STUDY OF AUTO-CALIBRATION AND VALIDATION METHOD ON SWAT MODEL IN RIVER BASIN

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Abstract: *The SWAT model (Soil and Water Assessment Tool) has been widely used. It is a semi-distributed hydrological model built to simulate the effects of land use management and climatic factors on water source, sediment and organic matter content in river basin system with soil types, with different land use conditions for a period or forecast for a long time. Besides its outstanding advantages, the SWAT model also requires a large number of input parameters, the process of parameterizing, calibrating and verifying the model with manual methods is facing many difficulties in the implementation process. This is an extremely important step to evaluate the accuracy of simulation model results, however, with a large number of parameters and complexity across sub-basins, changing and detection each parameter to determine the sensitivity in the process of calibration and validation really takes a lot of time and affects the quality of the model. Therefore, in this study, it is necessary to focus on detailed research on the method of auto-calibration and validation the model to reduce time, volume and improve the quality of the model to determine the highest sensitivity parameters and influence in the model*

The SWAT model result was calibrated and validated by comperison of observed data against simulated of monthly streamflow where parameters were adjusted based on the sensitivity analysis in auto-calibration methods. The research results provide a useful method with powerful tools, saving time and effort to increase the quality, consistency and accuracy of the model.

Keywords: *Auto-Calibration, Validation, Hydrology model, Nakdong river basin.*

1. INTRODUCTION

Recent years with development of technology, the hydrological models are widely used and available. In this study, the Soil and Water Assessment Tool (SWAT) was selected for carrying out the hydrological simulations, is a continuous-time, semi-distributed, processbased river basin model. It was developed to evaluate the effects of alternative management decisions on water resources and nonpoint-source pollution in large river basins [1]. ArcSWAT is used ArcGIS interface for Soil and Water Assessment Tool. It is a physically-based continuous-event hydrologic model developed 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 basic model inputs are rainfall, maximum and minimum temperature, radiation, wind speed, relative humidity, land cover, soil and digital elevation model.

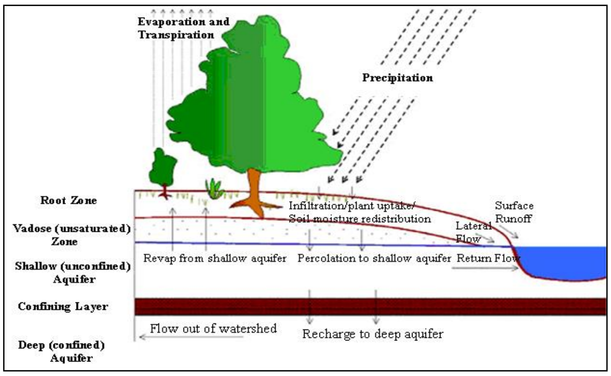

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Figure 1: Schematic representation of the hydrologic cycle in ArcSWAT

In simulation of ArSWAT, the watershed is subdivided into subbasins that are spatially related to one another. This configuration preserves the natural channels and flow paths of the watershed. The subbasin watershed components can be categorized into the following components hydrology, weather, erosion and sedimentation, soil temperature, plant growth, nutrients, pesticides and land management. In the land phase of the hydrologic cycle, runoff is predicted separately for each hydrologic response unit (HRU) and routed to obtain the total runoff for the watershed. Once the loadings (water, sediment, nutrients and pesticides) to the main channel are determined, they are routed through the stream systems of the watershed. The hydrologic cycle is based on the water balance equation

$$SW_t = SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - W_{deep} - Q_{gw}) \quad (1)$$

where SWt is the final soil water content (mm H_2O), SW_0 is the initial soil water content on day i (mm H_2O), t is the time (days), R_{day} is the amount of precipitation on day i (mm H_2O), Q_{surf} is the amount of surface runoff on day i (mm H_2O), E_a is the amount of evapotranspiration on day i (mm H_2O), Wdeep is the amount of water into the deep aquifer on day i (mm H_2O), and Q_{gw} is the amount of return flow on day i (mm H_2O). The hydrologic cycle is involved processes when precipitation fall to the soil surface. Water on the soil surface will infiltrate into the soil profile or flow overland as runoff. Runoff moves relatively quickly toward a stream channel and contributes to short-term stream response. Infiltrated water may be held in the soil and later evapotranspired or it may slowly make its way to the surface-water system via underground paths. The runoff volume are calculated based on the SCS curve number procedure, this curve number is a function of the soil's permeability, land use and antecedent soil water conditions. Certain assumptions about initial abstractions are made. These include surface storage, interception and infiltration prior to runoff and a retention parameter that varies spatially due to changes in soils, land use, management and slope and temporally due to changes in soil water content. A modified rational formula is used to estimate the peak runoff rate. Moreover, in evapotranspiration's calculation, there are three potential evapotranspiration (PET) methods available in SWAT. They vary in the amount of required inputs. The Penman-Monteith method requires solar radiation, air temperature, relative humidity and wind speed. The Priestley-Taylor method requires solar radiation, air temperature and relative humidity while the Hargreaves method requires air temperature only. The simulation processes of runoff, the SWAT predicts the runoff based on rule of separation for each HRU and routed to obtain the total runoff for the watershed. The first subdivision of the catchment is the subbasin. Subbasins are spatially related to one another and contain at least one HRU, a tributary channel and a main channel or reach. The next subdivisions are the hydrologic response units. These are portions of a subbasin that possess unique land use, land cover and soil attributes although their geographic locations are unknown. In other words, an HRU is the total area in the subbasin with a particular landuse, land cover, and soil. While individual HRUs may be scattered throughout a subbasin, their areas are lumped together to form one HRU. Thus, the HRUs serve to account for the complexity of the landscape within the subbasins. An assumption is made that there is no interaction between HRUs in one subbasin. Loadings (e.g runoff) from each HRU are calculated separately and then summed together to determine the total loadings from the subbasin. If the interaction of one landuse area with another is important, rather than defining those landuse areas as HRUs they should be defined as subbasins because it is only at the subbasin level that spatial relationships can be specified. The benefit of HRUs is the increase in accuracy it adds to the prediction of loadings from the subbasin. For example, the growth and development of different plants can differ greatly and when the diversity in plant cover within a subbasin is accounted for, the net amount of runoff entering the main channel from the subbasin will be much more accurate.

