Flood Potential Mapping of Pesanggrahan River Watershed in South and West Jakarta with LIDAR Data Segmentation

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Article

Flood Potential Mapping of Pesanggrahan River Watershed in South and West Jakarta with LIDAR Data Segmentation

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Abstract: Degradation of environment quality is currently the prime cause of the recent occurrence of natural disasters; it also contributes in the increase of the area that is prone to natural disasters. This research is aimed to map the potential of areas around Pesanggrahan river in DKI Jakarta by segmenting the Digital Elevation Model derived from LIDAR data. The objective of this segmentation is to find the watershed lines of the DEM image. Data processing in this research is using LIDAR data which take the ground surface data, which is overlaid with Jakarta river map and subsequently, the data is then segmented the image. The expected result of the research is the flood potential area information, especially along the Pesanggrahan river in South Jakarta.

Keywords: Flood mapping; Urban flood potential; LIDAR; image segmentation; Digital Surface Model; Digital Elevation Model.

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1. Introduction

Jakarta's rapid growth without sufficient water supply system results in high sub-surface water usage, which in turn causes land subsidence. Degradation of the city's drainage and sewer system, including downtown rivers further makes this complicated. Flood is concentration of water in the flat area around the river as a result of overflow of river water that cannot be accommodated by the river. In addition, flooding is a phenomenon that almost always happens every year in Jakarta. One aspect that is often overlooked is that the flood is closely related to the unity of the so-called watershed (Daerah Aliran Sungai or DAS) [1]. In addition to flooding, problems that occur in the watershed include increased erosion and sedimentation, reduced land productivity, and acceleration of land degradation and river water pollution [2-3].

This study aims to map flood-prone areas based on 5-year flood data that can clarify water level rise by using remote sensing data in the form of Digital Surface Model data as any existing surface shape such as tree height, buildings and any objects on the ground. This research is expected to compare the results of the DSM data segmentation as which will produce accurate data on the prediction of the flood. Remote Sensing is the science and art of obtaining information about an object, region or phenomenon through analysis of data obtained by a device without direct contact with the object, area or phenomenon under study [4].

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2. Materials and Methods

2.1. Digital Surface Model

DSM is a digital surface model or can be interpreted as a model of digital surface. DSM is also an elevation model that displays surface heights; DSM displays any existing surface shapes such as tree height, buildings and any objects on the ground. DSM is a system, model, method, and tool in collecting, processing, and presentation of terrain information. The arrangement of digital values representing the spatial distribution of the field characteristic, the spatial distribution represented by the values in the horizontal coordinate system x, y and the field characteristics are represented by the field altitude in the Z coordinate system [3].

One method to obtain surface model is through the use of Synthetic Aperture Radar (SAR) which uses radar reflection to determine the shape of the ground surface under the buildings, vegetation, and even water bodies [5, 6]. This work is also in conjunction with image processing-based flood early warning method using ALOS/PALSAR image [5], and to further extent is also supporting the research on land deformation in Jakarta city area [6, 7].

2.2. Data Preparation

The methods used in this study include surface height extraction from DSM data, incorporation of river map data with ground level data obtained from DSM data, and object classification with watershed segmentation technique on DSM data. In this study, the data used is digital data from the height of the surface (Digital Surface Model / DEM) in 2016 with a resolution of 1 meter. The map of the sub-district administrations in DKI Jakarta whose boundaries are represented by the color difference is shown in Figure 1. This DSM data will be processed with each parameter, namely: contour data, ground surface height, slope. The value of the surface contour has different color changes and the color will determine the height of the soil surface so that the expected result from the contour will produce ground level data.

In addition to DSM data, supporting data also used in this research is the image of Landsat 7 satellite, where image data used is 1: 168,719 scale DKI Jakarta image obtained on May 2017 [8]. Landsat image is taken from the official website of the United States Geological Survey (USGS). The data obtained will be identified to divide some of the criteria for land cover classes.

