COMPUTER APPLICATION MODEL TO SIMULATE THE LAND USE CHANGE SCENARIO. (A CASE STUDY IN UPPER CILIWUNG WATERSHED, BOGOR, WEST JAVA, INDONESIA)

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1. INTRODUCTION

1.1. Background

The degradation of many watersheds or sub watershed was influenced by population pressure. The other reasons are the rate and the quantity of the water that infiltrates into the ground. The water that infiltrates into the ground is a function of soil type, land use, land cover, drainage conditions, soil moisture, and soil permeability.

Watershed is a fundamentally important area to manage, since land-use, climate cycles, plant cover, rock and soil types, water demands and human impacts all work together to modify the quality and quantity of water draining through the watershed. The physical condition of watershed and the changes in land use pattern influence to the peak flow. Specifically they influence to the maximum runoff volume that flow on a particular location during a storm event. It is necessary to make measurements. Watershed characteristics that are often required for hydrologic design methods include the drainage area, linear measurements such as the watershed or length, the shape of watershed, the slope of the watershed or channel, the drainage pattern, channel roughness, rainfall, soil types, land cover, and land use. Case study in this research focused to the upper Ciliwung watershed, part of Bogor, West Java, Indonesia. Regarding to the case study, upper Ciliwung watershed hydrological characterization can give many information in planning and managing of the environmental such as to make a prediction on how to repair the watershed, to estimate the volume of water that will flow into the downstream area, to give information to the government to do the treatments of upper Ciliwung watershed area and to monitor its hydrologic system.

Floods are still a major unresolved problem, because of many factors, for instance, the slope of watershed, the soil type of watershed, the land cover and land use of watershed, as well as the amount of storage within the channel and vegetation. Beside hydrological reasons such as its geographical position, the floods problem is worsened by population pressure and socio-culture problem. Development of Dynamic Spatial Analysis to Support Hydrologic Modeling will be the starting point for developing Flood Early Warning System in the future.

Upper Ciliwung watershed represents one of flooding contributing area that happened in the downstream, such as in Jakarta. That's why the serious effort needed to support the conservation and the environmental repairmen program of upper Ciliwung watershed area.

1.2. Objectives

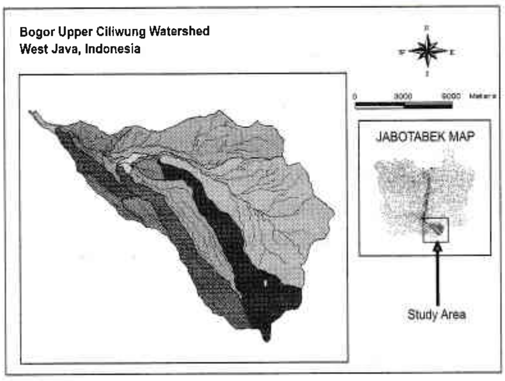
The objectives of this research are to simulate the land use change scenario and develop its computer application model.

2. METHODOLOGY

2.1. Duration and Location of Research

The research has been conducted from June 2004 to December 2004 and conducted in MIT Laboratory - SEAMEO BIOTROP, IPB Campus.

The area under investigation is located in small part of Bogor, West Java, Indonesia. The name of study area is upper Ciliwung watershed; the area size is 14,977 ha (45.37% of the whole area). The whole area is 33,145 ha. The location is $6^{0}05'$ and $6^{0}50'$ South latitude and $106^{0}40'$ and $107^{0}00'$ East longitude. In general water flow direction from the South part area (Mountain Gede Pangrango) to the North part area (bay of Jakarta).



Source: Bakosurtanal 2003, Map Index: 1209-141, 1209-142, 1209-143, Scale 1:25000

Figure 1. Location of Study Area

2.2. Materialand and Tools

The material involved in this research including data vector and data raster. The computer including hardware and software is the tools to do the problem solving in this research.

2.2.1. Data

The data involved in the research including Landsat TM, data acquisition 2001, IKONOS data acquisition 2003, digital topographic map with scale 1:25000, and secondary hydrology data. The following data used in the research are catchments area, contour, land use, land cover, soil type, curve number, flow direction and rivers.

2.2.2. Tools

The software tools used by the research are ER Mapper 5.5, Arc/View 3.2, Arc/Info 3.5, Visual Basic 6.0, ESRI Map Object 2.1, and MS Office 2003.

