

USING REMOTE SENSING MULTI-TEMPORAL IMAGE TO ANALYSE THE LAND USE CHANGES AND ITS IMPACT ON THE PEAK DISCHARGE IN GARANG WATERSHED CENTRAL JAVA

Ahmad Cahyadi (ahya.edelweis@gmail.com)

Program On BEASISWA UNGGULAN BPKLN KEMDIKBUD RI, Master Program On Planning and Management for Coastal Area and Watershed, UGM Yogyakarta

Henky Nugraha

Emilya Nurjani

Department of Environmental Geography, Faculty of Geography, UGM Yogyakarta

Ardila Yananto

Muhammad Sufwandika Wijaya

Department of Cartography and Remote Sensing, Faculty of Geography, UGM Yogyakarta

ABSTRACT

Change due to land use in the city of Semarang as an impact of population growth and economic activity has led to urban sprawl. Rob flooding, land subsidence, seawater intrusion and contamination of ground water in the northern part of Semarang lead to the development of the southern part. Consequently, this leads to changes in land use so that the amount of rain water runoff will increase. This may cause the danger of flash floods in the greater city of Semarang. This study were aimed to: (1) determine the changes that occur in the Garang watershed lands during 1994 and 2001, and (2) determine the impact of land use changes on the size of the peak discharge occurring in the Garang watershed. The data used in this study were the 1994 Landsat TM, Landsat ETM 2001, and Citra Alos AVNIR 2008, Garang watershed soil map, slope map of Garang watershed stream network, and daily rainfall data at Ungaran Station of 1952 until 2009. It was found that developed land has been increasing more than doubled from 2001 to 2008, agricultural land increased by nearly 50% and the forest area were decreased from year to year. However, the peak discharge at the Garang watershed has not increased to the extreme though there was a slight change.

Keywords: land use change, peak discharge, urban sprawl

ABSTRAK

Perubahan penggunaan lahan di Kota Semarang akibat pertumbuhan penduduk dan aktivitas ekonomi telah menyebabkan terjadinya urban sprawl. Banjir rob, land subsidence, intrusi air laut dan tercemarnya air tanah di Kota Semarang Bagian Utara menyebabkan terjadinya perkembangan Kota Semarang dominan ke arah selatan. Hal ini menyebabkan perubahan penggunaan lahan dari lahan non terbangun menjadi lahan terbangun sehingga jumlah air hujan yang langsung menjadi limpasan akan semakin banyak. Hal ini akan menyebabkan bahaya banjir bandang di Kota Semarang semakin besar. Penelitian ini bertujuan untuk: (1) mengetahui perubahan lahan yang terjadi di DAS Garang selama tahun

1994 dan 2001, dan (2) mengetahui dampak perubahan penggunaan lahan terhadap besarnya debit puncak yang terjadi di DAS Garang. Data yang digunakan dalam penelitian ini adalah Citra Landsat TM tahun 1994, Citra Landsat ETM tahun 2001, dan Citra Alos AVNIR 2008, peta tanah DAS Garang, peta kemiringan lereng DAS Garang, peta jaringan sungai DAS Garang, dan data curah hujan harian Stasiun Ungaran tahun 1952 sampai dengan tahun 2009. Ditemukan bahwa luas lahan terbangun bertambah lebih dari dua kali lipat dari tahun 2001 sampai dengan 2008, lahan pertanian meningkat hampir 50% dan luas hutan mengalami penurunan dari tahun ke tahun. Namun demikian, debit puncak di DAS Garang tidak bertambah secara ekstrem meskipun mengalami sedikit perubahan.

Kata kunci: debit puncak, perubahan penggunaan lahan, urban sprawl

Population growth and development of economic activity in Semarang Cities and surrounding areas has led to urban sprawl. Coastal flooding that often occurs and land subsidence in the northern part of Semarang has led to the development of Semarang city dominant to the southern parts. It is also associated with the presence of a good source of groundwater in the Southern, while in the northern part of Semarang many are not feasible due to consumption of contaminated or becomes salty (seawater intrusion).

The development in the southern part needs to get serious attention because it is upstream of the rivers that flow across the city, including Garang River. Changes in land use from unbuilt-up area to built-up area can disrupt the hydrological cycle. The more runoff so that the danger of flash floods will increase. Windarto (2010) mentions that the date January 25, 1990 recorded more than 45 people died and economic losses reached 8.5 billion dollars. Therefore, it would require an analysis of land use change and its impact on the Garang Watershed with peak discharge were strongly associated with the danger of flash floods in the city of Semarang.

