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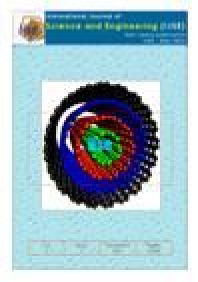

Watershed Modeling with ArcSWAT and SUFI2In Cisadane Catchment Area: Calibration and Validation to Prediction of River Flow

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Abstract *- Increasing of natural resources utilization as a result ofpopulation growthandeconomic developmenthas causedseveredamage on the watershed. The impactsof naturaldisasterssuch asfloods, landslides anddroughtsbecome more frequent. Cisadane Catchment Area is one of 108 priority watershed in Indonesia.SWAT is currently applied worldwide and considered as a versatile model that can be used to integrate multiple environmentalprocesses, which support more effective watershed management and the development of betterinformed policy decision. Theobjective of this study is to examine the applicability of SWAT model for modeling mountainous catchments, focusing on Cisadane catchment Area in west Java Province, Indonesia. The SWAT model simulation was done for the periods of 2005 – 2010 while it used landuse information in 2009. Methods of Sequential Uncertainty Fitting ver. 2 (SUFI2) and combine with manual calibration were used in this study to calibrate a rainfall-runoff. The Calibration is done on 2007 and the validation on 2009, the R^2 and Nash Sutchliffe Efficiency (NSE) of the calibration were 0.71 and 0.72 respectively and the validation are 0.708 and 0.7 respectively. The monthly average of surface runoff and total water yield from the simulation were 27.7 mm and 2718.4 mm respectively.This study showedSWAT model can be apotential monitoring tool especially for watersheds in Cisadane Catchment Area or in the tropical regions. The model can be used for anotherpurpose,especiallyin watershed management.*

Keyword *- Model, SWAT, SUFI2, watershed, Hydrology, Cisadane.*

Submission: 27 November 2013 Corrected : 20 December 2013 Accepted: 4 January 2014

Doi: 10.12777/ijse.6.1.12-21

[How to cite this article: Ridwansyah, I., Pawitan, H., Sinukaban, N., and Hidayat, Y. 2014. Watershed Modeling with ArcSWAT and SUFI2 In Cisadane Catchment Area: Calibration and Validation to Prediction of River Flow. International Journal ofScienceandEngineering, 6(2):12-21. Doi: 10.12777/ijse.6.2.12-21

INTRODUCTION

Water is arenewableresource, butavailability is anconformitywith the needs ofthelocation, number, time and quality. Totaldemand for domestic water(household), industry andagriculturewouldincrease along withthe increase in populationandstandard of livingdue to development. Conversely, the potential water availability is relatively fixed andvaries according toplace and time. The situation resulted insupply and demand problems fora particularplace and time, so itneeds to be designedoptimal management and utilization of water.

Less effortof soil and waterconservationandconversionofforestsinto agricultural landoragricultural land changes to urban area willreduce the ability ofthe watershedtoinfiltratewaterinto the soiland willincreasethe process oferosionand sedimentation. It giveimpact onthe environmentsuch as floodsoh rainy season anddroughton the dry season. Excessiveerosionalso resulted sedimentation inreservoirs andriver channels.

Indonesian land resources tend to have high soil erosion; it is influenced by three main factors: high rainfall intensity, steep slopes, and potentiallyerodedsoils type. According to data from the Meteorology and Geophysics Agency in 1994, 23.1% of Indonesia has an annual rainfall greater than 3,500 mm, about 59.7% of them an annual rainfall between 2000-3500 mm, and only 17.2% of it has an annual rainfall of less than 2000 mm. About 77% area in Indonesia has slope more than 3%. (Subagyo*et al*, 2000 in Adimiharja, 2008).

Increasingof natural resourcesutilization as a result ofpopulation growthandeconomic development, conflict of interestand less ofintegration betweensectors, upper-middle-downstream area, especially the era ofregional autonomyhas causedseveredamage on the watershed.

The impactof naturaldisasterssuch asfloods, landslides anddroughtsbecome more frequent.CisadaneCatchment Area (CCA) is one of 108 priority watershed in Indonesia based onDecree of the Ministryof Forestry. SK.328/Menhut-II/2009.

Thisdevelopmentshows thepressureexpansiontowards the west(Tangerang), East(Bekasi) andSouth(BOPUNCUR) formJakarta area. Conversionof landin the regionBOPUNCUR upper Ciliwung-Cisadane (BOPUNCUR) form ofencroachmentinto landcultivation.There will be adischargeextremitiesthatwouldpose a threatof floodingonrainyseasonandthedry seasonwillthreatenthe availability of water (Malazi and Sabar, 2010).

