APPLICATION OF SIMPLE HYDROLOGIC MODEL FOR PREDICTING THE EFFECT OF WATER CONSERVATION MEASURES AT THE UPPER WATERSHED OF DAM [1]

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A B S T R A C T

The recent condition of degraded land at the upper watershed of dam in Java is increasing significantly. It implies on sedimentation problem flowing to the dam. The aim of study was directed to apply a simple method for simulating the effects of water resource conservation measures. Hydrologic model of Mock was proposed for the study. The model is basically rainfall-run-off relationship containing three tanks arranged in vertical position. Finding optimal six parameters in the model were conducted by trial and error. Two degraded upper watersheds of dam at Central Java were used as the study. This area study falls into tropical monsoon region. The results show that the model is sensitive enough to predict hydrologic regime in the upper watershed of dams studied. The model was then used to simulate the effects of water resource conservation measures applied in the upper watersheds. The simulations were directed to design optimal vegetation landscape in the form some realistic scenarios of land use pattern. Comparing with the existing condition, the simulation results showed that they give significantly effect in reducing surface run off coefficient (from 10% to 20%), sedimentation (15%-20%), increasing water resources availability (5%-15%).

Key words: hydrologic model, water resource conservation measures, realistic scenarios of land use pattern

1. INTRODUCTION

The condition of degraded land at upper watershed of the dams in Java is increasing significantly. Climate at Java Island fall into tropical monsoon region. Land degradation form of erosion and sedimentation caused by excessive farming activity at the upper of watersheds without conservation principles. Its gives effect on erosion and sedimentation flowing to the dam and decreasing its function in providing water for various needs and electric source of power plants. The aim of study was directed to apply a simple hydrologic model for simulating water flowing to the dam as implication of the effect of water resource conservation measures in these two upper watershed of dam.

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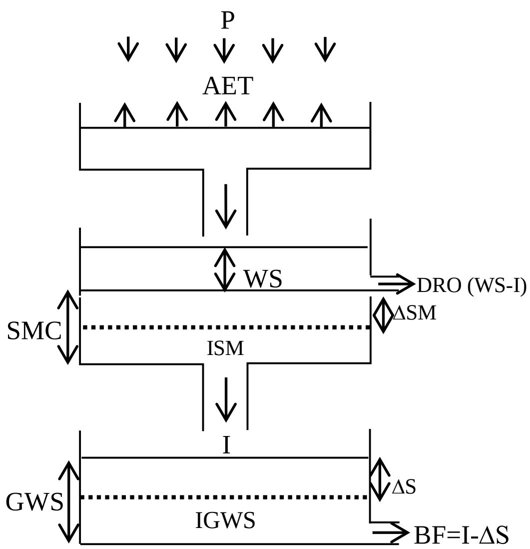
2. METHOD

A simple of hydrologic model of Mock was chosen in this study. Basically, the model is rainfall-runoff relationship analogized by tanks concept (**Figure 1**). The model contains three artificial tanks arranged in vertical position (Brooks, 2003 and Mock, 1973). There are six parameters in the model. Trial and error technique is used to find optimal parameters of the model. Some statistic and graphical criteria is apply to achieve the best performance of the model.



AET	=	CF x Eto	GWS	=	0.5x(1+k)xI+(kxIGWS)
ER	=	P - AET	IGWS	=	GWS_{I-1}
WS	=	ER - ΔSM	BF	=	I - ΔS
ISM	=	SM_{I-1}	ΔS	=	GWS - IGWS
I	=	IC x WS	Q_{Tot}	=	DRO + BF

Where:

P	=	rainfall (mm)
CF	=	crop factor
Eto	=	potential evapotranspiration (mm)
AET	=	actual evapotranspiration (mm)
ER	=	excess rainfall (mm)
DRO	=	direct runoff (mm)
ΔS	=	change of ground water volume
ΔSM	=	change of soil moisture (mm)
SMC	=	soil moisture capacity (mm)
ISM	=	initial soil moisture (mm)
WS	=	water storage (mm)
IGWS	=	initial ground water storage
GWS	=	ground water storage (mm)
IC	=	infiltration coeficient
BF	=	base flow
I	=	infiltration

Figure 1. Simple Hydrologic Model of of Mock

The hydrologic model is then applied to simulate the effects of hydrologic regime due to water resource conservation activities at the upper watershed of dams. The simulation is conducted by manipulation of land use pattern in the form of some realistic scenarios. Principally the scenario is oriented to convert open agricultural cultivation land at the upper watershed of dam to become forest area, mainly at high slope (more than 45%) and high erosion area. Three parameters are applied in the simulation. Those are: (a) change in hydrologic regime in the form of run off coefficient and water availability, (b) erosion and, (c) sedimentation.

