Towards the consistent hydrological simulation using SWAT model.
Case Study: Vilcanota Andean basin in Peru

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What is the primary problem during the model calibration procedure?

- **Uncertainty in the determination of model parameters**, owing to the mismatch between model complexity and available data (Devak and Dhanya, 2017; Razmkhah et al., 2017).

To overcome this issue, recent studies have highlighted that the **well-known sensitivity analysis (SA) of model parameters must be carried out prior to calibration** (Devak and Dhanya, 2017; Shen et al., 2012; Song et al., 2015).

How is the SA performed in SWAT?

- **Manual** and **global** SA approaches
- **Discharge** is used as the most common response variable

- Signature measures , e.g., **FDC** (Pfannerstill et al. 2014; Shafii and Tolson 2015; Guse et al. 2016b; Pfannerstill et al. 2017)

Problem: it fails in the **partitioning** of water among the different flowpaths (Shafii et al., 2017)

- **Soft data** in multi objective calibration (e.g. Pfannerstill et al. 2017)
- **Remote sensing data**: evapotranspiration (Parajuli et al., 2018), and soil moisture (Patil and Ramsankaran, 2017)

Problem in automatic SA and Calibration

- Inter-actions among SWAT parameters (Zhang et al. 2018)
- Not considered by sampling design schemes (Devak and Dhanya, 2017; Razmkhah et al., 2017; Song et al., 2015)
- Automatic methods can not control the **equifinality** or non-uniqueness issue.

Consequently, using automatic methods unrealistic parameter values could result despite good performance statistics.

Objective

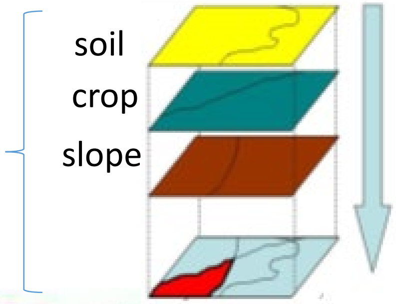
This study aims to improve the parameter identification in order to achieve hydrologically consistent parameter set.

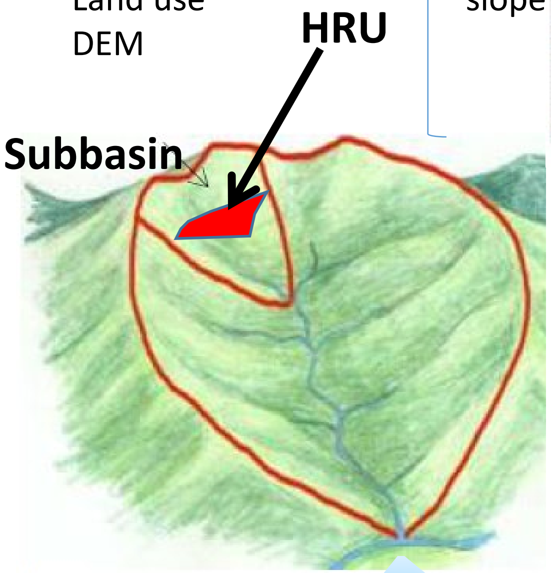
Soil and Water Assessment Tool (SWAT) - USDA

Inputs

Wheather
Soil
Land use
DEM

Defined by unique combination of:



