EFFECT OF LAND USE ON SPATIAL AND SEASONAL VARIATION OF WATER QUALITY IN CILIWUNG RIVER, WEST JAVA-INDONESIA

Eleonora Runtunuwu, Akihiko Kondoh and Kasdi Subagyono

ABSTRACT Study on water quality aspects of Ciliwung river has been conducted from January 2008 to November 2009 to address the impact of land use change on its seasonal variation. Nitrogen compound of NO_2 and NH_4 were monitored along the Ciliwung river with different time. Land use change within the Ciliwung watershed was analyzed using remote sensing data and correlate with NO_2, NO_3, NH_4 concentration, conductivity and pH along the river. The results showed that in area with higher populated areas such as found in the middle and downstream area of Ciliwung watershed, NO_3 concentration is higher. This obvious variation was also observed for conductivity and pH. It was also observed that the more dense area as in the middle and downstream area the change of land use was obvious. The NO_3 concentration is much influenced by land use and vegetation change prior to human activity. In general, NO_3 observed on October 2008 was higher compared with that observed on January, April and July 2008. In October where it is rainy season, flushing of NO_3 is higher and it was transported into the Ciliwung river. The temporal variation is seemed to be due to variation of rainfall generating different runoff and nutrient flushing surrounding river.

Keywords: Water quality, Land use, Anthropogenic, Spatial and seasonal variation, Ciliwung river.

ABSTRAK *Studi kualitas air sungai Ciliwung telah dilaksanakan dari bulan Januari 2008 sampai dengan November 2008 untuk mengkaji dampak perubahan penggunaan lahan dan variasi musiman terhadap kualitas air. Komposit Nitrogen dari NO_2 dan NH_4 telah diamati sepanjang sungai Ciliwung dengan waktu pengamatan yang berbeda. Perubahan penggunaan lahan yang dianalisis dengan menggunakan citra satelit telah dikaitkan dengan kosentrasi NO_2, NO_3, dan NH_4, konduktifitas dan pH air pada beberapa titik pewakil sepanjang sungai Ciliwung. Hasil menunjukkan bahwa daerah dengan populasi yang cukup tinggi seperti di daerah tengah dan hilir sungai Ciliwung, kosentrasi NO_3 cukup tinggi, sebagaimana juga yang terjadi pada variasi konduktifitas dan pH. Perubahan penggunaan lahan juga lebih luas terjadi di bagian tengah dan hilir Sungai Ciliwung. Kosentrasi NO_3 paling banyak dipengaruhi oleh perubahan penggunaan lahan dan vegetasi akibat aktifitas manusia. Pengamatan kualitas air pada bulan Oktober 2008, ternyata kosentrasi NO_3 lebih tinggi dibandingkan dengan pengamatan bulan Januari, April, dan Juli 2008. Di bulan Oktober sebagai musim hujan, pencucian NO_3 lebih tinggi dan dibawa ke Sungai Ciliwung. Variasi antar waktu kelihatannya terjadi karena variasi*

Naskah masuk: 8 Januari 2010
Naskah diterima: 1 April 2010

Eleonora Runtunuwu
Indonesian Agroclimatology and Hydrology Research Institute, Bogor, Indonesia
E-mail: runtunuwu2001@yahoo.com

Akihiko Kondoh
Centre for Environmental Remote Sensing, Chiba University, Japan
Email: kondoh@faculty.chiba-u.jp

Kasdi Subagyono
Central of Java Assessment Institute for Agricultural Technology, Ungaran, Indonesia
E-mail: bptd-jateng@litbang.deptan.go.id

curah hujan yang mempengaruhi limpasan dan kosentrasi pencucian Nitrogen di daerah sekitar sungai.

Kata kunci: *kualitas air, penggunaan lahan, kegiatan manusia, variasi antar waktu dan tempat, sungai Ciliwung.*

INTRODUCTION

Recent concern over increased human-induced atmospheric N-deposition, in addition to diffuse source N-inputs to surface waters from agriculture and forestry practices, has stimulated investigations of controls on the biogeochemistry and transport of N. Meanwhile, the hydrologic routing of N from the hill slope through the near-stream zone is relatively unstudied (Cirmo and McDonnel, 1997). This phenomenon has also been studied in the Ciliwung watershed, West Java, Indonesia.

