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Water quality in Ci Danau Watershed, with focus on TN and TOC

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1. Introduction

Water quality of a watershed responds to changes in land use/land cover and associated human activities. These factors can, in turn, potentially produce negative and positive impacts upon water quality. Sustainable production of fresh, reliable water supplies is a natural function of a watershed. Ci Danau watershed is heavily responsible for supplying water for industries and drinking in Cilegon city (Goto et al. 2003). In order to maintain the appropriate function of watershed as a supplier of water, it is crucial to grasp the function of each land use/land cover and its influence upon water quality.

This paper presents the quality of water circulating in Ci Danau watershed focusing on TN (Total Nitrogen) and TOC (Total Organic Carbon) concentration. Although some water quality data in this area have been already reported, they do not seem to be fully reliable. Based on our data set, the composition of different forms of nitrogen i.e. NO_3^- NO_2^-, NH_4^+ and organic nitrogen is also analyzed. Water samples are, then, examined according to categories by type of water for the sake of identifying main sources of nitrogen and carbon supply.

2. Location and Topographic Feature of Study Area

Ci Danau watershed is located at the west edge of Java island, Indonesia (lies between 105°52'E-106°03'E and 6°8'S- 6°17'S) , and drains an area of roughly 220,000ha. This area is encompassed by a colline zone in the north and Mt. Karang, Mt. Angusana, and Mt. Jaru in the south, and runoff in the watershed enters Ci Danau river, which, in turn, flows westwards into the to the Sunda Strait about 35km from the headstream. Air temperature is 27℃ on average and is almost constant over a year.

The field under research was originally a caldera lake, and is currently converted into paddy fields and swamp forest after the excavation of the river canal so as to lower the water level. The area comprises a flat open wetland zone in the center, gently sloping mountainous (foothills zone) at low elevations and mountain zones that reach elevations over 1,700 meters.

3.Field survey and water sampling

Two field survey trips were conducted: First trip between the 30^{th} of September and 7^{th} of October in 2003 (dry season); second trip between the 30th of January and the 7th of February in 2004 (rainy season). The field survey consists of collection of water samples, measurement of discharge rate at each sampling point, and interviews to farmers and head of communities for obtaining information regarding agricultural management methods such as quantity of fertilizer application.

Water samples have been obtained at 48 locations and 111 locations in the first and second survey trip respectively, covering the watershed extensively. Particularly samples were collected intensively along the three stem rivers – Ci Danau (Ci Omas), Ci Suwarna, and Ci Kalumpan – in order to track the process of nitrogen concentration changes from upstream to downstream depending upon type of land use and land cover. Furthermore, these samples include water from wells in residential areas, paddy field and rainfall given that these are presumed to be the principal source of nitrogen.

4. Water quality analysis

4.1. Analytical method for measuring water quality

The water samples are brought back chilled to our laboratory in Tokyo university and analyzed for nitrogen and TOC. Nitrogen concentration was analyzed by utilizing two devices, namely ion chromatography and a TN analyzer. Total organic carbon (TOC) concentration was analyzed by a TOC analyzer. Ion chromatography measures the composition of nitrate-N (NO_3^--N), nitrite-N (NO_2^--N), and ammonium-N (NH_4^+-N). We refer to the sum of the concentration obtained by ion chromatography as TIN (Total Inorganic Nitrogen). Organic nitrogen, presumably existing in the form of urea ($CO(NH_2)_2$), protein and others can be given as the residual, TN-TIN. The reproducibility was also assured by carrying out a duplicate analysis.

4.2. Results of water quality analysis

4.2.1. Nitrogen concentration measured by Total Nitrogen Analyzer and Ion Chromatography

Figure 1 and 3 show the results of TN and TIN concentration (mg/L) for the water samples in dry season and figure 2 and 4 in rainy season. For dry season, TN and TIN values present apparently significant correlation with a coefficient of determination of 0.984 and a slope of 1.05 (figure 4). In other words, almost all of the nitrogen detected in the water samples exists in the form of inorganic nitrogen. Although some of the

TIN values slightly surpass TN values, the difference is so small that these can be considered as measurement errors. This result also assures the reliability and reproducibility of the measured TN values.