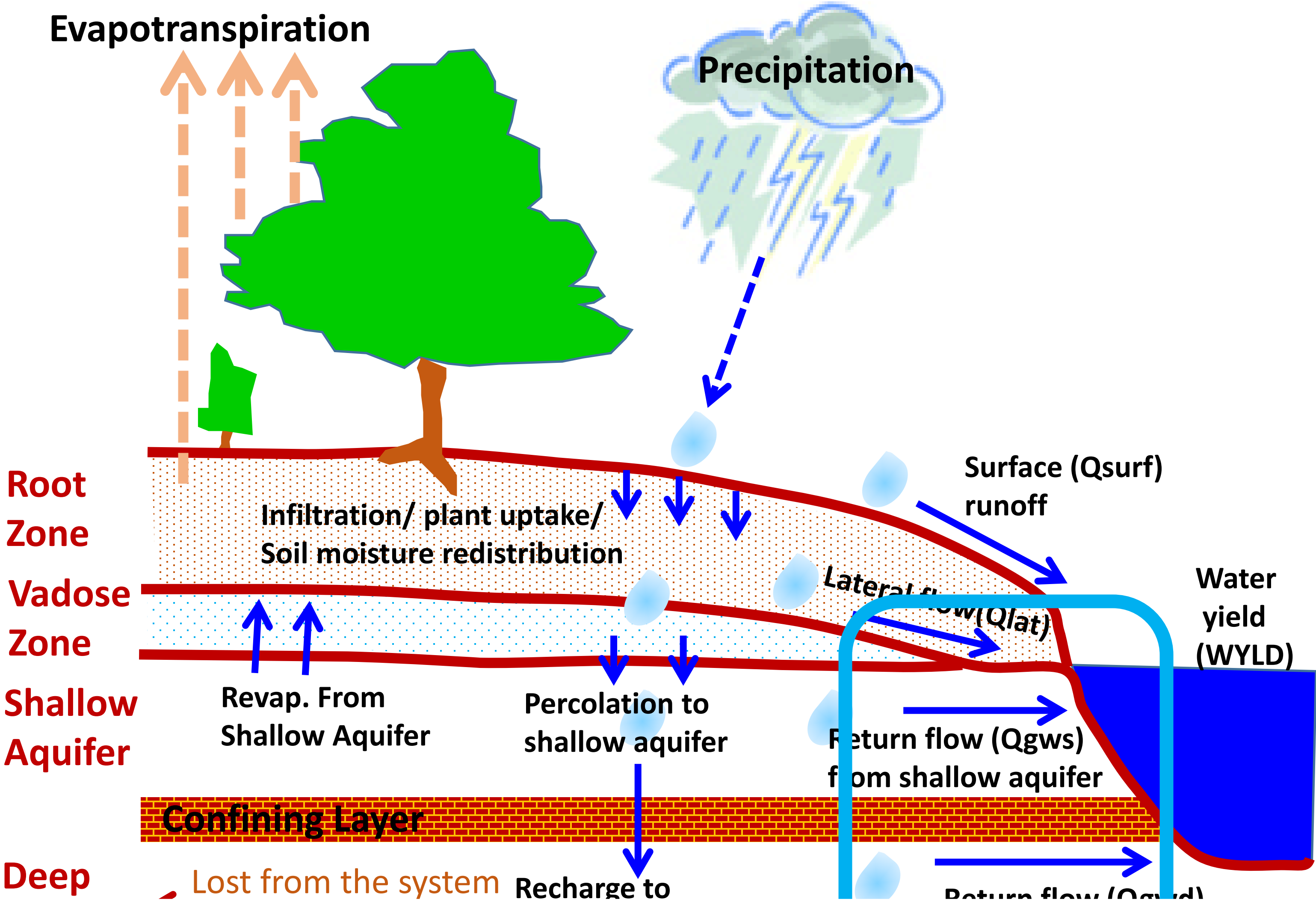


outputs

Water 

Sediments 

Nutrients 



- Suggestion: the official SWAT literature needs to be updated regarding the deep aquifer behavior.
- Be careful with SWAT Check program in the baseflow index estimation

Proposed methodology: Multi-objective Process-Based sensitivity analysis.

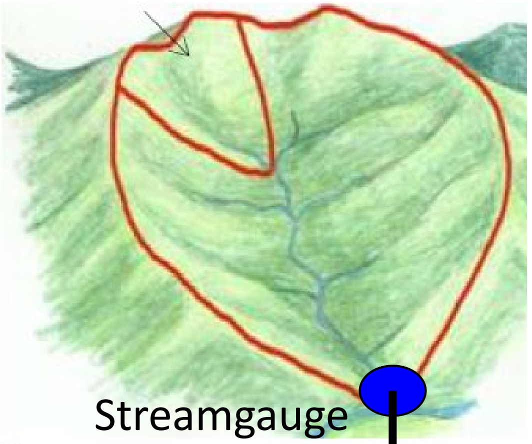
Where is analyzed the parameter influence on:

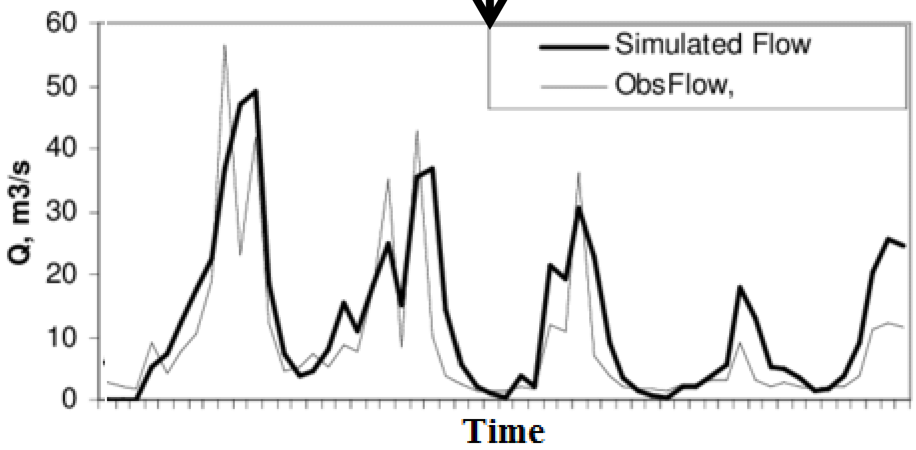
- **Model performance on discharge simulation**

