Analysis of Debris Flow Kuranji River in Padang City Using Rainfall Data, Remote Sensing and Geographic Information System

Z Umar[1], W A A Wan Mohd Akib[2] and A Ahmad[3]

Faculty of Geoinformation & Real Estate, Universiti Teknologi Malaysia
81310 UTM Johor Bahru, Johor, Malaysia.

Email: zahrul_umar@yahoo.co.id

Abstract. Flash flood is the most common environmental hazard worldwide. This phenomenon is usually occurs due to intense and prolonged rainfall spells on saturated ground. When there is a rapid rise in water levels and high flow-velocities of the stream occur, the channel overflows and the result is a flash flood. Flash floods normally cause a dangerous wall of roaring water carrying rocks, mud and other debris. On Tuesday, July 24, 2012 at 18:00 pm, a flash flood (debris flow) struck Kuranji River whereby 19 urban villages in seven (7) sub-districts in the city of Padang were affected by this flood disaster. The temporary loss estimated is 40 Billion US Dollar reported by the West Sumatra Provincial Government due to many damages of the built environment infrastructures. This include damaged houses of 878 units, mosque 15 units, irrigation damaged 12 units, bridges 6 units, schools 2 units and health posts 1 unit. Generally, widely used methods for making a landslide study are Geographic Information System (GIS) and Remote Sensing techniques. The landslide information extracted from remotely sensed products is mainly related to morphology, vegetation and hydrologic conditions of a slope. While GIS is used to create a database, data management, data display and to analyze data such as thematic maps of land use/land cover, normalized difference vegetation index (NDVI), rainfall data and soil texture. This paper highlights the analysis of the condition of the Watershed Kuranji River experiencing flash floods, using remote sensing satellite image of Landsat ETM 7 in 2009 and 2012 and Geographic Information System (GIS). Furthermore, the data was analyzed to determine whether this flash flood occurred due to extreme rain or collapse of existing natural dams in the upstream of the Kuranji River.

1. Introduction

Landslide is one of the most costly and damaging natural geohazard of the world and has direct and indirect influence on a number of human activities. The terms landslide includes a wide range of mass movement, such as rock falls, deep failure of slopes and shallow debris flows on slopes due to gravity. Landslide may be huge or small and its movement from low to high speed. Also known as mud flows, debris flows, earth failures, slope failures, etc. They can be triggered by heavy rainfall, floods, earthquakes, and other natural causes as well as human-made causes, such as grading, terrain cutting and filling, excessive development, etc.

Flash floods (debris flows) had struck the Kuranji River on Tuesday, July 24, 2012 at 18:00 pm. The area affected by this flood disaster comprising of 19 urban villages in 7 Sub districts in the city of Padang. Temporary loss estimated 40 Billion US Dollar reported by the

West Sumatra Provincial Government with the details of damaged houses of 878 units, mosque 15 units, irrigation 12 units, bridges 6 units, schools 2 units, and health posts damaged 1 unit (Figure 1). Irrigation network damage affected an average of ± 3000 hectares which eventually disrupt the food security of Padang. The aims of this paper to determine the cause of the flash floods that occurred in Kuranji River in Padang city on Tuesday, July 24, 2012 at 18:00 pm.

Figure 1. Image infrastructures by Debris flows.

2. Location

Kuranji River is located in Padang city where it is the largest city on the west coast island of Sumatra as well as the capital of West Sumatra province, Padang city has an area of 694.96 km² with a hilly geography form a height reaches 1853 m from mean sea level. Located between 0 ° 57 '2.76 ″ LS and100 ° 21' 41.64 ″ BT. More than 60% of the city of Padang (± 434.63 km²) is an area of hills covered by protected forest, while the rest is effective urban areas, the population based on the census of 2010 as many as 833,562 people. Temperature during the day is between 23-32 ° C and 22-28 ° C at night, with moisture 78-81%. Precipitation levels reached an average of 405.58 mm per month with an average of 17 days of rain days per month.

3. Literature Review

Flash floods (debris flow) is the mass flow of sediment (sand, gravel, rock and water) in a single unit with a high speed. The flow is due to the balance between the static shear forces caused greater than withstand shear forces, and because of this mass flow acceleration has the height and speed will always increase. At some extent because local condition the ramp slope, the reduced mass of water, the changing character of sediment and other flood flow is speed will slow down, the amount of mass to be reduced and eventually a mass will be deposited [1].