In evaluating for the ArcSWAT, it consists of a number of tools that can be used to assist model users in evaluating parameter sensitivity, aid in model calibration, and assess parameter uncertainty. These tools were developed by [2] and in recent years have been employed increasingly by SWAT users worldwide. The sensitivity analysis tool is helpful to model users in identifying parameters that are most influential in governing streamflow or water quality response. The sensitivity analysis tool in the ArcSWAT Interface allows model users to conduct two types of analyses. The first analysis may help to identify parameters that improve a particular process or characteristic of the model, while the second analysis identifies the parameters that are affected by the characteristics of the study watershed and those to which the given project is most sensitive [3].

2. DESCRIPTION STUDY AREA AND METHODS

The South Korea has five major river basins in which Nakdong river basin is one of the biggest basin in Korea, and it is an important water resource to supply for the southeastern area, located in the monsoon region of (35–37° N, 127–129° E) (Figure 2). The river basin has an area about 23700 km2 and length of the main stream is over 525 km. Currently, more than 13 million people intake a drinking water from the river, which has provided big resources an played important role in support the life for many people in region such as providing the agriculture products, hydropower, wastewater disposal and specially in water resource for domestic agricultural and industrial.

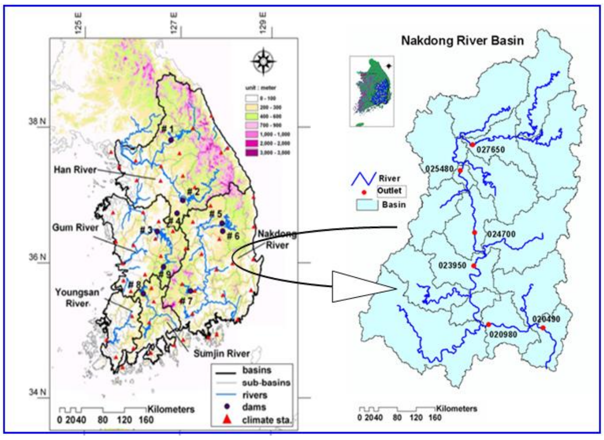

Figure 2: Location of study area, river systems

In this study, the ArcSWAT model (the Soil and Water Assessment Tools) were combined to assess impacts of climate on streamflow in Nadong river basin. First, ArcSWAT model was set up, calibrated and validated for Nakdong River Basin (to determine the best parameters for model in study area). The SWAT model setup with the steps were implemented of this study as: First, the observed data was completely setup into the ArcSWAT model, and then was calibrated and validated with observation using monthly for the periods of 1995-2004 and 2005-2011, respectively at three stations. To create a ArcSWAT dataset, the interface will need to access ArcGIS compatible raster (Grids) and vector datasets (shape files) and database of temporal files which provide certain types of information about the watershed. There are major two types of data will be setup for ArcSWAT included as spatial datasets (ESRI Grid, Shape file format) and temporal files (.dBase or .ASCII or .txt format), the more detail for data making can be found in ArcSWAT User's. All data prepared and the model setup steps are following as:

The first step, a digital elevation model (DEM) raster for Nakdong river basin was to load in the ArcSWAT interface. This map was created with resolution in meters and the elevation in meters. After DEM was loaded, selections of option for automatic create the stream network, delineate the catchment boundary from the DEM and further subdivide the catchment into subbasins. Then, selection of the locations of the five river gauging locations with climate data series were added as subbasin outlets. In these locations, they were to ensure that the model calibration was done at some their locations. Once the entire watershed outlet is selected, the subbasins are delineated and their parameters calculated. *(4)* Next, the land use and soil maps are loaded. The lookup table for each map is also loaded in order for the interface to know which codes or names to assign to the different categories. Once the land use and soil map have been loaded and reclassified, an overlay is done, resulting in land use and soil distribution within the subbasins. Then, the HRUs were then created with total number of 15 subbasins. *(5)* Next, the climatic data are loaded and the interface assigns the different weather station data sets to the subbasins in the watershed. *(6)* In the final step, the SWAT input files are built and the model is ready to run.

