Runoff modeling in Cidanau watershed, West Java, Indonesia
インドネシア西ジャワ・チダナウ流域における流出モデリング

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Introduction

The integrated watershed management, which aims at restoration of a sound hydrologic regime in the watershed considering water resources utilization, appropriate land use, water quality control and environmental conservation, is becoming crucially important in such developing countries as Indonesia. Proper watershed modeling is a most essential part for the watershed management. In this study, performance of a Tank Model with some modifications was examined by applying it in three types of application manners to the Cidanau watershed, West Java. The model's performance for water quality was also examined. Besides, GIS techniques and an optimization algorithm were utilized for the model application and effectiveness of them was tested.

Methodology and Model Configuration

Potential evapotranspiration was calculated using an empirical radiation method. Areal average rainfall was calculated by the Thiesen polygon method. The maps that needed by GIS techniques are digitized, such as Soil Type, Land Slope, Land Use, and tributaries.

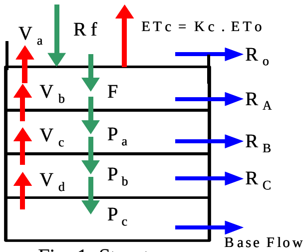

Fig. 1. Structure

The Tank Model used in this study consists of 5 tanks, as shown in Fig.1, to represent water balance in land surface (first tank), root zone (second tank) and deeper soil layers (third to fifth tanks). As difference from the common Tank Model, each tank of this model has a maximum limit of water storage, so that water moves up to the upper tank when stored water reaches the limit. Coefficients of discharge (CR), storage capacity (X), percolation (CP) and runoff threshold (CH) of each tank (shown in Fig.2) are the parameters to be calibrated. To calculate EC (electric conductivity) as a water quality index, LQ formulation was adopted. Namely, EC load is calculated by $L = a\,Q^{b}$, where Q is discharge, and a and b are the parameters to be calibrated.

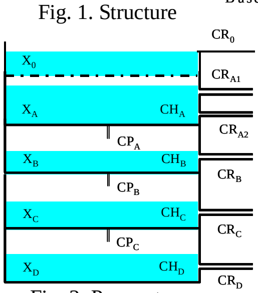

Fig. 2. Parameter

A random search method was used as the optimization algorithm, and goodness of fit was evaluated by the coefficient of model efficiency. Though performance of this algorithm was dependent on initial values, it could work properly to find the optimum values quickly by giving different sets of initial values. After optimizing the runoff parameters, water quality parameters were optimized.

Study Area and Model Application

The Cidanau watershed (267.1km^2) is located at 5^{o}21'-6^{o}21' South and 105^{o}7'-106^{o}22' East. Runoff discharge is observed at the intake weir near the sea. Annual rainfall in the watershed is ranging 2390-3920 mm and annual river discharge (in depth) is ranging 790-1290 mm. Considering distribution of physical characteristics such as soil types, land slope, tributaries and so on, the watershed is divided into 6 sub-catchments (shown in Fig.3): namely, Rawa Danau (2.4 km^2), Ciomas (112.0 km^2), Mandalawangi (30.4 km^2), Padaringcang (53.0 km^2), Cibojong (39.7 km^2) and Cinangka (29.6 km^2).

The Tank Model was applied in 3 types of application manners. In the first application manner, one Tank Model was applied to the whole watershed (Model I). In the second manner, based on the division of the watershed into 6 sub-catchments, each sub-catchment was represented by one Tank Model, and all the parameters of the 6 Tank Models were calibrated (Model II). For connecting the sub-catchments to obtain the total discharge from the whole watershed, 1-day time lag was considered for discharge from Ciomas and Padaringcang sub-catchments. In the third manner, though the watershed was represented by 6 Tank Models in the same way as the second manner, the parameter set of each of the 6 Tank Models was assumed the same one (Model III).

Fig. 3. Sub Catchments

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Keywords *: Watershed Modeling, Tank Model, Water Quality, Indonesia*

Result and Discussion

The results of Model I and Model II are presented in Tables 1 and 2, respectively. The calculated discharge hydrograph by Model I could show fairly good agreement with the observed hydrograph, whereas agreement in EC between observed and calculated values was poor. Model II that has many parameters produced better results in discharge for the calibration period (1996-98) than Model I, but the results of Model II for the validation period (1999-2001) was not so good. Concerning EC, Model II also showed poor performance.

