The effect of small dams in Rawa Pening catchment area on sedimentation rate of Rawa Pening Lake

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Abstract. Rawa Pening Lake is one of fifteen priority lakes. The problem in Rawa Pening Lake is the rapid sedimentation rate and blooming of water hyacinth which has an impact on the decreasing of storage capacity and water quality. The handling has not shown significant results. Therefore, that it needs to innovate on improvement and maintenance of Rawa Pening Catchment Area that has never done that is in the form of small dam development in Rawa Pening catchment area. The construction of a small dam in the Rawa Pening catchment area can temporarily hold water and prevent the rate of sediment from entering the lake. The purpose of this research is to analyse the influence of small dams in the Rawa Pening catchment area to sedimentation rate in Rawa Pening Lake. Sedimentation is calculated based on soil erosion in the catchment area, using the USLE formula. If There are 40 small-dams in Lake Rawa Pening catchment area, the sedimentation decreased to 78.75%. If there are only 2 small-dams constructed in the Klegung sub-watershed and the Legi sub-watershed, the sedimentation decrease to 67%.

1 Introduction

Rawa Pening Lake is a natural lake that has role as a natural reservoir used for hydropower, raw water sources, irrigation, fisheries, and tourism. Under the Bali Agreement of 2009, Rawa Pening Lake is one of fifteen priority lakes. The Ministry of Tourism seeks to make Rawa Pening a tourist attraction as a world tourism destination. Rawa Pening Lake located in Salatiga Regency and Semarang Regency, Central Java Province (Figure 1). The catchment area of Rawa Pening Lake is upstream of the Tuntang watershed. Administratively, the catchment area of Rawa Pening Lake covers 72 villages in 11 sub-districts in Semarang and Salatiga Regencies.

Fig. 1. Research Location (Google Map, 2018)

Hydrologically, the water of Rawa Pening Lake comes from rainfall, groundwater, and surface water from 17 river streams. The catchment area of Rawa Pening Lake covers an area of 25,041.50 Ha. The water release of Rawa Pening Lake through 1 outlet without the controller that is the Tuntang River and this is the cause of flooding in the Grobogan. Rawa Pening Lake water is 80% wasted into the sea during the rainy season, and only 20% can be utilized [1].

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According to [2] sediment loads in the tributaries which entering Rawa Pening Lake higher than in the outlet. This indicates that Rawa Pening Lake acts as a shelter of sediment deposition and nutrients from the surrounding rivers. Spatially and temporally the condition of water quality in the lake shows high variation. High nutrient concentrations in the lake during the rainy and dry seasons indicates that the nutrients source not only comes from outside but also from within the lake itself. The results of this study indicate that Rawa Pening Lake is a eutrophic lake. Phosphorus is thought to be the main factor causing eutrophication and growth of water hyacinth. The land functions conversion that occurred in the Rawapening Sub-watershed triggered an increase in erosion rate which resulted in high sedimentation in Rawapening Lake [3].

Tributaries of Rawa Pening Lake carry river mud and various kinds of agricultural, livestock, and industrial wastes from communities around the river flow with nitrogen and phosphorus content. This causes another problem that occurs in Rawa Pening Lake that is water hyacinth blooming. Even in 2011, the water hyacinth weed covered the surface area of the lake approximately 1,080 hectares or about 70 percent of the lake area [1].

Returning of the capacity and function of Rawa Pening Lake was carried out starting in 2016 by the Ministry of PUPR through the Balai Besar Wilayah Sungai Pemali Juana. Measurements were taken covering sedimentation control in the form of dredging and construction of check dams, determination of border zones of the lake, construction of embankments of border zones of the lake, and control of aquatic weeds by routine cleaning of water hyacinth [4].

The planning of Rawa Pening Lake management is developed to determine the potential locations of the small dams which are useful to reduce the peak hydrograph of Tuntang River floods and increase low flows of Rawa Pening Lake [1]. From this research, there are 40 potential locations of small-dams in 16 tributaries entering Rawa Pening Lake (Figure 2). This study proves that the small-dams in the Rawa Pening Watershed can reduce the flood, so the risk of flooding along the Tuntang River can be reduced.