In conclusion, the interface helped to create the stream network, delineate the catchment boundary from the DEM and further subdivide the catchment into subbasins. The land cover and soil layers were used to generate HRUs. The climatic data was also integrated spatially to assign these data as the main drivers of the model to the various subbasins. Specifically, the steps to carry out for climate data such as: First, the observed data was completely setup into the ArcSWAT model, and then was calibrated and validated with observation using monthly for the periods of 1995-2004 and 2005-2011, respectively at three stations. Model calibration and validation efficiency were based on evaluation of statistical regression as Nash-Sutcliffe coefficient (ENS), and the Coefficient of determination (R2) values. Figure 3 describes the methodology applied to Auto-calibrate, validate and simulate the ArcSWAT model.

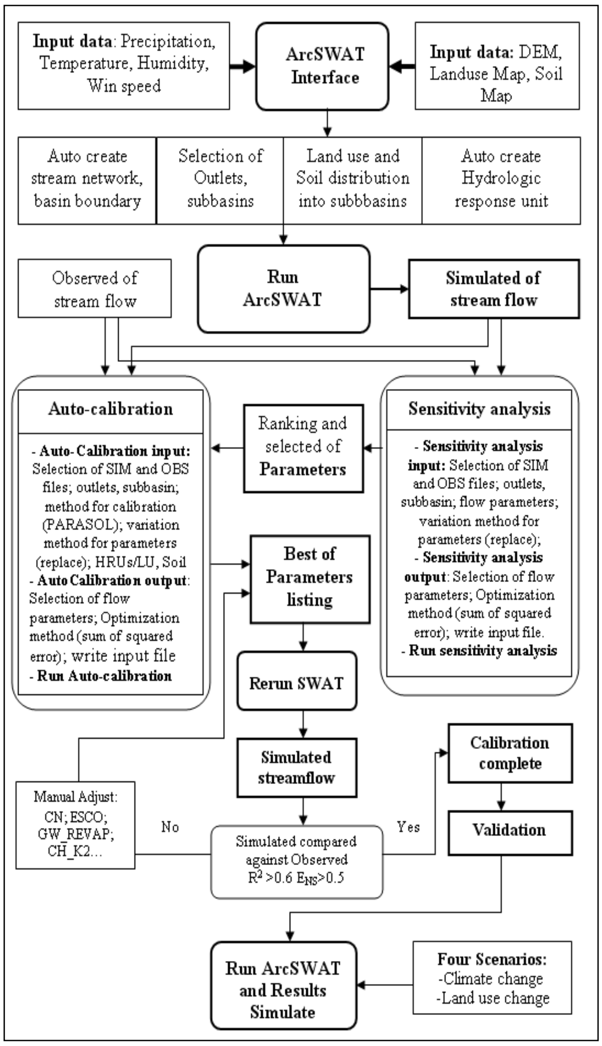

Figure 3: Method of auto-calibrate, validate and simulate the ArcSWAT model

3. RESULT OF STUDY

a) Model sensitivity analysis results

The selection of model parameters are often faced with the difficult task of determining which parameters to calibrate so that the model response mimics the actual field, subsurface, and channel conditions as closely as possible. Therefore, sensitivity analysis is the process of identifying the model parameters that exert the highest influence on model calibration or on model predictions. Some researchers noted that sensitivity analysis and calibration are difficult with large number of parameters. Hamby (1994) reviewed more than a dozen sensitivity analysis techniques. In general an important aim of the parameter sensitivity analysis is to allow the possible reduction in the number of parameters that must be estimated, thereby reducing the computational time required for model calibration. Model parameters that have high sensitivity must be chosen with care because small variations in their values can cause large variations in model output, and therefore it is important to ensure that the parameter value is the best possible estimate. Model parameters that have low sensitivity do not require as much examination in their selection because small changes in their values do not cause large changes in model output. In such cases, sensitivity analysis is helpful to identify and rank parameters that have significant impact on specific model outputs of interest (Saltelli et al., 2000). Sensitivity analysis demonstrates the impact that change to an individual input parameter has on the model response and can be performed using a number of different methods [3]. The method in the ArcSWAT Interface combines the Latin Hypercube (LH) and One-factor-At-a-Time (OAT) sampling [2]. During sensitivity analysis, SWAT runs (p+1)*m times, where p is the number of parameters being evaluated and m is the number of LH loops. For each loop, a set of parameter values is selected such that a unique area of the parameter space is sampled. That set of parameter values is used to run a baseline simulation for that unique area. Then, using one-at-a-time (OAT), a parameter is randomly selected, and its value is changed from the previous simulation by a user-defined percentage. SWAT is run on the new parameter set, and then a different parameter is randomly selected and varied. After all the parameters have been varied, the LH algorithm locates a new sampling area by changing all the parameters [3].

The sensitivity analysis tool in ArcSWAT has the capability of performing of analyses. After model obtained the result from running, and then the files are inputted to sensitivity analysis. The SWAT simulation of Sim1_M9504 file is used for performing the sensitivity analysis, and the locations of the subbasin of Sub.5, Sub.7 and Sub.13 where are also existing stations as shown in Figure 4. Then, these subbasins are selected to sensitivity analysis parameter, respectively. Next, after enters the desired input settings and observed data file in box of observed data file name. Then, the Number of intervals within Latin Hypercube is the number of sub-range as shown in Figure 4 (include input of the ArcSWAT simulation files, subbasin location, sensitivity analysis parameters setting, observed data and, selected parameters and associated lower and upper bounds).

