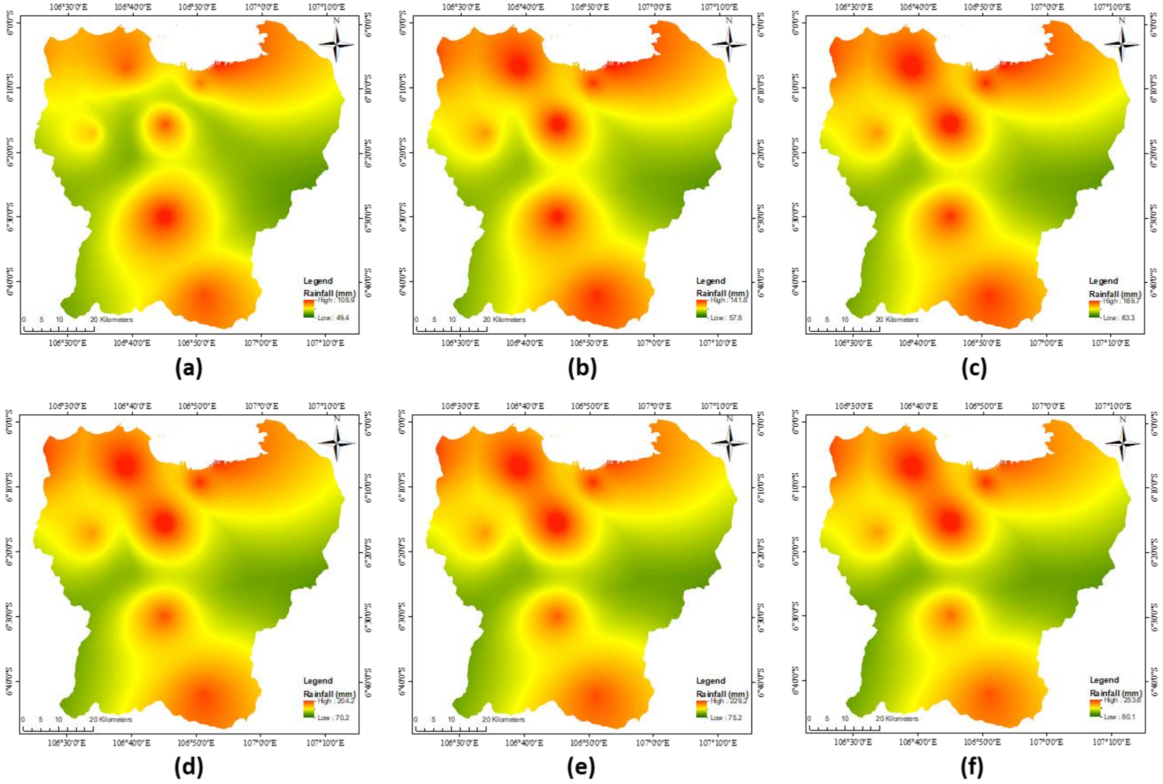

Figure 3 Rainfall return period datasets (a) Rainfall return period of 2 years, (b) Rainfall return period of 5 years, (c) Rainfall return period of 10 years, (d) Rainfall return period of 25 years, (e) Rainfall return period of 50 years and (f) Rainfall return period of 100 years

The forecasting of return period rainfall used BMKG (Meteorological and Geophysical Institution of Indonesia) rainfall dataset in a period of 1986-2010 as a reference. The data was distributed throughout study area as presented in **Figure 3**. Compared with the rainfall was occurs on January 1st, maximum rainfall on that event exceeded the maximum data in 100-years period which has good corresponding with the previous study.