N-losses from the agricultural and forested lands have been reported by many researchers. According to Walton *et al.* (2000), the removal of chemicals in solution by overland flow from agricultural land has the potential to be a significant source of chemical loss, although the chemical loss can be incorporated with the sediment loss through the erosion. Furthermore, it was identified that the most common chemical loss through the runoff is in the form of solution. A proportion of nitrogen (8 to 80%) losses in runoff is in solution (Menzel *et al.,* 1978; Hubbard *et al*., 1982). In-stream processes resulted in net removal of about 17% of the NO_3^- flux from the catchment to the stream (Mulholland and Hill, 1997). In addition, attempt to identify the increase of N in stream water requires a knowledge of N-sources and its pathways from hillslope through the riparian zone within a catchment.

The JSPS-DGHE Joint Research Project titled "Watershed Management for Sustainable Water Resources Development in a Humid Tropical Region" dealt with water quality aspect of Ciliwung river as a part of the activities set up since 2007. The purpose of the project is to clarify what the necessary watershed management should be for sustainable water resources development and water uses with an emphasis on the land use management for water resources conservation and to construct a new model of "Integrated Watershed Management" which will lead the decision making, together with the capacity building and the water governance (Tanaka, 2008). In the second year of the project, water quality study along the Ciliwung river has been the concern to deal with its relation to land use change and human activities.

The objective of the study is to elucidate the relationship between water quality and land use change as well as human activities along the Ciliwung river. The results are used for building up best bet menu of integrated watershed management as water quality is important indicator to identify the change of watershed condition.

METHODS

A total of 41 sampling points were selected along the Ciliwung river from Mount Pangrango at about 3000 m.asl to the Jakarta coast at 0 m.asl (Figure 1).

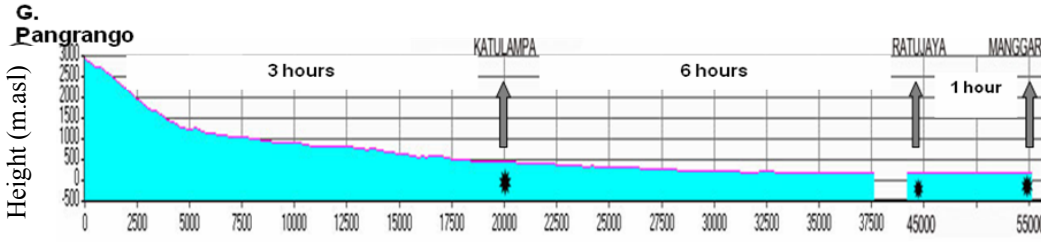

Figure 1. Transect of Ciliwung river.

Figure 2. Location of water sampling.

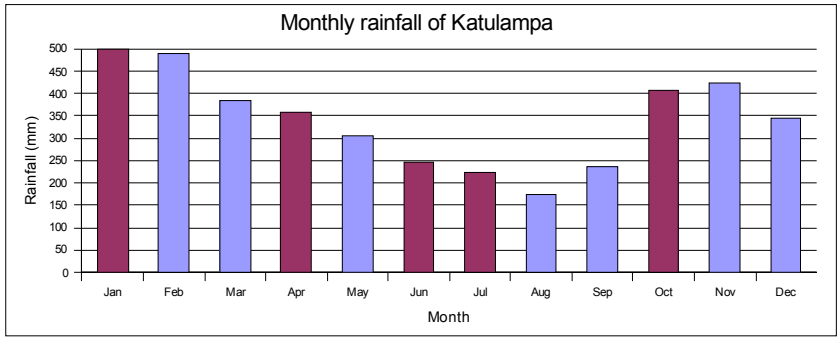

Figure 3. Mean monthly rainfall at Katulampa station (1996-2007)

Sampling points were divided into three parts, i.e. the upper (17 points), middle (12 points), and lower (12 points) part (Figure 2). To monitor seasonal variation of the water quality along the river, water sampling has been conducted at the different time of Jan08, Apr08, Jul08, and Oct08 to understand the effect of rainfall variation (Figure 3) on water quality. Besides in situ measurement of pH, temperature, and EC, Nitrogen analysis (NH4, NO2, and NO3) will be considered as indicator of water quality as influenced by anthropogenic factor, as will be correlated with population data and land use conditions.