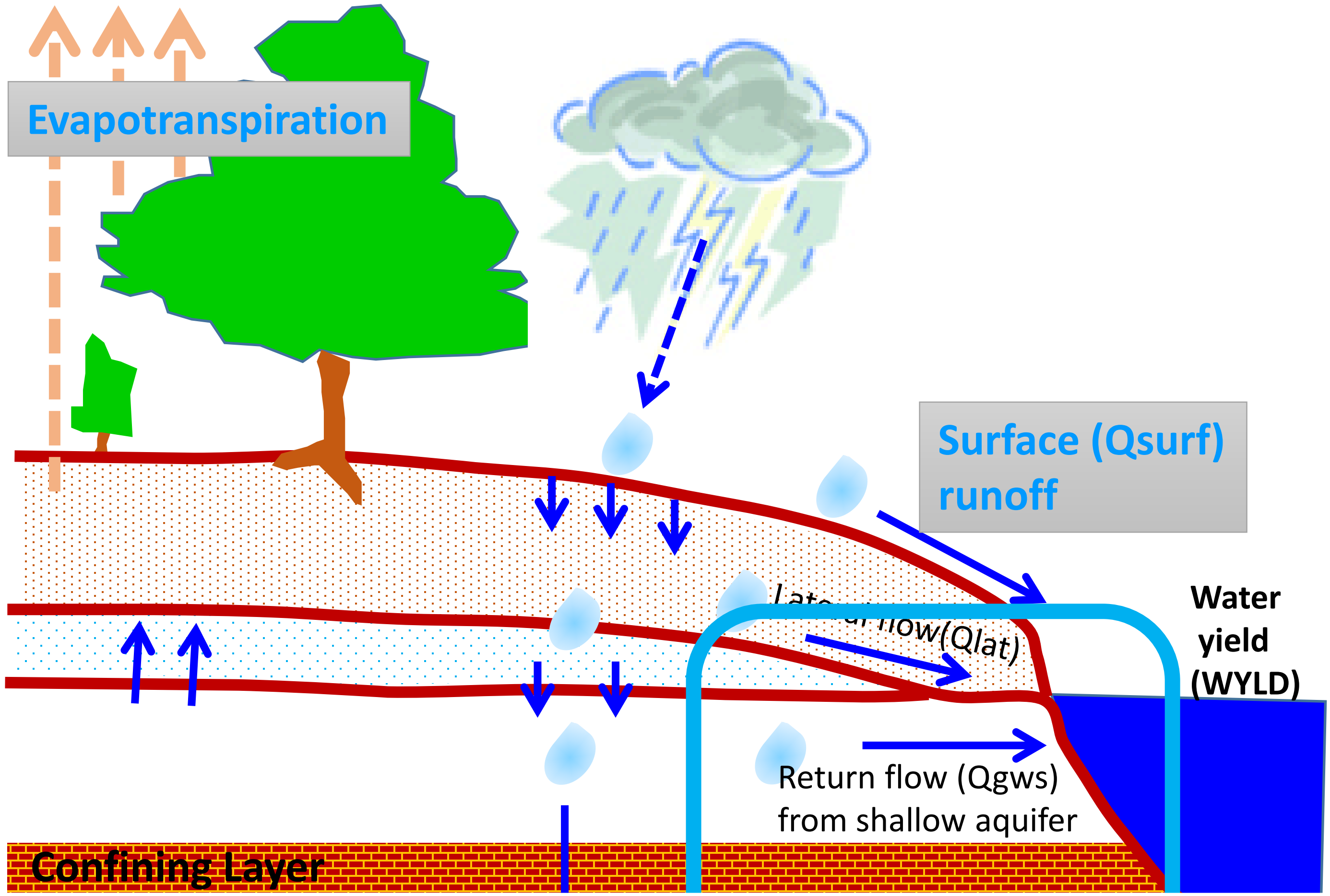
Nash-Sutcliffe – NSE, Percentage of bias - PBIAS

- **hydrological processes**

Evapotranspiration, surface runoff and baseflow quantification







Desired values:
NSE=1, PBIAS=0%

SWAT_BFI (BF/WYLD) equal to BFI estimated by the baseflow filter program (BFLOW)

Hydrological simulation for Vilcanota river basin

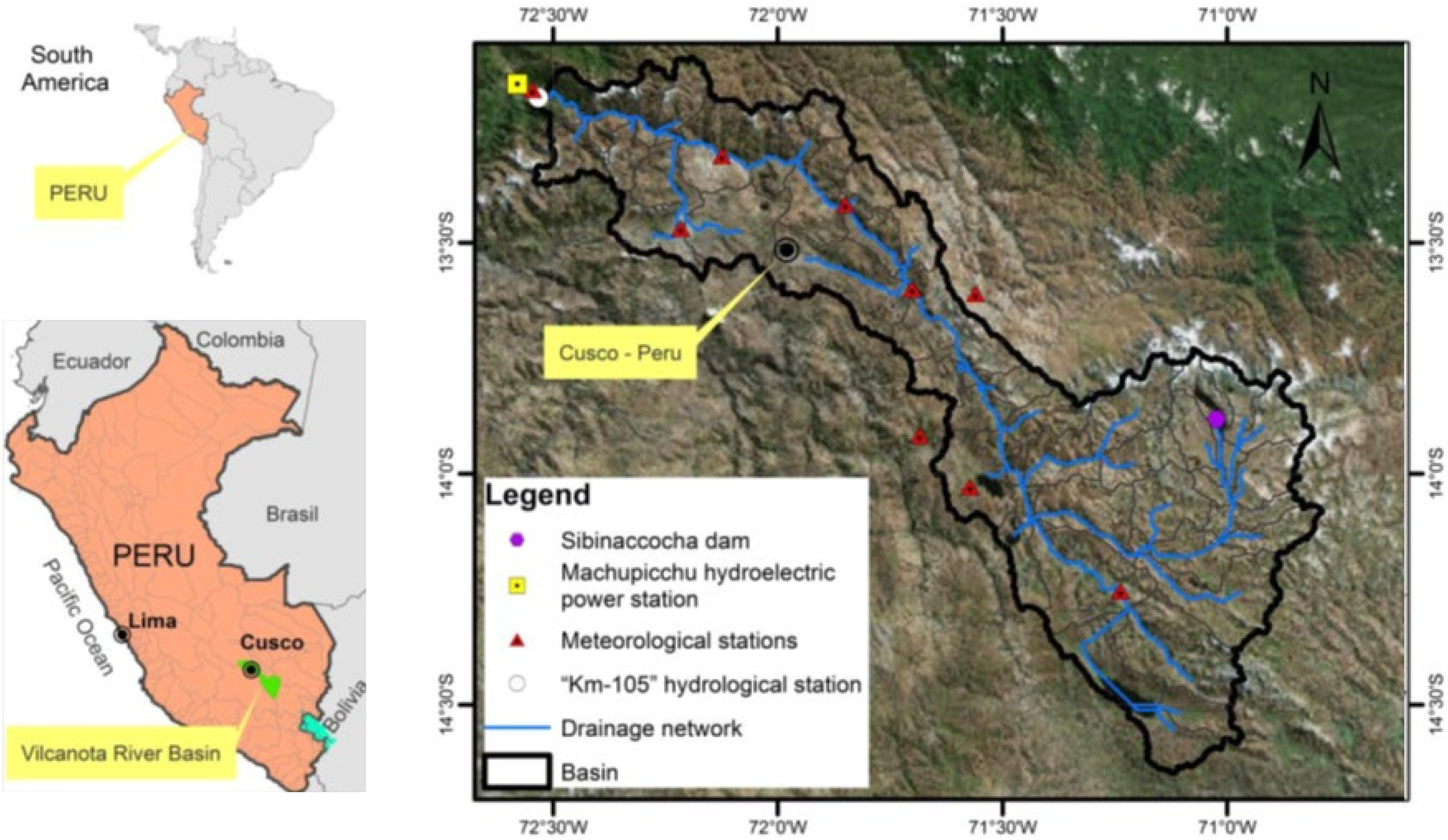


Figure: Location of the study area and hydrometeorological stations network

Surface: 9613 km^2

Altitudes ranging from
2124 to 6309

Precipitation: 800 mm/year
(>80 % ; October – March)

