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LAND COVER CHANGES STUDY OF UPSTREAM COKROYASAN WATERSHED ON MAXIMUM RETENTION

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Abstract

This research takes location on upstream of Cokroyasan watershed, especially on Bandung weir catchment on Purworejo and Wonosobo District. Research objective is knowing maximum retention changes which represented by upstream Cokroyasan watershed curve number, related to land cover data series, soil type, rain, and peak flow (Qp). Research data quality controlled with data survey and overland flow data observed. Thus the relationship of particular land cover and watershed responses in generating peak flow can be determined.
The land covers determine using multispectral classification of Landsat which detailed with manual interpretation and Google Earth image. Sampling selection defines by stratified random sampling technique of the smallest unit of land form. Effective rain determines by consistency test of rainfall data, frequency analysis, survey data and curve number composites. The effective rainfall generate using SCS model (Soil Conservation Service) which influenced by design rainfall, soil type, texture, and land cover.
The results showed that within 15 years, the land cover of Bandung weir catchment change significantly. Especially plantation was reduced by 56% or 40.76 km^2 while the settlements increased 412% to 64.20 Km^2, and other land cover changes not significant (2% <). The analysis showed the peak flow in the upstream of Cokroyasan watershed changes on different return period. Although the different can only see on a more than two years return period. This means there was an increase of peak flow (discharge), as a result of maximum retention DAS dropped from 16- 18.29 m^3/ s.
The conclusion of this research indicate that land cover changes that occur within 15 years, influence on Curve Number changes, maximum retention, effective precipitation, and peak flow of upstream Cokroyasan watershed.

Kata kunci: Penutup Lahan, Retensi Maksimum, SCS.

Abstrak

Penelitian ini dilaksanakan pada tahun 2016, dan berlokasi pada DAS Cokroyasan bagian hulu, atau pada hulu Bendung Bandung yang terletak pada sebagian Kab. Purworejo dan Wonosobo. Tujuan dari penelitian ini adalah untuk mengetahui perubahan retensi maksimum yang direpresentasikan dalam bentuk *Curve Number* dari DAS Cokroyasan bagian hulu terhadap data temporal tutupan lahan, jenis tanah, hujan, dan debit maksimum (Qp). Kualitas data penelitian dikontrol melalui data survey dan pengamatan debit terukur. Dengan demikian hubungan jenis-jenis penutupan lahan tertentu, dan respon DAS dalam menghasilkan debit aliran puncak dapat diketahui.
Metode yang digunakan dalam menentukan jenis tutupan lahan adalah dengan klasifikasi multispectral dan didetailkan dengan interpretasi manual pada citra Landsat dan citra google *earth*. Penentuan sampel menggunakan teknik *stratified random sampling* dengan ukuran kajian terkecil satuan lahan (Pendekatan Bentuk Lahan). Penentuan hujan efektif dengan menggunakan analisis kepanggahan data hujan, analisis frekuensi, hasil survey dan

penentuan CN komposit. Besar kecil hujan efektif ditentukan dengan model SCS (*Soil Conservation Service)* yang dipengaruhi oleh besar hujan rancangan, jenis tanah, tekstur, dan jenis tutupan lahan.

Hasil penelitian menunjukkan bahwa dalam kurun waktu 15 tahun daerah tangkapan Bendung Bandung mengalami perubahan penutup lahan secara signifikan, khususnya perkebunan berkurang sebesar 56 % atau 40,76 Km^2 sedangkan permukiman bertambah 412 % menjadi 64,20 Km^2, dan jenis penutup lahan lain berubah secara tidak signifikan (2 %<). Analisis menunjukan adanya perubahan debit maksimum pada DAS Cokroyasan hulu untuk berbagai kala ulang, meskipun perubahan hanya bisa dilihat pada kala ulang lebih dari 2 tahun. Hal ini artinya terjadi peningkatan debit banjir maksimum, akibat dari kemampuan penyimpanan air DAS turun 16-18,29 m^3/dt.

Kesimpulan dari penelitian ini menunjukkan bahwa perubahan penutup lahan yang terjadi dalam kurun 15 tahun berpengaruh pada perubahan *Curve Number*, retensi maksimum, hujan efektif, dan banjir maksimal di DAS Cokroyasan Hulu.

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1. INTRODUCTION

Water resources is a basic need such as drink, bath, wash, and health porpuse (especially sanitation). At a broader level, water resource need is increasingly and rather complex following the development needs, such as irrigation, river flushing, industrial, and energy. Water resource is very useful on a proportionate but when the amount is less or excess, it will cause a serious problem. Watershed as a system is an objects/stream collection that become subsystems, including interaction within. Watershed is a land total and surface water delimited by a water boundary (topography) and in a way to contribute to river flow at a certain cross-section (Seyhan, 1990).