The hardware tools including PC Pentium-4, 1400 MHz, 256 MB RAM, CD ROM Read/Write Drive 48X24X52X, and Canon Pixma iP1000 Color Printer.

2.3. Method

The method used in this research is combination between theory analysis methods and research experiment method through the simulation and modeling. The research methodology explains about data collecting, data preparing, data analysis, spatial model development procedure, spatial model implementation, simulation and verification. Simulation and verification are the method to proof the simulation model compare with the real world. The following is the research scheme:

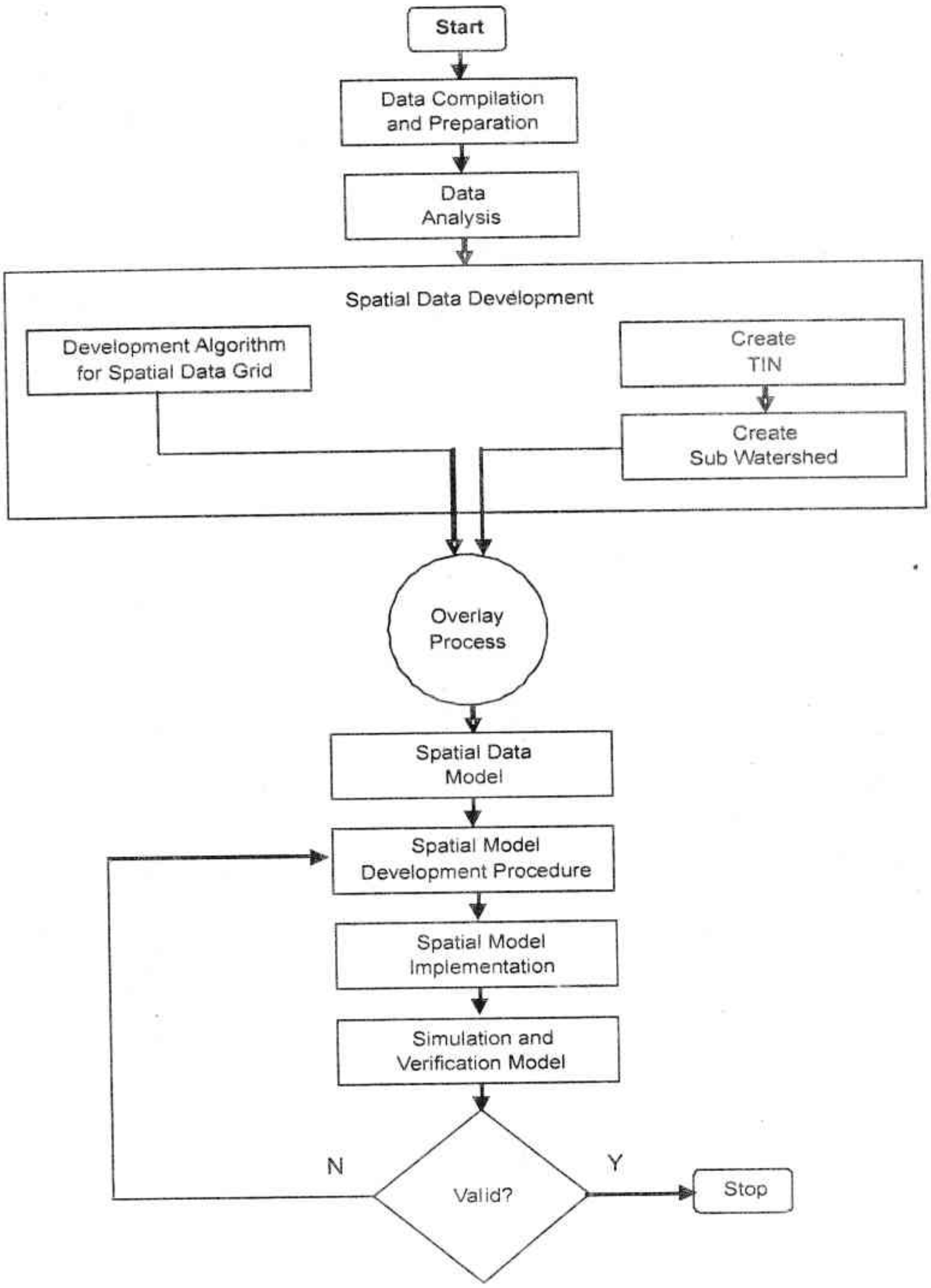


Figure 2. Flowchart of Research Procedure

2.4. Data Compilation and Preparation

The data used by the research are Landsat TM data acquisition 2001 was collected from SEAMEO BIOTROP Bogor Indonesia.