Daily discharges:
30 m^3/s (dry season)
to 1100 m^3/s (rainy season)

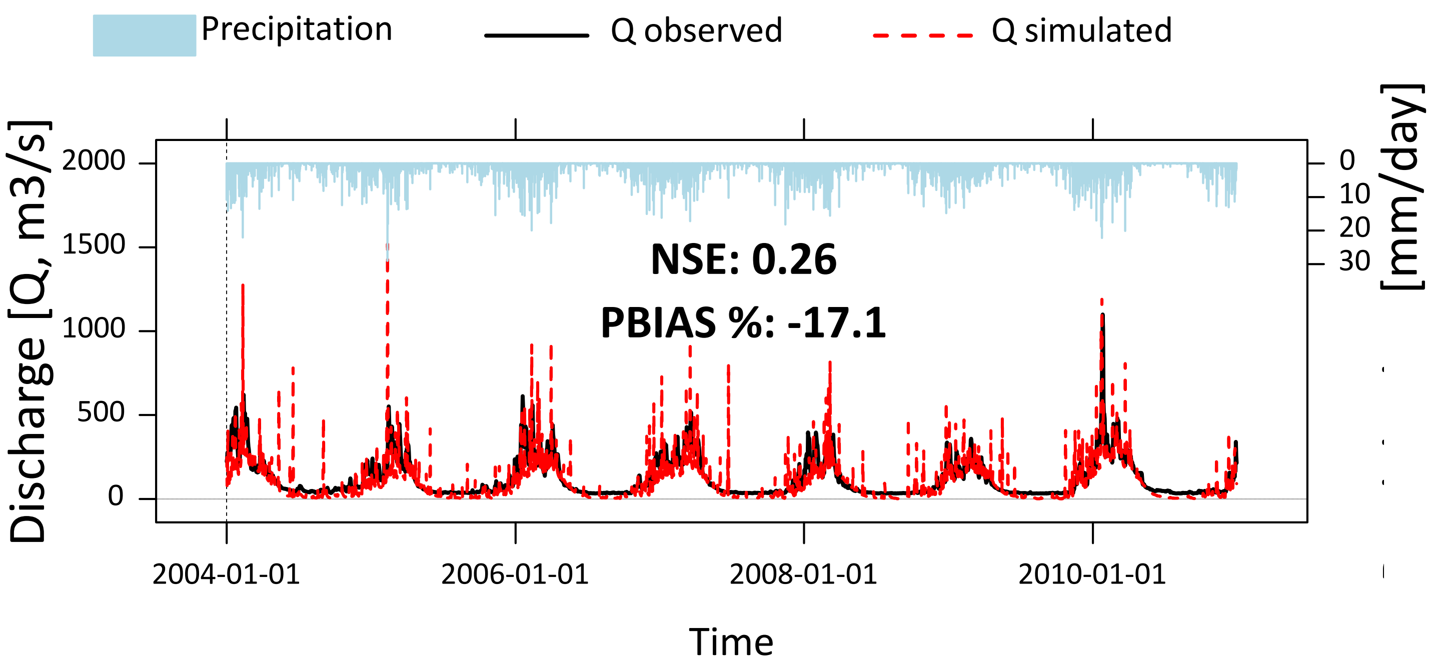
Average daily discharge :
133 m^3/s

Data

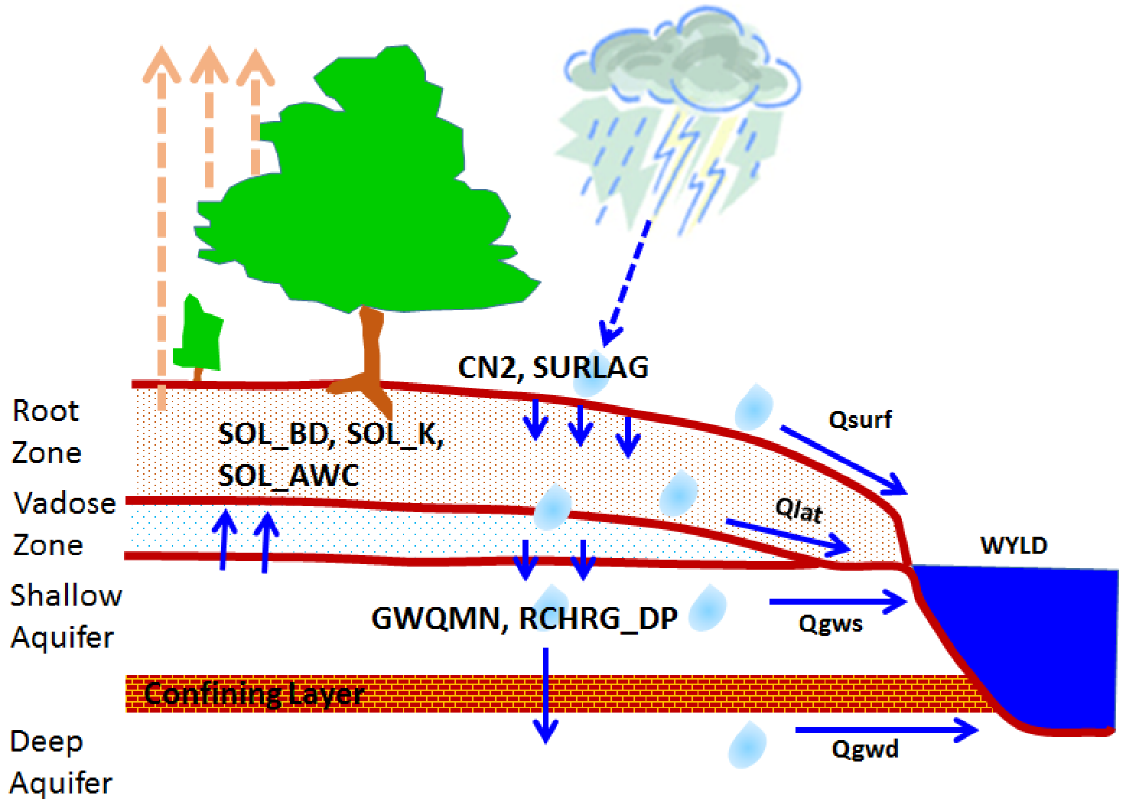
Table : Data type, resolution and data source