The amount of rain falls on a watershed affects the effective rain/precipitation. Spatio-temporal distribution of rainfall in the watershed is the main input into the runoff configuration, further influenced by topography, slope, geology, and land cover.

Topography aspects, geology, and land cover became an indicator of watershed response to converse rainfall into evaporate, surface water/ run off, shallow water, groundwater, and evapotranspiration. On this process, land cover function impact directly on watershed ability of retaining water, and turn it into runoff.

Cokroyasan watershed as one of the "conservation space" in Central Java, has been the catchment areas and provide of water resources for the region within, such as Purworejo, Magelang, and Wonosobo district

However, in line with population growth and the upstream land cover change, the balance between groundwater and runoff began to fail. These condition triggering greater runoff and became a flood in the downstream. Since 1998, on Cokroyasan watershed almost all of the water needs can be met during the rainy season. But lack of water in the dry season. (Triatmodjo, 1998).

The research objectives are :

- To determine the relation of certain types of land cover, and the response to run off.
- To determine the maximum retention of upstream Cokroyasan watershed, through the Curve Number compiled by land cover approach, rainfall and measured discharge as a control.

2. METHODS

The research limitation are :

- Research location spatially focused on the catchment of Bendung Bandung (Cokroyasan upstream). Associated with calibration flood analysis using the measured flow through AWLR
- The land cover data length, rainfall and discharge data series are on 1995-2015.
- The time lapse is annual land cover, because land cover changes is inherently slow.
- The type of soil, and the texture is not temporarily generated because soil development is very slow.

Number and samples location selection using stratified random sampling method (Ebdon, 1985) with the smallest unit use is land form. Based on the amount of land forms, and uniformity of land cover, the chosen sample to soil texture, soil type, and land cover identification take 25 location.

Land cover data series obtained by multispectral classification to distinguish the variety of land cover through channel spectral response of object (Danoedoro, 1996) and be detailed with manual interpretation of Landsat and google earth image.

Rainfall data station which used are Jrakah stations (1 & 2), Kedungputri, Sawangan, Banyuurip, BPSDA Kutoarjo and BPSDA. While discharge data using a AWLR station of Bandung weir. Double mass curve method are use to rainfall data consistency test. (Triatmodjo, 2009). The results test showed quality data correlation of station is very high, with an average of 0.99.

In calculating the maximum discharge requires Pe (effective rainfall) or excess amount of rain which flow directly into the river. SCS method use to calculate the effective rainfall, which is calculated by comparing the rain depth (P) and; S as the max potential retention groundwater largely due to infiltration (mm) (Triatmodjo, 2009).

The maximum potential retention is calculated by CN. Curve number is a function of watershed characteristics. CN value for different types of land cover either impermiable or not to the different types of soil texture. (US SCS 1972 Asdak, 2004)

The soil type divided into four hydrologic soil group:

- Soil Type A: low runoff potential, high infiltration. Soil texture is sand (deep) with silty and very small amount clay, also gravel.
- Soil Type B: runoff potential is rather low, moderate infiltration rate. Medium texture (sandy soil).
- Soil Type C: runoff potential is rather high, slow infiltration rate if the land is completely wet. Medium to fine texture (clay and colloids).
- Soil Type D: high runoff potential, infiltration is a very slow. texture clay (clay) with degree of soil shrinkage (swelling) high, land with permanent high level groundwater level, a layer of clay with water-resistant material. (Triatmodjo, 2009).

Flood characteristics analysis were calculated using synthetic hydrograph SCS model, with dimensionless hydrograph. SCS model chosen because it has a better accuracy than other models such as rational model. (Murtiono, 2008) also provide land cover and soil texture approach.

Hydrograph characteristic comprises time lag (TL), which is calculated from the Ct: time coefficient; L: length of the river (km). Then, Peak Time (Tp) is calculated by Tr: Rain Duration (h) and cross-sectional area of the watershed. While Qp or peak discharge hydrograph unit (m^3/s); R calculated as precipitation unit (1 mm); Tp, A, and also Time Base (Tb). (Dantje 2011 and the US Army, 2000).

3. RESULTS AND DISCUSSION

Landforms Interpretation show that in the Cokroyasan watershed there are several fluvial, volcanic and marine landform which can be described as follows:

- Alluvium : generally in alluvial form and flood plains
- Coastal Deposit : a young beach shoals form, old shoals beach, lagoon and swale
- Peniron Formation : alluvial plain form, fault scarp, foothills slopes, middle slope of denudational hill, natural levee, and river terrace
- Sentolo Formation: an isolated hill
- Volcanic Landform: upper slope of denudation hill, foot slope of the volcano.

