SENSITIVITY ANALYSIS OF DEM RESOLUTIONS ON FLOOD INUNDATION SIMULATIONS IN JAKARTA, INDONESIA

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Jakarta has experienced many floods in the past, and those floods resulted in not only human casualties but also economic damages. The aim of this paper is to check a newly available bathymetry of 5 m resolution from ALOS by using a developed flood inundation model whether this fine resolution DEM can be useful to reproduce a better simulation result in Jakarta. The 5 m resolutions show the river width more detail than 30 and 90 m resolutions but a high building in a target area was not captured well in any DEM. As the result of analysis, it was found that there are no significant differences between simulation results using 90, 30 and 5 m DEM resolutions because these DEMs were obtained from satellite images and show no big differences in accuracy.

Key Words: *flood inundation model, bathymetry, Digital Elevation Models (DEMs), Jakarta, Indonesia*

1. INTRODUCTION

Jakarta is located in northwest part of Java Island, Indonesia. Jakarta, officially Special Capital Region of Jakarta, is the capital and most populous city of Indonesia. Jakarta has experienced many floods in the recent period such as in 1996, 2002, 2007, 2013, 2014, and 2015. Kure et al[1)] emphasized that these floods resulted in not only human casualties but also terrible economic damages.

There have been a number of studies related to flood modelling in Jakarta and surrounding areas. Moe et al[2)] developed a rainfall-runoff and flood inundation model for Jakarta and surrounding areas in order to understand the flood inundation situation in the city. Farid et al[3)] developed a flood inundation model for the Ciliwung River and they showed good comparisons between simulated and observed flood map. It should be emphasized that the topography data is crucial and important to obtain an accurate flood inundation simulation result and it is always required to use much higher resolutions of the topographic data[4)]. Topography plays a major role in determining the accuracy of hydraulic modeling and flood inundation mapping[4)]. In developing country, it was difficult to find a fine resolution of bathymetry. Patro et al[5)] proposed that a bathymetry data with 90 m resolution can be used as the river cross sections for the large rivers in the flood modelling. However, water drainages system in Jakarta is complicated, so that it was difficult to obtain the cross section information of local canal in the city from the bathymetry with resolution of 30 m. This is the reason why a parameterization of urban flooding was introduced in the previous study[2)]. However, a recent remote sensing technology makes it possible to provide the fine resolution DEM over the world through the operation of the satellites. The Japan Aerospace Exploration Agency (JAXA) through Advanced Land Observing Satellite (ALOS) newly provided a good precision of 5 meter in spatial resolution to express land terrain all over the world. It should be emphasized that this kind of information from JAXA is very good news for developing countries. The main objective of this study is to check the bathymetry of 5 m resolution by using flood inundation model whether this finer resolution can be useful to reproduce a better simulation result in Jakarta. In order for that, this finer 5 m resolution was compared with the bathymetry of 30 and 90 m resolutions.

2. STUDY AREA

Jakarta is the largest metropolitan city in Indonesia and its development is progressing rapidly[6)]. There are thirteen rivers flowing into Jakarta, and the main and the longest river is the Ciliwung River which passes through the city center from upstream region located in the border of Cianjur and Bogor cities as shown in **Figure 1**. The Ciliwung River has a catchment area of 382.6 km^2 with the river length of 117 km. The Ciliwung River brings the largest flood damage to Jakarta compared to other rivers that flow into Jakarta. The target area selected in this study includes Jakarta and the Ciliwung River basin totally covering 1346.6 km^2 as shown in **Figure 1**.

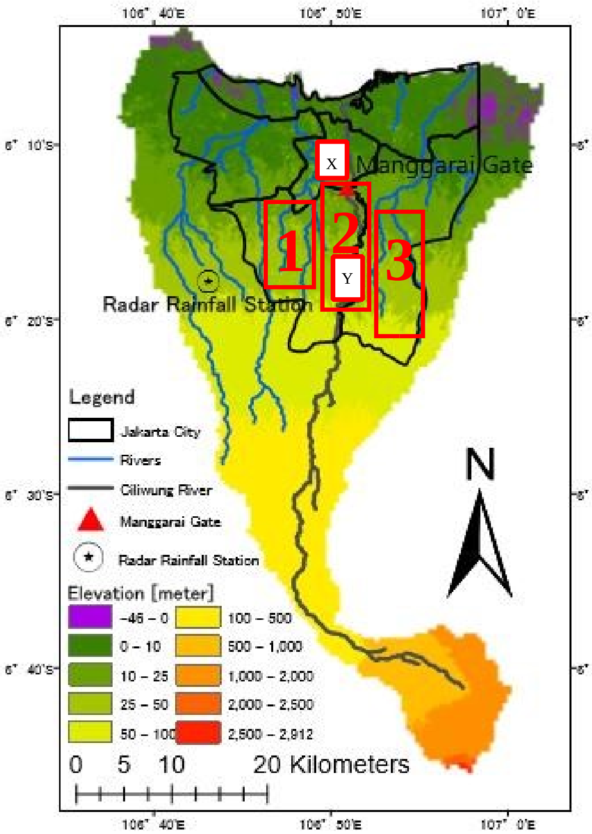

Fig 1. Study area and the location of Jakarta City

In this study the DEM of 90 m was obtained from the US National Aeronautics and Space Administration (NASA) Shuttle Radar Topographical Mission (STRM). The ALOS 30 and 5 m DEM were obtained from the Japan Aerospace exploration Agency (JAXA), Advanced Land Observation Satellite (ALOS).

