STREAM FLOW MODELING IN THE NACUNDAY RIVER BASIN (PARAGUAY, SOUTH AMERICA) USING SWAT MODEL

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Hydrological Models

- WEPP(Water Erosion Prediction Project)
- HSPF (Hydrologic Simulation Program Fortran)
- SHETRAN(System Hydrologique Europeen-TRANsport)
- SWAT (**S**oil and **W**ater **A**ssessment **T**ool)

SWAT (Soil and Water Assessment Tool)

- User-friendly
- ARC VIEW Interface
- Realistic representation of spatial variability of catchment characteristics
- Free-availability

...availability and user-friendliness in handling input data (Arnold et al.,1998)

... is a model coupled with geographic information system (GIS). The principal advantage of such a model is that it can realistically represent the spatial variability of catchment characteristics (Mishra et al., 2007).

Developed and maintained by the USDA

SWAT in South America

- BRAZIL :from 1999 to 2010, over 70 publications such as theses, dissertations and articles about the use of the model in Brazilian watersheds were identified.

- URUGUAY : simulation of hydrologic response of two catchments during the pretreatment period and prediction of the hydrologic effects of converting the native pasture to pine plantation. (VON Stackelberg et al. 2007).

- PARAGUAY No studies using SWAT Model were identified.

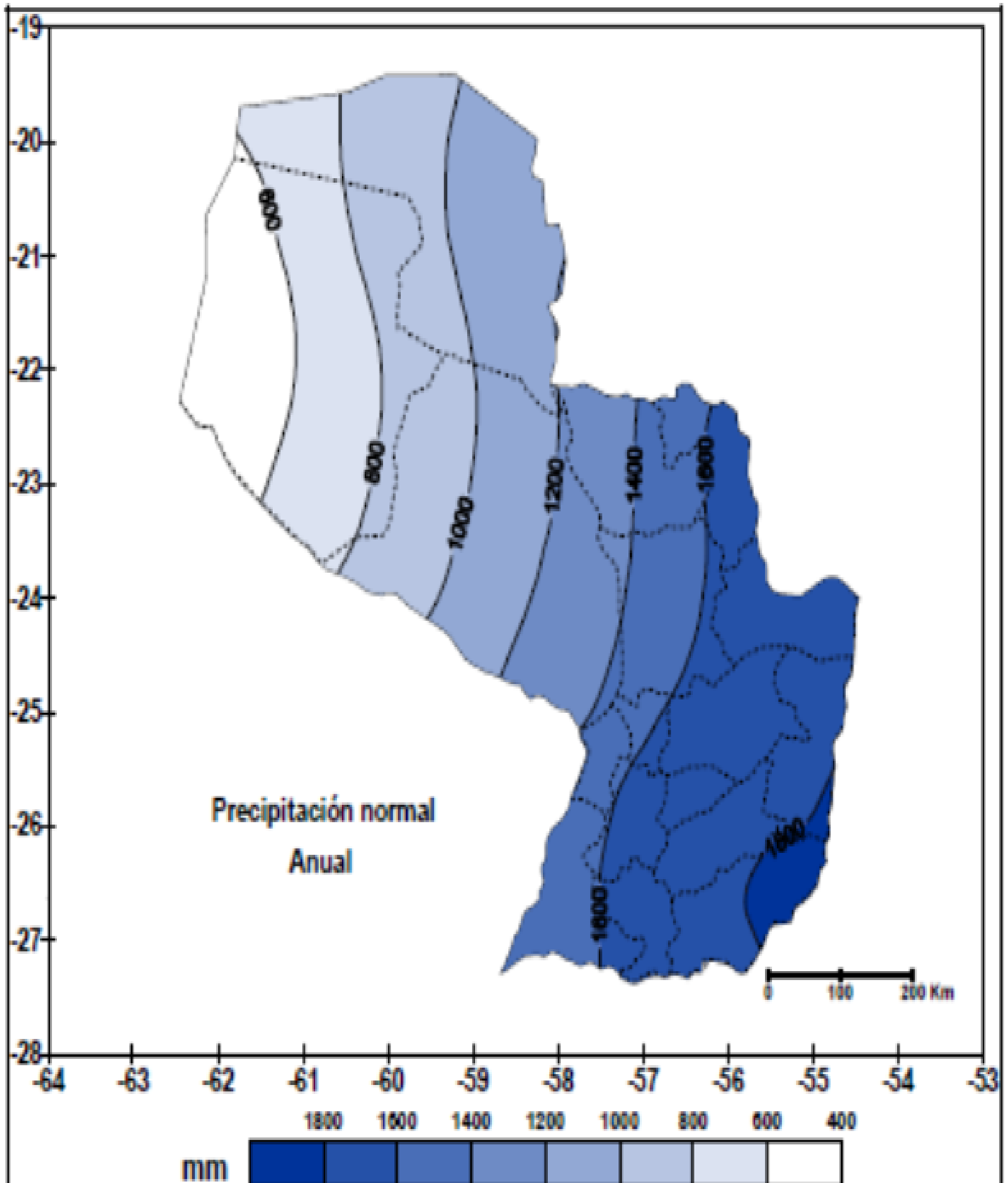
- ARGENTINA SWAT model was applied to calibrate and validate stream flow in an agricultural micro basin in the Pampa Ecoregion, with successful results on daily basis and poor results on monthly basis (Behrends et al. 2011).

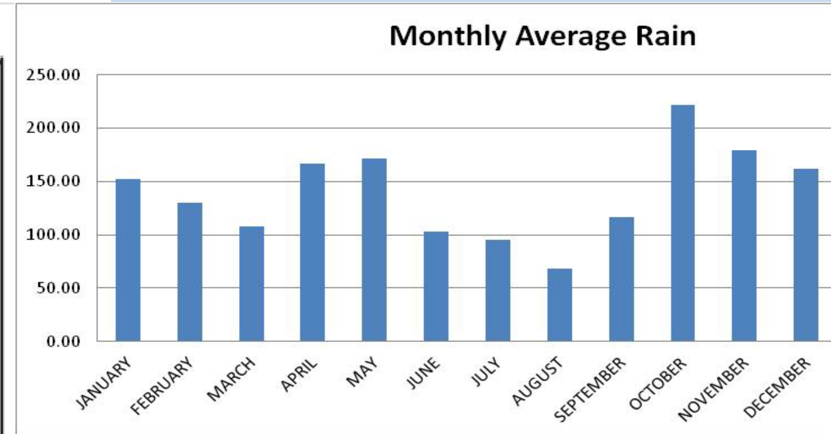
Objectives of the work

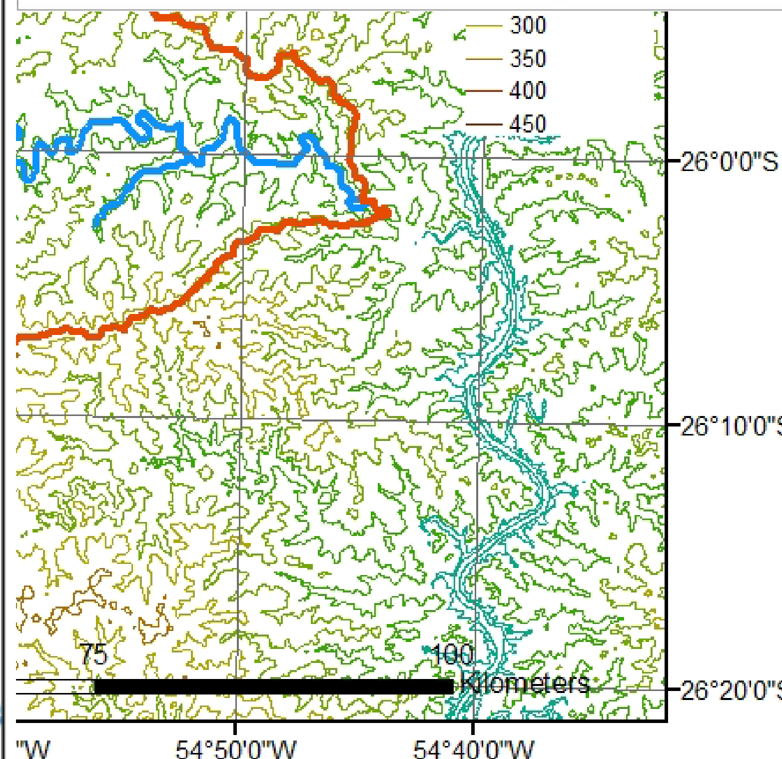
1. **Sensitivity analysis of the parameters assumed in the model**
2. **Calibration of the parameters considered in the model.**
3. **Validate the performance of SWAT and the feasibility of using this model as a simulator of runoff at a catchment scale in the sub tropical region of Nacunday river catchment area.**

1. Sensitivity analysis of the parameters assumed in the model
2. Calibration of the parameters considered in the model
3. Validate the performance of SWAT and the feasibility of using this model as a simulator of runoff at a catchment scale in the sub tropical region of Nacunday river catchment area.