RESULTS AND DISCUSSION

Temperature, Conductivity and pH

Temperature, conductivity and pH data monitoring is presented in Table 1. Those three parameters have similar trend along the river, where the higher magnitude of those parameters is found in the middle and lower river (downstream area). If the average values are considered, the temperature different between upstream, middle and downstream ranged about 5 to 6 digit. The middle and downstream part of the river are higher than the upstream part. Conductivity is differed with about 10, while that of the pH was differed with about 1 to 2 digit.

Table 1. Temperature, conductivity, and PH of water sampling

Variable	Upper		Middle		Down	
	Min	Max	Min	Max	Min	Max
Temperature (^oC)	19,6	25,2	26	29,4	27,1	32,8
Conductivity (μs/cm)	0,20	184,00	0,20	192,00	0,20	190,00
pH	1,9	8,1	4,9	7,4	6	7,1

Nitrate (NO_3) Concentration

NO3 concentration is higher in the middle and downstream area compared with that in upstream area. It is obvious that in area with higher populated areas such as found in the middle and downstream area, NO_3 concentration is higher. This is the fact that NO_3 concentration is much influenced by human activity. The activity is prior to those affecting land use and vegetation. In populated area, disturbance of land use and vegetation by converting forest into agricultural land and other uses. In upland-urban area as found in Bogor regency area, NO_3 concentration was observed at the highest level among the area in Ciliwung watershed. At the area with tea plantation and secondary crops, NO_3 concentration was the lowest level.

It did not only vary spatially, the NO_3 concentration also varies with time. The data observed on January, April, July and October 2008 shows very significantly the difference between those dates. In general, NO_3 observed on October 2008 was higher compared with that observed on January, April and July 2008. In October where it is rainy season, flushing of NO_3 is higher and it was transported into the Ciliwung river.

NH4 Concentration

In general, NH_4 concentration in river water at the lower area was higher compared with those at the upper and middle areas. The temporal variation of NH_4 concentration was obvious at the lower area compared with that at the upper and middle areas. In the upper area its concentration at 8 sampling point was significantly higher compared that at other sampling points.

Temporal variation of NH_4 concentration at the middle area was not obvious except at 18-22 sampling points. The variation of NH_4 concentration at lower areas seems to be due to human activities either directly or indirectly through the disturbance to land use. The disturbance of land use due to human activities is in function of population density meaning that the more dense population the more NH_4 are flushed to the river and cause its concentration in the river water increase.