3.1. Remote Sensing

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data obtained with a device without any direct contact with the object, area, or phenomenon under study [2]. Remote sensing data are recordings of the interaction between electromagnetic energy with the object recorded by a sensor or sensing devices such as cameras, and scanning, radiometric each equipped with a detector in it. Remote sensing data can be either digital data and visual data. The data consists of visual images and non-image. Image data in the form of images that resemble the original form or in the form of an overview planimetric, non-image data was generally in the form of lines or graph.

By using remote sensing data Landsat 7 ETM satellite image of 2009 and Landsat 7 ETM of 2012, these data are compared. It will show the changes in land use/land cover and NDVI in Kuranji River watershed. Where land use is related to human activities in the field of land in a watershed, while the land cover associated with the appearance on the surface of the earth [2]. The NDVI is an index that reflects vegetation cover on the Earth's surface [3].

3.2. Georaphic Information System (GIS)

Geographic Information System (GIS) is a computer-based system that is used to store and manipulate a variety of geographic information. GIS is designed to collect, store and analyze the various objects and phenomena where geographic location is an important characteristic or critical analysis [4]. In GIS there are two kinds of data, spatial data and attribute data. Spatial data is data about geographic objects or elements that can be identified and have reference to the location specified by the coordinate system. Data is data in the form of graphic images in the computer. Map is in a computer graphics data. Based on the data structure, it can be in the form of vector and raster data. Vector data is data that is expressed in terms of coordinates (x, y). Vector data in a map form of points, lines, and polygons.

3.3. Runoff

The rainfall fell in an area causes runoff (surface runoff) and in part into the soil or called infiltration. Runoff is a major contributor to the production of components of the water in the event of flooding. According to[5], surface runoff occurs when rainfall intensity exceeds the infiltration capacity of the soil, while the flood is one form of extreme runoff where river water level or river water yield (discharge) exceeds the capacity of the river. Flood and drought is a natural phenomenon in which watershed system cannot absorb, store, and distribute optimal changes in input (rainfall), causing an increase in peak discharge and shorten the time to the peak discharge (flood). The impact of subsequent incremental backup is ground water during the rainy season to be reduced the supply of water in the dry season production (drought). Rainfall data used in this study was obtained from the several post rainy station such as Batu Busuk, Gunung Nago and Ladang Padi. These locations are in the watershed of Kuranji River.

4. Methodology

4.1. Calculating floood discharge based on rain data

In determining the cause of the flood, it is one way to estimate the discharge. A commonly used method is the rational method. This method is very simple, easy to use and popular among other empirical formulas as follows:

$$Q = 0.278\ C\ I\ A$$

where
Q = the discharge in m^3/sec.
C = the runoff coefficient ($0 \leq C \leq 1$).
I = the rainfall intensity in mm/hour
A = the area of watershed (km^2).

The coefficient C is defined as the ratio between the intensity of the rainfall runoff. This factor is the most crucial variable in the calculation of flood discharge. The main factors that affect the coefficient C is the infiltration rate, slope of the land, crops cover, rainfall intensity, nature and condition of soil, ground water, the degree of soil density, soil porosity. Infiltration rate is reduced by rain for a long time and is also affected by the rain before.

4.2. Image data used in this study is Landsat

Seven (7) ETM image with 7 band (Band 1, 2, 3, 4, 5, 7, and 8). Band 6 is not used because it is a special band for thermal. Landsat imagery used is level 1, the system corrected (1G). According to [6], this class has been corrected radiometric, geometric and free of distortion.The texture of the soil in the study area based on geomorphological map sheet Padang Sumatra is a sandy loam (Sandy clay).

4.3. Water bodies

To distinguish between bodies of water and land in the Landsat-7 satellite imagery, it can be done using ArcGIS 10 software by comparing the band 2 and band 5. If band 2/band 5> 1 then the object is water body (black), and if band 2/band 5 <1 then the object is land other than a body of water (white color), [7,8].

5. Results

The results of the level of greenness of vegetation indicate that there has been a decrease in the level of greenness in Kuranji River basin. It is presented with impairment of quality NDVI moderate in 2009 of 92.55 km² (Figure 2) to 73.68 km² in 2012 (Figure 3). Decrease in NDVI values show that the vegetation in the watershed Kuranji River suffered a significant reduction.