Study Area: **NACUNDAY BASIN**







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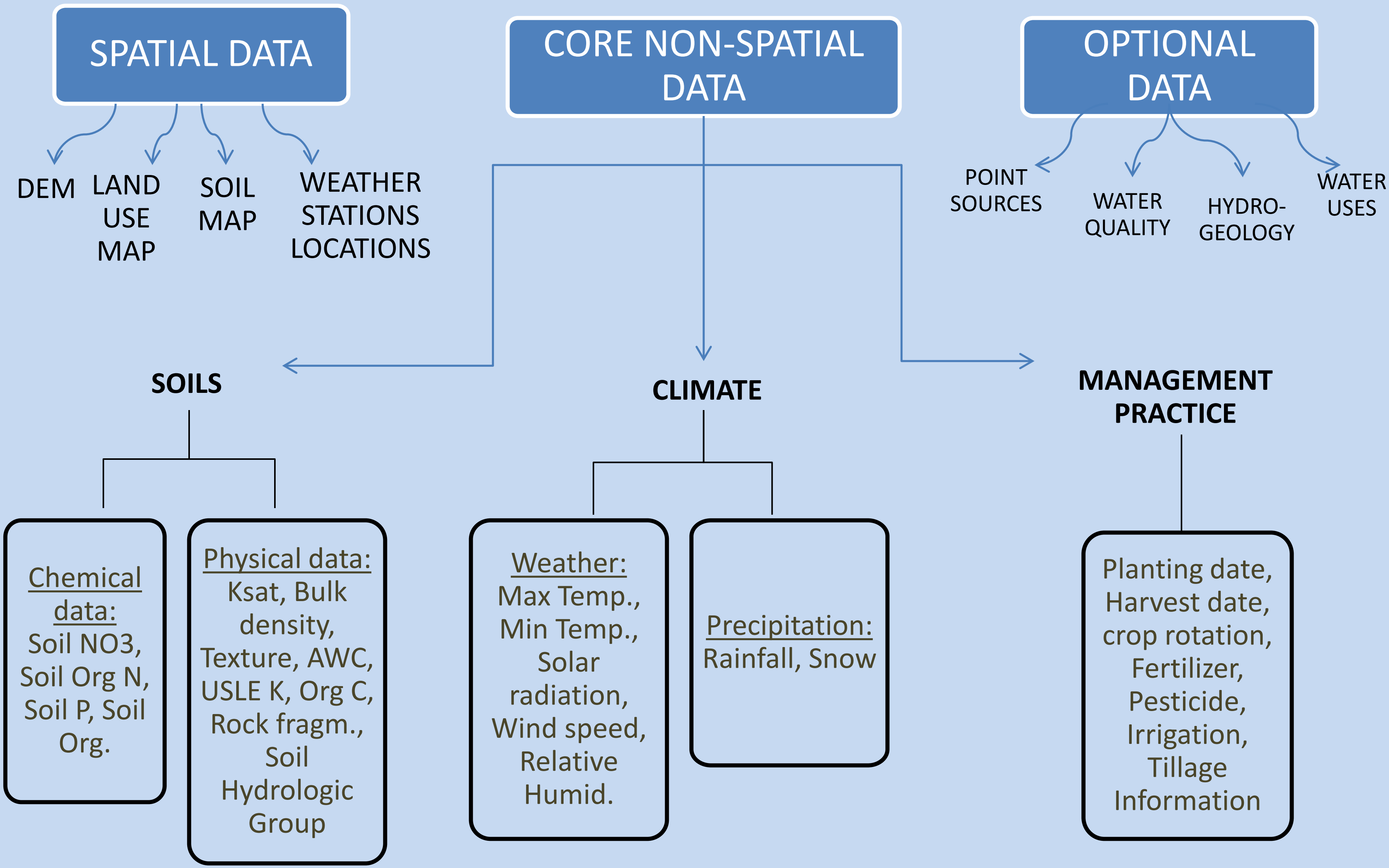
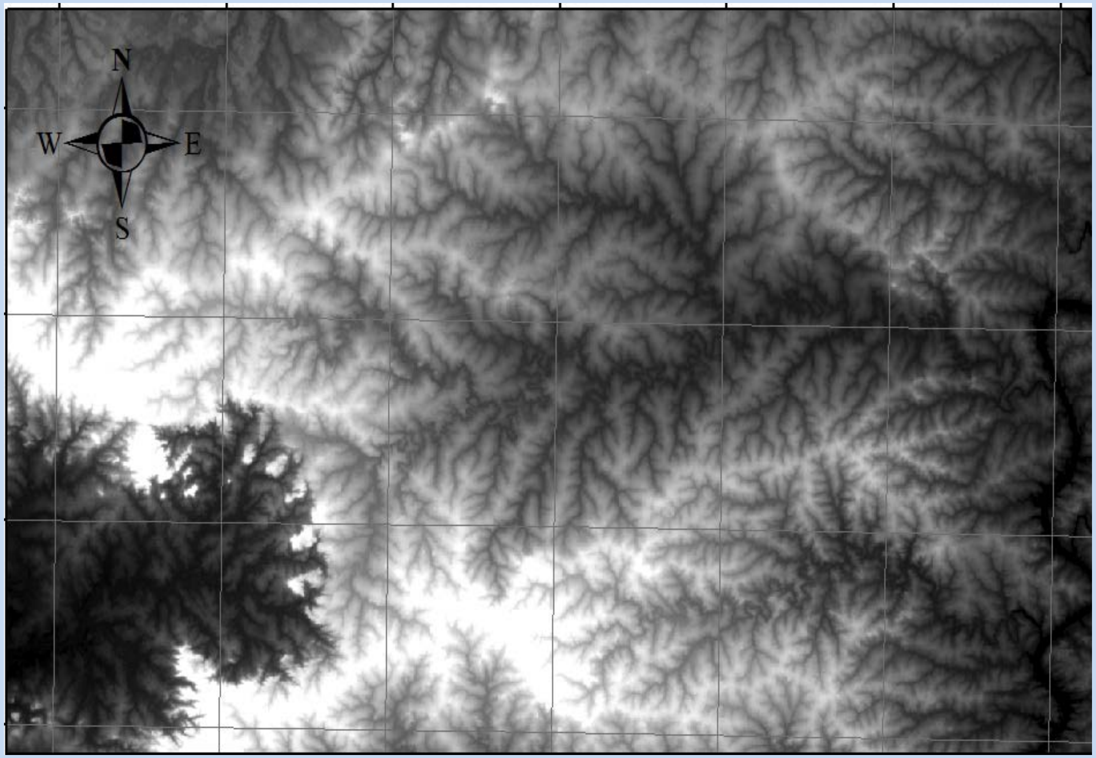
ARC SWAT INPUT DATA TREE



DEM

Digital Elevation Map

- Global SRTM data (http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp)
- 90-m resolution
- Geographic coordinate system: GCS_WGS_1984,
- Projected to: WGS_1984_UTM_ZONE_21S

