Calibration and Uncertainty Issues

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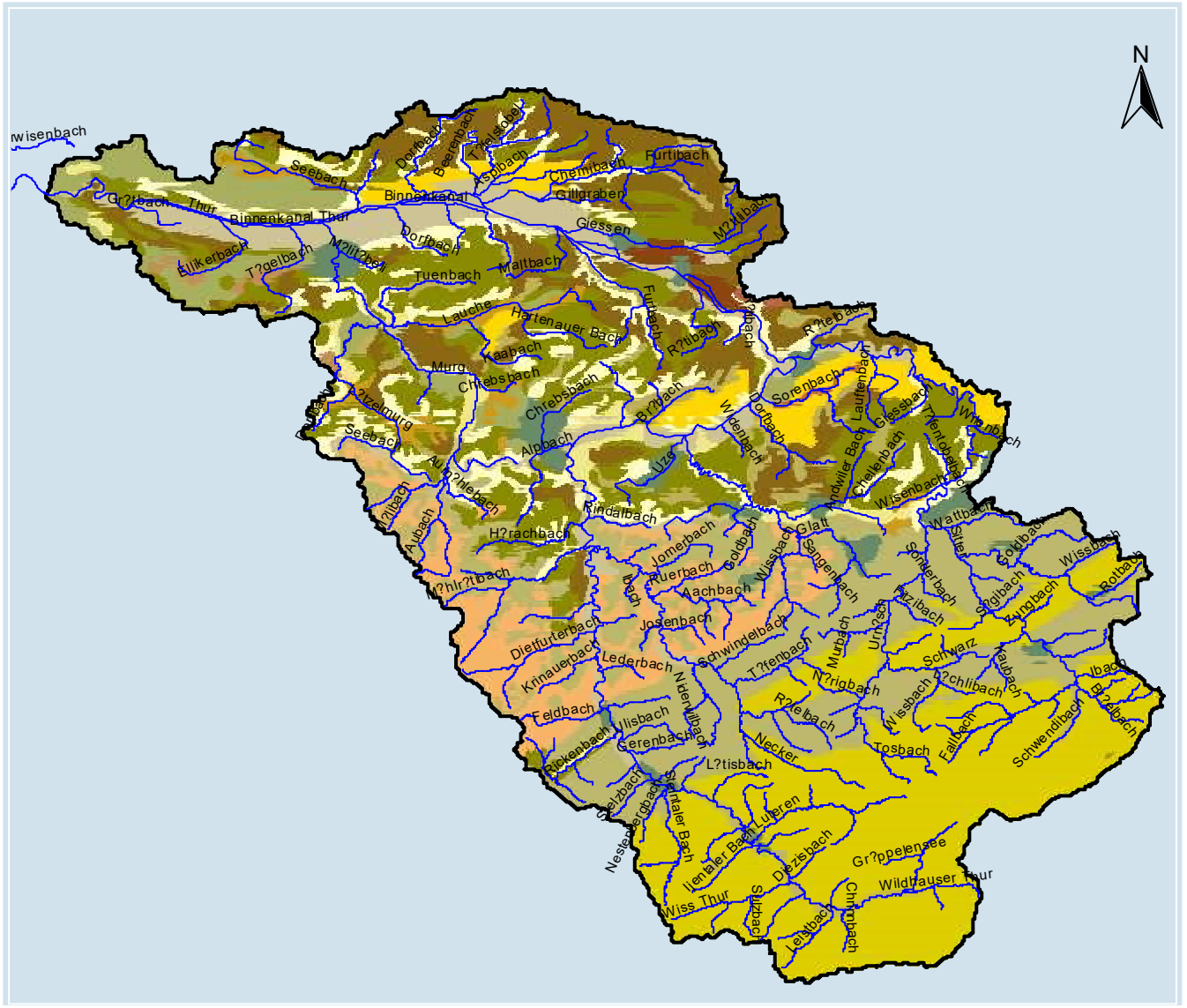
Calibration Issues…

- Parameterization (regionalization of parameters)

(most important, difficult, and neglected aspect of calibration)



Calibration Issues…

- Objective function definition

(most surprising aspect of calibration)

$$R^2 = \frac{\left[\sum_i (Q_{m,i} - \overline{Q}_m)(Q_{s,i} - \overline{Q}_s)\right]^2}{\sum_i (Q_{m,i} - \overline{Q}_m)^2 \sum_i (Q_{s,i} - \overline{Q}_s)^2}$$

$$SSQR = \frac{1}{n}\sum_{i=1}^{n}\left[Q_{i,m} - Q_{i,s}\right]^2$$

$$g = w_1 \sum_{i=1}^{n_1} (Q_m - Q_s)_i^2 + w_2 \sum_{i=1}^{n_2} (S_{\cdots} - S_{\cdot})_{\cdot}^2 + w_{\cdot} \sum^{n_3} (N_{\cdots} - N_{\cdot})_{\cdot}^2 + \ldots..$$

