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SPATIAL ANALYSIS FOR EUTROPHICATION MANAGEMENT IN THE RAWAPENING LAKE, SEMARANG DISTRICT CENTRAL JAVA

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Abstract

Rawapening Lake in Semarang District is one of the priority lakes to be addressed related to eutrophication isses. The high concentration of nutrients, particularly Nitrogen (N) and Phosphor (P), has caused the water eutrophication and thus trigger a rapid growth of the water hyacinth. Those nutrients may come from agricultural land such as irrigated rice field, rainfed and vegetable farms. The objectives of this study are i) to determine the total amount of nutrients supply from agricultural land from each catchment area of the lake and ii) provide alternative solutions to reduce nutrients concentration. Information of agricultural land can be obtained from Indonesian Topographic Map (RBI) in scale of 1:25.000 and updated with SPOT-2 image recorded in July 5th 2006. Surface water samples were taken during the dry and rainy season from agricultural land as much as 3 samples for each agriculture land types, therefore 18 samples were collected. The results show that Ringin Sub- catchment has the most extensive irrigated rice field (662.94 ha). While, Panjang Sub- catchment has the most extensive of rainfed (988.49 ha) and vegetable farms (643.74 ha). The agriculture land in the catchment area has supplied N and P nutrients up to 2.181,71 tons and 420,04 tons respectively to water of the lake, annually. Panjang river has supplied the highest N and P nutrients, ie 769,025 ton and 105,432 ton annually, while Kedung Ringin river has supplied lowest N and P nutrients, ie 19,479 ton and 4,790 ton, annually. Installation of buffer zone around the lake sould be developed to reduce the nutrients supply to the lake.

Keywords:
Rawapening Lake, eutrophication, N and P element, Agricultural land, SPOT-2 image and buffer zone

Abstrak

Danau Rawapening di Kabupaten Semarang merupakan salah satu danau prioritas yang perlu ditangani terkait dengan masalah eutrofikasi. Tingginya konsentrasi unsur Nitrogen (N) dan Phospor (P) pada perairan Danau Rawapening yang menyebabkan eutrofikasi telah memicu tingginya pertumbuhan enceng gondok. Unsur nutrisi tersebut dapat berasal dari lahan pertanian yaitu sawah irigasi, sawah tadah hujan dan lahan sayuran. Tujuan kajian adalah untuk menentukan jumlah total unsur nutrisi yang disuplai dari lahan pertanian pada Daerah Tangkapan Air (DTA) Danau Rawapening dan memberikan upaya alternatif untuk mengurangi konsentrasi nutrisi pada air Danau Rawapening. Informasi lahan pertanian dapat diperoleh dari peta Rupa Bumi Indonesia (RBI) skala 1:25.000 yang diperbarui dengan menggunakan citra SPOT-2 perekaman tanggal 5 Juli 2006. Sampel Air permukaan diambil pada musim kemarau dan musim hujan dari lahan pertanian sebanyak 3 sampel untuk masing – masing jenis lahan pertanian, sehingga terkumpul 18 sampel. Hasil kajian menunjukkan, sub DAS Ringin memiliki lahan sawah irigasi paling luas yaitu 662,94 ha, sementara itu sub DAS Panjang memiliki areal sawah tadah hujan dan lahan sayuran paling luas yaitu 988,49 ha dan 643,74 ha. Setiap tahun, lahan pertanian di DTA Danau Rawapening telah mensuplai unsur N dan P yaitu sebesar 2.181,71 ton dan 420,04 ton ke perairan danau. Setiap tahun Sungai Panjang telah mensuplai unsur N dan P paling tinggi yaitu 769,025 ton dan 105,432 ton, sementara itu Sungai Kedung Ringin telah mensuplai unsur N dan P paling rendah yaitu 19,479 ton dan 4,790 ton, setiap tahun. Areal penyangga mengelilingi danau harus segera dibangun untuk mengurangi suplai unsur N dan P ke Danau Rawapening.

Kata Kunci:
Danau Rawapening, eutrofikasi, unsur N dan P, Lahan Pertanian, Citra SPOT-2 dan Areal Penyangga.