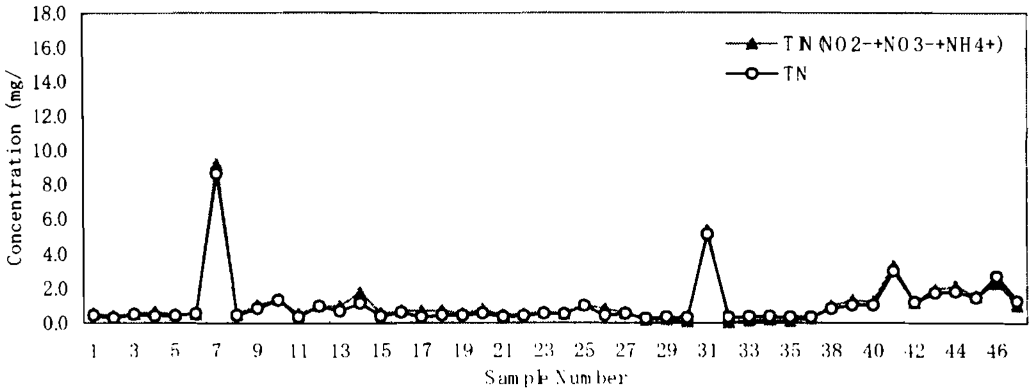

Figure 1. TN and TIN (NO_2^- NO_3^+ NH_4^+) for dry season

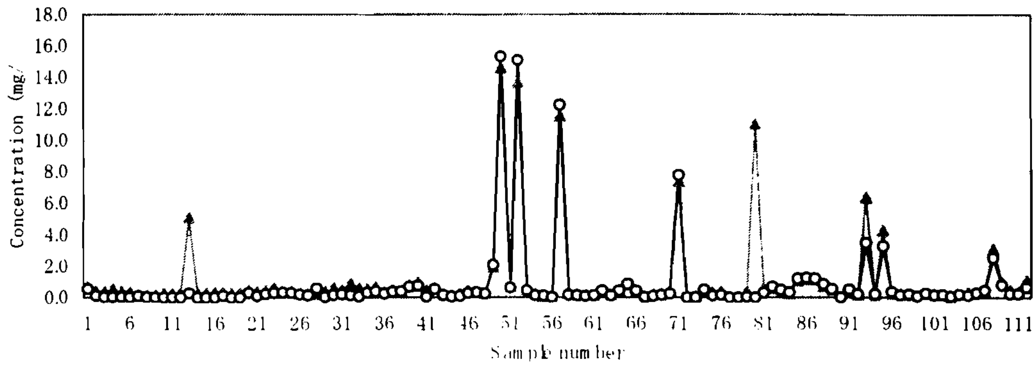

Figure 2. TN and TIN (NO2- NO3+ NH4+) for rainy season

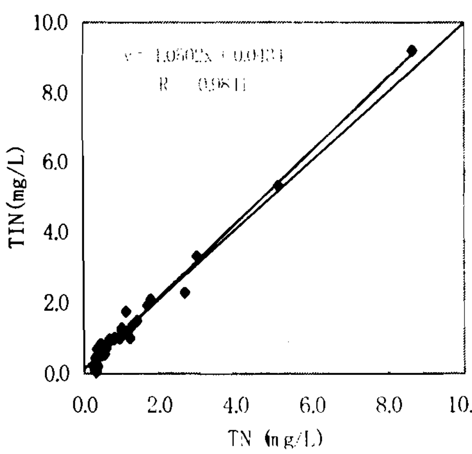

Figure 3. Correlation between TN and TIN for dry season

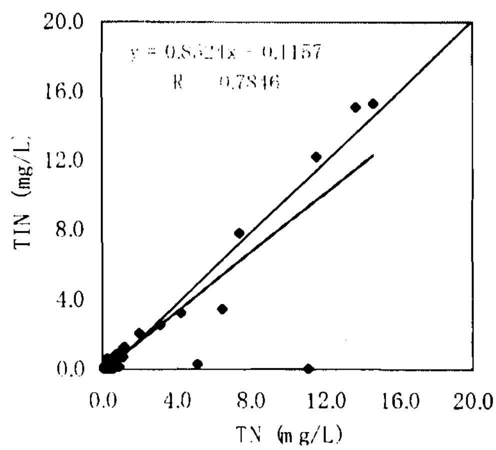

Figure 4. Correlation between TN and TIN for rainy season

With regard to the water samples obtained in rainy season, on the other hand, there seems to be a remarkable difference between TN and TIN values for some of the samples although majority of the samples indicates almost the same values of TN and TIN as shown in figure 3. As it turns out, the slope of the regression line is pulled down to 0.852 by these extreme samples (figure 4). This indicates the existence of organic nitrogen since the value of TN is greater than TIN. Identification of source of nitrogen will be examined by categorizing water samples in the following section.