The cross section data of rivers and the drainage system of the Ciliwung River in 2011 were obtained from the project authority of JICA. For rainfall data, radar rainfall information was provided by the BPPT (Badan Pengkajian dan Penerapan Teknologi: Agency for the Assessment and Application of Technology), and water level data of the Ciliwung River and flood inundation map of Jakarta were provided by the BPBD (Badan Penanganan Bencana Daerah: Jakarta Disaster Management Agency). Also, land use maps in 2002 was provided by the PU (Ministry of Public Works).

3. METHODOLOGY

(1) Flood inundation model

In this study a physically based rainfall-runoff and flood inundation model was employed in order to simulate the flood inundation situations in Jakarta. The model consists of rainfall-runoff module at each subbasin, hydrodynamic module in the river and canal networks, and flood inundation module for the floodplains. For the details of the model, see the reference[2)].

Radar rainfall information provided by BPPT was used as the input for the simulation. Soil parameters used in the simulation were calibrated based on 4 land cover classes of forest, cropland, paddy field, and urban area in the target area. Also, the manning's roughness coefficients of the river beds were set from 0.02 to 0.4 for river sections, and the said coefficients of the land surface were set as 0.1 for all the floodplains through the calibration. For the calibrated parameters and details of the simulation, see the reference[6)].

(2) Digital elevation models

The bathymetry of 5, 30, and 90 m were compared in this study. The coarse resolution such as 90 m has a disadvantage like inaccuracy in determining the correct elevations for local situations such as road, buildings, and embankments of rivers. The spatial resolution of a fine DEM has more number of cells per unit area compare to the coarse DEM (ESRI[7)]). **Figure 2** and **3** show the comparisons between 5, 30 and 90 m DEMs and the satellite image (Google Earth) at the zone X and Y

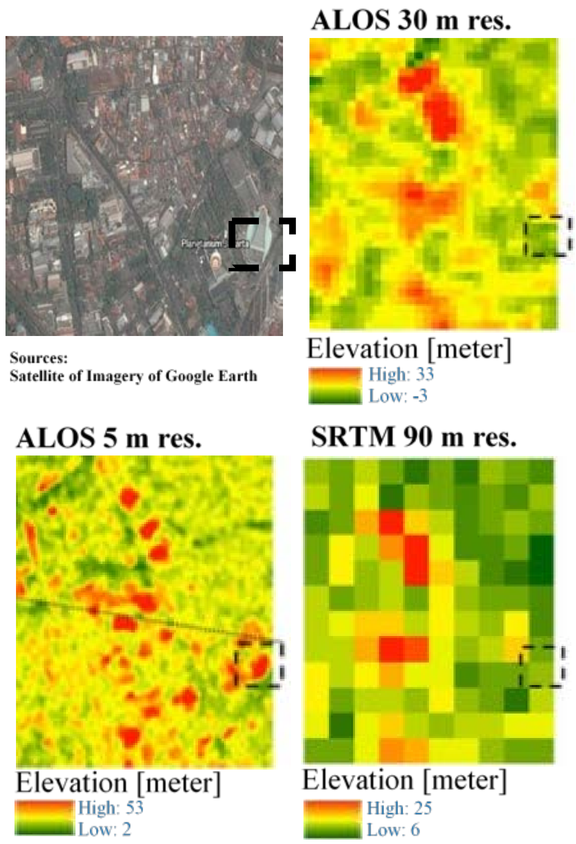

Fig 2. Comparisons between the bathymetries And satellite imagery of google earth (Zone X)