Digital topographic map data was collected from National Map Agency (Bakosurtanal) with scale 1:25000. Hydrological data was collected from Agrisoft Seameo Biotrop.

2.4.1. Data Analysis

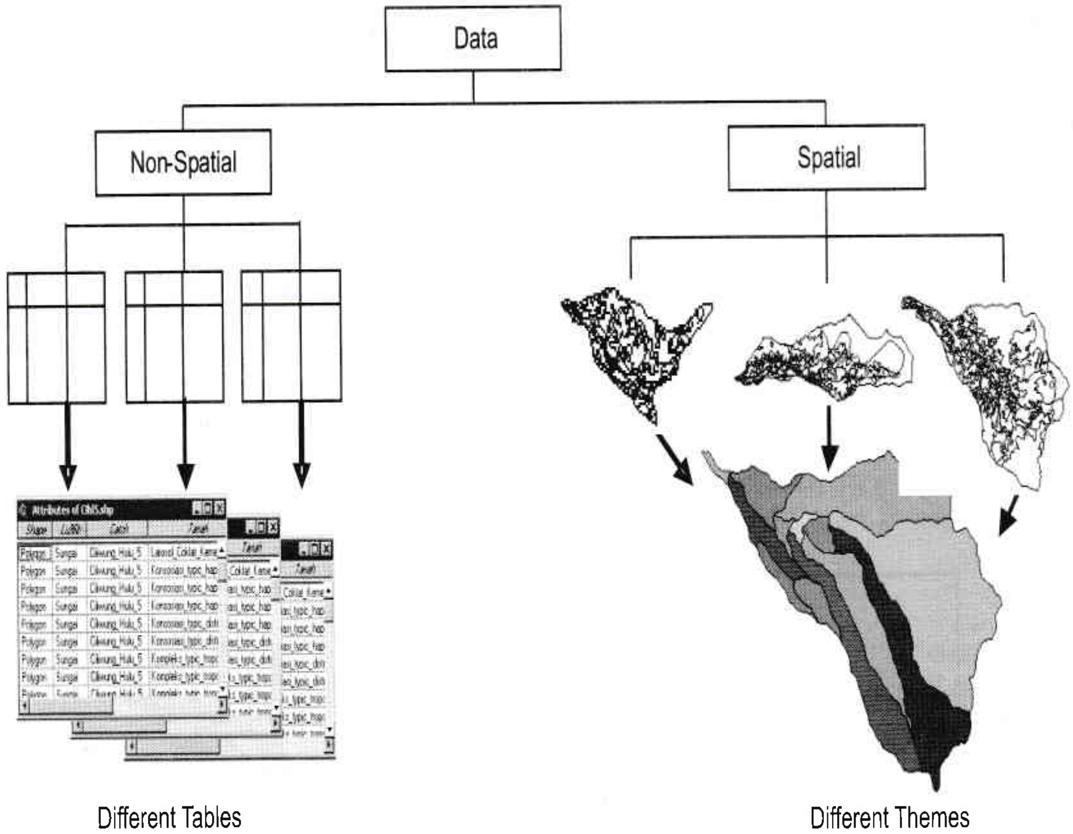


Figure 3. Scheme of Data Analysis

2.4.2. Land Cover

This land cover data give the information to the total effect of surface runoff volume in the outlet. It will be used to get the information on how the land covers influence the runoff. This data used for supporting in analyzing. This information implemented by identification tools.

2.4.3. Land Use

By knowing the correlation between land use dominant and area size is very useful for estimating the surface runoff volume, peak runoff rate and percentage contribution of every sub watershed.

2.4.4. Catchments Area

Data of catchments area further will be analyzed for knowing the volume of water contribution that will flow into the down stream. By using spatial data concept, it is possible to calculate the volume of runoff surface in every catchments area. Each catchment has the unique curve number; it means that it can determine the sensitivity of peak runoff rate value that will flow on its surface area.