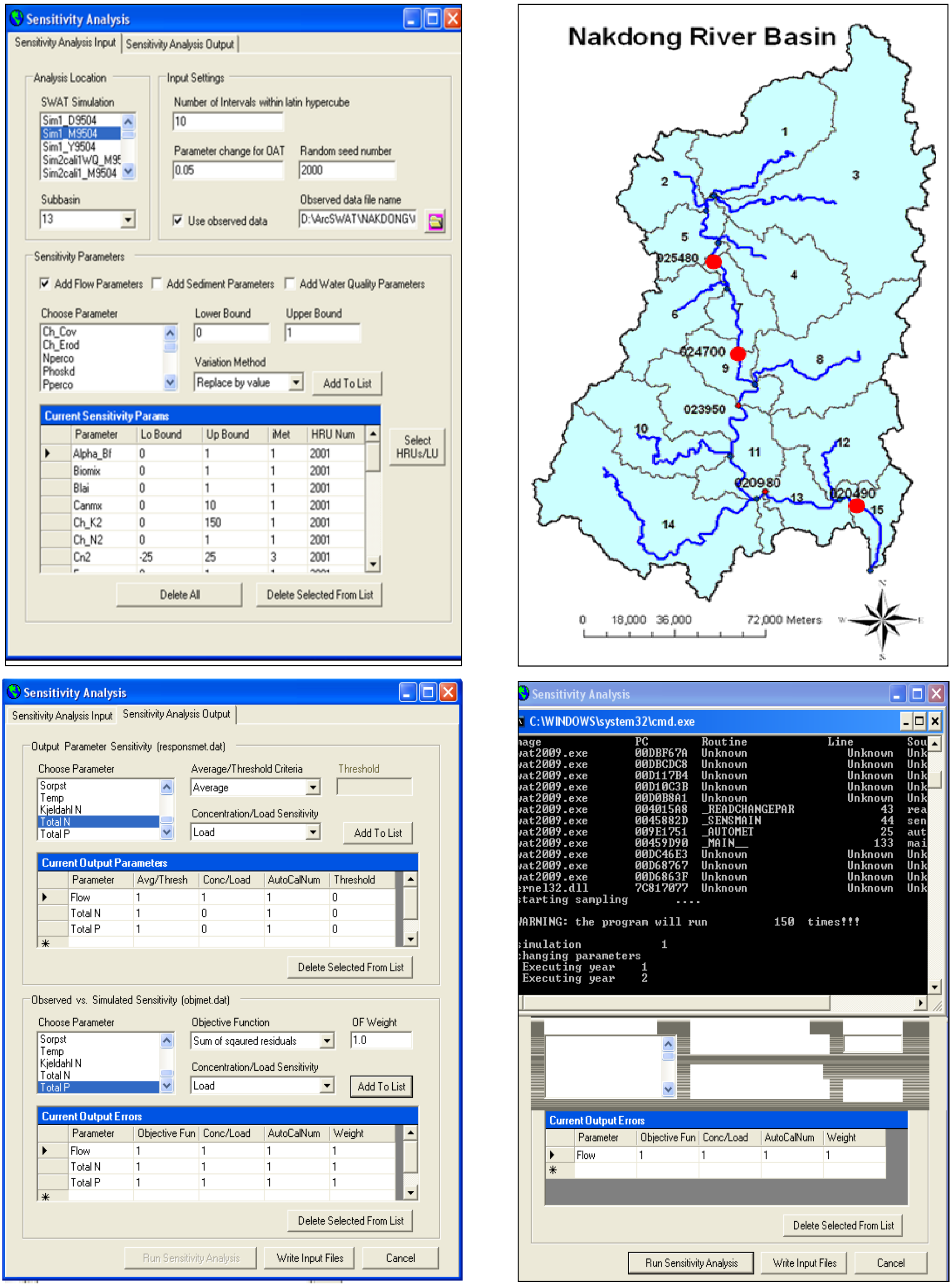

Figure 4: Input and output sensitivity analysis parameters

The second in sensitivity analysis output, choose parameter types for output as flow select objective function for select optimization method, and then write input files to project directory. Finally, the completion of the sensitivity analysis, the result of a number of files are generated in the output with file name as SENSOUT.out as shown in Figure 4. The results of the automatic sensitivity analysis were used just as a guideline in the selection of the parameters. For the Nakdong river basin sensitivity analysis was carried out against the measured streamflow at three hydrology gauge stations at outlets of sub5, sub7 and sun13 from 1995-2004 as calibration period. The objective function (i.e. the sum of the squared errors between the observations and the simulations) is calculated during each run. The effect of a change of a parameter value on this objective function is then calculated. The sensitivity analysis was carried out with 150 iteration have been done by SWAT sensitivity analysis at the three sites of Nakdong river basin for streamflow calibration with the out put of 18 parameters. A listing of the parameters ranking after sensitivity analysis is run and the parameters are ranked with decreasing sensitivity as shown in Table 1. Among 18 parameters, selected 14 of them have high and medium effect on the simulated result and chosen for calibration step of flow at three sites.