3. LOCATION OF STUDY

Two degraded upper watersheds of dam at Central Java were used as the study area. Those are upper watershed of *Sempor* dam and upper watershed of *Wadaslintang* dam having an area of 44.15 km^2 and 192.53 km^2, respectively. Water capacity of *Sempor* dam and *Wadaslintang* dam is 52 million m^3 and 443 million m^3, respectively. The irrigation common areas serving by the *Sempor* dam is 6.485 ha and for *Wadaslintang* dam is 32.064 ha **(Figure 2**). Besides supplying water for irrigation, this two dams have also play role in flood control, fisheries and electric source of power plants. Landscape at this two location of study are dominated by open agricultural cultivated land with 70%-80% of total area, even at the high slope land (**Figure 3a** and **3b**).

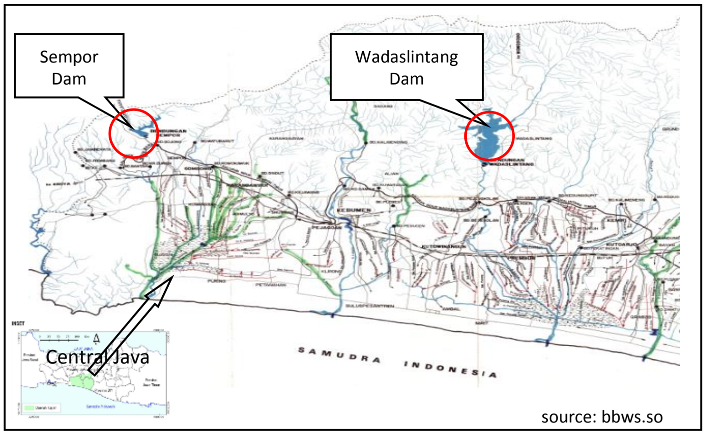
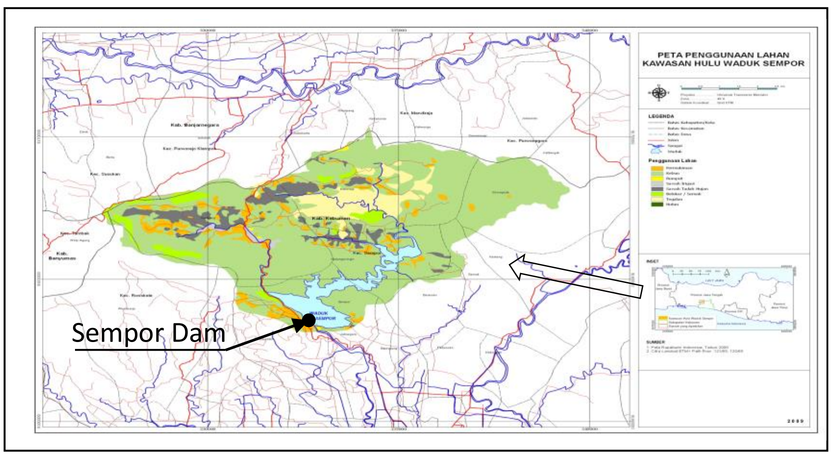


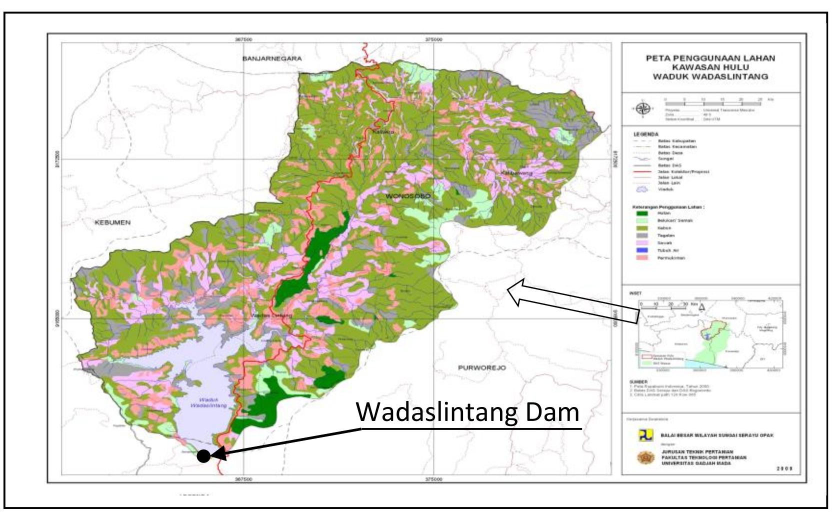
Figure 2. Location and land use of area study

Farmers who lives at this upper watershed area of dam are very dependents to agricultural cultivation land for upland crops. The farmers cultivate upland crops such as corn, soybean, peanuts as well as cassava. This upland crops are also planted even in the area with slope more 45%. It implies in increasing erosion at surface land even until high risk erosion. Further implication is increasing sedimentation flowing to the dams.