2.4.5. Topography

The topography of upper Ciliwung watershed is very a variety of. The topography conditions are from plain until the hilly with the surface is like plain surface, sloping, rather steep until steep (5 % until > 45 %). In general the condition of topography of upper Ciliwung watershed from upstream to the downstream is very different so that can express that type of watershed dissimilar. Upstream Ciliwung watershed predominated by rather precipitous bevel and at the south part area predominated by ramp > 40 %. This area formed by some mountains, for Instance Mount of Gede-Pangrango, mounts of Mandalawangi, mount of Kencong and others.

2.4.6. Sub Watershed and Main River Length

The research area divided into 13-sub watershed, within the rivers. Slope of the river and slope of the sub watershed data will be useful for determining the flow direction and the time concentration in the study area. Some of sub watershed in the study area linked to the same main river.

2.4.7. Soil Type and Curve Number

Commonly area of the research consisting of soil types and curve number as the following in Table 1, this data will be used as information in analyzing and also as the indicator of peak runoff in every contributing area. These data give the influence to the runoff volume. The research considers curve number data for analyzing, calculating, and predicting the runoff volume.

2.4.8. Flow Direction

The data sources used to define the flow direction actually two kinds of data. They are the flow direction and the altitude. The flow direction data was one of two alternatives used to define the direction in this research.

2.5. Spatial Model Development Procedure

Spatial model development is one of the methodologies that extended in the research. Arc View GIS Version 3.2 as the tools that involved by this method procedure. The procedures are creating sub watershed, surface hydrologic analysis, drainage system analysis, and spatial data grid development.

Table 1. Existing soil type and curve number

Land Use	Catchments	Soil Type	Curve Num	Area
Sungai	Cisarua	Konsosiasi_typic_distropepts	78	2923.06
Sungai	Cisarua	Kompleks_typic_troporthent	70	342.06
Sungai	Ciliwung_Hulu_1	Konsosiasi_typic_distropepts	81	1017.37
Sungai	Ciliwung_Hulu_1	Konsosiasi_typic_distropepts	78	3475.09
Sungai	Ciliwung_Hulu_1	Konsosiasi_typic_distropepts	78	4453.74
Sungai	Ciliwung_Hulu_1	Konsosiasi_typic_distropepts	78	61571.90
Sungai	Ciliwung_Hulu_1	Konsosiasi_typic_distropepts	78	523.14
Sungai	Ciliwung_Hulu_1	Konsosiasi_typic_distropepts	78	39930.14
Sungai	Ciliwung_Hulu_1	Konsosiasi_typic_distropepts	78	11385.81
Sungai	Ciliwung_Hulu_1	Konsosiasi_typic_distropepts	78	7039.14
Sungai	Ciliwung_Hulu 2	Konsosiasi_typic_distropepts	78	4050.33
Sungai	Ciliwung_Hulu 2	Konsosiasi_typic_distropepts	81	30.13
Sungai	Ciliwung_Hulu 2	Konsosiasi_typic_distropepts	78	35733.88
Sungai	Ciliwung_Hulu 2	Konsosiasi_typic_distropepts	78	16602.35

2.5.1. Surface Hydrologic Analysis

This method used to describes the physical characteristics of a surface of upper Ciliwung watershed. By using a digital elevation model as input, it is possible to delineate a drainage system of upper Ciliwung watershed and then quantify the characteristics of that system. Determine any location in a grid; the upslope area contributing to that point and the down slope path water would follow. Watersheds and stream networks, created from DEMs. These models are used for determining the height, timing, and inundation of a flood. These fields require an understanding of how water flows across an area, and how changes in that area may affect that flow. Before construct a model of behavior of water, must be determine where the water came from and where it is going. The term focused on how to model the movement of water across a surface in upper Ciliwung watershed.

2.6. Spatial Model Implementation

By using application programming tools, the dynamic spatial analysis model can be implemented. There are many kind of application programming tools can be implemented for the procedure that have been done in this research. Microsoft Visual Basic Version 6.0 and Map Object Version 2.1 are two applications tools used to implement the dynamic spatial analysis model in this research.

2.7. Simulation and Verification Model

After finish implementation of dynamic spatial analysis model development procedure, next step is simulation and verification. Simulation and verification of land use change are the method to proof the model compare with the real world. To simulate and verify the dynamic spatial analysis model application, the research used the imagery application, the research used the imagery data, such as IKONOS data with has the high resolution.