In last decades, hydrological models are more broadly applied by hydrologists and water resource managers as tools to analyses water resource management systems. The hydrologic modeling system is designed to simulate the precipitation and run-off process of dendritic watershed system. Hydrological process that represented by parameters can be declared conceptually by mathematical models after identified from field condition by hydrology system. In recent, many developed mathematical models it can simulate a lot of hydrology phenomena. Parsimony in parameter is a general orientation in developing a hydrology model, while model structure divided two classes of hydrology model which are conceptual model and physically base model (Pawitan, 2004). Whereas, (Singh 2002) stated that Hydrology model is an assemblage, a mathematical description of components of hydrology cycle. Singh also classified hydrology model based on; process description, time scale, space scale, technique of solution, land use, and model use.

In recent years, SWAT model has gained internationalacceptance as a robust interdisciplinary watershed modelling. SWAT is currently applied worldwide and considered as a versatile model that can be used to integrate multiple environmentalprocesses, which support more effective watershed management and the development of betterinformed policy decision (Gassman *et al*., 2005). But little have been published on theapplicability of SWAT model in the tropical catchments particularly in Indonesia.This study examines the applicability of SWAT model and combined with the Sequencial Uncertainty Fitting version 2 (SUFI-2 in SWAT-CUP Application)to quantify the uncertainty of parameters and to provide a necessary reference for hydrological modeling in for modeling mountainous catchments, focusing on Cisadane catchment Area in west Java Province, Indonesia.

METHODS

The study covers the period of March to July 2009, but collection of data has been obtained since 2005. The study area is located in CCA. Located at 107^{o} 42’ 21” E – 107^{o} 58’ 32” E and 7^{o} 7’ 4” S – 7^{o} 24’ 45” S, which the area about 4,486 km^{2}. Administratively the study area belongs to Bogor Regency and Bogor City in upper area and Tangerang Regency in lower area. DASCisadaneis aninter-provincialriver basin, whichis administrativelylocatedin the province ofWest Java andBanten, at a fractiondownstreaminto theregionof Jakarta. Most of thewatershedCisadaneinWest Java Provincewith an area of113,535.66ha(74.11%), the rest in Banten provincecovering39,500ha(25.78%) andJakarta172.61ha(0.11%).The populationin thebasinis4,163,799with population growthrate is 2%.

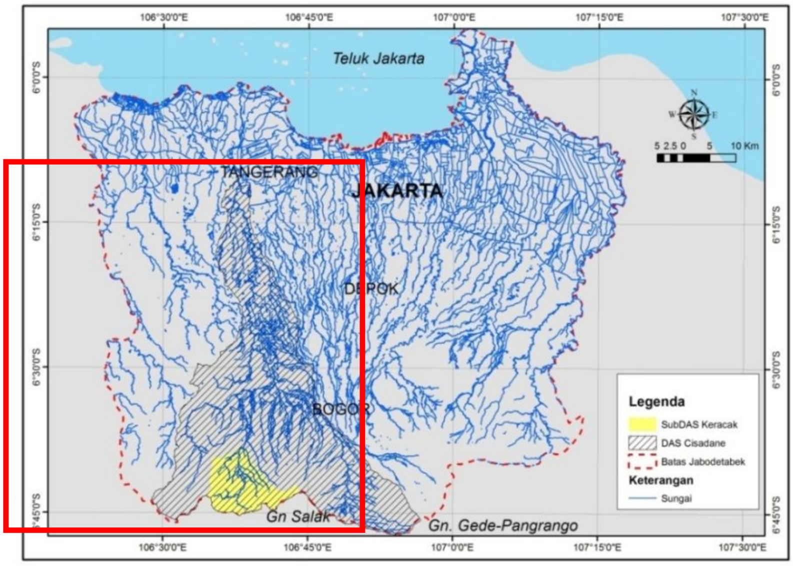

Figure 1. Study area Cisadane Catchment Area.

The methodology of this study is limited to the condition of the data and used hydrology model application SWAT for ArcGIS (ArcSWAT). ArcSWAT is a graphical user interface, written in FORTRAN and ***ArcGIS*** asan "Programmable Geographic Information System" that supports manipulation, analysis, and viewing of geospatial data which associated attribute data in several standard GIS data formats.

SWAT was developed and enhanced from previous earlier models by Arnold for the United States

Department of Agriculture in the early 1990s (Krysanova and Arnold, 2009). It was then extended to predict the impact of land management practices on water, sediment, agricultural and chemical yields in large river catchments with varying spatial and temporal aspects. The hydrologic cycle under consideration is based on the following water balance equation:

$$SW_i \quad SW \qquad {}_{i} \qquad {}_{day} - Q_{Surf} - E_a - W_S - Q$$

Where $SW_t$is the final soil water content, SW_0represent the initial soil water content on day *i*, *t* is the time (days), *Rday*is the amount of precipitation on day *i*, $Q_{surf}$is the amount of surface runoff on day *i*,*Ea*describe the amount of evapotranspiration on day *i*, w_{seep}represent the amount of water entering the vadose zone from the soil profile on day *i*, and $Q_{gw}$is the amount of return flow on day *i*.For the estimation of surface runoff the SCS curve number (CN) is used in the model. This method uses two equations for runoff computation. The first relates runoff to rainfall and retention parameter as :

$$Q \quad \frac{\;-\;0.2S}{0.2S} \qquad 0.5S$$

where, Q is daily surface runoff (in mm), R represents daily rainfall (in mm) and S is retention parameter, the maximum potential difference between rainfall and runoff (in mm) starting at the time the storm begins.

