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Land Use/Cover Changes in Puncak Area (Upstream of Ciliwung River) and Its Potential Impact on Flood Dynamics

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1. Introduction

Jakarta is the capital of Indonesia with its function as an economic and administrative center. The dynamic growth of Jakarta have an impact to the country especially to its surrounding areas. One of the capital complex issues that remain unresolved today is the environmental problems caused by the decline in the environmental carrying capacity of Jakarta and surrounding areas. Flood is one of the many environmental issues raised as a topic in this study.

Floods in Jakarta can occur locally or at a wider scale of region. The occurrence of floods in Jakarta is caused by one or the interaction of several factors: (1) daily rainfall (extreme rainfall), (2) sea tides, (3) discharged water (extreme river discharge) of upstream rivers that flow into Jakarta, (4) decreased level of some ground surfaces, and (5) poor drainage system of the city. The last three factors (no. 3, 4, and 5) are all those whose roles are getting bigger and are anthropogenic.

Ciliwung and Cisadane Rivers are the two main rivers that cross the city of Jakarta and have a major effect on the incidence of flood in the region. The upstream watershed ecosystem is an important part because of its conservation function for the entire watershed (Asdak, 2010). The environmental degradation in the upper watershed of Ciliwung has a direct impact on Jakarta as part of the watershed. The upper parts of these rivers are located on the areas which lie on the border between Bogor and Cianjur Districts, or precisely on the area Mount Pangrango known as Puncak Region.

Ciliwung watershed is one of several watersheds, which is nationally categorized as a critical watershed, and classified as the most priority to be addressed. This classification was made by the Ministry of Forestry, Ministry of Home Affairs and Ministry of Public Works because Ciliwung watershed is classified as damaged as a result of degradation in quality and therefore it requires conservation efforts as soon as possible.

Ciliwung watershed has similar characteristics to other critical watersheds, but there are some aspects that make Ciliwung watershed get more attention, hence the highest priority to deal with. First, the downstream watershed of Ciliwung includes the state capital (Jakarta), which is very rich in a variety of national assets and serves as the largest residential area in Indonesia. Second, the damage to the upstream watershed of Ciliwung is not solely caused by agricultural activities, but also more greatly by the construction of settlement areas and other infrastructure that is not environmentally friendly. Third, the upstream watershed of Ciliwung is a growing tourist area, thus giving more pressure on water resources (Lewolaba, 1997). Cliwung watershed management is faced with many obstacles since Ciliwung watershed involves a number of autonomous administrative regions. The policy system and management of watershed are still fragmented with the administrative boundary-based approach, so this is still not effective (Sabri, 2004).

According to various studies, the environmental condition in the upstream watershed of Ciliwung is continuing to decline in quality. Based on the study by Nurholipah (2011), the decreased quality of Ciliwung watershed is reflected from the frequency and quality of flood, maximum discharge and maximum-minimum discharge ratio. Previous studies by Janudianto (2004) and Sudadi et al. (1991) found the increasing difference between the maximum and minimum annual discharges in the sub-watershed of downstream Ciliwung. The decline of watershed quality was due to the land use change, in which vegetated areas have been converted into construction/settlement areas, causing a decline in the quality of soil to absorb water (Nurholipah, 2011; Charlos, 2010 and Sudadi et al., 1991). The tendency of land conversion in the sub-watershed of upstream Ciliwung is related to its strategic location as a tourism area that continues to grow along with the increasing population. The dominant livelihood of the people in the agricultural sector shows their high dependence on farming activities that push the conversion of forest cover areas including the agroforestry area.

The dynamic hydrological condition of sub-watershed of upstream Ciliwung is quite well monitored with the presence of the Flood Observation Station at Katulampa (Katulampa Station), Bogor City. The Station is located at the outlet point of upstream Ciliwung Sub-Watershed, which continuously records the height of surface water and water discharge of Ciliwung River. The degraded quality of upstream watershed is indicated by the water level that reaches the outlet of Katulampa Station, that is, the different of maximum and minimum water levels between the rainy and dry seasons. In the rainy season, water level entering the outlet of Katulampa will be very high and in the dry seasons it will be very low.