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1. INTRODUCTION

Lake has a specific character that is common property, multisectoral policies and interests, as well as the existence of various administrative areas. Lake water is very sensitive to nutrient and mineral inputs due to human activities (Lukman. 2013). Lake can provide social benefits optimally if managed in an integrated manner (Klessig, 2001)Lake is a water ecosystem which is very important for human life. Ecosystem of lake is the foundation of human life in fulfilling the needs of life in the present and future, because it provides a productive natural resources both as a source of fresh water, protein, mineral and energy sources, transportation media, as well as tourist areas (Haryani, 2013). Fresh waters are under serious threat and crisis; indicated by increasing pollution, domestic waste, fish mortality, eutrophication, algae blooming and siltation of lake (Soeprobowati, 2012). This is due to the destruction of catchment, high rates of deforestation and environmental destruction (Haryani, 2010). Through catchment management, problem of the catchment area (on site) and lower watershed area could be integrated holistically, and the role of involved institutions could be differentiated clearly (Gunawan, 2005).

The Rawapening Lake is 1 out of 15 national priority lake of 2010-2014. Eutrophication and sedimentation is main problem in Rawapening Lake. According to Effendi. (2003), eutrophication is a water enrichment process with nutrients especially Nitrogen (N) and Phospor (P), but sometimes others such as silicon, potassium, calcium, iron or manganese - on aquatic ecosystems**.** Eutrophication is, however not only a man-made problem because any changes within a catchment, natural or otherwise, will influence the biological state of its lakes and rivers (Harper, 1992). High concentration of nutrients especially Nitrogen (N) and Phospor (P) in the water that cause eutrophication of the lake has fueled the high growth of the water hyacinth (*enceng gondok*). Nutrients can come from agricultural land such as irrigated paddy field, rainfed and vegetable farms, that are located in the catchment area of the lake.

Based on the sedimentation rate, it was predicted that in the year of 2021, Rawapening Lake will full of sediment (Soeprobowati R.T.,2011). In addition, the sedimentation in the Rawapening Lake has increased from 133.75 m^3 in 1993 to 149.22 m^3 in 2003. As a result Rawapening's water capacity decreased by approximately 16 million m^3 during the 28 years (1976 s / d 2004) from 65 million m^3 to 49 million m^3 (Kompas, 2009).

Rawapening Lake has many functions i.e. hydroelectricity power, agricultural irrigation, fisheries and tourism, the mitigation is a must to be done urgently. In case of hydroelectricity, the increasingly growth of population and industry sector has lead to an enhanced demand for electrical energy (Marcelina, Sabar, Salami, and Marganingrum,. 2016.). Therefore, Rawapening Lake is necessary to be managed properly so that its function can be maintained.

Objectives of this study are to determine the total amount of nutrients supply from agricultural land (irrigated paddy field, rainfed and vegetable farms) on each catchment area of the Rawapening Lake and provide alternative solutions to reduce nutrients concentration.

2. Methods

a. Location

This research is located in catchment area of Rawapening Lake, which is geographically lied in the coordinate between 110^{o}17' to 110^{o}30' East and 7^{o}5' to 7^{o}25' South..The catchment area of Rawapening Lake is mostly located in Semarang district. The area can be devided into nine sub catchments namely Galeh, Kedung Ringin, Legi, Panjang, Parat, Rengas, Ringin, Sraten and Torong. Slopes of land in the catchment area vary from 0 % to more than 45 %. Slopes of land between 0 - 8% are located around the lake. The slopes of land between 8 - 15% are located at the foot slope of Merbabu Volcano, while slopes with more than 45 % are located at around Gajah Mungkur Mountain. The Research area is presented in Figure.1.