SWAT divides the watershed into sub-basins and these small hydrological parts are termed as hydrological response units (HRUs) as an unique landuse/management/soil attributes to help for improving the calculation accuracy (Neitsch et al., 2010). The SWAT model needs data from digital elevation model (DEM), soil map, and land use map. Meteorological data are also needed in daily or sub daily time steps. SWAT includes two methods for estimation of surface runoff - SCS CN and Green-Ampt infiltration method.In this research a first method is used for Hydrology model of CCA.

Landuse is one of the dynamic parameters caused by human activities. Landuse data have been classified from ALOS satellite image year 2009 by Hydro-informatics Laboratory in Research Centre for Limnology, Indonesia Institute of Science. The Landuse Class is classified based on Bakosurtanal Map. The classification has been compared with field data.

Within the process of setting up the model run/input files with ArcSWAT a series of operations are required. The first step in hydrologic data development for hydrology model SWAT is defining catchment area boundaries. These boundaries normally fall along the ridges in a watershed. On one side of the ridge, water flows into the watershed, while on the other side of the ridge, water flows into a separate watershed, after stream and sub-catchment delineated, the next step is creation of Hydrological Response Units (HRUs). An HRUs is an intersection of sub-catchment polygon with landuse, soil type and slope.

SWAT database used weather station and location and stored in SWAT2012 database. The Cisadane Catchment Area used two weather stations and eleven locations for rain gauges on 2005-2010 daily precipitation data. The weather stations belong to Climatology meteorology and Geophysics Agency (BMKG), and The Public Work Ministry (PU).After data file has been generated, SWAT model in Cisadane Catchment area is ready to simulate. The simulation has done on 2010 landuse data.

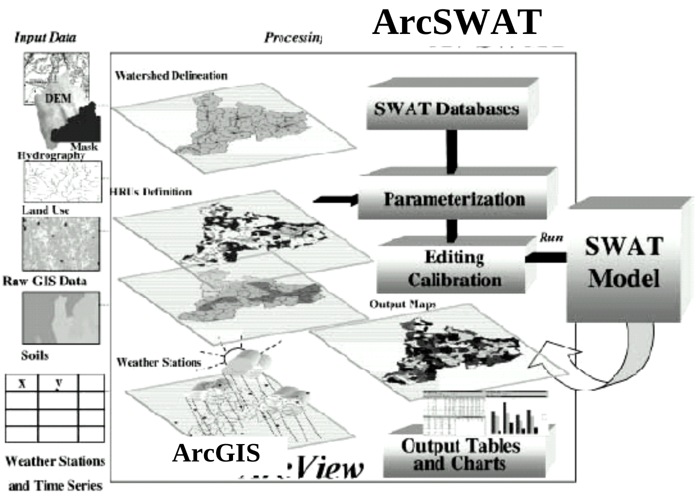

Figure 2.Schematic framework of ArcSWAT (Revised from Diluzio and Arnold, 2004).

Calibration and Validation

The simulation of the Cisadane catchment was completed using the ArcSWAT interface of SWAT model, whereas model calibration and validation were done by manual calibration and automatic calibration. The Automatic calibration and sensitivity analysis have been done using SWAT CUP tool. SWATCUPis aprogramthat canbe usedandfreeware application. The SWAT-CUP hasfourprograms for calibration, namelySUFI2, GLUE, parasolandrelatedMCMC. The model uncertainties have been tested and analyzed using SUFI-2 (Sequential Uncertainty Fitting) uncertainty analysis procedures.SUFI2 is convenientand easy. The modeler, however, should check a set of suggested posterior parameters to be prepared for next iterations (Bilondi, 2013)(Rouholahnejad and Abbaspur, 2010).Model SUFI2is a modelwhichis rather lowdegree of difficultycompared byGLUEmodels, ParasolandMCMC (Abbaspour, 2011), despite MCMC more recommended because Bayesian inference has a statistical assumptions underlying the likelihood functionbased on the autoregressive error model is testableand did not indicate significant violations of the assumptions (yang *et al*, 2008).Based on availability and simplicity SUFI2 is used in this study.SUFI2 performs the parameter uncertainty analyses by determining all sources of uncertainties, namely uncertainty in driving variables, conceptual model, parameters and measured data.