Figure 2. NDVI in year 2009

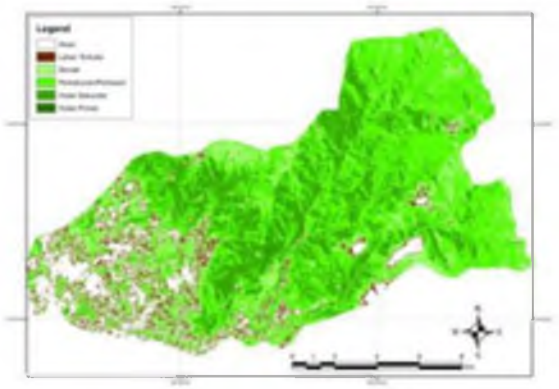

Figure 3 NDVI in year 2012.

The results also showed that many puddles that occured in the Kuranji River. In 2009, a water body covering an area of 14 km², and in 2012, it increases to 20 km². This water body may be standing water in the fields and can also be reservoir formed naturally. Because the location of inundation are very far in the upstream of the Kuranji River, there is possibility of formation of very large natural reservoirs. Figure 4 and 5 show the water bodies in 2009 and 2012 respectively.

The results of the calculation of flood discharge by rainfall obtained a debit of 319.37 m³/sec, while the weir discharge flowing in Weir Gunung Nago during flood event amounted to 1045 m³/sec, so there is a difference of 725.63 m³/sec. So the discharge is most likely derived from a pool of natural reservoir dam collapse. This is one cause of flood water murky brownish colored and carrying silt.

Figure 4. Water Bodies in 2009.

Figure 5. Water bodies in 2012.

Results of land use/land cover showed that a broad decline in secondary forests of 67.88 km² in 2009 to 46.27 km² in 2012, primary forest from 1.28 km² to 0.22 km² in 2012 and increased garden of 62.98 km² to 82.55 km² and shrubs of 29.69 km ² to 39.54 km ² with less forest become gardens and shrub resulting in increased flow coefficient (C) and further increase of flood discharge.

6. Conclusion

Based on the above results it can be concluded that the factors causing flash flooding are establishment of a natural dam which caused inundation in the upstream of Kuranji River and the collapse of a natural dam that cannot be able to withstand water flow caused by rain dated of July 24, 2012.

The definition of physical activity is the construction of infrastructure and other measures in order to prevent damage/disaster caused by the destructive force of water, while the non-physical activity is an activity of the preparation and/or application software that includes among others, the setting, coaching, supervision, and controls. Physical activity and/or non-physical implemented include:

- Sabo dam construction (Check Dam); Groundsill; Dam Consolidation, Normalization and canalization of rivers and hill slope work
- Integrated forest management by not doing illegal logging or reduce the conversion of forest lands, and protect and conserve vegetation in accordance with the carrying capacity of the environment.
- Control and implementation of spatial planning needs to be done because land is used for settlement. These efforts need to be supported by monitoring and sustainable evaluation system. Monitoring the right to know the initial indication any misuse or misappropriation of land allotment in flood-prone locations.
- Watershed management by conducting reforestation and afforestation on degraded/barren land and apply engineering-soil and water conservation techniques.

Acknowledgements

The authors wish to thank Faculty of Geoinformation & Real Estate, Universiti Teknologi Malaysia for the support of this study. The authors also wish to thank Ministry of Education, Malaysia for the financial support through the Research University Grant Q.J130000.2527.03H68.

References

[1] Maryono A 2005 Dealing with floods, drought and environmental. Gajah Mada University Press
[2] Lillesand T M and Keifer R W 1999 Remote sensing and image interpretation Wiley New York
[3] Jensen J R 2007 Remote sensing of the environment an earth resources perspective Prentice hall 2nd ed.
[4] Aronoff S 1984 Geographic Information System: A Management perspective WDL Publications Ottawa Canada.
[5] Horton R E 1940 An Approach toward a Physical Interpretation of Infiltration Capacity
[6] Prahasta E 2008 Remote sensing: Practical Remote Sensing And Digital Image Processing Software With ER Mapper, Informatika Bandung.
[7] Smith R B 2006 Remote Sensing of Environment.
[8] Alesheikh A A 2007 Coastline Change Detection Using Remote Sensing