



THE IMPACT OF SOIL AND WATER CONSERVATION PRACTICES ON HYDROLOGICAL PROPERTIES USING SWAT MODEL

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 WRI INDONESIA

THE PRESENTATION CONSIST OF :



INTRODUCTION



METHODOLOGY



DATA REQUIREMENTS & TOOLS



BIOPHYSICAL INFORMATION

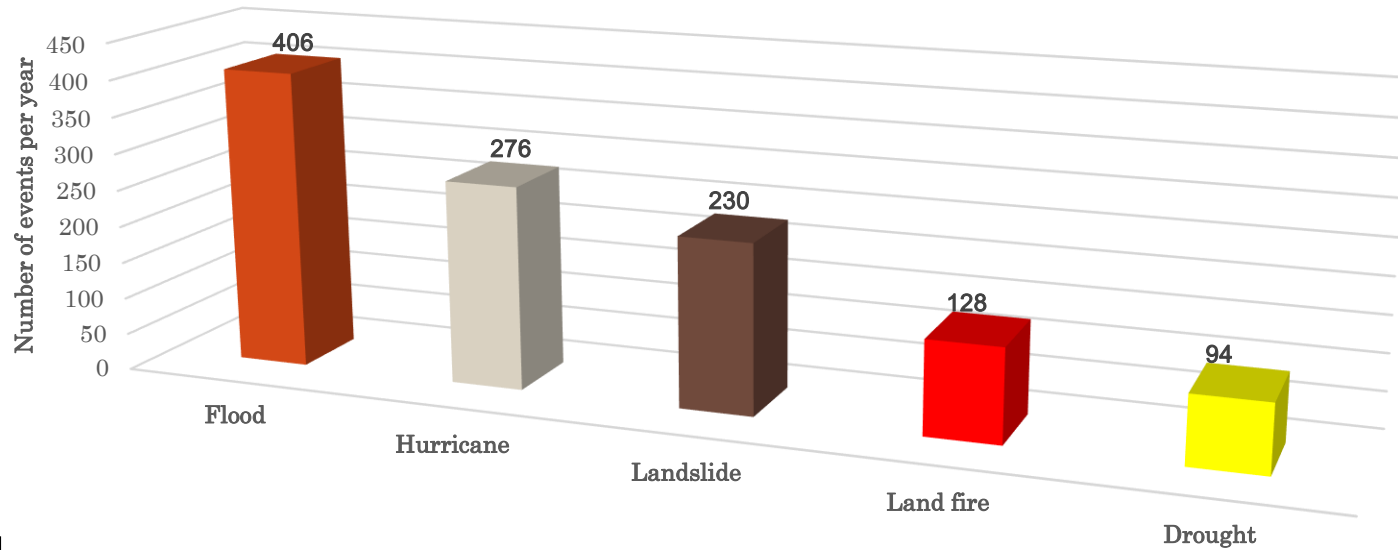


RESULT



CONCLUSION

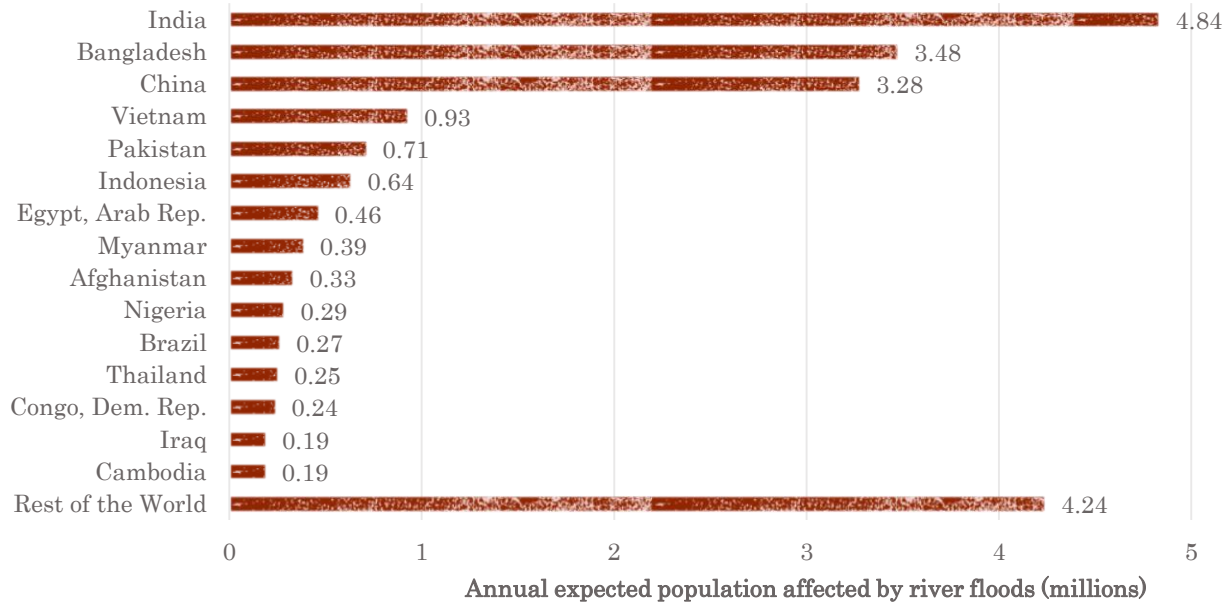




Source : Indonesian National Board for Disaster Management

The most often disaster occurred in Indonesia (1999-2018)





Source: **The Aqueduct Global Flood Analyzer**, a new online tool, quantifies and visualizes the reality of global flood risk. World Resources Institute co-developed the tool with four Dutch research organizations: Deltares, the Institute for Environmental Studies of the VU University Amsterdam, Utrecht University and PBL Netherlands Environmental Assessment Agency, supported by the Netherlands' Ministry of Infrastructure and the Environment





Ciujung Watershed :

- ▶ Forest area < 30%
- ▶ Landuse change
- ▶ Agricultural Practices
- ▶ Degraded Watershed
- ▶ Flooding : Annually occurred


SWAT Model

Christmas Island Flying Fish Cove

The study aims to:

- (1) Assess the impact of soil and water conservation practices on hydrological properties
- (2) Determine the best management practice to maintain watershed condition