The area of this study is Garang watershed, Central Java. Garang watershed is the watershed that encompasses two regency i.e Semarang Regency and Semarang Municipality. Tributary contained in the river basins are Kreo River, Garang River and Kripik River. Garang watershed has a total area of about 220 km².

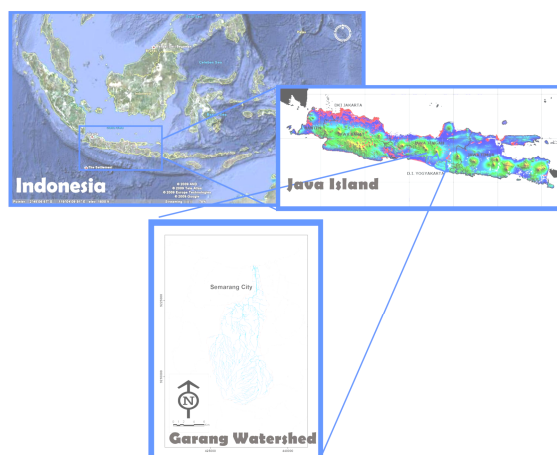


Figure 1. The study area, the Garang watershed

RESEARCH METHOD

Land use Classifications

Classifications were performed for temporal data, Landsat TM 1994, Landsat ETM 2001, and ALOS AVNIR 2008. Classifications were done by using ENVI 4.5 software. This process was done by performing spectral classification based on the value of each land use.

Determination of Peak Discharge

Peak discharge was determined using the Rational Formula. The amount of flow is proportional to the runoff coefficient (C), proportional to the rainfall intensity (I) and drainage area (A), (Chow, 1964 in Gunawan, 1991). Thus, by the rational method peak discharge expressed as:

$$Q = 0,278.C.I.A \quad (1)$$

where :

Q : Peak Discharge (m³/s), C : Runoff Coefficient
I : Rainfall Intensity (mm/hr) A : Drainage area (km²)

Determination of Runoff Coefficient

Table 1. Runoff Coefficients Classification

Watershed characteristics are taken into consideration	Characteristics that can produce a flow			
	100% (Extreme)	75% (High)	50% (Normal)	25% (Low)
Slope using 3d analyst (W)	Slope >30% (40)	Slope 10-30% (30)	Slope 5-10% (20)	Slope 0-5% (10)
Infiltration (W), derived from image interpretation and map soil	There is no effective ground cover, a thin layer of soil, infiltration capacity is ignored (20)	Slow to absorb water, the material clay / soil with low infiltration capacity (15)	Clay in the soil infiltration type with prairie (10)	The sand or other soil can absorb water quickly (5)
Land cover, with Multi Spectral Classification approach	There is no effective cover or the like (20)	Little to moderate cover crops, no crops and natural cover slightly (15)	Approximately 50% of watershed covered by both trees and grasses (10)	Approximately 90% of watershed covered either by wood or the like (5)
Drainage density (W), by comparing the channel length with an area of watershed	>8 km/km ² (20)	3,2 -8 km/km ² (15)	1,6 – 3,2 km/km ² (10)	< 1,6 km/km ² (5)

Sources: Cook Methods in Gunawan, 1991 with modifications

Runoff coefficient (C) was determined by using a data from soil map (infiltration), slope, land use resulting from the spectral classification process of land use and river network map to determine the value of drainage density. Data analysis was done by using Weight Score of the pixel values that have been reclassified. Scoring can be seen in Table 1.

Determination of Return Period

Rainfall intensity calculations performed with the Mononobe formula (Hadisusanto, 2011) with the following formula:

$$I = (R_{24}/24) \times (24/T_c)^{2/3} \quad (2)$$

where :

- I = rainfall intensity (mm/hr)
- T_c = time of concentration (hours)
- R₂₄ = daily rainfall or rain during 24 hours (mm)

T_c values can be determined using Kirpich's formula (in Hadisusanto, 2011) as follows:

$$T_c = 0,01947 L^{0,77} S^{-0,385} \quad (3)$$

where :

- T_c = time of concentration (hours)
- L = channel length (m)
- S = slope of the watershed, $S = \Delta H/L$
- ΔH = different elevation between the highest in the upper part and the lowest elevation in the outlet (m)

