Water quality of Cisadane River based on watershed segmentation

Hefni Effendi[1,2*], Prita Ayu Permatasari[1], Sri Muslimah[1], Mursalin[2]

[1] Environmental Research Center, Bogor Agricultural University, Bogor 16680, Indonesia
[2] Department of Water Resource Management, Faculty of Fisheries and Marine Science, Bogor Agricultural University, Bogor 16680, Indonesia

E-mail: hefni_effendi@yahoo.com

Abstract. The growth of population and industrialization combined with land development along river cause water pollution and environmental deterioration. Cisadane River is one of the river in Indonesia where urbanization, industrialization, and agricultural are extremely main sources of pollution. Cisadane River is an interesting case for investigating the effect of land use to water quality and comparing water quality in every river segment. The main objectives with this study were to examine if there is a correlation between land use and water quality in Cisadane River and there is a difference in water quality between the upstream section of Cisadane River compared with its downstream section. This study compared water quality with land use condition in each segment of river. Land use classification showed that river segment that has more undeveloped area has better water quality compared to river segment with developed area. in general, BOD and COD values have increased from upstream to downstream. However, BOD and COD values do not show a steady increase in each segment Water quality is closely related to the surrounding land use.Therefore, it can not be concluded that the water quality downstream is worse than in the upstream area.

1. Introduction

River is an important natural features of ecological life and really related with human activities such as industry, agriculture, and others [1]. Some of important function of river include the transport of deposits and nutrients that support biological community [2]. Rivers and other water bodies have own an important function for urban water resource and waste disposal. This role has changed over time during urban development [3]. River provides many ecological service functions for human life such as water source, ecological protection, etc. It also socially, economically, and environmentally provide urban area life [4].

Since 2008, most of of the world's population lives in urban area and it is estimated only one-third of the world's population lives in rural areas [5]. Population growth and an increase of human activities along watershed lead to an increased water pollution and environmental damage [6]. Nowadays, urbanization has caused some significant changes in watershed. Some of drainage system in the cities has been altered by human through channelization, containment, diversion, and burial [7]. Previous study also found the effect of urban development to rivers as well as to the effects of urban development on landscapes and river systems [8].

The amount of organic contamination which occurs due to high populations of microorganisms, has typically been monitored by Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) testing methods. A high level of BOD decreases river water quality due to decomposition of biodegradable organic matter that can be biologically oxidised, while COD represents organic compounds can be chemically oxidised than biologically oxidised [9]. Human economic activities such as animal husbandry and agriculture play higher position in supplying pollution of river water compared to others pollutants [10]. Wastewater of animal husbandry contains high concentrations of organic and inorganic nitrogen compound, pathogenic bacteria, and ammonia nitrogen [11]. In more rivers in urban areas, levels of phosphorus, sulfur, nitrogen, and other nonmetallic metals tend to be higher and affect the water quality [12].

Cisadane River is one of the river in Indonesia where urbanization, industrialization, and agricultural are extremely main sources of pollution. Cisadane River has a very important function as a source of raw water for the people of Bogor City. Cisadane River crosses several administrative areas ranging from Bogor Regency to Tangerang City with high urban activity that cause the river receives high enough pollutant load. Similar to Ciliwung River, Cisadane River is one of the main rivers in Jabodetabek area (Jakarta, Bogor, Depok, Tangerang and Bekasi) and has great influence for those areas. Cisadane River is an interesting location for examining the effect of land use to water quality and comparing water quality in every river segment.

2. Research method

2.1. Study area

Cisadane is a 138 km long river. The upstream of Cisadane River are coming from Gede-Pangrango and Salak Mountains and flow into Java Sea through Teluk Naga coastal waters. This river has some important role in agricultural, domestic, and industrial needs [13]. For convenience of analysis the river channels are divided into 7 segments. Segments were delineated beginning at upstream to the end of downstream of the stream reach of Cisadane River watershed through some administrative areas such as Bogor Regency, Bogor City, South Tangerang City, Tangerang Regency, and Tangerang City. In this study only 6 segments that will be discussed since there is no data availability in 7th segment. River segmentation from segment 1-6 based on administrative area can be seen in table 1 and map of study location can be seen in figure 1.

Table 1. River segments based on administrative area.

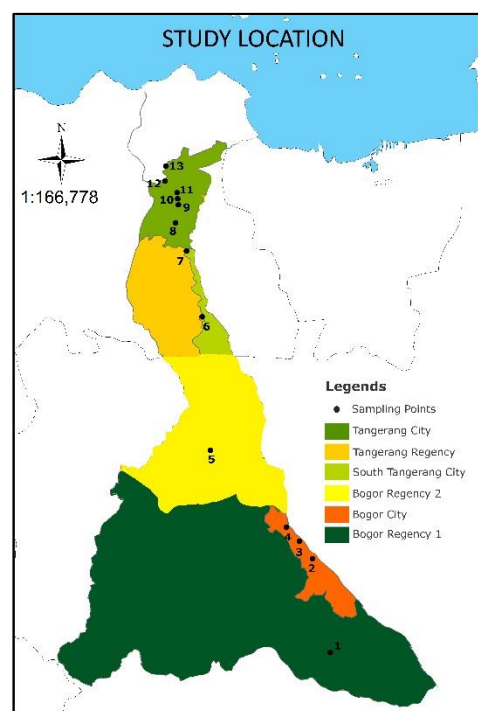| Segment Code	Description
1	Bogor Regency 1
2	Bogor City
3	Bogor Regency 2
4	South Tangerang City
5	Tangerang Regency
6	Tangerang City

Figure 1. Map of study area.