Landscape	The upper watershed of Sempor dam
Open cultivated upland crop	3,718 ha (84.2%)
Forest land	164 ha (3.7%)
Settlement	278 ha (6.3%)
Water storage	256 ha (5.8%)

Figure 3a. Landscape at the upper watershed *Sempor* dam



Landscape	The upper watershed of Wadaslintang dam
Open cultivated upland crop	13,936 ha (72.4%)
Forest land	1,524 ha (7.9%)
Settlement	2,398 ha (12.5%)
Water storage	1,395 ha (7.2%)

Figure 3b. Landscape at the upper watershed *Wadaslintang* dam

4.1. Results

Data at the year of 2000 and 2001 both at the upper watershed of *Sempor* dam and *Wadaslintang* dam was use as calibration and verification process of the hydrologic model, respectively. Optimal parameters result in calibration process is tabulated at **Table 1**, both for the two location study. With the optimal parameters, statistically the model gives the best performance with value of correlation coefficient (R) and volumetric error (VE) for upper watershed of *Sempor* dam is 0.98 and 34%, respectively. For the upper watershed of *Wadaslintang* dam gives 0.93 (R) and 20% (VE), respectively. Graphically, using scatter and time series diagram show that observed and predicted discharge is relatively matched. Both for the two location study. **Figure 4a** and **4b** shows in scatter diagram for the upper watershed of *Sempor* dam and *Wadaslintang* dam, respectively. In the form of time series diagram is presented in **Figure 5a** and **5b** for the upper watershed of *Sempor* dam and *Wadaslintang* dam, respectively.

Table 1. Optimal parameter of calibration process

Parameter	unit	Simbol	*Sempor*	*Wadaslintang*
1. Area of watershed	km^2	A	44.15	192.53
2. Infiltration coefficient in rainy season	-	WIC	0.5	0.1
3. Infiltration coefficient in dry season	-	DIC	0.5	0.4
4. Initial soil moisture	(mm)	ISM	200	100
5. Soil moisture capacity	(mm)	SMC	200	250
6. Initial groundwater storage	(mm)	IGWS	1500	1500
7. Groundwater recession constant	-	K	0.99	0.94

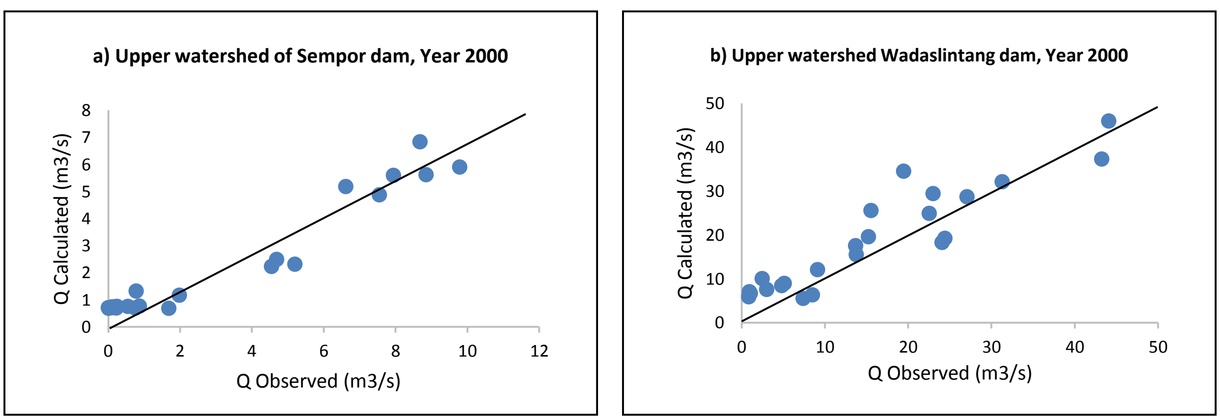


Figure 4. Scatter diagram in calibration process, Year 2000: (a) at the upper watershed of *Sempor* dam, (b) at the upper watershed of *Wadaslintang* dam

