SIMULATION OF DAILY RUNOFF AND SENSITIVITY ANALYSIS WITH SOIL AND WATER ASSESSMENT TOOL

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Abstract: Soil and water assessment tool (SWAT) was simulated based on the default parameters and a priori soil parameter estimation method in Bocheong watershed of Korea. The performance of the model was tested against the measured daily runoff data for 5 years between 1993 and 1997. The sensitivity analysis of SWAT model parameters was conducted to identify the most sensitive model parameters affecting the model output. The results of SWAT simulation indicate that the overall performance of SWAT in calculating daily runoff is reasonably acceptable. However, there is a problem in estimating the low flow components of streamflow since the low flow components simulated by SWAT are significantly different from the measured low flow. The sensitivity analysis with SWAT points out that soil related parameters are the most sensitive parameters affecting surface and ground water balance components and groundwater flow related parameters exhibit negligible sensitivity.

Keywords: SWAT, Daily Runoff, Sensitivity Analysis, Bocheong Watershed

1. INTRODUCTION

Soil and water assessment tool (Arnold et al., 1998; Neitsch et al., 2001) has been applied for analyzing agricultural management practices, water supply management and climate change effects on water and agricultural chemicals in large watersheds with varying soils, land use and management conditions. The HUMUS (Hydrologic Unit Model for the United States) project has applied SWAT model in order to simulate the surface and sub-surface water quality and quantity (http://srph.brc.tamus.edu/humus/). SWAT was also used in the lower Michigan and southeastern Minnesota for developing ecological indictors for streams within two large, highly agricultural areas(http://www.nrri.umn.edu/indictors/hydrologic%20 modeling.htm). The hydrologic components of SWAT have been validated for numerous watershed of United States (Arnold and Allen, 1996; Arnold et al., 1999). And the modified version of SWAT, called SWAT-G, was tested for application to low mountain range catchment conditions in central Germany using an automatic calibration approach (Eckhardt, 2001).

Kang and Park (2003) applied SWAT to develop the total maximum daily loads simulation system in the Balhan HP#6 watershed of Korea. In this small watershed the runoff, TN and TP behaviors calculated by SWAT were in good agreement with the observed runoff, TN and TP data. However, the applications of SWAT to Korea's watershed have been very limited and model performance has not been fully tested for medium to large scale watersheds.

Hence, there is a need to evaluate SWAT model in predicting daily streamflow and to understand any improvements to be made for application to Korea's watershed. The objectives of the present paper are to understand the applicability of SWAT model to simulating a daily runoff in Korea's watershed, and to perform analysis of SWAT parameters for identifying the sensitive parameters affecting surface and ground water balance behavior.

2. METHODS AND MATERIALS

2.1 Hydrologic Simulation Model

Soil and Water Assessment Tool (SWAT) is to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time. The SWAT model is integrated by ArcView GIS and requires specific input data concerning weather, soil properties, topography, vegetation, and land management practices occurring in the watershed. SWAT operates at three levels of basin, sub-basin, and hydrological response unit (HRU). Within the sub-basin, HRU is defined by combining soil and land use maps. SWAT adopts daily time step and simulates the water quantity and quality processes of the hydrologic cycle.

The main water quantity processes included in SWAT model are precipitation, surface runoff, evapotranspiration, lateral flow, ground water and channel flow. The SWAT model is based on the water balance equation and the major hydrologic processes represented by SWAT model are shown in Table 1. The detailed procedures for the water quantity processes are explained in SWAT theoretical documentation (Neitsch, 2001).

2.2 Study Site and Data

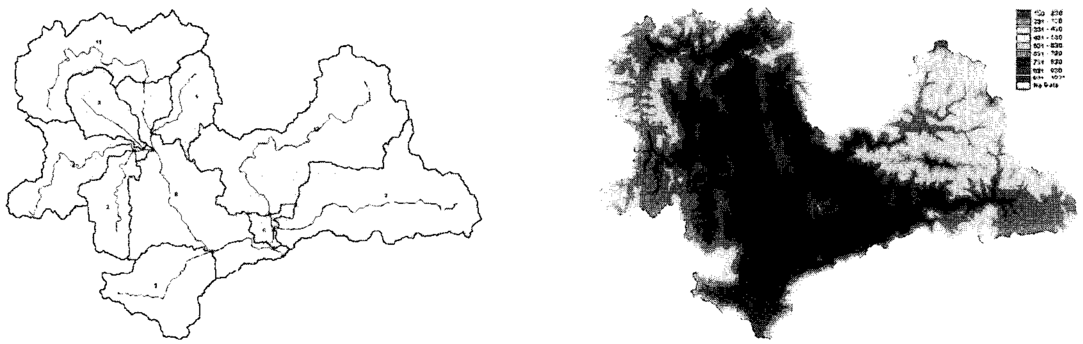
Bocheong watershed was chosen to evaluate SWAT model and to perform the sensitivity analysis with SWAT. Fig. 1 shows the division of sub-basin, topography, soil and land use maps for Bocheong watershed. The daily runoff data measured at Gidai water level station of Table 2 are compiled between 1990 and 1998. The area of Bocheong watershed based on Gidai station is