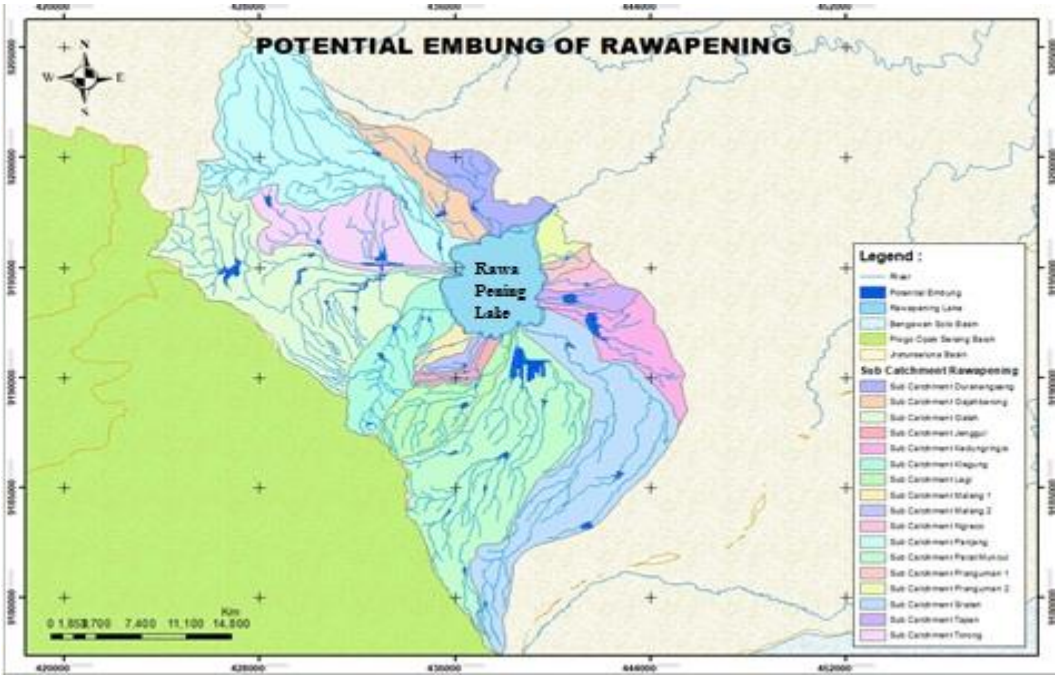

Fig. 2. Location of potential small dam in the Lake of Rawa Pening Watershed (Darsono et al., 2018)

Based on the description above, the construction of small-dams in the Rawa Pening catchment area can be used as a water discharge controller to reduce flooding in the rainy season and regulate water supply in the dry season. The small dams built in the Rawa Pening catchment area in addition to holding water while also receiving and depositing a part of sediment which carried by the stream.

So that the root causes of the high sedimentation rate of the Lake Rawa Pening will overcome and the concept of a lake Rawa Pening as world tourism will realize. Therefore, it is necessary to determine the effect of small dams in the Rawa Pening catchment area on sedimentation rates of Lake Rawa Pening.

2 Method

This study aims to analyze the erosion and the rate of sedimentation in Rawa Pening Lake in condition with small-dams and without small-dams. This research is part of the main research in preparing the management plan of Lake Rawa Pening to become an ecotourism-based world tourism. The previous research phase was about potential small dams. Sedimentation is calculated based on soil erosion in the catchment area which is calculated using the USLE formula. Not all materials resulting from soil erosion will be transported and arrive at the outlet of the watershed. The amount of erosion material transported to the watershed outlet (Yield sediment) will obtain from the

magnitude of the material resulting from the erosion multiplied by the sediment delivery ratio. In the reservoir, this material will undergo a process where some part of the sediment will settle, and some will go carried by the stream to downstream. The stages of the research illustrated in the flowchart of Figure 3.