4.2.2. Nitrogen concentration categorized by type of water samples

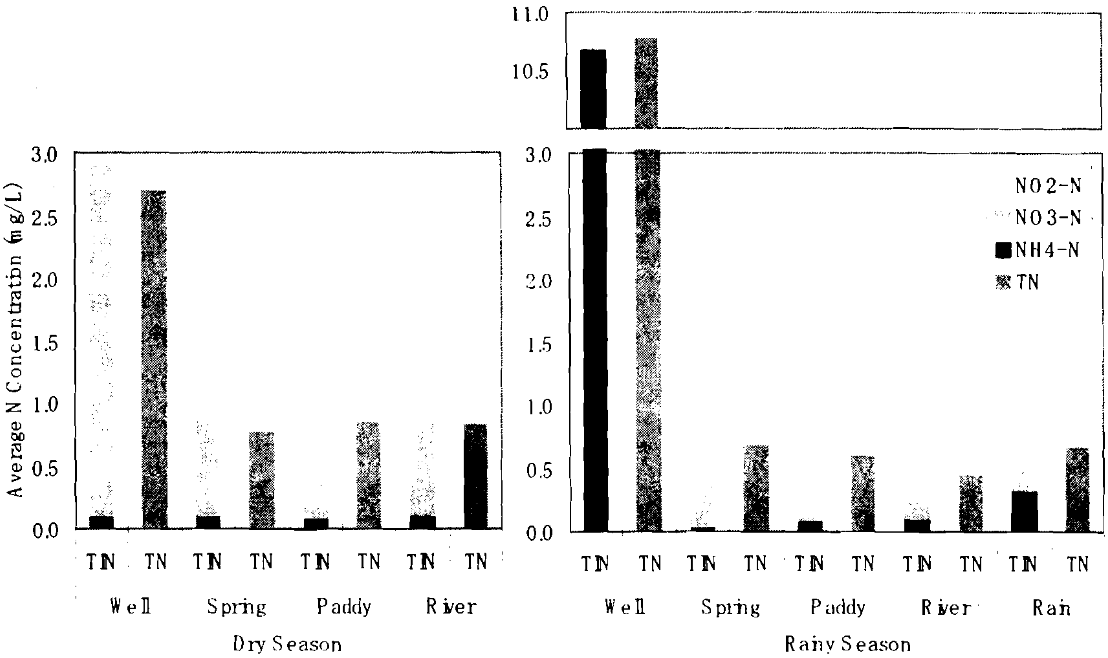

Figure 5. TN concentration by type of water samples

In figure 2 and 4, some water samples show significantly higher nitrogen concentration than the others. In order to identify the nitrogen sources, figure 5 illustrates the average nitrogen concentration categorized by type of water samples in dry and rainy seasons respectively.

First of all, outstandingly higher total nitrogen concentration is detected from samples from wells in resident houses in both dry season (19.78mg/ L) and rainy season (2.71mg/L) measured in TN. The reason for this high concentration is the leakage of contaminated sewage water infiltrating into the wells. In some houses septic tanks of toilet are placed adjacent to the wells. The nitrogen concentration is higher especially in rainy season since the infiltration rate is greater with abundant rainfall in rainy season.