2.2. Analytical methods

The thirteen location were sampled along the primary downstream segment of Cisadane River. Water sampling was conducted in rainy season (April) and dry season (September) in 2014. Water quality data consists of BOD and COD are measured and studied along these segments. These two variables were

selected because they provide an index to measure the effect discharged wastewater on environment. The 13 sampling points will be grouped and averaged according to their segment. Sampling data will be used to relate the water quality and land cover in each segment of Cisadane River. Water quality data were attained from Ministry of Environment and Forestry Republic Indonesia. Sampling points location on Cisadane River can be seen in figure 1.

2.3. Spatial analysis

This research was using 30 m resolution of Landsat Thematic Mapper (TM) satellite imagery 2014. This data was attained from Indonesian Planology Agency. The land use classes were produced using a supervised classification technique with a maximum likelihood algorithm in the Erdas Imagine 9.2 (ERDAS Corporation, Norcross, GA, USA). The Landsat images has been corrected using aerial photographs and field survey data. Interpretation accuracy of the land use categories reached 88% according to the field survey (i.e., 85% more accurate than a random classification) [14]. The land use classes were classified into five groups: built area, bare land, agricultural land, forest, and water body. Built area consists of settlement and airport. Bare land consists of abandoned area and mining area. Agricultural land consists of plantation, rice field, shrubs, and secondary crops field. While water bodies including lake and pond.

3. Result

3.1. Land use classification on each river segment

Cisadane Watershed are grouped into five classes: built area, forest, agricultural land, water bodies, and bare land. These five classes are representatives of the actual landscape in the study region and could be determined using a moderate resolution Landsat image. Land use classification from segment 1-6 can be seen in figure 2 and table 2.
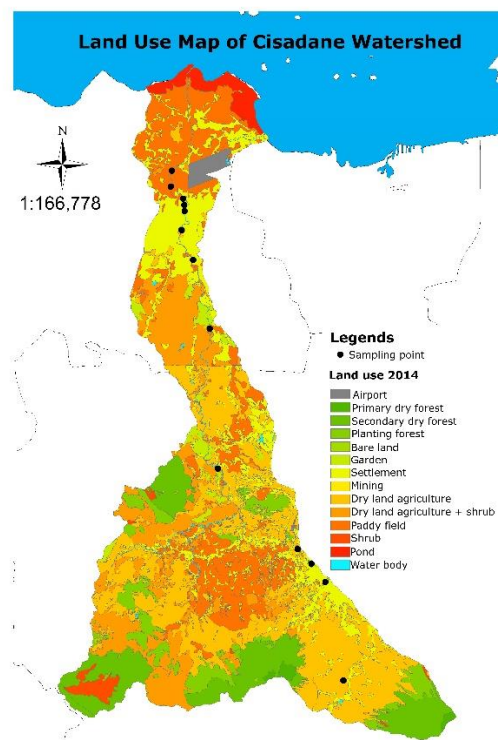

Figure 2. Land use map of Cisadane Watershed.

Table 2. Land use classification on segment 1-6 Cisadane River.

Segment	Land use	Total Area (Ha)	Percentage
1. Bogor Regency 1	Forest	6,662	32.8%
	Agricultural Land	12,431	61.2%
	Built area	1,188	5.9%
	Water bodies	26	0.1%
	Total	**20,307**	**100.0%**
2. Bogor City	Forest	109	2.2%
	Agricultural Land	2,176	44.1%
	Built area	2,649	53.6%
	Water bodies	5	0.1%
	Total	**4,939**	**100.0%**
3. Bogor Regency 2	Forest	19,453	22.4%
	Agricultural Land	58,754	67.8%
	Built area	7,922	9.1%
	Water bodies	559	0.6%
	Bare land	30	0.0%
	Total	**86,718**	**100.0%**
4. South Tangerang	Forest	-	0.0%
	Agricultural Land	1,563	55.8%
	Built area	1,156	41.3%
	Water bodies	83	3.0%
	Total	**2,802**	**100.0%**
5. Tangerang Regency 1	Forest	-	0.0%
	Agricultural Land	9,526	78.5%
	Built area	2,521	20.8%
	Water bodies	91	0.7%
	Total	**12,138**	**100.0%**
6. Tangerang City	Forest	-	0.0%
	Agricultural Land	1,849	21.9%
	Built area	6,488	76.7%
	Water bodies	118	1.4%
	Total	**8,455**	**100.0%**

Table 2 show that in the segment 1 the built area has a smaller area than the forest, agriculture, and water bodies. The amount of built area is quite high in segment 2 considering the urban activity in Bogor City is higher than the upstream river area in Puncak. In segment 3, agricultural land dominate the area and while built area is less than 10%. In segment 4, built area has a fairly high amount even though the agricultural area still dominates the segment. In segment 5, the number of built areas decreases and agricultural land still dominates the segment. In segment 6, built area dominates land use. In the last three segments of the study area there was no forest area in land use classification. This is due to the higher economic activity in the downstream area, which requires more land to be built than open areas.