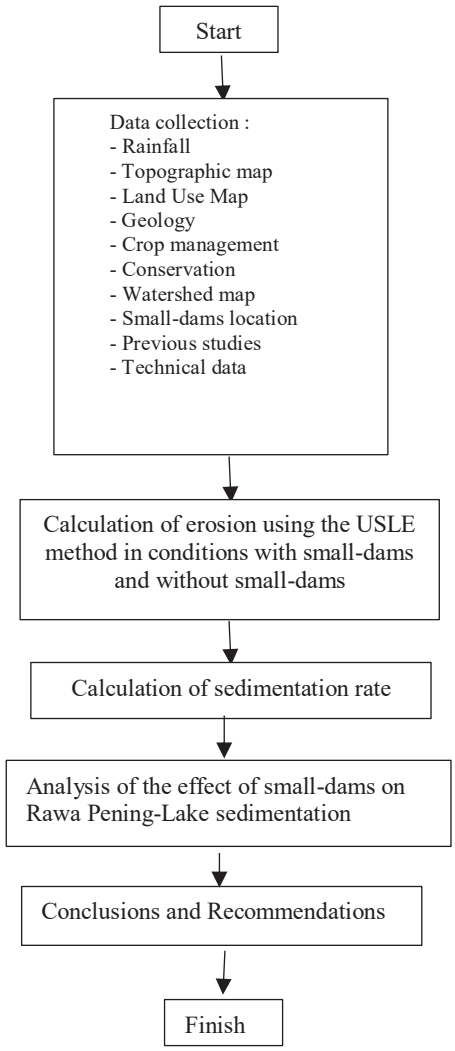

Fig.3. Flowchart of research

3 Result and discussion

Based on the results of calculations in Table 1, the erosion rate in each sub-watershed ranges from 0.004 to 35.93 tons/ha/year. The erosion rate that occured in the Klegung and Legi sub-watersheds exceeds the maximum erosion limit of 10 tons/ha/year [5]. In both sub-watersheds, the topography has a steep slope so that the erosion energy produced is also high resulting in high erosion rates. The Klegung sub-watershed is the first supplier of sediment yield to Lake Rawa Pening, and the second supplier is the Legi watershed (Table 2). The total yield of sediment in Lake Rawa Pening under conditions without a small dam is 33,820.47 m^3/year.

In conditions with small-dams, the Legi sub-watershed is the first supplier of sediment yield to Lake Rawa Pening and the second supplier is the Klegung sub-watershed (Table 3).

In Figure 4, the decrease in sediment yield in the Klegung sub-watershed and the Legi sub-watershed are quite high in condition with small-dams. The total sediment yield of Lake Rawa Pening under conditions with small-dams is 7,469.98 m^3/ year, and the sediment yield decreases by 77.91%. If small dams will build in the Klegung sub-watershed and the Legi sub-watershed, the total sediment yield of Lake Rawa Pening is 11,139.39 m^3/year, and the sediment yield decreases by 67%.

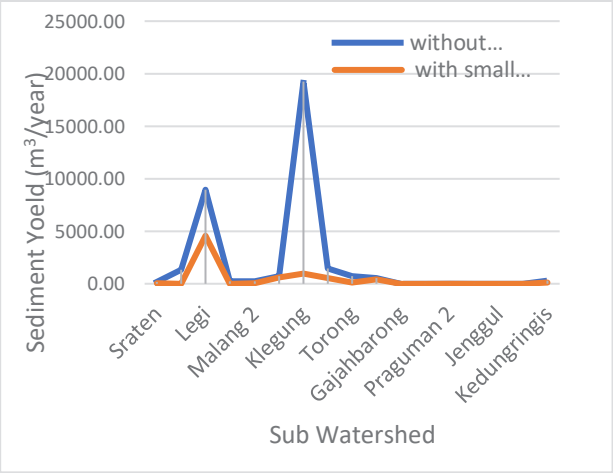

Fig.4. Sediment yield for each sub watershed in conditions without small-dams and with small-dams