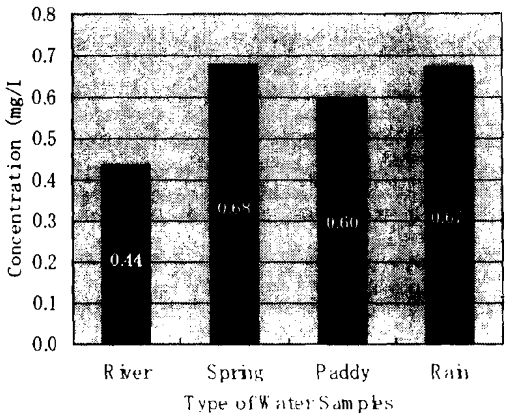

Figure 6. Average TN values in rainy season

The average TN value for the river water (0.44mg/L) is considerably low in comparison with that in Japan. For instance, the TN values of the rivers flowing into lake *Kasumigaura* in *Ibaraki* prefecture range between 1.0mg/L and 5.7mg/L with the mean value of 3.7mg/L in 2001 (Ibaraki Prefecture).

The most important observation derived from this data set is the fact that the average TN value of river water (0.44mg/L) is lower than that of spring (0.68mg/L), paddy (0.60mg/L) and even rainfall (0.67mg/L) in rainy season. Although the TN value of rainfall in dry season has not been obtained, it may be higher or the same as that in rainy season. Since total discharge of water outflows from any types of land is less than the amount of rainfall due to evapotranspiration, the lower TN concentration in river water than in rainfall indicates that the total amount of nitrogen that outflows from the land (TN-concentration×discharge) is, at most, lower than nitrogen input with rainfall (TN-concentration×amount of rainfall). This fact is surprising because there are other sources of nitrogen inputs besides rainfall. Rice in the paddy field contributes more as a supplier than an absorber to nitrogen load status. According to our survey approximately 50kg of nitrogen is applied to 1 ha of paddy per crop as fertilizer ([urea application (110kg)]×[nitrogen content of urea (46%)]). On the other hand, the average productivity of the paddy field in Ci Danau watershed is considered to be more or less 2.5 ton/ha/crop, that is, only less than 30kg/ha of the nitrogen is taken away by harvesting rice ([average harvest (2500kg)]×[protein content in Rice (0.07)])×[nitrogen content in protein (1/6.25)]). The difference, about 20kg/ha, is estimated to be the nitrogen surplus from the paddy field. Therefore, the lower TN value of river water than that of rainfall implies that nitrogen emission to the atmosphere in the form of either denitrification or ammonia volatilization all over the watershed exceeds the net N input by human activity, and may significantly reduce TN input from fertilizer from paddy fields and sewage from residential areas and also rainfall.

Although the values of TN and TIN (NO_2^--N + NO_3^--N + NH_4^+-N) of river water are similar in dry season, two values are obviously different in rainy season (table 1). The fertilizer and sewage seem to overflow when large rainfall occurs while, in dry season, water in paddy field or septic tanks may drain to river only through subsurface or ground water flow.

Table 1. Comparison between average TN and TIN value

	Dry Season				Rainy Season				
	Well	Spring	Paddy	River	Well	Spring	Paddy	River	Rain
TN	**2.71**	**0.77**	**0.85**	**0.83**	**10.78**	**0.68**	**0.60**	**0.44**	**0.67**
TIN	**2.97**	**0.89**	**0.95**	**0.84**	**10.78**	**0.72**	**0.11**	**0.24**	**0.55**
NH4-N	0.10	0.10	0.09	0.10	10.68	0.03	0.08	0.10	0.31
NO3-N	2.81	0.77	0.86	0.74	0.08	0.69	0.03	0.14	0.24
NO2-N	0.05	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00

4.2.3. TN and TOC concentration along rivers

Water samples have been obtained along three main rivers in the watershed flowing through paddy field area, namely Ci Danau (Ci Omas), Ci Suwarna, and Ci Kalumpang . TN and TOC concentration and C/N ratio changes from upstream to downstream are shown in figure 8, 9 and 10. Ci Danau (Ci Omas) river originated from Mt. Karang and flows westwards into the Sunda Strait approximately 35km from the headstream. Ci Suwarna and Ci Kalumpang, on the other hand, flow into Ci Danau river.

TOC is a standard indicator for contaminations of water and environmental control. C/N ratio, the ratio of TOC and TN, is a parameter for water quality, which can be used to monitor environmental condition for living microorganisms. Denitrification efficiently occurs under the condition of high NO_3^- concentration and high C/N ratio.