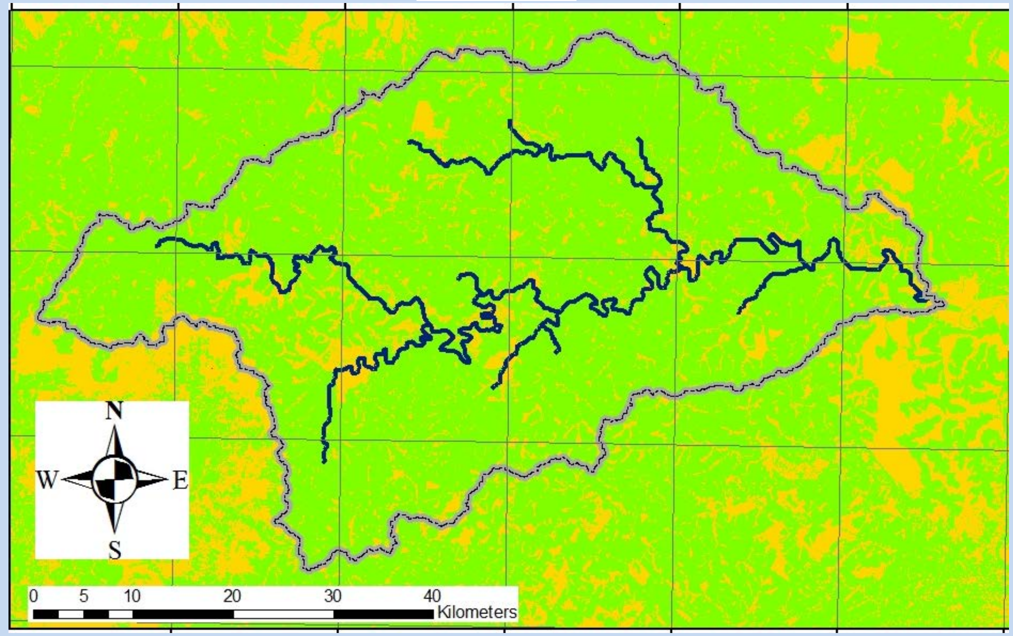


LAND USE MAP

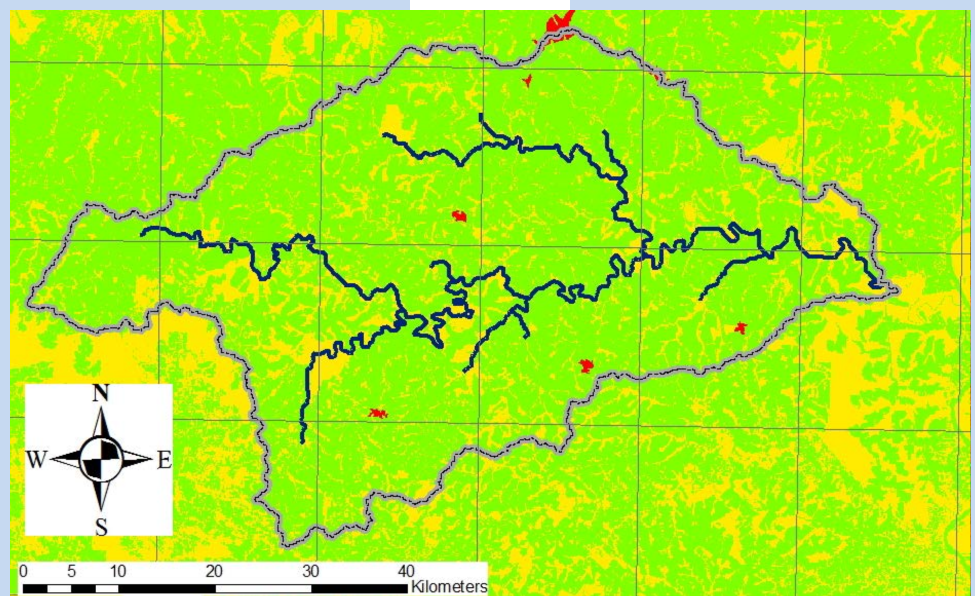
- 2003 and 2009 Landsat-5 Thematic Mapper images
- 30-m spatial resolution
- Geographic coordinate system: GCS_South_American_1969.
- Projected to : WGS_1984_UTM_ZONE_21S

Reclassification

2003

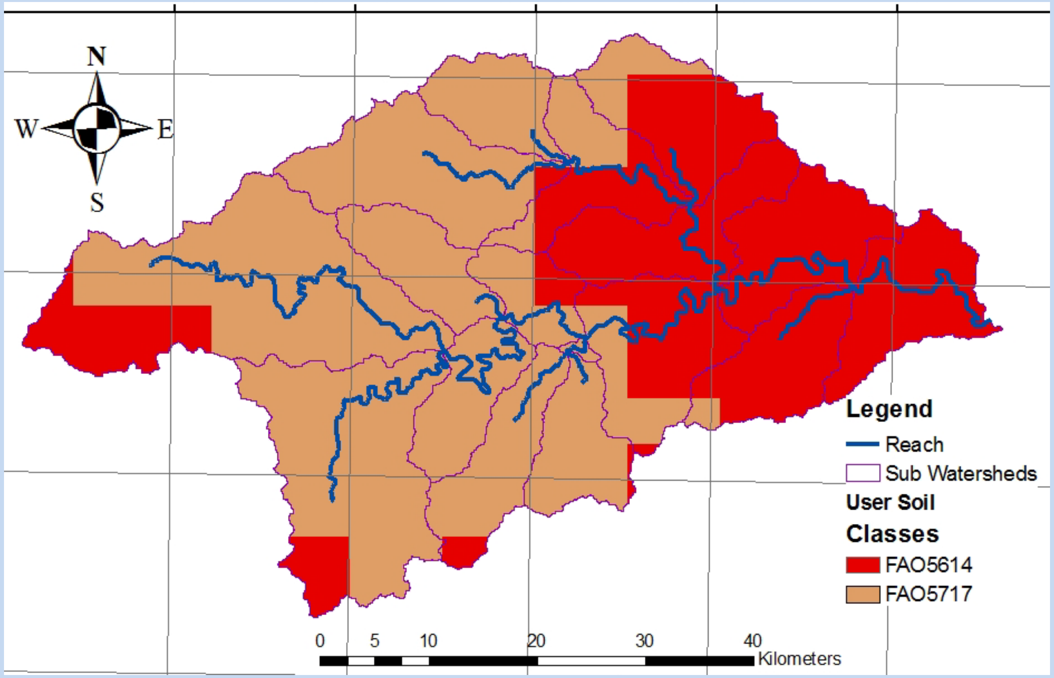


2009



SOIL MAP

- FAO-UNESCO Soil Map of the World 1971-1981 (DSMW)
- downloaded from the World Soil Information (ISRIC) website (http://www.isric.org/).
- The spatial data's resolution is 5 by 5 arc-minutes grid (Batjes, 2006)
- Geographic coordinate system: GCS_South_American_1969
- Projected to the WGS_1984_UTM_ZONE_21S



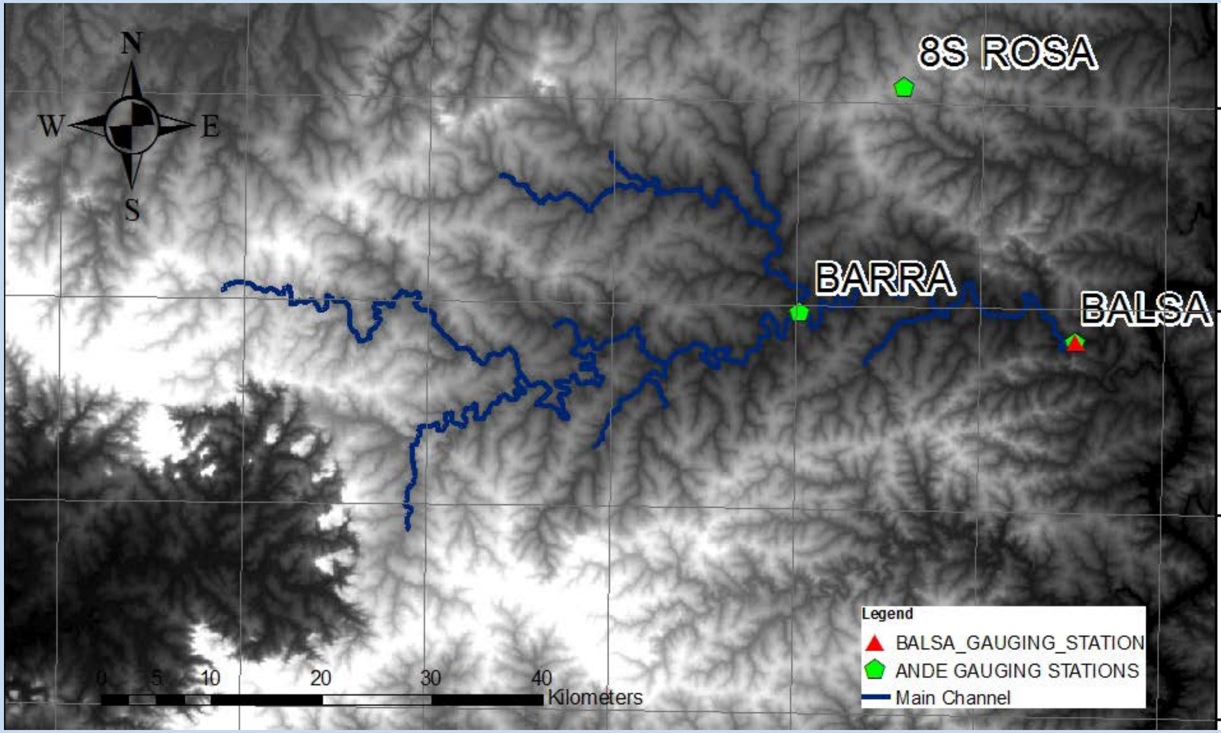
WEATHER STATIONS LOCATIONS

- Daily Rainfall , Temperature, Relative Humidity

- From

01-01-1999 to 30-09-2009.

