A Spatiotemporal Analysis of Water Quality and Land Use in Tambayakbayan River, Yogyakarta

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Abstract. The Special Region of Yogyakarta is one of the areas that experienced a fairly high population growth rate and is directly proportional to the rate of development which has an impact on land use, especially in Tambakbayan watershed. This study aims to identify the types of land use that affected water quality of the Tambakbayan River using spatiotemporal analysis and Pearson correlation methods. Land use in Tambakbayan watershed is divided into three segments which are vegetation (VA), agriculture (AG), and building (BU). This study used water quality data from the Environmental Agency of Yogyakarta Province which consists of 14 parameters, i.e., pH, TDS, TSS, DO, BOD, COD, nitrate, nitrite, total phosphate, Zn, Cu, Pb, E. coli, and total coli. Landsat 8 image data from 2013 to 2020 is used from USGS. The result of this study found that vegetation has no correlation on Tambakbayan River water quality. However, agriculture and building areas significantly affected the decreasing water quality of the Tambakbayan River.

1. Introduction

Water quality influenced by land use has been a concern since the 1970s. Initially by a study about correlations between water quality and different land-use types in the watersheds was done by Shi et al [1]. It was specifically known that watershed hydrology depended on many factors in the region itself. Those factors included land use, climate, and soil condition [2]. As an example, in Africa continent consist of 30% land-rocks, urbanization and agriculture were the most important environmental factors influencing the basin water resources, with evapotranspiration playing a dominant role [3]. Besides, the river basin of Northwest China reported that land-use changes have been dominated by the expansion of grassland and the decrease of farmland [4]. Nevertheless, it generated slight decreases in surface runoff, groundwater discharge, and streamflow, whereas climate changes cause significant increases in it. In Indonesia, Indriyani et al. [5] discovered BOD and COD loading from residential areas affected by poor water quality on the Ciracab River. Those findings were related to Camara et al [6], the degradation of water quality is affected by urban development, agriculture activities, and deforestation. That result is obtained from monitoring of several parameters such as pH, turbidity, dissolved oxygen (DO), conductivity, salinity, E. coli, cadmium (Cd), copper (Cu), lead (Pb), and mercury (Hg).

Furthermore, Yogyakarta (DIY Province), a special region in Indonesia, is well-known as a student and tourism city, with thousands of visitors coming and going each year. The increase of students corresponds to the rising in the number of boarding houses, around 33% on average each year based on
data from one of Yogyakarta public universities. In 2018, DIY Province had 143-star hotels and 1,475 non-star hotels [7]. Moreover, the Indonesian government wants to make Yogyakarta as a leading tourism destination in Southeast Asia [8]. To fulfill that, Yogyakarta increased in the rate of growth also followed by positive and negative effects. One of the negative effects is the decreasing river water quality. According to the Ministry of Environment and Forestry of the Republic of Indonesia [9], Opak River, the hugest watershed in Yogyakarta, was determined as priority watershed area compiled in the middle-term development plan between 2010 and 2014. Furthermore, Opak River watershed becomes one of the pivotal water resources including the restoration efforts, such as physical or social-economic aspects. Opak watershed has sub-watershed whose existence is quite important for natural balance in Yogyakarta Province, such as Gajawahong River, Code River, Winongo River, Tambakbayan River, and so on. By comparing Code and Winongo River, Tambakbayan River owns the equal role as an initial sub-watershed, unfortunately, the study of water quality regarding Tambakbayan River is still limited.