Ci Suwarna river is originated in a terraced paddy field area in mountainside, and flow through a plane paddy field area situated in the northern half of the watershed, and then swamp forest. In rainy season, total nitrogen concentration along the river remains fairly low and constant (0.06-0.14mg/L) up to 8km from the headstream and it abruptly rises (0.59mg/L) at confluence with a stream from springs in rainy season indicated by the point □ in figure 7 and 8. This spring, flowing out from densely inhabited area, exhibits significantly higher total nitrogen concentration (1.16mg/L in rainy season and 0.99mg/L in dry season). There is another confluence at point □, and thereafter the river penetrates in the middle of the swamp forest up to where it merges with Ci Danau river (□). A considerable reduction in total nitrogen is observed after the river flowing through swamp forest. The TN concentration of the influent water to and the effluent water from the swamp forest are 0.46mg/L and 0.13mg/L.

The value of TOC, on the contrary, rises once the river enters to the swamp forest, and accordingly the C/N becomes high in the swamp forest.

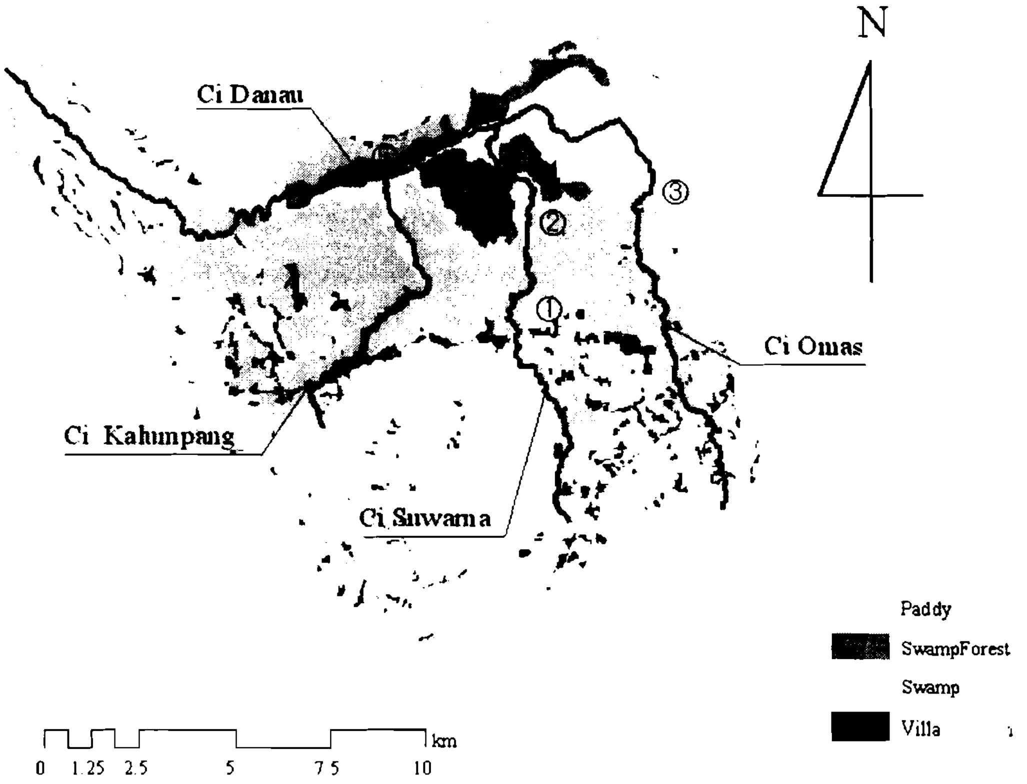

Figure 7. Location of Ci Danau (Ci Omas), Ci Suwarna and Ci Kalumpang river

The surrounding area of Ci Kalumpang river, on the other hand, is predominantly characterized by paddy field and residential area, and it flows directly into Ci Danau river (□) without passing through the swamp forest (figure 7 and 9). The gradually risen TN concentration does not decline as much as Ci Suwarna before flowing into Ci Danau river (0.45mg/L). The TOC values along Ci Kalumpang river fluctuate more or less in a coherent manner with TN values. As a consequence, C/N ratio remains constant at the range between 4 and 6 in rainy season.