DATA REQUIREMENTS & TOOLS

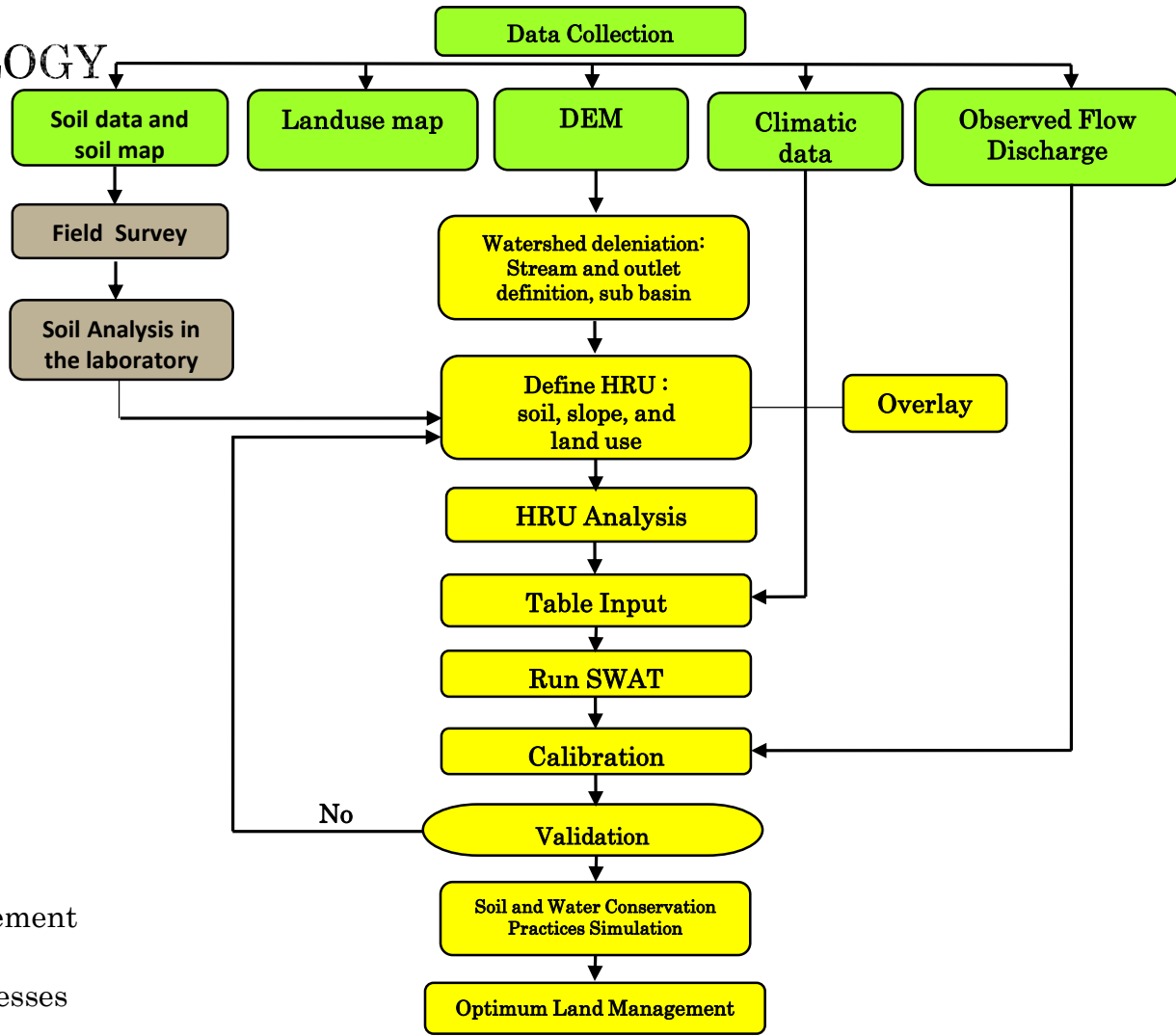
Dat Set	Source	Scale	Data Description
Terrain	USGS (https://earthexplorer.usgs.gov/)	30 m	Digital Elevation Model
Soil	Indonesian Center for Agricultural Land Resources Research and Development (BBSDLP)	1 : 250,000	Soil map
Landuse	Directorate General of Forestry Planning and Environmental Management, MoEF	1 : 250,000	Landuse map (extracted from Landsat 8)
Weather	Meteorological, Climatological, and Geophysical Agency (BMKG)	Daily	precipitation, temperature, humidity, wind, and solar radiation (2002-2017, 21 stations)
Streamflow	a. Center for River Region of Cidanau-Ciujung-Cidurian (BBWS)	Daily	Observed flow discharge (2002-2017)
	b. Water Resources Management Agency of Ciujung-Cidanau (PSDA)		

Tools : ArcGIS 10.1, ArcSWAT 2012 (10.1.14) as an interface, pcpSTAT, SWAT BFlow, and SWAT CUP, SWAT Plot





METHODOLOGY



 Data Collection

 Soil Data Measurement

 SWAT Model Processes





CALIBRATION AND VALIDATION

- Coefficient determination (R^2)

$$r^2 = \left(\frac{\sum_{i=1}^n (O_i - \bar{O})(P_i - \bar{P})}{\sqrt{\sum_{i=1}^n (O_i - \bar{O})^2} \sqrt{\sum_{i=1}^n (P_i - \bar{P})^2}} \right)^2$$

$R^2 \geq 0.5$ the acceptable value of R-squared in predicting river flow discharge (Moriasi *et al.* 2007)

- Nash-Sutcliffe Efficiency (NSE)

$$NSE = 1 - \left[\frac{\sum_{i=1}^n (Y_i^{obs} - Y_i^{sim})^2}{\sum_{i=1}^n (Y_i^{obs} - Y^{mean})^2} \right]$$

Performance	NSE
Very Good	$0.75 \leq NSE \leq 1.00$
Good	$0.65 \leq NSE \leq 0.75$
Satisfactory	$0.50 \leq NSE \leq 0.65$
Unsatisfactory	$NSE \leq 0.50$