3. RESULT AND DISCUSSION

3.1. Data Preparation

3.1.1. Determine where the water comes from and where it is going.

The research describes the physical characteristics of a surface of upper Ciliwung watershed. Through identification result that the water flows across an area from south part to the north part and the movement of water across give the affect to the peak flow rate. The shape of a watershed surface within river used for determining the slope either land slope or channel slope.

3.1.2. Preparing for stream network.

Data of stream network produced by perform Arc View GIS 3.2, this data used for identifying which one the sub-rivers and which one the main rivers. This method verifies that the water flows from sub-rivers into main rivers.

Base on simplification of model can be determined that, raindrop use only one main river in one catchment area. This method used to get the land slope and channel slope data. Land slope = (Highest contour inlet Lowest contour outlet / Watershed length), Channel slope = (Highest contour inlet Lowerst contour outlet / Main river length). Figure 5 is the example of simplification of Cibogo catchment area.

3.1.3. Preparing for Knowing the Contributing Sub Watershed.

To get such contributing sub watershed by using identification tools providing by Arc View GIS 3.2. This method used as the guidance to create the contributing area.

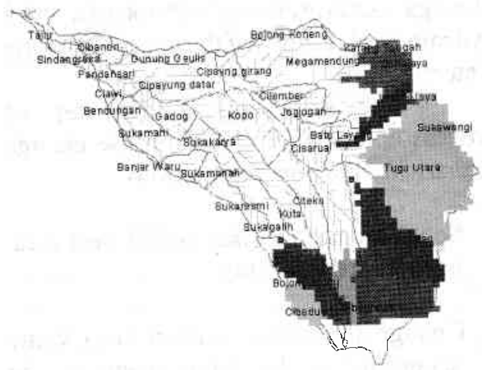


Figure 4. Contributing Area of Sub Watershed

3.1.4. Scenario of land use change dynamic spatial analysis model

Basically the environmental change occure caused by its own nature factor, like disaster. There are other factors that cause the physical environmental changes; the human being is one of the factors of that. The effort to increase their prosperity, the human being is always to change or to create something. The human being either individually or in a community does the changes of their environmental. Commonly, the aim of their activity is to get the good living in the future. But in the fac, it is not as the expected. Therefor it is necessary to create the management tools for controlling the affects of such human being activities.

There are so many strategies to anticipate disaster that will occur. One of the strategies is to create a management tools including simulation and modeling of the real wolrd. By using simulation and modeling at least the affects of disaster is predictable. This chapter is to disscuss about the implementation of the land use change scenario in a dynamic spatial analysis model. The goal of the land use change scenario is to know the hydrological respons of the upper Ciliwung watershed area.

The following is the step of process understanding of land use change scenario model implementation:

1. Setup scenario (urban area, forest area, agriculture area, etc).

2. Change the curve number (cn) value according to the setup scenario (the value of urban area is 90, forest area is 40, agriculture area is 78, etc).

3. Setup the rainfall intensity (mm/hr) and the duration (min) of rainstorm.

4. Doing the calculation process (rational formula).
   A. Duration, D = D/60 (convert minute into hour)
   b. S, S = (1000/cn) -10

$$t_{lag} = \frac{2.587 * L^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1900 * H^{0.5}}$$

   c. Time lag,
   d. Tlag *60 convert minute to second
   e. Time of concentration (s), Tc = Tlag / 0.6
   f. Time to peak (s), Tp = Tlag + (D * 3600 / 2)
   g. Time to resess (s), Tr = 1.67 * Tp
   h. Time base (s), Tb = Tp + Tr
   i. Peak runoff rate (m^3/s), Qp = C * I * A * 0.00278
   j. 0.00278 is convertion factor of I (mm/jam) and area 1 ha.
   k. Volume = 0.5 * Qp * (Tp + Tr)
   l. Volume per hectare (mm), Volume/ha = 0.1* Volume / A

3.1.5. Application Testing and Analizizng

The purpose of aplication testing is to know the hydrological response if the land use change scenario is used. By using this application, the hydrological response can be analized through the output of application model, weather it is true or false.