$$KGE = 1 - \sqrt{(r-1)^2 + (\alpha - 1)^2 + (\beta - 1)^2}$$

$$PBIAS = 100 * \frac{\sum_{i=1}^{n} (Q_m - Q_s)_i}{\sum_{i=1}^{n} Q_{m,i}}$$

$$NS = 1 - \frac{\sum_i (Q_m - Q_s)_i^2}{\sum_i (Q_{m,i} - \overline{Q}_m)^2}$$

$$\chi^2 = \frac{\sum_i (Q_m - Q_s)_i^2}{\sigma_m^2}$$

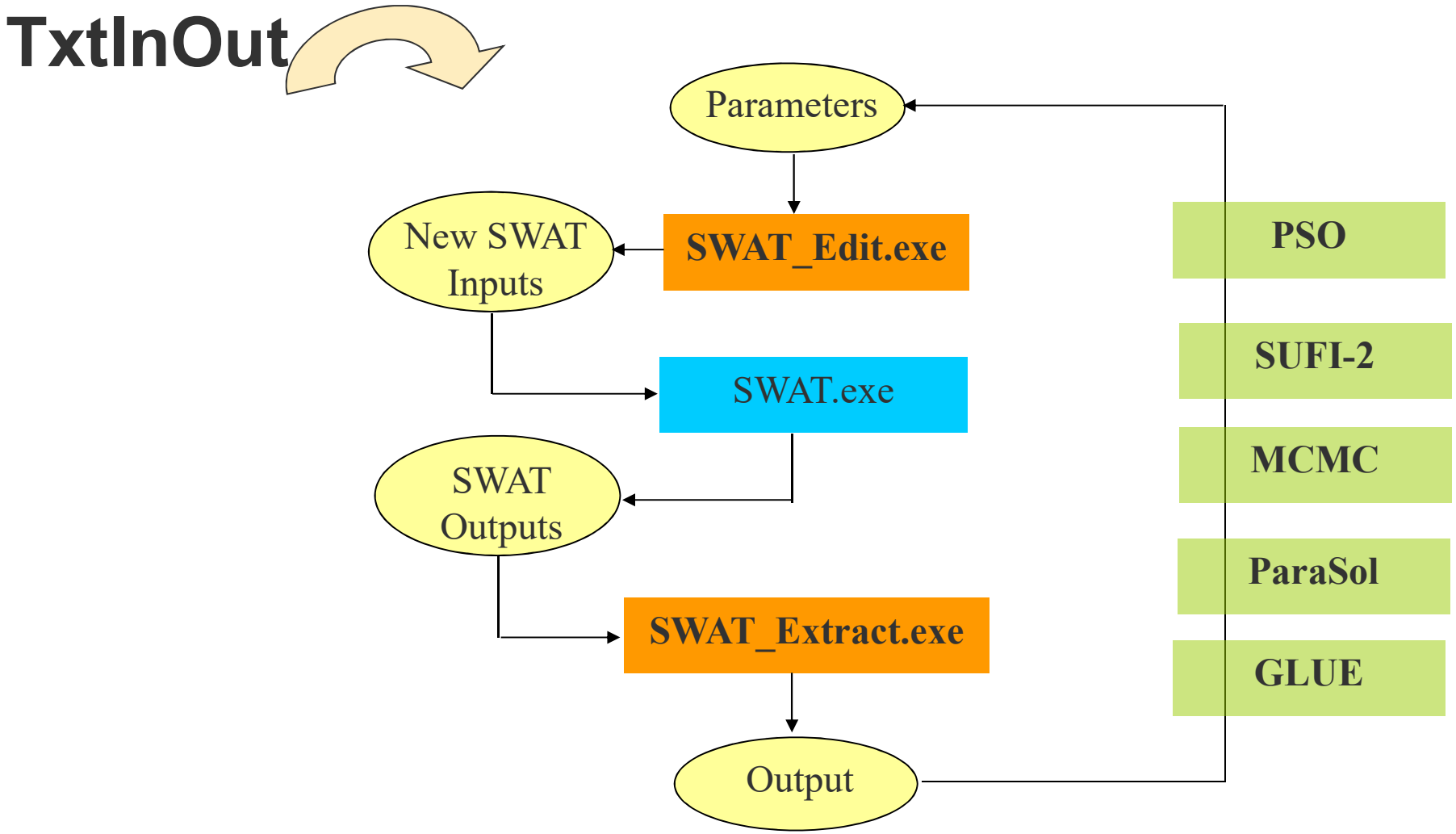
$$MNS = 1 - \frac{\sum_i |Q_m - Q_s|_i^p}{\sum_i |Q_{m,i} - \overline{Q}_m|_i^p}$$

$$f_{\mathbf{Y}^M|\boldsymbol{\Theta}}(\mathbf{y}|\boldsymbol{\theta}) = \frac{1}{\sqrt{2\pi}} \frac{1}{\sigma} \exp\left(-\frac{1}{2} \frac{\left[g(y_{t_0}) - g\left(y_{t_0}^M(\boldsymbol{\theta})\right)\right]^2}{\sigma^2}\right) \cdot \left|\frac{dg}{dy}\right|_{y = y_{t_0}} \cdot \prod_{i=1}^{n} \left[\frac{1}{\sqrt{2\pi}} \frac{1}{\sigma\sqrt{1 - \exp\left(-2\frac{t_i - t_{i-1}}{\tau}\right)}} \exp\left(-\frac{1}{2} \frac{\left[\begin{array}{l} g(y_{t_i}) - g\left(y_{t_i}^M(\boldsymbol{\theta})\right) \\ -\left[g(y_{t_{i-1}}) - g\left(y_{t_{i-1}}^M(\boldsymbol{\theta})\right)\right]\exp\left(-\frac{t_i - t_{i-1}}{\tau}\right) \end{array}\right]^2}{\sigma^2\left(1 - \exp\left(-2\frac{t_i - t_{i-1}}{\tau}\right)\right)}\right) \cdot \left|\frac{dg}{dy}\right|_{y = y_{t_i}}\right]$$

Calibration issues

- Optimization algorithm

(most confusing aspect of calibration)