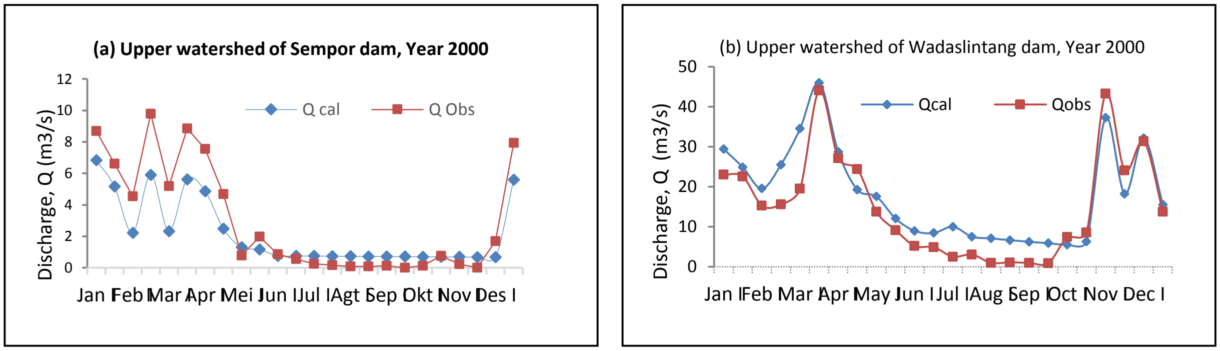


Figure 5. Time series diagram in calibration process, Year 2000: (a) at the upper watershed of *Sempor* dam, (b) at the upper watershed of *Wadaslintang* dam

In the model verification process, discharge was simulated by the optimal parameters model obtained from the calibration process. The hydrologic data of the year 2001 was used in the verification. Verification process was also conducted for both at the two location studies. The result show that statistically the model gives the best performance with value of correlation coefficient (R) and volumetric error (VE) for the upper watershed of *Sempor* dam is 0.91 and 29%, respectively. For the upper watershed of *Wadaslintang* dam gives 0.81 (R) and 29% (VE), respectively.

In the form of scatter diagrams are presented in **Figure 6a** and **6b** for the two location of studies. **Figure 7a** and **7b** show in the form of time series diagram. From these calibration and verification process, the results prove the model is sensitive enough to simulate discharge in tropical monsoon region.

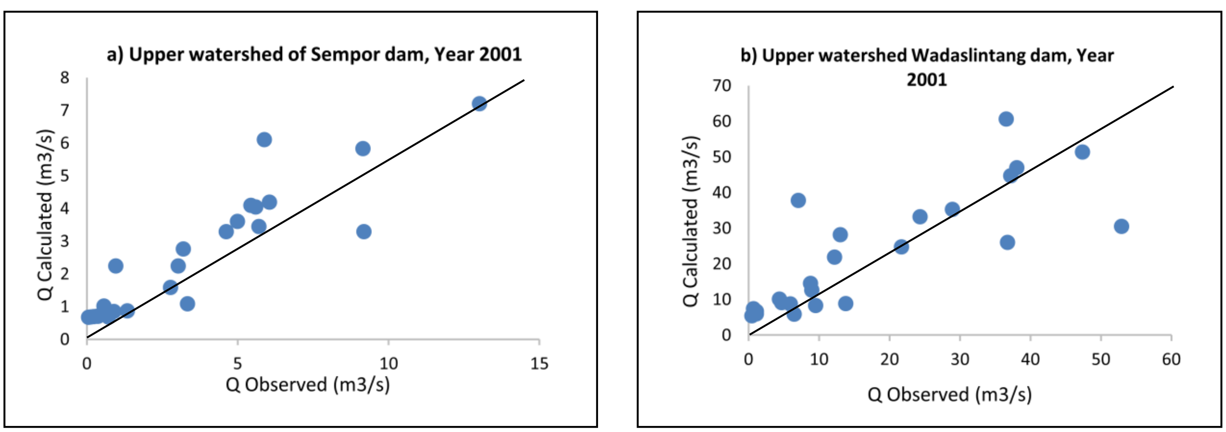


Figure 6. Scatter diagram in verification process, Year 2001: (a) at the upper watershed of *Sempor* dam, (b) at the upper watershed of *Wadaslintang* dam

Application of hydrologic model in executing the realistic scenarios at the two upper watershed studies gave results, as follows (**Table 2**):

a) reducing surface run off coefficient (from 10% to 20%),
b) reducing sedimentation flowing to the dams (15%-20%), and

c) increasing water resources availability (5%-15%).

