Flood Disaster Analysis Using Landsat-8 and SPOT-6 Imagery for Determination of Flooded Areas in Sampang, Madura

B M Sukojo* and F Alfiansyah
Departemen of Geomatics Engineering, Faculty of Civil Engineering and Planning, Sepuluh Nopember Institute of Technology (ITS) Surabaya, Indonesia
bangunms@gmail.com

Abstract. Based on data of disaster which is defaced by Badan Penanggulangan Bencana Daerah (BPBD) of Sampang that in the period of 2015 - 2017 as many as 25 cases from 31 cases of disaster caused by flood disaster or 80.65% from total disaster. Therefore, the purpose of this research is to create a map of flood vulnerability in Sampang. From the vulnerability map, we can know the area with the impacted flood level in Sampang so that from the map of flood affected areas can be known the extent of the affected area in each class. In this study, two Landsat-8 and SPOT 6 data were used. For Landsat-8 imagery used for land cover on district level disaster level vulnerability maps, while high-resolution SPOT-6 images were used for land cover making maps of flood affected areas Sampang district. With the flood affected areas in this study, it is expected to be used as a determinant of flood affected areas in Sampang district.

Based on data processing and analysis it is found that the highest impacted area is located in Sampang district with 12 cases of 17 cases of total flood disaster in Sampang district based on data from BPBD Kabupaten Sampang in 2016. There are 4 classes of flood affected areas in Sampang district i.e. not affected by 9039,540 ha, low impact 46262.881 ha, medium impact 43012.431 ha and high impact of 14009,760 ha.

Keywords: Flood, Landsat-8 Image, SPOT-6 Image, Remote Sensing, Geographic Information System

1. Introduction
Definition of Disaster according to Law Number 24 Year 2007 on Disaster Management mentions the definition of Disaster is an event or series of events that threaten and disrupt the life and livelihood of the community caused by both natural factors and / or non-alam factors or human factors resulting in the occurrence of human lives, Environmental damage, property loss, and psychological impact [1].

In Indonesia there are frequent disasters, one of which is the flood. Flood is an event or condition in which an area or land is inundated due to an increased water volume [2]. In general, floods occur in the rainy season. This is caused by the intensity of rain water is very high and lasted for a long time and the river cannot accommodate again so that the river has increased intensities water debit, consequently river water overflows and impacts on settlements or agricultural areas of citizens.

Sampang Regency is a district with high flood vulnerability. Every year floods occur not only during the rainy season but during high tide. According to the Regional Disaster Management Agency, one of
the flood-prone areas in East Java. Floods that occur can cause harm to the community and local government.

The purpose of this research is to utilize Remote Sensing and Geographic Information System in determining flood vulnerability in Sampang Regency with the method used is scoring and weighting method. With the map of flood prone levels, it can be known areas with high levels of vulnerability. Referring to the disaster data of BPBD Kabupaten Sampang as a booster data, information obtained from the area affected by flood is mostly located in Sampang district. Furthermore, the analysis of flood-affected areas using high-resolution SPOT-6 images, rainfall data, altitude, slope type of soil and river buffer as a determinant variable of flood, expected to obtain the results of detail and accurate impact areas so that it can be used as the basis for determining the region Affected by the flood in Sampang district.

2. Materials and Methods

The location of this research is in Sampang Regency. Astronomically, Sampang District is located between 70 10" - 70 20" South Latitude and 1130 13' - 1130 23 'East Longitude.

2.1. Data Used

The data used in this research such are:

a. Landsat 8 OLI WRS imagery with Surface Reflectance correction date off acquisition 21th August 2016 path/raw 116/65. (Source: https://espa.cr.usgs.gov)
b. SPOT-6 ortho image with spatial resolution 1.5 m, district Sampang (Source: LAPAN)
c. Indonesian Hypsography maps scale 1:25.000 (Source: http://tanahair.indonesia.go.id)
d. Sampang Rainfall data on 2016 (Source: BMKG Karangploso Malang)
e. Soil Type maps Sampang scale 1:100.000 (Source: BPTP Karangploso Malang)
f. Administrative maps of Sampang (Source: Bappeda Kabupaten Sampang)
g. Data Flood Sampang (Source: BPBD Kabupaten Sampang)

1. Equipment used

Equipment used in this research such as:
1. Hardware
   a. GPS Handheld
   b. UAV
   c. Laptop
2. Software
   a. Satellite Imagery Processing Software
   b. Geospatial processing Software
   c. Word and number Processing software

Data Collection Stages: Data used in this research are Landsat 8 OLI WRS imagery with Surface Reflectance correction date off acquisition 21th August 2016 path/raw 116/65 from this data will be made a net design for measurement of GCP point in field and sampling location.