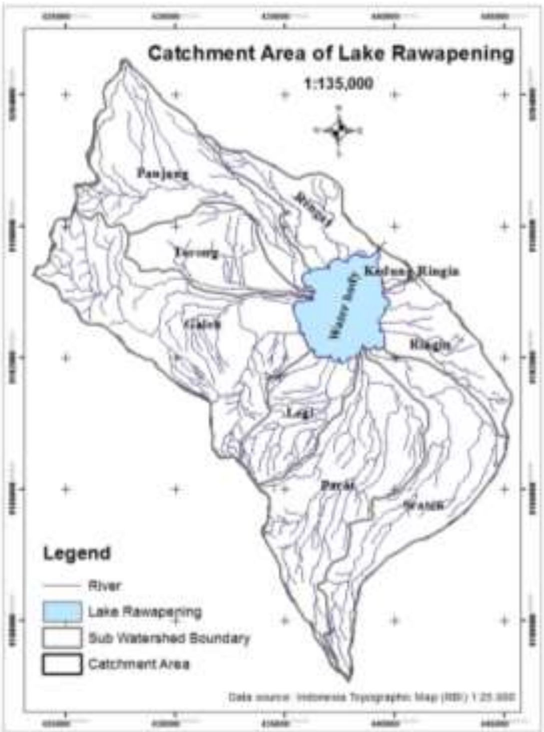

Figure 1. Research location map

Rawapening Lake, one of the Indonesia's conservation priority lakes, is a natural lake located in Semarang district Central Java Province. The lake is extremely important for ecological system. Furthermore, it supports power plants generation for the people, capture fisheries, irrigation, water supply, domestic uses, and more importantly for tourism activities. In brief, with the extent of 25.079 ha area, the lake is a pierce ecosystem to support human welfare in the area (Kurniawan,. Nishihiro,. and Yuniarti,. 2012).

According to Central Java Environmental Agency (Badan Lingkungan Hidup) (2012), water volume maximum of Rawapening Lake is 65 million m^3 and minimum 25 million m^3 approximately.

b. Material and Tools

The materials used in this research are Indonesian Topographic Map (RBI) scale of 1:25.000 produced on 2001, SPOT-2 image recorded in July 5th 2006 and thematic map such as soil type map scale 1:100.000 and geological map scale 1:100.000. Tools can be devided into three i.e. digital image processing and GIS analysis such as hardware and software (Erdas Imagine version 9.1 and ArcGIS 10.2). Field survey equipment consists of compas, Global Positioning System (GPS), balpoint, clipboard. Printing equipment consists of cartriges and papers.

c. Research Procedures

Information of agricultural land can be obtained from Indonesian Topographic Map (RBI) scale of 1:25.000 and updated with SPOT-2 image recorded in July 5th, 2006. Research procedure is presented in figure 2.

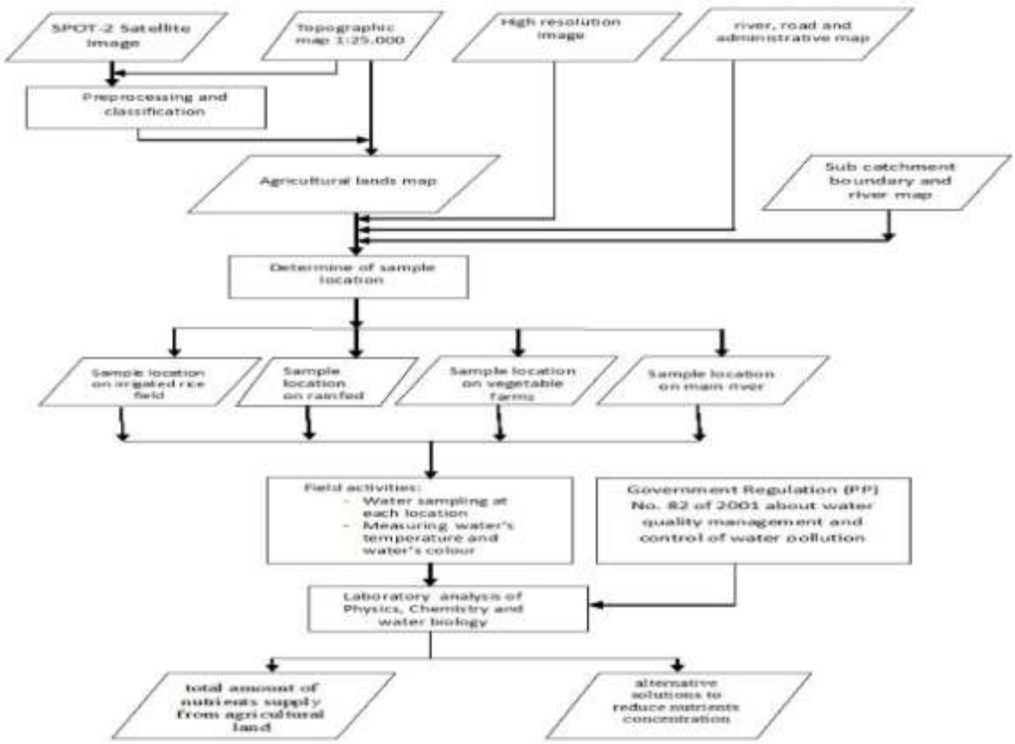

Figure 2. Chart of Research procedures

All images obtained through sensor recording mechanism can not be separated from errors that can be caused by the mechanism of recording, satellite movement, topography of the earth's surface and atmospheric conditions at the time of recording. The error needs to be corrected so that the image can be used for resource mapping and environmental assessment (Danoedoro,. 2012). In case of satellite imageries which experience topographically induced illumination effects, one measure that can be done to improve the land cover classification results is by conducting topographic correction (Santosa,. 2016). Topographic maps can be used to perform geometric corrections. The corrected image is further classified to obtain agricultural lands information.