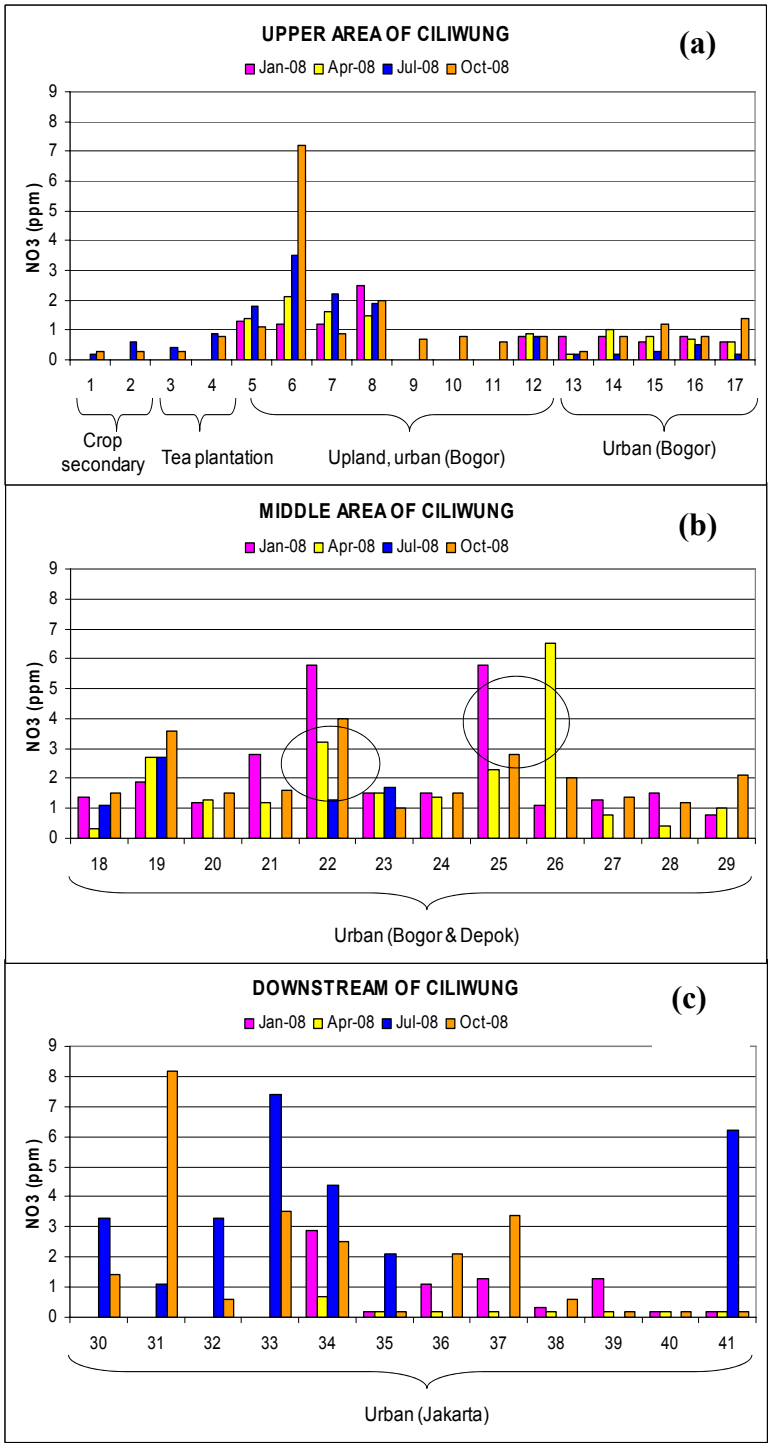

Figure 4. NO_3 concentration at (a) upstream, (b) middle and (c) downstream area of the Ciliwung river.