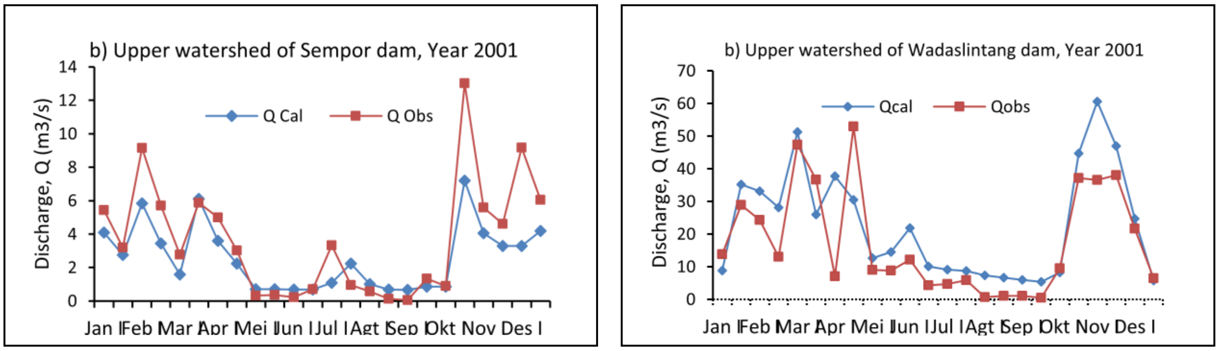


Figure 7. Time series diagram in verification process, Year 2001: (a) at the upper watershed of *Sempor* dam, (b) at the upper watershed of *Wadaslintang* dam

Table 2. Simulation result with realistic scenarios of landscape in the form of landuse pattern at the upper of watershed of Wadaslintang and Sempor dam

Realistic Scenarios of Land Use Pattern	**Hydrology,** (run off coef.)	**Erosion (mm/thn)**	**Sedimentation (mm/thn)**	**Water availability**
Existing condition	0.27-0.50	19.5-21.0	5.5-6.0	Surplus
Scenario I 70-80% LcDi & 20-30% LcPi	0.24-0.25	9.85-12.5	2.85-3.5	Surplus
Scenario II 60-70% LcDi & 30-40% LcPi	0.18-0.21	7.34-10.5	1.86-2.5	Surplus
Scenario III 50-60% LcDi & 40-50% LcPi	0.13-0.15	4.77-5.1	0.94-1.2	Surplus

Notes: LcDi= Land Covering Production Index; LcPi= Land Covering Permanent Index

4.2. Discussion

From the results as mentioned above prove that the simple hydrologic model can be applied to predict the effect of water conservation meaures at the two upper watershed of dams in the form of convertion of vegetation landscape in three realistic scenarios. To realized the scenario depends on social and economic charateristics that is different from region to region. However, the social and economic charateristics generally are in similar conditions at the degraded upper watershed of dam. The conditions are characterized by poor economic and simple social way of life with low level education.

As metioned above that landscape at the two upper watersheds studied is dominated (more than 70% of total upper watershed area) by open area of agricultural cultivation. This is due to densely populated area with more or less 700 people per square km. The population mainly works in subsistence agricultural cultivation with small land ownership. It gives an environmental stress. Generally it happens at mountainous area of upper watershed at Java Island.

Implementation of the best realistic scenarios should be considered not only from the aspect of land and water conservation principles but more from the economic and social characteristics of people who live and strongly dependent to land for agricultural cultivation in the upper watershed of dam.

4. CONCLUSSION

a) The Mock simple hydrologic model has been applied at watershed in tropical monsoon region. The upper watershed of Sempor and Wadaslintang dam which are located at Central Java was used as location study. The result shows that the model gives good performance and sensitive enough to simulate discharge at the two location study.

b) The model then was applied to simulate discharge flowing to the dam as the response of water conservation measures at the two upper watershed of dams. The water conservation measure was simplified by realistic scenarios with modification of vegetation landscape in the form of land use pattern in the upper watershed of dams. The scenarios were directed to convert open agricultural cultivation land at the upper watershed of dam to become forest area. Using three parameters of water regime, i.e: (a) change in hydrologic regime in the form of run off coefficient and water availability, (b) erosion and, (c) sedimentation, the significant effects of water conservation measure can be evaluated. Comparing with the existing condition, the simulation results showed that they give significantly effect in reducing surface run off coefficient (from 10% to 20%), sedimentation (15%-20%), increasing water resources availability (5%-15%).

c) Implementation of the best realistic scenarios should be considered not only from the aspect of land and water conservation principles but also from the economic and social characteristics of people who live and strongly dependent to land for agricultural cultivation in the upper watershed of dams.

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