From the facts mentioned above, it can be said that the upstream watershed of Ciliwung is becoming increasingly vulnerable and at the risk of flooding as a result of the changing land use patterns. Therefore, a study is required to assess the extent to which the dynamics of land use/cover change in the upstream Ciliwung Sub-watershed is linked to the decrease of watershed quality by observing the dynamics of river water discharge and the onset of potential flooding. The study is aimed in more details to: (1) analyze the pattern of land use/cover change (LUCC) in sub-watershed area of Ciliwung, and (2) examine the contribution of land use/cover change (LUCC) to the potential flooding in the region.

2. Materials and Methods

This study uses several kinds of data and maps, including data on daily rainfall in the Sub-Watershed of Ciliwung in 1990-2010 (obtained the Stations Katulampa, Citeko and Gunung Mas), record of daily water height at Katulampa Station, flood occurrences (primarily) in Jakarta and maps of land use/cover in sub-watershed area of upstream Ciliwung in 1990, 2001, and 2010. Some analyses used in this study are of land use change (LUCC). correlation analyses of some specific variables and regression analyses to identify the factors that significantly influence the occurrence of flooding in Jakarta.

3. Results and Discussion

Flood is the water that exceeds the holding capacity of soil, waterways, rivers, lakes or seas because the excess water in the soil, waterways, rivers, lakes, and seas will overflow and inundate the plains or lower areas in the vicinity (Kristianto, 2011). According to the Early Warning Systems of Jakarta, there is a classification of flood warning with the criteria based on a combination of information on the water height/level at the three stations of flood observations, namely Katulampa, Depok and Manggarai Stations.

Below are the four criteria of flood status (alert) in Jakarta based on the water level at the three Stations (Promise Indonesia, 2009):

- Alert 4 (Siaga 4) : Normal condition with water levels at Katulampa <80 cm, Depok <200 cm and Manggarai <750 cm
- Alert 3 (Siaga 3) : Katulampa 80 cm, Depok 200 cm and Manggarai 750 cm
- Alert 2 (Siaga 2) : Katulampa 150 cm, Depok 270 cm and Manggarai 850 cm
- Alert 1 (Siaga 1) : Katulampa 200 cm, Depok 350 cm and Manggarai 950 cm

The flood occurrence in Jakarta is closely related to the high rainfall in both Jakarta itself and Puncak Area. The data of daily rainfall at Ciliwung Sub-Watershed and the reeords of flood occurrences in Jakarta from 1990 to 2010 are presented in the graph of Figure 1.

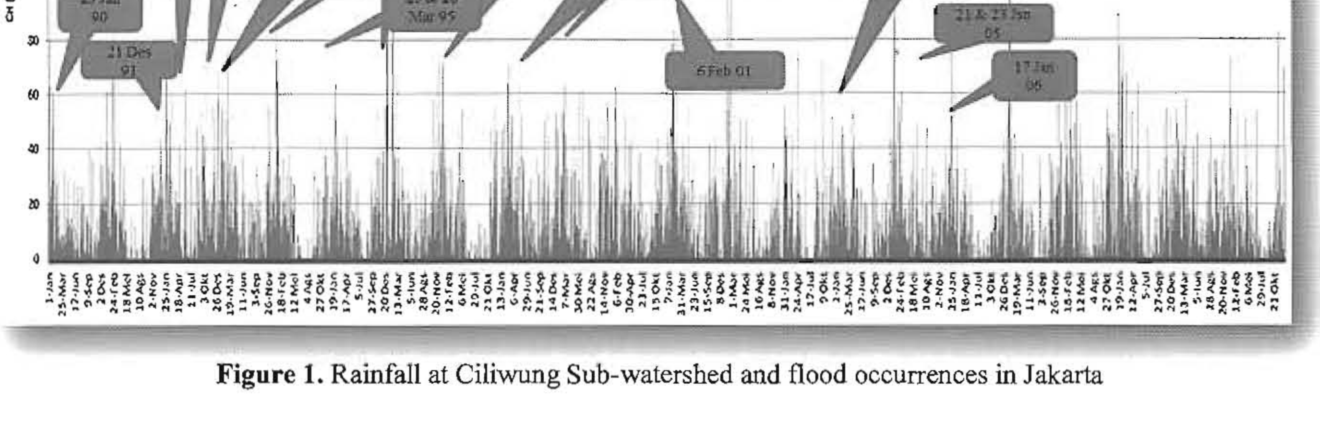


Figure 1. Rainfall at Ciliwung Sub-watershed and flood occurrences in Jakarta

As part (downstream) of the Ciliwung Sub-Watershed, Jakarta get much impact from the activities in its upstream region. From the graphs presented in Figure 1 the relationship can be seen between the amount of rainfall in the upstream Sub-Watershed area of Ciliwung and the flood occurrence in Jakarta. The graph also shows a strong relationship between the high rainfall in the upstream region and the floods occurring in Jakarta. Indirectly this indicates that the incidence in the upper watershed affects the downstream region.