In the application results of Model II, relationships between calibrated values of some parameters and watershed's physical characteristics, such as land slope, soil types, land use and so on, were analyzed using GIS data. As a result, a high and reasonable correlation between the discharge coefficient (CR) and gray alluvial area was identified (Fig.4). Based on this, for application of Model III, these parameter values for the discharge coefficient were employed, though, except the discharge parameter, the set of the other parameters are assumed to be the same for all the 6 sub-catchments. The results of Model III are presented in Fig.5 and Table 3. In spite of reduction in the number of parameters from Model II, performance of Model III for discharge is found in the same level as that of Model II. The result on EC was also improved, though it is still unsatisfactory

Table. 1 Goodness of fit for Model I

Criteria	Discharge		Electric Conductivity	
	Calibration	Validation	Calibration	Validation
Mean Relative Error	49.6%	48.7%	356.5%	436.0%
Model Efficiency	70.8%	70.1%	22.7%	3.5%

Table. 2 Goodness of fit for Model II

Criteria	Discharge		Electric Conductivity	
	Calibration	Validation	Calibration	Validation
Mean Relative Error	43.6%	45.2%	51.1%	73.7%
Model Efficiency	82.0%	73.9%	65.5%	1.6%

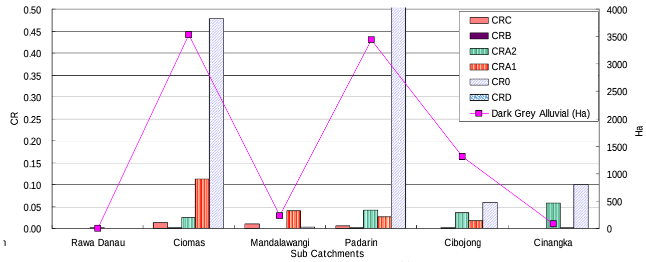

Fig.4. Relationship between discharge coefficients (CR) and soil type

Table. 2 Goodness of fit for Model II

Criteria	Discharge		Electric Conductivity	
	Calibration	Validation	Calibration	Validation
Mean Relative Error	43.4%	45.4%	76.5%	83.6%
Model Efficiency	80.0%	72.6%	53.1%	28.9%

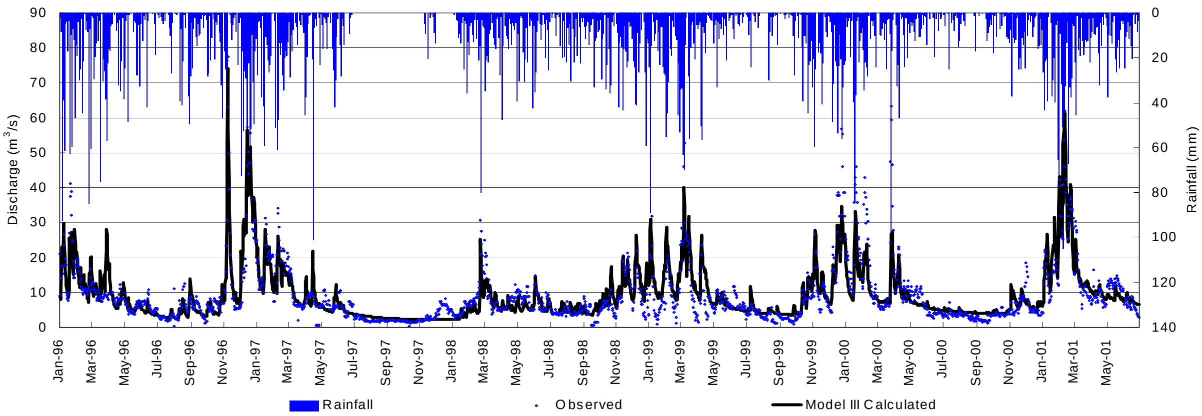

Fig.5. Hydrograph of Model III

Conclusions

The results of this study are summarized as follows:

(1) The auto optimization algorithm could work well to calibrate the model parameters quickly.

(2) A high and reasonable correlation between the discharge coefficients (CR) from application of Model II and gray alluvial area was identified.

(3) Model III could represent the watershed's runoff accurately with small number of parameters. To determine some parameters of Model III, the approach of Model II is also a necessary step before application of Model III.

References

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