- Barra Station given by the National Agency of Electricity (ANDE)



NAME	XPR	YPR	LAT	LONG
BARRA	700 560.44	7 122 162.72	26°00’20.16” S	54°59’45.96”W

CLIMATE

- Meteorology data provided by ANDE
- Daily data for:

❖ Rainfall (mm) — Pcp.dbf

❖ Temperature (Maximum, Minimum) (°C) — Tempe.dbf

❖ Relative Humidity(%) — Rh.dbf

- From Jan 1, 1999 to Sept 30, 2009.
- Wind speed and Solar Radiation generated by weather generator.

Formulas

Data

SOIL

FAO-UNESCO Soil Map (http://www.isric.org/).

- Two types of soils units were identify in the study area
- Units are 5614 and 5717
- Several physical and chemical parameters of soil layers.

OBJECTID	MUID	SEQN	SNAM	S5ID	CMPPCT	NLAYERS	HYDGRP	SOL_ZMX	ANION_EXCL	SOL_CRK	TEXTURE
1.00	5614.00	2.00	FAO5614			5.00	C	1000.00	0.50	0.50	CL
2.00	5717.00	1.00	FAO5717			5.00	B	1000.00	0.50	0.50	FSL-FC

SOL_Z1	SOL_BD1	SOL_AWC1	SOL_K1	SOL_CBN1	CLAY1	SILT1	SAND1	ROCK1	SOL_ALB1	USLE_K1	SOL_EC1
200.00	1.15	0.05	1.50	12.27	34.00	24.00	42.00	2.00	0.27		0.00
200.00	1.40	0.10	3.40	9.20	20.00	20.00	60.00	8.00	0.27		0.00

SOL_Z2	SOL_BD2	SOL_AWC2	SOL_K2	SOL_CBN2	CLAY2	SILT2	SAND2	ROCK2	SOL_ALB2	USLE_K2	SOL_EC2
400.00	1.24	0.04	1.00	6.41	44.00	21.00	35.00	1.00	0.00		0.00
400.00	1.40	0.10	1.50	4.90	27.00	19.00	54.00	8.00	0.00		0.00

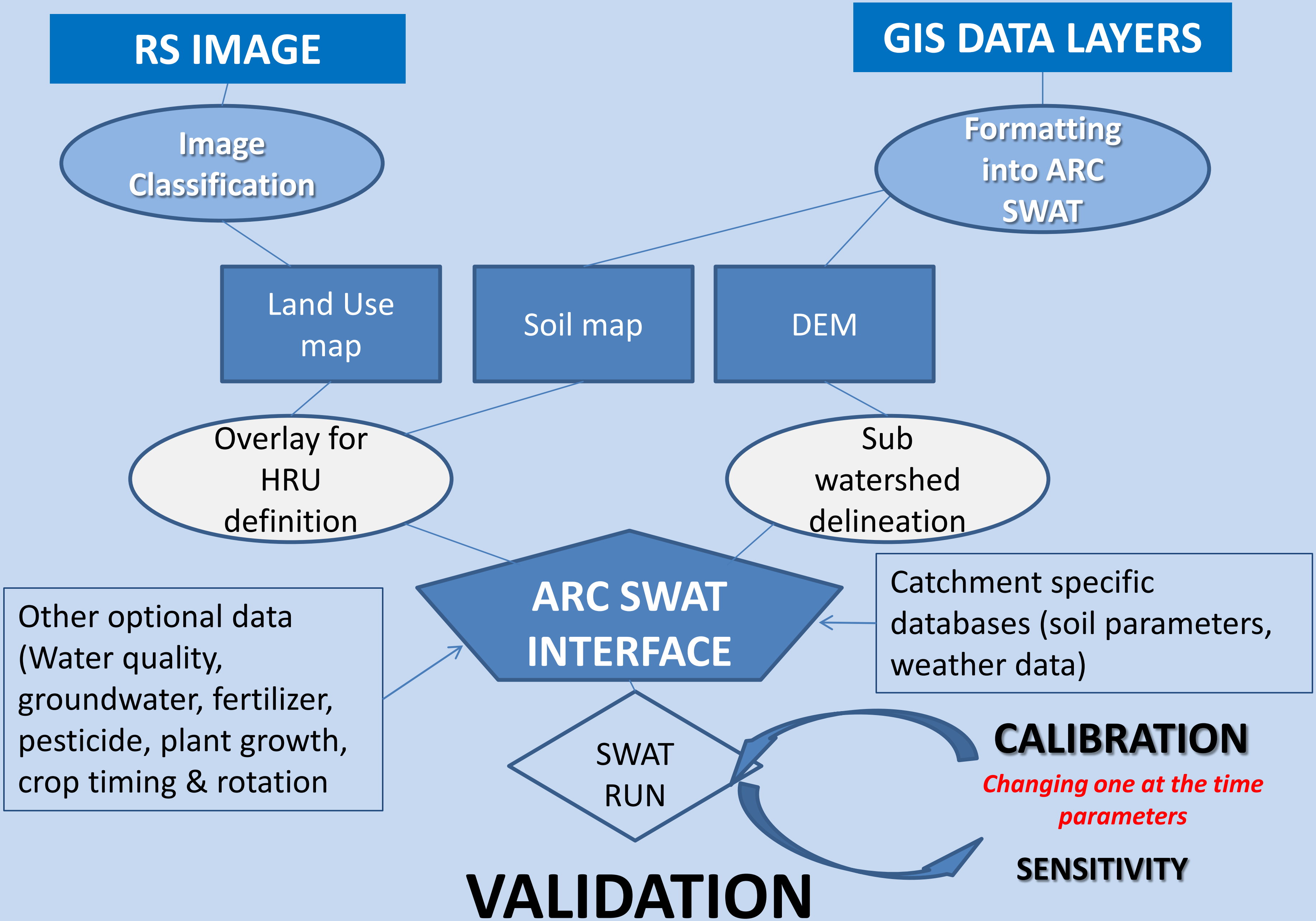
SOL_Z3	SOL_BD3	SOL_AWC3	SOL_K3	SOL_CBN3	CLAY3	SILT3	SAND3	ROCK3	SOL_ALB3	USLE_K3	SOL_EC3
600.00	1.25	0.04	1.00	4.92	50.00	19.00	31.00	4.00	0.00		0.00
600.00	1.40	0.10	1.30	4.00	32.00	18.00	50.00	10.00	0.00		0.00