3.1.6. Application Testing

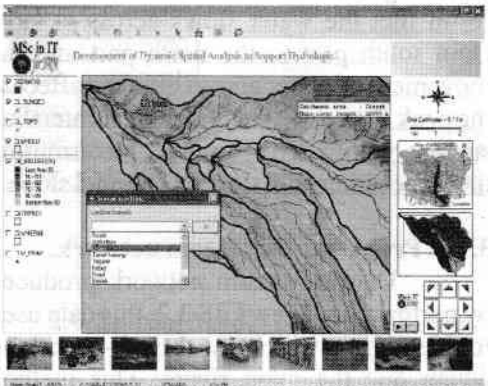
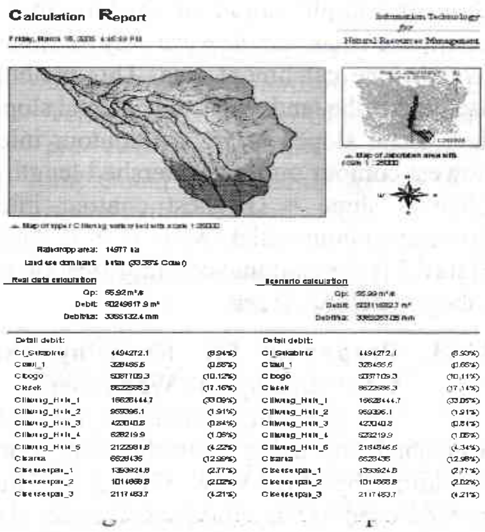


Figure 3. Scenario Land Use Change



To know the contributing area in any location, the application model provided by the tracking tools area, such this icon , and then the application will show the characteristics of a certain watershed or sub-watershed by tracking the contributing area of the location. See in figure 9. By using identify tools the application will show the information about sub watershed or the contributing area. The red area in figure 9 is a certain sub watershed and its size is 70 ha, the slope average is 3.57% and the heigh has the average 528.57 m from above sea level

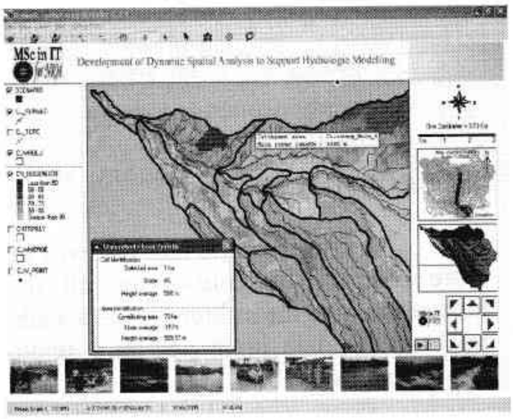


Figure 7. Sub Watershed and its characteristics

3.2. Analizing

Scenario 1 (without land use change):

Real data calculation			Scenario calculation		
Qp:	937.55 m³/s		Qp:	937.55 m³/s	
Volume:	2404070.75 m³		Volume:	2404070.75 m³	
Volume/ha:	16.05 mm		Volume/ha:	16.05 mm	
Volume detail (m³)			**Volume detail (m³)**		
Ci_Sukabirus	220136.14	(9.16%)	Ci_Sukabirus	220136.14	(9.16%)
Ciawi_1	15097.23	(0.63%)	Ciawi_1	15097.23	(0.63%)
Cibogo	241020.56	(10.03%)	Cibogo	241020.56	(10.03%)
Ciesek	414027.86	(17.22%)	Ciesek	414027.86	(17.22%)
Ciliwung_Hulu_1	800606.92	(33.3%)	Ciliwung_Hulu_1	800606.92	(33.3%)
Ciliwung_Hulu_2	43506.8	(1.81%)	Ciliwung_Hulu_2	43506.8	(1.81%)
Ciliwung_Hulu_3	19147.71	(0.8%)	Ciliwung_Hulu_3	19147.71	(0.8%)
Ciliwung_Hulu_4	23919.8	(0.99%)	Ciliwung_Hulu_4	23919.8	(0.99%)
Ciliwung_Hulu_5	100335.23	(4.17%)	Ciliwung_Hulu_5	100335.23	(4.17%)
Cisarua	316362.44	(13.16%)	Cisarua	316362.44	(13.16%)
Ciseuseupan_1	64271.32	(2.67%)	Ciseuseupan_1	64271.32	(2.67%)
Ciseuseupan_2	47495.45	(1.98%)	Ciseuseupan_2	47495.45	(1.98%)
Ciseuseupan_3	98143.29	(4.08%)	Ciseuseupan_3	98143.29	(4.08%)