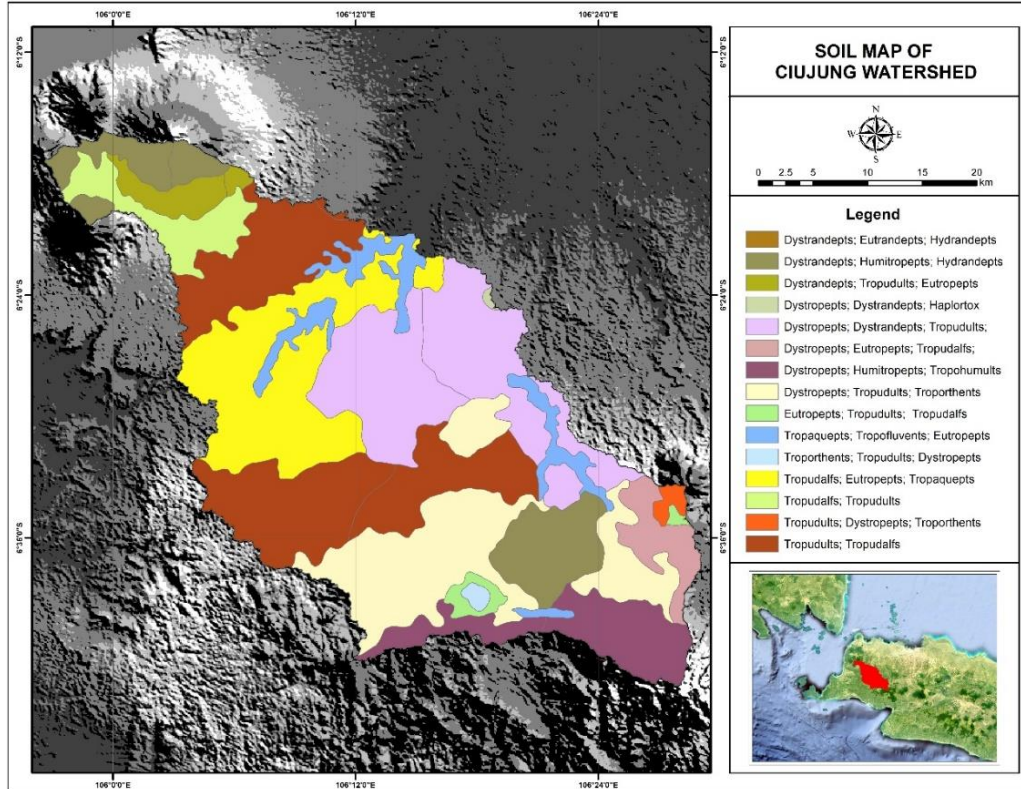


SIMULATION

Scenario	Land Management	Soil and Water Conservation Practices Implementation	Parameters Simulation	Simulation Location (Sub Basin)	Area	
					hectare	%
1	Forest implementation based on forest function map	Reforestation	CN2, SOL_K, SOL_C , dan SOL_BD	4, 7, 9, 10, 11, 20	17,333	12
2	Degraded land rehabilitation	Reforestation	CN2, SOL_K, SOL_C, SOL_BD, dan SOL_AWC	4, 5, 7, 10, 11, 12, 15, 17, 18, 20, 21	42,946	30
		Agroforestry	CN2, SOL_K, SOL_C, SOL_BD, dan SOL_AWC	1, 2, 4-7, 9-21		
3	Soil and water conservation practices (vegetative method)	Reforestation	CN2, SOL_K, SOL_C, SOL_BD, dan SOL_AWC	1, 2, 4-7, 9-21	40,202	28
		Agroforestry	CN2, SOL_K, SOL_C, SOL_BD, dan SOL_AWC	1, 2, 4-7, 9-21		
		Stripcropping	STRIP_CN, STRIP_P, STRIP_C, dan STRIP_N	1, 2, 4-7, 9-21		
4	Soil and water conservation practices (mechanical method)	Dam	RES_VOL, RES_EVOL, dan RES_PVOL	15	47,954	34
		Contouring	CONT_P dan CONT_CN	1, 2, 4-7, 9-21		
		Biopore Infiltration hole	SOL_BD dan SOL_K	1, 2, 4-7, 9-15, 17-21		



BIOPHYSICAL INFORMATION



Soil Association	SWAT Code	Area	
		ha	%
Troporthents; Tropudults; Dystropepts	TTTD	454.48	0.32
Dystrandeps; Humitropepts; Hydrandeps	TDHH	11,804.95	8.31
Dystrandeps; Tropudults; Eutropepts	TDTE	3,273.23	2.30
Dystropepts; Dystrandeps; Tropudults	TDDT	25,480.33	17.94
Dystropepts; Eutropepts; Tropudalfs;	TDET	4,230.03	2.98
Dystropepts; Humitropepts; Tropohumults	TDHT	9,335.69	6.57
Dystropepts; Tropudults; Troporthents	TDTT	22,513.40	15.85
Eutropepts; Tropudults; Tropudalfs	TETT	1,337.16	0.94
Tropaquepts; Tropofluvents; Eutropepts	TTTE	6,287.11	4.43
Tropudalfs; Eutropepts; Tropaquepts	TTET	20,230.12	14.24
Tropudalfs; Tropudults	TTAT	5,843.41	4.11
Tropudults; Tropudalfs	TTUT	30,711.14	21.62
Tropudults, Dystropepts, Troporthents	TTDT	554.93	0.39
Total		149,055.96	100

User Soils Edit

Soil Component Parameters

SNAM: STOCKBRIDGE
 NLAYERS: 3
 HYDRGRP: C

TTDD

SOL_ZMX (mm): 1150
 ANION_EXCL (fraction): 0.5
 SOL_CRK (m3/m3): 0.5

TEXTURE: SIL-VFSL-S

Soil Layer Parameters

Soil Layer: 1

SOL_Z (mm): 400
 SOL_BD (g/cm3): 1.22

SOL_AwC (mm/mm): 0.13
 SOL_CBN (% wt.): 1.25
 SOL_K (mm/hr): 34.3

CLAY (% wt.): 59.9
 SILT (% wt.): 15.8
 SAND (% wt.): 24.3

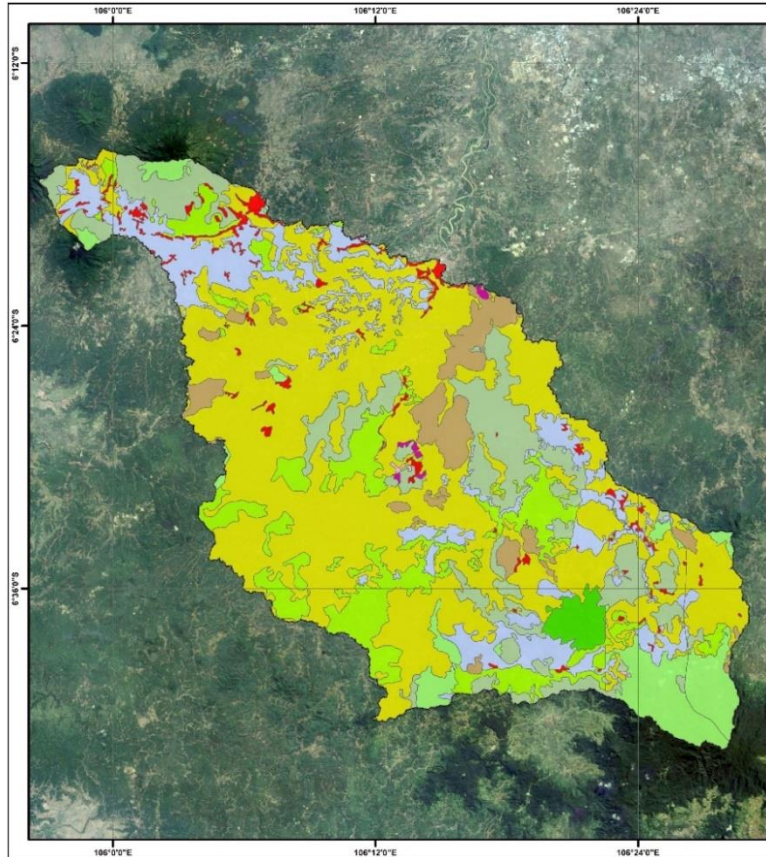
ROCK (% wt.): 0
 SOL_ALB (fraction): 0.13
 USLE_K: 0.18

SOL_EC (dS/m): 0
 SOL_CAL (%): 0
 SOL_PH: 0

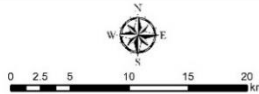
STISSING
 STOCKBRIDGE
 STOWE
 STRATTON
 SUCCESS
 SUDBURY
 SUN
 SUNAPEE
 SUNDAY
 SUNNY
 SWANTON
 TACONIC
 TDDT
 TDET
 TDHH
 TDHT
 TDTE
 TDDT
 TEEL
 TETT
 THORNDIKE
 TIGA
 TISBURY
 TNH3
 TNH6
 TTAT
 TTDT
 TTET
 TTTD
 TTTE
 TTUT
 TUNBRIDGE

Add New
 Cancel Edits
 Save Edits
 Delete
 Exit

BIOPHYSICAL INFORMATION



LAND COVER MAP OF CIUJUNG WATERSHED



Legend

- Primary Dryland Forest
- Secondary Dryland Forest
- Plantation Forest
- Settlements
- Plantation
- Dryland Agriculture
- Mixed Dryland Agriculture
- Paddy Field
- Shrubs
- Bare Land
- Water Bodies