Table 1. Erosion in each sub-watershed of Lake Rawa Pening in condition without small-dams

No.	Sub Watershed	Area (Ha)	K (Ton/KJ)	LS	C	P	R (KJ/Ha/Year)	Ea (Ton/Ha/Year)
1	Sraten	3,984.0	0.32	0.56	0.008	0.06	2,079.75	0.168
2	Parat	4,413.0	0.32	3.05	0.003	0.22	2,170.90	1.363
3	Legi	1,149.0	0.38	1.31	0.030	0.64	2,108.55	20.352
4	Ngreco	243.0	0.35	0.31	0.032	0.35	1,775.74	2.178
5	Malang 2	175.0	0.44	0.34	0.032	0.28	1,765.82	2.394
6	Malang 1	225.0	0.40	0.37	0.033	0.73	2,174.24	7.817
7	Klegung	1,461.0	0.42	1.64	0.054	0.51	1,887.16	35.930
8	Galeh	3,359.0	0.32	0.33	0.013	0.66	1,779.79	1.642
9	Torong	1,769.0	0.42	0.30	0.008	0.68	1,772.97	1.256
10	Panjang	4,354.0	0.33	0.59	0.012	0.12	1,802.96	0.497
11	Gajahbarong	908.0	0.35	0.14	0.010	0.02	1,786.83	0.018
12	Duranangsang	814.5	0.37	0.17	0.002	0.02	1,765.82	0.005

No.	Sub Watershed	Area (Ha)	K (Ton/KJ)	LS	C	P	R (KJ/Ha/Year)	Ea (Ton/Ha/Year)
13	Praguman 2	85.0	0.31	0.19	0.002	0.02	1,765.82	0.005
14	Praguman 1	221.0	0.31	0.19	0.002	0.33	1,765.82	0.076
15	Jenggul	226.0	0.31	0.15	0.002	0.02	1,765.82	0.004
16	Tapen	326.0	0.31	0.15	0.009	0.02	1,765.82	0.015
17	Kedungringis	1,329.0	0.31	0.13	0.011	0.76	1,827.84	0.611

Table 2. Sediment yield of Rawa Pening Lake in condition without small-dams

No.	Sub Watershed	Ea (m^3/Year)	Sediment Delivery Ratio	Sediment Yield (m^3/year)
1	Sraten	557.27	0.29	161.61
2	Parat	5,011.08	0.26	1,302.88
3	Legi	19,486.71	0.46	8,963.89
4	Ngreco	441.03	0.51	222.72
5	Malang 2	349.15	0.59	206.00
6	Malang 1	1,465.69	0.51	747.50
7	Klegung	43,744.74	0.44	19,247.68
8	Galeh	4,595.53	0.31	1,424.61
9	Torong	1,851.31	0.38	703.50
10	Panjang	1,803.67	0.30	532.08
11	Gajahbarong	13.78	0.43	5.92
12	Duranangsang	3.60	0.41	1.47
13	Praguman 2	0.33	0.58	0.19
14	Praguman 1	13.98	0.50	6.99
15	Jenggul	0.69	0.51	0.35
16	Tapen	4.16	0.50	2.08
17	Kedungringis	676.70	0.43	290.98
Total sediment Yield of Rawa Pening Lake				**33,820.47**

