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Input-Output Model of Nitrogen at the Rembangan River Caused by Fertilization on Coffee Plantations

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ABSTRACT

In general, agricultural wastes that pollute rivers are liquid wastes that come from the activity of plant fertilization. This waste is a type of non-point source of waste. One of macro elements contained in the fertilizer is Nitrogen. To keep the quality of water remain on the condition that is in accordance with its allocation will require efforts to manage river water quality and monitoring, one of them is by using water quality modeling of mass balance model of pollutant loads in river. The basic concept of this mass balance model is a calculation of how much load of fertilizer (N element) on the plant, how much load is going into the river as the load of pollutants in the river through surface runoff as well as how much load is dropped in river as a load of pollutant resulting from the fertilization events? The objectives of this research are to identify characteristics of types of pollutants in the area of coffee plantations, the pattern of spatial distribution of pollutants in the river, to identify the relationship between changes in load Dissolved Oxygen (DO) of river water and the addition of nitrogen pollutant load in the area of coffee plantations and to find out the load of pollutants entering the rivers. This research was initiated with the river and soil water sampling in plantation areas which were then tested for the concentration of nitrogen in the form of ammonium and nitrate, and were further analyzed with regression and correlation methods. Results of primary and secondary data analysis would be used as a basis for preparing a mass balance model of river pollutant load. The results of this research were that the correlation between DO concentration changes and the addition of nitrate showed conflicting relationships, as indicated by the regression equation for the events of time before fertilization: $y = 80.89586 - 1.80801\ x$ the closeness of the relationship of $r = -0.837$. Meanwhile, for the time after fertilization, it was indicated by the regression equation: $y = 80.89586 - 1.80801\ x$ the closeness of the relationship of $r = -0.977$. Input-output model of nitrogen in Rembangan river which is a tributary of Bedadung river that flows and divides coffee plantations Renteng Afdeling Rayap Jember was able to show the decrease of nitrate load in the river, so that this could provide information that the activities in coffee plantation of Rayap Jember both before and after fertilization had not caused a significant increase in nitrate concentration, which means that it did not cause pollution of water of Rembangan river.

KEY WORDS: modeling, input, output, nitrogen, dissolved oxygen, regression, correlation.

INTRODUCTION

In general, agricultural wastes that pollute the river are liquid wastes that come from the activity of plant fertilization. These wastes are waste types that spread (non-point sources) because there is no specific outlet for waste disposal. One of macro elements contained in fertilizer is Nitrogen (Anonymous, 2007). At high concentrations and the addition of

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phosphate, nitrogen element will potentially lead to pollution of river water, that is the river water enrichment or eutrophication. The occurrence of eutrophication will cause dissolved oxygen in the water to decrease, so that the quality of river water will gradually decrease.
The addition of fertilizer nutrients in the soil can also release nutrients, and pollute the water supply. A recent study by researchers at the University of Minnesota shows that agricultural activities contribute to the increase of nitrate levels in surface and ground water due to fertilizer use in modern or conventional way (Anonymous, 2007).
To keep the quality of river water to remain in the condition that is in accordance with the land use will require efforts to manage river water quality and monitoring; one of them is by using water quality modeling of input-output model of nitrogen in rivers. The same theme had do by previous researchers are Winaryo, Pujiyanto, Aris Wibawa, 1999; Korsaeth, Audun dan Eltun, Ragnar. 2000; Wahyuningsih, Sri. 2001, Lee, Anne Jones and G. Fred Lee, 2002; Suk-Cheol Kim, Sun-Kuk Kwon, 2003; Kim, Jin-Ho, Jong-Sik Lee, Sun-Gang Yung, Mun-Hwan Koh,2003; Lee, Anne Jones and G. Fred Lee, 2005; Salo, Tapio dan Turtola, Eila. 2006; Karnaningroem, Nieke. 2006; Graeff, Simone., Judith Pfenning, Wilhelm Claupein and Hans-Peter Liebig, 2008.
The specific objectives of this research are:
1. to identify the characteristics of river nitrogen in the area of coffee plantations.
2. to identify the relationship between load changes of dissolved oxygen (DO) of river water and the addition of nitrogen pollutant load in the area of coffee plantations.
3. to study the equilibrium model of river nitrogen due to the contribution of coffee fertilization waste

METHODS

2.1 Inventory and identification of data

This study used primary data. The primary data were taken directly in the field. The water quality testing was conducted in the laboratory of Chemistry Department, Jember University and Laboratory of Environmental Control and Conservation Engineering, Department of Agricultural Technology, Faculty of Agricultural Technology, Jember University. Primary data taken were concentration data of N, DO, velocity and discharge on the measurement of surface runoff.