3.2. Water quality

According to Government Regulation No. 82/2001, the water quality classification in Indonesia includes four quality classes based on its designation:

Table 3. Water quality of classification in Indonesia.

Class	Designation	Standard (mg/L)	
		BOD	**COD**
I	Drinking water	2	10
II	Water recreation facilities	3	25
III	Freshwater fish farming and husbandry	6	50
IV	Crops irrigation	12	100

Based on its allocation for drinking water source, the water quality of Cisadane River should be in class II. Based on BOD measurements in each segment, water quality in Cisadane River for BOD and COD parameters is quite bad. BOD value in six segments range from 12-18 mg/L. BOD values in some segments are still suitable for class IV while others do not even meet the criteria of class IV. For COD parameters, segments 1-3 still meet class III criteria while the downstream area only meets the criteria of class IV (figure 3).
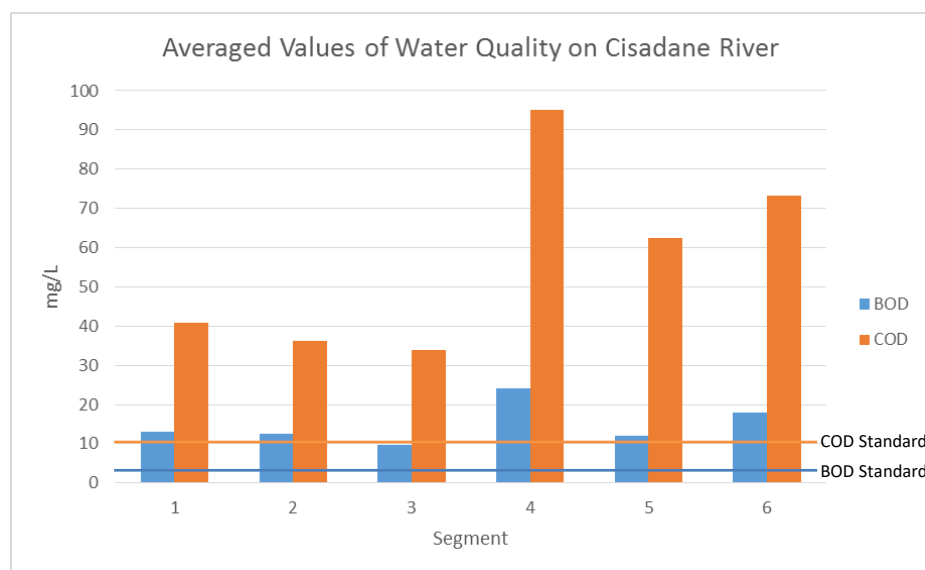

Figure 3. Averaged values of water quality on Cisadane River.

Water quality from upstream to downstream shows very fluctuate results. BOD and COD values from segment 1 to segment 3 show a decrease. In segment 4 both variables increase, then show a decrease in segment 5 and rise again in segment 6.

4. Discussion

4.1. Land use effect on water quality

Undeveloped areas such as natural forest area has positive correlation with good water quality while developed area such as settlement and commercial area usually give negative impact on water quality [15]. Land use classification showed that river segment that has more undeveloped area has better water quality compared to river segment with developed area. The high value of BOD in each segment shows the high development along the river. Tu *et al.* [16] explained that BOD had a significant positive

correlation with developed areas such as residential and commercial lands. Huang *et al.* [17] also said that the areas of the forest land and grassland has negative correlation to COD. Thus, development areas in Cisadane River really give negative impact on water quality.

4.2. Water quality differences in upstream and downstream area
Based on figure 3, in general, BOD and COD values have increased from upstream to downstream. However, BOD and COD values do not show a steady increase in each segment. A study of water quality differences in upstream and downstream has been conducted before. The study revealed that upstream and downstream water qualities of River Tano in Ghana, do not differ much in terms of temperature, pH, sulphide, sulphate, ammonia, nitrite, manganese, and total alkalinity [18]. Water quality is closely related to the surrounding land use. Therefore, it cannot be concluded that the water quality downstream is worse than in the upstream area.

5. Conclusion
This study showed that developed area was positively correlated to the deterioration of water quality, While, forest, agricultural area, and water area were negatively correlated to the deterioration of water quality. While, segment location doesn't affect water quality. Based on these results, it is necessary to increase the area of green open space (forest and agricultural land) and water body in the local land use planning of Cisadane Watershed. It is therefore recommended that the relevant stakeholders should come together to enforce the environmental laws regarding protection of water bodies.

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