Scenario 2 (with land use change):

Real data calculation			Scenario calculation		
Qp:	937.55 m³/s		Qp:	991.55 m³/s	
Volume:	2404070.75 m³		Volume:	2520575.96 m³	
Volume/ha:	16.05 mm		Volume/ha:	16.83 mm	
Volume detail (m³)			**Volume detail (m³)**		
Ci_Sukabirus	220136.14	(9.16%)	Ci_Sukabirus	220136.14	(8.73%)
Ciawi_1	15097.23	(0.63%)	Ciawi_1	15097.23	(0.6%)
Cibogo	241020.56	(10.03%)	Cibogo	241020.56	(9.56%)
Ciesek	414027.86	(17.22%)	Ciesek	414345.9	(16.44%)
Ciliwung_Hulu_1	800606.92	(33.3%)	Ciliwung_Hulu_1	916780.46	(36.37%)
Ciliwung_Hulu_2	43506.8	(1.81%)	Ciliwung_Hulu_2	43520.44	(1.73%)
Ciliwung_Hulu_3	19147.71	(0.8%)	Ciliwung_Hulu_3	19147.71	(0.76%)
Ciliwung_Hulu_4	23919.8	(0.99%)	Ciliwung_Hulu_4	23919.8	(0.95%)
Ciliwung_Hulu_5	100335.23	(4.17%)	Ciliwung_Hulu_5	100335.23	(3.98%)
Cisarua	316362.44	(13.16%)	Cisarua	316362.44	(12.55%)
Ciseuseupan_1	64271.32	(2.67%)	Ciseuseupan_1	64271.32	(2.55%)
Ciseuseupan_2	47495.45	(1.98%)	Ciseuseupan_2	47495.45	(1.88%)
Ciseuseupan_3	98143.29	(4.08%)	Ciseuseupan_3	98143.29	(3.89%)

Scenario 1:

The total watershed area is 14.977 ha, and the rainfall intensity is 30 mm over the duration of a storm event with interval period 60 minutes, then the peak runoff rate (Qp, m^3/sec) will be equal with runoff coeficien (C, dimensionless) multifly by rainfall intensity (i, mm/hr) multifly by watershed area (A, square km); with the runoff coeficien (C) has the value between 0.40 up to 0.92. The peak runoff rate (Qp) will be equal with 937.55 m^3/sec. Debit is peack runoff rate (Qp) multifly by duration (D) is 2404070.75. m^3, and debit per 100 square km is 16.05 mm.

Scenario 2:

The total watershed area is 14.977 ha, and the rainfall intensity is 30 mm over the duration of a storm event with interval period 60 minutes, then the peak runoff rate (Qp, m^3/sec) will be equal with runoff coeficien (C, dimensionless) multifly by rainfall intensity (i, mm/hr) multifly by watershed area (A, square km); with the runoff coeficien (C) has the value between 0.40 up to 0.95. The peak runoff rate (Qp) will be equal with 991.55 m^3/sec. Debit is peak runoff rate (Qp) multifly by duration (D) is 2520575.96 m^3, and debit per 100 square km is 16.83 mm.