2.2 Data Analysis

The data obtained were made to be data plot to identify trends and patterns that occurred on each type of data. Furthermore, regression analysis and correlation was carried out to find out the relationship and the closeness of relationship between independent variable x and the dependent variable y. The results of data analysis were used as the basis for building the structure model of mass balance of nitrogen content of the river originating from wastewater of coffee plantations.

2.3. Concept of Research Model

The concept design of mass balance model to predict the pollutant load in this research is as follows:

Input $\longrightarrow$ System $\longrightarrow$ Output

Concept of Mass Balance Model of River Pollutants Emission from Liquid Waste of Plantation (2 Dimensions) is as follows:

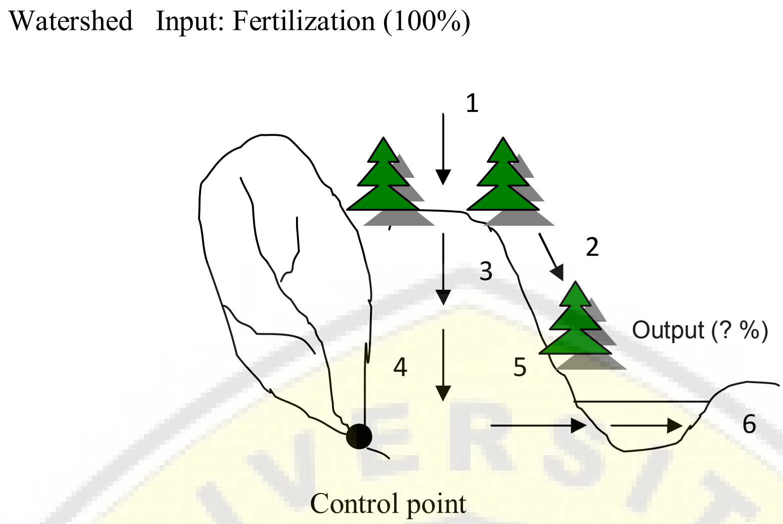

Fig. 1. Concept of Mass Balance Model River Pollutant Load Emission from Liquid Waste of Plantation

RESULTS AND DISCUSSION

Based on analysis of data, the following results were obtained:

3.1. Identification of Characteristics of Types of Pollutants in Coffee Plantation Area

Coffee Plantation Rayap Jember is a coffee plantation owned by PTPN XII located in Jember Regency with a total of coffee plantation area of 185.16 hectares and a population of coffee Robusta coffee plant as many as 133,000 species of plants with productivity of 123 tons of coffee annually. So the average productivity of each crop of coffee per year amounted to 0.925 kg. The types of fertilizers used for fertilizing coffee plants were NPK, Urea, KCl, TSP and Kieserit within of fertilizing period of twice a year at the beginning and end of the rainy season. Catchment area of networks of Rembangan river is presented in the following figure:

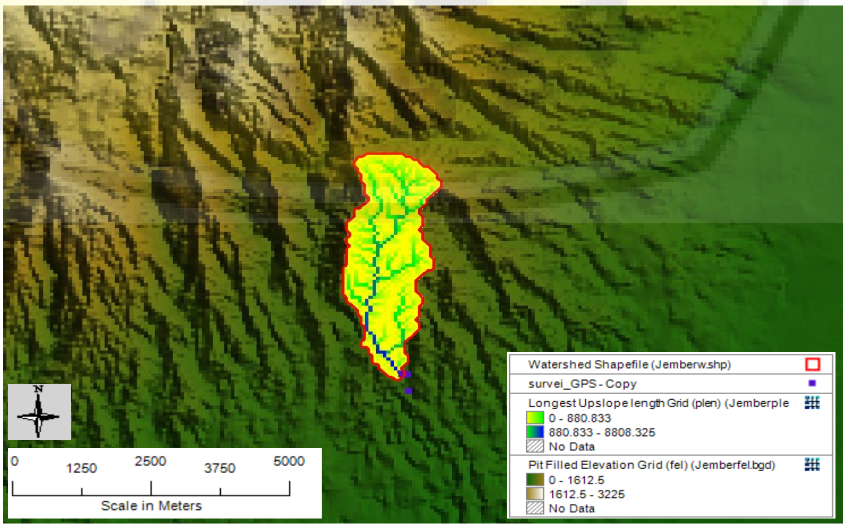

Fig. 2. Catchment area of network Rembangan river Jember (Source: Water Resource Development Research Centre of Jember University, 2011)

Analysis results of dissolved oxygen (DO) content are presented on the table below.