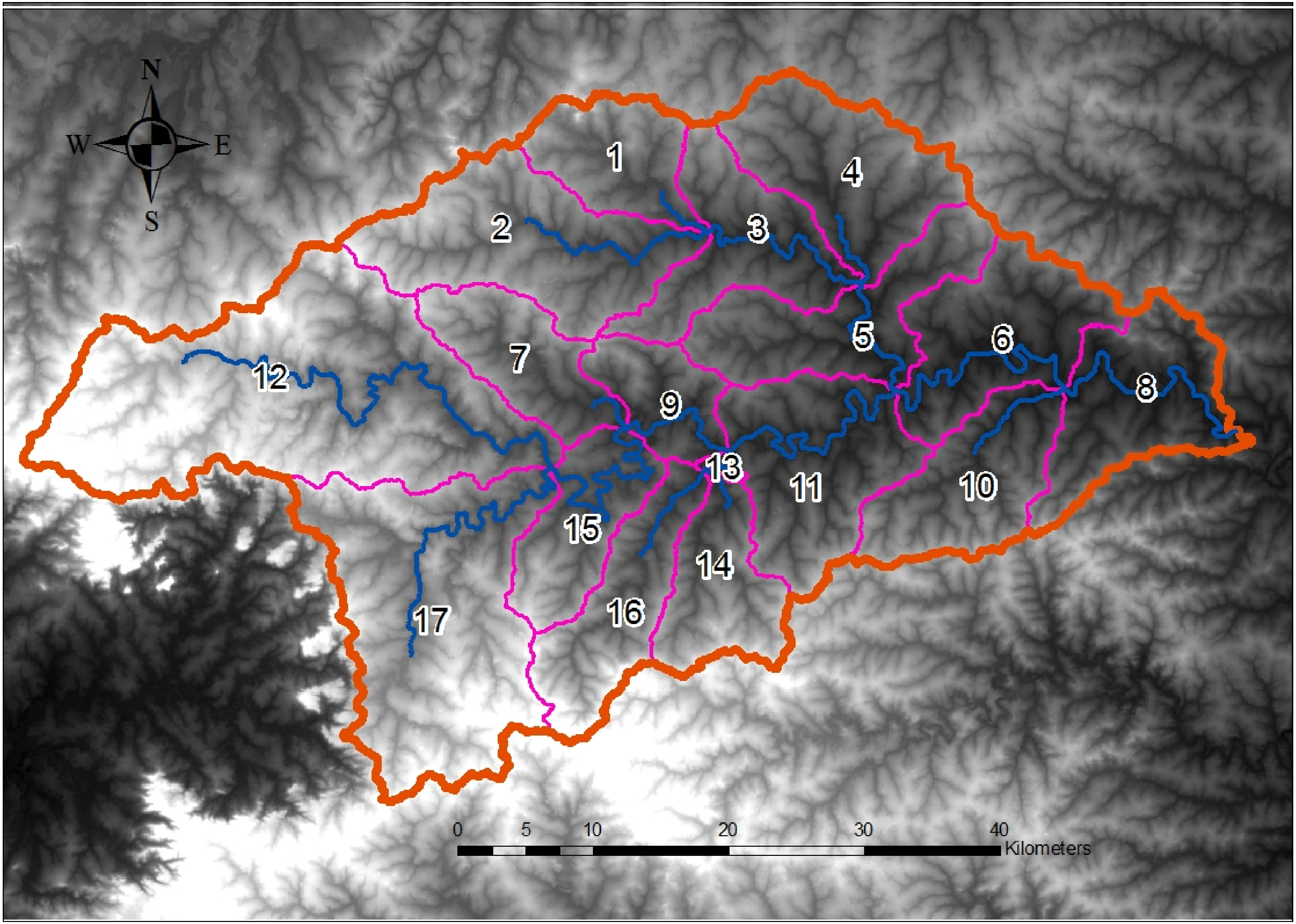
SOL_Z4	SOL_BD4	SOL_AWC4	SOL_K4	SOL_CBN4	CLAY4	SILT4	SAND4	ROCK4	SOL_ALB4	USLE_K4	SOL_EC4
800.00	1.40	0.05	0.90	3.65	52.00	18.00	30.00	4.00	0.00		0.00
800.00	1.45	0.11	1.20	3.00	35.00	18.00	47.00	10.00	0.00		0.00

SOL_Z5	SOL_BD5	SOL_AWC5	SOL_K5	SOL_CBN5	CLAY5	SILT5	SAND5	ROCK5	SOL_ALB5	USLE_K5	SOL_EC5
1000.00	1.39	0.05	0.80	3.50	54.00	17.00	29.00	4.00	0.00		0.00
1000.00	1.40	0.09	1.10	2.80	36.00	18.00	46.00	6.00	0.00		0.00

DEFINITIONS

METHODOLOGY

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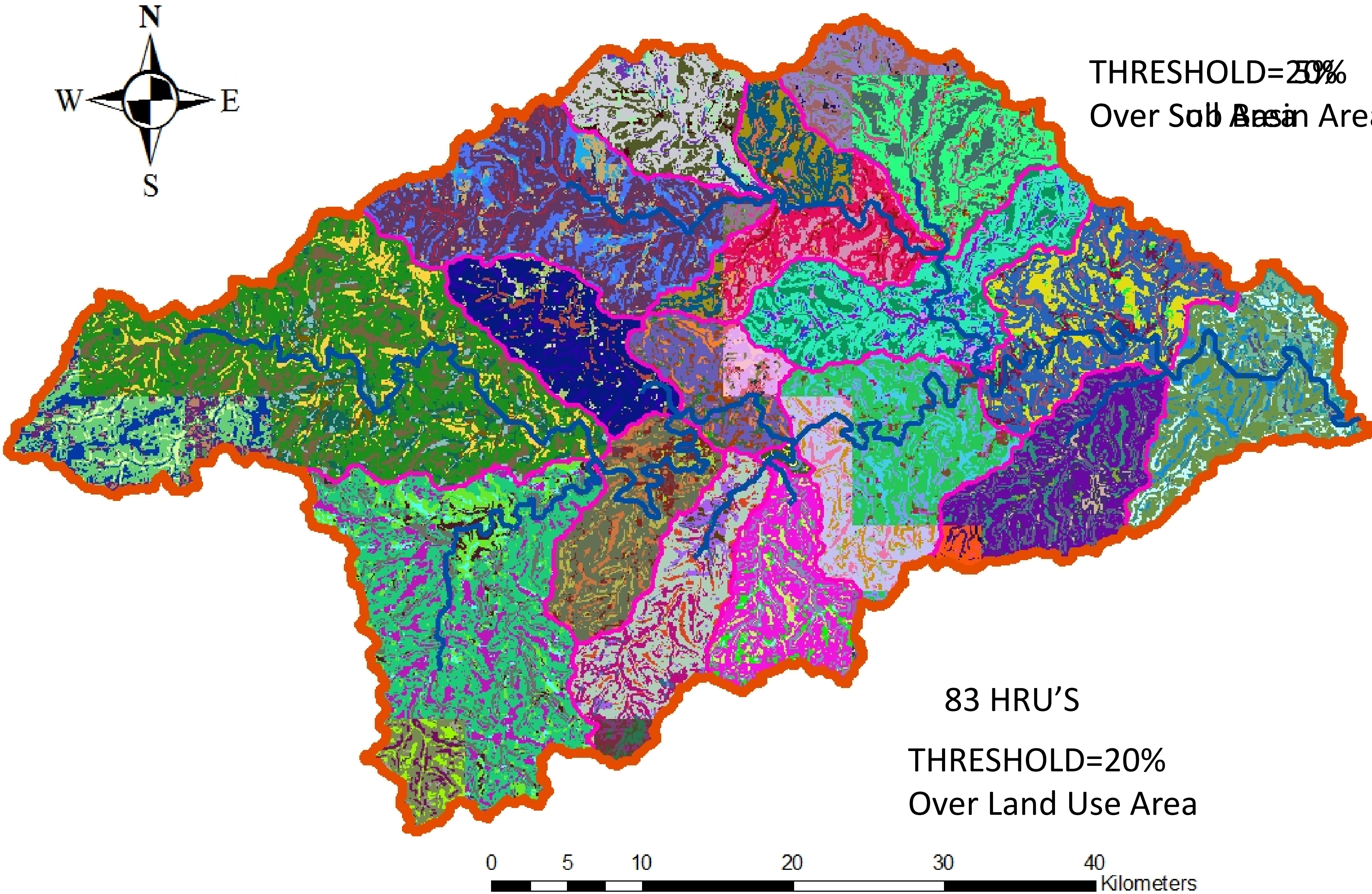
Kilometers


N
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S
THRESHOLD=20%
Over Sub Basin Area
83 HRU'S
THRESHOLD=20%
Over Land Use Area
0
5
10
20
30
40
Kilometers

For any process studied with SWAT, water balance is the driving force behind what is happening in the watershed.

$$SW_t = SW_0 + \sum_{i=1}^{t} (Ri - Qi - ETi - Pi - QRi)$$

SW_t is the final soil water content (mm H_2O); **SW_0** is the initial soil water content(mm H_2O);

t is the time for the simulation period(days);

