# TOPOGRAPHICAL CHARACTERISTICS OF TANGERANG CITY FREQUENT INLAND INUNDATION AREAS BASED ON PRINCIPAL COMPONENT ANALYSIS

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## 1. INTRODUCTION

Flooding is one of the most frequent and damage-causing natural disasters in the world. Just in 2010, 178 million people around the world were affected by the flood (Emergency events database, http://www.emdat.be). The impacts of urban floods are also higher than rural flood due to the concentration of population and assets in the urban environment (Jha, Abhas K., et al., 2012). The Indonesian economy expanded over recent decades impacted high urbanization rates, especially in Jakarta, Indonesia's capital city, and its satellite cities. Tangerang city, as a sub-urban area of Jakarta, potential to be hit by the urban flood.

Several methods for flood hazard mapping have developed using various hydrological, meteorological and geomorphological approaches. Some authors also tried to analyze characteristics of frequent inundation areas. Kakehashi, et.al. (2014) succeed to define the characteristics of Japan inundated areas using inundated areas map. Moreover, Sato et al., (2014) and Nakaguchi, et al. (2018) successfully analyzed the main topographical components of the frequent flood in a city. The aim of this study is to investigate the topographical inundation characteristics in Tangerang city, then it can be used as additional information for the government to take a policy.

## 2. STUDY AREA AND DATA USED

Tangerang municipality is located at 6º6'-6º13 south latitude and 106º36'-106 º42'east longitude. It has an area of 164.54 square kilometers, and the population is 2,047,105 (official census population, 2015).

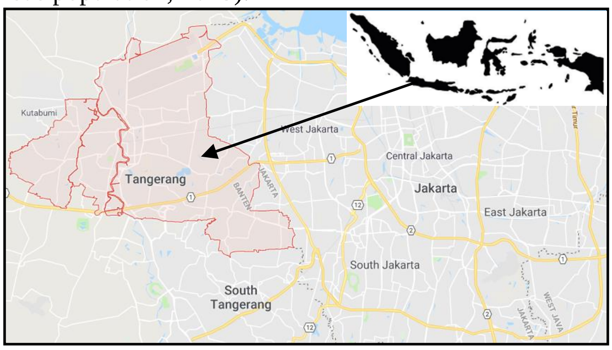


Figure 2.1 Tangerang city map

## 3. METHODOLOGY

### 3.1. Frequent Inland Inundation Area Map

In this study, we used the recorded flood maps from 2008 to 2015. The flood maps have been made by the Tangerang city government to record yearly flood in the city.

To decide "frequent inundation area" and to avoid the biased result due to the dominance of some areas, Nakaguchi, et al. (2018) using comparison between times of inundation and mesh scale, then classified it as an area occurring flood for four or more times and used 100 m mesh scale. Therefore, using the same methodology, this research categorized "frequent inundation areas" in Tangerang as three or more times flooded areas, aligned with 22-inundation-area. In addition, to avoid the biased result due to the dominance of some areas, the mesh size to be extracted is set to 360 m .

### 3.2. Extraction of Topographical Characteristics in Frequent Inundation Areas

In this study, we adopted the same methodology of Sato et al., (2014) to extract the topographical elements of in Tangerang. Table 3.1 explains how we get a set of topographical data.

Table 3.1. Data Creation Method

| No | Element | Unit | Data Set Creation Method |
|---|---|---|---|
| 1 | Elevation | m | Convert inundation area map (from Tangerang Municipality Gov.) to raster data. |
| 2 | Slope | % | Calculate slope of each mesh from (1) |
| 3 | Depth of concave | m | Extract area where the altitude is lower than its surrounding and the countur line is close, then we can get the depth and volume of concave |
| 4 | Capacity of concave | $m^3$ | |
| 5 | Area of watershed | $m^2$ | Create flow direction from data (1) then calculate the area of watershed |
| 6 | Slope of upstream | % | Calculate average of the slope in the upstream watershed |
| 7 | Slope of downstream | % | Calculate average of the slope in the downstream watershed |
| 8 | Different of slope | % | Calculate (6)-(7) |
| 9 | Flow length of upstream | m | Extract and calculate the longest upslope distance along the flow path, from each cell to the top of the drainage divide. |
| 10 | Flow length of downstream | m | Extract and calculate the downslope distance along the flow path, from each cell to a sink or outlet on the edge of the raster. |
| 11 | Different of flow length | m | Calculate (9)-(10) |
| 12 | Distance to river | m | Calculate the shortest distance from each mesh to a river |

### 3.3. Principle Component Analysis (PCA)

Based on 12 topographical elements obtained at 3.2, we evaluated it by PCA to get a set of principal component. Then, to get principal component score, we used following formula.

$$\mathbf{P}_{n(i,j)} = \sum_{m=1}^{12} (\mathbf{a}_{m(i,j)} \cdot \mathbf{l}_m)$$

$\mathbf{P}_{n(i,j)}$ : Principal component score of number n at the mesh (I,J)

$\mathbf{a}_{m(i,j)}$ : Standardized value of m factor at the mesh (I,J)

$\mathbf{l}_m$ : Factor loading of m factor

Furthermore, to examine the similarities rate of topographical characteristics between frequent inundation areas and all area in the city, we got by the coming formula.