Table 1: Parameters selected as significant after the automatic sensitivity analysis

Parameters	Description	Location	Lower bound	Upper bound	Rank of sensitivity parameters		
					Sub5	Sub7	Sub 13
Alpha_Bf	Baseflow alpha factor	*.gw	0.00	1.00	1	1	2
Esco	Soil evaporation compensation factor	*.hru	0.00	1.00	2	2	3
CN2	Initial SCS CN II value	*.mgt	-25%	25%	3	3	1
Gw_Delay	Groundwater delay	*.gw	0.00	100	4	4	4
Revapmn	Threshold water in the shallow aquifer for revap	*.gw	-100	100	5	5	6
Surlag	Surface runoff lag time	*.bsn	0.00	10	6	6	5
Ch_K2	Channel effective hydraulic conductivity	*.rte	0.00	150	7	7	7
Gwqmn	Threshold depth of water in the shallow aquifer	*.gw	0.00	1000	8	8	8
Sol_K	Saturated hydraulic conductivity	*.sol	-25%	25%	9	9	9
Slope	Average slope steepness	*.hru	-25%	25%	10	11	12
Sol_Awc	Available water capacity	*.sol	-25%	25%	11	10	10
Sol_Z	Soil depth	*.sol	-25%	25%	12	12	11
Ch_N	Manning's n value for main channel	*.rte	0.00	1.00	13	13	13
Gw_Revap	Groundwater revap coefficient	*.gw	-0.036	0.036	14	14	14
Canmx	Maximum canopy storage	*.hru	0.00	10.0	15	15	15
Biomix	Biological mixing efficiency	*.mgt	0.00	1.00	16	17	16
Epco	Plant uptake compensation factor	*.hru	0.00	1.00	17	16	17
Sol_Alb	Moist soil albedo	*.sol	-25%	25%	18	18	18

***.bsn:** *Basin input file,* ***.hru:** *HRU general input file,* ***.gw:** *Groundwater input file,* ***.mgt:**

*Management input file, ***.rte:** Main channel input file, ***.sol:** Soil input file*

*(**Sub5_025480:** Nakdong station; **Sub7_024700**: Goeagwan; **Sub13_020490**: Samyanjin satations)*

b) Model efficiency

The methods for goodness-of-fit measures of model simulations were used during the calibration and validation periods, model performance measures with the regression statistical parameters are coefficient of regression (R^2 coefficient) and the Nash-Suttcliffe simulation efficiency (ENS) (Nash and Suttcliffe 1970). The range of values for R^2 is 1.0 (the best) to 0.0 (the worst). The R^2 value is an indicator of strength of relationship between the observed and simulated values. It is calculated by the following equation:

$$R^2 = \frac{\left[\sum_{i=1}^{n}(Qsi-\bar{Q}s)(Qoi-\bar{Q}o)\right]^2}{\sum_{i=1}^{n}(Qsi-\bar{Q}s)^2\sum_{i=1}^{n}(Qoi-\bar{Q}o)^2} \qquad (2)$$

Where: Q_{si} is the simulated values of the quantity in each model time step (in this case, monthly); Q_{oi} is the observed values of the quantity in each model time step (in this case, monthly); $\bar{Q}_s$ is the average simulated value of the quantity in each model time step (in this case, monthly); $\bar{Q}_o$ is the average observed value of the quantity in each model time step (in this case, monthly); n is the number of observations. In this study, each model time step is monthly. Nash-Sutcliffe simulation efficiency, E_{NS}, indicates the degree of fitness of the observed and simulated plots with the 1:1 line [4]. It is calculated as follows with the same variables defined above:

$$E_{NS} = 1 - \frac{\sum_{i=1}^{n}(Qoi-Qsi)^2}{\sum_{i=1}^{n}(Qoi-\bar{Q}o)^2} \qquad (3)$$

Where Q_{si} is the simulated values of the quantity in each model time step; Q_{oi} is the observed values of the quantity in each model time step; $\bar{Q}_o$ is average observed value. In this study, each model time step is monthly. The statistical index of modeling efficiency (E_{NS}) values range from 1.0 (best) to negative infinity. E_{NS} measures how well the simulated results predict the measured data relative to simply predicting the quantity of interest by using the average of the measured data over the period of comparison. A value of 0.0 for E_{NS} means that the model predictions are just as accurate as using the measured data average to predict the measured data. E_{NS} values less than 0.0 indicate the measured data average is a better predictor of the measured data than the model predictions while a value greater than 0.0 indicates the model is a better predictor of the measured data than the measured data average. If the R^2 values are close to zero, and the E_{NS} values are less than (negative) or close to zero, when the model prediction is unacceptable. If the values equal one, when the model prediction are considered perfect. However, In SWAT developers in [4] assumed an acceptable calibration for hydrology at $R^2>0.6$ and $E_{NS}>0.5$ and these values were also considered in this study as a reference.

c) Model calibration

Model calibration is a means of adjusting or fine tuning model parameters to match with the observed data as much as possible, with limited range of deviation accepted. Similarly, model validation is testing of calibrated model results with independent data set without any further adjustment at different spatial and temporal scales. Parameter estimation for calibration is various techniques designed to reduce the uncertainty in the estimates of the process parameters. A typical approach is to first select an initial estimate for the parameters, somewhere inside the ranges previously specified. The parameter values are then adjusted to more closely match the model behaviour to that of the watershed. The process of adjustment can be done manually or using computer-based automatic methods. In this study, both of auto-calibration and manual implemented the model calibration because the auto-calibration option provides a powerful, labor saving tool that can be used to substantially reduce the frustration and uncertainty that often characterize manual calibrations [5]. Firstly, in Auto-calibration input, specifies the SWAT simulation that will be used for performing the auto-calibration and the location of subbasin where observed data where be compared against simulated output (in this case, simulated of Sim1_M9504 was used for auto-calibration parameters).