Table 1. Concentrations of Dissolved Oxygen (DO) Rembangan River Rayap Jember

Sampling point	Concentration of Dissolved Oxygen (DO) (mili gram/liter)	
	Before Fertilization	After Fertilization
Upstream	8.58	8.54
Middle	7.70	7.66
Downstream	7.49	7.40

Based on the analysis of water quality data before and after fertilization, it was known that organic nitrogen content in the water of Rembangan River Rayap Jember tested using Kjeldahl nitrogen method was not detected in value, while the nitrate content was successfully detected. This showed that the types of pollutants that potentially entered into the Rembangan River Rayap Jember were nitrate compounds with results as shown on Table 2 below.

Table 2. Nitrate Concentration of Rembangan River Rayap Jember

Sampling point	Nitrate Concentration (mg/liter)	
	Before Fertilization	After Fertilization
Upstream	0.62861	0.811192
Middle	0.65751	0.832636
Downstream	0.73077	0.848366

Analysis of soil samples indicated the amount of soil porosity in soil of Rayap Jember Plantation was 53.53% with sand texture: dust: clay at 28.41: 32.41: 39.18 and total nitrogen content as presented on the following table:

Table 3. Total Nitrogen Content of Soil of Rayap Jember Plantation

Sampling point	Total Nitrogen Concentration (%)	
	Nitrate Concentration (miligram/liter)	DO Concentration (milligram/liter)
Upstream	0.140	0.178
Middle	0.139	0.177
Downstream	0.137	0.176

3.2 Effect of Fertilization on Distribution Patterns of Pollutants in the River .

The analysis of nitrate concentrations in Rembangan River Rayap Jember in time before fertilization and after fertilization showed the same pattern from the upstream side the concentrations further declined in the middle and downstream. At the time before fertilization on the upstream side, the concentration was 0.62861 millimeter gram/liter, in the center it increased to 0.65751 millimeter gram/liter, while in the downstream it increased again to 0.73077 milligrams/liter. Meanwhile, the results after fertilization showed the concentration of nitrate in the upstream reaching 0.811192 milligrams/ liter, in the center it increased to 0.832636 milligrams/liter and in the downstream it rose again to 0.848366 milligrams/liter.

The patterns of distribution of nitrate concentrations which increased in the middle and rose again in the downstream were affected by the distance between the observation point on the upstream side and that in the central area that was approximately 10 km that possibly enabled the natural purification of river water, so it could reduce the nitrate concentration. However, because the coffee plantations were large plantations and homogenous population and there was no activity other than fertilization, this resulted in the greater contribution of nitrate into the river and accumulated from the upstream to downstream. Although the distance between sampling points in the middle and downstream was approximately 15 km, because the number of plant populations in the region was also relatively more, the natural purification had not been able to reduce nitrate concentrations due to the entry of nitrate into the river in a spread (non-point sources) along the river.

3.3. Correlation between changes in DO load of river water and the addition of N pollutant load in the area of coffee plantation

To find out the correlation between changes in load Dissolved oxygen (DO) due to the input of nitrate in the river, it was necessary to know first the correlation between discharge and nitrate and DO concentrations. It was intended to facilitate in the identification of each parameter.

3.3.1. Correlation between Debit and Nitrate Concentrations and Dissolved Oxygen (DO)

The relationship between discharge and nitrate concentrations in the Rembangan river Rayap Jember in the time before fertilization can be seen in Figure 3 and written in a regression equation as follows:

y = 0,548421 + 0,000856x which means that in the Rembangan river Rayap Jember the level of nitrate concentration before fertilization can be obtained by using the equation:

C Nitrate = 0,548421 + 0,000856Q

Correlation between discharge and nitrate concentration prior to fertilization was r = 0.819. This indicated that there was a correlation between changes in river discharge and those in nitrate concentration in the river.