Land cover	SWAT Code	Area	
		hectare	%
Mixed dryland agriculture	PLKC	60,168.80	42.36
Settlements	PMKN	1,238.10	0.87
Plantation forest	HTTN	18,302.02	12.88
Shrub	SMBK	7,299.67	5.14
Paddy field	PADI	27,993.10	19.71
Dryland Agriculture	PTLK	8,347.54	5.88
Secondary dryland forest	HLKS	8,235.93	5.80
Plantation	PKBN	8,925.43	6.28
Primary dryland forest	HLKP	1,544.46	1.09
Total		142,055.96	100

Land Cover/Plant Growth Database Edit

Crop types

- Garden or Canning Peas
- Grain Sorghum
- Greengrass
- Green Beans
- Hay
- Head Lettuce
- Honey Mesquite
- Honeydew Melon
- Hutan Lahan Kering Primer**
- Hutan Lahan Kering Sekunder
- Hutan Tanaman Keras
- Indragrass
- Itan (Annual) Ryegrass
- Johnsongrass
- Kentucky Bluegrass
- Lentils
- Lima Beans
- Little Bluestem
- Meadow Bromegrass
- Mung Beans
- Oak
- Oil Palm
- Olives
- Onion
- Orange
- Orchard
- Papayas
- Pasture
- Peanut
- Pearl Millet
- Pemukman
- Peppers
- Perkebunan
- Petanian Lahan Kering
- Petanian Lahan Kering Campur
- Pine
- Pineapple
- Pinto Beans
- Plantains
- Poplar
- Potato
- Rango Bush
- Rango Grasses
- Red Clover
- Rice
- Rubber Trees

Crop type Parameters

Crop Name: Hutan Lahan Kering Primer CPMN (4 character): HLKP

IDC: Warm season annual legume Crop is fertilized: Op Schedule: FRSE

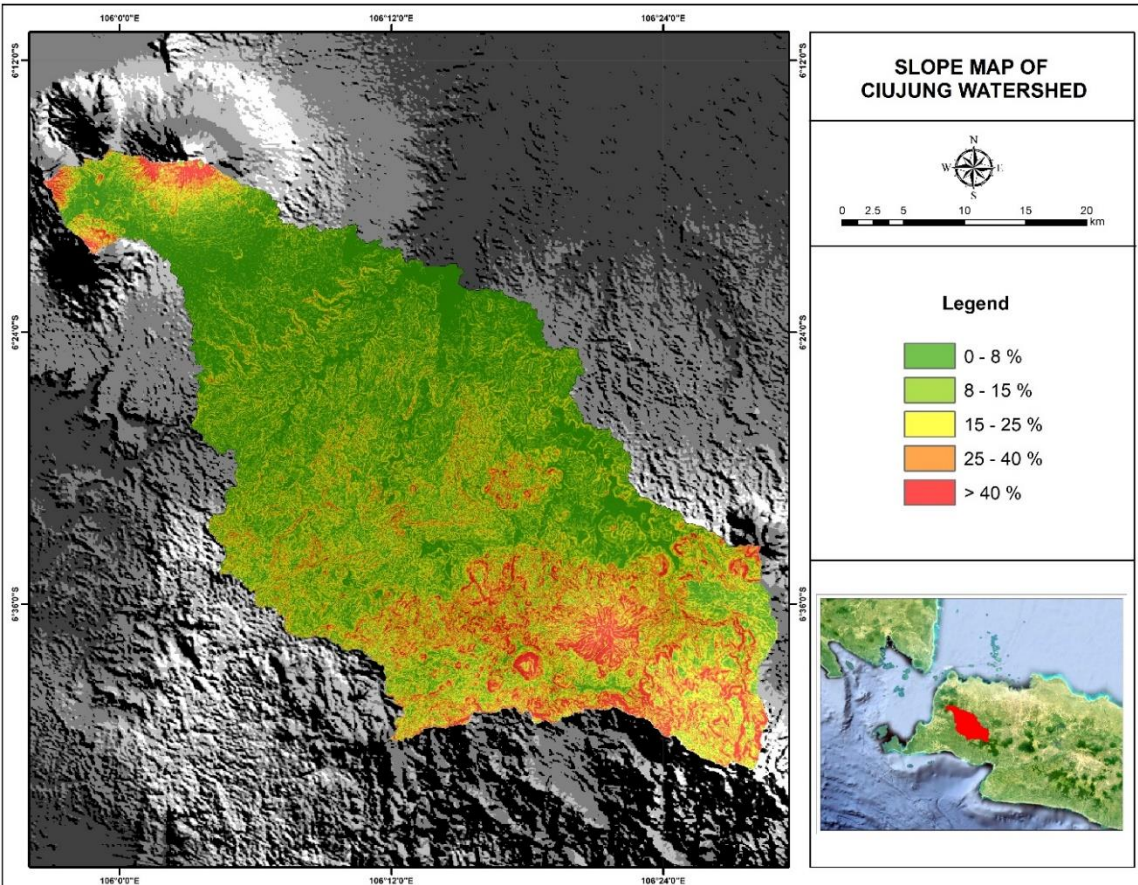
BIO_E [(kg/ha)/(M/m ²)]	HVSTI [(kg/ha)/(kg/ha)]	BLAI (m ² m)
15	0.76	5
FRGRV1 (fraction)	LAIMX1 (fraction)	CHTMX (m)
0.15	0.7	10
FRGRV2 (fraction)	LAIMX2 (fraction)	DLAI (heat units/heat units)
0.25	0.99	0.99
T_OPT (C)	T_BASE (C)	CNYLD(kg N/kg seed)
30	0	0.0015
BN1 (kg N/kg biomass)	BN2 (kg N/kg biomass)	BN3 (kg N/kg biomass)
0.006	0.002	0.0015
BP1 (kg P/kg biomass)	BP2 (kg P/kg biomass)	BP3 (kg P/kg biomass)
0.0007	0.0004	0.0003
VSFY [(kg/ha)/(kg/ha)]	USLE_C	GSI (m/s)
0.6	0.001	4
FRGMAX (fraction)	VIWVP (rate)	COZH (u/L)
0.75	8	16
RSOCO_PL (fraction)	ALAI_MIN (m ² m)	BIO_LEAF (fraction)
0.05	0.75	0.3
MAT_YRS (years)	BMX_TREES (tons/ha)	EXT_COEF
30	1000	0.65

