A Quantitative Assessment Model of Land and Water Conservation Measures Case Study at Upper Watershed of Kali Progo

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Abstract

A quantitative assessment model for evaluating land and water conservation measures was developed using scoring system. The model contains three indicators: (i) basic performance indicators as the output reflecting the integrated effects, (ii) proxy indicator as the input reflecting the intervention of watershed through water resource conservation measures, and (iii) impact indicators reflecting the social and environment effects. The indicators are performed by scoring with applying weighting factors in each indicator. Range of the total score is 1-3. Hydrologic model of Mock is installed in the model to simulate the effects of land and water conservation measures.

Using hydrologic data of 2007 to 2011, the model was applied in the degraded upper watershed of Kaliprogo River located at Central Java. Area of the watershed is 418 km^2. The watershed is densely populated area and opening land for agricultural cultivation has been increasing. The result shows that the model is sensitive enough to simulate the effects land and water conservation of watershed using some realistic scenarios of land use pattern. They gave significantly effect in reducing surface run off coefficient (8-10%), maximum discharge (9-18%), erosion (0-15%), and sedimentation (20-40%), and increasing water yield (14-28%). With the scenarios, make increasing total score of the watershed, ranging from 2.4-2.8, means that the watershed is in a good condition.

Keyword: quantitative assessment model, degraded upper watershed, land and water conservation measures

Introduction

The present environmental of watersheds in Indonesia, particularly Java is degrading. The watershed degradation is also happened in the upper watershed of Kali Progo. It is located in the head of Kali Progo River Basin. Administratively it lies at Temanggung Regency, Central Java Province. The watershed is dominated by upland cultivation area (82.2%) and only 4.8% of forest covers the watershed (**Figure 1**).

The Government of Indonesia cq. The Directorate General of Water Resources has implement many water conservation measures programs in almost all degradated watershed at Java, such as constructing of check dams, gully plugs, and terrace rehabilitation but the rate of degradation is still exceed that of the programs. An innovation assessment model for evaluating land and water conservation measures is still needed to ameliorate the situation.

A quantitative assessment model for evaluating land and water conservation measures was created using system approach modified from Kodoatie, 2005 is proposed. The aim of the study is directed to evaluate land and water conservation measures at the upper watersheds using a quantitative assessment model.