SWAT model uses more than 500 parameters for simulation, but not all of them are used to develop a model for Upper Cimanuk Catchment Area, due to limited time and data support. The selection of those parameters is continued during calibration, especially in manual calibration process. Calibration is focused on surface, the procedure for calibration uses basic water balance and total flow calibration on SWAT user manual (Neitsch *et al*, 2012). The procedure started by adjust Curve Number (CN2 in .mgt file) until surface runoff is acceptable. If surface run off value is not acceptable the calibration is continued by adjusting soil available water capacity (SOL_AWC in .sol) and soil evaporation compensation (ESCO in .bsn or .hru). Once surface calibration is conducted it should be compared with the observed and simulation value of base flow resulting two condition; higher base flow or lower one. Figure 3 shows sensitive parameters to water discharge for calibration.

Simulation result from SWAT model can be compared to observed data to evaluate the capability of model prediction. The Nash-Sutcliffe model efficiency coefficient (*NSE*) (Nash and Sutcliffe, 1970) and the correlation coefficient (R^2) as a method to evaluate and analyze simulated Daily data and the R^2value is a measure of the strength of the linear correlation between the predicted and observed values. The *NSE* value, which is a measure of the predictive power of the model, is defined by :

$$NSE \quad \frac{\sum \quad Q' \; - Q'}{\sum \quad Q' \; - Q'}$$

Where, NSE (Nash-Sutcliffe coefficient), $Q_o$represnet Observed discharge, Q_m is Model discharge, $\bar{Q}_o$ point out mean observed discharge and Q_t is Discharge at time t. R^2 describe of the proportion of variance in observed flows explained by the model and value of NSE and R^2 close to 1 indicates a complete harmony between observed and simulated stream flow.

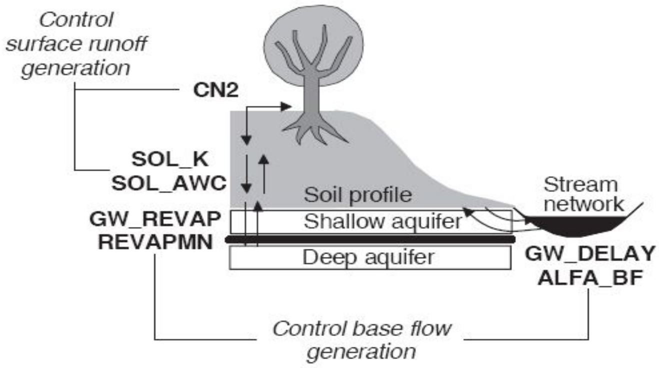

Figure 3. Sensitive parameters to water discharge for Calibration (Heuvelmans *et al*, 2004).

RESULT AND DISCUSSION

SWAT Model Setup

The first step in hydrology model SWAT development is defining catchment area boundaries. These boundaries normally fall along the ridges in a watershed. On one side of the ridge, water flows into the watershed, while on the other side of the ridge, water flows into a separate watershed. Elevation data for this process is derived from Bakosurtanal topographic map (RBI Map, scale 1 :25.000). The result of this process was divided Cisadane Catchment Area on 49Sub-catchment.The next step is creation of Hydrological Response Units (HRUs). An HRU is an intersection of sub-catchment polygon with landuse, soil type and slope.Thelanduse class of Cisadane Catchment Area is dominated by paddy plantation (27%) and plantation area (21.85) especially on flat areas, whereas on steep area is covered by forest. Soil type is dominated by Association TypicHumitropepts-TypicEutropepts (25.8%) and typhichumitropic (19%). The Slope of Cisadane Catchment area mostly plat area, about 43% of area is located on slope less than 8% slope. composition of landuse class, soiltype and slopearepresented on Table 1 and the distribution of the area on figure 4.

After input file have been generated, SWAT is ready to do simulation, the simulation period is from 1 January 2005 to 31 December 2010. The calibration is done on 2007 and the validation on 2009. The options are to get comparison between river discharge simulation and observed data. Several options must be considered; time step for rainfall and routing (daily), method for calculating runoff-Curve Number Method, rainfall distribution-skewed normal and method for evapotranspiration used Penman-Monteith method.

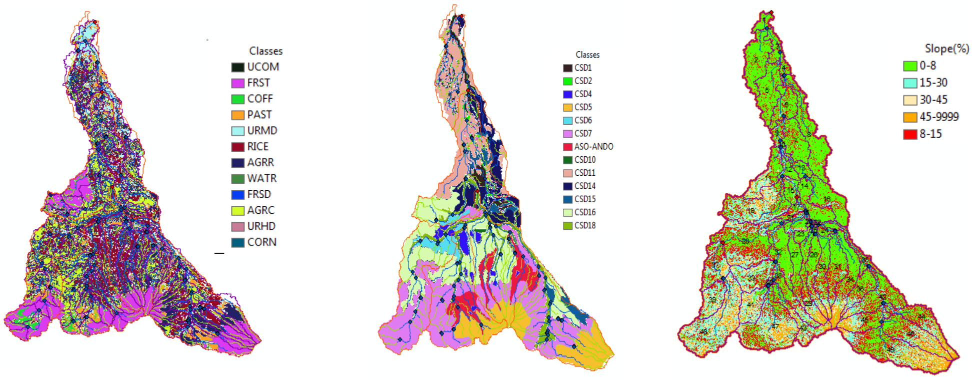

Figure 4. Model input landuse, soiltype and slope of Cisadane Catchment Area

Table 1.Characteristik of Landuse and Soil type in Cisadane Catchment Area

Landuse Class	SWAT ID	Area (ha)	%
Pasture and open Area	PAST	12419.1	9.9
Residential	URMD	19065.79	15.2
Tea Plantation	TEA	27275.46	21.8
Rice	RICE	34239.91	27.4
Agricultural	AGRR	9331.001	7.5
Forest	FRSD	22751.98	18.2
Water	WATH	2.1271	0.0
		125085.4	100