Hydrological Parameters

OV_N

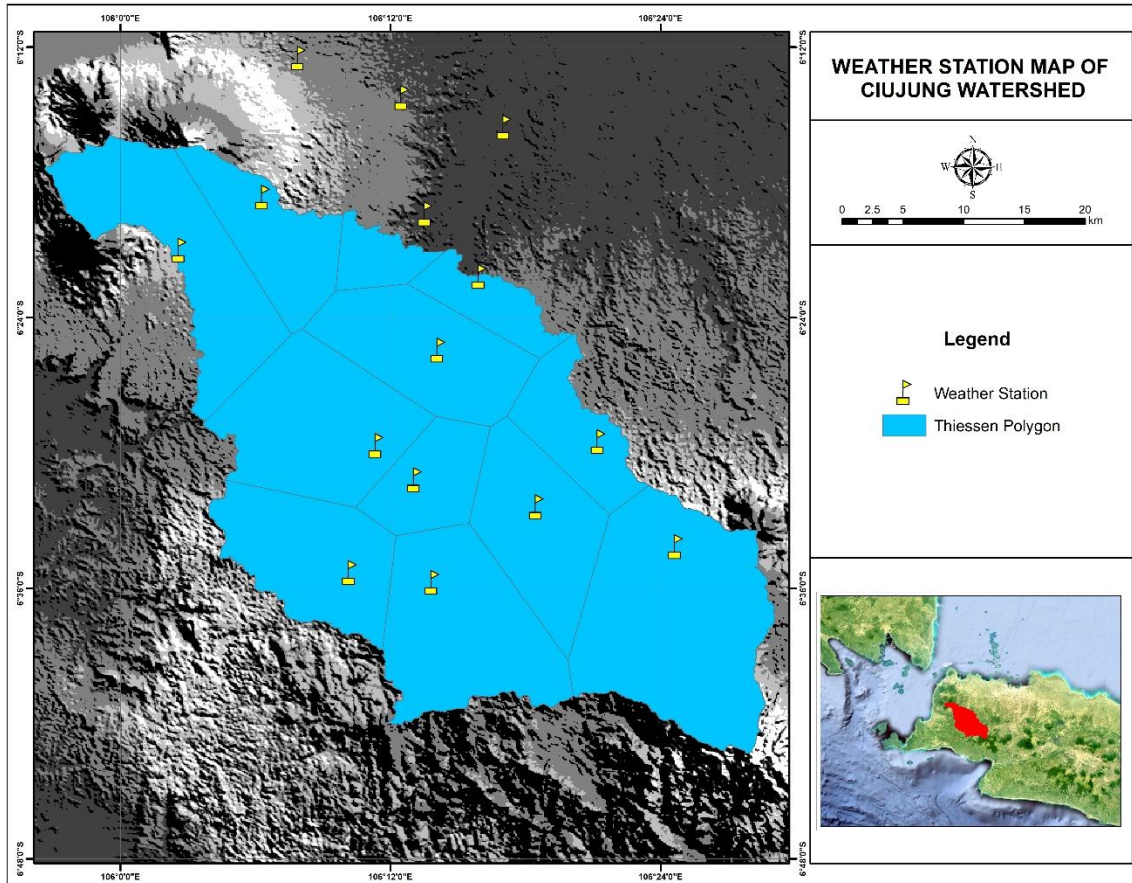
Manning's N (roughness)

0.41	LU	SCS Runoff Curve Numbers			
		A	B	C	D
		32	58	72	79
					LU



Slope (%)	Classification	Area	
		ha	%
0-8	Flat	34,719.13	24.44
8-15	Sloping	40,826.65	28.74
15-25	Rather steep	34,610.46	24.36
25-40	steep	20,609.62	14.51
>40	Very steep	11,290.11	7.95
Total		142,055.96	100



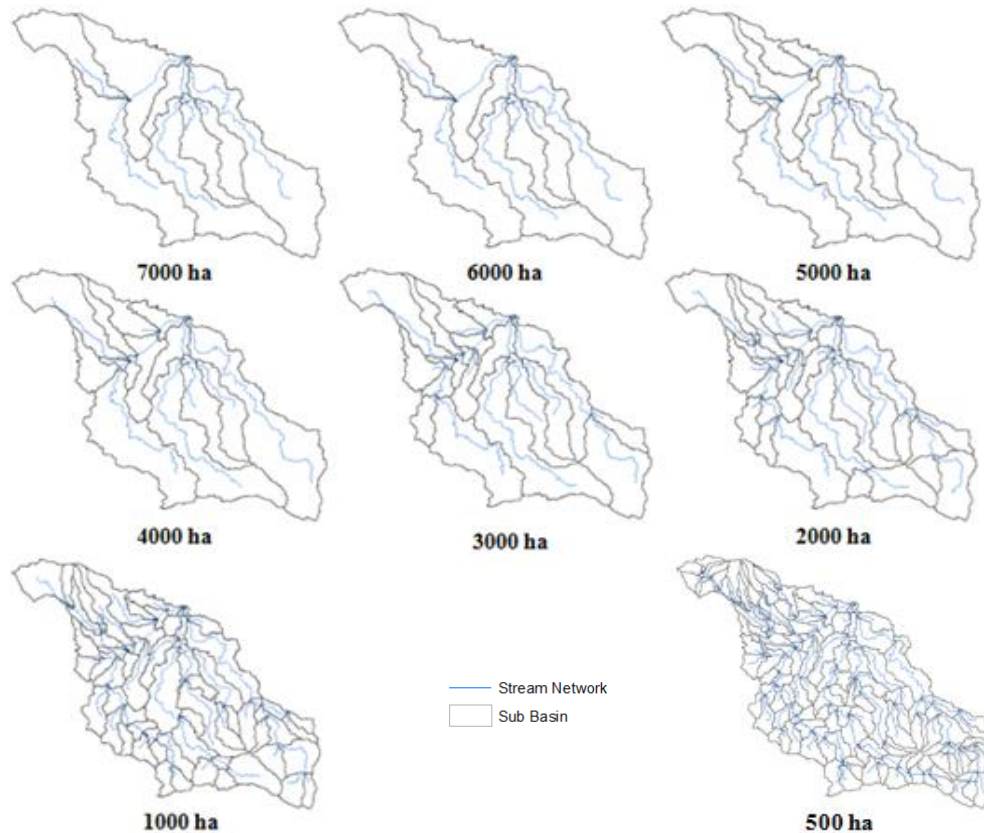


Precipitation (mm)	2000-3000
Max. Temperature (oC)	31.81
Min. Temperature (oC)	23.22
Wind Speed (km/hour)	0.68
Relative Humidity (%)	87





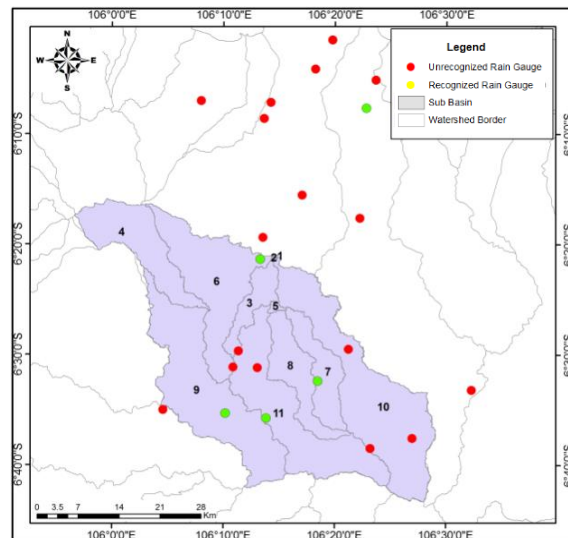
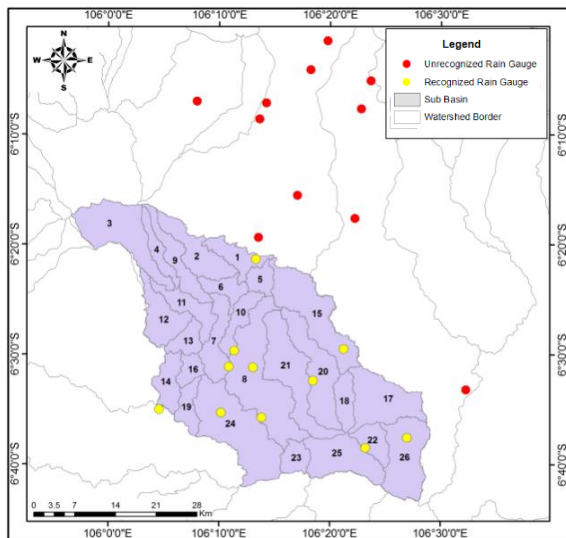
RESULT : WATERSHED DELINEATION