Table 1. Major processes included in SWAT

Flow process	Method
Surface runoff	SCS curve number equation
Potential evapotranspiration	Penman-Monteith equation; Priestley-Taylor equation; Hargreaves equation
Percolation	Storage routing model
Lateral flow	Kinematic storage model
Channel flow	Muskingum routing method; Variable Storage routing method
Baseflow	Hooghoudt storage model

approximately 346.5㎢. The elevation below 400m occupies 84% of the watershed and the hillslope less than 30% covers most of the watershed. The climatic input data at six stations shown in Table 3 are used to define the daily maximum and minimum temperature, solar radiation, wind speed, and relative humidity from the year 1990 to 1998. The rainfall data measured at twelve rain gage stations of Table 4 are used in the simulation of SWAT over 9 years.

Since the topography, soil and land use digital maps are required to prepare the input data of SWAT model, the digital maps for topography, soil and land use are compiled and used in the development of SWAT model. The scale of topography and land use maps applied in the study is 1:25,000 while 1:50,000 soil map scale is used. Table 5 exhibits dominant soil series present in Bocheong watershed. Seven soil series of Mac, Mvb, Mmb, Rab, Ro, Anb, and Mma occupies about 68% in the watershed. Table 6 shows the dominant land use types. The Bocheong watershed is mainly covered by mixed forest and agricultural land.


Sub-basin **DEM**

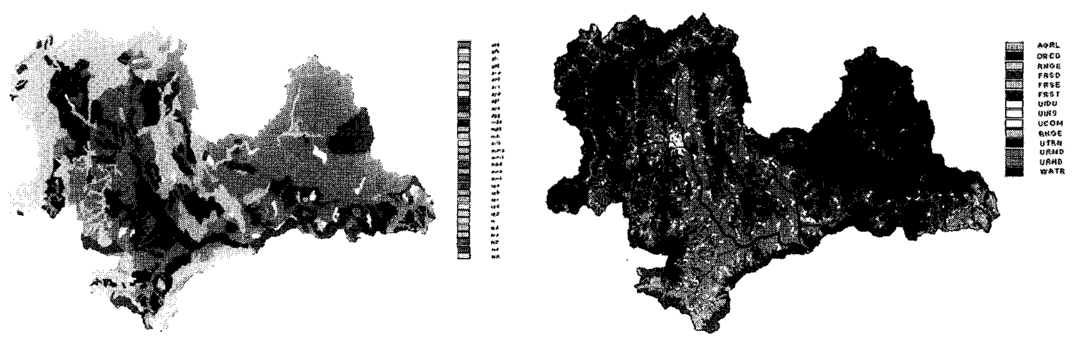

Soil map **Land use map**

Fig. 1 Sub-basin, DEM, soil and land use maps for the study watershed

Table 2. Water stage station

Station	Transverse Mercator		Elevation (m)
	X	Y	
Gidai	273862.85	324061.01	125.7

Table 3. Climatic stations in Bocheong watershed

Station	Transverse Mercator		Elevation (m)
	X	Y	
Cheongju	238751.3	348425.7	59
Geumsan	242018.4	289264.0	67.1
Daejeon	241875.9	318851.4	170.7
Chupungryong	289907.1	302571.0	245.9
Munkyung	123970.2	346825.7	172.1
Boeun	265706.6	331944.7	170