Katulampa is one of several opening gates that serve as early warning stations for Jakarta floods. The alert status of flood at Katulampa may indicate a potential flood in the downstream region. Figure 2, 3, and 4 respectively are the graphs that present the frequency and the status of flood that has occurred in the last 20 years (1990-2010) at Katulampa Station.

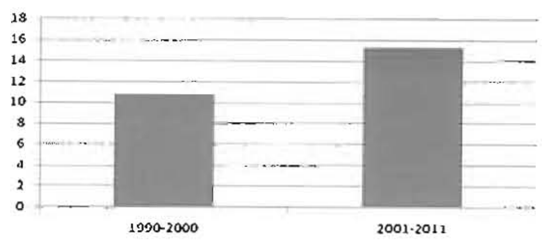


Figure 2. Flood Frequency in Katulampa Station

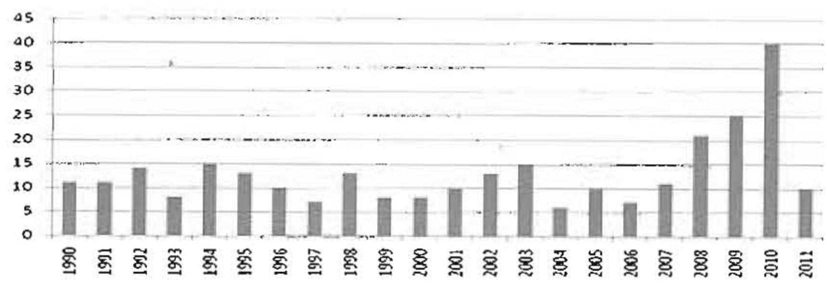


Figure 3. Yearly Flood Frequency at Katulampa Station

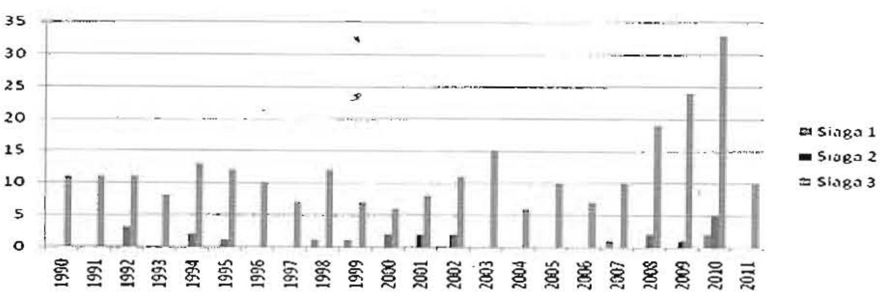


Figure 4. Yearly Flood Status Frequency at Katulampa Station

Figure 2 shows the average frequency of flood in two year periods, namely 1990-2001 and 2001-2010. Based on this graph, the average flood occurrence increased in the second period. The graph in Figure 3 shows the frequency of flood occurrence every year. From the graph it can be seen that the pattern of flood occurrence was highly fluctuating in frequency, but in general the flood frequency tended to increase every year. Figure 4 presents the data on the flood status based on the alertness level (Siaga 1 = high, Siaga 2 = moderate and Siaga 3 = low). From the graph in Figure 4 it can also be seen that the frequency of flood during the period 1990-2011 tended to increase.

Rainfall is an input from the Watershed system, while flood is an output from the watershed. Thus rainfall is the determinant factor of flood occurrence if other factors are not considered. Figures 5 and 6 below present the data on the monthly precipitation level and monthly average from 1990 to 2010 in Puncak Area.