TOPOGRAPHY

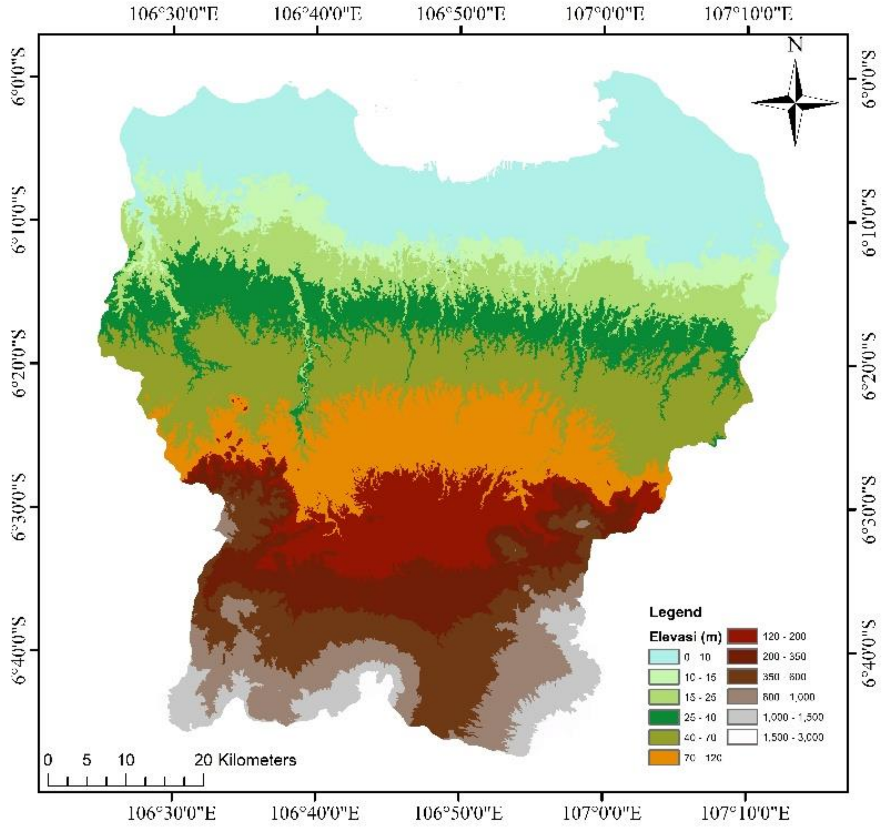

Figure 4 Digital Elevation Model (DEM) of Ciliwung-Cisadane Watershed

The topography data is derived from the Digital Elevation Model (DEM) obtained from the Shuttle Radar Topography Mission (SRTM). The data was open-source data provided by the United States Geological Survey (USGS). For the SRTM, the vertical accuracy is 16 m for 90% confidence level [45].

LAND COVER

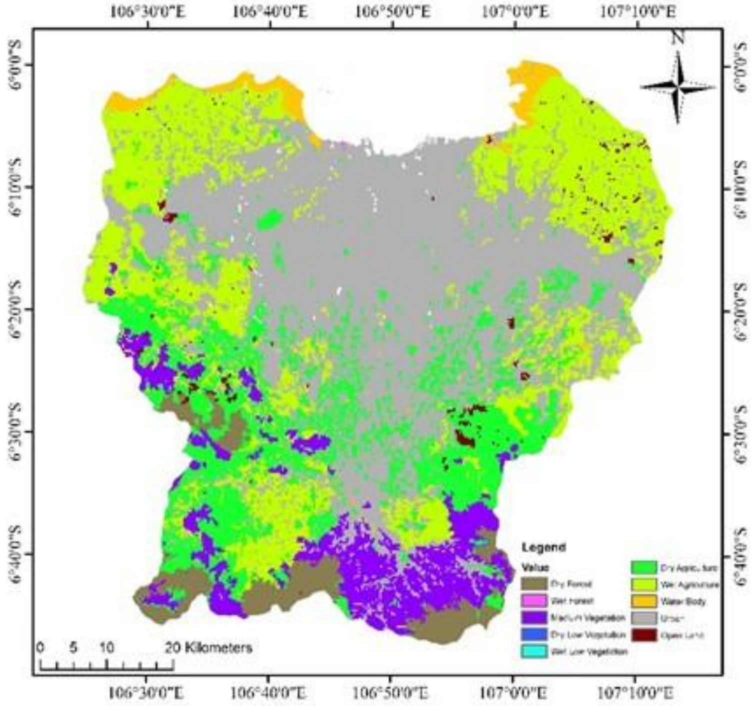

Figure 5 Land cover of Ciliwung-Cisadane Watershed

Parameters	Land Cover		
	Clay	Loam	Sandy Clay Loam
Soil depth (m)	1	1	1
Porosity (-)	0.475	0.463	0.398
k_v (m/s)	0 - 8.33E-08	0 - 9.44E-07	0 - 4.17E-07
S_f	0.361	0.089	0.219
k_a (m/s)	0 - 0.3	0 - 0.3	0 - 0.3
Unsat. porosity (-)	0	0	0
Beta	8	8	8