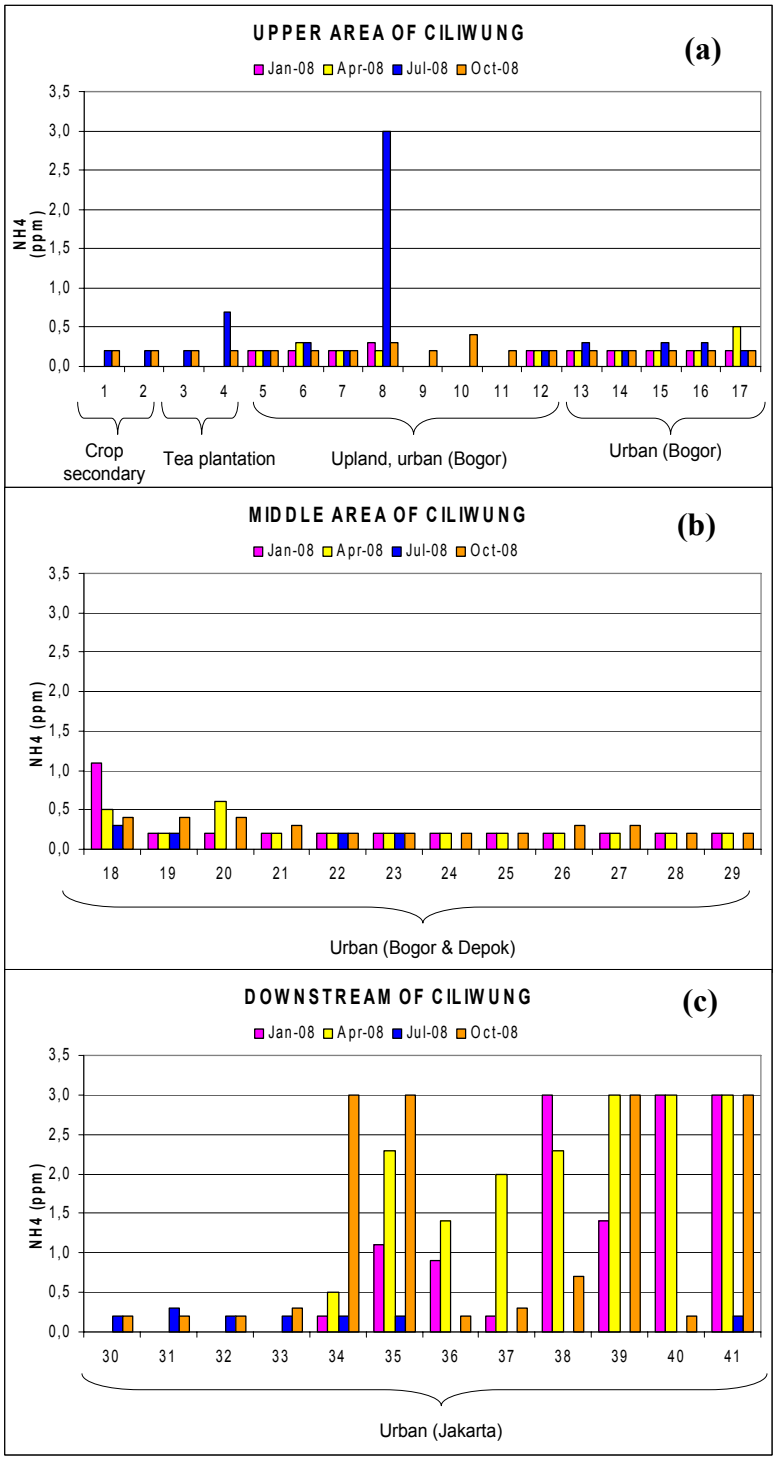

Figure 5. NH4 concentration at (a) upstream, (b) middle and (c) downstream area of the Ciliwung river.

NO_2 Concentration

Spatial and temporal Variation of NO_2 concentration was more obvious compared with that of NO_3 and NH_4 concentration. Spatially NO_2 concentration varies at upper, middle and lower areas despite the magnitude of variation was obviously different. Land use and population density are assumed to be the most factors influencing the variation. In urban area such as it was found in the upper, middle and lower areas within the watershed, the variation of NO_2 concentration was significantly varies.

NO_3 Concentration vs Runoff

NO_3 concentration increased with the increase of runoff meaning that NO_3 was transported by water flow during runoff process. This is the fact that NO_3 is transported through water flow. The higher the flow the higher the transported NO_3 will be. It also means that NO_3 is easily transported by water flow during runoff process. The data on January and October 2008 showed very clearly that the relationship between NO_3 concentration and runoff is obvious, as it is respectively shown by $R^2 = 0.57$ and $R^2 = 0.90$. Although R2 are low, it was shown a positive relationship between NO_3 concentration and runoff. This data provides insight that NO_3 was flushed during runoff process and discharged into the Ciliwung river.

Depending upon the NO_3 concentration which is much affected by human activity, the magnitude of flushed NO_3 varies with area. The Middle and downstream areas have higher NO_3 concentration and provides contribution to the magnitude of NO_3 to be transported into the river. As NO_3 is mobile, it is easily to transport by water flow during runoff process.