Table 3. Sediment yield of Rawa Pening Lake in condition with small-dams

No.	Sub Watershed	Sub sub-Watershed	Ea total (m^3/Year)	Sediment Delivery Ratio	Sediment Yield (m^3/year)
1	Sraten	Batur	294.73	0.58	170.95
2		Taju	8.91	0.56	4.99
3		Kumpul Rejo	16.28	0.52	8.47
4		Candi Rejo	158.49	0.25	39.62
5		Sraten Hilir	58.45	0.53	31.15
6	Parat	Kopeng 2	27.46	0.56	15.38
7		Wates	8.96	0.53	4.75
8		Kopeng 1	0.90	0.50	0.45
9		Manggihan	120.37	0.47	56.57
10		Kalibeji	25.18	0.50	12.59
11		Nogosaren	1,794.84	0.60	1,076.90
12		Rowosari	120.05	0.46	55.22
13		Parat Hilir	8.85	0.56	4.95
14	Legi	Sepakung	5,130.25	0.57	2,924.25
15		Kebumen	16,040.84	0.54	8,662.05
16		Legi Hilir	8,620.87	0.53	4,569.06
17	Ngreco	Tegaron 1	231.22	0.58	134.11
18		Tegaron 2	264.00	0.58	153.65
19		Ngreco Hilir	36.89	0.56	20.59
20	Malang 2	Tegaron 3	337.53	0.60	202.52
21		Malang 2 hilir	78.93	0.57	44.68
22	Malang 1	Banyubiru	564.82	0.58	327.59
23		Malang 1 Hilir	1,081.05	0.56	603.22
24	Klegung	Kalimalang	1,652.20	0.61	1,007.84
25		Kebondowo 1	26,055.70	0.50	12,897.57
26		Kebondowo 2	14,861.98	0.56	8,367.29
27		Wirogomo 2	2,248.64	0.57	1,283.97
28		Wirogomo 1	1,533.16	0.57	866.24
29		Klegung Hilir	1,845.36	0.52	961.43

No.	Sub Watershed	Sub sub-Watershed	Ea total (m^3/Year)	Sediment Delivery Ratio	Sediment Yield (m^3/year)
30	Galeh	Ngrapah	116.00	0.57	66.35
31		Lopait	945.85	0.52	489.01
32		Banyukuning	3,113.91	0.51	1,594.32
33		Delik	141.85	0.52	74.33
34		Jambu	272.36	0.58	157.42
35		Pojoksari	561.60	0.56	316.18
36	Torong	Brongkol 2	52.05	0.57	29.77
37		Brongkol 1	357.66	0.50	178.83
38		Baran	1,515.69	0.51	773.00
39		Torong Hilir	245.28	0.56	137.36
40	Panjang	Lodoyong	44.08	0.49	21.60
41		Kranggan	1,805.78	0.48	866.77
42		Tambakboyo	204.80	0.25	51.20
43		Panjang Hilir	746.46	0.58	432.94
44	Gajah Barong	Kupang	8.76	0.49	4.32
45		Gajah Barong hilir	6.72	0.50	3.37
46	Duranangsang	Rejosari	1.58	0.50	0.79
47		Duranangsang Hilir	2.42	0.52	1.26
48	Praguman 2	Praguman 2	0.33	0.58	0.19
49	Praguman 1	Ngrapah 2	9.51	0.60	5.70
50		Praguman 1 Hilir	3.75	0.58	2.17
51	Jenggul	Kesongo	0.29	0.69	0.20
52		Jenggul Hilir	0.41	0.56	0.23
53	Tapen	Pramuka	3.39	0.50	1.70
54		Tapen Hilir	0.87	0.57	0.49
55	Kedungringis	Kebondowo 3	950.52	0.47	446.75
56		Kedungringis Hilir	178.76	0.53	95.28
Total sediment Yield of Rawa Pening Lake					**7,469.98**

4 Conclusion

There are 40 small-dams in 16 tributaries that enter Lake Rawa Pening which affect the rate of sedimentation in Lake Rawa Pening. With these 40 small-dams, the amount of sedimentation decreased to 77.91%. The decrease in sediment yields in Lake Rawa Pening is due to the decrease in sediment yields in the two sub-watersheds that have high erosion levels, namely the Klegung and Legi sub-watersheds. If the reservoir (7 small-dams) will build in the Klegung and the Legi sub-watershed, the decrease in sediment yield is 67%.

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