Several previous studies investigated the correlation between river water quality and land use. For example, Suharyo and Hamid [10], [11] investigated the water quality of the Opak watershed and discovered that chemical and microbial parameters had a positive relationship between land use. Munawar [12] conducted a comprehensive and multi-analysis study on Code River using spatial data, water quality analysis, and economic analysis. In addition, Kudubun et al. [13] investigated the type of vegetation along the river that affects to river water quality and found qualitatively land use and pollutant sources have a direct influence on water quality. On the other hand, a few studies have employed an integrated approach involving the use of statistical and spatiotemporal analysis to examine the effects of land use on water quality. Wardhana [13] imaged sediment transportation and model of Opak River applying the HEC-RAS 4.1.0 program, but no support about the statistical method. Then, the utilizing multivariate analysis and spatiotemporal on water quality and land-use change in Yogyakarta were initiated by Pratama et al. [14] for monitoring Code River. As substantial as other rivers in Yogyakarta, Tambakbayan River is specified and crossed two main of Yogyakarta regions, i.e., Sleman Regency and Bantul Regency, and is used for water drinking resources, irrigation, fish farming, and many so on. The correlation between land use and water quality analyzed through a multivariate and spatiotemporal method in Tambakbayan River is valuable needed. This research would be important, and it can be used as consideration for the Yogyakarta Province government decision making to manage the land use along to watershed.

2. Materials and Methods

2.1 Study Area
The Tambakbayan River is one of the Opak watersheds in the Special Region of Yogyakarta. According to an environmental management report [15], the river flows from the slopes of Mount Merapi. This river length is 27.68 km with 27.5 meters as the width of surface river and 9 meters of a base width, and 2.05 meters average depth. The water flows possessed between 0.5 and 3.15 m³/s. It can be seen in Figure 1, Tambakbayan River flows upstream through Sleman Regency and then downstream in the Opak River in Bantul Regency. Tambakbayan river is divided into three segments which are upstream, middle stream, and downstream (Figure 1). The upstream watershed starts from Mount Merapi to the SP1 as the first sampling point at Plosokuning Bridge, Sleman Region. In the upstream of a watershed, land use is dominated by vegetation and agriculture. The middle watershed starts from the SP1 to the second sampling point, SP2, at Jayakarta Bridge and the third sampling point, SP3, at Sekarsuli Bridge, Sleman Region. The middle stream covered area consists of building areas mainly. Then, downstream watershed starts from the SP3 to the last sampling point, SP4, at Tempuran Bridge, Bantul Region. The bridge over the river is chosen to facilitate access to the sampling and monitoring.
2.2 Spatiotemporal and statistical analysis

In this study, river water quality data was obtained from the Environmental Agency (DLHK) Yogyakarta Province from 2013 to 2020. The data included 14 parameters such as pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nitrate, nitrite, total phosphate, Zn, Cu, Pb, *E. coli*, and total coliform. It was taken at four different sampling points, SP1 to SP4. Sampling was held three times a month which is in February, May, and October. For compiling temporal data, the water quality of Tambakbayan River was presented into a box plot in both wet and dry seasons. For this study, the peak study of wet season (or rainy season) was in February and the peak of dry season was in October.

The spatial data was created using Landsat 9 on (a scale of 1:250,000) that was obtained from the United States Geological Survey (USGS) website for 2013 to 2020. According to Indonesian National Standard SNI 7645-1:2014 about Land Cover Classification, land use was determined three land use categories, i.e., Vegetation (VA), Building (BU), and Agriculture (AG). The percentage of land use is shown in Table 2. Data processing used ArcGIS 10.8 software through employing an interactive supervised classification. It was classified by approaching based on the colour of Landsat and the area of each category will be shown in the attribute table tool. In the 1970s, the scientist has been used various types of remote sensing data acquired by the Landsat series satellites and they classified them into several categories [16].
For multivariate analysis, the raw water quality data was transformed into multivariate normal data using the two-step transformation data normalization approaching employing software IBM SPSS Statistics 22. Then, the proportion of land use was collected for 7 years and was presented by a grouping of land use each year. A Pearson correlation coefficient was used to quantify the relationship between land use and water quality. Pearson correlation was appropriate for normally distributed data whereas others, such as Spearman and Kendall-tau were not regularly distributed.