Table 4. Rain gage stations

Station	Transverse Mercator		Elevation (m)
	X	Y	
Neung Weol	265706.9	331945.0	170
An Nae	259604.6	321698.3	80
Myo Geum	266008.3	308675.8	140
Cheong San	271434.1	316578.6	120
Jung Nyul	278786.8	322437.2	180
Kwan Gi	273818.7	326431.4	160
Pyeong On	280804.5	327850.1	200
Sam Ga	277249.8	332687.9	380
Song Jug	266070.9	326646.2	130
Sam San	264388.2	331873.4	150
Dong Jeong	259742.8	330545.5	210
Yi Weon	260858.4	338259.1	220

Table 5. Relative area for dominant soils

Soil	Area (%)	Soil	Area (%)
Mac	15.77	mvb	11.34
Mmb	11.49	Rab	9.18
Ro	8.40	Anb	6.98
Mma	5.53		

Table 6. Relative area for dominant land use

Symbol	Land use	Area (%)
FRST	Forest-Mixed	63.37
AGRL	Agricultural Land-Generic	25.69

2.3 Sensitivity Index

The dimensionless sensitivity index needs to be defined to quantify the sensitivity of output variable with respect to input variable. The definition of sensitivity in the paper follows Lenhart (2002). The sensitivity index (I') explains the change of an output variable y with respect to the change of a parameter x and can be defined by the partial derivative $\frac{\partial y}{\partial x}$. If we define two output variables y_1 and y_2 which correspond to two input parameters x_1 and x_2, the sensitivity index I' is expressed by central finite difference approximation of the partial derivative as

$$I' = \frac{y_2 - y_1}{x_2 - x_1} \tag{1}$$

Let x_0 be the midpoint parameter between x_1 and x_2, and y_0 be the model output calculated with the parameter x_0. Then we can define the dimensionless sensitivity index I as follows.

$$I = \frac{(y_2 - y_1)/y_0}{(x_2 - x_1)/x_0} \tag{2}$$

The dimensionless sensitivity index represents the relative change of output variable with respect to the relative change of input parameter. In the sensitivity analysis the parameters were varied by 50% of the base parameter value x_0 (i.e., $(x_2 - x_1) = 0.5x_0$).

The parameters considered in the sensitivity analysis are shown in Table 7, where the lower limit, upper limit, and base values for each parameter also appear. In the table 'non-uniform' for base values of CN2, SOL_K, SOL_AWC, and SOL_BD indicates that these parameters spatially vary with HRU. So the CN2 parameter values are different between each HRU and depend on the soil and land use characteristics of HRU. The soil parameters of SOL_K, SOL_AWC, and SOL_BD also vary with soil layer and HRU and depend on the soil types. The other parameters such as CH_N, GWQMN, ALPHA_BF, GWREVAP, GW_DELAY, and ESCO are specified by constant base values. Thus these parameters are assumed to be spatially uniform within the watershed.

The surface water and groundwater budget components (runoff, surface runoff, evapotranspiration, percolation, and baseflow) were first extracted from the simulated output of SWAT in Bocheong river basin. Then, the averaged values of each water budget variable were obtained for nine years and used in calculating the dimensionless sensitivity index based on the Equation (2). After calculating the dimensionless sensitivity index for each parameter, the qualitative sensitivity class can be classified into four classes according to Table 8.

Table 7. Parameters used for sensitivity analysis

Input File	Parameter	Definition	Lower limit	Base value	Upper limit
*.mgt	CN2	SCS curve number for moisture condition II	35	Non-uniform	98
*.rte	CH_N	Manning's roughness coefficient for the channel	0.01	0.155	0.3
*.gw	GWQMN	Threshold depth of water (mm)	0	2500	5000
	ALPHA_BF	Baseflow recession constant	0.02	0.5	1
	GW_REVAP	Groundwater revap coefficient	0	0.11	0.2
	GW_DELAY	Delay time for aquifer recharge (days)	0	250	500
*.sol	SOL_K	Saturated hydraulic conductivity (mm/hr)	0	Non-uniform	2000
	SOL_AWC	Available water capacity (mm/mm)	0	Non-uniform	1
	SOL_BD	Bulk density (g/cm^3)	1.0	Non-uniform	2.5
*.hru	ESCO	Soil evaporation compensation factor	0	0.5	1

Table 8. Sensitivity classes

Class	Index Range	Status
I	$0 \le \mid I \mid < 0.05$	Small to negligible
II	$0.05 \le \mid I \mid < 0.2$	Medium
III	$0.2 \le \mid I \mid < 1$	High
IV	$\mid I \mid \ge 1$	Very High