Land over was obtained from Global Land Cover Characterization Version 2 (GLCC-V2). This database has been developed by The U.S. Geological Survey (USGS), the University of Nebraska-Lincoln (UNL), and the European Commission's Joint Research Centre (JRC) since 1992. The land cover projection has 1-km nominal spatial resolution and unique geographic elements. The land classification for this model has been simplified from GLCC-V2 for calculation purpose (**Figure 5**).

RRI MODEL

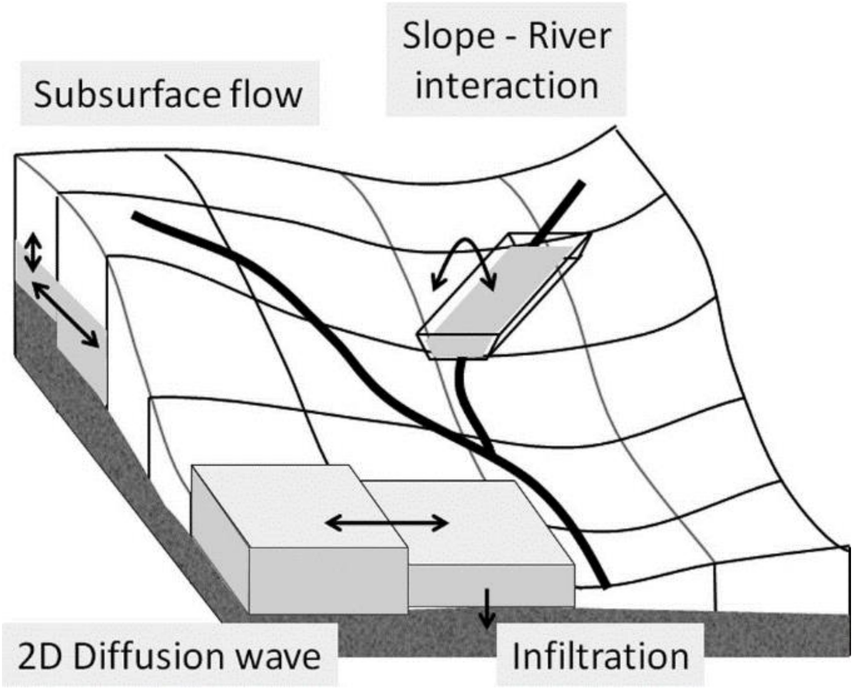

Figure 6 Rainfall-runoff-inundation (RRI) model schematic diagram (Source: Sayama *et al.*, 2012)

$$\frac{\partial h}{\partial t} + \frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} = r - f$$

$$\frac{\partial q_x}{\partial t} + \frac{\partial u q_x}{\partial x} + \frac{\partial v q_x}{\partial y} = - g h \frac{\partial H}{\partial x} - \frac{\tau_x}{\rho_w}$$

$$\frac{\partial q_y}{\partial t} + \frac{\partial u q_y}{\partial x} + \frac{\partial v q_y}{\partial y} = - g h \frac{\partial H}{\partial y} - \frac{\tau_y}{\rho_w}$$