3. Results and Discussions

3.1. Spatiotemporal analysis of Tambakbayan River

In general, data trends of Tambakbayan River water quality are measured by mean, median, and average by box plot. The parameters of Tambakbayan River water quality are divided into two trend data: spatial and temporal trends. Temporal trends can be grouped into wet Season and dry Season. Meanwhile, spatial trends are grouped into an upstream, middle stream, and downstream watershed. The water quality characteristics are divided into two seasons, wet and dry, based on the temporal trend analysis from 2013 to 2020.

Figure 2. The temporal trends of water quality in Tambakbayan River
It can be seen in Fig. 2 that several parameters in the wet season were higher than the dry season such as Dissolved Oxygen (DO), nitrate, nitrite, and microbial parameters. The finding was supported by finding from Munoz et al. [17] that rainfall has a positive correlation with DO. Aeration of the water body is enabled by rainwater entering the river, which increases the river current and speed flows. Consequently, the more oxygen dissolved in the water, the increased the oxidation process of organic matter, particularly for nitrogen elements. So that, the nitrification process produced nitrite and nitrate in the water body is also rising.

**Figure 3.** The spatial trends of water quality in Tambakayan River, i.e. (1) upstream, (2) middle stream, and (3) downstream

Furthermore, rainwater flowing through agricultural land and open landfills can carry pathogenic bacteria into bodies of water so that the amount of Total coli and *E. coli* inside the river tended to be high. Besides that, heavy metal parameters, such as Cu, Pb, and Zn increased in the dry season. Heavy metal concentrations were higher in the dry season than in the wet season. It might be caused by slower river flow in the dry season thus no dilution occurs in water body. Heavy metals are often suspended and accumulated easily in sediment and river water [18]. In addition, during the dry season, the river
Water discharge was fell which caused the decreasing depth of the river. Hence, the sediment at the river bottom was easily stirred up to the river surface. The finding was an assumption for high TSS levels during the dry season.

According to the average data of water quality, there is an increasing trend from upstream to downstream on several parameters, such as pH, TDS, BOD, COD, nitrate, Zn, Cu, Pb, E. coli, and total coli bacteria. Based on the location of the water quality sampling, S1 to S4, the majority of the parameters increased significantly. The increasing of those parameters generated concentration to exceed the water quality standard of DIY Province Number 20/2008. Most parameters rose significantly depending on the location of the water quality measurement. Align to the locations, the upstream area was still dominated by vegetation whereas the middle and downstream areas were dominated by buildings including housing or industries. The huge populations of fecal coli bacteria are strongly influenced by human activities [19]. High concentration of some parameters might be caused by human activities in domestic activities, industrial, agricultural which become the sources of pollution, both point and non-point sources along the Tambakbayan River. Those phenomena were supported by Nugraha [20] those anthropogenic activities in the rivers were the primary source of Zn contamination in bodies of water. Industrial and domestic wastes in the river basin were the biggest contributors to metal pollution in rivers. The decrease in water quality between upstream and downstream can also be seen from the decrease in DO concentration. Dissolved Oxygen has an important role as an indicator of water quality because it plays a role in the oxidation and reduction of organic and inorganic materials [21].

3.2 Correlation of land use and water quality

Figure 4 shows the results of land use classification from 2013 to 2020 for the entire Tambakbayan River watershed. On the other side, generally the building category shows an increasing trend in 7 years. However, in 2017 it occupied 65.3% of the watershed area, while in 2018 the percentage decreased to 64.0%. The proportion of land use is shown in Table 1. Moreover, Fig. 4 also describes that the least development occurred in the upstream area correlated with a wild area on Mount Merapi, which is most likely due to relatively frequent eruptions. The proportion of land use category of agriculture and vegetation has increased and decreased as shown in Table 1 because during the classification process using ArcGIS software, the Landsat 8 data obtained was partly cloudy in the Mount Merapi area. So that, the results of land use mapping are not presented optimally. The increase and decrease in VA are also due to parks and green roof spaces in urban areas. In addition, reforestation also causes an increase in vegetation. Meanwhile, the fluctuation proportion of land use in the agricultural area was caused by vacant ex-agricultural land classified as building by Landsat satellite. In general, agriculture and vegetation have decreased due to development growth and population expansion in urban areas which increase every year from the total area of the Tambakbayan River watershed.
The correlation between land use and water quality were quantified by means of a Pearson correlation coefficient. This analysis has 0.707 as based-R significance. Thus, parameters own scores greater than 0.707 were categorized as significant parameters. A positive correlation means that if one variable moves higher or lower, the other variable moves in the same direction. According to Table 2, seven parameters that have a strong correlation with land use, those parameters are BOD, COD, total coli, E. coli bacteria, TDS, nitrite, and Cu. Based on those parameters, the parameters can be grouped into positive and negative correlations. Meanwhile, the negative correlation moves in different directions [22].