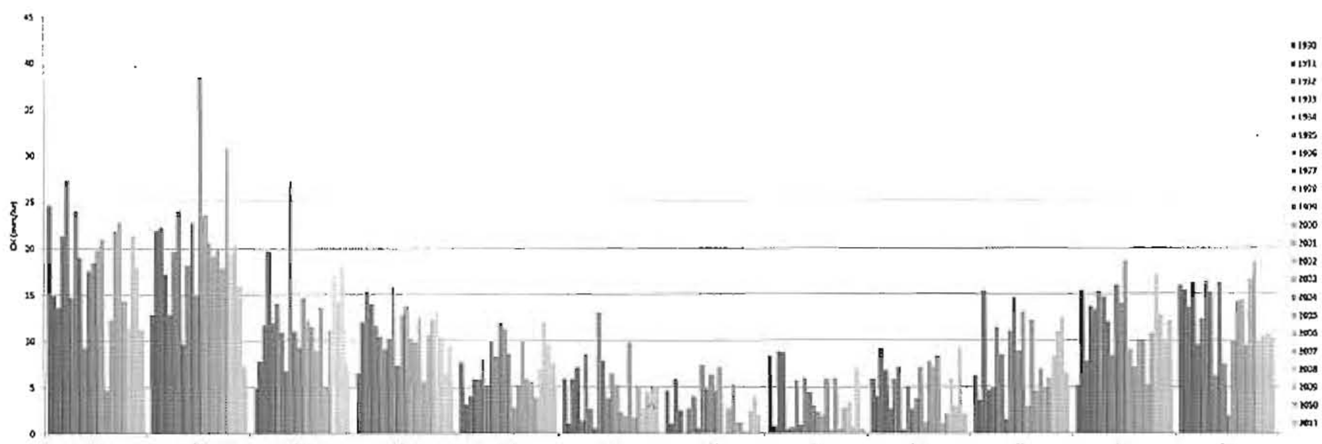


Figure 5. Monthly Precipitation Level (mm/day) 1990-2010 of Puncak Area (monthly wise)

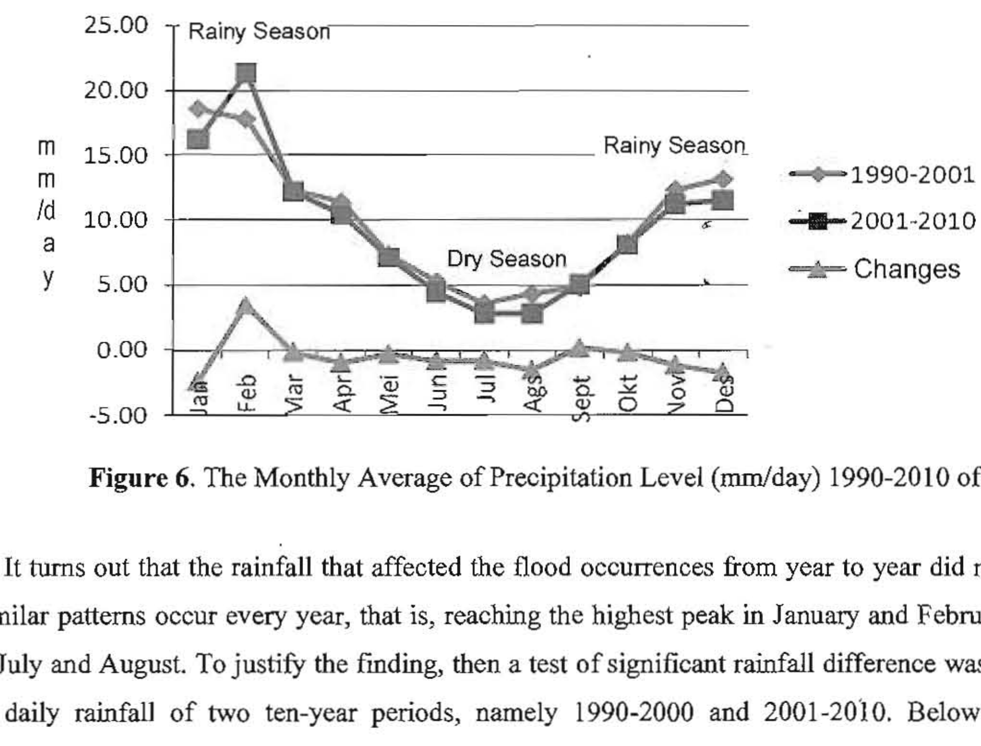


Figure 6. The Monthly Average of Precipitation Level (mm/day) 1990-2010 of Puncak Area