The TN concentration of abovementioned rivers has an influence upon that of Ci Danau river. The point □ and □ in figure10 are confluence with Ci Suwarna and Ci Kalumpang respectively. It is obvious that Ci Suwarna river dilutes the TN concentration of Ci Danau river and Ci Kalumpang adds to it. While Ci Danau river flows in the middle of the swamp forest, the TN concentration remains more or less constant until Ci Kalumpang river merges. Even after the confluence with Ci Kalumpang river, there is a declining tendency in the TN concentration. With these observations together with the fact along Ci Suwarna river, it is possible to assume that the swamp forest is responsible for reducing TN concentration, and therefore nitrogen load.

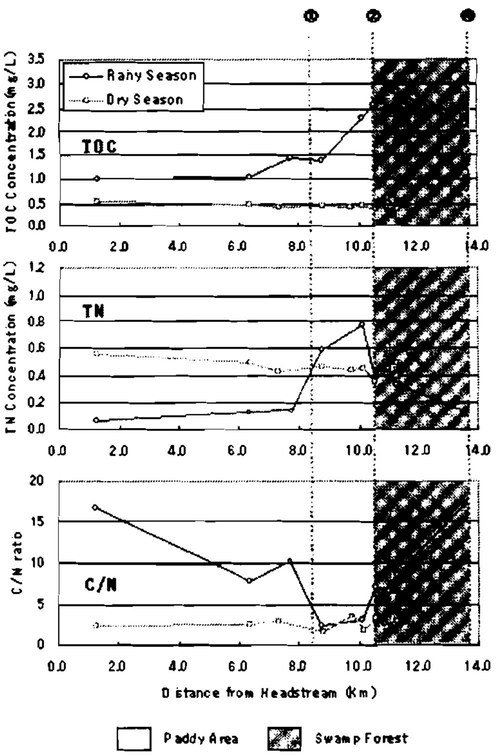

Figure 8. TOC, TN and C/N ratio along Ci Suwarna river

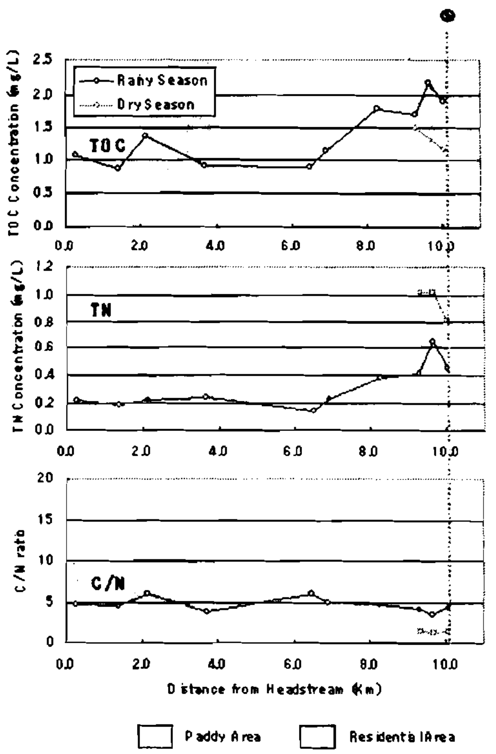

Figure 9. TOC, TN and C/N ratio along Ci Kalumpang river

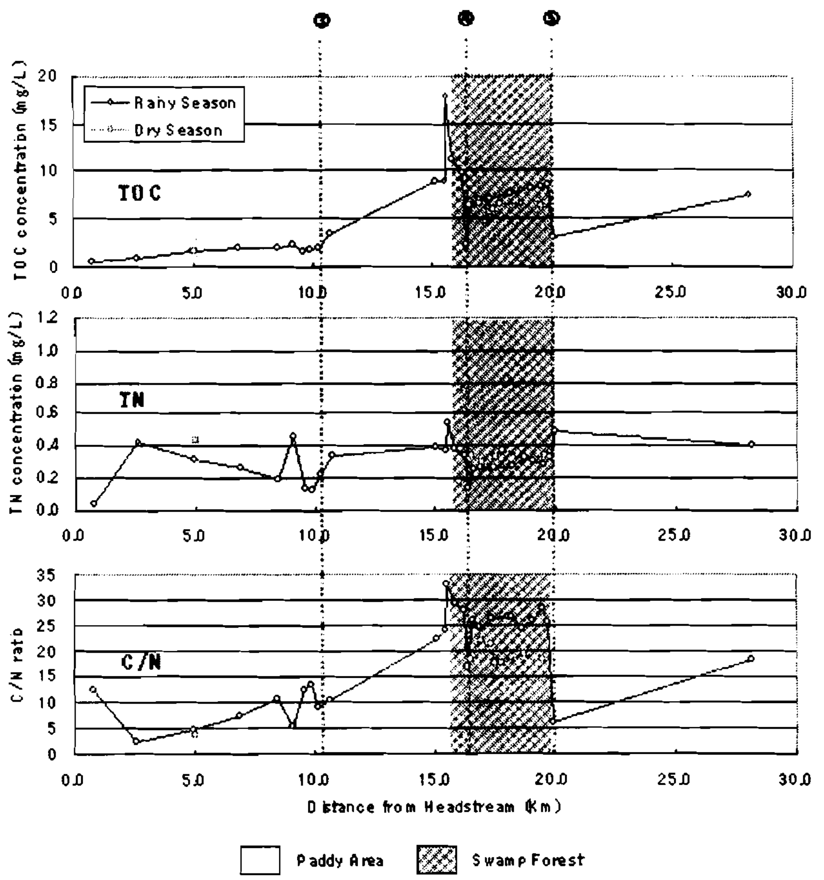

Figure 10. TOC, TN and C/N ratio along Ci Omas and Ci Danau river

Because the TN concentration at the headstream, where no contamination through human activities is involved, is measured to be almost zero, the development of the watershed may have significantly increased the TN input in the Rawa Danau swamp, and the fertile water quality may have affected plants in the swamp.

5. Conclusion

In this paper, the water quality of Ci Danau watershed has been analyzed by focusing on TN and TOC. Our findings are as follows:

1. The TN concentration of the three main rivers ranges between 0.1 and 0.6mg/L. This concentration is remarkably lower than those of rivers flowing through similar paddy areas in Japan.
2. The TN concentration of river water is even lower than that of rainfall, indicating that nitrogen loss to the atmosphere (denitrification and ammonium volatilization) exceeds total net nitrogen input by human activities in the watershed.
3. Because of the leakage of contaminated water from sewage, extremely high TN concentration is detected in wells of resident houses.