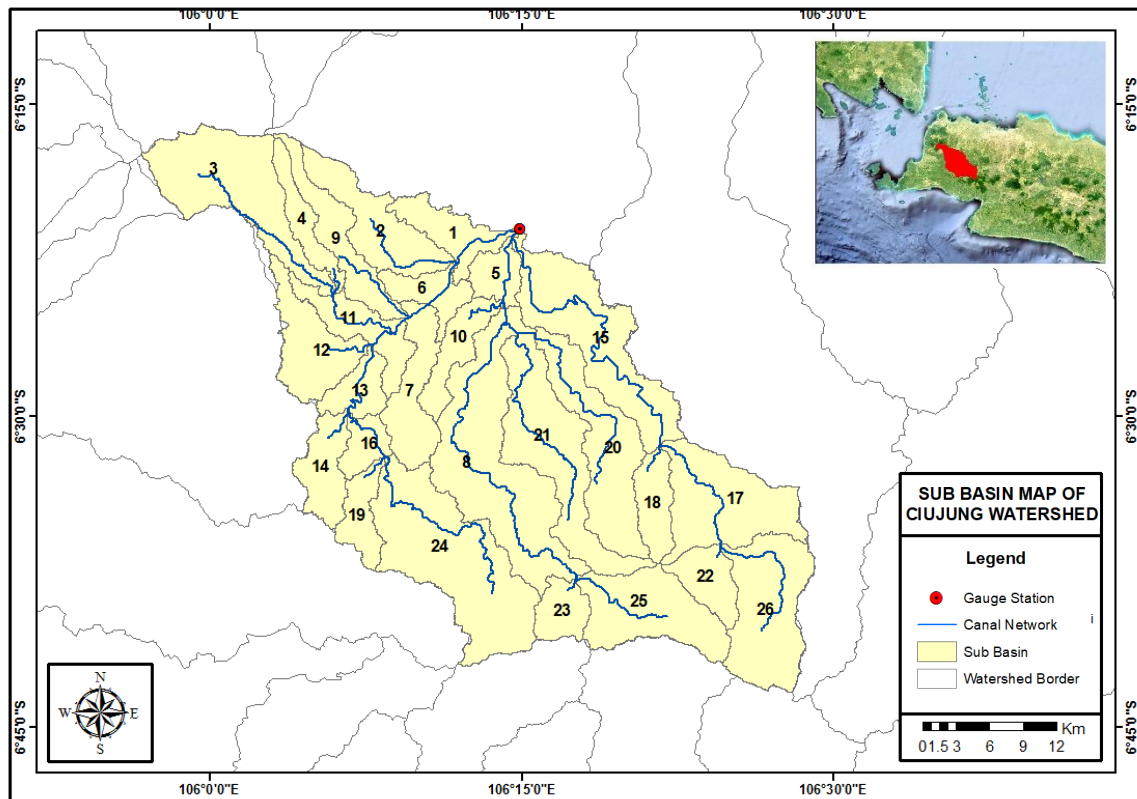
RESULT : WATERSHED DELINEATION

Threshold (ha)	Number of Sub Basin	Rain Gauge	PCP (mm)	SURQ (mm)	LATQ (mm)	GWQ (mm)	Q (m ³ /s)	R ²	NSE
7000	11	5	1724.43	496.77	233.99	158.24	40.22	0.395	-0.208
6000	11	5	1724.42	496.77	234.00	158.25	40.21	0.403	-0.120
5000	15	6	1804.35	519.07	238.04	197.47	43.26	0.449	0.054
4000	17	6	1792.61	516.31	236.96	190.26	42.71	0.442	0.029
3000	23	8	1860.02	548.47	242.76	202.81	45.02	0.526	0.144
2000	35	11	1945.71	579.27	259.01	210.54	47.49	0.547	0.177
1000	71	12	1899.66	548.31	255.04	198.94	45.37	0.553	0.234
500	155	12	1882.64	542.13	247.38	195.32	44.56	0.558	0.233





RESULT : WATERSHED DELINEATION



Sub Basin	Area	
	hectare	%
1	3,256.49	2.29
2	5,540.90	3.90
3	9,595.00	6.75
4	2,353.97	1.66
5	1,963.24	1.38
6	2,369.27	1.67
7	4,481.32	3.15
8	14,479.40	10.19
9	4,152.16	2.92
10	2,853.31	2.01
11	3,651.49	2.57
12	5,018.47	3.53
13	2,264.08	1.59
14	3,318.63	2.34
15	10,286.57	7.24
16	1,764.55	1.24
17	8,210.54	5.78
18	2,702.99	1.90
19	2,390.56	1.68
20	8,201.70	5.77
21	9,452.18	6.65
22	2,716.67	1.91
23	2,208.68	1.55
24	13,495.83	9.50
25	7,071.42	4.98
26	8,256.53	5.81
Total	142,055.96	100



RESULT : SENSITIVITY ANALYSIS

Parameters	t-Stat	P-Value	Sensitivity Rank
r_CN2,mgt	-55.145	0.0000	1
v_SHALLST,gw	6.4028	0.0000	2
v_SURLAG,bsn	-6.0224	0.0000	3
r_SOL_BD,sol	3.9222	0.0001	4
v_GWQMN,gw	-3.4268	0.0007	5
v_ESCO,bsn	-2.5448	0.0128	6
r_SOL_K,sol	-1.6157	0.1073	7
v_RCHRG_DP,gw	1.5256	0.1282	8
v_ALPHA_BNK,rte	1.4028	0.1618	9
v_GW_REVAP,gw	-1.4003	0.1625	10
v_EPCO,bsn	1.3830	0.1678	11
r_CH_N2,rte	-0.9405	0.3478	12
r_CH_K2,rte	0.9061	0.3676	13
v_ALPHA_BF,gw	0.8654	0.3875	14
r_OV_N,hru	0.8201	0.4146	15
r_SOL_AWC,sol	0.7987	0.4252	16
v_GW_DELAY,gw	0.5736	0.5667	17
v_REVAPMN,gw	0.0879	0.9300	18