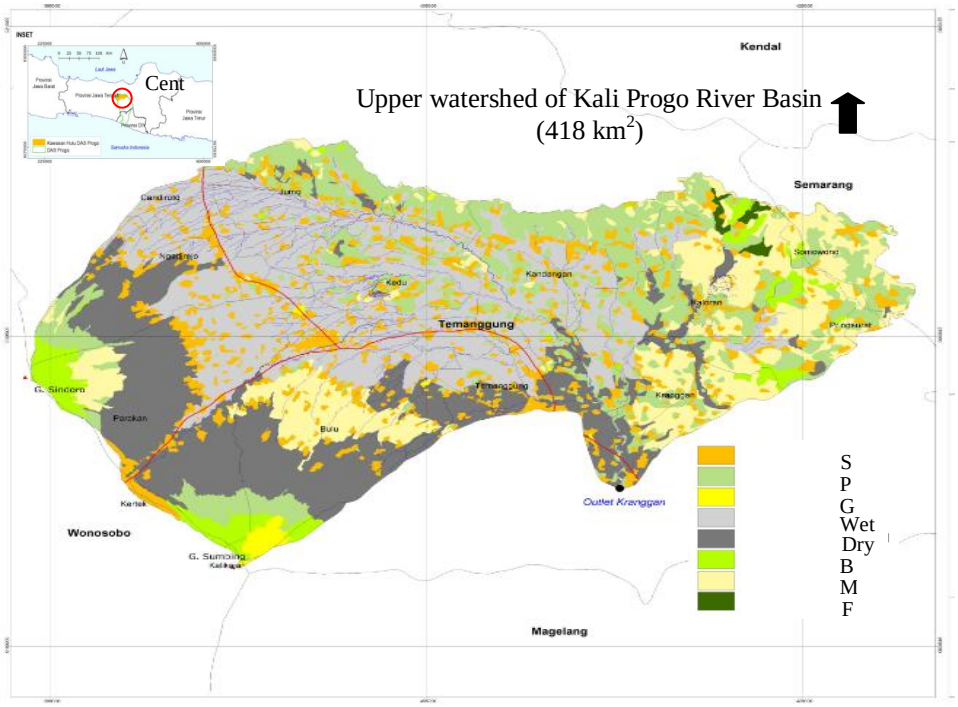

Figure. 1. Land Use Pattern Upper Watershed of Kali Progo

Materials and methods

The assessment model

The basic principle of hydrologic system was applied to the watershed in the assessment model (Ponce, 1989). Those are input, process, output and impact. The model has two indicators: a) basic indicator and b) proxy indicator. Output of the watershed system is used as a basic indicator containing erosion and sedimentation, hydrology and water availability at the watershed. Meanwhile input, process and impact are applied as a proxy indicator. The input and process has indicator of civil engineering and biological conservation measures, internal management performance and empowerment society. The impact has indicator of environmental and social and economic impact. All indicators are calculated in quantitative based, and then they transfer to a scoring system with applying weighting factors in each indicator. Range of the total score is 1-3. The general condition of watershed is indicated from the total calculated score (**Table 1**).

Table 1. Score of watershed condition

No	Condition of watershed	score
1	Very good	2,5 - 3
2	Good	2 - < 2,5
3	Moderate	1,5 - < 2
4	Poor	1 - < 1,5

Simulation of water yield, erosion and sedimentation

Mock hydrologic simple model of rainfall-discharge (Mock, 1973) is installed in the model to simulate the effect of land and water conservation measures on water yield. Sedimentation from suspended load can be approached by using regression of discharge and suspended load. Bad load sedimentation is calculated using *Meyer-Peter and Muller's* method (Soemarto, 1999). The USLE method is applied to calculated of erosion (Fangmeier, 2006).

Result and discussion

Environmental condition of watershed study

The environmental condition of the watershed study is densely populated area (802 people/km^2) with opening upland for agricultural cultivation covering 82.2% of total watershed area has been increasing. This condition causes unstable water yield, erosion on the land and sedimentation in the rivers (**Figure 2)**.

Figure 2. Cultivated Land on the Upper Watershed of Kali Progo

Watershed assessment

Table 2 indicates the result of assessment model of the existing condition of watershed using scoring approach for the upper watershed of Kali Progo. The table shows that the model describes score value in each element. Score value of the output system of watershed is basically an integrated effect of input and process in the watershed (Asdak, 1995; Grigg, 1996). It is also as a basic indicator of watershed condition. Meanwhile, score values of impact give the effect of output of the watershed system.

From the value of total score (2.2) meaning that the watershed generaly is already in good condition but still in lower position. It can be said that land and water conservation measures conducted by Serayu-Opak Water Resources Main Office (Balai Besar Wilayah Sungai Serayu Opak, BBWS Serayu-Opak) has significantly effects in improving the upper watershed condition. This effect can be indicated in the present condition of the upper watershed with score values from the parameter output are mostly good. Meanwhile, score values from the process, especially for internal management gave mostly bad.