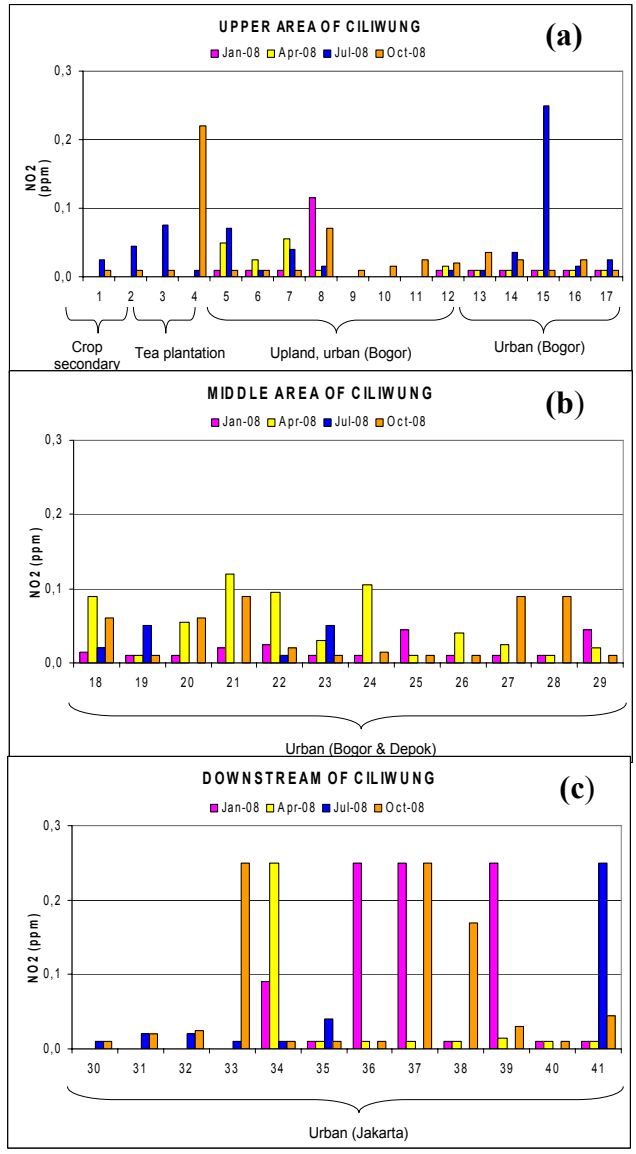

Figure 6. NO_2 concentration at (a) upstream, (b) middle and (c) downstream area of the Ciliwung river.

