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Correlation Between Water Quality and Land Use Change in Ciliwung Watershed

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ABSTRACT

Due to the change of land use, Ciliwung watershed suffered from physical degradation. Considering the increasing land use change along the Ciliwung watershed, it was necessary to perform a research on land use change and its impact on the river water quality (BOD, COD, DO). The land-use forms were divided into six categories: waterbody, bareland, forest, built-up area, agriculture and paddy field. The level of correlation was measured by Pearson correlation. The change of land use of waterbody, bareland, forest, built-up area and dry land agriculture influenced the river water quality. Waterbody had positive effect on water quality, while bareland and built-up area had a negative effect on water quality.

INTRODUCTION

Ciliwung is the biggest river flowing in Jakarta. It is 119 km long with a catchment area of 476 km^2. It flows from upstream Bogor Regency and crosses Bogor City, Depok City and Jakarta, finally reaching the Java Sea through Jakarta Bay (Permatasari et al. 2017). Administratively, Ciliwung watershed is divided into several segments including Bogor Regency, Bogor, Depok and Jakarta. The source of Ciliwung watershed is the Mount Gede Pangrango Bogor, West Java province. Watershed is highly influenced by the presence of several land uses, human settlement and industry along the watershed. Hence, these factors can pollute rivers, which then could be characterized by a decrease in water quality. Also, the changing patterns of land use to agriculture and settlement and increased industrial activity has an impact on the hydrological conditions in a watershed (Djadjadilaga et al. 2013, Effendi et al. 2015, 2016, 2017, Sun et al. 2014, Zhao et al. 2015). In addition, chemicals such as herbicides, pesticides, etc. from agriculture, that are carried by river flow also influence the decrease in water quality (Allam et al. 2015, Effendi 2003). The aim of this work is to study the effect of changes in land use to the water quality of Ciliwung watershed.

MATERIALS AND METHODS

Ciliwung watershed was divided into seven administrative regions, including Bogor regency, Bogor city, Depok, East Jakarta, South Jakarta, Central Jakarta and North Jakarta (Ali et al. 2016) with 8 sampling points (Fig. 1 and Table 1). The assessed water quality data were in the form of time series data in 2011 and 2014 derived from Ministry of Environment and Forestry, Indonesia. These data would be used to compare the water quality and land cover change effect from 2011 and 2014. Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO) were selected as the key water quality parameter indicators.

Satellite data image (Landsat TM/ETM in 2011 and 2014) were used to determine the condition of land use at the sites. These digital image data were obtained from the USGS (United States Geological Survey). Erdas Imagine 9.2 (ERDAS Corporation, USA) was used to analyse the land use change in the area of Ciliwung. The land-use forms were divided into six categories: waterbody, bare land, forest, built-up area, agriculture and paddy field.

SPSS was applied to analyse the land use and water quality status. The dependent variables were water quality parameters, and the independent parameters were the six types of land use. The degree of correlation was measured by Pearson correlation (Seebongruang 2012) with significance value (Sig. 2-tailed).

On the other hand, to analyse the influence of land use on water quality, multiple linear regression analysis was selected. The method for incorporating parameters was a