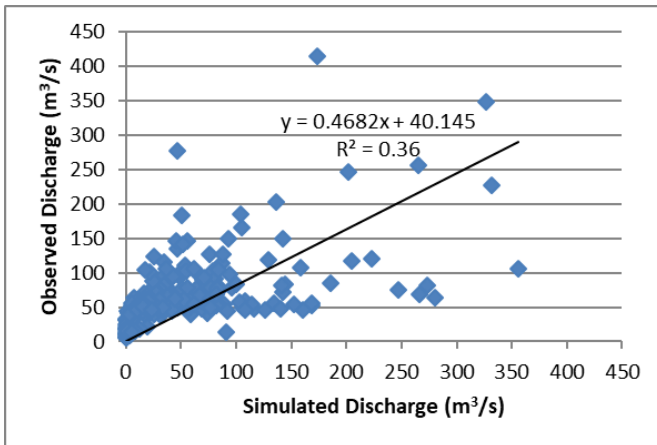
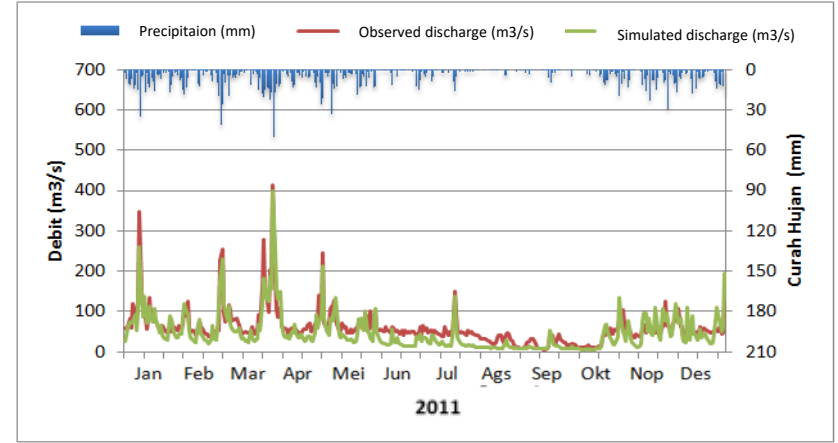
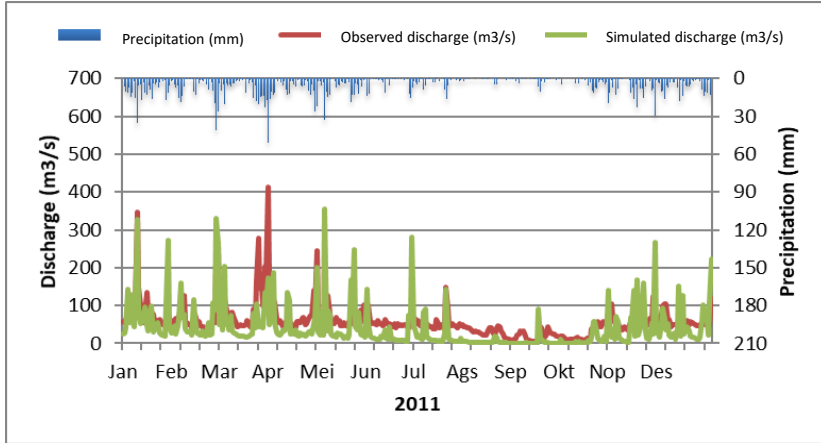
RESULT : MODEL CALIBRATION

No	Parameters	Definition	Minimum Value	Maximum Value	Used Value
1	CN2	Initial SCS Curve Number for moisture condition 2	35	92	35-94**
2	SHALLST	Initial depth of water in the shallow aquifer (mmH2O)	1000	5000	4000
3	SURLAG	Surface Runoff Lag Coefficient	1	4	2
4	GWQMN	Threshold Depth of water in the shallow aquifer required for return flow to occur (mmH2O)	1000	4000	3500
5	ESCO	Soil evaporation compensation factor	0.6	0.98	0.85
6	RCHRG_DP	Deep aquifer percolation fraction	0.05	0.25	0.1
7	ALPHA_BNK	Baseflow alpha factor for bank storage (days)	0.2	0.9	0.55
8	GW_REVAP	Groundwater "revap" coefficient	0.02	0.2	0.02-0.1**
9	EPCO	Plant uptake compensation factor	0.5	0.8	0.56
10	CH_N(2)	Manning's N value for the main channel	0.02	0.1	0.04-0.1*
11	CH_K(2)	Effective hydraulic conductivity in main channel alluvium (mm/hr)	0.001	0.025	0.004-0.025*
12	ALPHA_BF	Baseflow alpha factor (1/days)	0.1	1	0.52
13	OV_N	Manning's N value for overland flow	0.01	0.48	0.011-0.41**
14	GW_DELAY	Groundwater delay time (days)	15	80	65
15	REVAPMN	Threshold depth of water in the shallow aquifer for "revap" or percolation to the deep aquifer to occur	350	1000	500