High resolution images, administrative maps, road networks and river channels are used to determine surface water sample location on agricultural land. Surface water samples were taken from agricultural land such as irrigated rice field, rainfed, vegetable farms. Each type of agricultural land has 3 surface water samples and were taken in rainy and dry season. Total amount of samples are 18 samples. Samples were taken in rainy season have same coordinate with the ones were taken in dry season.

All the samples were analyzed in the hydrological laboratory of the Center for Environmental Health Engineering and Disease Control (BBTKLPP) Yogyakarta.

Average amount of nutrients concentration especially Nitrogen (N) and Phospor (P) the samples were calculated for each sub catchment.

3. RESULT AND DISCUSSION

3.1 Agricultural Land In The Catchment Area

Agricultural land can be devided into three types namely irrigated paddy field, rainfed and vegetable farms. Area of agricultural land of each sub catchment was presented in table 1.

Table 1. Area of Agricultural Land in the Catchment Area of Rawapening Lake

No.	Sub Catchment	Agricultural Land (Ha)			Total
		Irrigated rice Field	Rainfed	Vegetable Farms	(ha)
1	Galeh	503,05	504,62	0,00	1.007,67
2	Kedung Ringin	74,62	10,42	0,00	85,04
3	Legi	256,23	127,89	0,00	384,12
4	Panjang	231,58	988,49	643,74	1.863,81
5	Parat	474,04	668,06	358,33	1.500,43
6	Rengas	488,84	248,13	0,00	736,97
7	Ringin	662,94	65,03	0,00	727,97
8	Sraten	265,17	402,71	218,29	886,17
9	Torong	509,97	117,40	0,00	627,37
10	Water body/lake	0,00	0,00	0,00	0,00
Total		**3.466,46**	**3.132,74**	**1.220,36**	**7.819,56**
Prosentage		**44,33 %**	**40,06 %**	**15,61 %**	**100%**

Based on Table 1, the total area of agricultural land in the catchment area of Rawapening Lake is 7.819,56 ha which is derived from irrigated rice field (3.466,46 rice field, i.e. 662,94 ha. Panjang sub catchment has the most extensive rainfed and vegetable farms. In irrigated rice fields, rice cultivation is done at least 2 times a year. While in rainfed area, rice is grown at least 1 time a year, this is due to lack of water supply during the dry season. Most of the villagers around Rawapening Lake had livelihood as farmers (6,970 people or 21.36%) or farm laborers (9,749 people or 9.88%), and only 11.20% became industrial laborers (Kementerian Lingkungan ha), Rainfed (3.132,74 ha) and Vegetable Farms (1.220,36 ha). Irrigated rice field is mostly located around the lake. Ringin sub catchment has the most extensive irrigated HidupRepublik Indonesia. 2011.). Spatial distribution of agricultural land in the catchment area was presented in figure 3.

Rawapening lake is surrounded by irrigated rice field and aquaculture activities such as fish farming that can product several chemical elements such as N and P. High concentration of nutrients especially Nitrogen (N) and Phospor (P) in the water that cause eutrophication of the lake has fueled the high growth of the water hyacinth (*enceng gondok*).

