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Optimization of Improvement and Management on Sumber Brantas Watershed, East Java, Indonesia

Lily Montarcih Limantara

Department of Water Resources, Faculty of Engineering, Brawijaya University, Malang 65145, Indonesia

ABSTRACT

This paper studied the optimization of improvement and management watershed. Location of study was at Sumber Brantas watershed, Malang-East Java Province Indonesia, with area number was 43,529.25 ha. The methodology consisted of erosion analysis and its conservation, and then to analyze run off and optimized erosion due to optimization of land using. Result was used as consideration to improve and manage Sumber Brantas watershed.

KEY WORDS: improvement, management, optimization, erosion, land using.

INTRODUCTION

International experiences with water policy and governance arrangements are shared through various international meetings and reports. The underlying assumption is that these experiences provide useful information to policy makers who are looking for ways to improve water resources management in their home country or region. However, little has been written about analytical support for these potentially interested policy makers (Hermans, 2011). The wealth of international reports and websites shows that there is no shortage of interesting cases and good practices from various sources. Organization and individuals are often quite willing to showcase and share their experiences in international forum. In fact, reporting experiences with water policy and management arrangements at international platforms can be considered recognition of those experiences as hallmarks of an innovative spirit and of being at being at the forefront of water governance.

Land use planning is significant for watershed conservation and management (Chia and Chung, 2011). Most land use restriction strategies assume that land use activities close to watershed outlet must have large impacts on downstream environments. However, watershed characteristics usually vary in space; land use restrictions should depend on multiple criteria other than the watershed vulnerability index on the distances from subdivisions to the outlet. Therefore some analysis has to consider the geographical and meteorological characteristics of the subdivisions in the watershed. Soil property, surface cover, land-use conditions, and topography can influence the hydrologic responses and pollutant transport in a watershed.

Design of water distribution networks that do not consider performance criteria would possibly lead to less cost but it could also decrease water pressure reliability in abnormal conditions such as a breakage of pipes of the network (Sultanjalili, *et al.,* 2011). Thus, awareness of the situation of consumption nodes by considering water pressures and the amount of water that has been supplied could be an affective source of information for designing high performance water distribution networks. It is clear that searching in such an expanded discrete decision space, without using an optimization tool is not possible. In addition, calculating a solution in a reasonable time is an important factor. Linear programming and nonlinear programming are optimization tools capable of determining optimal solutions.

***Corresponding Author:** Lily Montarcih Limantara, Department of Water Resources, Faculty of Engineering, Brawijaya University, Malang 65145, Indonesia.

METHODS

Location of this study was at Batu city, East Java Province, Indonesia. Map of location study was as below. Detail of area number of Sumber Brantas sub-watershed was as Table 1 below.

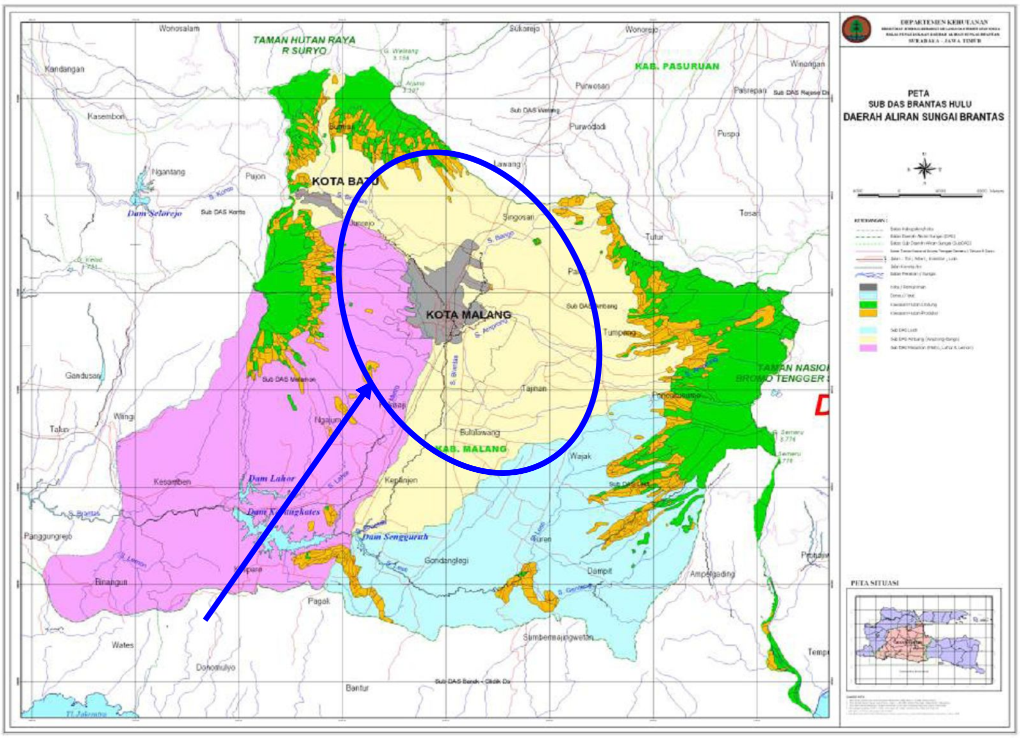

Figure 1 Map of Location

Table 1 Area number of Sumber Brantas sub-watershed

No.	City/ Regency	District	Area number (ha)	Percentage of area number (%)
1	2	3	4	5
I	Batu city	Batu	3.117,39	7,16
		Bumiaji	11.176,10	25,67
		Junrejo	642,26	1,48
	Total I		14.935,75	34,31
II	Malang city	Blimbing	214,35	0,49
		Lowokwaru	723,45	1,66
		Klojen	948,11	2,18
		Sukun	396,03	0,91
		Kedungkadang	2.603,45	5,98
	Total II		4.885,39	11,22
III	Malang Regency	Karangploso	536,49	1,23
		Dau	62,12	0,14
		Tajinan	4.075,39	9,36
		Tumpang	564,04	1,30
		Bululawang	4.781,16	10,98
		Gondanglegi	4.713,13	10,83
		Pakisaji	2.104,05	4,83
		Kepanjen	2.049,73	4,71
		Wajak	1.372,01	3,15
		Poncokusumo	3.449,99	7,93
	Total III		23.708,11	54,46
	Total Area		**43.529,25**	**100,00**