RESULT : MODEL CALIBRATION

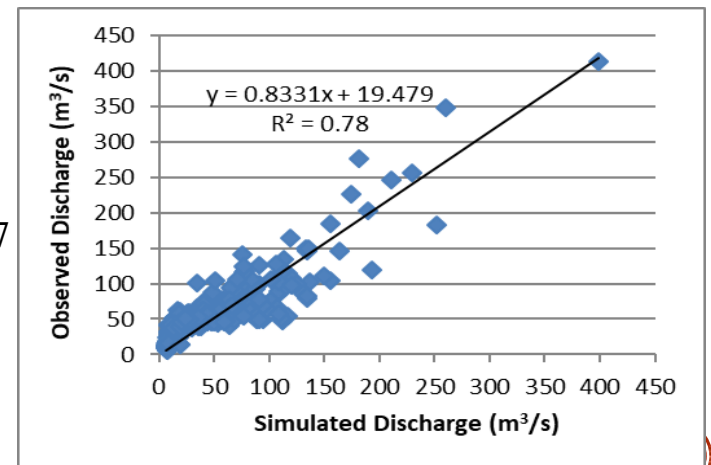


Uncalibrated

$R^2 = 0.36$
NSE = 0.17

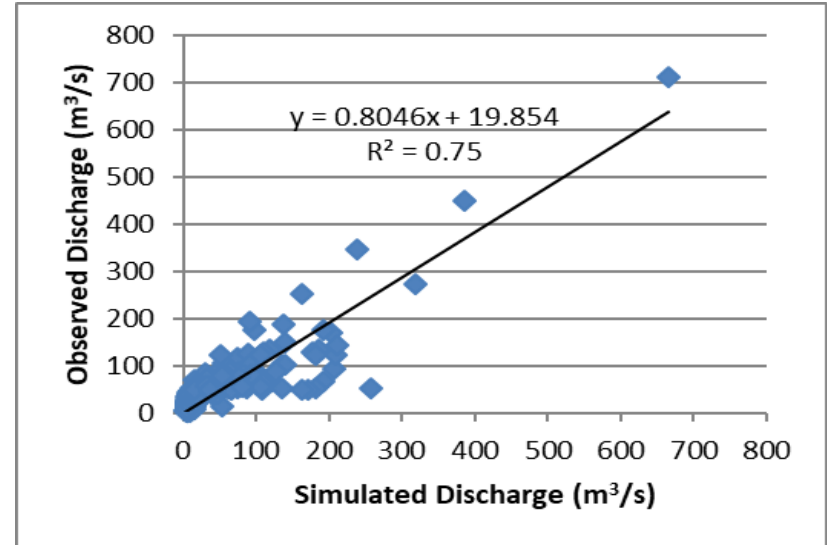
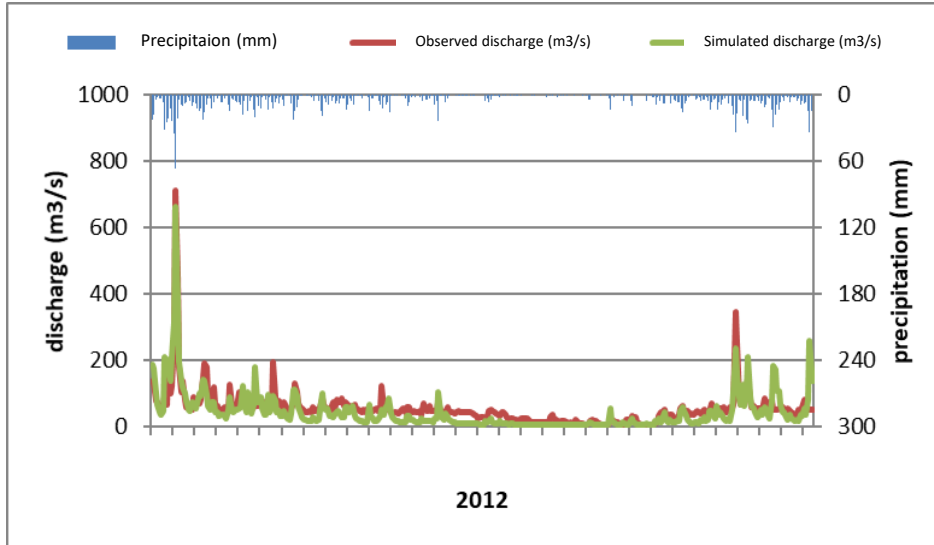
Calibrated

$R^2 = 0.78$
NSE = 0.67





RESULT : MODEL VALIDATION



Validated

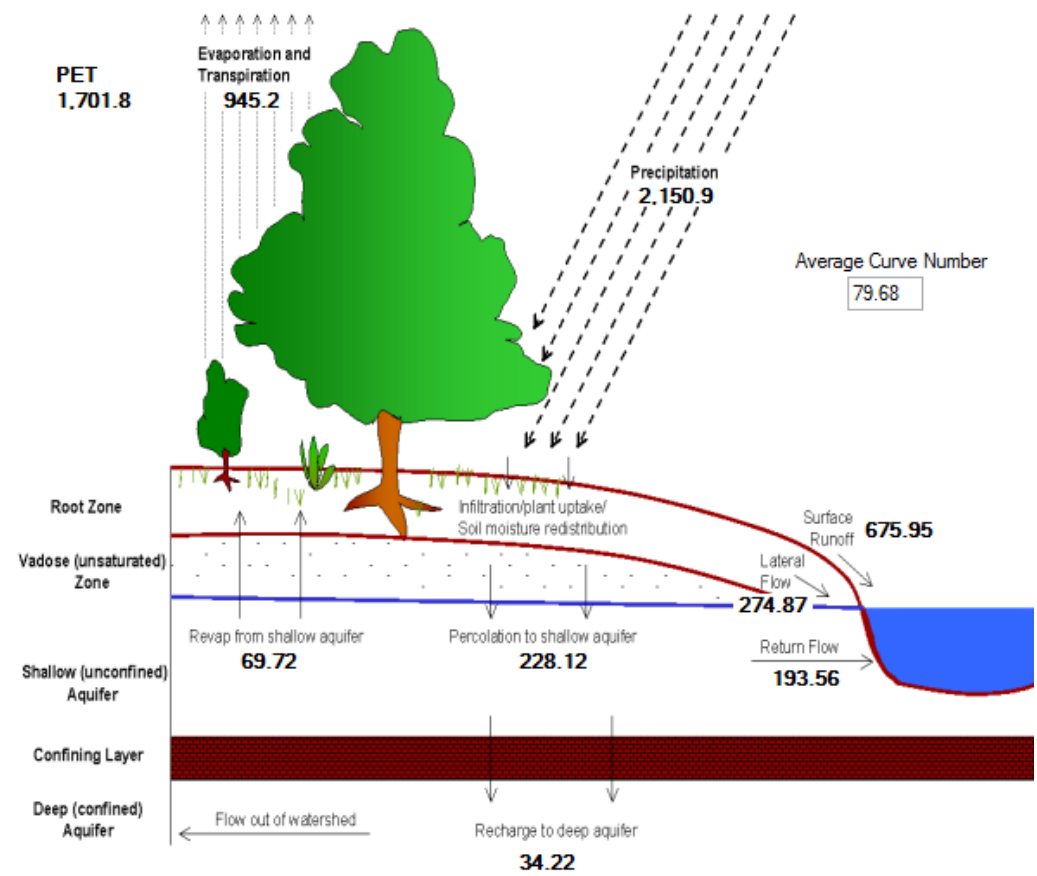
$$R^2 = 0.75$$

$$NSE = 0.67$$





RESULT : WATER BALANCE





RESULT : MODEL SIMULATION

	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Qmax	511.8	493.1	480.0	510.3	457.0
Qmin	2.6	3.3	4.4	3.3	5.0
Qmax/Qmin	198	148	109	155	91

Scenarios	PCP	SURQ	Δ SURQ		LATQ	Δ LATQ		GWQ	Δ GWQ	
	mm	mm	mm	%	mm	mm	%	mm	mm	%
Baseline	1873	575	-	-	236	-	-	211	-	-
1	1873	487	-87	-15	276	39	19	218	7	3
2	1873	400	-175	-30	286	50	23	279	68	32
3	1873	515	-60	-10	262	26	12	204	7	3
4	1873	393	-182	-32	288	52	22	240	29	1





1. Floods is the most common natural disaster in Indonesia
2. SWAT model can be used to predict flow discharge in ciujung Watershed
3. SWC practices with mechanical method is the best management practices to reduce surface runoff
4. Degraded land rehabilitation (reforestation and agroforestry) is the best management practices to increase ground water storage

CONCLUSION



THANK YOU

TERIMA
KASIH



DATA TEKNIS BENDUNGAN KARIAN

Scheme	Description
Catchments area	288 km ²
DAM type	CCRD
DAM crest elevation	72.5 EL.m
Flood high water level	70.85 EL.m
Normal high water level	67.5 EL.m
Low water level	46.0 EL.m
Maximum DAM height	60.5 EL.m
Reservoir area	1,740 Ha
Effective storage volume	207.48million
Embankment volume of main DAM	1.23 million
Design flow discharge	
a. Inflow	3,672 (lt/s) atau 3.672 (m ³ /s)
b. Outflow	3,190 (lt/s) atau 3.190 (m ³ /s)
Spillway gate	
a. Type	Radial gate
b. Dimension	2 nos x width 12.5m x height 14.2 m
Side overflow spillway weir	50.0 m
Flood control volume	60.8 million



Scheme	Description
Length	36.5 km
Type of conveyance	Pressured by pump
Maximum flow capacities	12.4 cm/s atau 0.124 m/s
Type of waterway	Steel pipeline
Dimension	Dia 2.0 x 2 (20 km) Dia 1.4 x 2 (16 km)
Related Structures	
a. Booster pump station	1 nos
b. Railway crossing	1 nos
c. Control valves	280 nos
d. Flow meters	5 nos