2.2. Stages of Data Processing

2.2.1 High Resolution Satellite Image Processing. High resolution satellite imagery is done by making nets to find the SoF value, then test the accuracy with rectification process using image processing software to know the value of accuracy of image with RMSE requirement of ≤1,5 pixel.

2.2.2 Land Use Classification. Land use obtained from Landsat 8 and SPOT-6 image processing. The classification method used is the Supervised Maximum Likelihood Classification. To test the accuracy of the classification results used matrix confusion.
2.2.3 **Rainfall Data Processing Station.** The rainfall map is obtained from the interpolation of rainfall using the Inverse Distance Weighted Method (IDW) then classified and scored the classification.

2.2.4 **Processing Altitude and Slope.** Tilt Height and slope maps are obtained from the interpolation of contour RBI data and then classified and scored.

2.2.5 **Type of Soil.** From georeferenced soil map was to classify type of soil with digitation, after that score was given from classification data.

2.2.6 **River Buffer.** River Buffer map was obtained from buffer process, after that scoring is given.

2.2.7 **Scoring.** Scoring on each variable in this research, based on some references and previous research, but with many improvements like study area. There are table of scoring for each variable:

| Parameter          | Skor | Weight |
|--------------------|------|--------|
| Slope (%)          |      |        |
| 0-8                | 9    | 0.02   |
| 8-15               | 7    |        |
| 15-25              | 5    |        |
| 25-40              | 3    |        |
| >40                | 1    |        |
| Height (m)         |      |        |
| 0-25               | 0.01 |
| 25-50              |      |
| 50-100             |      |
| 100-150            |      |
| >150               |      |
| Rainfall (mm)      |      |        |
| 51-75              | 0.02 |
| 76-100             |      |
| 101-125, >125      |      |
| Soil Texture       |      |        |
| Very Smooth        | 0.01 |
| Smooth             |      |
| Medium             |      |
| Heavy              |      |
| Very Heavy         |      |
| Rivers Buffer (m)  |      |        |
| 0-50               | 0.02 |
| 50-100             |      |
| 100-150            |      |
| >150               |      |
| Land Use           |      |        |
| Water Area         | 0.02 |
| Fields             |      |
| Residence          |      |
| Vegetation         |      |
| Forest             |      |

Source: Reference and Previous Research

2.2.8 **Weighting and Overlay.** Determine flooded potential, is use that equation (Suhardiman 2010).

\[
K = \sum_{i=1}^{n} W_i X_i
\]

Explanation:
- \( K \) = potential
- \( W_i \) = weight for parameters i
- \( X_i \) = Score Class Parameter i

2.2.9 **Flood Vulnerability Mapping On Distric.** While creating map of flood vulnerability areas, must calculate interval for each class with calculation of total weight with the score of each flood causes variable. Referring to Kingma 1991 in Purnama, 2008, using with the formula

\[
K_i = \frac{X_t - X_r}{K}
\]

Explanation:
- \( K_i \) = Interval Class
- \( X_t \) = maximum value
- \( X_r \) = minimum value
- \( K \) = Number of classs

2.2.10 **Flood Vulnerability Mapping On SubDistric.** From the result of Flood Vulnerability Maps on distric Scale, it can be seen where the region with the highest vulnerability level. Using high
resolution imagery SPOT-6, map can be made map of Flood-Affected Area in high risk areas with data from BPBD Sampang.

2.2.11 Vegetation Indeks Map. Vegetation Indeks Maps made from Normalized Difference Vegetation Index (NDVI) algorithm.

2.2.12 Reflectant Value between Image Data Test. Calculate reflectant value, with correlation test between image, Landsat-8 Imagery and SPOT-6 imagery with ratio of NDVI value on each RGB value image. This is formula for correlation according Sugiyono (2008):

\[
r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n(\sum x^2) - (\sum x)^2][n(\sum y^2) - (\sum y)^2]}}
\]

Where:
- \( r \) = Correlation of variable
- \( x \) = independent variable
- \( y \) = dependent variable
- \( n \) = Number of observation

3. Results

3.1. RMS Error accuration
To calculate RMS Error and SoF value, a net design and GCP distribution was made.

![Figure 1. GCP distribution map SPOT-6 Imagery of Sub-district Sampang](image)

Sof Calculation:
- Number of baseline : 18
- Number of Point : 7
- N_size : Number of baseline x 3 = 54
- N_parameter : Number of point x 3 = 21
- \( u \) = N_size – N_parameter = 33

\[
SOF = \frac{\text{Trace } ([A^T][A])^{-1}}{u} = 0.2242
\]

From the calculation of SoF value is 0.2242. Where the smaller number of network strength factors mentioned above, the better the network configuration [3]. GCP coordinate from measurement converted to point SRGI by using calculation of Least Square Adjustment then that coordinate used for rectification process using image processing software until got
required RMSE <1.5 pixel, that is equal to 1,395 pixels. So, from these results, the image of SPOT-6 is acceptable.