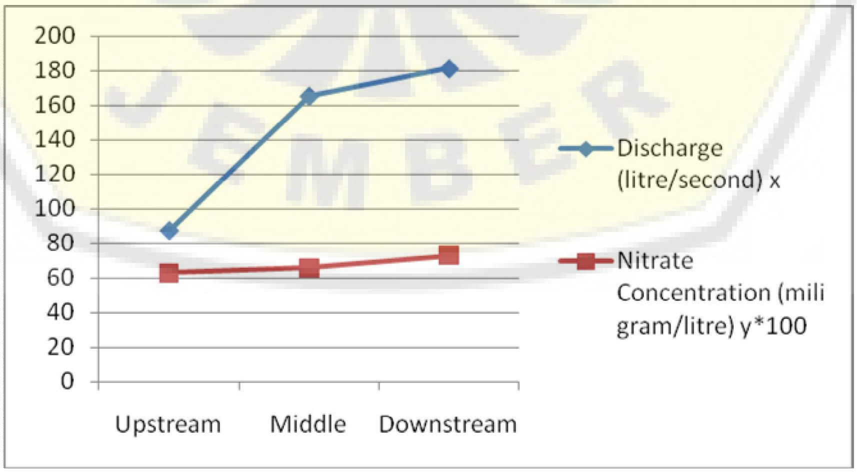

Fig. 3. Chart of Correlation between Discharge and Nitrate Concentrations before Fertilization in the Rembangan River Rayap Jember

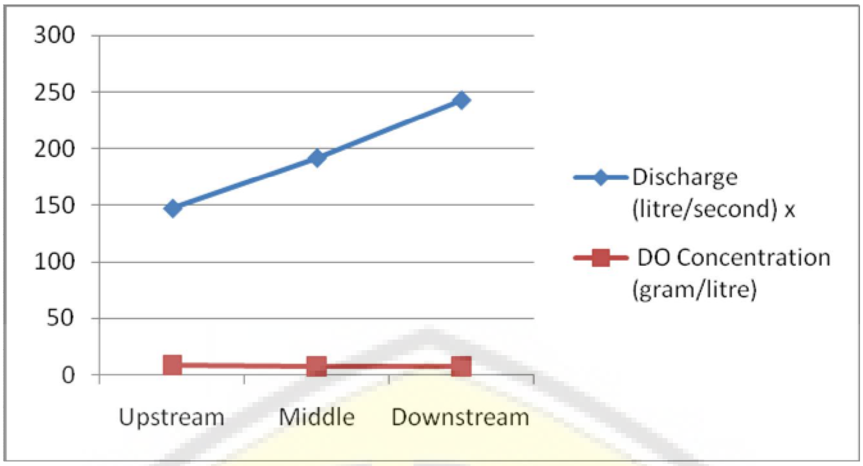

Fig. 4. Chart of Correlation between Discharge and Nitrate Concentrations after Fertilization in Rembangan River Rayap Jember

The correlation between discharge and nitrate concentration in the Rembangan river Rayap Jember in time after fertilization can be seen in Figure 4 and is written in the regression equation y = a + bx (Walpole, 1995) as follows:

$y = 0{,}75548 + 0{,}000388x$

which means in Rembangan river Rayap Jember the level of nitrate concentration after fertilization can be obtained by using the equation:

C Nitrate = 0,75548 + 0,000388Q

Significance of correlation between discharge and nitrate concentration after fertilization was r = 0.99.

Correlation coefficient value above showed that there was a correlation between changes in river discharge and those in nitrate concentration in the river that was equal to 99% which means there was a reciprocally influential correlation between changes in river discharge and those in nitrate concentration, that is the greater the discharge that occurred, the greater the concentration of nitrate.

The correlation between discharge and DO concentration in Rembangan river Rayap Jember in the time before fertilization can be seen in Figure 5 and is written in a regression equation as follows:

$y = 9{,}58335 - 0{,}01147x$

which means that in Rembangan river Rayap Jember, the level of DO concentration before fertilization can be obtained using the equation:

C DO = 9,58335 - 0,01147Q

The significance of correlation between discharge and DO concentration before fertilization was r = - 0.999. This indicated that the negative value of the correlation coefficient showed that there was no or there was a conflicting correlation between river discharge change and changes in the concentration of DO in the river.