CALIBRATION

MODEL CALIBRATION

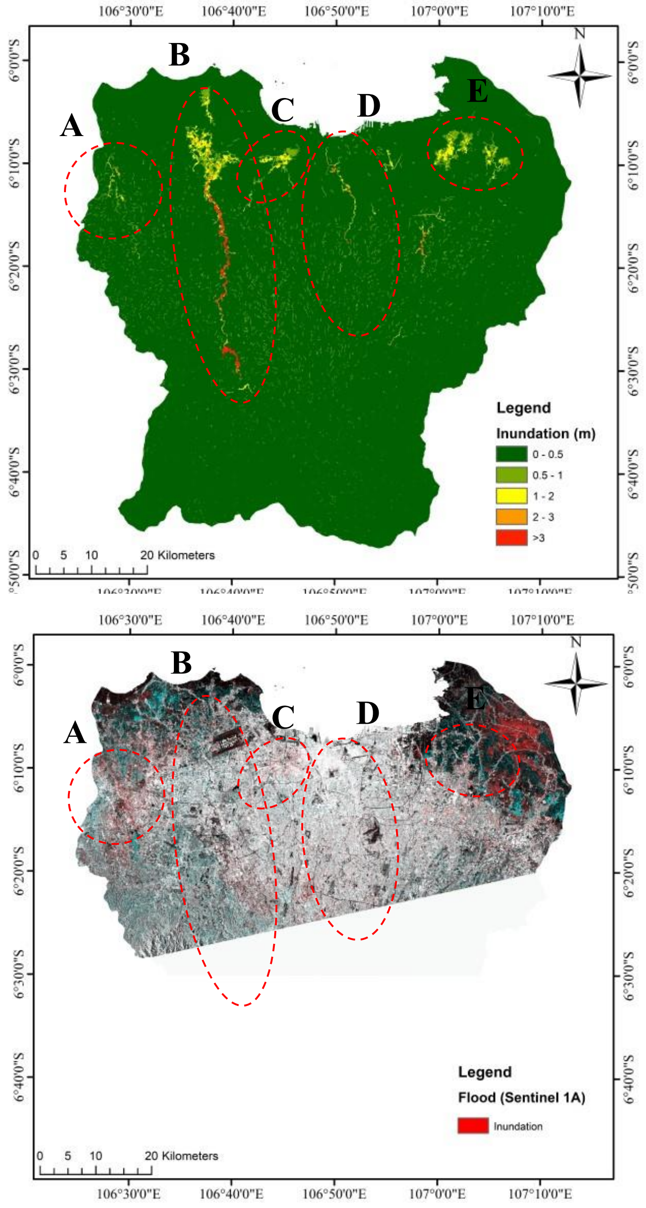

Figure 7 Rapid Assessment of Jakarta Flood Inundation: (a) simulated 1st January flood inundation (b) flood inundation of sentinel 1A acquired on January 2nd, 2020

Location	River Basin	Inundation Area (km²)	Affected City(ies)
A	Cimanceuri	6.3	Tanggerang
B	Cisadane	51.05	Tanggerang,
C	Angke	11.9	West Jakarta
D	Ciliwung	5.03	East Jakarta, South Jakarta, Central Jakarta
E	Bekasi	32.26	Bekasi

The model was calibrated before being used to simulate the return period flood. It was calibrated with a flood event that occurred on January 1st, 2020. The simulation has calculated the distribution of flood inundation in the condition of maximum water depth and compared by the inundated area from satellite data at the same event (**Figure 7**). **Figure 7** shows the comparison of simulated flood inundation and flood inundation of sentinel 1A acquired on January 2nd, 2020. The flood inundation of sentinel 1A generated using an algorithm that proposed by Chini et al [48]. The algorithm can detect the flood water not only on bare soil but also on the urban regions. Even though the Sentinel 1-A acquired a day after flood event, some inundation still remains on the land. **Figure 7** shows a similar inundation on the north-east part between simulation and satellite data. Whereas in the middle part near ocean, the figure shows that the simulated inundation areas are larger than the satellite data. Because the flood waters in urban area of Jakarta receded on January 2nd, 2020.