Type of data	Resolution	Source	Link
Hydrometeorological data	Daily	SENAMHI and EGEMSA	http://www.senamhi.gob.pe/
DEM	90 m	CGIAR-CSI	http://srtm.csi.cgiar.org/
Land cover	300 m	ESA CCI-LC	http://maps.elie.ucl.ac.be/CCI/viewer/
Soil map	1:5 000 000	FAO-1995, 2003	http://www.waterbase.org/download_data.html

Initial simulation of the model

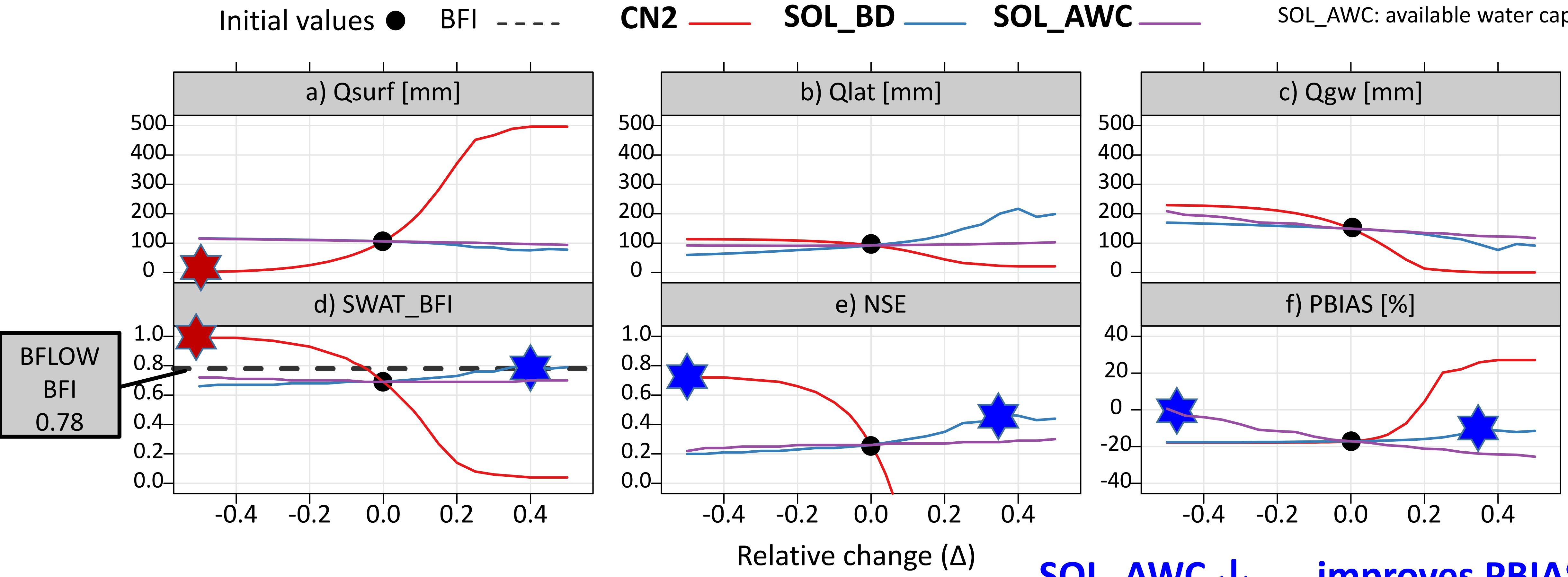


CN2: Curve number
SOL_BD: wet bulk density
SOL_AWC: available water capacity
GWQMN: water depth threshold needed in shallow aquifer so that return flow occurs.
RCHRG_DP: recharge fraction into the deep aquifer.



