Reservoir Life Time Service Estimation Based on Agroforestry System

Devianti, Nurpilihan Bafdal, Chay Asdak, Edy Suryadi

Abstract— Reservoir service life time is largely determined by the amount of erosion and sedimentation as a consequence of land use management system in water catchment area especially related to the land use pattern in a cultivated area. Actual life time service in Jatigede reservoir, recorded in 2009, was estimated 69,274.97 ha (87%) from a total of Jatigede reservoir catchment area 80,522.35 ha. The widest cultivated area was Tegal field cultivation 35,972.32 ha, As a result, this affected on the amount of erosion 44,993,316.14 ton and sedimentation into the reservoir 38,995,344.24 ton, with a service life time Jatigede reservoirs remaining 13 years from its initial 50 years estimation in 1986, where the percentage of the area cultivation of 70%. One way to improve reservoir service life time can be performed by applying Agroforestry system. This system generated erosion volume 23,540,224.77 ton with corn intercropping turmeric+maize+red beans+local chili. On the other hand, agroforestry models with intercropping patterns turmeric+maize+red beans decreased erosion volume to 30,691,255.23 ton and monoculture agroforestry local cayenne can reduce the amount of erosion 40,592,682.02 ton of the amount of erosion of the mixed field. This resulted a decrease in the amount of erosion and sedimentation volume entering the reservoir in a row to be 14,930,267.70 ton, 17,399,355.72 ton, 31,857,924.77 ton with a service life time 30, 26 and 14 year of the actual condition of 13 years.

Index Terms— Estimation, Reservoir Life Time, Agroforestry System.

1 INTRODUCTION

Reservoir service life time is largely determined by the amount of erosion and sedimentation as a consequence of land use management system in water catchment area. In the reservoir design, service life time is one of the most important parameters affected economic reliability and water resources availability [1]. Sedimentation, occurred one percent per year, may decrease reservoir catchment capability.

The reservoir life time may decrease resulted from watershed erosion and sedimentation which are affected by land use management in water catchment area. The erosion amount was increased every as the implications of land use changes due to land use management system from 26,658,648.21 tons in 1994 to 44,993,316.15 tons in 2009. Numerous studies also reported that land use management system implicated to the sedimentation rate. The unbalanced reservoir may decrease irrigation water availability and other function as a water catchment systems.

To maintain and extend reservoir service life time, there are some efforts that can be performed in which one of them is applying Agroforestry system based on the principle of soil and water conservation to reduce erosion amount to maximum 17%. Agroforestry system identified with its vegetation ground cover that has a multi-storage structures reduced rainwater kinetic energy raindrops diameter [2]. Agroforestry systems can reduce erosion by 17%, whilst contour planting can reduce erosion only 35% [3].

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2 RESEARCH METHOD

This research was conducted in Jatigede watershed which is geographically located at 060 52 '00 "south latitude and 1080 06' 00" east longitude. This watershed is part of the subzone Cimanuk upstream as shown in Figure 1. Study, aimed to determine the erosion amount in Agroforestry systems, consisted with forest plant white teak (*gmelina*) and located in the village of Simpen Kaler, Limbangan, Garut. This also categorized in Sub-Sub-Cipancar Cianten watershed group.

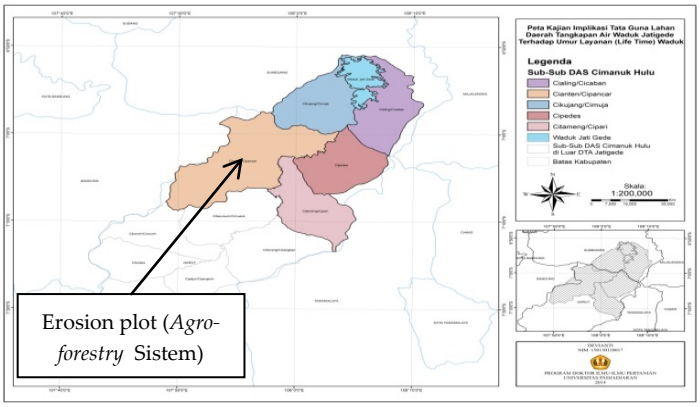

Fig. 1 DTA waduk Jatigede

Service life time of Jatigede reservoirs was estimated and predicted based on initial existing condition and the implementation of agroforestry systems. Several parameters, influenced to the service life time of reservoir are: erosion, and sedimentation amount, and the trap efficiency. Erosion amount was analyzed using MUSLE equation [4], while sedimentation amount was analyzed using sediment routing equation [5]:

$$Ry = \sum_{i=1}^{n} Y_i \exp\left(-\beta T_i \sqrt{d_i}\right) \quad (1)$$

Ry is the sum of river sediment, Y_i is MUSLE erosion, while β is the coefficient of sediment routing, calculated by an iterative algorithm using Solver in Microsoft Excel. B value obtained by equating the value equation as shown in the following equation:

$$= 11.8(Q, qp)^{0.56} K C P L_s$$

$$= 11.8 \sum_{i=1}^{n} (Q_i qp_i)^{0.56} K_i C_i P_i Ls_i \exp\left(-\beta T_i \sqrt{d_i}\right) \quad (2)$$