Keyword: Inland inundation area, Urban flood, Topographical characteristic, Principal component analysis.
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$$H = \sum_{n=1}^{5}\left(\left|P_{n(i,j)}-\overline{P'_n}\right|\cdot w_n\right)$$

$H_{(i,j)}$ : Indicator which means how similar the topographical characteristics at the mesh (I,J) is

$P_{n(i,j)}$ : Principal component score of number n at the mesh (I,J)

$\overline{P'_n}$ : Average principal component score of number n at frequent inundation area mesh (I,J)

$w_n$ : Contribution ratio of number n

## 4. RESULT

### 4.1. Principal component of frequent inundation areas

Topographical characteristics in frequently flood areas were extracted and analyzed by the principal component analysis. From the calculation we got five principal components which have eigenvalue exceed 1 and 82% of cumulative contribution ratio.

Table 4.1. Principal Component (PC)

| Factor Loading | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 |
|---|---|---|---|---|---|
| Eigen value | 1.75 | 1.66 | 1.23 | 1.14 | 1.09 |
| Contribution ratio | 0.25 | 0.23 | 0.13 | 0.11 | 0.10 |
| Cumulative contribution ratio | 0.25 | 0.48 | 0.61 | 0.72 | 0.82 |
| Elevation | 0.30 | -0.09 | 0.27 | -0.50 | 0.26 |
| Slope | 0.01 | -0.23 | 0.12 | -0.58 | 0.39 |
| Depth of concave | 0.11 | 0.48 | 0.33 | -0.15 | -0.30 |
| Capacity of concave | 0.11 | 0.48 | 0.33 | -0.15 | -0.30 |
| Area of watershed | 0.14 | 0.34 | -0.07 | 0.20 | 0.48 |
| Slope of upstream | 0.37 | -0.30 | 0.30 | 0.33 | -0.03 |
| Slope of downstream | -0.11 | -0.19 | 0.44 | -0.03 | -0.17 |
| Different of Slope | 0.37 | -0.30 | 0.30 | 0.33 | -0.03 |
| Flow length of upstream | -0.40 | 0.16 | 0.19 | 0.20 | 0.29 |
| Flow length of downstream | 0.39 | 0.28 | -0.23 | 0.09 | 0.22 |
| Different of flow length | -0.51 | -0.08 | 0.27 | 0.08 | 0.05 |
| Distance to river | 0.04 | -0.17 | -0.40 | -0.23 | -0.46 |

Regarding the Table 4.1., it can be seen that the first principle component (PC1) has significant value on Flow length of upstream, Flow length of downstream and Different of flow length. In ArcGIS, terminology flow length is to calculate the upstream or downstream distance along the flow path within a basin. Hence, PC1 indicates that inundation area mainly about the length of the flow path. The marked element on PC2 is depth and volume concave, it means concave characteristics is a dominant element on PC2. In PC3, slope of downstream and distance to river are dominant factors for emerging an inundated area. Therefore, we assumed PC3 is about downstream slope and distance from a river. Further, from PC4 we concluded that inundated areas have similarities on elevation and slope condition. Finally, there is no significant component from PC5, it is concluded that PC5 does not have a strong tendency.

### 4.2. Visualization of topographical inundation area vulnerability

Based on principal component score of frequent inundation area mesh and all mesh in the city, we calculated to perceive how similar the topographic among them, it is represented by $H_{(i,j)}$ . In other words, the smaller $H_{(i,j)}$ value of such mesh means that the mesh has high topographical similarities features with frequent inundation areas, and vice versa. To delineate the distribution of $H_{(i,j)}$ value in Tangerang, we present it by Figure 4.1.

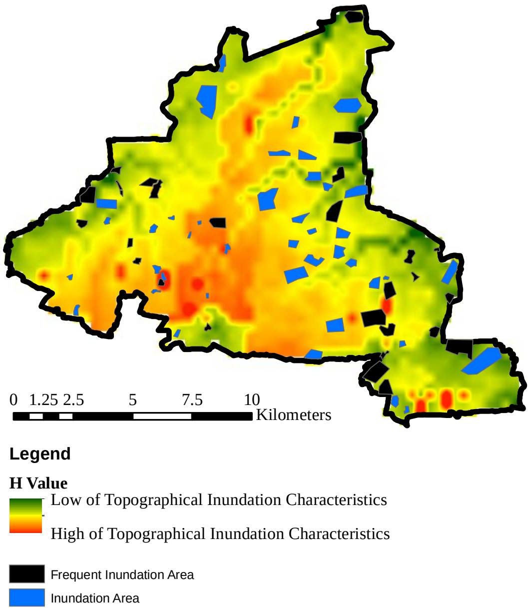


Figure 4.1. Visualization of topographical inland inundation area map

## 5. CONCLUSION

From this research, we get the following conclusion:

a) There are only 57% of the total frequent inundated areas and 63% of inundated areas are located on high topographical inundation area.
b) The map indicates that topographical characteristic alone is not sufficient to explain the emerging of an inundation area.

## ACKNOWLEDGEMENT

In this study, we provided inundation area map, which is the essential material, from Tangerang Municipality Government. In addition, this research was conducted with the support by Professional Human Resources Development-IV-Ministry of National Development Planning Republic of Indonesia and International Post-Graduate Program in Human Security, Tohoku University.

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