Table 2. Score Value of the Upper Watershed of Kali Progo

No	Parameter	Unit	Weighting Factor (%)	Year of Data	Average*	Category	Score	Score Value Each Element
1	Erosion loss	ton/ha/yr	**4**	2001-2011	111.76	moderate	2	0.08
2	Sedimentation on the river	mm/yr	**4**	2001-2011	4.075	moderate	2	0.08
3	Maximum discharge	$m^3/sec/km^2$	**4**	2003-2009	0.124	good	3	0.12
4	Minimum discharge	$m^3/sec/km^2$	**4**	2003-2009	0.007	good	3	0.12

5	River regime coeffcient	-	**4**	2003-2009	16.89	good	3	0.12
6	Sedimentation control on the river	-	**15**	2009	appropriate (3)	good	3	0.45
7	Gully Plug on tributaries	-	**7.5**	2009	appropriate (3)	good	3	0.225
8	Land: terraces, drainage canals	-	**7.5**	2009	appropriate (2)	moderate	2	0.15
9	Replanting on stream bank	%	**5**	2009	81.09	good	3	0.15
10	Permanent coverage index	%	**5**	2009	5.0	poor	1	0.05
11	Production of land coverage index	%	**5**	2009	78.8	poor	1	0.05
12	Data base management system	%	**2**	2012	< 50	poor	1	0.02
13	Management system of monev of watershed	%	**2**	2012	50-80	moderate	2	0.04
14	Human resources management system	%	**2**	2012	< 50	poor	1	0.02
15	Internal watershed Monev system	%	**2**	2012	< 50	poor	1	0.02
16	Reporting watershed Monev system	%	**2**	2012	< 50	poor	1	0.02
17	Capacity building on conservation measures	%	**2.5**	2012	< 50	poor	1	0.025
18	Economic investment	%	**2.5**	2012	< 50	poor	1	0.025
19	Land productivity	-	**5**	2012	constant	moderate	2	0.1
20	Depth of soil solum	cm	**5**	2012	>80	good	3	0.15
21	Dependency of social income from land	%	**2.5**	2012	76	poor	1	0.025
22	Population density	person/km^2	**2.5**	2012	802.00	poor	1	0.025
23	Social income	Rp/month	**2.5**	2012	minimum wage	moderate	2	0.05
24	Social instituition	-	**2.5**	2012	moderate	moderate	2	0.05
Sum			100	**Total Score**				**2.2**

*) Source of data was collected from various report of Main Office of Serayu-Opak River Basin Development

Hydrologic performance

Using hydrologic data of 2003 and 2004, calibration result of the model is presented in **Figure 3**. In the calibration process, optimizing parmeter model was conducted by trial and error. **Table 3** shows the optimal parameter from the calibration process.