Based on land form, soil sample taken in numerous position of Cokroyasan watershed. The survey shows some of soil types found in the research area among other associations gray alluvial, humic gley associations, associations latosol, reddish brown, yellow red latosol complex, konsosiation alluvial hidromorf, konsosiation regosol brown and gray regosol konsosiation. Soil type is related with soil texture which can be transfor into hidrologyc coil type.

Field survey also take land cover sample, which is used to acuration test of multispectral classification and visual interpretation. By comparing the results of 2000-2015 land cover data in the upstream Cokroyasan watershed (Bandung weir) can be seen on following table.

Table 1. Land Cover Changes 2000-2015 Data On upstream Cokroyasan watershed (Bandung weir)

Land Cover	Year 2000 (Km^2)	Year 2015 (Km^2)	Changes (%)
Agriculture/ Field	18,50	19,65	1,15
Water Body	1,00	0,73	(0,28)
Shoal	0,02	0,02	(0,01)
Built Area	0,03	0,03	(0,01)
Thatch, Sabana	0,19	0,03	(0,16)
Dry Forest	0,02	0,51	0,49
Shrub	4,85	4,80	(0,04)
Plantation	94,27	40,76	(53,51)
Settlement	12,52	64,20	51,68
Rice Field	27,35	28,03	0,68
Sum	**158,75**	**158,75**	

Source : Data Analysis 2000-2016

Analysis result showed that land use changes in the watershed upstream area of Cokroyasan (Bandung Weir) mainly to decrease of plantation area by 56% to 40.76 Km^2, while the settlements increased by 412% to 64.20 km^2. While other types of land cover change is not significant (less than 2%). Thus condition showed the growth of population is medium, or 0,51% average growth population. With assumption one person space need are 7,5 m^2, every years need space for home about 0,2 ha or 2025 m^2. If the settlement space is not adequate, the other landuse (plantation) will converted to fullfill the space need. The curve number analysis results using texture and land cover changes data showed that within 15 years there were changes that affect CN value. In 1999 with the CN: 79.01 and S: 67.48 mm, in 2015 to 85.27 with S: 43.88 mm. S or maximum retention has decreased by one third in 15 years.