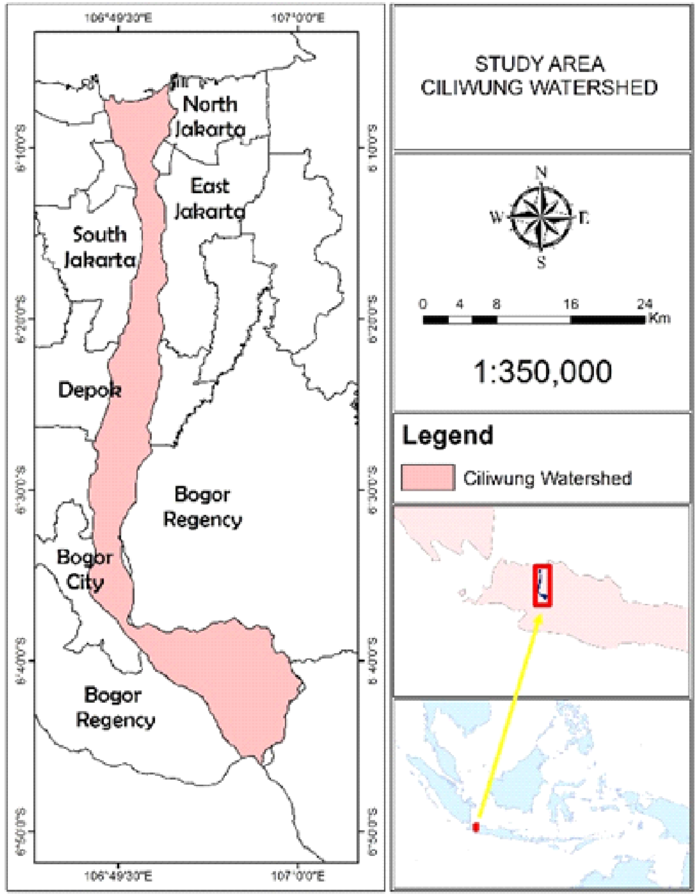

Fig. 1: Location of study area in Ciliwung Watershed.

stepwise method; this method used the probability of F as criteria for selecting independent parameters. To test the accuracy of the regression model, represented by the coefficient of determination (R^2) value between 0-1, principally, the value > 0.5 had a very strong correlation (Seebonruang 2012). If both variables had normal distribution and linear correlation, then the functional relationship was described as follows:

$$Y = \alpha + \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_k X_k + \varepsilon i \quad ...(1)$$

Where, Y = Water quality parameter (mg/L), α = Constant, $\beta_1 - \beta_6$ = Regression coefficient, X_1 = Waterbody, X_2 = Bareland, X_3 = Forest, X_4 = Built-Up Area, X_5 = Dryland Agriculture, X_6 = Paddy Field, εi = Disturbance error

RESULTS AND DISCUSSION

As presented in Table 2, the average concentration of DO from eight sampling points ranged between 0.8 and 7.1 mg/L. The mean concentrations of BOD from eight points of sampling ranged between 1.7 and 15.1 mg/L. The mean concentration of COD from eight sampling points ranged from 6.9-59.6 mg/L. The mapping of land use based on the classification results can be seen in Figs. 2 and 3, while the area of each land use can be seen in Table 3.

The biggest landuse surrounding the Ciliwung watershed area is dryland agriculture and constructed built-up area. Dryland agriculture occupied 36.59% of the total area in 2011 (Fig. 2). The decline in dryland farming area occurred in 2014, which amounted to 66.6 ha (Fig. 3). Built-up area as the second largest landuse area increased from 2011 to 2014 occupying 27.9% of the total area. This built-up area increase was due to the decrease of dryland agriculture. The decline of dryland agriculture was highly related to dryland agriculture conversion into a built-up area. In 2011, the paddy fields had quite wide area, which was 151213.7 ha (20.4%) with no increase or decrease in the area until 2014. In 2011, the waterbody area was 17661.4 ha, but it decreased to 17645.6 ha in 2014. On the other hand, the wide open land increased in 2014, amounted to 280.6 ha.

Dissolved oxygen (DO): The result of correlation analysis on the change of land use by using DO concentration showed

Table 1: Ciliwung watershed sampling points.

	Sampling Point	Latitude	Longitude
1	Atta'awun	06°41'56.2"	106°59'14.5"
2	Katulampa	06°37'59.7"	106°50'12.6"
3	KedungHalang	06°33'54.4"	106°48'29.5"
4	PondokRajeg	06°26'43.7"	106°48'46.2"
5	JembatanPanus	06°24'02.4"	106°49'54.3"
6	KelapaDua	06°20'56.2"	106°50'18.2"
7	Condet	06°17'34.2"	106°51'12.5"
8	Manggarai	06°12'45.7"	106°51'28.0"

Source: Ministry of Environment and Forestry, Indonesia (2015)

Table 2: Water quality parameters along Ciliwung watershed during 2011 and 2014.

Sampling Point	Parameters (mg/L) BOD (QS=3)		COD (QS=25)		DO (QS=4)	
	2011	2014	2011	2014	2011	2014
1	5.0	8.1	59.6	38.6	7.1	5.2
2	1.9	12.2	23.7	30.0	6.5	5.0
3	2.6	11.3	7.5	26.5	6.1	4.8
4	3.0	7.0	12.2	22.8	5.8	4.6
5	1.7	15.1	6.9	26.8	6.5	4.6
6	14.5	6.7	50.8	41.0	4.8	5.3
7	10.0	7.4	40.0	46.6	4.3	4.3
8	14.4	8.3	46.7	41.0	0.8	3.2
Mean	6.6	9.5	30.9	34.2	5.3	4.6

Source: Ministry of Environment and Forestry, 2015, QS = Quality standard referring to class II (GR 82/2001)

Table 3: Land use change of Ciliwung watershed between 2011 and 2014.