DKI Jakarta is categorized as a delta city, a city located at the mouth of a river that is generally below sea level, and quite vulnerable to climate change. Nevertheless, the existence of rivers and seas causes a delta city to have a strategic advantage, especially in terms of water transport. The delta city is generally below sea level, and quite vulnerable to climate change. The Watershed Map, Channel and Flood Way through Jakarta Region, can be seen in Figure 2.

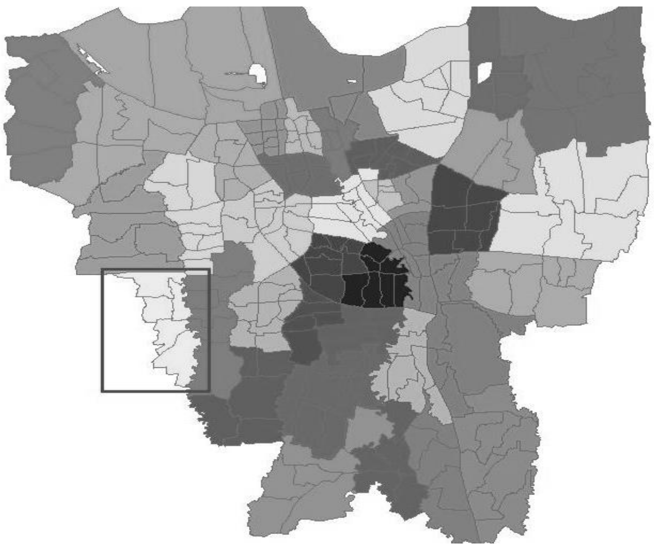

Figure 1. DKI Jakarta Sub-District boundary map, each shade represents a District, with area of interest marked by a box

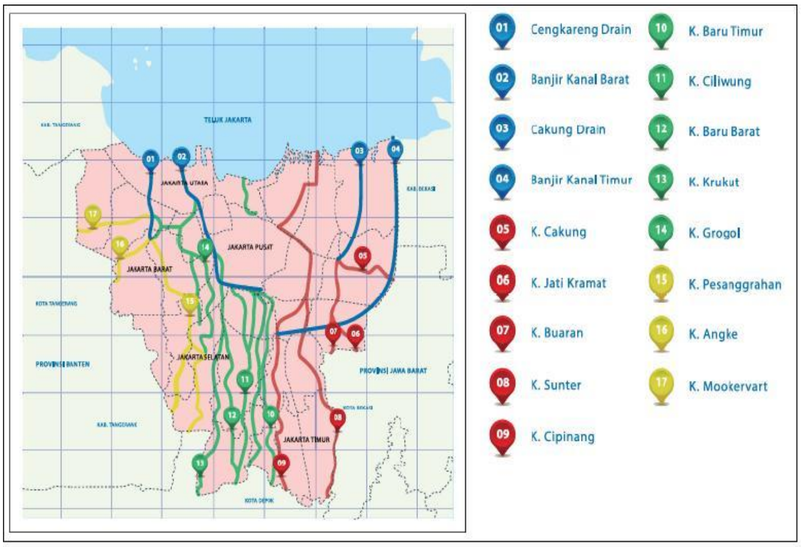

Figure 2. Jakarta river map: Blue represent flood control rivers, Red represents rivers running through eastern part, Green for rivers through central part, and Yellow marked rivers in the western part of Jakarta

Pesanggrahan River, or locally known as Kali Pesanggrahan, passes through Bogor and Depok in West Java Province finally reaches South, West and North Jakarta. All Pesanggrahan Basin has a flat and elongated shape with several tributaries entering the main river. Kali Pesanggrahan has a river area of 142,500 km2 with a length of 11,400 km. The initial capacity of Pesanggrahan River is 210 m3/s, condition of the river currently only 75 m3/s, while the flow that must be accommodated by Pesanggrahan River for the current 25-year period is 198.9 m3/s so that the runoff always occurs mainly due to backwater from Cengkareng Drain and overflow at Pesanggrahan River meeting and Angke River. With the addition of water discharge, the countermeasures by the public works office are needed for flood control in the western region today.