Data in this study was included administrative map such as rainfall and land use map, hydrological data: 10 years monthly rainfall in the year of 1999 to 2009, geological data such as type and distribution of soil, and land use. The steps of study were analysis hydrological data such as rainfall analyses due to Arithmetic Method, design rainfall, design flood, critical discharge, and run off, analysis of erosion using USLE method; optimization of land using; and solution of effective area conservation. Methods of analysis using in this study were as follow.

Arithmetic Method for rainfall analysis (Soemaro, 1999**)**

$$d = \frac{(d_1 + d_2 + d_3 + ... + d_n)}{n} \quad .... (1)$$

with : d = average rainfall depth

$d_1, d_2, d_3, \ldots d_n$ = rainfall depth at each rainfall station

n = the amount of rainfall station

Estimation of erosion (Asdak, Chay 2004**):**

A = R . K . L S . C . P .... (2)

With: A = soil losses per-unit area number

R = factor of rainfall erosivity

K = factor of erodibility

S = factor of gradient

C = factor of cropping management

P = practical factor of soil conservation

Linear Programming was used to optimize discharge of runoff and erosion due to using combination at the certain level. The constraints were concluded constraint of discharge, erosion and combination of land using. Objective function and constraints was described as follow (X_1 = area number of forest, X_2 = area number of garden, X_3 = area number of rice field, X_4 = area number of real estate)

Objective function:

Minimize Z (combination of land using) = $0.108\ X_1 + 0.157\ X_2 + 0.049\ X_3 + 0.091\ X_4$

Minimize Z (erosion velocity) = $9.757.97\ X_1 + 1{,}341.94\ X_2 + 1{,}268.92\ X_3 + 638.27\ X_4$

Subject to:

a. Constraint of discharge
   $q_1 X_1 + q_2 X_2 + q_3 X_3 + q_4 X_4 \geq Q$
   q_1 = discharge due to 1 ha X_1 (m^3/s/ha)
   Q = discharge of average run off (m^3/s)
b. Constraint of erosion
   $e_1 X_1 + e_2 X_2 + e_3 X_3 + e_4 X_4 \geq E$
   e_1 = erosion of X_1 (ton/ha/year)
   E = erosion per year (ton/ha)
c. Scenario of land using combination:
   - Area number of available forest: 70 % of watershed area number.
   - Available area number of real estate (as existing)
   - Area number of avaiable rice field: 50% of existing condition.

RESULTS AND DISCUSSION

There were 2 alternatives optimization result. The results were included optimization of runoff discharge (it was described as Table 2 and 3) and optimization of erosion (it was described as Table 4 and 5). Recapitulation of the whole result was described as Table 6. Based on the results, alternative-1 was the optimal runoff discharge and erosion. This alternative was designed with 70% forest area of existing condition. The biggest activity was agriculture.

Gardening would be carried out at 30% of forest area and area for rice field was as existing condition.

Table 2 Optimization of runoff discharge (alternative-1)

Land using	Area (ha)	Runoff discharge (m3/s)
X1 (forest)	5.999,07	3.820,717
X2 (garden)	8.485,51	
X3 (rice field)	18.904,45	
X4 (real estate)	10.140,22	

Table 3 Optimization of runoff discharge (alternative-2)

Land using	Area (ha)	Runoff discharge (m3/s)
X1 (forest)	5.999,07	4.832,105
X2 (garden)	17.937,73	
X3 (rice field)	9.452,23	
X4 (real estate)	10.140,22	

Table 4 Optimization of erosion (alternative-1)

Land using	Area (ha)	Erosion (ton/year)
X1 (forest)	5.999,07	6.739.851
X2 (garden)	8.485,51	
X3 (rice field)	18.904,45	
X4 (real estate)	10.140,22	

Table 5 Optimization of erosion (alternative-2)

Land using	Area (ha)	Erosion (ton/year)
X1 (forest)	5.999,07	6.739.851
X2 (garden)	17.937,73	
X3 (rice field)	9.452,23	
X4 (real estate)	10.140,22	

Tabel 6 Recapitulation of optimization result

Condition	Land using	Area (ha)	Runoff discharge (m3/s)	Erosion (ton/year)
Existing	Forest	8.570,10	4.702,516	56.189.445,61
	Garden	5.914,49		
	Rice field	18.904,45		
	Reak estate	10140,22		
Alternative-1	Forest	5.999,07	3.820,717	6.739.851,00
	Garden	8.485,51		
	Rice field	18.904,45		
	Reak estate	10.140,22		
Alternative-2	Forest	5.999,07	4.832,105	6.739.851,00
	Garden	17.937,73		
	Rice field	9.452,23		
	Reak estate	10.140,22		

Conclusion

Based on the erosion analysis using USLE method, the value of erosion in Sumber Brantas watershed was 81,229.825 ton/ha/year. After conservation, the erosion would became to 13,007.103 ton/ha/year. Alternative-1 was selected as optimal solution. Each of runoff discharge and erosion was 4,820.717 m^3/s and 6,739.851 ton/tahun.

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