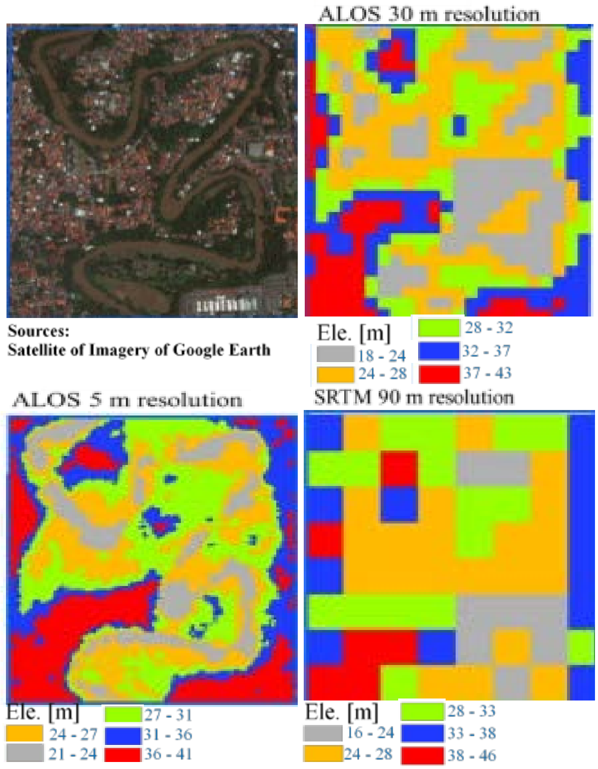

Fig 3. Comparisons between the bathymetries and satellite imagery of google earth (Zone Y)

shown in **Figure 1**. It can be seen from **Figure 2** that the 5 m resolution identified detailed land surface information of the high building and others. However, the land surface information of 5 m resolution did not match perfectly with the scene of the satellite image. Also, it can be seen from **Figure 3** that the 5 m resolution by ALOS is more accurate than SRTM 90 m and ALOS 30 m, in terms of determining the elevation such as road, buildings, and river embankments. As such, we can confirm advantages of the 5 m DEM compare to other coarse ones.

At the next chapter, these bathymetries are used as the data of flood plains in the flood inundation simulations.

4. SENSITIVITY OF ELEVATION DATA

A sensitivity analysis of the DEMs on the flood inundation simulations was conducted in this study. The 5 and 30 m resolution DEMs were employed for the flood inundation simulations. **Figure 4** shows the comparison between the bathymetry of 5 and 30 m resolutions at the location number 1, 2 and 3 of the target area (**Figure 1**). **Figure 5** shows the flood inundation simulation results using the 5 and 30 m DEMs at these 3 locations. It can be seen from **Figure 5** that the distribution of the flood inundation depth between the simulation results using the 5 and 30 m resolutions have no significant differences in terms of accuracy. There are, of course, some differences but considering the challenging purpose to use a finer resolution DEM for identifying the water drainage system in Jakarta and the expensive computation time of the 5 m DEM these differences are much smaller than that we expected. It is because those elevation data were captured by using satellite images. It should be noted that only the zone A in the location number 1 have significant differences between 5 and 30 m simulations because of the DEM differences as shown in **Figure 4**.

5. CONCLUSIONS

In this study a physically based rainfall-runoff and flood inundation model was developed and applied to Jakarta in order to understand the flood inundation situation in the city. A sensitivity analysis of the model DEMs was conducted in this study. Different DEMs such as ALOS 5 m and 30 m and SRTM 90 m were compared to get a better simulation result.

The 5 m resolution shows the river width and embankments more detail compared to 30 and 90 m