R₂₄ obtained from Ungaran Raingauge Station 1952-2008. The value of R₂₄ for each year sorted then determined when repeated using Weibull method (Hadisusanto, 2011). This is the formula used to determine return period.

$$Return\ Period = ((n+1)/m) \quad (4)$$

where :

- n = Number of data used
- m = The sequence number in ascending order of R₂₄

RESULTS AND ANALISYS

Land Use Changes in Garang watershed

The results of analysis of land use changes show that built up area, ponds and fishponds and agricultural lands are increasing, while the extent of forests and mixed gardens are decraising. Added fishponds and ponds a lot happening in the lower reaches where the deposition process occurs. Development of built up area are situated in the Northern and Southern of Semarang City, while many developing agricultural land in the South to shift the existence of forests and mixed gardens.

THE LAND USE MAP OF THE GARANG WATERSHED IN 1994 THE LAND USE MAP OF THE GARANG WATERSHED IN 2001 THE LAND USE MAP OF THE GARANG WATERSHED IN 2008

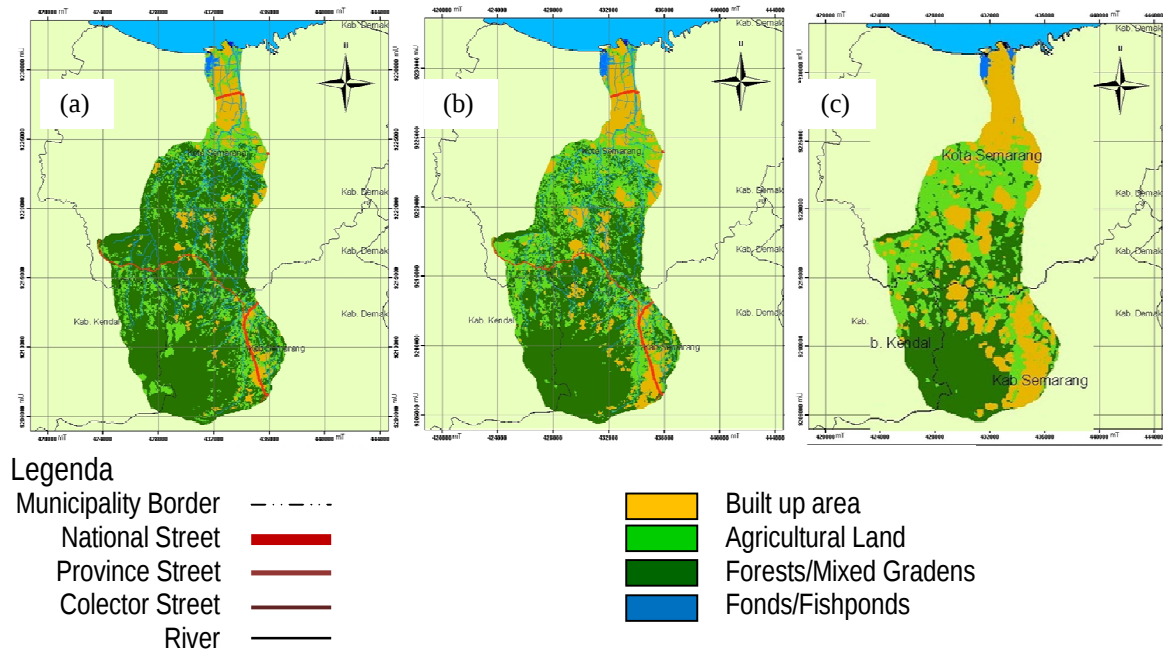


Figure 2. The land use map of the Garang watershed in (a) 1994 (b) 2001 and (c) 2008

Table 2. Land Use Area in Garang Watershed

Land use	Area (km ²)		
	1994	2001	2008
Built up area	20,6	34,0	48,8
Agricultural Land	49,9	67,4	69,3
Forests/Mixed Gardens	134,3	103,0	85,8
Ponds/Fishponds	0,8	1,1	1,6
TOTAL	205,6	205,6	205,6

The results analysis of runoff coefficient shows that although rapid changes in land use with major changes, the runoff coefficient tends to increase along with the existing land cover changes. Runoff coefficient values in a row from 1994, 2001, 2008, were 0.6068; 0.6256; and 0.6376. Based on these results, it can be seen in the time span of 7 years, the average runoff coefficient increased approximately by 1%. However, the runoff coefficient of 4 years has been relatively high, where more than 60% of rainfall that fell in Garang watershed will become runoff that could cause flooding.