R_i precipitation,

Q_i runoff

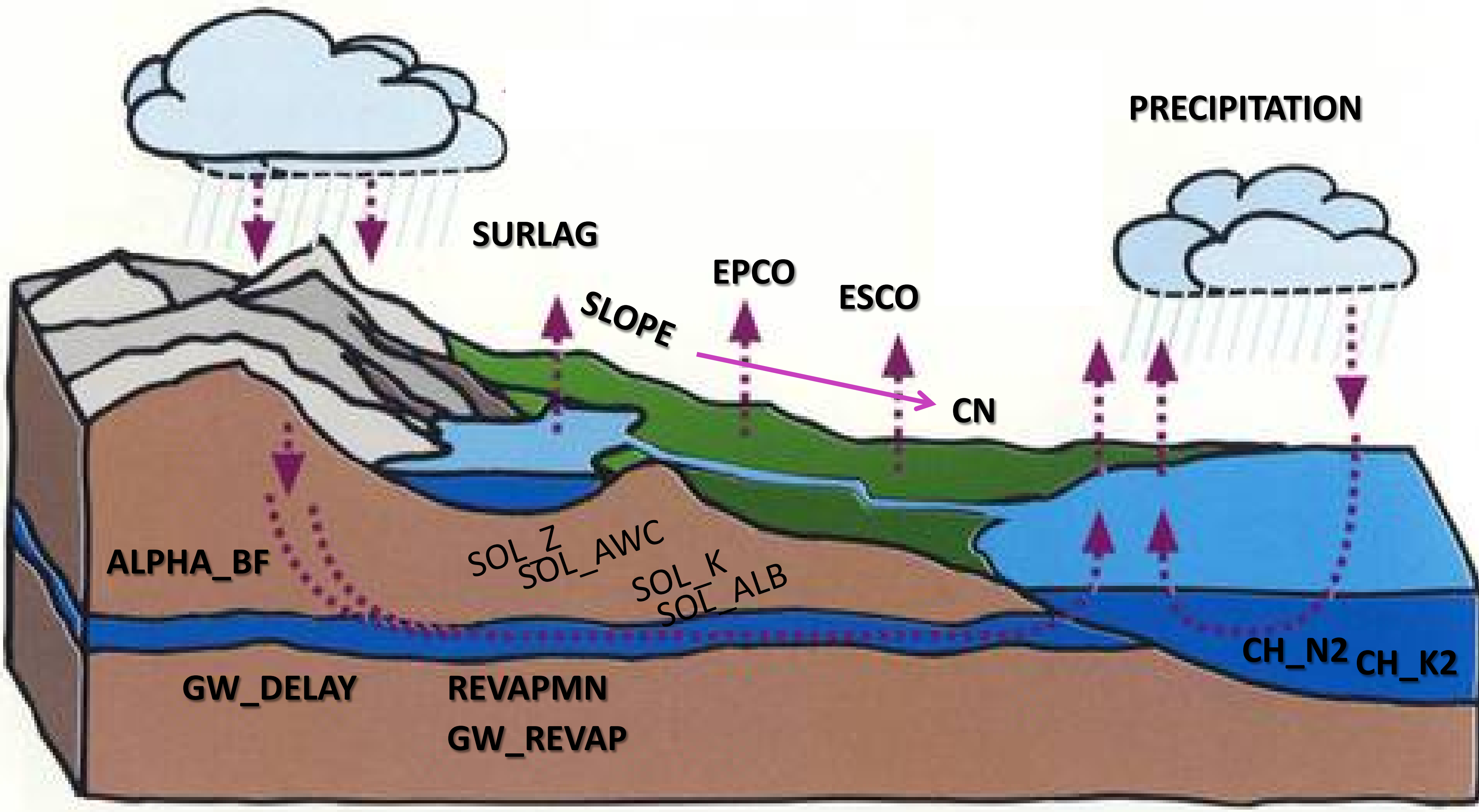
$$SW_t = SW_0 + \sum_{i=1}^{t} (Ri - Qi - ETi - Pi - QRi)$$

Et_i evapo-transpiration

P_i Percolation

QR_i return flow, on day i(mm H_2O).

Parameters involved in stream flow modeling.