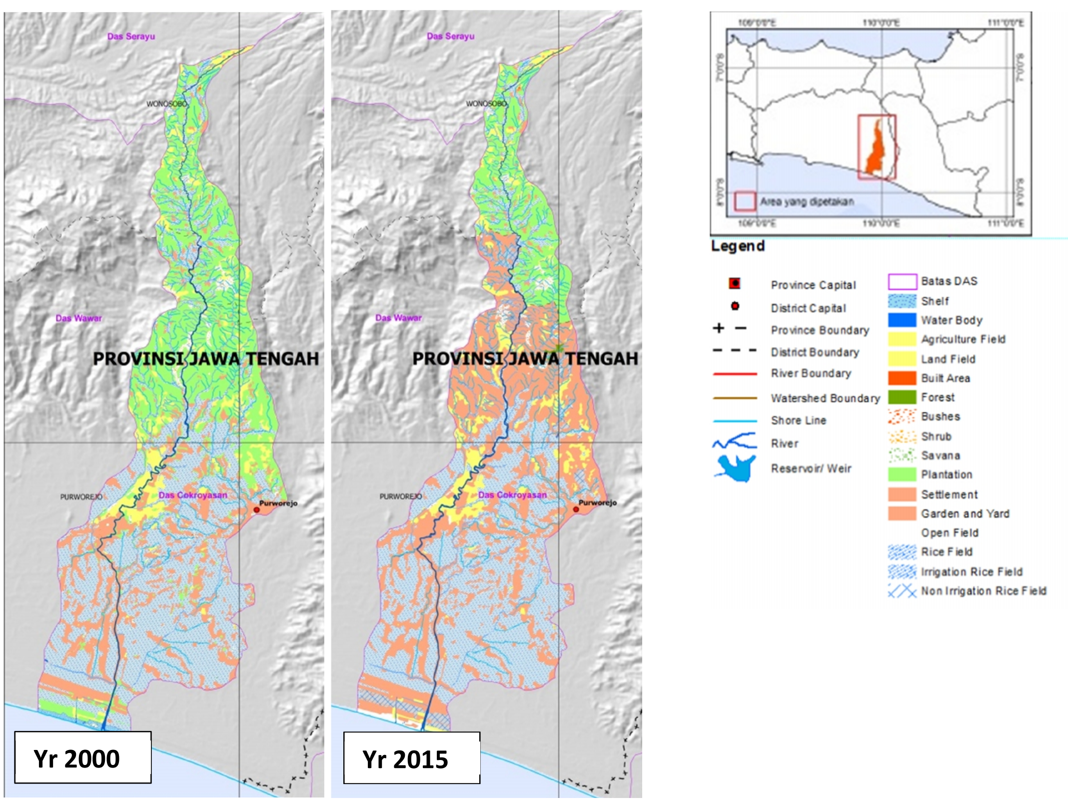

Figure 1. Land Cover On Cokroyasan Watershed Of 2000 And 2015
(Source : Landsat, Google Earth interpretation)

In the hydrological analysis, to get a specific return period flood forecast requires an input of rain data, which further as design rainfall. This relates to the effective rainfall or excess amount of rain which flow directly into the river. Design rainfall used as a design discharge data which can be selected through the frequency analysis, but usually rain detailed parameters are unknown. Input of frequency analysis is daily maximum rainfall on years of catchment area of Bandung weir.

Average depth of rainfall data made using the polygon method Thissen with maximum rainfall years 1995-2015 data input. Average rainfall maximum of Bandung weir catchment shown in the table below.

Table 2. Daily Maximum Rainfall Data of Upstream Cokroyasan Watershed (Bandung Weir)

Years	Daily Maximum Rainfall Data	Years	Daily Maximum Rainfall Data
1997	91.0	**2006**	149.4
1998	115.9	**2007**	193.2
1999	123.0	**2008**	230.6
2000	263.4	**2009**	137.2
2001	101.3	**2010**	174.8
2002	103.1	**2011**	161.2
2003	167.6	**2012**	139.2
2004	223.7	**2013**	200.7
2005	188.5	**2014**	133.1
		2015	209.3

Hydrological analysis study not only on event condition, but also consider a frequency or periodical event. On statistics is referred to as a probability. distribution probability is a major patterns in the statistical analysis design flood return period, where each type of distribution have different characteristics in the data loop.

The data used as input frequency analysis can be divided into partial duration series is when data is less than 10 years, and the annual maximum series when the data is at least 10 years is long enough. Some continuous probability analysis that can be tested include the normal distribution, log-normal, Gumbel and log-Pearson III. (Triatmodjo, 2009)

The data used as frequency analysis input can be divided into partial duration series when data is less than 10 years, and the annual maximum series when the data is at least 10 years. Continuous probability analysis that can be tested are the normal distribution, log-normal, Gumbel and log-Pearson III. (Triatmodjo, 2009) Following table describe design rainfall test distribution.

Table 3. Results of Design Rainfall Distribution Test of weir Bandung (Cokroyasan upstream)

P(x >= Xm)	T	Karakteristik Debit (m^3/dt) Menurut Probabilitasnya							
Probabilitas	Kala-Ulang	NORMAL		LOG-NORMAL		GUMBEL		LOG-PEARSON III	
		X_T	K_T	X_T	K_T	X_T	K_T	X_T	K_T
0,5	2,	159,617	0,	152,034	-0,151	151,361	-0,164	153,438	0,028
0,2	5,	201,917	0,842	199,707	0,798	195,778	0,719	200,166	0,849
0,1	10,	224,029	1,282	230,309	1,407	225,185	1,305	228,843	1,262
0,067	15,	235,062	1,501	247,291	1,744	241,777	1,635	244,341	1,464
0,04	25,	247,608	1,751	268,126	2,159	262,342	2,044	262,969	1,691
0,02	50,	262,84	2,054	295,796	2,709	289,907	2,592	287,088	1,962
0,01	100,	276,541	2,326	323,117	3,253	317,269	3,137	310,244	2,201
0,001	1000,	314,934	3,09	413,876	5,059	407,68	4,936	382,975	2,851

From the distribution analysis, calculate design rainfall on 2, 5, 10, 25, 50, 100, and 1000 years. The distribution results test, the giving a different result. For the chi square test results are to use normal distribution, while according to Kolgorov Smirnov test is best used Log Pearson III distribution. Furthermore, to be used is Kolgorov Smirnov test results, because quite well at data distributing with n less than 50. (Justel, 1997).

Design rainfall used as a design discharge selected through the frequency analysis, but usually rain detailed parameters are unknown. The parameters in question is IDF (Intensity, duration, frequency) and distribution patterns. Several methods can be used to obtain characteristic hourly rainfall include: Tadashi Tanimoto, Mononobe, or ABM (Alternate Block Method). (Triatmodjo, 2009)

In this research, distribution of hourly rainfall using alternating Block Method because this model accommodates rainfall data at successive intervals. Data input from the results of frequency analysis with the Log Pearson III distribution.