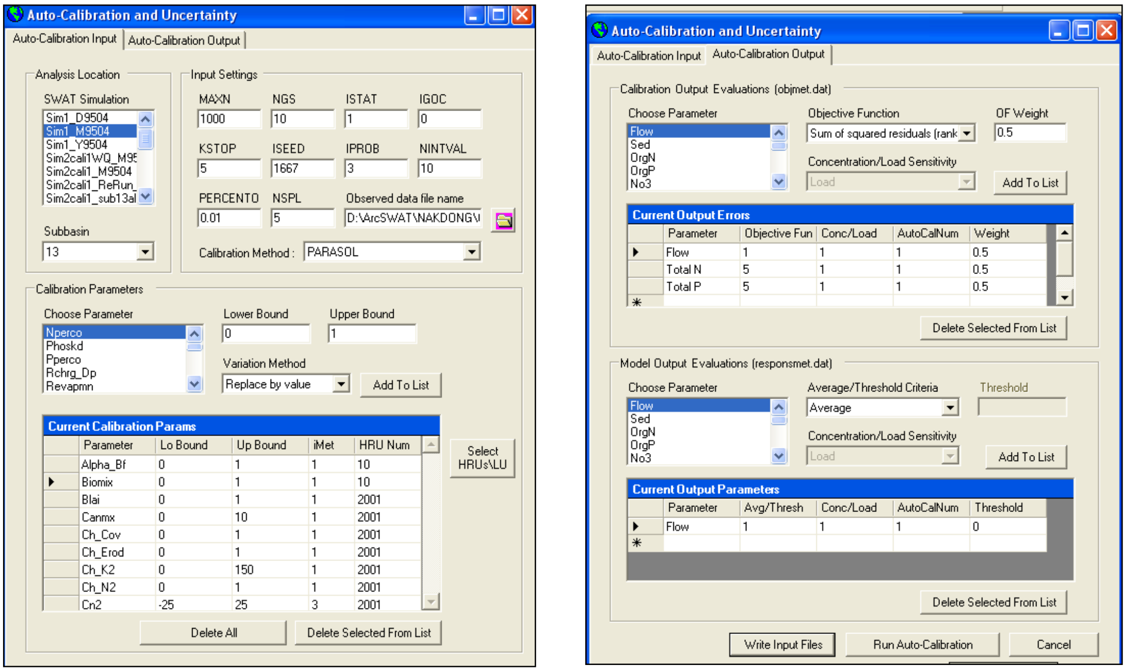

Figure 5: Auto-calibration input and calibration output evaluations

Then enter the desired optimizing settings, observed data file, maximum number of iteration (MAXN=1000), and method of calibration, put into of 14 parameters were chosen to model calibration, and using the select HRU/LU button to select model parameters by subbasins as shown in Figure 5. Secondly, in Auto-calibration output evaluations that are used to enter information to perform calibration output evaluations. This includes the parameter or parameters to be calibrated, the type of objective function (sum squares or sum of squares ranked), the weight assignments for output variables and selection of either concentration. Moreover, the auto-calibration way be used model parameters for calibration against observation data at each site (outlet) where are also stations with method from upstream to downstream order of priority as sub5, sub7 and sub13, respectively.

The results of auto-calibration output included parasolout.out, goodpar.out, bestpar.out, and autocal1.out files are output files that are particularly useful for viewing upon completion of the auto-calibration run. Where file of parasolout.out lists the maximum and minimum parameter values for all solutions in the Parameter Uncertainty Analysis. Goodpar.out is a record of all solutions having an objective function value within the uncertainty analysis confidence Interval, while bestpar.out represents the parameter set with the optimal solution among all the goodpar.out solutions. The autocal1.out file provides a listing of the simulated streamflow at the point for the designated time step used during the running. Once the auto-calibration has completed, the model can rerun with bestpar.dat data file set to simulated streamflow generated from the outocal.out file that can be compared against observed streamflow. The rerun of model with new bestpar.data (sensitive parameters were changed again and again in the allowable range recommended by SWAT) until the simulated against observed streamflow are suitable and acceptable as until the best fit curve of simulated versus observed data (by using E_{NS} and R^2). In this study, the calibration method was combined between auto-calibrated with manual calibrate helper tool, (after some re-run used Auto-calibrated to choose good parameters, then manual calibrate helper tool was used for some parameters to change until acceptable by checking with statistical parameters. In computing the efficiency, The model was calibrated for the period 1994 to 2004 with the firs year of simulated model result was excluded, because it considered as model priming (warm up) period, so that the influence of the initial conditions such as soil water content will be minimized. Thus, only results for the period 1995-2004 were used in the evaluation of the calibration exercise. In this, model calibration was done at Nakdong, Goeagwan and Samyangjin station. The final calibration parameters for flow at three subbasin were estimated as given Table 2.