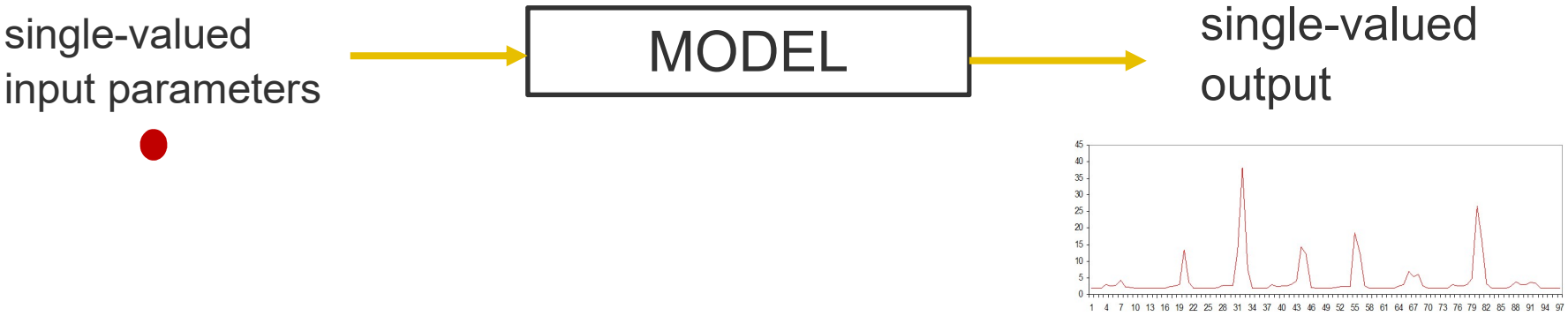


Calibration issues

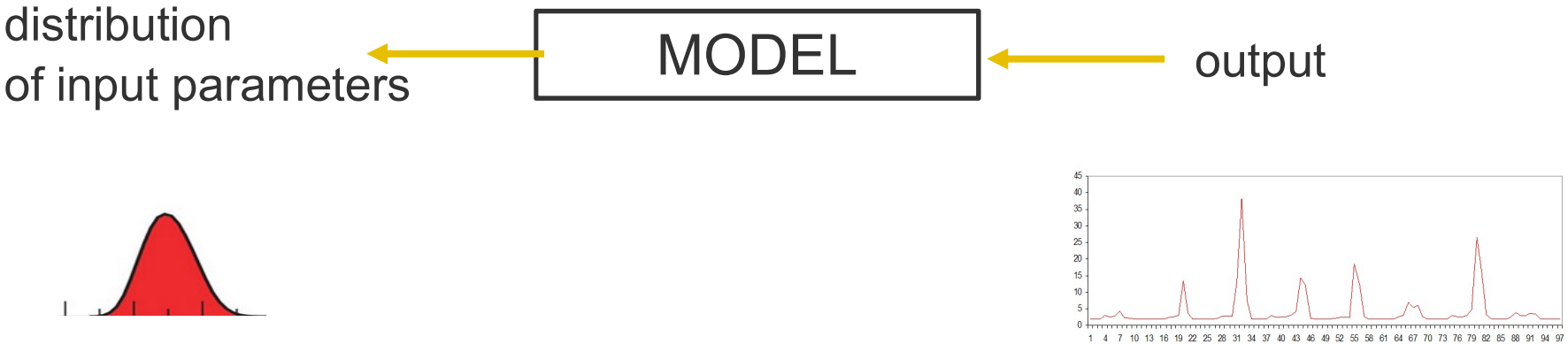
- Non-uniqueness (Uncertainty)

(most difficult part to quantify and to communicate)

Deterministic Modelling:



Calibration (Stochastic Process):



Calibration issues

- Conditionality of calibrated models

(most disappointing aspect of calibration)

(B)

- watershed parameterization
- type of the objective function
- weights used in the objective function
- conceptual model (model structure)
- experimental procedure (to collect the calibrating data)
- input data used
- objective function
- data used to calibrate
- ……

Calibration issues

- Time constraint

(makes some projects impossible to calibrate)

Important points about calibration

- Non-unique
- It is not an exact science (subjective)
- It is conditional (limited use)
- It is still a research issue…

water

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Editorial

A Guideline for Successful Calibration and Uncertainty Analysis for Soil and Water Assessment: A Review of Papers from the 2016 International SWAT Conference

Karim C. Abbaspour [1,*], Saeid Ashraf Vaghefi [1] and Raghvan Srinivasan [2]