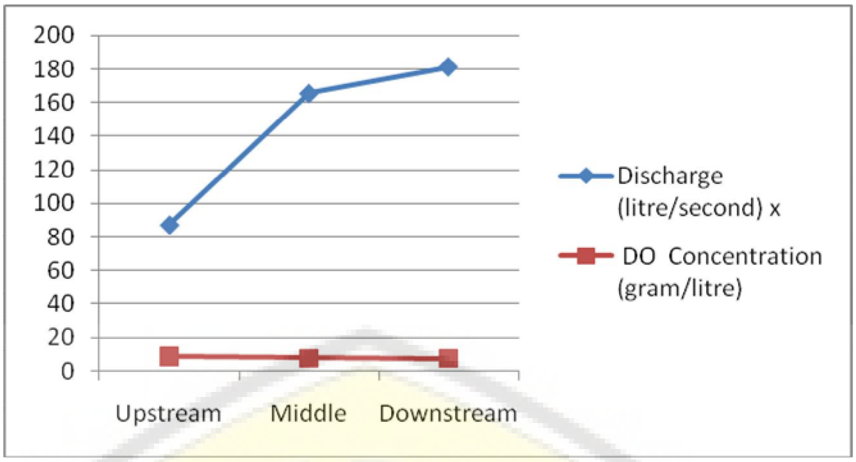

Fig. 5. Chart of Correlation between Discharge and Concentration Dissolved Oxygen (DO) before Fertilization in the Rembangan River Rayap Jember

The correlation between discharge and DO concentration in Rembangan river Rayap Jember in the time after fertilization can be seen in Figure 6 and written in a regression equation as follows:

y = 10,15445 - 0,01178x

which means in the Rembangan river Rayap Jember, the level of DO concentration after fertilization can be obtained by using the equation:

C DO = 10,15445 - 0,01178Q

The closeness of relationship between discharge and with DO concentration after fertilization was r = - 0.942. This indicated that the negative value of the correlation coefficient showed that there was no or there was an opposite correlation between changes in river discharge and those in the DO concentration in the river.

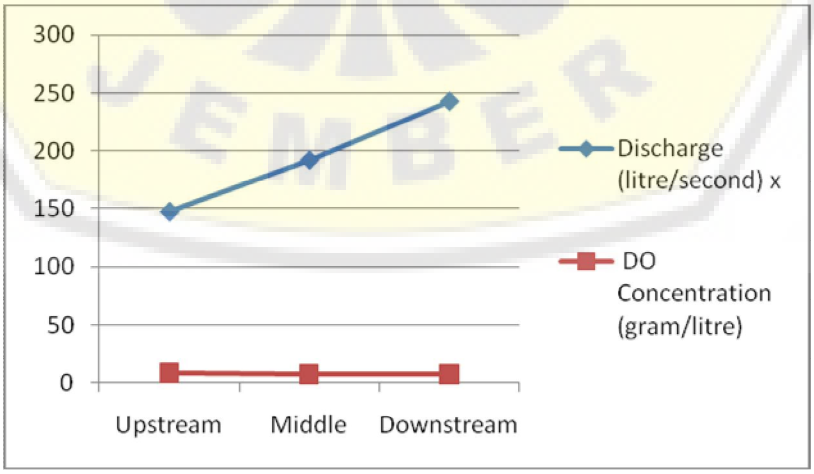

Fig. 6. Chart of Correlation between Discharge and Dissolved Oxygen (DO) Concentration after Fertilization in Rembangan River Rayap Jember.

3.3.2 The correlation between changes in DO of river water and the addition of nitrate

The correlation between changes in DO of river water and the addition of nitrate before to fertilization in coffee plantation of Rayap Jember can be shown by the Table 4, Figure 7 and regression equation below.

$$y = 14{,}07185 - 9{,}14553x$$

The significance of correlation between DO concentration changes and the addition of nitrate prior to fertilization ws of r = - 0.833. This indicated that the negative value of the correlation coefficient showed that there was a contrast correlation between DO concentration changes and the addition of nitrate concentration in the river. This means that the increasingly high concentration of nitrate will cause the increasingly low river DO concentration.