Table 2: Parameters after choose for final Auto-calibration

Parameters	Description	Lower bound	Upper bound	Calibrated final values		
				Sub5	Sub7	Sub 13
Alpha_Bf	Baseflow alpha factor	0.00	1.00	0.36	0.5	0.7
Esco	Soil evaporation compensation factor	0.00	1.00	0.85	0.90	0.95
CN2	Initial SCS CN II value	-25%	25%	-10%	-10%	-10%
Gw_Delay	Groundwater delay	0.00	100	55	50	31
Revapmn	Threshold water in the shallow aquifer for revap	-100	100	5.00	1.00	1.00
Surlag	Surface runoff lag time	0.00	10	4.4	5.0	6.15
Ch_K2	Channel effective hydraulic conductivity	0.00	150	60	50	50
Gwqmn	Threshold depth of water in the shallow aquifer	0.00	1000	250	350	354.5
Sol_K	Saturated hydraulic conductivity	-25%	25%	15.0	15.0	13.1
Slope	Average slope steepness	-25%	25%	-5.5	-6.5	-7.7
Sol_Awc	Available water capacity	-25%	25%	-10.2	-11.0	-11.9
Sol_Z	Soil depth	-25%	25%	-15.0	-20	-20
Ch_N	Manning's n value for main channel	0.00	1.00	0.55	0.60	0.74
Gw_Revap	Groundwater revap coefficient	-0.036	0.036	0.036	0.03	0.03

d) Model validation

In the validation process, the model is operated with input parameters set during the calibration process without any change and the results are compared to the remaining observation to evaluate the model prediction. This testing of a model on an independent data set is commonly referred to as model validation. Model calibration determines the best or at least a reasonable, parameter set while validation ensures that the calibrated parameters set performs reasonably well under an independent data set. Provided the model predictive capability is demonstrated as being reasonable in the calibration and validation phase, the model can be used with some confidence for future predictions under somewhat different management scenarios. Streamflow validation was carried out at stations similar to the calibration. The statistical criteria (R^2 and E_{NS}) used during the calibration procedure were also checked here to make sure that the simulated values is still within the accuracy limits.

4. RESULTS AND DISCUSSIONS

The ArcSWAT model was used to calibrate against observed and simulated monthly streamflow for period of (1995–2004), and validate by period of five years (2005-2011) at three locations in basin that includes of Nakdong, Goeagwan and Samyanjin stations. The relationship between the observed and simulated of streamflow values are compared of both calibration and validation that are based on method for determination of model efficiency with statistical parameters as coefficient of regression (R^2) and Nash–Sutcliffe model efficiency (E_{NS}) and the results as shown in Table 3. The results are determined specifically as at Nakdong Station_025480: the results values are determined for calibrated of (R^2=0.86, E_{NS}=0.79), and for validated of (R^2=0.81, E_{NS}=0.75) as shown in Figure 6 and Figure 7. At Goeagwan Station_024700: the results values are determined for calibrated of (R^2=0.83, E_{NS}=0.76), and for validated of (R^2=0.78, E_{NS}=0.72) in Figure 8 and Figure 9. At Samyanjin Station_020490: the results values are determined for calibrated of (R^2=0.81, E_{NS}=0.72), and for validated of (R^2=0.77, E_{NS}=0.69) as shown in Figure 10 and Figure 11. Final, the results are summarized in Table 3 calibrated and validated for Nakdong, Goeagwan and Samyanjin stations, respectively. In general, SWAT simulated values accurately tracked the observed streamflows for the time period, all most of values showed a strong correlation between the simulated and observed flows, although some peak flow months were under simulated and the low flow months were over simulated. Except several years during which simulated peaks are greater than observed ones, most of the years have a good agreement between the simulated and observed streamflow. In addition, the calibration period statistics were stronger than those computed for the validation period as shown in Table 3. In particular, the low flow were simulated very well in shape but different in values, and in year of 2001, the peak flow values of simulated are significantly higher than observed values. However, the errors is acceptble [4] by an acceptable calibration for hydrology when errors among at R^2>0.6 and E_{NS}>0.5. Thus, result was good agreement between the simulated and observed streamflow.

Table 3: Evaluation statistics criteria for model calibrated and validated

<table>
<tr><td rowspan="2">Types</td><td rowspan="2">Stations</td><td colspan="2">Calibrated (1995-2004)</td><td colspan="2">Validated (2005-2011)</td></tr>
<tr><td>R^2</td><td>E_{NS}</td><td>R^2</td><td>E_{NS}</td></tr>
<tr><td rowspan="3">Monthly streamflow</td><td>Nakdong</td><td>0.86</td><td>0.79</td><td>0.81</td><td>0.75</td></tr>
<tr><td>Goeagwan</td><td>0.83</td><td>0.76</td><td>0.78</td><td>0.72</td></tr>
<tr><td>Samyangjin</td><td>0.81</td><td>0.72</td><td>0.77</td><td>0.69</td></tr>
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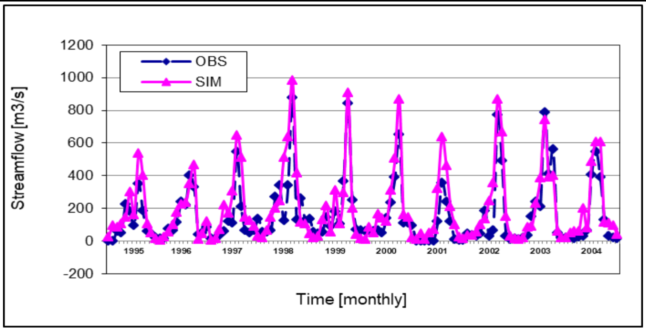

Figure 6: Monthly streamflow calibrated and observed versus simulated for period 1995-2004 at Nakdong station