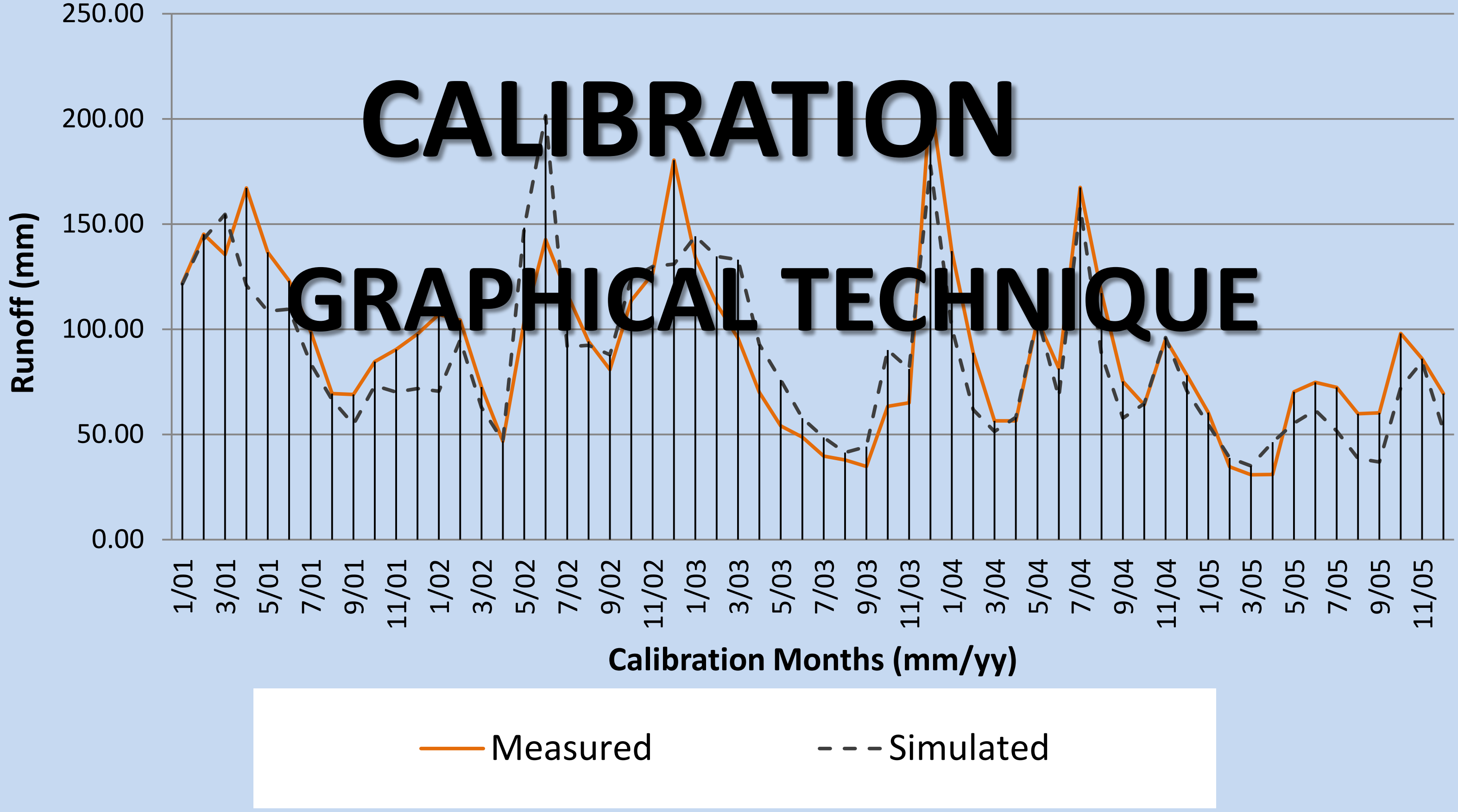


RELATIVE ORDER OF SENSITIVITY OF PARAMETERS GOVERNING RUNOFF RESPONSE

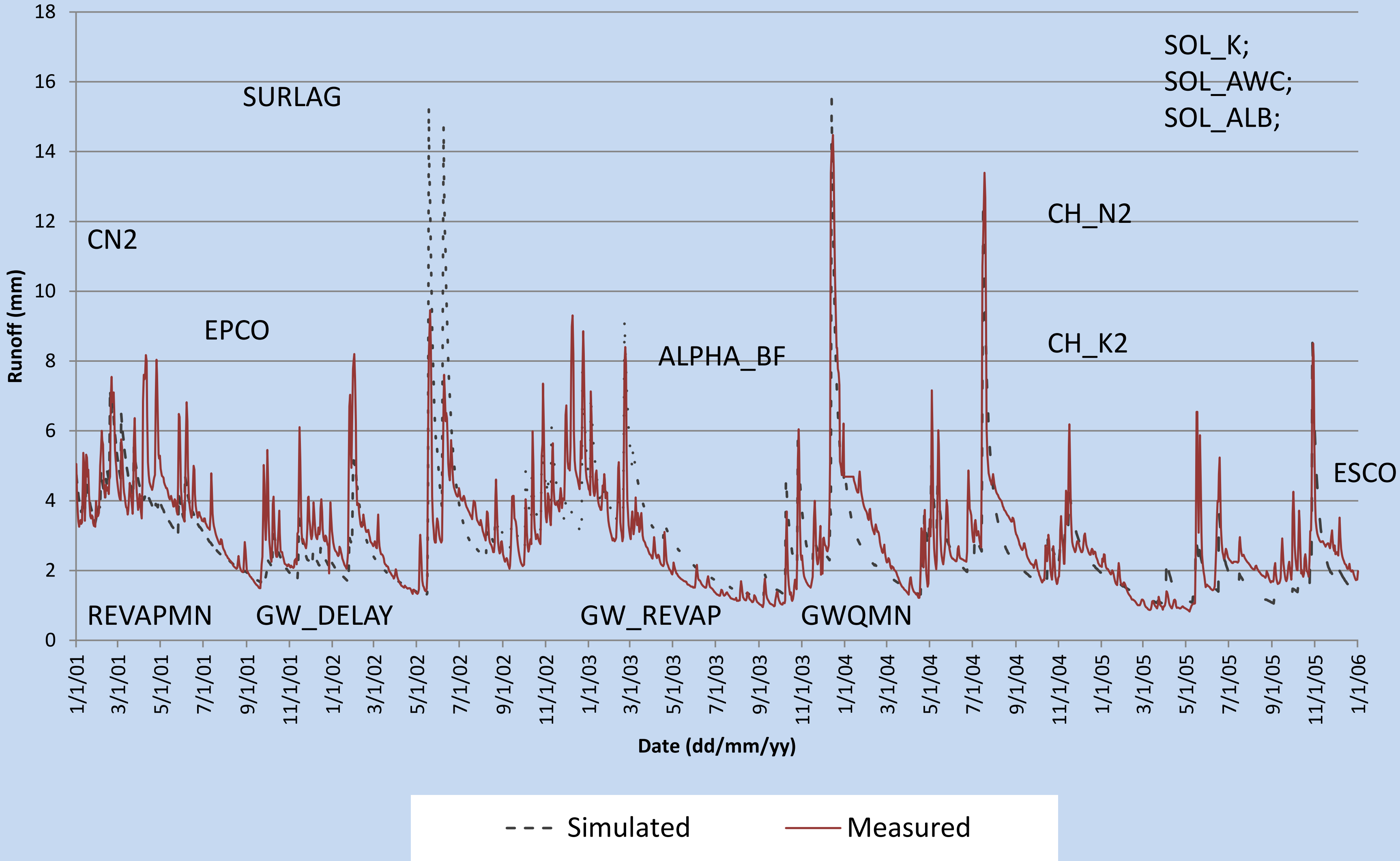
INITIAL SENSITIVITY ANALYSIS

Sensitivity Order	Parameter code*	Range Lower	Range Upper	Sub basin data
1	Alpha_Bf	0	1	*.gw
2	Surlag	0	10	*.bsn
3	Ch_N2	0	1	*.rte
4	Ch_K2	0	150	*.rte
5	Cn2	-25	25	*.mgt
6	Esco	0	1	*.hru,*.bsn
7	Gwqmn	0	1000	*.gw
8	Sol_Z	-25	25	*.sol
9	Gw_Delay	-10	10	*.gw
10	Sol_Awc	-25	25	*.sol
11	Canmx	0	10	*.hru
12	Blai	0	1	*crop.dat
13	Gw_Revap	-0.036	0.036	*.gw
14	Sol_K	-25	25	*.sol
15	Epco	0	1	*.hru,*.bsn
16	Revapmn	-100	100	*.gw
17	Sol_Alb	-25	25	*.sol
18	Slope	-25	25	*.hru
19	Biomix	0	1	*.mgt

Monthly runoff
Calibration Period 2001-2005



Daily Runoff
Calibration Period 2001-2005



STATISTICAL TECHNIQUE

Coefficient of Determination (R^2):

$$R^2 = \left[\frac{\sum_{i=1}^{n}(O_i - O_{aver})(P_i - P_{aver})}{\left[\sum_{i=1}^{n}(O_i - O_{aver})^2 \ \sum_{i=1}^{n}(P_i - P_{aver})^2\right]^{0.5}}\right]^2$$

Nash-Sutcliffe efficiency (NSE):

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

Percent bias (PBIAS):

$$PBIAS = \left[\frac{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right) * 100}{\sum_{i=1}^{n} Y_i^{obs}}\right]$$

PREFORMANCE RATING

Coefficient of Determination (R^2):

Greater than 0.5 are considered acceptable (Santhi et al., 2001, Van Liew et al., 2003).

Nash-Sutcliffe efficiency (NSE):

Model	Value	Performance Rating
SWAT	>0.65	Very Good
SWAT	0.54 to 0.65	Adequate
SWAT	>0.5	Satisfactory

Percent bias (PBIAS):

Model	Value	Performance Rating
SWAT	<10%	Very Good
SWAT	<10% to <15%	Good
SWAT	<15% to <25%	Satisfactory
SWAT	>25%	Unsatisfactory

(Moriasi et al.2007).

CALIBRATED VALUES OF PARAMETERS

Parameters Code*	Unit	Initial Value	Calibrated Value
ALPHA_BF	days	0.018	0.0075
CH_K2	mm/hr	0.5	9.7
CH_N2	n/a	0.04	0.09
CN2	n/a	73,60,85,78	42,65,61
EPCO	Fraction	1	0.8
ESCO	Fraction	0.95	0.9
GW_DELAY	days	31	3.24
GW_REVAP	n/a	0.02	0.02
GWQMN	mm	0	500
REVAPMN	mm	1	50
SOL_ALB	top layer	0.27	0.17
SOL_Z	mm	1000	1000
SURLAG	days	4	0.45
SOL_AWC	(mmH2O/mm)	0.05,0.04,0.04,0.05,0.05	0.15,0.2,0.2,0.21,0.25
SOL_AWC	(mmH2O/mm)	0.1,0.1,0.1,0.11,0.09	0.11,0.15,0.15,0.17,0.20
SOL_K	(mm/hr)	1.5,1,1,0.9,0.8	4.2,4.21,2.34,1.17,0.7
SOL_K	(mm/hr)	3.4,1.5,1.3,1.2,1.1	42.05,23.36,17.52,11.68,4.67