2.3. Mapping Method

Flood mapping method is done by using DSM (Digital Surface Model) data of DKI Jakarta which is result of contour data processing of Jakarta. DSM data is segmented by watershed segmentation method to get predicted flood potential. After obtaining the DSM segmentation result, then the data is registered to coordinate the corresponding position so as to facilitate further processing. The registered data is then cropped to determine the area of interest before conducting the analysis. The expected output of this process is information on potential floods along the Pesanggrahan River Basin located in South Jakarta Municipality [3].

DSM data as main data is processed by using ArcGIS application to get contour data and ground surface height. The results are then correlated to obtain the image of land cover in the Pesanggrahan area. After correlation processing results, the data were analyzed with field data of flood distribution. The expected output of this process is information on potential flooding along Pesanggrahan River Basin located in Pesanggrahan Sub district.

Research methods can be divided into three stages of DSM data processing, data analysis and comparison of final results with actual flood data. The method used is the result of DSM contour data in Pesanggrahan District as well as the ground surface height of the local area then the data will be correlated with for later will be matched with field data.

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2.4. Land elevation and gradient

Areas with higher ground elevation have less chance of flood events compared to lower regions because water falling on the surface tends to flow to the lower regions where the accumulation of water flow capacity that flows over the surface due to saturation water discharge in the soil. The yield value of the slope class is determined where the higher slope of the land or the steeper the area will cause less time for the rainwater to be filtered so that it will easily escape the flow of water flowing over the surface due to the full capacity of the incoming water flow into the soil. While the lower the value of the soil's soil or the flatter surface will cause the water to have a lot of time to process the flow of water into the soil so that the capacity of the field more quickly fulfilled, thus the possibility of the occurrence of larger puddles. So the flatter or small the value of the slope of the land the value of the result is increasing.

2.5. Land cover

The type of land cover has different water capacity figures. The water capacity figures show how large the portion of the rainfall will flow as the capacity of the stream surface. The growing number of vegetation will increase the soil's ability to absorb rainwater that retains the flow rate of water flow. Unlike the case with paddy fields that have water content in high field capacity so that the ability to absorb water is lower. Especially when the surface of the built area covered by many buildings and roads so that the surface is not exceeded by water resulted in high capacity water flow that supports the occurrence of floods.

From the results of the data already obtained, then the data in the overlay to apply the weighting of the values that already exist. Formulation of calculation of flood vulnerability that includes: Soil Surface height, Soil Contour, and Land Cover is the formula as follows,

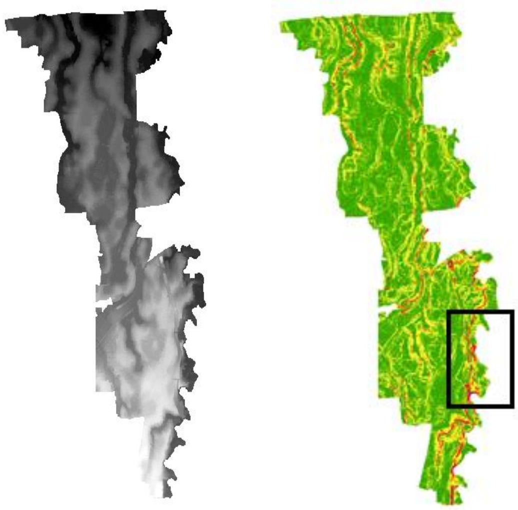
$$X = \sum_{0}^{i} (Bi \; x \; Si) \quad (1)$$

X : Total result of flood vulnerability
Bi : The Weight of i-th Parameter
Si : The result of i-th parameter

The weight of each parameter in the determination of the flood vulnerability is determined based on the parameters on the flood data that has been done. The greater the weight value of a parameter indicates that the parameter has a great effect as well as vice versa.