MODEL APPLICATION

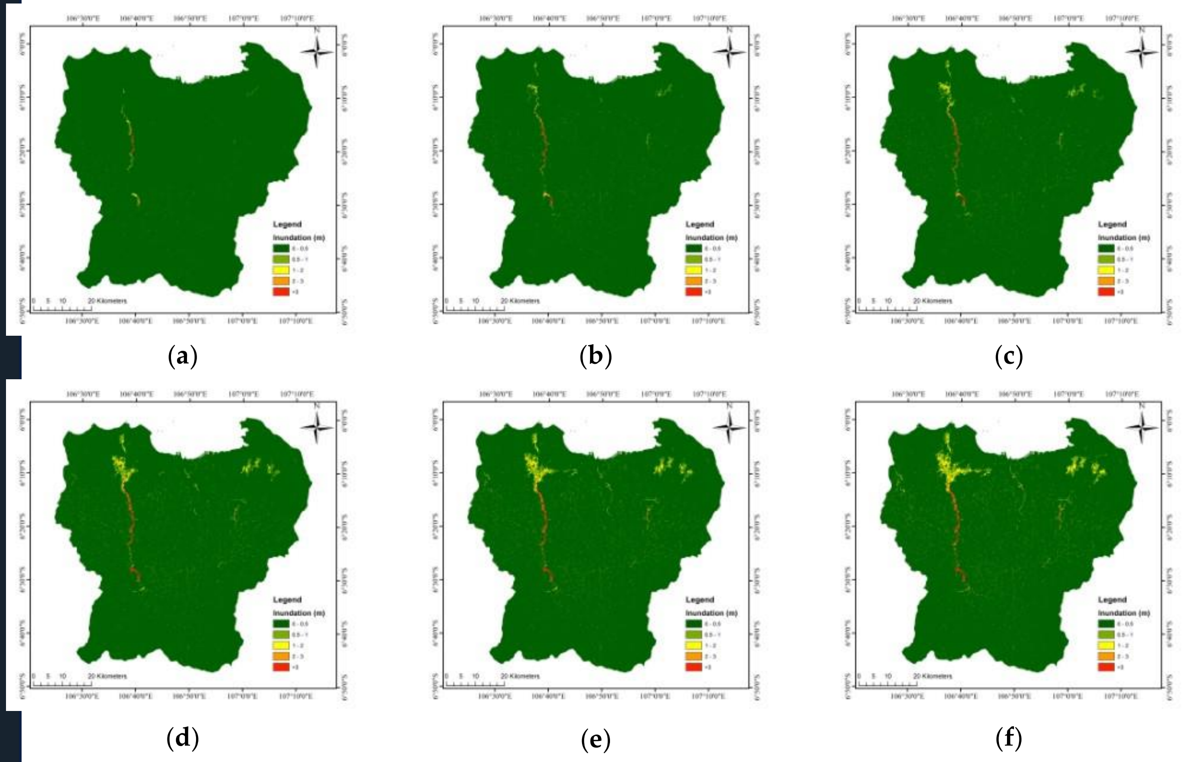

Figure 8 The inundation of flood return period (a) Flood return period of 2 years, (b) Flood return period of 5 years, (c) Flood return period of 10 years, (d) Flood return period of 25 years, (e) Flood return period of 50 years and (f) Flood return period of 100 years

Flood Simulation	Volume (1000 m^3)	Max. Discharge (m^3/s)
Return period of 2 years	16475	199.75
Return period of 5 years	22059	260.88
Return period of 10 years	25797	297.85
Return period of 25 years	30397	340.95
Return period of 50 years	33450	365.67
Return period of 100 years	36355	389.97
Jakarta Flood	40204	420.76