Land Use	2011		2014	
	ha	%	ha	%
Waterbody	17661.4	2.38	17645.6	2.38
Bareland	1391.3	0.19	1671.9	0.23
Forest	93364.1	12.59	93099.3	12.56
Built-up area	206496.4	27.85	206563.0	27.86
Dryland agriculture	271252.2	36.59	271185.5	36.58
Paddy field	151213.7	20.40	151213.7	20.40
Total area	741379.05	100	741379.05	100

Table 4: Correlation analysis between DO and land use change.

	Y	Waterbody	Bareland	Forest	Built-up area	Dryland agriculture	Paddy field
Y Pearson correlation	1	1.0*	-1.0*	1.0*	-1.0*	1.0*	NA[a]
N	2	2	2	2	2	2	2

*Correlation is significant at the 0.01 level (2-tailed); a. Cannot be computed because at least one of the variables is constant.

Table 5: Coefficient regression of land use change and DO.

Model	R^2	Unstandardized Coefficients		Standardized Coefficients
1	1.0	B	Std. Error	Beta
(Constant)		-676.963	.000	
Waterbody		.039	.000	1.0

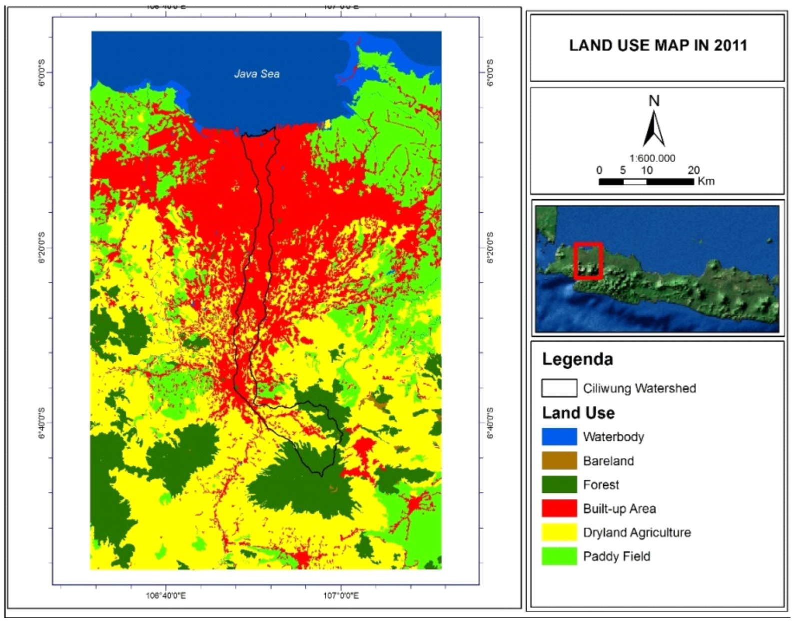

Fig. 2: Land use map of Ciliwung watershed in 2011.