3. RESULTS

3.1 Evaluation of SWAT

The performance of SWAT model is evaluated against the measured daily streamflow at Gidai station of Bocheong river watershed. Since SWAT contains a lot of parameters and the dimension of parameter space is almost infinity, the calibration process for SWAT model requires additional study. Thus at this phase of the research the calibrated model parameters are minimized such that a priori parameter estimation approach is used for the estimation of soil properties, and the remaining parameters are specified by trial and error estimation method and default parameters automatically determined by SWAT GIS interface. Table 9 shows the parameter values estimated by trial and error method. And as shown in Table 10, the SCS CN values for the average antecedent moisture condition are estimated by SWAT GIS interface based on soil and land use maps.

The soil physical parameters estimated by a priori method include bulk density, available water capacity, saturated hydraulic conductivity of each soil layers. This approach generally attempts to estimate the soil hydraulic properties based on more readily available information such as soil texture. In this study we used soil water hydraulic properties calculator developed by Saxton(http://www.bsyse.wsu.edu/saxton/soilwater).

Since SWAT offers various methods for calculating potential evapotranspiration (PET) and channel flow routing, we first evaluate the effects of different methods on the performance of SWAT model by keeping other parameters and conditions be the same. For the potential evapotranspiration process SWAT includes Penman-Monteith, Priestley-Taylor, and Hargreaves methods. For the hydrologic channel routing SWAT adopts two options of Muskingum and variable storage routing methods.

For the comparison and evaluation purposes, we used two performance measures such as Nash-Sutcliffe efficiency index (Nash and Sutcliffe, 1970) and correlation coefficient. The Nash-Sutcliffe efficiency index(EI) can be defined by Nash and Sutcliffe (1970) as the following equation:

$$\mathrm{EI} = \frac{F_o - F}{F_o};$$

$$F_o = \sum\{Q_o(t) - M_o\}^2 ; F = \sum\{Q_o(t) - Q_s(t)\}^2$$

where $Q_o(t)$ is the observed runoff at time t, $Q_s(t)$ is the simulated runoff at time t, and M_o is the average of observed runoff.

Table 11 shows the performance of SWAT for three different PET methods. The Hargreaves PET method performs better than other two methods in terms of efficiency index, but Priestley-Taylor method exhibits slightly better performance than other two methods in term of correlation coefficient. The overall performance measures for Penman-Monteith method and Hargreaves method are about the same and seem to be better than that of Priestley-Taylor method. Hence, this result suggests that either Penman-Monteith method or Hargreaves method can be used for selecting PET methods in SWAT.

Table 9. The parameter values used in the simulation

Parameters	Value	Parameters	Value
GW_REVAP	0.02	GW_DELAY (day)	31
ALPHA_BF (d^{-1})	0.048	CH_N	0.035

Table 10. SCS CN parameter values used in the simulation

Sub-bain	CN2	Sub-bain	CN2
1	36	6	83
2	36	7	36
3	60	8	77
4	35	9	36
5	77	10	36

Table 11. Comparison of performance measure for different evapotranspiration methods

Method	Penman-Monteith	Priestley-Taylor	Hargreaves
Efficiency Index	0.62	0.6	0.64
Correlation	0.83	0.84	0.82

Table 12. Comparison of performance measure for two different channel routing methods

Method	Muskingum	Variable storage
Efficiency Index	0.62	0.11
Correlation	0.83	0.46

Table 13. Evaluation of SWAT model

Year	1993	1994	1995	1996	1997	1993 – 1997
Efficiency Index	0.68	-2.7	0.72	0.41	0.61	0.62
Correlation	0.89	0.63	0.9	0.75	0.85	0.83

Table 14. Comparison between simulated and measured average daily runoff

Year	1993	1994	1995	1996	1997	1993 – 1997
Simulated (m^3/s)	5.4	3.1	5.0	5.5	9.9	5.8
Measured (m^3/s)	10	6.8	7.5	10.8	17.1	10.5

The effect of two different channel routing methods on the performance measure is shown in Table 12. The variable storage routing method performs poorly compared to Muskingum routing method. So Muskingum routing method should be used in selecting channel flow routing method.