Table 4. Correlation between Changes in DO and the Addition of Nitrate before Fertilization in the Rembangan River Rayap Jember

Sampling point	Nitrate Concentration. (miligram/liter)	DO concentration (milligram/liter)
Upstream	0.629	8.58
Middle	0.658	7.70
Downstream	0.731	7.49

The correlation between changes in DO of river water and the addition of nitrate after fertilization in coffee plantation of Rayap Jember can be shown by the regression equation, Table 5 and Figure 8 below.

$$y = 33{,}84748 - 31{,}2746x$$

The significance of correlation between DO concentration changes and the addition of nitrate after fertilizer application was = -0.977.

This indicated that the negative value of the correlation coefficient showed that there was a contrast correlation between DO concentration changes and the addition of nitrate concentration in the river. This means that the increasingly high concentration of nitrate will cause the increasingly low river DO concentration.

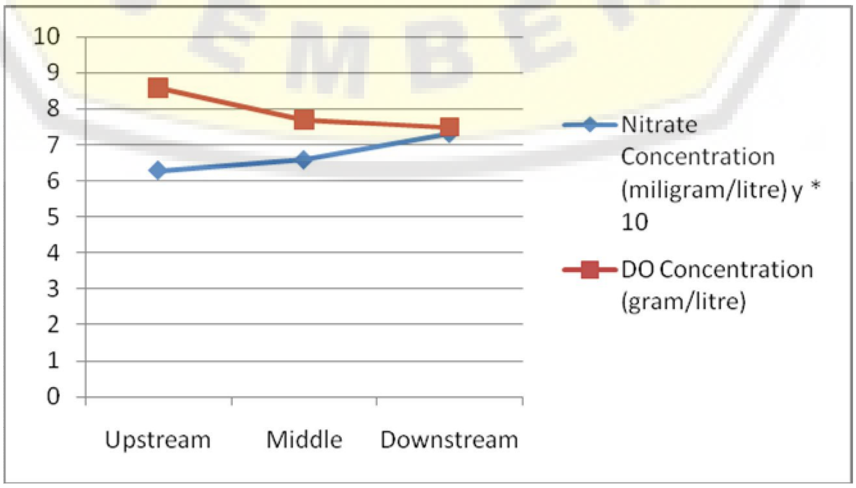

Fig. 7. Correlation between Changes in DO and the Addition of Nitrate before Fertilization in Rembangan River Rayap Jember.

Table 5. Correlation between Changes in DO and the Addition of Nitrate after Fertilization in Rembangan River Rayap Jember

Sampling point	Nitrate Concentration (miligram/liter)	DO Concentration (milligram/liter)
Upstream	0.8112	8.54
Middle	0.8326	7.66
Downstream	0.8484	7.40

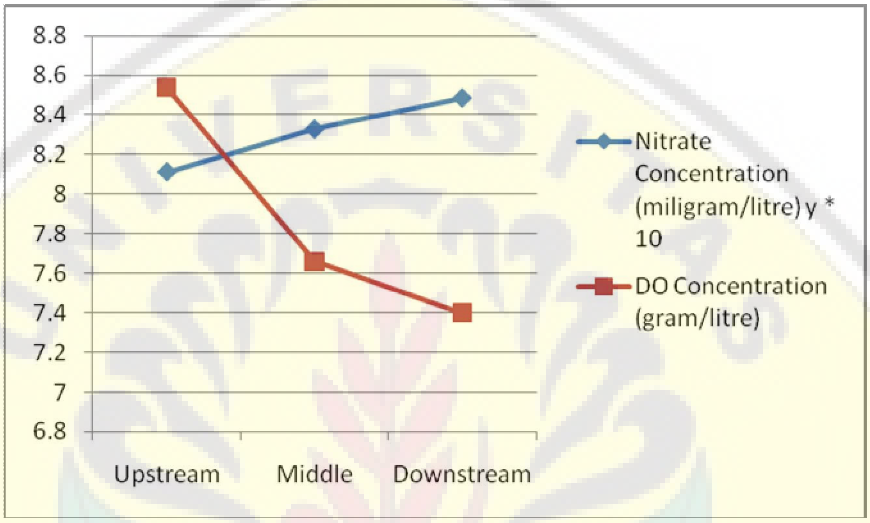

Fig. 8. Correlation between Changes in DO and the Addition of Nitrate after Fertilization in Rembangan River Rayap Jember

3.3.3 Input-Output Model Nitrogen Pollution Charges

Input-output model of pollutant loads of nitrogen, in this case the nitrate load in the Rembangan river Rayap Jember is obtained by the following equation:

Input = Output

$Io + Ip \pm \Delta S = O$

With:

Io = initial nitrate load

Ip = Input nitrate load coming from plantations

ΔS = Storage

O = Output.