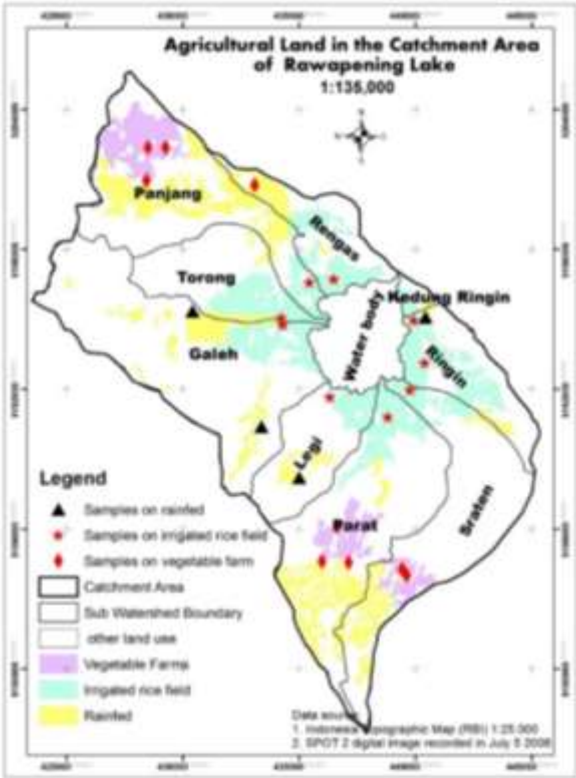

Figure 3. Spatial distribution of agricultural land in the catchment area

3.2 Chemical Fertilization in Agricultural Land in the Catchment Area

Chemical Fertilization used in rainfed and irrigated rice field are urea (NH_2CONH_2) and ponska, while for vegetable farms are ZA $(NH_4)_2SO_4$ and manure. N and P element supplied of each sub catchment is presented in table 1. The chemical content in the urea (NH_2CONH_2) fertilizer is Nitrogen (N = 46%), while the chemical content in the phonska fertilizer is Nitrogen (N) = 15%, Phoshor (P) = 15%, Kalium (K) = 15%, and Sulfur (S) = 10%.

Table 5. Average amount of Nitrogen (N) and Phorpor (P) supply from agricultural land of each sub catchment

		Irrigated rice filed		Rainfed		Vegetable farms		total		Total N and P element
No	**Sub Catchment**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	
		Ton/year	**Ton/year**	**Ton/year**	**Ton/year**	**Ton/year**	**Ton/year**	**Ton/year**	**Ton/year**	**Ton/year**
1.	Galeh	122,745	30,183	61,564	15,139	0	0,000	184,309	45,322	229,631
2.	Kd. Ringin	18,208	4,477	1,271	0,313	0	0,000	19,479	4,79	24,269
3.	Legi	62,52	15,374	15,603	3,837	0	0,000	78,123	19,211	97,334
4.	Panjang	56,506	13,895	120,596	29,655	591,923	62,282	769,025	105,832	874,857
5.	Parat	115,666	28,442	81,504	20,042	329,483	34,668	526,653	83,152	609,805
6.	Rengas	119,278	29,331	30,272	7,444	0	0,000	149,55	36,775	186,325
7.	Ringin	161,757	39,776	7,934	1,951	0	0,000	169,691	41,727	211,418
8.	Sraten	64,702	15,910	49,13	12,081	200,715	21,119	314,547	49,11	363,657
9.	Torong	124,433	30,598	14,323	3,522	0	0,000	138,756	34,12	172,876
		845,816	**207,988**	**382,194**	**93,982**	**953,712**	**118,070**	**2.181,722**	**420,04**	**2.601,762**
Prosentase			**49,52 %**			**43,71 %**		**85.85 %**	**14,15 %**	

Based on table 2, The total element of N and P from agricultural land in the cathment area that flows to the Rawapening Lake is 2.601,762 ton annually, the N element contributes 2.181,722 ton**,** while the P element contributes 420,04 ton. Panjang sub catchment supplies the highest N and P elements i.e. 874,857 ton annually, this is because Panjang sub catchment has the most extensive agricultural land. While Kd.Ringin sub catchment supplies the lowest N and P elements i.e. 24,269 ton annually. According to Sudarmadji,. Wantasen,. and Suprayogi,. 2012. Irrigation channels will carry nutrient residues from fertilizing activities, especially the use of Urea fertilizer. Urea: NH_2CONH_2 will be hydrolyzed to produce ammonium nitrate, and the plant absorbs the nutrients form of ammonium (NH_4^+) and nitrate (NO_3^-). Losing nitrogen is mainly due to volatilization, denitrification, leaching or becoming unavailable due to immobilization. Applying fertilizer method by sowing above ground can cause nitrogen loss through washing, evaporation and drainage. Nitrogen is the main nutrient for plant growth, which is necessary for the forming of leaves, stems and roots (Sutedjo,.2002).

The excessive enrichment of waters with anthropogenic sources of nutrients especially nitrogen (N) and phosphorus (P) lead to the transformation of oligotrophic water bodies to mesotrophic, eutrophic, and finally hypertrophic. Mesotrophic and eutrophic phases exhibit intermediate and rich levels of nutrients and show increasing and serious water quality problems, respectively. Eutrophication restricts water use for fisheries, recreation, industry, and drinking because of increased growth of undesirable algae and aquatic weeds and the oxygen shortages caused by their death and decomposition (M. Nasir Khan Nasir. M. and Mohammad F. 2014). According to Novisan (2002), continuous and uncontrolled used of Chemical fertilizers will have an adverse impact on soil fertility and the environment around agricultural land, such as soil pH decreased, soil structure deterioration, disturbed organisms in the soil and decreasing water quality in agricultural land and river areas.