3.2. Classification Accuracy Test

From the result of classification with Supervised classification, obtained accuracy test with confusion matrix at Landsat 8 equal to 74.31%, while in SPOT-6 equal to 87.54%. The accuracy test in medium resolution image is ≥70% while in high resolution image is ≥85%. Thus, from the results of accuracy tests on Landsat 8 and SPOT-6 imagery was acceptable.

3.3. Flood Vulnerability Mapping On District Sampang

The map of the flood vulnerability area in this study refers to research conducted by Primayuda, 2006 obtained from scoring, overlay and weighting of flood variables i.e. slope, altitude, rainfall, soil texture, river buffer and land cover. For the class used there are 4 classes. By using Landsat 8 image as land cover variable, we get the map of flood vulnerability as shown below:

![Flood Vulnerability Map District Sampang](image)

**Figure 2. Flood Vulnerability Maps District Sampang**

| No. | Class                  | Interval Class | Area (ha)       | Area (%) |
|-----|------------------------|----------------|-----------------|----------|
| 1   | Very Low Vulnerability | 2.6 – 4.2      | 9039.540        | 7.39     |
| 2   | Low Vulnerability      | 4.3 – 5.8      | 46262.881       | 37.82    |
| 3   | Medium Vulnerability   | 5.8 – 7.4      | 53012.431       | 43.34    |
| 4   | High Vulnerability     | 7.5 - 9        | 14009.760       | 11.45    |

Table 2. Wide Flood Insectity of Sampang Regency

According to disaster data of BPBD, the highest disaster-affected area is located in Sampang District with disaster data of 12 cases from 17 cases of flood disaster in 2016. In this study, the data is used as a reference to analyse the determination of flood affected areas.
4. Result of Flood Variable on Sampang District

In analysing the flood affected area in Sampang Sub district, 6 parameters of flooding area are determined as below.

4.1. Rainfall Station

Rainfall data used the rainfall station data located in Sampang district in September 2016. From the interpolation results it can be seen that Sampang District has a very high rainfall. Classification and scoring refers to BMKG, 2013 with the results as in the following table:

| No | Class (mm) | Information | Area (ha)   | Area (%) |
|----|------------|-------------|-------------|----------|
| 1  | >125       | Heavy Rain  | 7345.177    | 100      |

4.2. Height and Slope on Sampang District

The height affects the process of flooding. The lower the height of the area the greater the potential for flooding. Classification and scoring on the class height refers to previous research by [7] with the results as in the table below:

| No | Class (m) | Area (ha) | Area (%) |
|----|-----------|-----------|----------|
| 1  | 0 – 25    | 5766.369  | 78.44    |
| 2  | 26 – 50   | 1134.214  | 15.43    |
| 3  | 51 - 75   | 375.701   | 5.11     |
| 4  | 75 - 100  | 69.882    | 0.95     |
| 5  | >100      | 5.577     | 0.08     |

As for the slope class, Sampang district is also dominated by broad flat class of 83.3%. The results of the classification results are shown in the following table:

| No | Class (%) | Information | Area (ha)   | Area (%) |
|----|-----------|-------------|-------------|----------|
| 1  | 0 – 8     | Flat        | 6160.357    | 83.80    |
| 2  | 8 – 15    | Choppy      | 1062.089    | 14.45    |
| 3  | 15 - 25   | Wavy        | 113.278     | 1.54     |
| 4  | 25 - 45   | Hilly       | 14.895      | 0.20     |
| 5  | >45       | Steep       | 1.018       | 0.01     |

4.3. Type of Soil

With the result of classification of soil type map which refers to Primayuda, 2006 hence obtained of soil texture class shown in following table:

| No | Class       | Area (ha) | Area (%) |
|----|-------------|-----------|----------|
| 1  | VerySmooth  | 3393.06   | 46.21    |
| 2  | Smooth      | 1033.32   | 14.07    |
| 3  | Medium      | 382.64    | 5.21     |
| 4  | Heavy       | 1033.32   | 14.07    |
| 5  | Very Heavy  | 802.43    | 10.93    |
4.4. River Buffer

River buffer criteria refer to Government Regulation of the Republic of Indonesia no. 38 Year 2011 About the River where, for the river line flood exposure at least 50 meters from the edge of the river water will be classification refers to Purnama (2006) with the results shown in the following table:

| No | Class (m) | Area (ha) | Area (%) |
|----|-----------|-----------|----------|
| 1  | 0-50      | 559.6570087 | 51.80    |
| 2  | 50-100    | 520.8443293  | 48.20    |