Trap Efficiency (TE) can be calculated using the equation Brown [6]:

$$TE = 100 \times \left[1 - \frac{1}{1 + 0.0021 D \left(\frac{SC}{A}\right)}\right] \quad (3)$$

Description: TE is a sediment trap efficiency, Sc is planned reservoir capacity (m^3) and A is watershed area (km^2). D is the coefficient of reservoir characteristics, the value of D is between (0.046 -1), with an average value of 0.1 and obtained by using Brown curve. Having obtained the efficiency trap then according [7], the reservoir service life time be calculated using the equation

$$Y = 100 \times \frac{SV \cdot \rho_b}{RY \cdot TE} \quad (4)$$

Description: RT is a sediment routing (to $year^{-1}$), SV sediment volume (m^3), TE trap efficiency (%), ρb is dry bulk density ($ton.m^{-3}$) and Y is a reservoir service life time (years).

3 RESULTS AND DISCUSSIONS

Jatigede multipurpose reservoir service life was estimated based on initial existing condition using land use management map in 2009 [8] as shown in Table 1, and land use agroforestry systems management of (Table 1).

Analysis results of the Jatigede reservoir service life based on initial existing land use management are shown in Table 2.

Land use management in 2009 has implications for the amount of erosion Jatigede reservoirs of 44,993,316.15 ton. The amount of erosion in the watershed Cianten Sub-Sub-Cipancar of 13,166,548.97 ton, and the erosion of the smallest in the sub-sub-watershed reservoirs Jatigede of 1,027,696.78 tons. Results of the analysis of sediment routing models, obtained a total of 38 995 344.24 ton. sediment gravity 1.164 ton/m^3 [9]. The volume of sediment into the reservoir (sediment inflow) is the ratio of the amount of sediment routing divided by the density of the sediment, and the result is: 33,501,154.85 m^3, while the volume of sediment that dissolved at 26,766,564.39 m^3 is the result of the multiplication trap efficiency 0.8% with sediment inflow. Based on the comparison of the capacity of the sediment and dissolved one, the reservoirs service life was estimated for 13 years.

As shown in Table 2 contained the greatest amount of erosion on the sub-sub-watershed Cianten Cipancar. Thus, it is being used as the implementation of agroforestry systems. Making the erosion plot in the village of simpen Kaler, District Limbangan, Garut, precisely at the point of coordinates 070 00 '24.3 ", with altitude between 940-994 m above sea level (asl). Initial conditions land Agroforestry system of annual crops such as white teak (*Gmelina*) 3 years, and annual crops such as cassava and turmeric grown in monoculture. Measurement of the erosion plot by converting annual crops into three plots of measurement; (1) Plot 1 with annual crops intercropping planting patterns: turmeric + red beans + maize + local chili. (2) Plot 2 is turmeric + red beans + maize, (3) Plot 3 monocultures local chili. Agroforestry systems can be categorized as plot 1 sealed lid plant cover, 2 lid less dense plot, and plot 3 is included in the unsealed cover. The measurements results, derived for each rain even in erosion plot, is used to determine the CP value, by comparing the erosion amount predicted by MUSLE equation and actual erosion amount. The analysis results obtained value of CP measurements on plots 1, 2, and 3 were 0.04, 0.17 and 0.35 respectively. CP value measurement is then used to analyze the amount of erosion on the calculation of the service life of the Jatigede reservoir based on land use Agroforestry management system. The results of the analysis it is presented in Table 3.

The decrease in the amount of erosion on the plot 1 (CP 0.04) amounted to 23,540,224.77 ton, followed by plot 2 (CP 0.17) of 30,691,255.23 ton and plot 3 (CP 0.35) was 40,592,682.02 tons, and a mixed farms existing condition (CP 0.43) was 44,993,316.15 ton. The decrease in sediment found in plot 1 of 17,378,831.60 ton, followed by a second plot of 20,252,850.05 ton, and plot 3 amounted to 37,082,624.43 tons of the existing condition of 38,995 344.24 ton. Further, the amount of sediment entering the reservoir on plot 1 was 14,930,267.70 m^3, with the dissolved sediment was 11,944,214.16 m^3 and an estimated service life is approximately 30 years. In the second plot, the amount of entering sediment was 17,399,355.72 m^3 and dissolved sediment was 13,919,484.57, with the predicted service life time is approximately 26 years. Furthermore, in the plot 3, the amount of entering sediment was 31,857,924.77 m^3, with the dissolved sediment was 25,486,339.81 m^3, and the predicted service life was approximately 14 years.