Soil Category	SWAT Code	Area (ha)	%
Aerictropaquept	CSD1	4102.7	3.28
Aeric tropic fluvaquent	CSD2	1454.4	1.16
Association TypicDystropepts-TypicPaleudults	CSD4	2044.0	1.63
AssociationTypicHapludands-TypicTropopsamment	CSD5	14184.8	11.34
AssociationTypicHapludults-AquicHapludults	CSD6	3076.9	2.46
AssociationTypicHumitropepts-TypicEutropepts	CSD7	32361.4	25.87
AssociationTypicTropopsamments-AndicHumitropepts	CSD8	7579.1	6.06
OrthoxicTropudults	CSD11	15754.0	12.60
KompleksTypicHumitropepts-LitihcTroporthen	CSD10	66.2	0.05
TypicDystropepts	CSD14	9728.0	7.78
TypicEutropepts	CSD15	24438.2	2.53
TypicHumitropepts	CSD16	7810.9	19.54
TypicTroporthents-TypicFluvaquents	CSD18	7125.7	5.70

Slope Class	Area (ha)	%
<8%	53859.7	43.2
8% – 25%	27898.9	22.4
25% - 30%	24174.5	19.4
30% - 45%	10.383.3	8.3
>45%	8286.5	6.7

Sensitivity Analysis, Calibration and Validation

Parameters and sensitivity analysis using SUFI-2

The analyzed of relative sensitivity of the parameters during model calibration and twelve parameters were found to be more sensitive according to the relative sensitivity values. Table 3 is showed the minimum and maximum ranges of parameters in the SUFI-2 uncertainty techniques. The parameters has given ranks for their sensitivity to the model calibration for both procedures. Parameter specification and estimation were important to identify sensitive parameters ensuring correct representations of hydrologic processes (Binhanu, 2009). The most sensitive parameters recorded after sensitivity analysis for daily calibration in SUFI-2 procedures is presented in Table 4, it has been showed that these sensitive parameters were mostly responsible for the model calibration and parameter changes during iteration processes.

The final result of the sensitivity analysis are parameters arranged in the ranks, where the parameter with a maximum effect obtains rank one, and parameter with a minimum effect obtains rank which corresponds to the number of all analyzed parameters. After sensitivity analysis, 12 parameters that significantly influenced the rainfall-runoff model for Cisadane Catchment Area were established.

Parametersensitivity resultsalsoshowedthatthe mostsensitiveparameterto changes indischarge, thecalibrationprocessshows theCNparameteristhe mostsensitiveparameter, this showsCisadane Catchment Areawill be severely affecteddueto changes inlandis representativeofCNandinfiltration in the watershed, the value ofCNcalibrationresultsvarybetweenadded20orminus20ofits originalvalue dependingon the type ofland use. Other parametersafterCNis a parameterrelated togroundwater, among which*ALFA_BF*parameterisan index valuethat describes theundergroundflow responseto changes inflow. Value of about0,1 - 0,3found onlandwithslow responseto changes inflow. Value of0.9 to 1areonlandwith arapid response tochanges inflowunderground.AtCisadane Catchment Area0.35whichshows thevalueobtainedwasa responsetochanges ingroundwater flow.

Table 3. Stream flow calibration parameter uncertainties

No	Parameter_Name	Fitted_Value	Min_value	Max_value
1	R__CN2.mgt	-0.14	-0.2	0.2
2	V__ALPHA_BF.gw	0.35	0	1
3	V__GW_DELAY.gw	32.5	10	60
4	V__GWQMN.gw	0.7	0	2
5	V__GW_REVAP.gw	0.01	0	0.2
6	V__ESCO.hru	0.89	0.8	1
7	V__CH_N2.rte	0.135	0	0.3
8	V__CH_K2.rte	111.25	5	130
9	V__ALPHA_BNK.rte	0.45	0	1
10	R__SOL_AWC(..).sol	0.17	0.2	0.4
11	R__SOL_K(..).sol	0.24	0.1	0.8
12	R__SOL_BD(..).sol	0.5	0.1	0.6