4.5. Land Use

Land Use was derived from the classification result using the Supervised Maximum Likelihood classification method on SPOT-6 high-resolution satellite images. The classification refers to Primayuda, 2006 as the reference shown in the table below:

| No | Class        | Area (ha) | Area (%) |
|----|--------------|-----------|----------|
| 1  | Water        | 74.392    | 1.01     |
| 2  | Ponds        | 550.948   | 7.49     |
| 3  | Rice Field   | 2802.132  | 38.11    |
| 4  | Field        | 1083.555  | 14.74    |
| 5  | Mangrove     | 165.825   | 2.26     |
| 7  | Recidence    | 1543.325  | 20.99    |
| 8  | Meadow       | 38.823    | 0.53     |
| 9  | Garden       | 1029.851  | 14.01    |
| 10 | Prod Forest  | 63.175    | 0.86     |

4.6. Impacted Flood Area Maps of Sampang

Sampang’s Flood Affected Area Maps was Map Sampang flood affected area is obtained from the overlay of variable rainfall, altitude, slope, rainfall, soil texture of river buffer and land cover. Referring to Primayuda, 2006 obtained classification of flood affected areas into 4 classes shown with the image below:

![Figure 3. Sampang Flood Affected map on September 2016](image_url)

From the results of the classification that has been done got the area of each affected area as the following table:
Table 9. Area Classification of Impacted Area of Sampang District Flood

| No. | Class            | Interval Class | Area (ha)  | Area (%) |
|-----|------------------|----------------|------------|----------|
| 1   | Not Affected     | 2.6 – 4.2      | 9039.540   | 7.39     |
| 2   | Low Affected     | 4.3 – 5.8      | 46262.881  | 37.82    |
| 3   | Medium Affected  | 5.8 – 7.4      | 53012.431  | 43.34    |
| 4   | High Risk        | 7.5 - 9        | 14009.760  | 11.45    |

4.7. Vegetation Index Maps
Vegetation Density Map is generated from NDVI algorithm which aims to determine the level of vegetation density. Referring to Regulation of the Minister of Forestry of the Republic of Indonesia No.P.12 / Menhut-II / 2012 resulted classification of NDVI into 5 classes, as shown below:

![Vegetation Index Maps](image)

From the map, Sampang sub-district is dominated by non-vegetated land of 2297.55 ha. This can strengthen the causes of flooding in District Sampang due to lack of vegetated so that the lack of water absorption.

4.8. Reflectant Variable Data Result
In this research, the test of reflectance value with correlation test on image, SPOT-6 image and Landsat -8 image by using ratio of NDVI value on each RGB value of image. The RGB value of the image is defined as the nearest wavelength in the two correlated images. It aims to find out how big the relation of reflectance value in the image data shown with the value of R that produced.

![Reflectance Value](image)

(a)
From Figure 3.4 above shows that the result of correlation of NDVI ratio value in figure (a) gives R^2 value equal to 0.8761 with R equal to 0.6764, figure (b) yields R^2 value equal to 0.8633 with R equal to 0.9289, while in figure (c) with R of 0.7984. Referring to Sugiyono, 2007 for interpretation of Correlation Coefficient (R) in the interval range 0.8 - 1 has a very strong relationship level. So, the strongest correlation result is shown in figure (b) that is correlation of NDVI value between Landsat-8 with SPOT-6 equal to 0.8633. This is because the wavelength of the RGB between SPOT-6 and Landsat-8 has an approximate wavelength.

5. Conclusions
Based on the processing and data analysis that has been done, here are the conclusions that the authors get in the author of this thesis.
1. From the classification result, got 4 class area flood vulnerability level in Sampang Regency that is very low, low, medium and very high.
2. Sampang District is a sub-district that has high flood vulnerability and one of the flood affected areas in accordance with disaster data BPBD Kabupaten Sampang. From the classification of the affected areas, the total area was not affected by 9039.540 ha, the low impact was 46262.881 ha, medium impact 53012.431 ha, and the high impact was 14009.760 ha.
3. From the results of analysis of each parameter in the flood affected areas in Sampang district, it can be seen that the most dominant parameters are rainfall, altitude and slope.
6. Recommendation
The advice given from the results of this research are:
1. Preferably in rectifying high-resolution images using GCP coordinate data obtained from GPS Geodetic, this is done so that the RMSE results are smaller.
2. Need for further research in the form of flood risk modeling in Sampang Regency that can be used to anticipate in flood prevention.

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