Distributed Hydrological Modeling of Prek Thnot River Watershed, Cambodia,
for Irrigation Planning

カンボジア・プレックタノート 川流域における灌漑計画のための分布型水文モデリング

○SAM Chhom Sangha*, Akira GOTO ** and Masakazu MIZUTANI **

1. Introduction

Prek Thnot River is one of major tributaries of Mekong River in Cambodia, whose watershed has high potential in water resources development to increase agricultural production (**Fig.1**). This watershed has an area of 5,000 km^2. Most of irrigation schemes were constructed with improper planning that resulted in low yield of agricultural production. If the irrigation planning is conducted properly, irrigation areas will increase and the cropping intensity will be doubled for all schemes. Hence, an assessment of spatial distribution of water availability in the watershed is necessary. Irrigation practices will strongly affect the river flow, and such influences must be assessed too when the irrigation schemes are rehabilitated. For these purposes, a distributed hydrologic model plays a significant role in these issues. Meanwhile, river flow runoff is largely influenced by actual evapotranspiration (ET) in the watershed having a distinct dry season. An accurate estimation of actual ET is crucially important for proper watershed modeling. Therefore, the objective of this research was set as establishing a distributed system hydrologic model by combining a distributed hydrologic model and an ET sub-model.

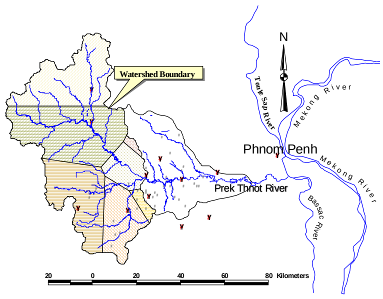

Fig.1 Location map of Study Area

2. Model development

A basic structure of a distributed system hydrological model was developed by combining a modification of the distributed hydrological model (Mohammed's model) and modification of Sakai's ET sub-model (root zone model) as shown in **Fig.2**. The basic structure of this model having two layers and distributed parameters includes infiltration, evapotranspiration, sub-surface saturated lateral flow, overland flow and channel flow. A two-stored storage tank as **Fig.2** of root zone model was considered as the upper layer. A grid cell was considered as one storage tank. Rainfall was applied to the storage tank. Green-Ampt method was applied to compute infiltration rate. Rainfall in excess of surface detention was routed as overland flow by using kinematic wave equation. The amount of stored water in the tank at the upper layer was taken by evapotranspiration using Sakai`s equation. Some stored water at the upper layer transferred to lower layer where it was available as saturated lateral flow. Overland flow and saturated lateral flow were routed through each cell to the downstream cell until they reached the cell containing the channel element, where they were routed as channel flow by Muskingum-Cunge method. The model was performed for each cell for each time step (1 hour).

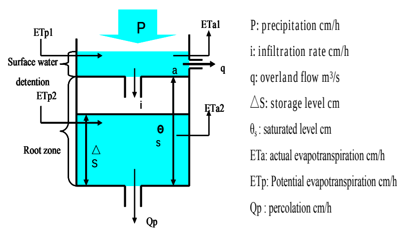

Fig. 2 Root zone model for ET sub-model

*United Graduate School of Agricultural Science, Tokyo University of Agriculture and Technology, **Utsunomiya Univ.
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3. Model application

The model was applied to the Prek Thnot River watershed. Three-year periods (2001-2003) of data were employed. The year 2001 was used for model calibration for this time. Daily observed discharge at Peam Kley station was used to compare with the calibrated one. The simulated area was 3,650 km^2. There were four soil types such as sandy loam, loam, clay loam and clay. There were six major land uses, which were reclassified into two vegetative types such as forest and paddy field.

4. Results and discussion

Calibrated parameter values are shown in **Table 1**. The result of simulated discharge is shown in **Fig. 3.** It was found that the calculated hydrograph was not sufficiently good when compared with the observed one. The discharge peaks appear in the dry season (calculated hydrograph) when trying to increase discharge in rainy season. **Fig. 4** shows the effect of change in infiltration rate through increasing the values of saturated hydraulic conductivities. It was found that when the discharge peaks in dry season decrease, the discharge peaks in rainy season also decrease. Because the ratio of runoff discharges in dry season and rainy season is quite different, it suggests that hydrological models developed for watersheds in the humid region may not be able to cope with this phenomenon. Therefore, this model structure needs to be modified to improve the model performance.

Table 1: Calibrated parameter values

Parameter	Symbols	Layer	Unit	Forest condition				Paddy field condition				Remark
				Sandy loam	Loam	clay loam	Clay	Sandy loam	Loam	clay loam	Clay	
Depth	d	Upper	m/h	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
Saturated hydraulic conductivity	k_s	Upper	cm/h	0.18	0.14	0.1	0.1	0.18	0.14	0.1	0.1	Trial error based on field data
Subsurface lateral saturated hydraulic conductivity	k_l	Lower	m/h	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	Trial error
Wetting front capillary pressure head	h_f	Upper	cm	11.01	8.89	20.88	31.36	11.01	8.89	20.88	31.36	Trial error based on literature
Porosity	p	Low.	-	0.439	0.416	0.409	0.418	0.439	0.416	0.409	0.418	Trial error based on field data
Saturated soil moisture	θ_s	Upper	-	0.404	0.394	0.39	0.4	0.404	0.394	0.39	0.4	
Parameter for ET	A	Upper	-	14457.485	-1267.28	-1056.79	-145.145	-263.445	-4.31900	-4.31900	-4.319	Trial error based on standard values (Sakai K.)
Parameter for ET	B	Upper	-	0.1031	0.0778	0.0778	0.1007	0.1982	20.4242	20.4242	20.4242	
Conductivity shape	η	Upper		5.063	14.56	9.21	12.38	5.063	14.56	9.21	12.38	Trial error based on literature
Manning coefficient	n	Upper	-	0.15	0.15	0.15	0.15	0.045	0.045	0.045	0.045	

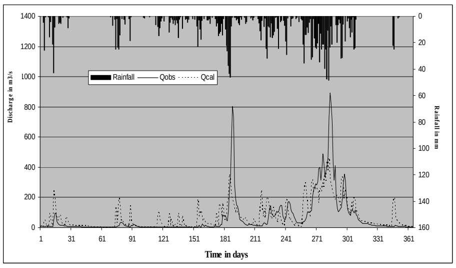

Fig.3: Calculated and observed hydrographs

5. Modification of the model

The purposes of this modification were to cope with the difference in infiltration property between the rainy season and dry season; to increase the peak in the rainy season and to improve the calibrated parameter values of Ks and Kl to be realistic ones. Therefore, to increase the peak calculated hydrograph in rainy season, the maximum storage water level (Bmax) at the lower layer should be set up. When the storage level at lower layer B1 is greater than the maximum value Bmax, the surplus water in the lower layer goes up to the upper layer.

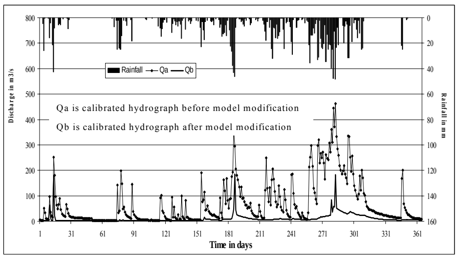

Fig. 4: Effect of change in infiltration rate

6. Conclusions

According to this research, we can make conclusions as the following: a basic structure of the distributed hydrological model was established; root zone model could perform properly; necessity of modification to cope with the difference in infiltration property between the rainy season and the dry season was clarified and modifications necessary to improve the model performance were proposed.

References

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