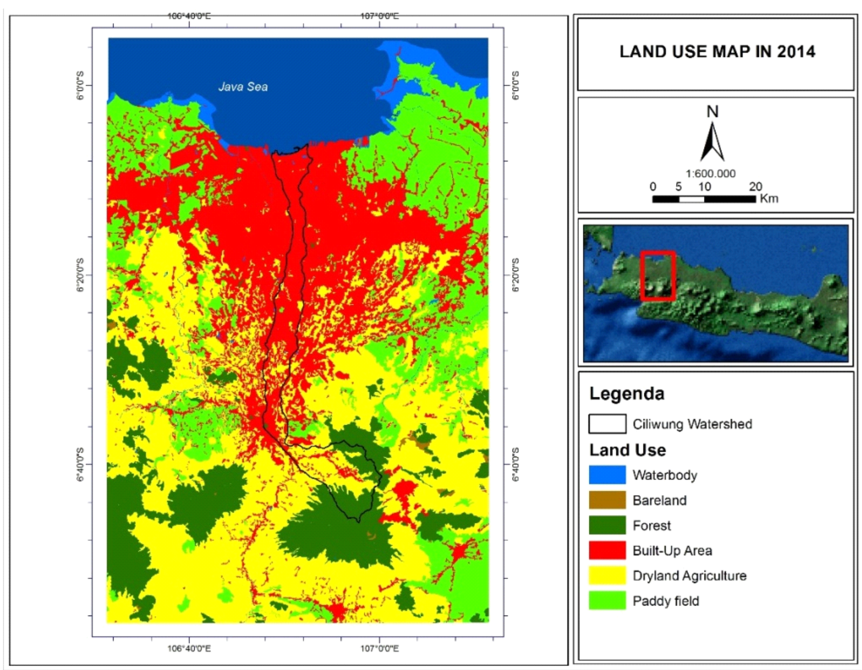

Fig. 3: Land use map of Ciliwung watershed in 2014.

that there were five types of land uses with correlation value (Table 4). Bare land and built-up area had negative or upside-down correlation with DO. This meant that with wider built-up area, DO concentration would decrease. The change of built-up area likely influences DO (Xizhi et al. 2017). The disposal of wastewater in large quantities would influence the balance of oxygen level (Gyawali et al. 2013). Waterbody had strong influence towards the fluctuation of DO with the functional relation of DO (mg/L) = -676.963 + 0.039 waterbody (Table 5). This equation was used to predict the change of waterbody area (Table 6).

As its functional relation showed, the minimum limit of waterbody area allowed was 17460.6 ha, resulting in DO concentration of 4 mg/L (quality standard referring to class

Table 6: Simulation of the influence of waterbody area towards DO concentration.

Waterbody area (ha)	DO Concentration (mg/L)
17434.9	3
17460.6	4.0
17510.2	5.9
17537.5	7
17588.8	9
17614.2	10
17645.6	11.2

II on GR 82/2001). The existing condition of waterbody area in 2014 was 17645.6 ha, in which predicted DO concentration should be 11.2 mg/L (Table 6). However, this DO concentration is not in line with the existing DO in the river. Other variables could also contribute and play a crucial factor on the river water quality characteristic, for instance industrial number, type and intensity.

Biochemical oxygen demand (BOD): Waterbody, forest, and dryland agriculture had inversely proportional relation with the fluctuation of BOD. On the other hand, bareland and built-up land had positive correlation with the fluctuation of BOD (Table 7). Different types of land uses release different organic wastes through run off, for instance bareland and built-up release much organic waste (Davis & Cornwell 1991). The number of residential areas or settlements along the river highly contributed on the increase of COD. High population density will cause high emission intensity and tends to increase the concentration of nutrients flowing into the river and reduced water quality (Xizhi

Table 7: Correlation analysis between BOD and land use.

	Y	Waterbody	Bareland	Forest	Built-up area	Dryland agriculture	Paddy field
Y Pearson Correlation	1	-1.0*	1.0*	-1.0*	1.0*	-1.0*	NA[a]
N	2	2	2	2	2	2	2

*Correlation is significant at the 0.01 level (2-tailed); a. Cannot be computed because at least one of the variables is constant.

Table 8: Regression coefficient of land use change on BOD.

Model	R^2	Unstandardized Coefficients		Standardized Coefficients
1	1.0	B	Std. Error	Beta
(Constant)		-7.69	.00	
Bareland		.01	.00	1.0

Table 9: Simulation of water body influence area towards BOD.

Bareland area (ha)	BOD Concentration (mg/L)
1069	3
1269	5
1469	7
1671.9	9
1869	11
1969	12

Table 10: Correlation between COD and land use change.

Y		Waterbody	Bareland	Forest	Built-up area	Dryland agriculture	Paddyfield
Y Pearson Correlation	1	-1.0*	1.0*	-1.0*	1.0*	-1.0*	NA[a]
N	2	2	2	2	2	2	2

* correlation is significant at the 0.01 level (2-tailed); a. Cannot be computed because at least one of the variables is constant.

Table 11: Regression coefficients of land use change towards COD.

Model	R^2	Unstandardized Coefficients		Standardized Coefficients
1	1.0	B	Std. Error	Beta
(Constant)		3654.435	.000	
Waterbody		-0.205	.000	1.0

Table 12: Simulation of the influence of waterbody area towards COD concentration.

Waterbody area (ha)	COD concentrations (mg/L)
17645.5	37
17655.8	35
17680.1	30
17694.8	27
17704.5	25

et al. 2017).