Table 4. Parameter sensitivities for SUFI-2

Parameter Name	rank	t-Stat	P-Value
R__CN2.mgt	1	1.324272387	0.227013
V__ALPHA_BF.gw	2	0.232031793	0.823151
V__GW_DELAY.gw	3	2.051756529	0.079324
V__GWQMN.gw	4	0.585847879	0.576371
V__GW_REVAP.gw	5	1.236567016	0.256124
V__ESCO.hru	6	1.049884034	0.328661
V__CH_N2.rte	7	1.565833881	0.161369
V__CH_K2.rte	8	-6.67780619	0.000283
V__ALPHA_BNK.rte	9	2.618492264	0.034485
R__SOL_AWC(..).sol	10	-0.955975391	0.370926
R__SOL_K(..).sol	11	3.552908082	0.009307
R__SOL_BD(..).sol	12	1.84147118	0.108111

GW_DELAY is parameter of time between the water flow from the soil profile to the saturated zone (aquifer) in a watershed. An area that has geomorphic (Landform) which has a value equal to the same *GW_DELAY* (Sangreyet al. 1984 in Neitsch et al., 2010).Based on the simulation results obtained for the Cisadane Catchment

Area *GW_DELAY* values by 32.5 days.*GWQMN* a threshold depth of water in the shallow aquifer to allow for water flow. The flow of underground water (groundwater) into the river can occur if the water depth in the shallow aquifer is equal or greater than the value *GWQMN*. *GWQMN* values obtained from the simulation results is 0.7 mm.

*GW_REVAP*is asignificantparameterin a watershedthataresaturatedzonelocatednot farfromthe surface of thesoilorvegetationtherethat haverootsdeep enough. *GW_REVAP*valueapproaching0indicatesthat themovement of waterfromthe shallow aquifertothe root zoneis limited. *GW_REVAP*valueclose to 1indicatesthat themovement of waterfromthe shallow aquifertothe root zoneclose to the averagepotentialevapotranspiration, whichusedthe valueobtainedafterthecalibrationvalue of 0.01whichindicatesthe limitedmovement of waterfrom theaquiferto theroot.

Plantuptakefactor(EPCO) takes into accountthat theamount of waterusedononedayis a functionofthe amount ofwater neededplantsfortranspirationand theamount of water availablein the soil. Iftoplayer ofthe soildoes not haveenoughwater contenttomeetpotentialwater use(water uptake) inthesoillayerbelowcanreplacethe role ofthe topsoillayer. *EPCO*valuesrangedbetween0.01 to1. The results of thecalibrationshowedthatthe value of0.89isthe optimalvalue. In addition tothe parametersassociated withthe movement ofgroundwateris thenextrankingparameters related tobothroutinginthe mainchannel(CH_N2) oronits tributaries (CH_K2).

The 95PPU as represented a combined model prediction uncertainty including parameter uncertainty resulting from the non-uniqueness of effective model parameters, conceptual model uncertainties, and input uncertainties (Schoul and Abbaspour, 2006). The SUFI-2 combined effect of all uncertainties is described by the estimates of parameter uncertainties. The 95PPU derived by SUFI-2 on Batubelah river gauge is presented on figure 5.

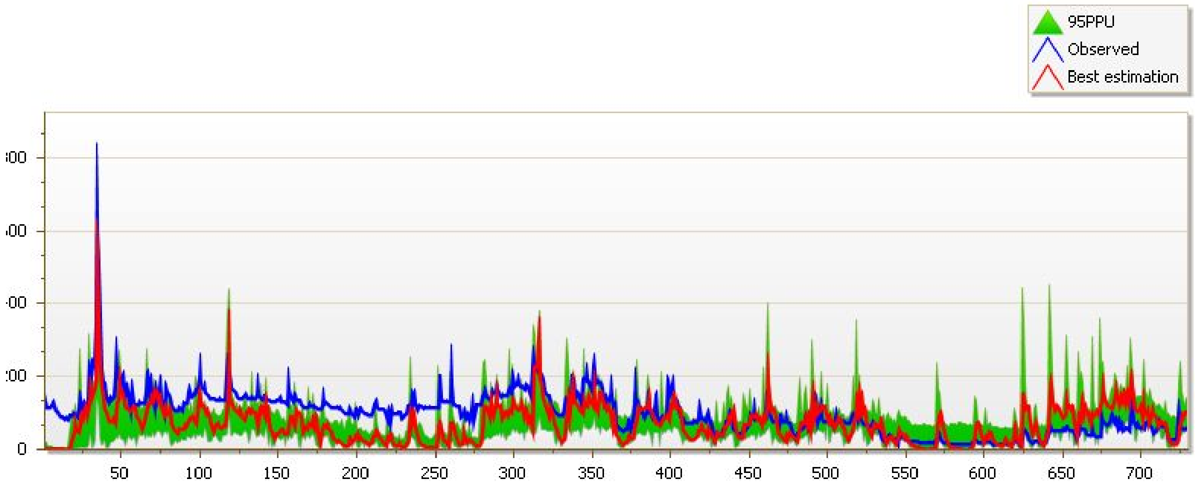

Figure 5.95PPUs derived by SUFI2 (dark gray area) during the calibration and validation period on Baubelah river gauge.