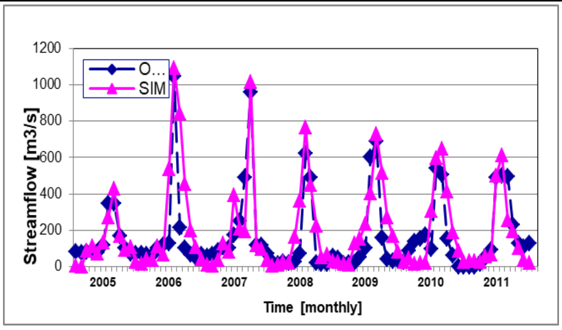

Figure 7: Monthly streamflow validated and observed versus simulated for period 2005-2011 at Nakdong station

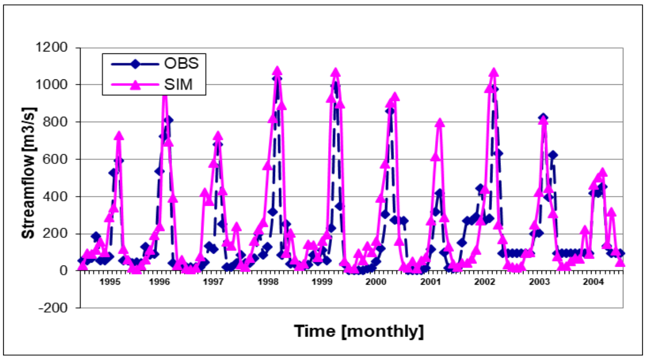

Figure 8: Monthly streamflow calibrated and observed versus simulated for period 1995-2004 at Goeagwan station

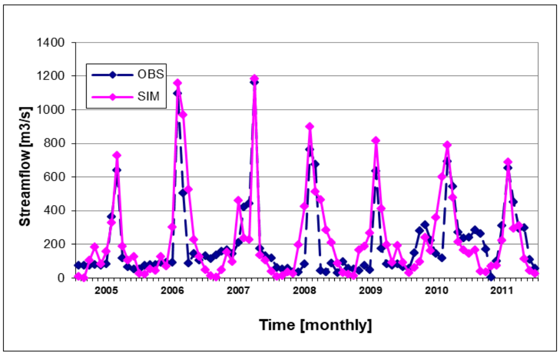

Figure 9: Monthly streamflow validated and observed versus simulated for period 2005-2011 at Goeagwan station

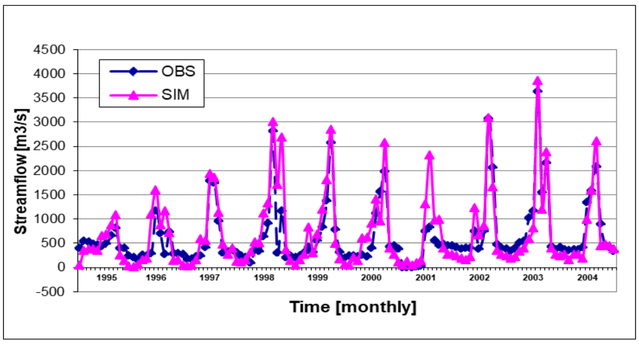

Figure 10: Monthly streamflow calibrated and observed versus simulated for period 1995-2004

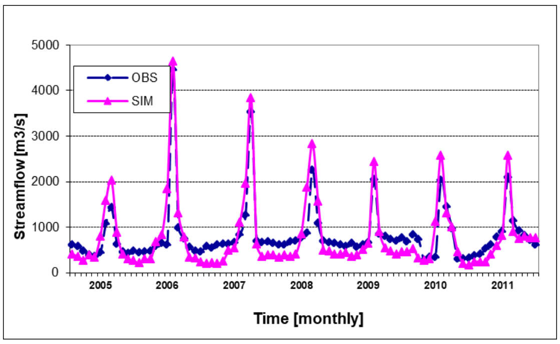

Figure 11: Monthly streamflow validated and observed versus simulated for period

at Samyangjin station *2005-2011 at Samyangjin station*

The ArcSWAT model was used to calibrate against observed and simulated monthly streamflow for period of (1995–2004), and validate by period of five years (2005-2011) at three locations in basin that includes of Nakdong, Goeagwan and Samyanjin stations. The relationship between the observed and simulated of streamflow values are compared of both calibration and validation that are based on method for determination of model efficiency with statistical parameters as coefficient of regression (R^2) and Nash–Sutcliffe model efficiency (E_{NS}).

Results of ArcSWAT model calibration and validation, the SWAT model was calibrated by observed data against simulated of monthly streamflow where parameters were adjusted based on the sensitivity analysis method, and combination of both of auto-calibration and manual calibration methods that provided a powerful, labor saving tool, and substantially reducing of the uncertainty. In general, most of values showed a strong correlation between the simulated and observed flows. Although some peak flow months of observed values were under simulated and the low flow months were over simulated, but most of the years have a very good agreement between the simulated and observed streamflow. In specific, the results values are determined for calibrated at Nakdong station of R^2=0.86, E_{NS}=0.79, and for validated of R^2=0.81, E_{NS}=0.75. Then at Goeagwan station for calibrated of R^2=0.83, E_{NS}=0.76, and for validated of R^2=0.78, E_{NS}=0.72. Final, at Samyanjin station for calibrated of R^2=0.81, E_{NS}=0.72, and for validated of R^2=0.77, E_{NS}=0.69, respectively. The result was good agreement between the simulated and observed streamflow.

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