It turns out that the rainfall that affected the flood occurrences from year to year did not change significantly. Similar patterns occur every year, that is, reaching the highest peak in January and February and the lowest peak in July and August. To justify the finding, then a test of significant rainfall difference was carried out for average of daily rainfall of two ten-year periods, namely 1990-2000 and 2001-2010. Below are the results of the significant difference tests (Table 1).

Table 1. Test of Significant Difference in rainfall between the periods of 1990-2000 and 2001-2010

	Mean - Group 1	Mean - Group 2	t-value	df	p	Valid N - Group 1	Valid N - Group 2	Std.Dev. - Group 1	Std.Dev. - Group 2	F-ratio - Variances	p - Variances
Var1 vs. Var2	9.880.155	9.712.574	0.074727	22	0.941107	12	12	5.377.022	5.606.942	1.087.348	0.892032

Note: var 1 = rainfall between the periods 1990-2000
var 2 = rainfall between the periods 2001-2010

Table 1 above is the resulted test of significant difference in the annual rainfall between the periods of 1990-2000 and 2001-2010. It can be seen that statistically there is no significant difference between the rainfall in the period 1990-2000 and the rainfall in the period 2001-2010.

Table 2. Test of Significant Difference in monthly rainfall in the periods of 1990-2000 and 2001-2010

	T-test for Independent Samples (Spreadsheet1) Note: Variables were treated as independent samples										
Group 1 vs. Group 2	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std. Dev. Group 1	Std. Dev. Group 2	F-ratio Variance	p Variances
Var1 vs. Var2	18.6	16.2	1.0	20.0	0.3	11.0	11.0	5.4	5.8	1.2	0.8

Table 2 above is the resulted test of significant difference in the average monthly rainfall in 1990-2000 and 2001-2011. The test results presented in Tables 1 and 2 show that the rainfall in the last twenty years is not significantly different. However, the fact is that the incidence of flood is increasing from year to year. Given these facts, it is predicted that there is another factor that more greatly determines the incidence of flood in Jakarta, namely the change in land use in the sub-watershed of Ciliwung. Therefore, the analysis of land use change in the Ciliwung sub-watershed was also conducted in this study, using maps of land use / land cover in 1990, 2001, and 2010. With this analysis, the patterns of land use changes can be easily determined over the past 20 years, i.e. in the period 1990 to 2010. The results of image analyses and maps of land use in the sub-watershed of upper Ciliwung are presented in Figure 7.