Calibration and Validation

SWAT is distributed hydrology model and consequently many potential parameters are involved. With the result that it would be impossible to calibrate all parameters, until reduction of the number of parameters to be estimated is done. Due to spatial variability, measurement error, incompleteness in description of both element and process present in the system, the value of all parameters will not be exactly known. To achieve a good fit between simulated and observed data, models need to be calibrated to match simulated and observed data by optimizing the same parameter. In most model applications, a calibrationis necessary to estimate model parameter values.Model calibration helps reduce the parameter uncertainty,which in turn reduces the uncertainty in the simulatedresults (Cibin*et al*, 2010).The calibration procedure can be done manually or automatically.

Calibration on Cisadane Catchment Area hydrology model was done during 2007, and then validation is done for 2009 period. The calibration used combination of automatic and manual calibration. Manual optimized is done by trial and error by comparison of observed and simulation data, where theparametersofthe results ofautomaticguidedon calibration process. The quality of each parameter for which the SWAT model was run and tested according of the following two criteria: Daily simulated stream flow data and annual water balance component. The annual simulation result of each component can showed by *SWATCHECK* application, afterthe resultsofannual water balance componentsense thenbe calibratedondailysimulation is conducted.

Hydrology model of Cisadane Catchment Area was calibrated by comparison of observed data from an in stream Public Works Department flow gauging station to model and to adjust the key of hydrologic parameter. Based on the fact of hydrograph comparison the calibration focused on several solutions which are adjusted to infiltration, interflow and base flow recession parameter. The calibration is done on groundwater parameter (.gw), Routing parameter (.rte) and management parameter (.mgt). Manual calibration is conducted by SWATEditorAplication, details of adjustment for calibration is showed in Table 2.

Manual calibration of several parameters resulted in correlation error (R^2) of 0.708where where $Q_{Obs} = 0.6663.Q_{Sim}+35.052$ and NSE is 0.71, and then the validation is conducted in2009bythe simulation resultsusing thesame parameters as theparameterscalibrated. The validation R^2 value are 0.709 where $Q_{Obs} = 1.63565.Q_{Sim}+9.7087$ and NSE is 0.72, respectively, for validation model The value of $R^2$and NSE is good criteria base on general performance ratings for recommended statistics(Moriasi*et al*, 2007) and the model can use for other purposes. Other studiesyielddifferent values butvalidatedonmonthlydischarge, thevalue of R2 and NSE obtainedwas0.79and0.63, Respectively (Junaedi, 2009).Thisvalueis better thanaswathydrologicmodelingobtainedinCimanukwith R^2andNSE is 0.64and 0.5, respectively (Ridwansyah, 2010). SWAT Model had better result on Upper Ciliwung Catchment Area with R^2 and NSE are 0.7 and 0.74, respectively (Yustika, 2013), but the process is done only on two months (February-March). swatmodelsare alsoappliedinCijalumpang Catchment Area where theratioof monthlydischargeandsimulatedyieldR^2values were0.88and0.72 for NSE (Suryani and Fakhmuddin, 2009).

Table 2 Initial and final value of SWAT Calibration parameters for stream flow

SWAT variable name	Parameter	Range	Final value
Alpha BF	Base flow alpha factor (days)	0 - 1	0.35
REVAP_MN	Percolation to the deep aquifer to occur (mmH_2O)	0 - 500	0.01
GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mmH_2O)	0 - 5000	0.7
GW-Delay	Groundwater delay (days)	0 - 500	32.5
CH_N2	Manning's value for main stream	0 – 0.3	0.25
CH_K1	Effective hydraulic conductivity in tributary stream	0-300	0.5
CH_K2	Effective hydraulic conductivity in main stream		0.5
CN2	Curve Number	0 - 100	±20%
Sol_BD	Soil Bulk Density (g/cm^3)	0.9 – 2.5	0.1
Sol_K	Saturated hydraulic conductivity of first layer (mm/hr)	0-2000	0.24
Alpha_Bnk	Bank flow recession constant or constant of proportionality	0-1	0.45

The hydrologic parametersare dominant in controlling water quality predictions.There are also clearly different results between thecatchments that are obviously due to climate, but theresults also reflect differences in soil and landproperties. Thus, each new basin model requires itsown sensitivity analysis to select a subset ofparameters to be used for model calibration oruncertainty analysis (Griensvenet*et al*, 2006).necessary to studythe sensitivity ofthe parametersonthe otherdasinIndonesiathat havediversecharacteristics.The result of calibrationin Cisadane Catchment Area is showed in figure 6 and the validation is showed in figure 7. Thecorrelation errorof calibration and validationis showed in figure 8.