SWAT parameters sensitivity analysis

CN2: Curve number
SOL_BD: wet bulk density
SOL_AWC: available water capacity

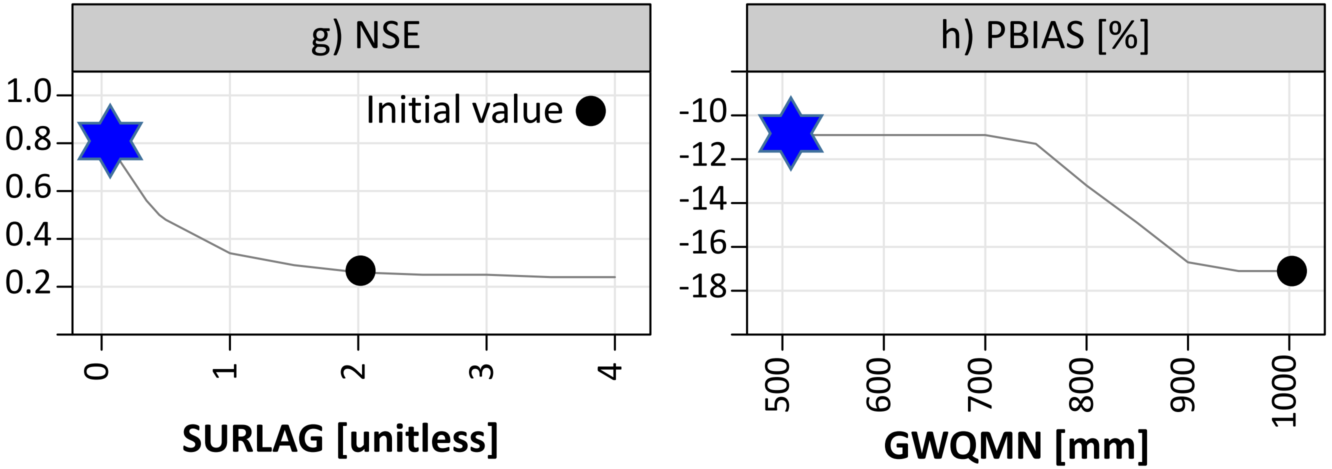


SOL_AWC ↓ improves PBIAS

Good NSE but unrealistic representation of surface runoff and BFI

CN2 calibration is no necessary since ↑SOL_BD improves SWAT_BFI, NSE, PBIAS

SWAT parameters sensitivity analysis



- **↓SURLAG improves NSE**
- **↓GWQMN improves PBIAS**

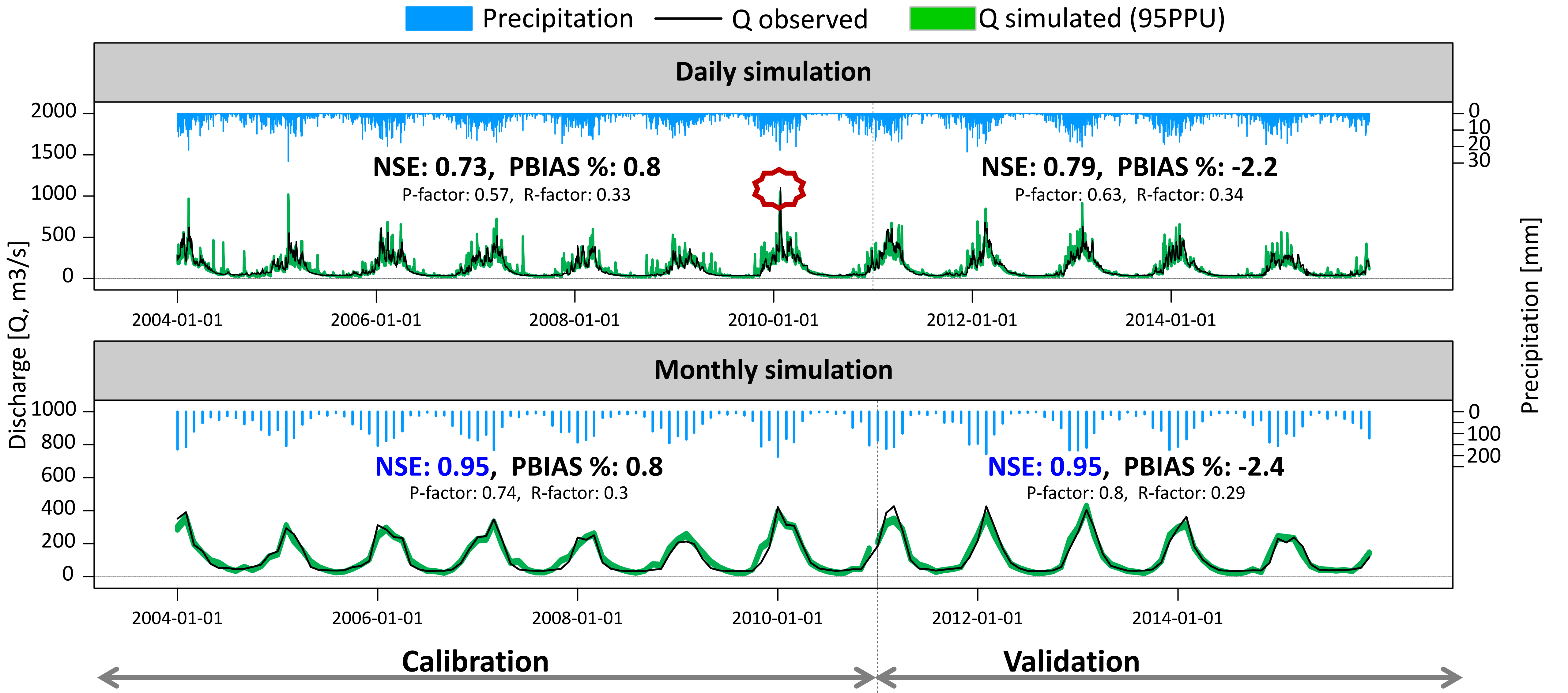