To inhibit the rate of eutrophication in Rawapening Lake is done by reducing N and P elements derived from chemical fertilizers on agricultural lands. N and P elements supplied to the lake can be reduced by reducing the total area of agricultural lands around the lake. The agricultural lands around the lake can be reduced by building border of the lake. Based on the regulation of the Minister of Public Works and Public Housing No. 28 in 2015 (No.28/PRT/M/2015) about The river buffer zone and the lake buffer zone, the lake buffer zone should be built 50 meters wide surrounding lake. The lake buffer zone (*sempadan danau*) is the certain area surrounds the lake which can be used to

Protect the lake. According to the regulation, the lake buffer zone of Rawapening Lake should be developed, existence of lake buffer zone of Rawapening Lake will reduce the area of agricultural land, especially irrigated rice fields surrounds the lake, thus the total elements of N and P that enter to the lake will decrease by 22.33 ton and 5.49 ton anually. Quantitative analysis of the impact lake buffer zone (*sempadan danau*) development is presented in Table 3The area of irrigated rice field should be reduced by 91.53 ha surrounding the lake. According to Maryono (2005), the lake buffer zone can be devided into 3 rings. Ring 1 is filled with large trees that is commonly found in the area while ring 2 is filled with smaller trees with lower density than ring 1 and ring 3 filled with trees with the lowest density than the other ring. Vegetations in the lake buffer zone can be used to decreasing seepage of the lake water horizontally, protecting landslides, decreasing of lake water temperature and improving the quality of lake ecosystems.

3.2 Reducing N and P elements from agricultural land

Eutrophication, which is the excessive growth of plants caused by anthropogenic nutrient enrichment, is recognized as the primary problem facing most surface waters worldwide (Smith and Schindler 2009). The main driving factor of eutrophication is a change by human activity on land use in water catchment areas and nutrient input from untreated sewages.

Table 6. Quantitative analysis of N and P supply from agricultural land impact of lake buffer zone development

No	Sub watershed	Area (ha)			%	N (early) ton/year	P (early) ton/year	N (reduction) ton/year	P (reduction) ton/year	N (remaining) ton/year	P (remaining) ton/year
		Irrigated rice field (early)	Lake buffer zone	Irrigated rice field (remaining)							
1	Galeh	503.05	16.514	486.54	3.28	122.75	30.18	4.03	0.99	118.72	29.19
2	Kedung Ringin	74.62	9.602	65.022	12.87	18.21	4.48	2.34	0.58	15.87	3.90
3	Legi	256.23	13.962	242.268	5.45	62.52	15.37	3.41	0.84	59.11	14.54
4	Panjang	231.58	7.613	223.967	3.29	56.51	13.90	1.86	0.46	54.65	13.44
5	Parat	474.04	2.504	471.537	0.53	115.67	28.44	0.61	0.15	115.06	28.29
6	Rengas	488.84	19.971	468.873	4.09	119.28	29.33	4.87	1.20	114.41	28.13
7	Ringin	662.94	15.765	647.174	2.38	161.76	39.78	3.85	0.95	157.91	38.83
8	Sraten	265.17	4.45	260.724	1.68	64.70	15.91	1.09	0.27	63.62	15.64
9	Torong	509.97	1.148	508.825	0.23	124.43	30.60	0.28	0.07	124.15	30.53
	Total	**3466.44**	**91.529**	**3374.93**		**845.82**	**207.99**	**22.33**	**5.49**	823.48	202.50

4. Conclusions

The total element of N and P from agricultural land in the water cathment area that enter to the Rawapening Lake is 2.601,762 ton annually, the N element contributes 2.181,722 ton**,** while the P element contributes 420,04 ton. Panjang sub watershed supplies the highest N and P elements i.e. 874,857 ton annually, Kd.Ringin Sub watershed supplies the lowest N and P elements i.e. 24,269 ton annually. Reducing N and P element can be done by reducing the total area of agricultural lands around the lake and developing lake buffer zone.

The used of chemical fertilizers on agricultural land should be reduced and replaced by applying organic fertilizer gradually. Lake buffer zone should be developed to prevent the occurrence of ecosystem damage in Rawapening Lake.

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