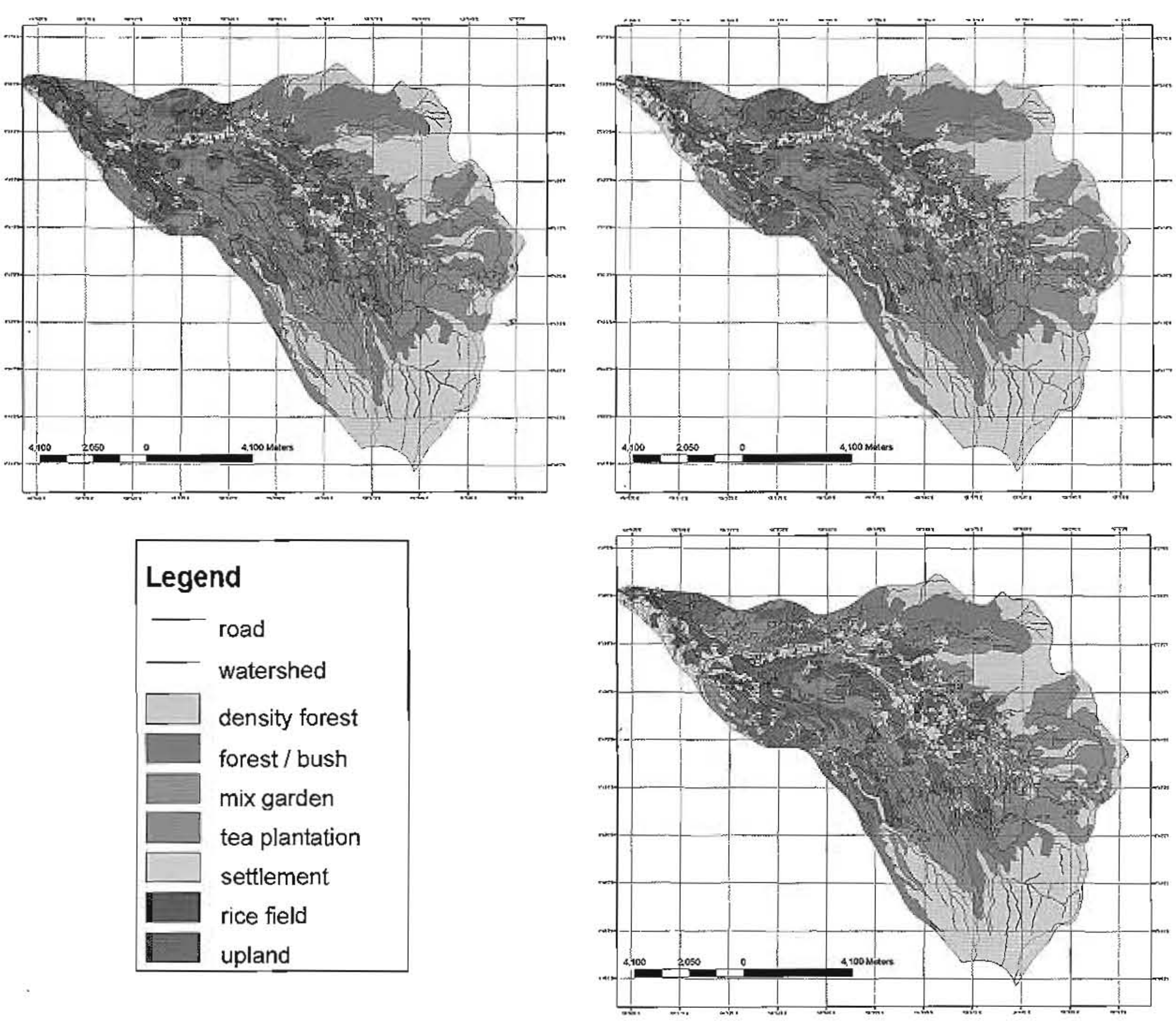
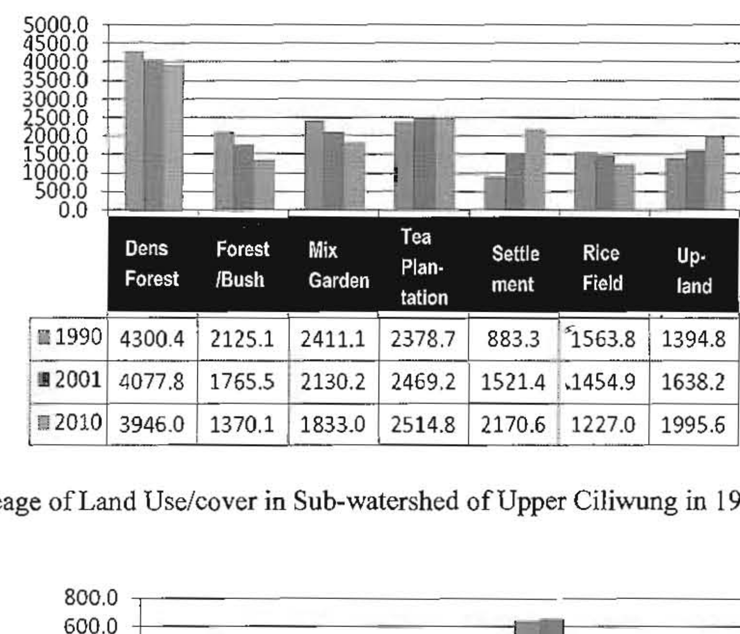