SUFI-2 SWATCUP

Table:
Parameter values of the calibrated SWAT model

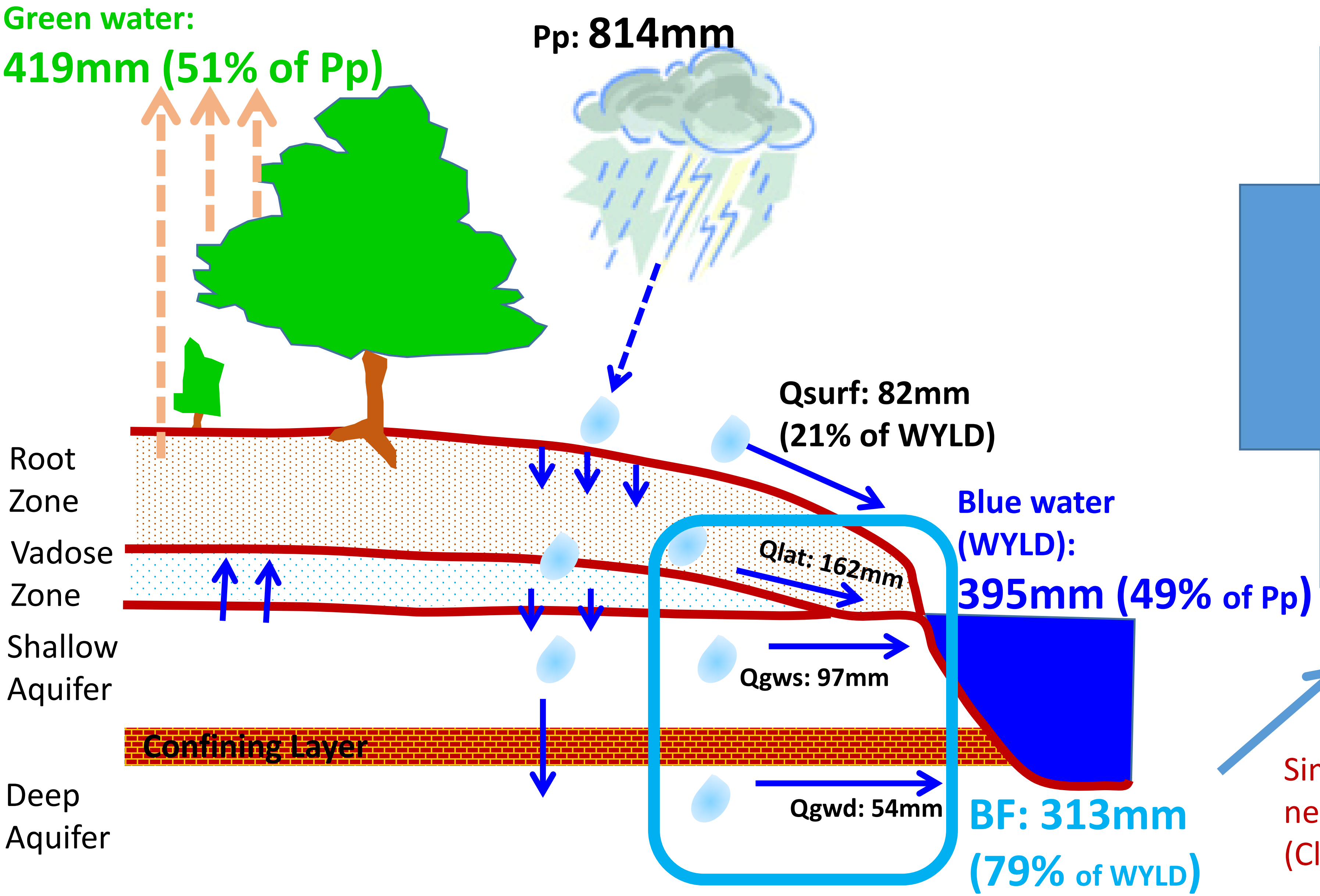
Order	Parameter	Range	Ajusted value
1	SURLAG(v)	[0.2, 0.5]	0.20
2	SOL_BD(r)	[0.2, 0.5]	0.34
3	SOL_AWC(r)	[-0.5, -0.2]	-0.33
4	GWQMN(v)	[600, 700]	681.30
5	RCHRG_DP(v)	[0.3, 0.5]	0.36

"v": replaced "r": relative change

observed versus simulated hydrograph



Average annual water balance of VRB



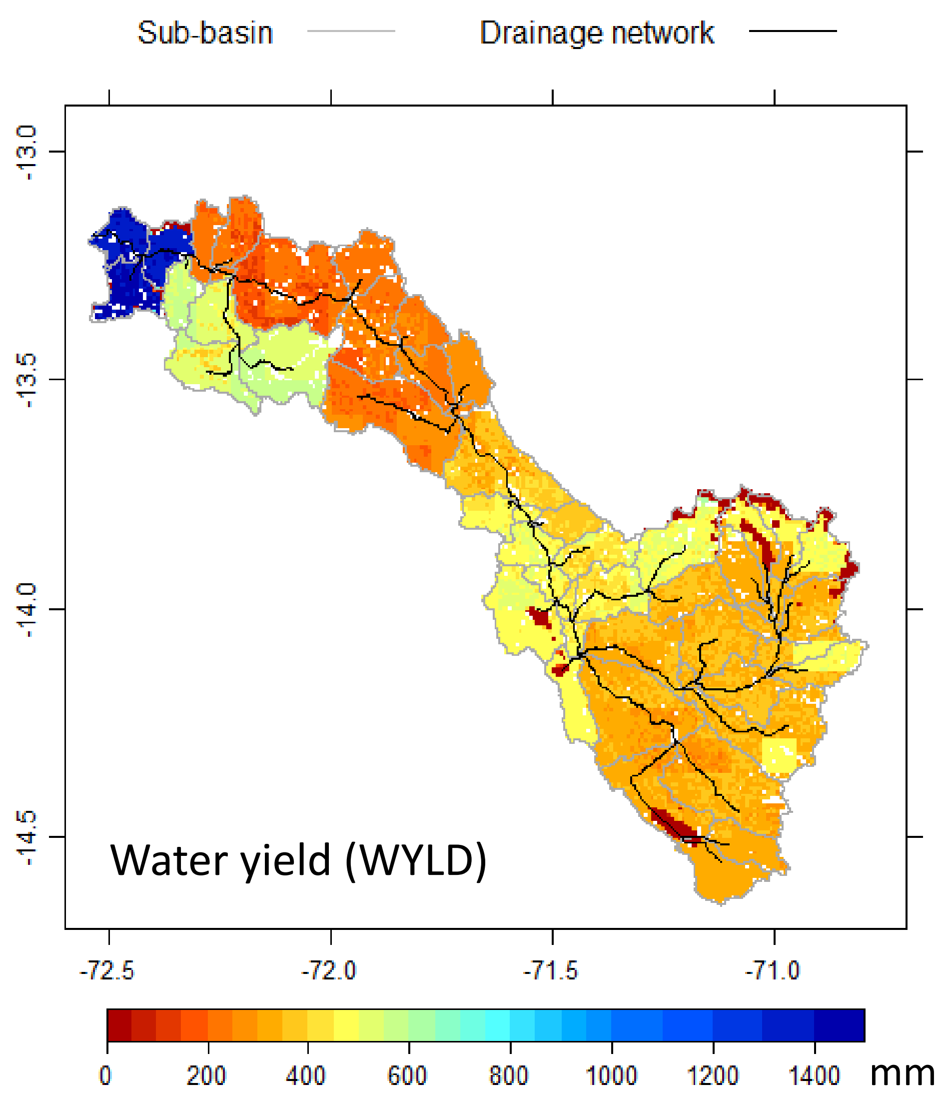
Finding:

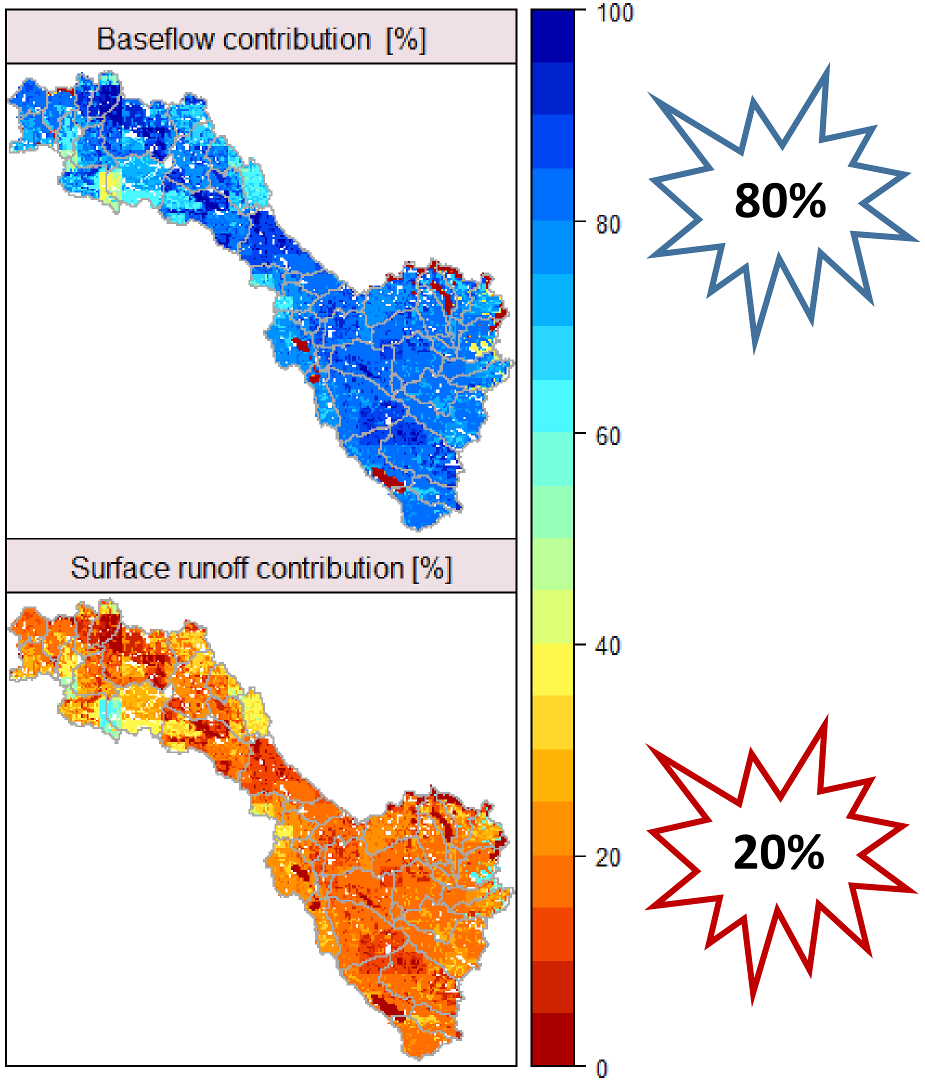
SWAT is capable to quantify the baseflow and surface runoff contribution.

SWAT_BFI 0.79 ≈ BFLOW_BFI 0.78

Similar to observed BFI (**0.77**) in the neighboring Andean Kosñypata basin (Clark et al. 2014)

Water potential (Qsurf + Qbf)





Conclusion

The results demonstrated that the set of sensitive parameters obtained with our approach provided consistency of SWAT results regarding the water balance components and discharges simulation.

Suggestions

Realistic hydrological simulation based on process-based calibration should be used for an appropriate assessment of:

- Basin hydrological processes,
- Sediments quantification,
- Land use change,
- Climate change,
- Usefulness of satellite-based precipitation in hydrological modeling and other hydrological studies.

THANKS