Peak Discharge Changes in Garang Watershed

The highest elevation in the upper part is 2037.5 meters above seawater level. So the height difference (ΔH) the highest elevation on the watershed with lowest elevation is 2037.5 5 meters a.s.l. (outlet located at 0 5 meters a.s.l.). The length of the main river is 77.05 km. This means that the slope of the watershed is 2.64% or 0.0264. Time of concentration (T_c) in Garang watershed is 2.24 hours. Table 3 present the results of rainfall intensity (I) calculation for several return period.

Table 3. The Rainfall Intensity in Garang Watershed for Several Return Period

Return Period (years)	Rainfall Intensity R_{24} (mm/ hr)	T_c (hours)	I (mm/ hr)
1	16.5	2.24	26.5
2	20.2	2.24	32.2
5	24.9	2.24	39.9
10	28.6	2.24	45.7
15	30.7	2.24	49.1
20	32.2	2.24	51.5
25	33.3	2.24	53.3
50	37.0	2.24	59.1
100	40.6	2.24	64.9

The results of peak discharge analysis shows that increases in peak discharges in Garang watershed due to land use changes is not too high. Nevertheless, there is a tendency to continue to rise from 1994 to 2008. Therefore, issues of land use change should still be an issue that has to be concerned seriously.

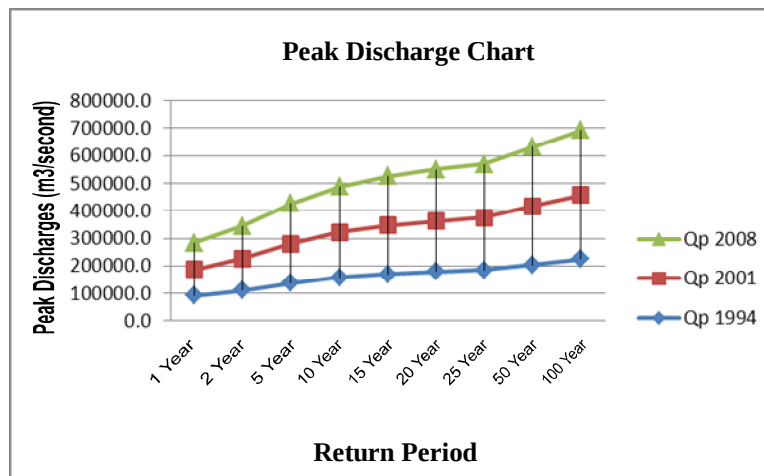


Figure 3. The peak discharge in Garang watershed for several return period

Table 4. The Peak Discharge in Garang Watershed With Several Return Period

Return Period (year)	Qp 1994 (m ³ /s)	Qp 2001 (m ³ /s)	Qp 2008 (m ³ /s)
1	919,9	948,4	966,5
2	1117,7	1152,3	1174,4
5	1385,0	1427,9	1455,3
10	1586,3	1635,5	1666,8
15	1704,3	1757,1	1790,8
20	1787,6	1843,0	1878,4
25	1850,1	1907,4	1944,0
50	2051,4	2115,0	2155,6
100	2252,8	2322,6	2367,1

CONCLUSION

From the results of the analysis, it can be conclude that in Garang watershed built up area increased more than doubled from 2001 to 2008, agricultural land rose nearly 50% and the forest has decreased from year to year. Peak discharge shows that the increase in peak discharge in Garang watershed due to land use changes is not too high. Nevertheless, there is a tendency to continue to rise from 1994 to 2008. Therefore, issues of land use change should still be an issue that has to be concerned seriously.

REFERENCES

- Windarto, J. , (2010). "Flood early warning system develop at garang river Semarang using information technology base on SMS and Web". *International Journal Of Geomatics And Geosciences*, 1 (1).
- Hadisusanto, N. (2011). *Aplikasi hidrologi*. Yogyakarta: Jogja Media Utama.
- Gunawan, T. (1991). *Penerapan teknik pengindraan jauh untuk menduga debit puncak menggunakan karakteristik lingkungan fisik DAS*. Bogor: Institut Pertanian Bogor.