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Article

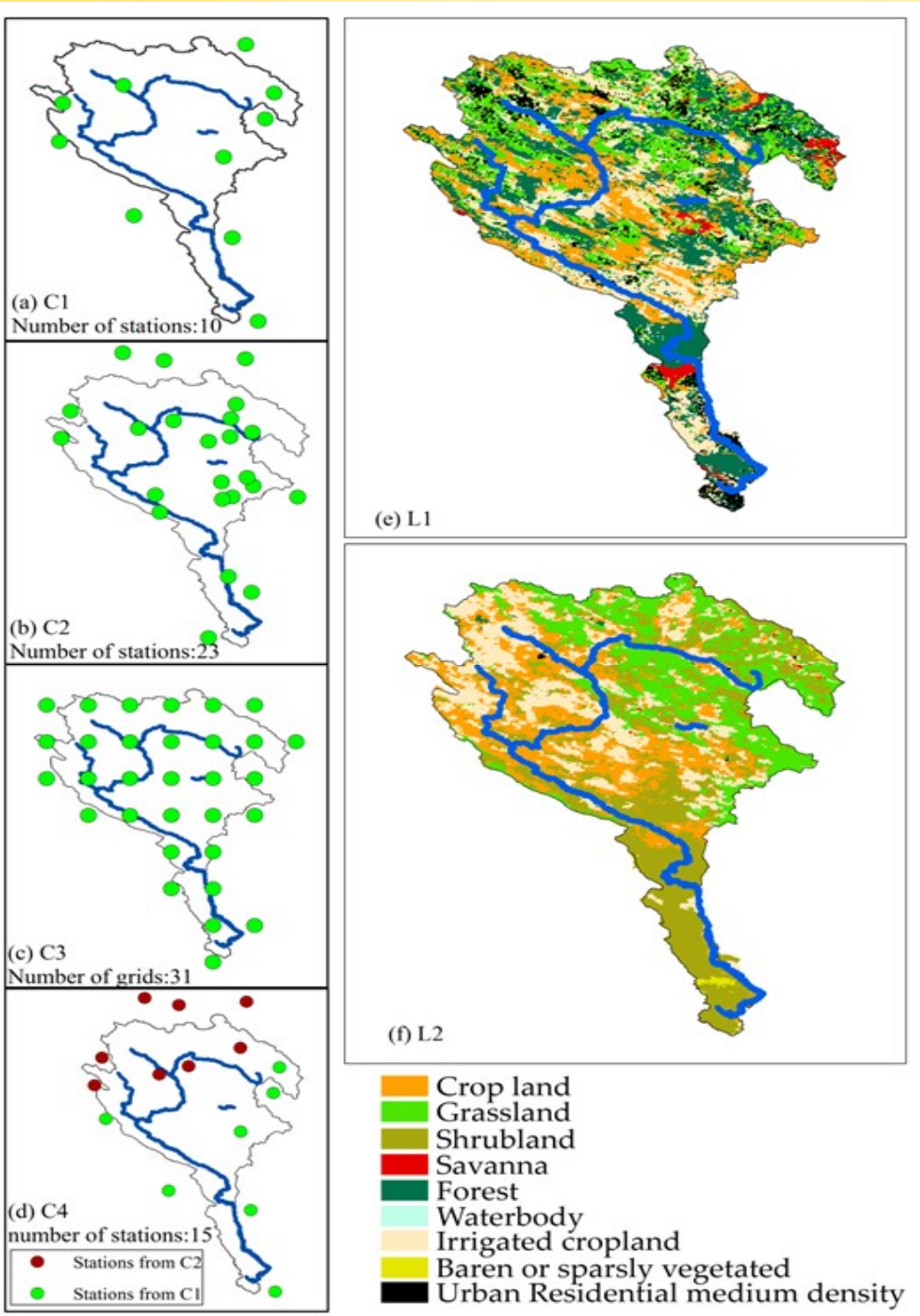
Assessing the Uncertainty of Multiple Input Datasets in the Prediction of Water Resource Components

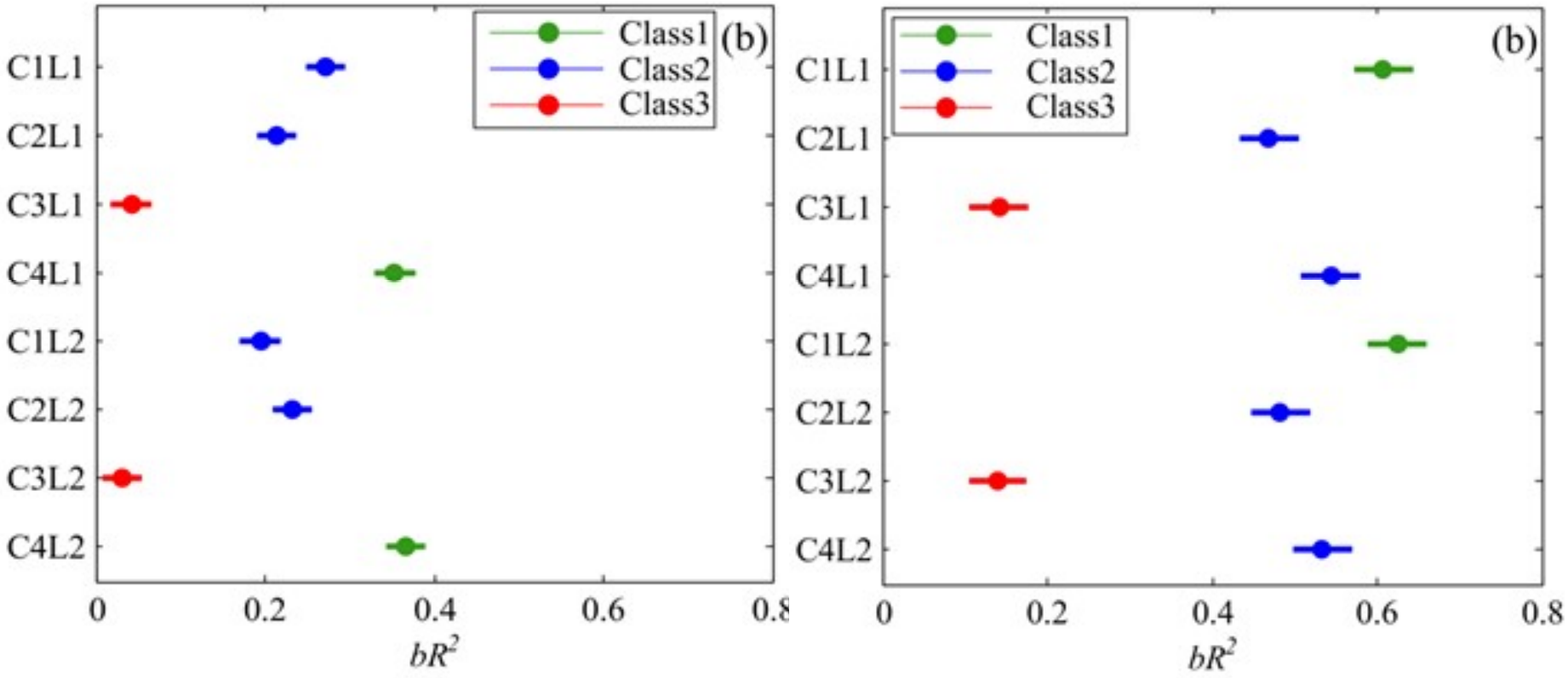
Bahareh Kamali [1,2,*], Karim C. Abbaspour [1] and Hong Yang [1,3]