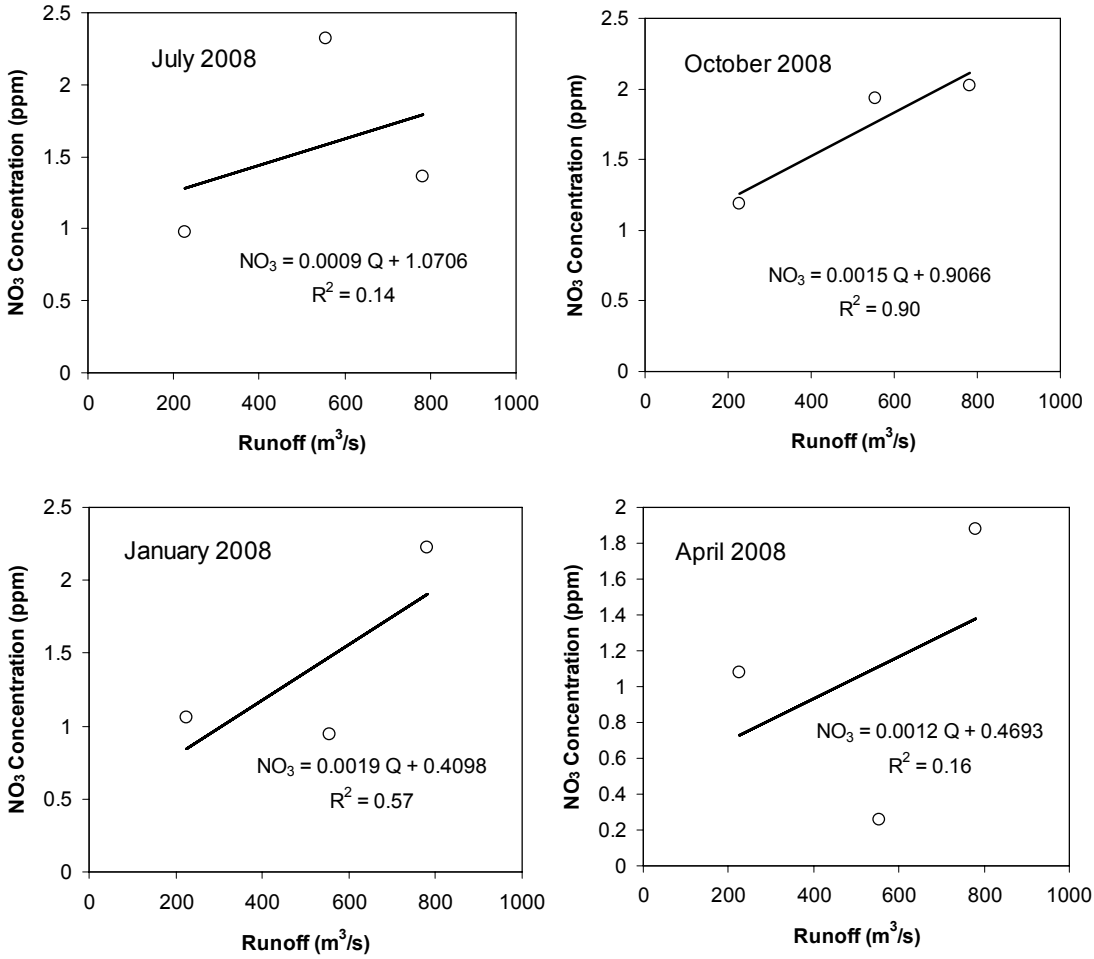

Figure 7. Relationship between NO_3 and runoff at the Ciliwung watershed.