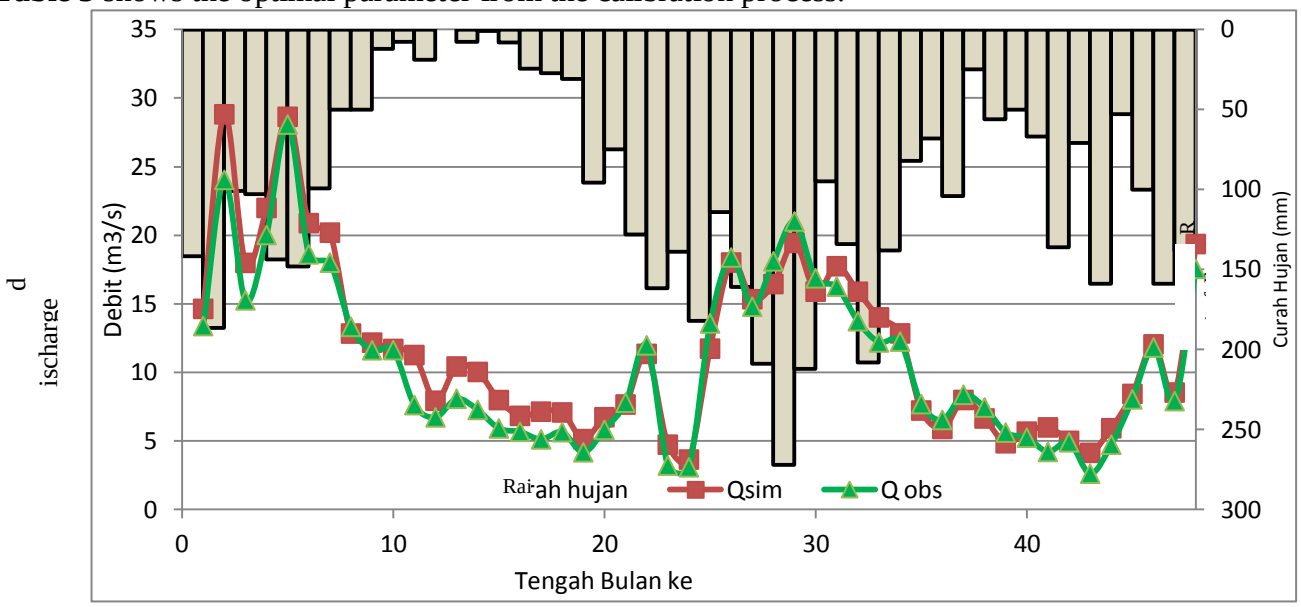

Figure 3. Hydrologic performance from in the Calibration Process

The results show that correlation coefficient (R) and volumetric error (VE) for upper watershed Kali Progo is 0.97 and 0.13 respectively. This value of R and VE indicates that the model is sensitive enough to simulate the effects of land and water conservation measures applied in the upper watershed.

Tabel 3. Optimal parameter result in the calibration process

Parameter	unit	Simbol	Optimal parameter
1. Area of watershed	km^2	A	417
2. Infiltration coefficient in rainy season	-	WIC	0.39
3. Infiltration coefficient in dry season	-	DIC	0.4
4. Initial soil moisture	(mm)	ISM	150
5. Soil moisture capacity	(mm)	SMC	281
6. Initial groundwater storage	(mm)	IGWS	1200
7. Groundwater recession constant	-	K	0.962121

Improving environmental condition of watershed through development of realistic scenarios

The scenario to improve environmental condision is using three type of land use pattern. The result shows that three scenarios of land use pattern are able to improve the watershed condition. The value of basic indicators is presented in **Table 3.**

Table 3. Watershed condition with realistic scenario of land use pattern

Realistic land use pattern scenarios	**Hydrology,** (runn off coef.)	**Erosion (mm/year)**	**Sedimentation (million m^3)**	**Water availability**	**Category**
Existing condition	0.27-0.50	6.21	1.51	Surplus	poor
Scenario I 70-80% LcDi & 20-30% LcPi	0.24-0.25	5.16	1.26	Surplus	moderate
Scenario II 60-70% LcDi & 30-40% LcPi	0.18-0.21	4.43	1.085	Surplus	good
Scenario III 50-60% LcDi & 40-50% LcPi	0.13-0.15	3.201	0.78	Surplus	good

Notes:
Lcdi= Land Covering Production Index
Lcpi= Land Covering Permanent Index

The following three elements of basic indicator reflect the effects of scenarios. For hydrologic indicators show that surface run off coefficient (2%-6%) and maximum discharge (1%-5%) can be reduced. For erosion and sedimentation give 2%-10% reduced, and show increasing water yield (4%-15%).

The real condition of degraded watershed is significantly due to socio-economic pressures. Open land for farming covers until 80% of total watershed area is closely related with densely populated area in this watershed with average people per square kilometer is 802. Natural carrying capacity of this area to support food for the people who live here is already exceeded. Therefore, the selection of the scenarios to be applied in the field depends on the socio-economic condition of the farmers. In the real condition, selected choosing one of the scenarios should be considered in order to get optimal watershed management.

Conclusion

The proposed quantitative assessment model for evaluating water resource conservation measures has been applied to evaluate the condition upper watershed of Kali Progo, located in Central Java. The model proved that water resources conservation, has significantly effects in improving the upper watershed condition. This effect can be indicated in the present condition of the upper watershed with score values from the parameter output are mostly good. Total score for the upper watershed of upper watershed of Kali Progo is 2.2, respectively, means that the present condition of watershed is in position of good condition.

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