Table 13 exhibits the performance measure of SWAT calculated from simulation based on Penman-Monteith PET method and Muskingum channel routing method. The performance of SWAT varies with the simulation years and is significantly different between years. The performance of SWAT is reasonably good for the years of 1993, 1995, and 1997 in which the Nash-Sutcliffe efficiency is above 0.6. But for 1994 and 1996 years, the performance of SWAT is poor compared to other years. Although the performance for total five years is reasonably good with the efficiency index of 0.62, SWAT significantly underestimates the measured average daily runoff component as shown in Table 14. Because of differences between the measured and simulated average daily runoff, the simulated annual runoff ratio is also underestimated compared to the measured annual runoff ratio as shown in Table 15. The performance of SWAT model for the peak daily runoff is different depending on the simulation years as shown in Table 16. The simulated peak daily runoff for 1994

Table 15. Comparison between simulated and measured annual runoff ratio

Year	1993	1994	1995	1996	1997	1993 - 1997
Simulated	0.43	0.37	0.45	0.44	0.56	0.47
Measured	0.8	0.81	0.69	0.87	0.97	0.84

Table 16. Comparison between simulated and measured peak daily runoff

Date	July 13, 1993	July 1, 1994	Aug 30, 1995	June 18,1996	Aug 4, 1997
Simulated (㎥/s)	135.7	86	189.2	151.2	491.1
Measured (㎥/s)	251.4	56	415.8	174.7	1156.4

and 1996 agrees with the measured peak daily runoff while there are big differences between measured and simulated peak daily runoff for other years. One of the reasons for the poor performance of SWAT model in calculating average and peak daily runoff might be due to the combined effects of uncertainty of measured daily runoff and the model structure error of SWAT.

The residual between the measured and simulated daily runoff is shown in Figure 2 for the year 1994 with the worst efficiency index and for the year 1995 with the best efficiency index. For the year 1994, the residual is distributed between 10㎥/s and 40㎥/s. For the year 1995, the residual is relatively low except for the period with peak runoff which has the residual of 200㎥/s. Figure 3 shows the scatter plot between measured and simulated daily runoff for all simulation periods.

3.2 Sensitivity Analysis Results

The results of sensitivity analysis for SWAT model parameters are shown in Table 17 and Table 18. In the tables the sensitivity index for different periods is investigated separately such that the winter period includes the period from November to April and the summer period includes the period from May to October. The sensitivity analyses were performed for various hydrologic components and the sensitivity index values for surface runoff, total runoff and evapotranspiration obtained in this study are consistent with the sensitivity analysis results determined in the artificial watershed by Lenhart et al. (2002).

For surface runoff component, SCS curve number (CN2) exhibits very high sensitivity while available water capacity (SOL_AWC) and soil evaporation compensation factor (ESCO) show high sensitivity index. However, the groundwater related parameters (GWQMN, ALPHA_BF, GWREVAP, GW_DELAY), Manning roughness coefficient (CH_N) and soil hydraulic conductivity (SOL_K) have small to negligible sensitivity index on surface runoff component. The most three important parameters affecting the behavior of surface runoff are in the order of CN2, SOL_AWC, and ESCO. The sensitivity index for CN2 during summer period is larger than that for winter period while the sensitivity index values for SOL_AWC and ESCO during summer period are smaller than the sensitivity index values for winter period.