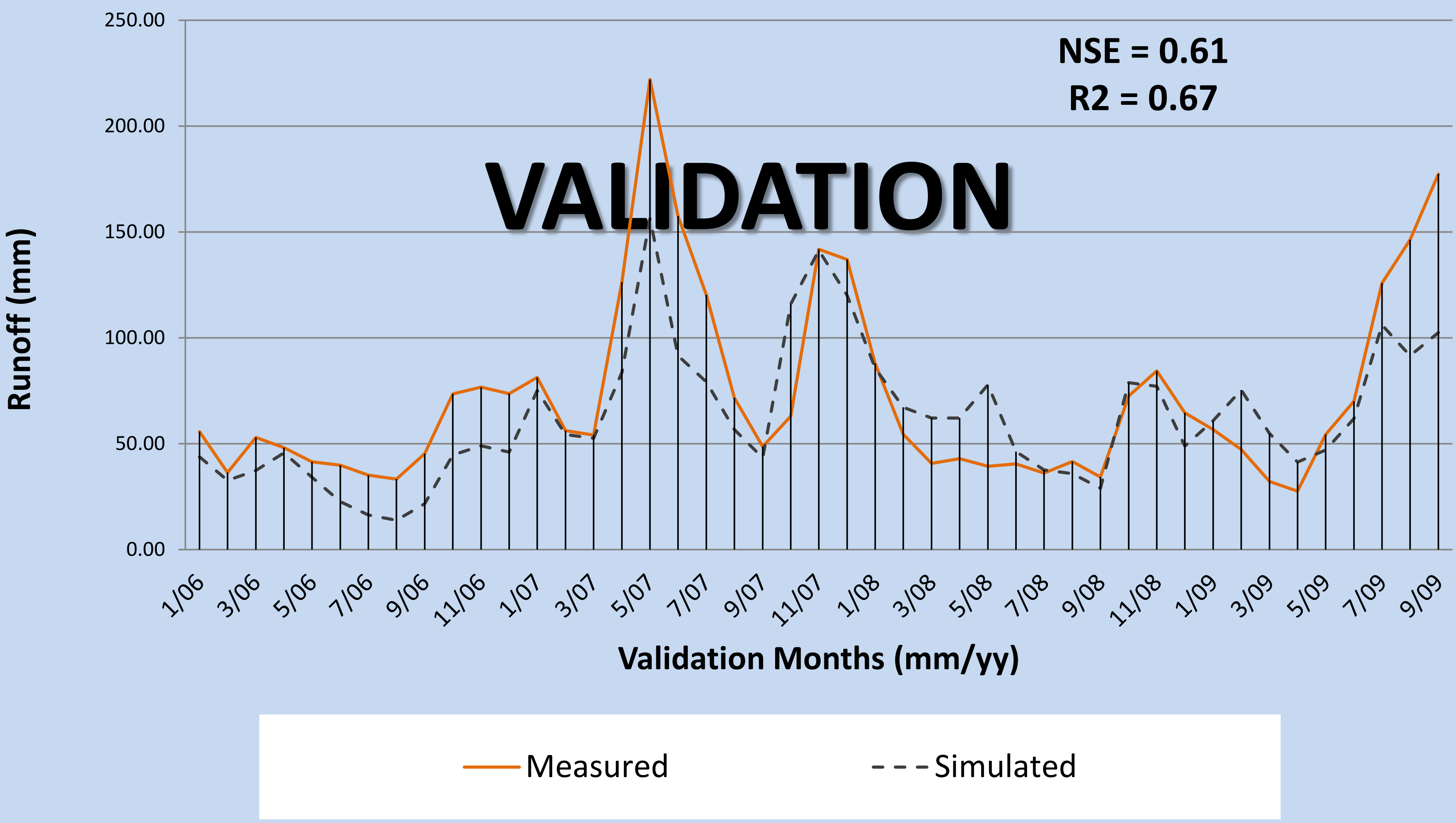
NSE AND R^2 INDEXES VALUES FOR MODEL EVALUATION IN MONTHLY AND DAILY BASIS.

	Daily		Monthly	
	NSE	**R2**	**NSE**	**R2**
Calibration Period 2001-2005	0.612	0.652	0.695	0.727
Validation Period 2006-2009	0.549	0.5844	0.610	0.670

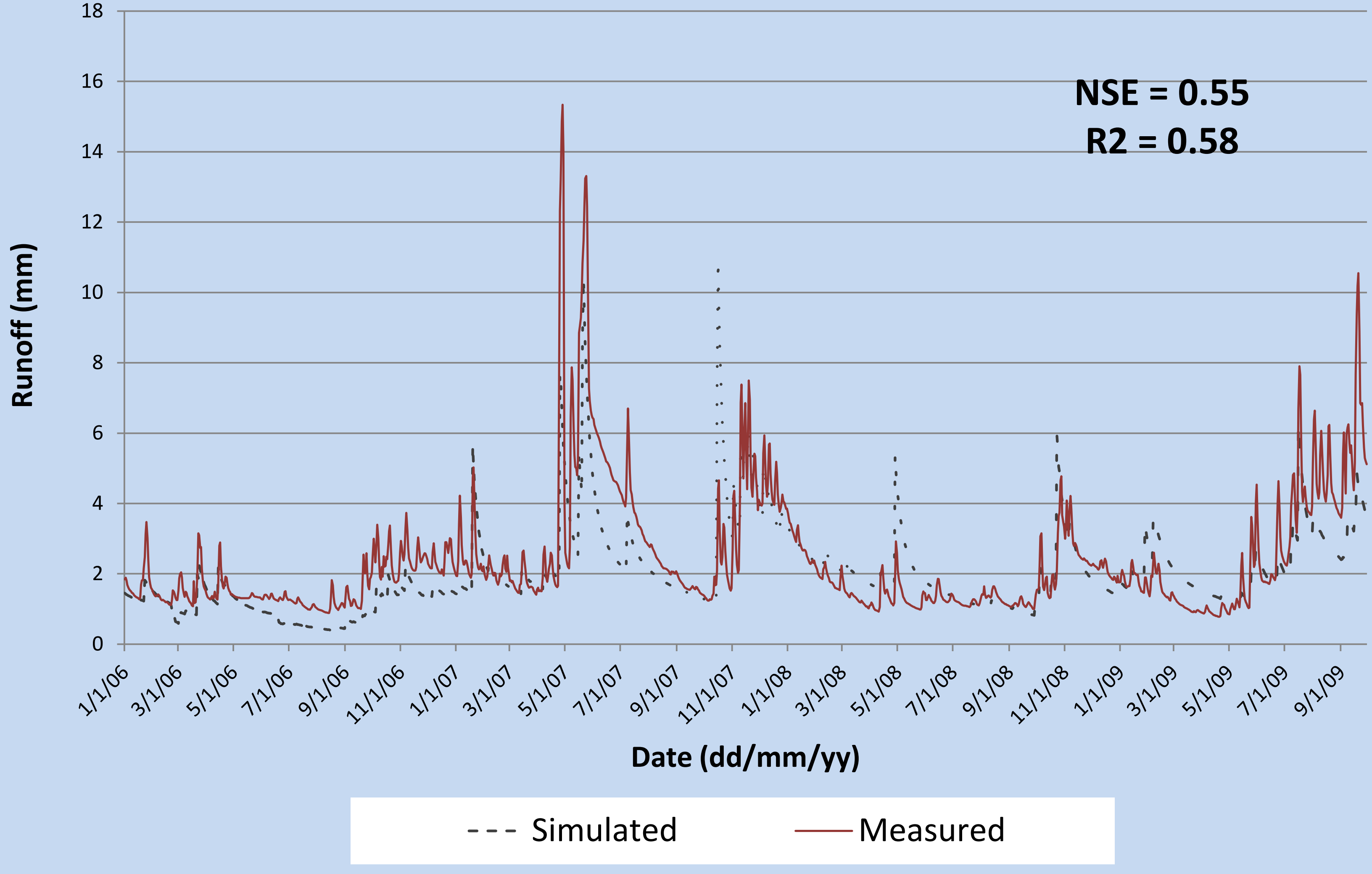
YEARLY PBIAS

Year	DISCHARGE (mm)	SIMULATED (mm)	BIAS
2001	1339.5	1178.4	12.0
2002	1289.3	1281.8	0.6
2003	965.2	1121.4	-16.2
2004	1122.1	981.3	12.5
2005	748.0	628.0	16.0
2006	612.5	408.2	33.4
2007	1282.0	1070.3	16.5
2008	639.5	708.4	-10.8
2009	737.7	641.6	13.0

Monthly runoff
Validation Period 2005-2009



Daily Runoff
Validation Period 2005-2009



CONCLUSIONS

1. During the calibration

	Daily	
	NSE	R2
Calibration Period 2001-2005	0.612	0.652

Satisfactory performance of the model

	Monthly	
	NSE	R2
Calibration period 2001-2005	[illegible]	[illegible]

Very good performance of the model

PBIAS varied between ±16% which could be considered as good overall annual simulation

CONCLUSIONS

2. During the Validation

The PBIAS remained within ±16.5% except for year 2006 where the annual PBIAS of 33.4% was obtained indicating under simulation of discharge from model. Therefore on the basis of PBIAS the model performance can be rated as good except for year 2006.

	Monthly	
	NSE	R2
Validation Period 2006-2009	0.610	0.670

	Daily	
	NSE	R2
Validation Period 2006-2009	0.549	0.5844

Satisfactory

performance of the model

CONCLUSIONS

The results obtained from model are rated **acceptable**

Despite the limitations of:

- Using large spatial resolution soil data
- Use of single rain gauge for representing catchment averaged rainfall.

The model captured rather well the dynamic of flow generation, with surface runoff uniformly distributed along the year and shallow aquifer contribution during winter’s months of July and August.

CONCLUSIONS

- The simulated discharge from SWAT model, both for **daily and monthly** basis in **Nacunday** watershed can be rated within acceptable range of errors, so future use of the SWAT model for various scenario testing is reasonable.

RECOMMENDATION FOR FURTHER STUDIES

- Further studies may be undertaken to incorporate field-measured parameters and better representation of soil and rainfall distribution information into the model.
- Using more field measurements and fewer default values for inputs may provide better opportunity to improve further the SWAT Model's representation of processes in the Nacunday River Basin.

THANK YOU