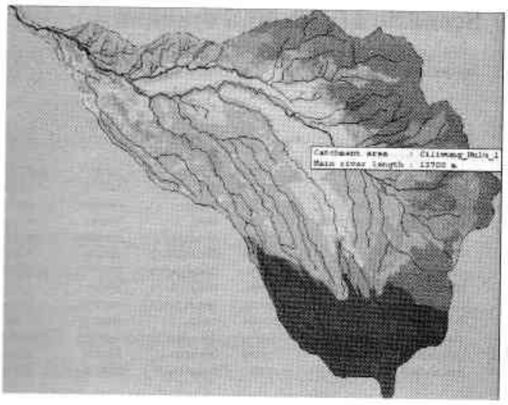


Figure 8. Real Condition

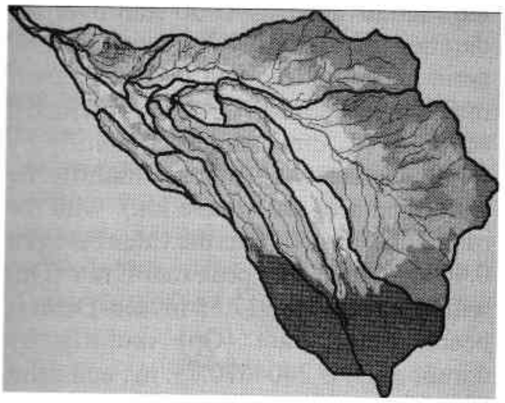


Figure 9. Scenario

The land use change scenario in this simulation just implemented in the small location, in part of Ciliwung Hulu 5. See in figure 11.

Though the simulation was implemented in a small area, but the research explained that there was a change. It means, if the simulation use the larger area, the changes value will very significant.

The existing data describes that the minimum curve number is 45 and the maximum curve number is 92. If the landuse change as the factor that very sensitive to influence to the peak runoff rate and debit, then the peak runoff rate and debit depends on curve number. The smaller curve number of the land use, the better to infiltrate the water.

Table 2. Result and comparison of real condition and scenario

No	Catcment of Ciliwung Hulu 1		Rainfall Intensity (mm/hr)	Duration (minute)	Qp (m^3/sec)	Volume (m^3)	Volume/ha (mm)	Desc
1	Real Condition		30	60	937.55	2404070.75	16.05	Inc
	Scenario:	Urban			991.55	2520575.96	16.83	
	Changes				54	116505.21	0.78	
2	Real Condition		30	60	937.55	2404070.75	16.05	Dec
	Scenario:	Forest			791.47	2073921.98	13.85	
	Changes				146.08	330148.77	2.2	
3	Real Condition		30	60	937.55	2404070.75	16.05	Inc
	Scenario:	Agriculture			944.02	2419060.02	16.15	
	Changes				6.47	14989.27	0.1	

4. CONCLUSION AND RECOMMENDATION

The result of the analysis will be more accurate by considering all the factors that give the influences to the data. Such as the data input not only single rainfall intensity, etc.

4.1. Conclusion

1. After conducting the research and perform the application model it can be stated that the land use dominant of the whool area of upper Ciliwung watershed until know is still the forest (5,083 ha) with 33.75% coverage area.
2. The cell size of spatial data model influences to the precision of result. In this research the cell size is 10000 M^2. The smaller the better precision.
3. The main functions of this model are utilized for the land use change scenario and predict its effect.

4. The model can be utilized for another objective, for example land use change detection, by using the different data acquisition; for knowing an illegal urban development and an illegal logging.

4.2. Recommendation

This Dynamic Spatial Analysis Model is really depending on the data input and the processes inside and its recommendations are:

1. This model can be utilized for predicting the effect of land use change through the simulation.
2. This model provided by the tool that can identify the contributing area of the runoff water volume.
3. This model is still need to be accomplish in the future.

REFERENCES

Aronoff, S. 1989, *Geographic Information System: A Management Perspective*, WDL Publications, Ottawa, Canada.

Arsyad, Sitanala. 2000. *Konservasi tanah dan air*. IPB PRESS. Bogor, p. 32, 36, 44-59.

Bedient, Philip B. 1988. *Hydrology and Floodplain Analysis*. Addison-Wesley Publishing Company. USA, p. 360-370.

de Bay, Rolf A. 2000, *Principles of Geographic Information System*, ITC, Enchede, The Netherlands.

Irianto, S. 2000, *Kajian Hidrologi Daerah Aliran Sungai Ciliwung Menggunakan Model HEC-1*, Tesis, Pasca Sarjana IPB.

Kopp S, Borup B, Willison J, Payne B. 2002. *Using ArcGis Spatial Analysis. ESRI*, 380 New York Street, Redlands, CA 92373-8100, USA.

McCuen, Richard H. 1989. *Hydrologic Analysis and Design*. Prentice-Hall, Inc., New Jersey, p. 278-349.

Pawitan, H. 1993, *Pemodelan dan Simulasi Hidrologi dalam Menunjang Pengembangan Sumberdaya Air di Indonesia*, Proseding Simposium Nasional Permasalahan Air Indonesia, Istitut Teknologi Bandung. Gugus Tugas Penelitian Sumberdaya Air.