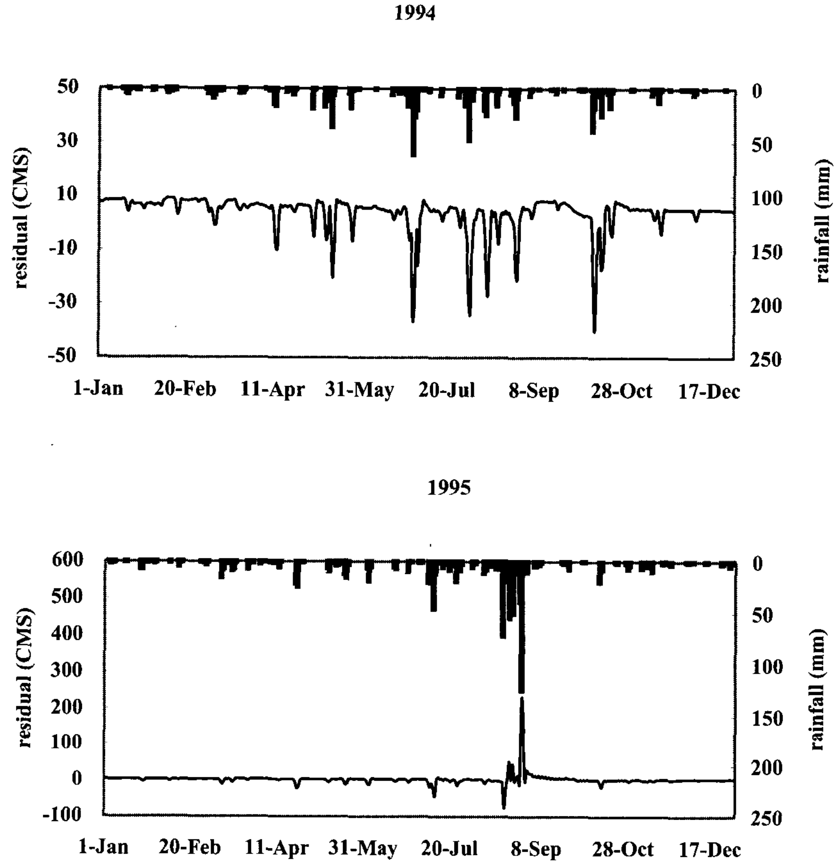


Fig. 2 Difference between measured and simulated daily runoff

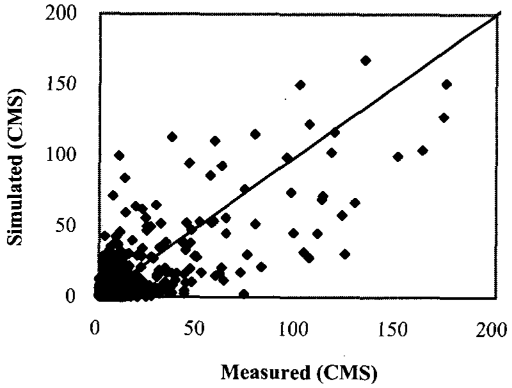


Fig. 3 Comparison between measured and simulated daily runoff

Table 17. Sensitivity index for surface runoff, channel runoff and evapotranspiration

Parameter	Surface Runoff			Total Runoff			Evapotranspiration		
	Winter Period	Summer Period	Total Period	Winter Period	Summer Period	Total Period	Winter Period	Summer Period	Total Period
CN2	4.26 (IV)	6.09 (IV)	5.89 (IV)	0.039 (I)	0.059 (II)	0.05 (II)	0.027 (I)	0.088 (II)	0.07 (II)
CH_N	0.0 (I)	0.0 (I)	0.0 (I)	0.05 (II)	0.008 (I)	0.02 (I)	0.0 (I)	0.0 (I)	0.0 (I)
GWQMN	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)
ALPHA_BF	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)
GWREVAP	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)
GW_DELAY	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)
SOL_K	0.0 (I)	0.0023 (I)	0.0 (I)	0.0097 (I)	0.0076 (I)	0.01 (I)	0.0079 (I)	0.0104 (I)	0.01 (I)
SOL_AWC	0.7 (III)	0.19 (II)	0.24 (III)	0.17 (II)	0.13 (II)	0.14 (II)	0.17 (II)	0.18 (II)	0.18 (II)
SOL_BD	0.027 (I)	0.043 (I)	0.04 (I)	0.24 (III)	0.19 (II)	0.2 (III)	0.25 (III)	0.27 (III)	0.27 (III)
ESCO	0.6 (III)	0.29 (III)	0.32 (III)	0.11 (II)	0.07 (II)	0.08 (II)	0.09 (II)	0.12 (II)	0.11 (II)

Table 18. Sensitivity index for percolation and baseflow

Parameter	Percolation			Baseflow		
	Winter Period	Summer Period	Total Period	Winter Period	Summer Period	Total Period
CN2	0.55 (III)	0.91 (III)	0.86 (III)	0.72 (III)	0.9 (III)	0.87 (III)
CH_N	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)
GWQMN	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)
ALPHA_BF	0.0 (I)	0.0 (I)	0.0 (I)	0.026 (I)	0.074 (II)	0.05 (II)
GWREVAP	0.0 (I)	0.0 (I)	0.0 (I)	0.034 (I)	0.049 (I)	0.05 (II)
GW_DELAY	0.0 (I)	0.0 (I)	0.0 (I)	1.09 (IV)	0.21 (III)	0.03 (I)
SOL_K	41.72 (IV)	37.45 (IV)	38.22 (IV)	40.73 (IV)	37.25 (IV)	38.07 (IV)
SOL_AWC	15.63 (IV)	9.21 (IV)	9.98 (IV)	12.67 (IV)	9.54 (IV)	10.12 (IV)
SOL_BD	0.89 (III)	1.17 (IV)	1.13 (IV)	0.95 (III)	1.23 (IV)	1.17 (IV)
ESCO	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)	0.0 (I)