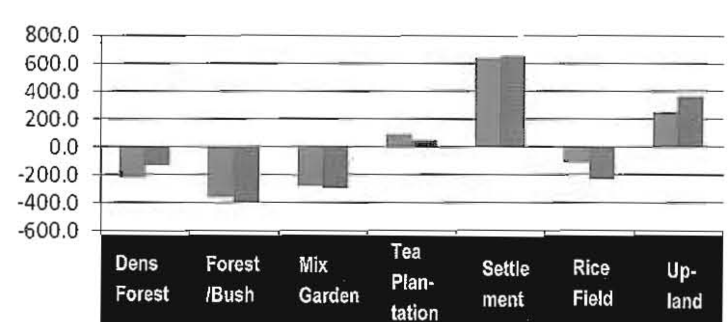
Figure 7. Maps of Land Use/Land Cover Sub-Watershed of Upper Ciliwung in 1990, 2001 and 2010

Upstream watershed should be used as a protective area because it has a very important role in sustaining the entire watershed area. From Figure 7 it can be seen that over time the land use pattern in the sub-watershed of upper Ciliwung continues to change. This change is the decrease in forest land use/cover types from shrubs, mixed farms and fields to tea plantations, settlements and rain-fed fields. With the decreasing area of forest and other green open space, then the function of the upstream watershed ecosystem of Ciliwung as a buffer region has become disturbed because of a lack of attention to land use sustainability principles. The following Figures 8 and 9 present the data on the size of each type of land use in Sub-watershed of Upper Ciliwung and the patterns of land use changes in the 20 years, covering 2 (two) periods of time, i.e. 1990-2000 and 2001-2010.



	Dens Forest	Forest /Bush	Mix Garden	Tea Plan-tation	Settle ment	Rice Field	Up-land
1990	4300.4	2125.1	2411.1	2378.7	883.3	1563.8	1394.8
2001	4077.8	1765.5	2130.2	2469.2	1521.4	1454.9	1638.2
2010	3946.0	1370.1	1833.0	2514.8	2170.6	1227.0	1995.6

Figure 8. Size/ Acreage of Land Use/cover in Sub-watershed of Upper Ciliwung in 1990, 2001 and 2010



	Dens Forest	Forest /Bush	Mix Garden	Tea Plan-tation	Settle ment	Rice Field	Up-land
90-01	-222.6	-359.6	-280.9	90.4	638.1	-108.8	243.4
01_10	-131.8	-395.3	-297.1	45.6	649.1	-227.9	357.4

Figure 9. Acreage of Land Use/Cover Changes in Sub-watershed of Upper Ciliwung in 1990-2001, and 2001-2010

From the graph in Figure 9 above it can be seen that there was a big change of land use/cover for settlement within the period of 20 years, both in the period 1990-2000 and 2001-2010. Another dominant change was the increased area of the dryland. Based on the results of the study by Nurholipah (2011), the changes in land use thought to have caused a decline in the watershed quality is the increasing catchment area and the decreasing area of scrubland.

Based on the study it was found that the change in land use/cover in the period of 20 years is likely to be the change of land into residential areas and the dryland, from the previous land uses; namely forest, bush, rice fields and mixed farms. According the studies by Sudadi et al. (1991) a similar pattern of land use changes also occurred in the period 1981-1990 in the same area, the changing patterns of land use to a settlement area.

Although rain is not the factor affecting the increased frequency of flood, but it is the determinant major factor of the flood occurrences because rainfall is an input factor and flood is the output. For these reasons, some analyzes were conducted to determine the most influential rainfall that causes the high water level at the outlet of Katulampa.

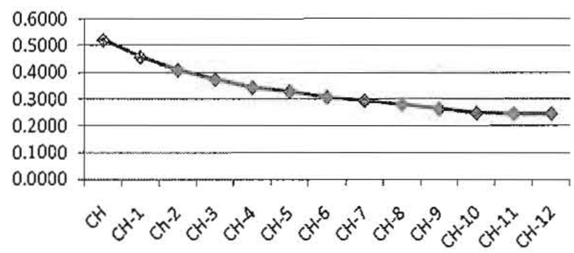


Figure 10. Correlation between Ln Disharge (Y, mm/day) and precipitation in the day (CH), a day before (CH-1), CH-2, ..., CH-12