4. The proportion of organic nitrogen in TN is considerably higher in rainy season, because the water may be overflowing from paddy fields or sewage with organic materials before its decomposition (ammonification).
5. The TN value along the rivers is higher in dry season while the TOC value is higher in rainy season. This results in the C/N ratio being significantly higher in rainy season than in dry season.
6. The TN concentration of rivers declines when they flow through the swamp forest, indicating that the swamp apparently reduces nitrogen load that flows out through river from input through rivers probably due to denitrification.
7. Since it is inferred that the TN concentration in rivers flowing into Rawa Danau was virtually zero when there was no human activity, the development of the watershed have significantly increased the TN concentration in the swamp, and the fertile water quality may have affected plants species in the swamp.

The most important finding here is the low TN concentration of river water that is a result of high nitrogen loss to the atmosphere. A greater denitrification may be responsible for the high nitrogen loss, occurring over the watershed due to higher temperature in the tropical climate than the temperate climate in Japan. Atmospheric temperature in Indonesia is 11□ higher than in Japan on average. Generally, a 10□ increase in temperature within a normal temperature raises the rate of bio-chemical reaction within microorganisms two or three times (Campbell and Norman, 1998), and so does for denitrification. Therefore, the high rate of denitrification and the resulting low TN concentration, in spite of a large fertilizer input, should be a common feature among tropical paddy areas.

The discussion in this paper is confined to water quality in terms of the concentration of TN and TOC. In order to comprehend overall nitrogen cycles in the watershed in more detail, further analysis by incorporating flow volume of the rivers as well as fertilization and cropping pattern is currently in progress.

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