For total runoff component, SOL_AWC and SOL_BD parameters are the most important parameters affecting the behavior of total runoff and exhibit medium to high sensitivity while other parameters show negligible or small sensitivity index. The sensitivity index values for SOL_AWC and SOL_BD during winter period are slightly larger than that for summer period. Since total runoff reflects the integrated effects of various hydrologic components, the parameters examined in this study do not exhibit very high sensitivity on total runoff.

For evapotranspiration component, similar sensitive parameters are observed as in the case of total runoff. The most three important parameters affecting the behavior of evapotranspiration are in the order of SOL_BD, SOL_AWC and ESCO. The groundwater related parameters, Manning roughness coefficient and soil hydraulic conductivity have small to negligible sensitivity index on evapotranspiration. The sensitivity index values for SOL_AWC and SOL_BD during winter period show similar sensitivity values for summer period.

For percolation, SOL_K, SOL_AWC and SOL_BD show very high sensitivity and are the most important parameters affecting the behavior of percolation. Especially, the sensitivity index value for SOL_K parameter exhibits very high index value. And CN2 parameter exhibited high sensitivity on percolation while groundwater related parameters and ESCO revealed negligible sensitivity. The sensitivity index values for SOL_K and SOL_AWC during winter period are larger than the sensitivity index for summer period, while the sensitivity index for SOL_BD during winter period shows smaller sensitivity index for summer period.

For baseflow component, SOL_K, SOL_AWC and SOL_BD parameters show very high sensitivity on baseflow as in the case of percolation component. The sensitivity index for SOL_K parameter is about three to four times as large as the sensitivity index value of SOL_AWC parameter. The CN2 parameter exhibited the sensitivity index less than 1 and the sensitivity index of CN2 for summer period is slightly higher than the index for winter period. The most of groundwater related parameters exhibit small to negligible sensitivity although the sensitivity index for GW_DELAY parameter reveals very high sensitivity for winter period. One of the reasons for small sensitivity of the groundwater related-parameters on baseflow is that baseflow component is dependent on the percolation such that the sensitive parameters on percolation also exhibit the sensitive impact on baseflow.

4. CONCLUSIONS

The applicability of SWAT model to simulating daily streamflow was evaluated against the daily measured runoff over five years in Bocheong river watershed. In addition to this, the quantitative sensitivity determined by the simulation of SWAT is classified into four classes as small, medium, high and very high. The Nash-Sutcliffe efficiency index of 0.62 and correlation coefficient of 0.83 were obtained based on the default parameters and a priori soil parameters. Hence, the performance of SWAT in predicting the daily runoff is considered to be relatively acceptable. However, the performance of SWAT in predicting the daily runoff is significantly different depending on the tested year. The performance of SWAT for the year 1994 and 1996 is very poor while the performance for the years 1993, 1995, and 1997 seems to be acceptable. One of the reason for poor performance in the year 1994 and 1996 is attributed to the combined effects of model uncertainty and error of measured runoff data exhibiting runoff coefficient greater than 0.8. SWAT model also needs to be improved in simulating baseflow since there are large differences between the simulated and measured daily low flow components.

This study used the default parameters and a priori parameter estimation approach in order to minimize the parameter calibration process. Saxton's soil physical parameter calculator seems to be applicable in specifying hydraulic conductivity, available water capacity, and bulk density only based on the information of soil texture. In the future study, the systematic and rigorous methods for model calibration need to be developed although the minimal model calibration approach taken in this study seems to be reasonable.

The sensitivity analysis with SWAT points out that the soil physical parameters of hydraulic conductivity, available water capacity, and bulk density are identified as the most significant parameters affecting model outputs for total runoff, evapotranspiration, percolation and baseflow. The groundwater related parameters of SWAT model are considered to be small to negligible sensitivity on the model outputs except for the baseflow component. The results of sensitivity analysis examined in the present paper generally agree with the previous results of sensitivity analysis being investigated in artificial catchment (Eckhardt and Arnold, 2001) and in Upper Mississippi River basin (Arnold et al., 2000).

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