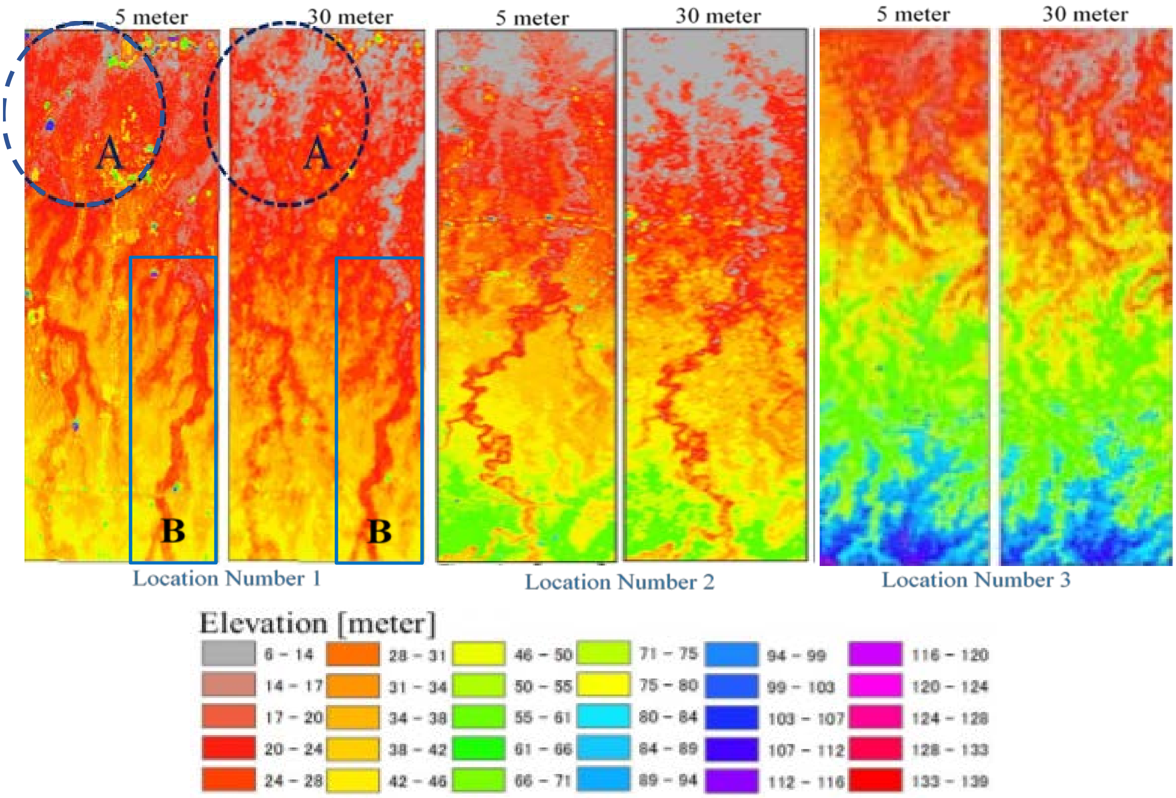

Fig 4. Comparison between the bathymetry with 5 m resolution and 30 m resolution with smaller domain

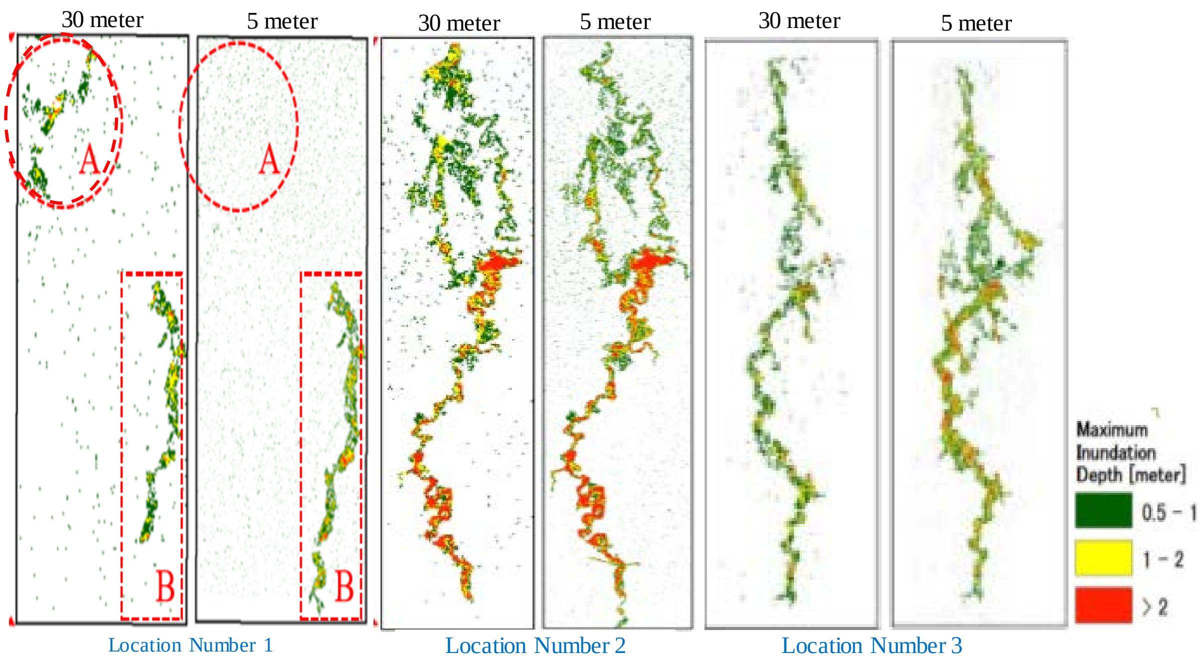

Fig 5. Flood Inundation comparison between the bathymetry with 5 m resolution and 30 m resolution

resolutions. Also it shows the land surface information of the high building similar to the satellite imagery of google earth. As such, we can find advantages of the 5 m DEM compared to the other coarse resolutions. However, as the result of flood inundation simulations, it was found that there are no significant differences between simulation results using 30 and 5 m DEMs at the 3 selected areas in this study. Considering the computation time of the 5 m DEM simulation and the challenging purpose to identify the river banks and width in the urban drainage system, these differences shown in this study are to be considered as the small differences. This is because these fine DEMs were obtained from satellite images and show no significant differences in accuracy in the target areas compared to the DEM obtained from a Light Detection and Ranging (LIDAR)[8)] data. The LIDAR data should be observed and analyzed for future studies in Jakarta to get a better flood inundation simulation.

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