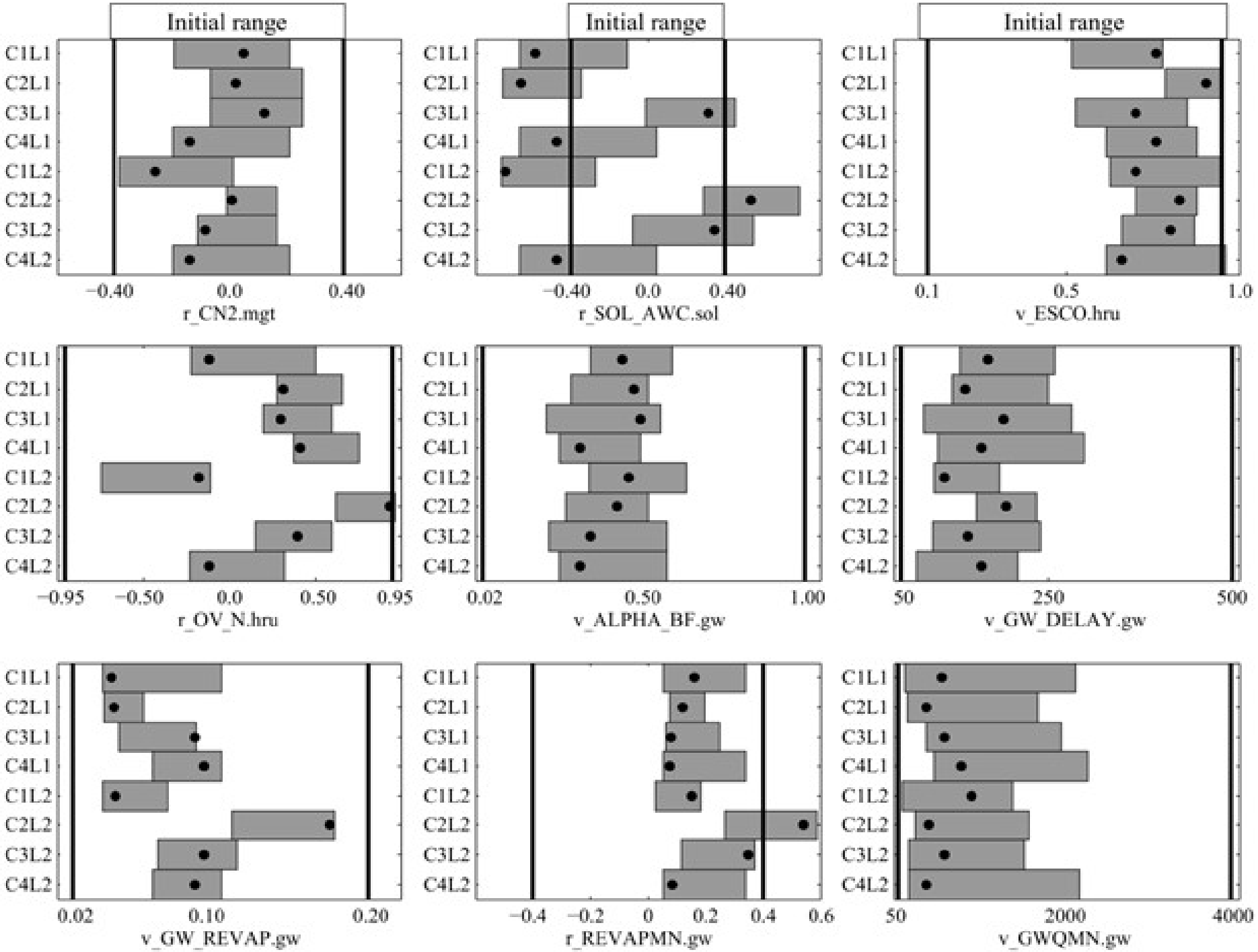
Table 1
Data description and sources used in the European SWAT project.