MODEL APPLICATION

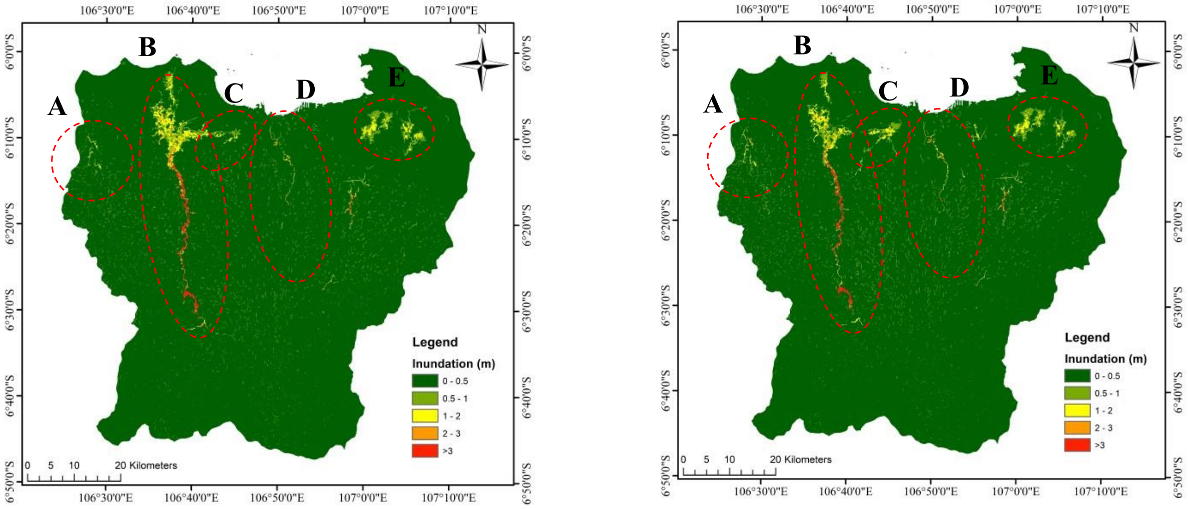

Figure 9 The comparison between : (a) 100 yearly flood and (b) Flood on January 1st, 2020

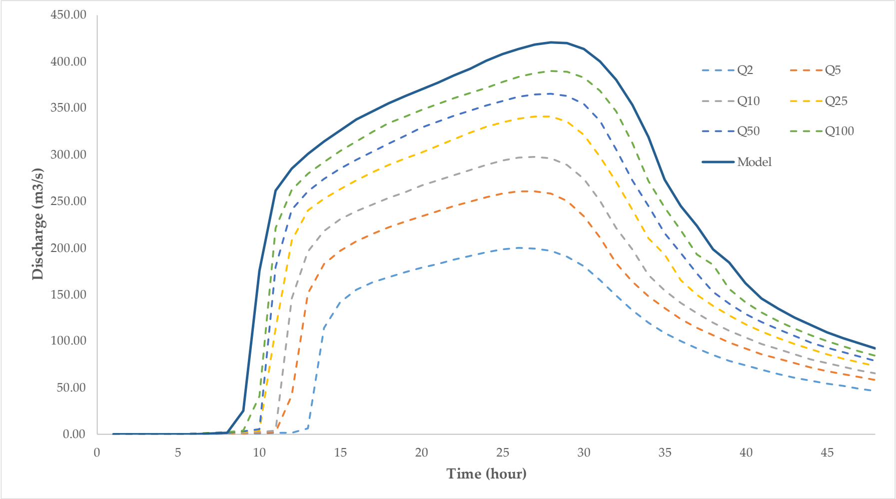

Figure 10. Discharge on Water Gate Manggarai

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

This study attempts to do a rapid assessment of flood on January 1st, 2020, in Ja-karta and several areas of the Ciliwung-Cisadane Watershed. The study was conduct-ed to find out the return period of the flood that occurred. Rainfall-Runoff-Inundation (RRI) is a distributed model that is able to simulate rainfall-runoff and flooding simul-taneously. The model based on the inundation map from remote sensing satellite was calibrated with ground station rainfall. The resolution of Digital Elevation Model (DEM) that too high hindered the simulation process, it made the resolution of DEM should be decreased. The DEM is upscaled, then the grid size is changed from 30 m to 100 m. After the model has been calibrated, a return period flood model is performed with a return period rainfall input. There are six return periods of rainfall are being simulated, there are 2, 5, 10, 25, 50, and 100 years of the return period of rainfall.

The discharge and inundation area of all return periods is compared with the simulation of flood on January 1st. The comparison showed that the discharge extent on January 1 is exceeded the discharge with a return period of 100 years. This result corresponds with the rain recorded at several rainfall stations which surpassed the 100-year rainfall return period. Thus, there are several conclusions. First, the flood that occurred on January 1st, 2020, is superior than a 100-year return period of flood. Sec-ond, the rainfall, which is the biggest in the history, is the main effect of the flood of this flood because it exceeded the 100-year return period of rainfall.

In this study, the DEM implemented in this model has low resolution because the limitation of data sources. In addition, the model need to be compared with the existing discharge during the flood. This conditions need to be considered in future research.

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