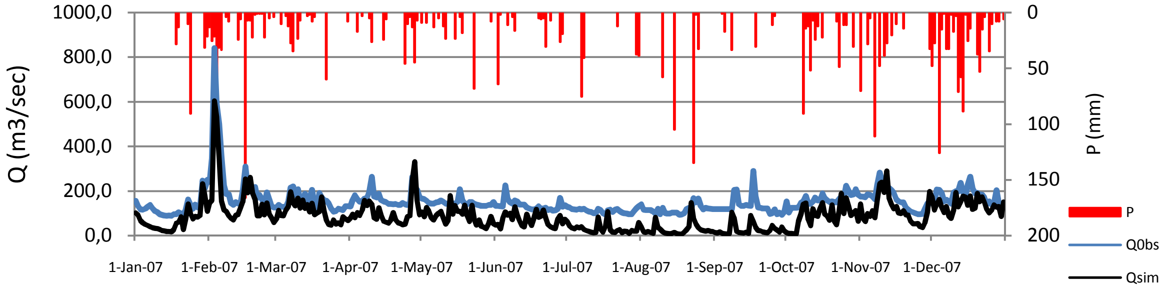

Figure 6. Comparison between observed and simulated daily stream flow atBatubelah rivergauge after calibration.

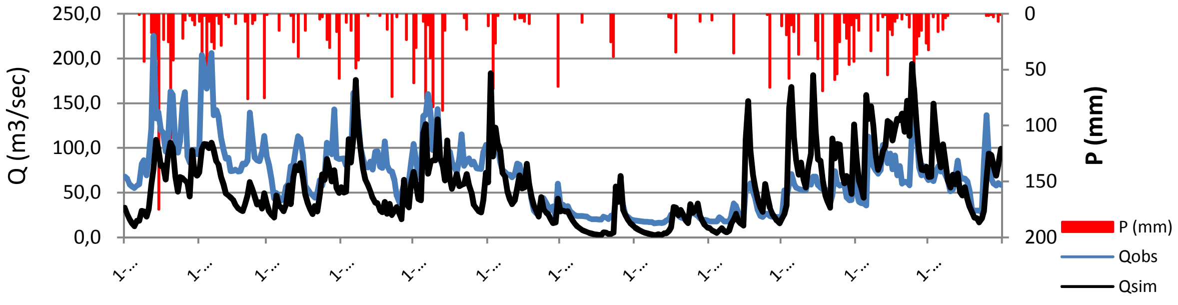

Figure 7. Comparison between observed and simulated daily stream flow atBatubelah rivergauge on validation process

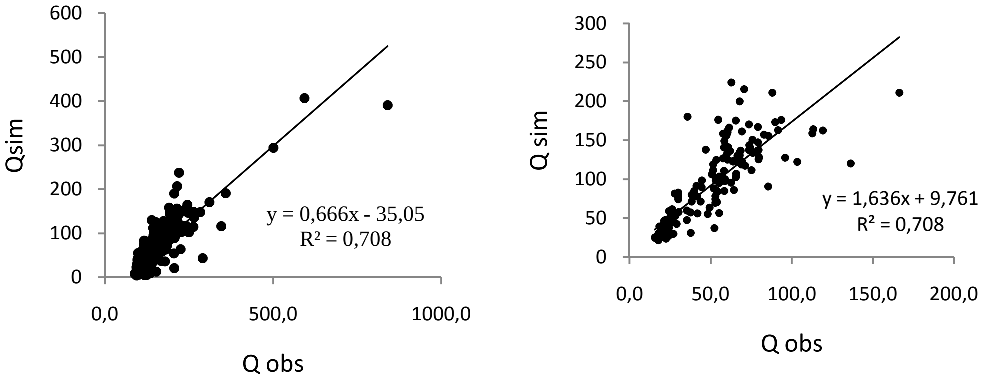

Figure8. Correlation error between Observed and simulation data in batubelah river gauge after calibration, model calibration (right) and model validation (left).

CONCLUSIONS

The ArcSWAT interface of SWAT model has been used successfully for analyzed hydrological characteristics of the Cisadane catchment Area. The calibration and validation by combination automatic and manual methods have good result and The SWAT-CUP advance calibration and uncertainty analysis tool has been used for automatic calibration of stream-flow measurements on period 2005–2010 using SUFI-2procedures. The sensitivity analysis adopted for the stream-flow calibration is showed variations between the parameter ranges which had been initialized for the model calibration. SUFI-2 procedures gave good results in minimizing the differences between observed andmeasurement data, by using SUFI-2, we could perform uncertainly analysis and calibrate the model for more number of parameters (Omani et al, 2007).

This study shows that SWAT model can be apotential monitoring tool especially for watersheds in Cisadane Catchment Area or in the tropical regions. This whole model uncertainty and calibration analysis can be used for futuristic prediction and assessment of water balance, impact of landuse change and other management scenarios for streamflow measurements especially for the Cisadane catchment Area.

Acknowledgement

The authors would like to thank The Research Center for Limnology (RCL) - Indonesia Institute of Science for the funding the research project. Many thanks to our partners in Hydroinformatic Laboratory-RCL who provided data and assistance.

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