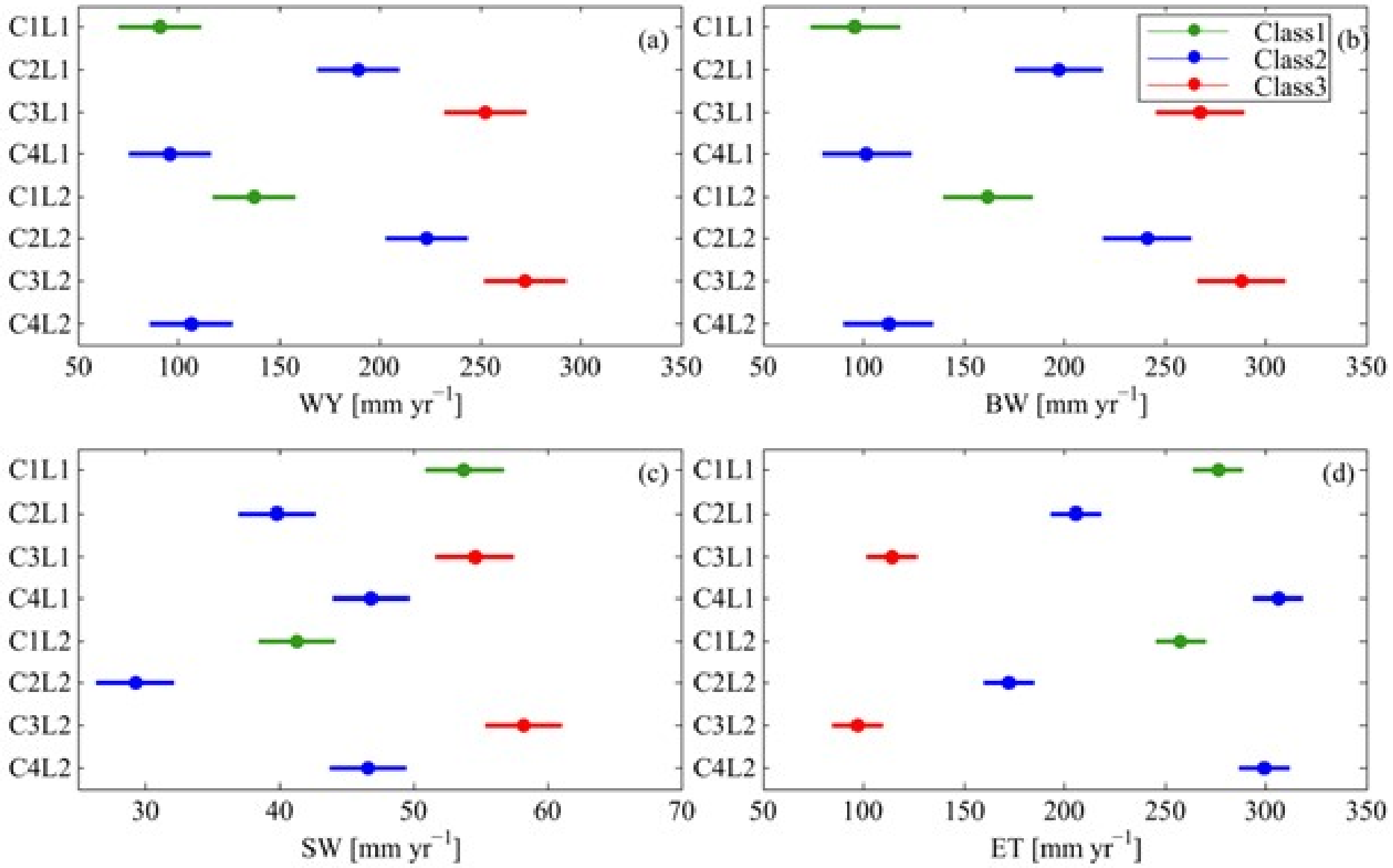
Data type	Resolution	Source
Soil	10 km 5 km	- FAO-UNESCO global soil map http://www.fao.org/nr/land/soils/digital-soil-map-of-the-world/en/ - European Soil Data Base (Eu DASM) https://esdac.jrc.ec.europa.eu/resource-type/national-soil-maps-eudasm
Landuse	-300 m -1000 m -500 m -300 m	- GlobCover European Space Agency http://due.esrin.esa.int/globcover/ -Global Landuse/Land Cover Characterization USGS http://landcover.usgs.gov/glcc/ - MODIS land cover http://modis-land.gsfc.nasa.gov/ - GlobCorine provided by European Space Agency http://www.esa.int/About_Us/ESRIN/Express_map_delivery_from_space
Climate	- Observed - 0.25° grid -0.5° grid -1° grid	- National Climate Data Center (NCDC), http://www.ncdc.noaa.gov/ - European Climate Assessment Dataset (ECAD), (http://www.ecad.eu/) - Climate Research Unit (CRU), http://www.cru.uea.ac.uk/ - Climate Data Guide (NCAR), https://climatedataguide.ucar.edu/
Crop yield	wheat, maize, barley	McGill Univesity http://www.geog.mcgill.ca/landuse/pub/Data/175crops2000/NetCDF/ FAOSTA - Country-based average crop yield
Agricultural management and water resources	Planting, harvesting, fertilization -Blue water	- FAOSTAT http://faostat.fao.org/site/339/default.aspx - AQUASTAT, FAO http://www.fao.org/nr/water/aquastat/water_res/index.stm
Point Source Pollution		- Eurostat http://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources/natural-resources/water/water-as-sink-for-emissions National Data Basis

Karkheh River Basin, Iran




Class1
Class2
Class3
(b)
C1L1
C2L1
C3L1
C4L1
C1L2
C2L2
C3L2
C4L2
0
0.2
0.4
0.6
0.8
bR^2
Class1
Class2
Class3
(b)
C1L1
C2L1
C3L1
C4L1
C1L2
C2L2
C3L2
C4L2
0
0.2
0.4
0.6
0.8
bR^2


Initial range
C1L1
C2L1
C3L1
C4L1
C1L2
C2L2
C3L2
C4L2
−0.40
0.0
0.40
r_CN2.mgt
Initial range
−0.40
0.0
0.40
r_SOL_AWC.sol
Initial range
0.1
0.5
1.0
v_ESCO.hru
−0.95
−0.50
0.0
0.50
0.95
r_OV_N.hru
0.02
0.50
1.00
v_ALPHA_BF.gw
50
250
500
v_GW_DELAY.gw
0.02
0.10
0.20
v_GW_REVAP.gw
−0.4
−0.2
0
0.2
0.4
0.6
r_REVAPMN.gw
50
2000
4000
v_GWQMN.gw


C1L1
C2L1
C3L1
C4L1
C1L2
C2L2
C3L2
C4L2
(a)
50 100 150 200 250 300 350
WY [mm yr^{-1}]
(b)
Class1
Class2
Class3
BW [mm yr^{-1}]
(c)
30 40 50 60 70
SW [mm yr^{-1}]
(d)
ET [mm yr^{-1}]