3. Results

3.1. Processing Surface Elevation Data



(a) (b)

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Figure 3. Data for Pesanggrahan River: (a) LIDAR data and (b) color-coded Elevation data from LIDAR

Description of land surface height around Pesanggrahan area is obtained from DEM data processing. Figure 3 shows the results of the altitude data processing. The elevation of the soil surface in Pesanggrahan Region is relatively homogeneous because it is a flat area. From the results of the processed data, Pesanggrahan area is divided into 7 different color classification class that is dark green color has a ground level of less than 5m, light green color shows height between 5m-10m, light yellow color has a height of 10-15 m, 15-20 m long yellow, pink color has a height of 20-25 m, dark red has a height of 25m-30m, and the color purple has a height of more than 30 m [8].

3.2. Deriving the contour data

From the DEM data processing, we found the contour data of the land surface area around the Pesanggrahan River Basin. Figure 5 shows the results of processing from DEM data, so that from the data visible contour of ground surface soil in Pesanggrahan River Basin. In Figure 4, the results of processed data contours Pesanggrahan have different colors, namely bright red, dark red, yellow, green, blue, purple, and orange. Each color has a different value, where the value with the smallest is the lowest point value of the contour [8]. From the image of the line height (contour) of the soil surface has a contour line density which means it reflects the steep slope against the surface. Yellow color is the river, and red area shows the lowermost elevation that is very prone to flooding. Contour derivation shows that the elevation ranges from -4 m to 29 m.

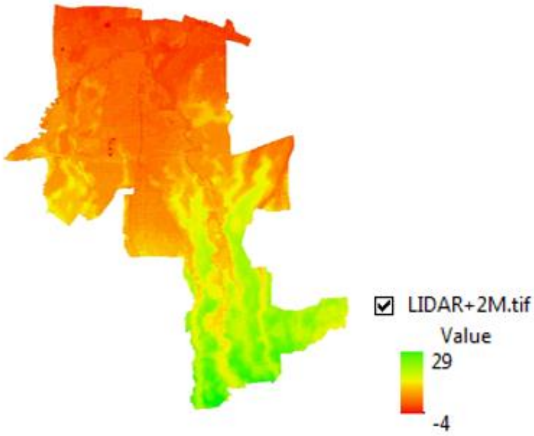

Figure 4. Detailed area of interest with color-coded elevation range

4. Discussion

The classification of elevation segmented into three categories, under 12 m; 12 to 17 m; and above 17 m. Plotting of the Pesanggrahan River's most prone areas from the southern border of DKI Jakarta to Jakarta-Tangerang Tollroad resulted in area of 332.4 hectares with the extent of flood from the riverbanks ranged between 300 m in the southern part to 600 m in the northern part. Areas around the toll road is a flat lowland which could disperse the water overflow. While this means shallow flooding, it covers much broader area and affected more residents. The flood vulnerability is shown in Figure 5 it also shows Government owned Oil and Gas Research Institute and Cipulir Market, a major textile market both located in the flood prone area.

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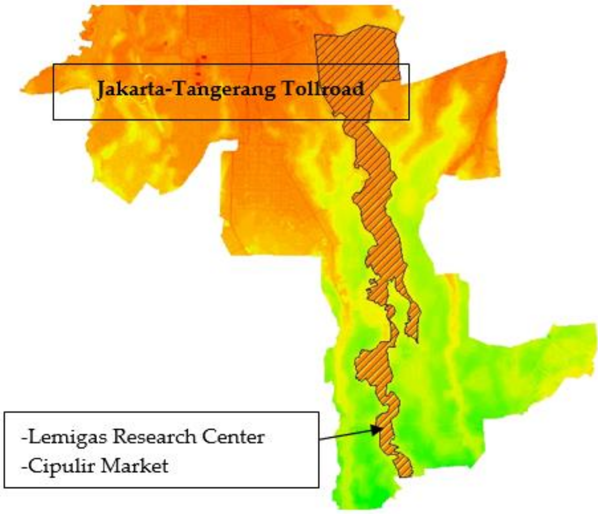

Figure 5. Mapping of flood prone area of Pesanggrahan River from DKI Jakarta southern border to Jakarta-Tangerang Tollroad

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Conflicts of Interest: The authors declare no conflict of interest.

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