The functional relation of land use change and BOD could be seen in Table 8. Bareland had strong impact on the fluctuation of BOD, with functional relation of BOD (mg/L) = -7.69 + 0.010 bareland (Table 8). This equation was used to predict the limits of bareland area allowed in the watershed area (Table 9). The maximum bareland allowed was 1969 ha, resulting in the maximum BOD concentration of 12 mg/L (quality standard referring to class IV on GR 82/2001) (Table 9).

Chemical oxygen demand (COD): Waterbody, forest and dryland agriculture was inversely proportional to COD, whereas, bareland and built-up area positively correlated to the fluctuation of COD (Table 10). Increase of built-up area will affect the increase of COD. High level of COD in all monitoring sites was likely to be influenced by the urban areas along Ciliwung watershed.

Waterbody influenced COD with the functional relation of COD (mg/L) = 3654.435 – 0.205 waterbody (Table 11). This equation was used to predict the limits of waterbody area allowed in the watershed area (Table 12).

The minimum limit of waterbody area allowed was 17704.5 ha, with COD maximum of 25 mg/L (quality standard referring to class II on GR 82/2001) (Table 12).

CONCLUSION

Change of land use in waterbody, bareland, forest, built-up area and dryland agriculture had an impact on the water quality parameters. Waterbody had positive effects on water quality, while bareland and built-up area had negative effects on the water quality. This result could be used to guide the policy decision of land use changes and water quality status of Ciliwung watershed.

ACKNOWLEDGEMENTS

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REFERENCES

Ali, M., Hadi, S. and Sulistyantara, B. 2016. Study on land cover change of Ciliwung downstream watershed with spatial dynamic approach. Procedia-Social and Behavioral Sciences, 227: 52-29.

Allam, A., Fleifle, A., Tawfik, A., Yoshimura, C. and El-Saadi, A. 2015. A simulation-based suitability index of the quality and quantity of agricultural drainage water for reuse in irrigation. Science of the Total Environment, 536: 79-90.

Davis, M.L. and Cornwell, D.A. 1991. Introduction to Environmental Engineering. 2nd Edition, McGraw-Hill Int. Singapore.

Djadjadilaga, M., Sigit, H. and Tejalaksana, A. 2013. From data to policy (Ciliwung River water quality management). Environment Ministry of Republic of Indonesia. Jakarta.

Effendi, H. 2003. Telaahkualitas air. Kanisius, Jogjakarta, 258 pp. (In Indonesian).

Effendi, H. Romanto and Wardiatno, Y. 2015. Water quality status of Ciambulawung River, Banten Province, based on pollution index and NSF-WQI. Procedia Environmental Sciences, 24: 228-237.

Effendi, H. 2016. Evaluation of water quality status of Ciliwung River based on pollution index. Proceedings IAIA 16 Nagoya, 11-14 May 2016. Japan.

Effendi, H. 2017. River water quality preliminary rapid assessment using pollution index. Procedia Environmental Sciences, 33: 562 -567.

Gyawali, S., Techato, K., Monprapussorn, S. and Yuangyai, C. 2013. Integrating land use and water quality for environmental based land use planning for U-Tapao river basin, Thailand. Procedia-Social and Behavioral Sciences, 91: 556-563.

Permatasari, P.A., Setiawan, Y., Khairiah, R.N. and Effendi, H. 2017. The effect of land use change on water quality: A case study in Ciliwung watershed. IOP Conference Series: Earth and Environmental Science, 54: 012026

Seebonruang, U. 2012. A statistical assessment of the impact of land uses on surface water quality indexes. Journal of Environmental Management, 134-142.

Sun, Y., Doan, C.D., Dao, A.T., Liu, J. and Liong, S. 2014. Improving numerical forecast accuracy with ensemble kalman filter and chaos theory: Case study on Ciliwung River model. Journal of Hydrology, 512: 540-548.

Xizhi, L., Jing, H., Peiqing, X., Pan, Z. and Hui, J.X. 2017. Correlation analysis between the water quality and land use composition in Chaobai River basin. Nature Environment and Pollution Technology, 16: 307-314.

Zhao, J., Lin, L., Yang, K., Liu, Q. and Qian, G. 2015. Influences of land use on water quality in a reticular river network area: A case study in Shanghai, China. Landscape and Urban Planning, 137: 20-29.