eawag aquatic research

water

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Article

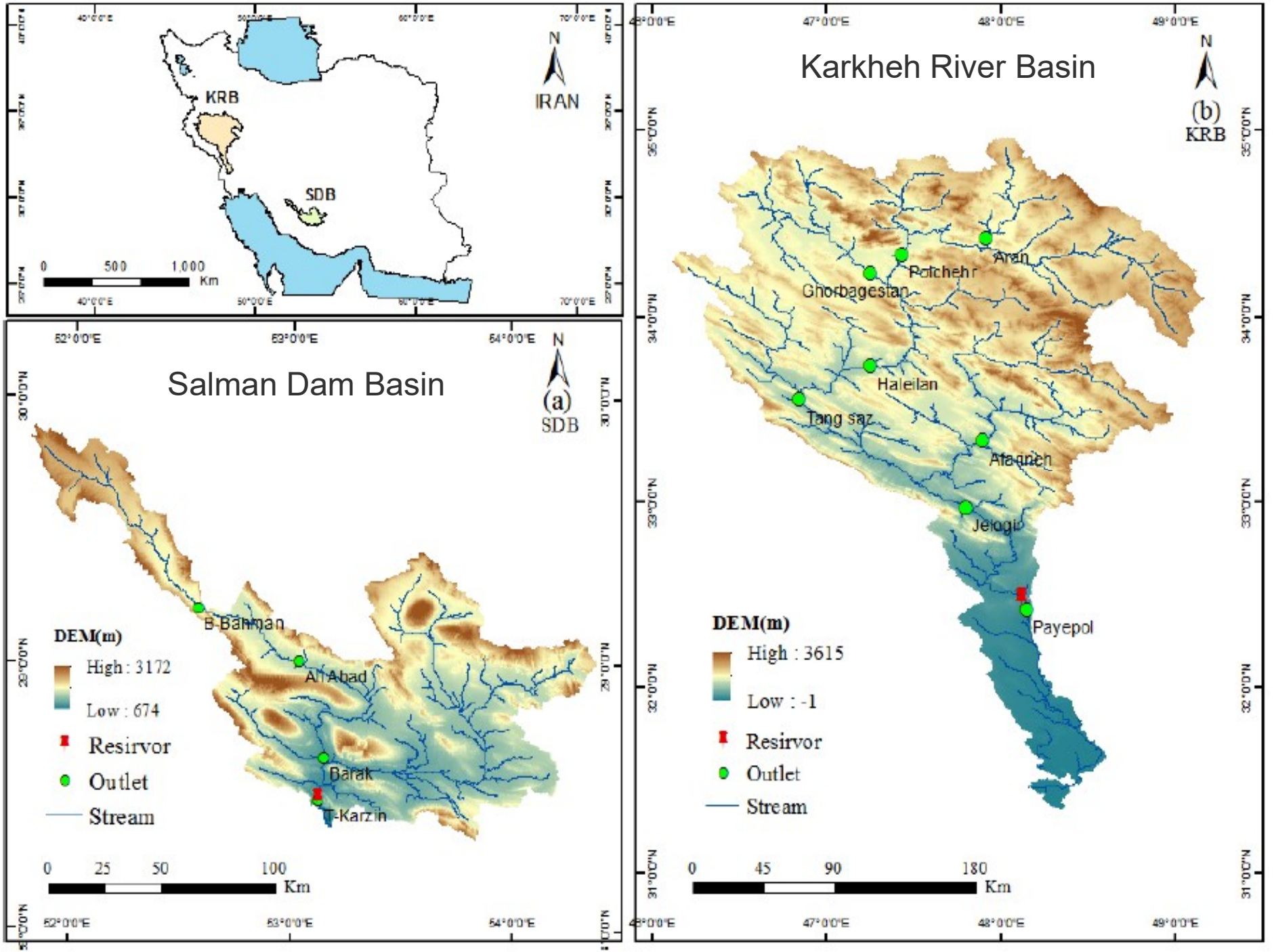
Sensitivity of Calibrated Parameters and Water Resource Estimates on Different Objective Functions and Optimization Algorithms

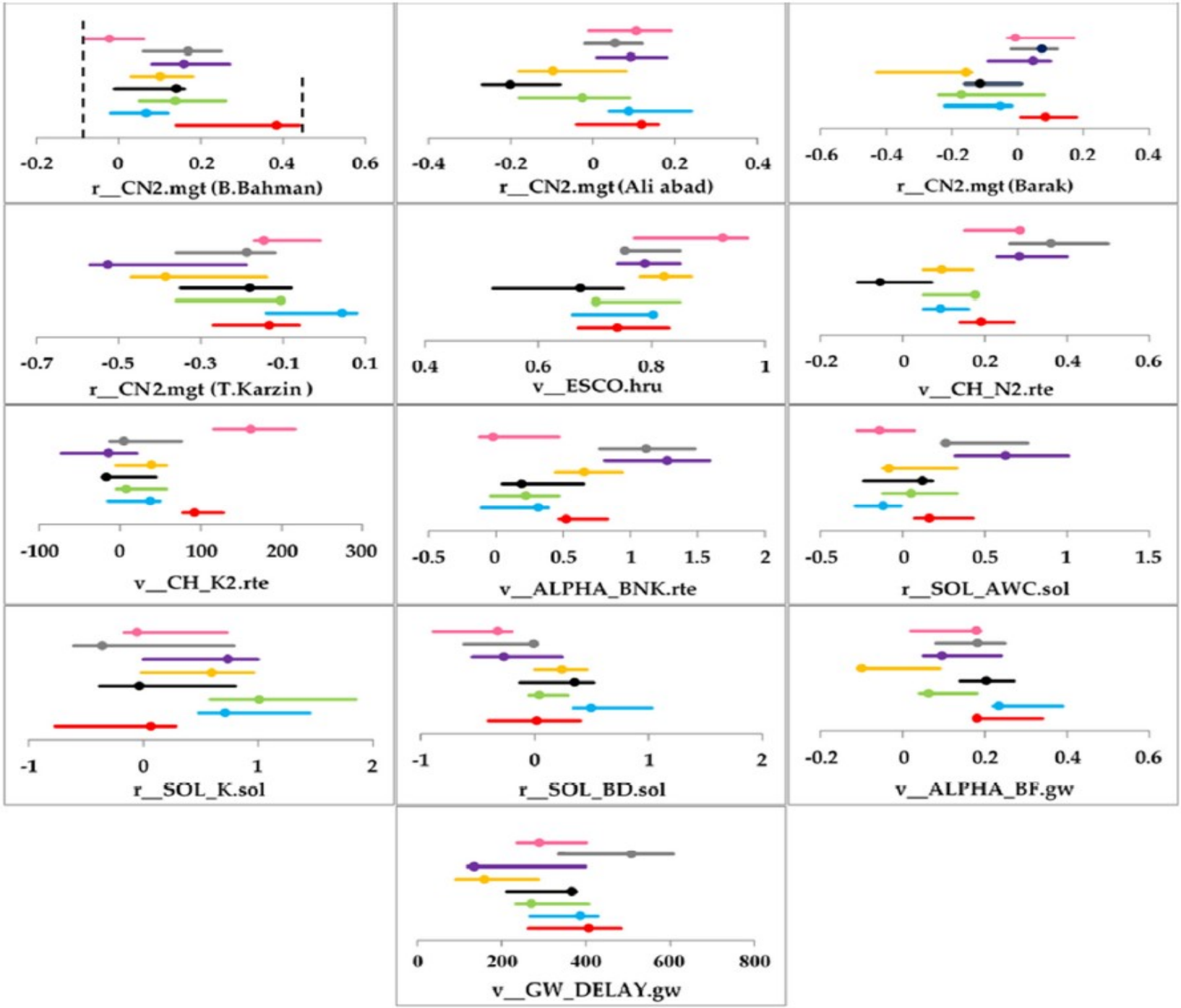
Delaram Houshmand Kouchi [1], Kazem Esmaili [1,*], Alireza Faridhosseini [1], Seyed Hossein Sanaeinejad [1], Davar Khalili [2] and Karim C. Abbaspour [3]