Analysis of hourly rain, calculated as the effective rain for each time re-using SCS model and infiltration through CN Number. The combination of design rain and curve number for 15 years showed changes in the value of the maximum retention S_{2000}: 67.48 mm, and S_{2015}: 43.88 mm. Meaning a decrease in the ability to hold water up to 1/3 of the maximum retention period of 15 years.

The SCS discharge analysis uses watershed parameter inputs such as area, slope, river length, total river (all order), effective rainfall, and rain duration. The results of GIS analysis on Bandung weir catchment/ Upstream Cokroyasan watershed is as follows.

A (Area) = 158.75 Km^2
L (Length) = 48.87 Km
s (Slope) = 0.02931374
C (Constanta) = 2.08
Rain Duration (tr) = 4 Hour
Tc = 5.158 Hour
tp = 3.095 Hour
Tp = 5.095 Hour
Qp = 64.81 m^3/sec/cm

Effective rainfall recapitulation hours with the ABM method showed on following table.

Table 4. Recapitulation of Effective Rain Year 2000 and 2015

LOG-PEARSON III		Effective Rain	
X_T	K_T	Year 2000	Year 2015
153.44	0.03	94.42	94.42
200.17	0.85	137.11	157.65
228.84	1.26	163.97	185.16
244.34	1.46	178.63	200.13
262.97	1.69	196.36	218.18
287.09	1.96	219.46	241.65
310.24	2.20	241.77	264.26
382.98	2.85	312.42	335.66

SCS method uses a dimensionless hydrograph, or hydrograph that can be adjusted with field discharge data or certain conditions. Figure 2 shows the flood hydrograph pattern in the study area.

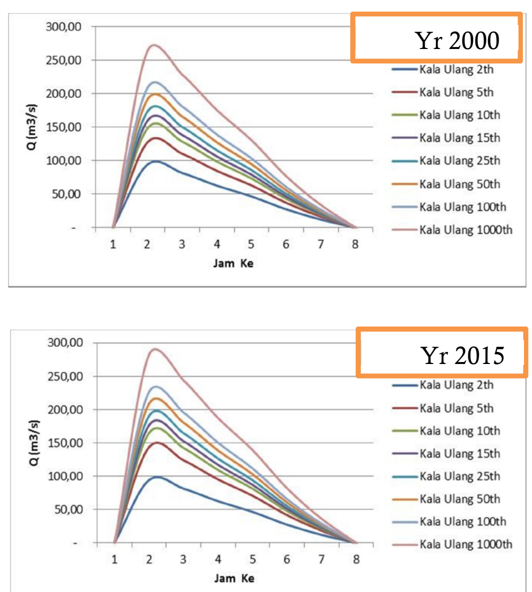

Figure 2. Upstream Cokroyasan Watershed Hydrograph on year 2000 and 2015

To analyse the maximum flood depth that occured, then calculated by correction factor and area of watershed. The results of the SCS discharge model calculation with various time and year 2000-2015 shown the following table.

Table 5. Discharge Changes Analyse

Return Periode (Years)	Qp (m^3/s) Year. 2000	Qp (m^3/s) Year. 2015
2	94.49	94.49
5	127.73	143.73
10	148.65	165.15
15	160.06	176.80
25	173.87	190.86
50	191.86	209.13
100	209.23	226.74
1000	264.23	282.52

The return period analysis showed that there is a significant difference between pair years data, especially from 5 years return periode. For better comparison, the pair data must included baseflow, unfortunately this research cannot facilitate the series data.

In the future, this research continued with spatial analysis which need river topographic addition data to obtained flooded area. Flood prone on each time periode can be analyst using Geohec ras, or Ras mapper and this analysis result as an input.

4. CONCLUSIONS

- Land cover changes dominant are plantation, 56% plantation area decrease to 40,76 km^2, settlement increased 412% to 64,20 Km^2. While other land cover changes not significant (2% <).
- In 15 years there is a maximum retention reduction. Year 2000, CN: 79.01 and S: 67.48 mm, while on 2015 to 85.27 with S: 43.88 mm. Storing capability of maximum retention decrease about 1/3 within 15 years.
- Maximum (peak) discharge changes occur on various time period, but can only be seen on a of more than 2 years time period. Meaning that on maximum flood discharge, watershed storage capability decreased 16-18,29 m^3/s.
- The land cover changes that occur influence Curve Number change, maximum retention, effective rain, and maximum (peak) flood in Upper Cokroyasan watershed.

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