4 CONCLUSION

Multipurpose Jatigede reservoirs service life time on its initial and existing land-use management condition was 13 years. We found that and concluded that with the application of Agroforestry systems in the area of 17,252.35 ha, with CP parameter values of 0.35, 0.17 and 0.04, would increase and extend the service life time to 14, 26 and 30 years respectively.
section.

Table 1 Existing land-use management and land use agroforestry systems management

No	Land use exiting	Land area (ha)	Percentage (%)	Land use scenario	Land area (ha)	Percentage (%)
1	Primary forests	87.55	0.12	Primary forests	87.55	0.12
2	Secondary Forests	10,878.22	13.51	Secondary Forests	10,878.22	13.51
3	Water body	281.62	0.35	Water body	281.62	0.35
Protected Areas		**11,247.39**	**13.97**	**Protected Areas**	**11,247.39**	**13.97**
4	Mixed Garden	17,252.35	21.43	Agroforestry	17,252.35	21.43
5	Plantation	80.49	0.09	Plantation	80.49	0.09
6	Settlement	792.50	0.98	settlement	792.50	0.98
7	Paddy field	14,633.47	18.17	Paddy field	14,633.47	18.17
8	Shrubs	359.26	0.45	Shrubs	359.26	0.45
9	Clearing	184.58	0.23	Clearing	184.58	0.23
10	Field	35,972.32	44.67	Field	35,972.32	44.67
Cultivation area		**69,274.96**	**86.03**	**Cultivation area**	**69,274.96**	**86.03**
DTA waduk Jatigede		**80,522.35**	**100**	**DTA waduk Jatigede**	**80,522.35**	**100**

Table 2 Erosion and sedimentation amount, Jatigede reservoir life-service on initial existing

No	Sub sub DAS DTA waduk Jatigede	Basin area (ha)	Erosi (ton)	β	Total sediment (ton)
1	Cialing Cicaban	12,640.34	6,904,326.49	0.19	29,746.49
2	Cianten Cipancar	25,885.54	13,166,548.97	0.19	15,313,292.38
3	Cikujang Cimuja	12,745.44	11,870,876.65	0.19	70,844.35
4	Cipedes	12,212.,10	5,628,820.20	0.19	604,079.52
5	Citameng Cipari	12,634.95	6,395,047.06	0.19	22,975,486.68
6	Waduk Jatigede	4,403.98	1,027,696.78	0.19	1,894.82
DTA Waduk Jatigede		80,522.35	44,993,316.15	0.19	38,995,344.24
Volume sedimen inflow (m^3)					33,501,154.85
Specific gravity Sedimen (ton/m^3)					1.164
Volume sedimen reservoir (m^3)					26,766,564.39
Reservoir capacity (SC.m^3)					359,100,000.00
Trap Efficiency					0.80
Life time reservoir (year)					13.42

Table 3 Erosion and sedimentation amount, Jatigede reservoir life-service Agroforestry systems on watershed land use management

No	Name of sub-sub-watershed DTA waduk Jatigede	Luas DAS (ha)	Plot 1 (CP = 0.04)			Plot 2 (CP = 0.17)		Plot 3 (CP = 0.35)	
			Erosion (ton)	β	Total sediment (Ton)	Erosion (ton)	Total sediment (Ton)	Erosion (ton)	Total sediment (ton)
1	Cialing Cicaban	12,640.34	3,816,694.74	0.18	15,254.38	4,845,905.32	20,185.17	6,270,966.13	27,375.45
2	Cianten Cipancar	25,885.54	9,130,764.61	0.18	7,658,075.62	10,476,026.06	8,596,395.67	12,338,695.77	14,789,952.71
3	Cikujang Cimuja	12,745.44	3,458,554.02	0.18	25,621.53	6,262,661.56	37,146.99	10,145,272.00	62,733.03
4	Cipedes	12,212.10	224,725.65	0.18	212,619.37	3,375,423.83	293,596.58	4,935,467.47	542,135.74
5	Citameng Cipari	12,634.95	4,183,156.03	0.18	9,466,000.09	4,920,453.04	11,304,103.55	5,941,325.82	21,658,632.92
6	Waduk Jatigede	4,403.98	702,329.72	0.18	1,260.61	810,785.41	1,422.09	960,954.82	1,794.58
DTA Waduk Jatigede		80,522.35	23,540,224.77		17,378,831.60	30,691,255.23	20,252,850.05	40,592,682.02	37,082,624.43
Volume sedimen inflow (m^3)					14,930,267.70		17,399,355.72		31,857,924.77
Specific gravity Sedimen (ton/m^3)					1.164		1.164		1.164
Volume sedimen reservoir (m^3)					11,944,214.16		13,919,484.57		25,486,339.81
Reservoir capacity (SC m^3)					359,100,000.00		359,100,000.00		359,100,000.00
Trap Efficiency					0.80		0.80		0.80
Life time reservoir (year)					30.06		25.80		14.09

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