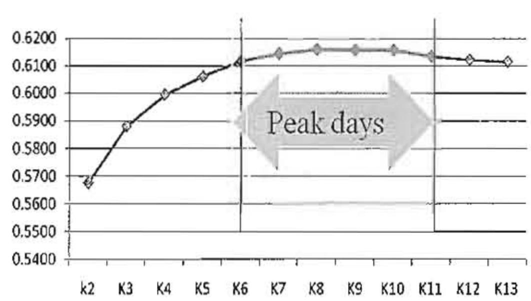


Figure 11. Correlation between Discharge` (Y, mm/day) and cumulative precipitation in the day (K), and prior day (K1), K2, ..., K13

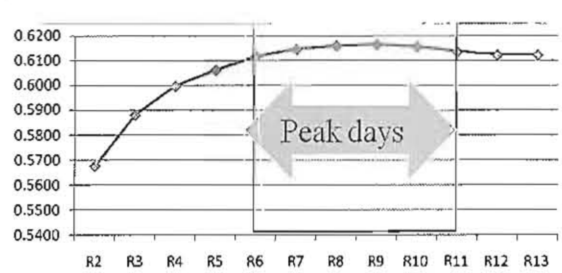


Figure 12. Correlation between Ln Discharge (Y, mm/day) and average cumulative precipitation in prior day (R), a day before (R1), R2, ..., R13

Figure 10 shows the relationship between the high rainfall and the resulted water level. The results of correlation analysis concluded that the rainfall that mostly affects the water height is the rainfall that fell on that (falling) day (CH), with its effect decreasing with the distance/interval away from the falling day/time (CH-1, CH-2, CH-3, ... , etc.). However, for the influence of cumulative rainfall and cumulative average rainfall (see Figures 11 and 12), the highest correlation between the water level at Katulampa and the rainfall is on the same day and the days afterward until the fifth day. In other words, it should be assumed that the rainfall that is most likely to cause flooding is the one that falls on five or more consecutive days.

3. Closing

Changes in the land use/cover (LUCC) in the Sub-watershed Area of Upper Ciliwung have a significant impact on the declining quality / carrying capacity of watershed and the increase of environmental vulnerability, thus potentially having the risk of flooding in downstream areas, especially in Jakarta City. Therefore, a system of spatial planning is required with the effective support of spatial information technology to facilitate supervision and control. Further, strong effective institutions are necessary to control the implementation of spatial plans.

Without any significant changes in the capacity building in the environmental planning and management, Jakarta and its surrounding areas (Greater Jakarta area) will be increasingly vulnerable to the risk of flooding.

References

Asdak, C. 2010. *Hydrology and Watershed Management.* Yogyakarta: UGM Press.

Janudianto. 2004. Analysis of Land Use Change and its Impact on Minimum-Maximum Water Discharge at Sub-Watershed of Upper Ciliwung. S-1 (Undergraduate) Script. Soil Department. Faculty of Agriculture IPB. Bogor. Unpublished.

Kristianto, A. 2010. *Flood Disaster Response.* Bandung: Angkasa.

Lewolaba, G. 1997. Public Participation in Water Resources Management in the Capital City of Jakarta. Paper presented in the seminar on Water Resource Management in the Official Opening of Forestry Master Program, UPN Yogyakarta in 1997.

Nur, S.H. 2012. The Effect of Land Use/Cover Changes on the Characteristics of Sub watershed of Upper Ciliwung. S-1 (Undergraduate) Script. Soil Department. Faculty of Agriculture IPB. Bogor. Unpublished.

Promise Indonesia. 2009. Flood and Its Mitigation Efforts. *Program for Hydro-Meteorological Risk Mitigation Secondary Cities in Asia.* Bandung: ITB.

Sabri. 2004. Analysis of Land Use Conversion Using Remote Sensing and Willingness to Pay at Sub-watershed of Upper Ciliwung, West Java. Thesis. IPB

Sudadi, U.D.P.T. Baskoro, K. Munibah, B. Barus dan Darmawan. 1991. A Study on the Effect of Land Use Change on River Flow and Decreased Land Quality at the Sub-watershed of Upper Ciliwung by an Approach of Hydrological Simulation Model. Research Report. Soil Department. Faculty of Agriculture, IPB.Bogor.

Togi, C. S. 2010. Evaluation of the Land Rehabilitation Performance at the Upstream Watershed of Ciliwung and Cicadae. S-1 (Undergraduate) Script. Soil Department. Faculty of Agriculture IPB. Bogor. Unpublished.