Table 1. Land use percentage from 2013 to 2020

| Year | Building | Vegetation | Agriculture |
|------|---------|-----------|-------------|
| 2013 | 39.8    | 19.2      | 41          |
| 2014 | 40.2    | 35.4      | 24.4        |
| 2015 | 47.6    | 10.2      | 42.2        |
| 2016 | 52.7    | 22.9      | 24.5        |
| 2017 | 65.3    | 4.1       | 30.6        |
| 2018 | 64.0    | 28.2      | 7.9         |
| 2019 | 69.2    | 17.8      | 13          |
| 2020 | 74.6    | 13.9      | 11.5        |

In general, all the positive correlations are regarded to the building area category. In upstream there is a strong positive correlation on Cu. That means if the larger the area, Cu will have a higher concentration. The source of Cu is suspected from domestic waste, electronic waste, and natural sources along upstream, for instance, the segregation of rocks releasing Cu into the water body. Otherwise, nitrite has a negative correlation with agriculture which means that the nitrite concentration will decrease as agricultural area increases. It assumed that the nitrite was converted to nitrate in nitrogen cycle rapidly.
Table 2. Pearson Correlation

| Water Quality parameters | Upstream | Middle stream | Downstream |
|--------------------------|----------|---------------|------------|
| BOD                     | BU 0.730 | VA 0.733      | AG -0.742  |
| COD                     |          |               | -0.726     |
| DO                      |          |               | 0.922      |
| TSS                     |          |               | -0.843     |
| Total coli              |          |               | 0.735      |
| E. coli                 |          |               | 0.847      |
| Total Phosphate         |          |               |            |
| pH                      |          |               |            |
| TDS                     |          |               | 0.773      |
| Nitrate                 |          |               |            |
| Nitrite                 |          |               | -0.744     |
| Zinc (Zn)               |          |               |            |
| Cuprum (Cu)             |          |               | 0.784      |
| Lead (Pb)               |          |               |            |

Next, in the middle stream, area there is a strong positive correlation in BOD and E. coli parameters. This result correlated with a significant building coverage area from upstream to midstream. Building area produces untreated domestic wastewater and it has become the main pollutant source in the water river [23]. Meanwhile, COD has a negative correlation with agricultural areas. It means that the larger area of agriculture will decrease the concentration of COD. It suggested that the coverage source such as agricultural area (AG) was not significantly affected to river water quality, specifically in the middle stream. The fact is in the midstream river is dominated by building area. In the downstream BOD, COD, Total coli bacteria, and TDS were positively correlated with building area. It was equal to spatial data that mapping of building area (BU) was increased from upstream to downstream. It shows that each segment has an accumulative effect. Thus, the pollutant in downstream river has the largest concentration than other segments.

4. Conclusions

To summarize, our findings show that utilizing spatiotemporal analysis and Pearson correlation, land use classified as VA (Vegetation) has a substantial relationship with water quality preservation. Contrary, agriculture land (AG) and building land (BU) have a significant impact on the Tambakbayan River's water quality degradation.

Acknowledgments

The member of surface and groundwater quality research, Ms. Suphia Rahmawati, Mr. Ergianzah Reezqiana Sihayuardhi, and Mr. Dhandhun Wacano, already had supervised and helped our research and completing the manuscript. We also sent our honour to Environmental Agency of Yogyakarta (DLH DIY) for supporting the secondary data.

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