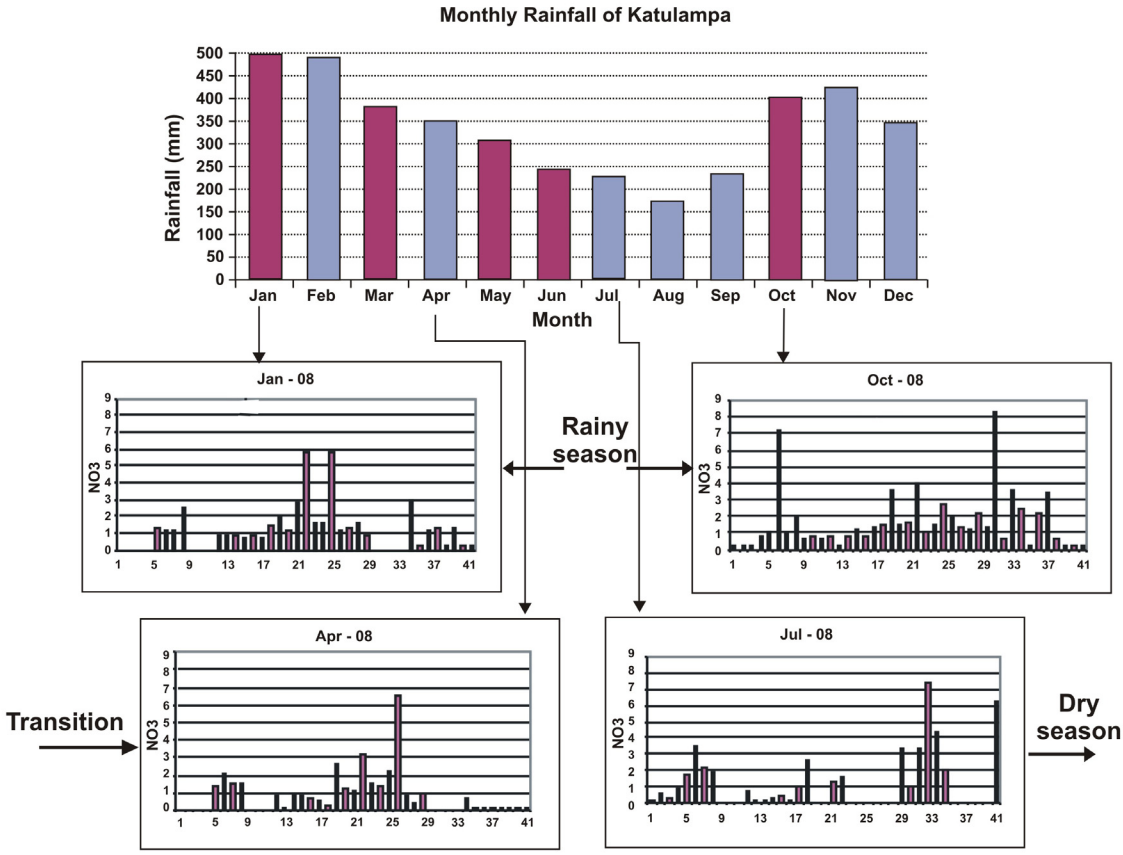

Figure 8. Seasonal distribution of NO_3 in relation to Katulampa rainfall

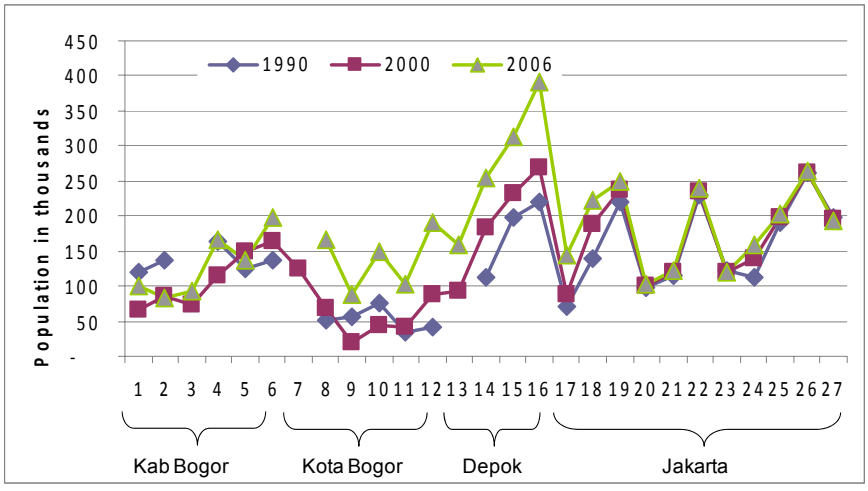

Figure 9. Population by sub-district along the Ciliwung river.

CONCLUSIONS

From water quality data and the analysis on relationship between runoff and water quality, it can be concluded that human activity and land use are most dominant factors influencing water quality variation along the Ciliwung River, west Java, Indonesia. The dynamic behavior of the variation of water quality at the middle and lower areas of Ciliwung river is much influenced by those factors. Since it was not any measurement of runoff inland especially at each area of upper, middle and lower part of the watershed, the river flow at each area is used and it is found that NO_3, NH_4, NO_2 concentration have good correlation with the river flow.

ACKNOWLEDGEMENTS

This study is conducted as a Joint Research Project between JSPS (Japan Society for the Promotion of Sciences) and DGHE (the Directorate General of Higher Education) – RI for the period of April 2007 to March 2010. Some of the results presented take the benefits of previous and on going research activities of each Team members that were financially supported by various sources.

REFERENCES

Cirmo, C. P. and McDonnell, J. J. 1997. Linking the hydrologic and biogeochemical controls of nitrogen transport in near-stream zones of temperate-forested catchment: a review. *J. Hydrol.*, 199: 88-120.

Hubbard, R. K., Erickson, A. E., Ellis, B. G. and Wolcott, A. R. 1982. Movement of difuse source pollutants in small agricultural watersheds of the Great Lake Basin. J. Environ. Qual.,11: 117-123.

Menzel, R. G., Rhodes, E. D., Olness, A. E. and Smith, S. J. 1978. Variability of annual nutrient and sediment discharges in runoff from Oklahoma cropland and rangeland. J. Environ. Qual.,7: 401-406.

Mulholland, P. J. and Hill, W. R. 1997. Seasonal patterns in streamwater nutrient and dissolved organic carbon concentrations: Separating catchment flow path and in-stream effects. Water Resour. Res., 33: 1297-1306.

Tanaka, T. (2008). Proceedings of Int'l Workshop on Integrated Watershed Management for Sustainable Water Use in a Humid Tropical Region, Tsukuba-Japan, 31 October, 2007. Bulletin of TERC, University of Tsukuba, No.8 Supplement No.2. 78p.

Walton, R. S., Volker, R. E., Bristow, K. L. and Smettem, K. R. J. 2000. Solute transport by surface runoff from low-angel slopes: theory and application. Hydrol. Process., 14: 1139-1158.