In the condition before fertilization of coffee plants, river nitrate load on the upstream side was 54.826 milligrams/second and got a load of nitrate inputs from the coffee plantations that went into the river amounted to 53.949 mg/sec, so that the nitrate load in the middle of the river amounted to 108.775 mg/sec, then obtained the nitrate load input again in the middle of the river until the river water downstream amounted to 23.745 mg/sec, causing the output load on the river downstream nitrate to increase up to 132.52 mg/sec.

Calculation of input – output model:

Io + Ip ± ΔS = O

54.826 + 108.775 = 132.52 ± ΔS

ΔS = 132.52 ± 163.601

± ΔS = 132.52 - 163.601

ΔS = - 31.081 mg/sec

Thus, the result of input-output model before fertilization was:

54.826 + 108.775 - 31.081 = 132.52

132,52 = 132,52

It can be concluded that during the flow from the upstream to downstream, nitrate loads have experienced a reduction by 31.081 mg/sec. This is because during the journey from the upstream to the downstream area, nitrate loads have experienced a self-purification naturally in river water, considering the condition of the river with lots of big stones that accelerate the addition of oxygen due to reaeration of the river water.

Meanwhile in condition after fertilization of coffee plants, nitrate concentration at the upstream of the river amounted to 119.66 mg/sec and got nitrate load inputs from the coffee plantations that went into the river amounted to 40.281 mg/sec, so that the nitrate load in the middle of the river amounted to 159,941 mg/sec and then got the nitrate load input again in the middle of the river until the river water downstream by 45.528 mg/sec, causing the output load on the river downstream nitrate to increase up to 206.135 mg/sec.

Calculation model of input - output:

Io + Ip ± ΔS = O

119.66 + 159,941 = 206.135 ± ΔS

ΔS = 206.135 ± 279,601

± ΔS = 206.135 - 279,601

ΔS = -73,466 milligram/second

Thus the result of input-output model after fertilization was :

119.66 + 159,941-73,466 = 206.135

206,135 = 206,135

From the analysis above, it can be concluded that at the time after fertilization there is a decrease of nitrate load of 73,466 milligrams/sec in the Rembangan river Rayap Jember caused by the natural purification of river water. Based on the analysis of nitrate concentrations using the spectrophotometric method in the laboratory of Faculty of Science, Jember University, in general, the nitrate concentration along the Rembangan river Jember from upstream to downstream before fertilization is at an average of 0.67 milligrams/liter and after fertilization is at the average of 0.83 milligrams/liter and, thus, based on the Indonesian Government Regulation number 20 Year 1990 (Anonim, 2003) the nitrate concentration in river water of Rembangan Rayap is still can be categorized as good because it belongs to class

A in water quality, that is as water that can be used as direct drinking water without any treatment with a maximum standard parameter of nitrate at 5 mg/liter. It can be concluded that agricultural activities on coffee plantations of Rayap Jember before and after fertilization has not yet caused a significant increase in nitrate concentrations that can cause a decrease in river water quality Rembangan rayap Jember.

Furthermore, these data will serve as the basis for preparing a mass balance model of nitrate load in the Rembangan river Rayap Jember.

Conclusion

Based on the above discussion, it can be concluded as follows:

1. Characteristics of nitrogen pollutants types in the river that flow across coffee plantations of Rembangan Rayap Jember are compounds of nitrate (NO3).
2. The effect of fertilization on the pattern of spread of nitrate in river has increased along the increasing nitrate inputs to the river.
3. The correlation between DO concentration changes and the addition of nitrate shows conflicting correlations, as indicated by the regression equation for the events of time before fertilization:

   y = 14,07185 - 9,14553x with the significance of correlation of r = - 0.833. Meanwhile, for the time after fertilization, it is indicated by the regression equation: y = 33,84748 - 31,2746x with the significance of correlation of r = - 0.977.
4. Input-output model of nitrogen in the Rembangan river which is a tributary of Bedadung river that flows and divides coffee plantations Afdeling Renteng Rayap Jember is able to show the decrease of nitrate load in the river, so it can provide information that Rayap Jember coffee plantation activities both before and after fertilization have not caused a significant increase in nitrate concentration, which means it has not cuased a pollution of Rembangan river water.

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