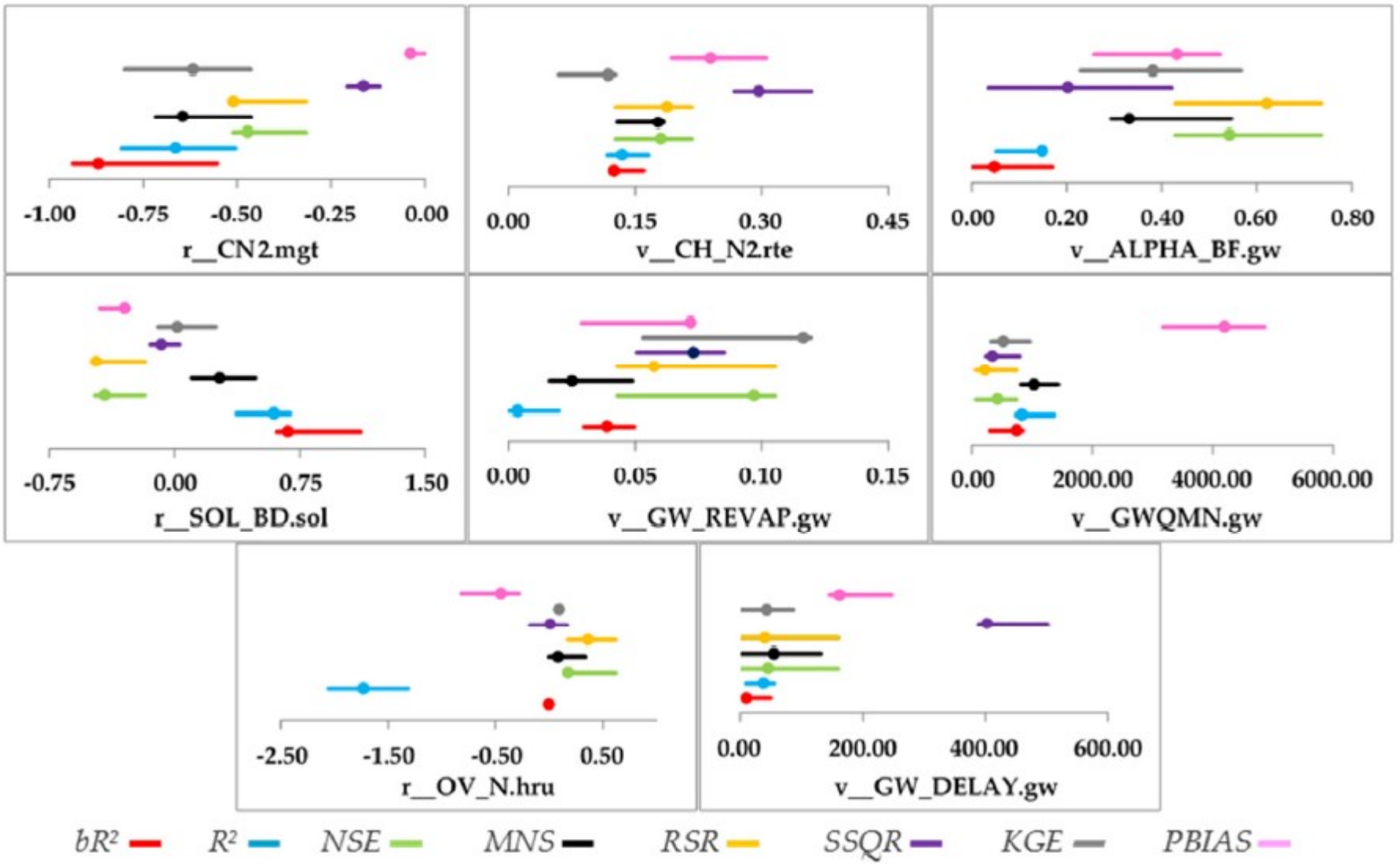
Table 1. Formulation of the objective functions.

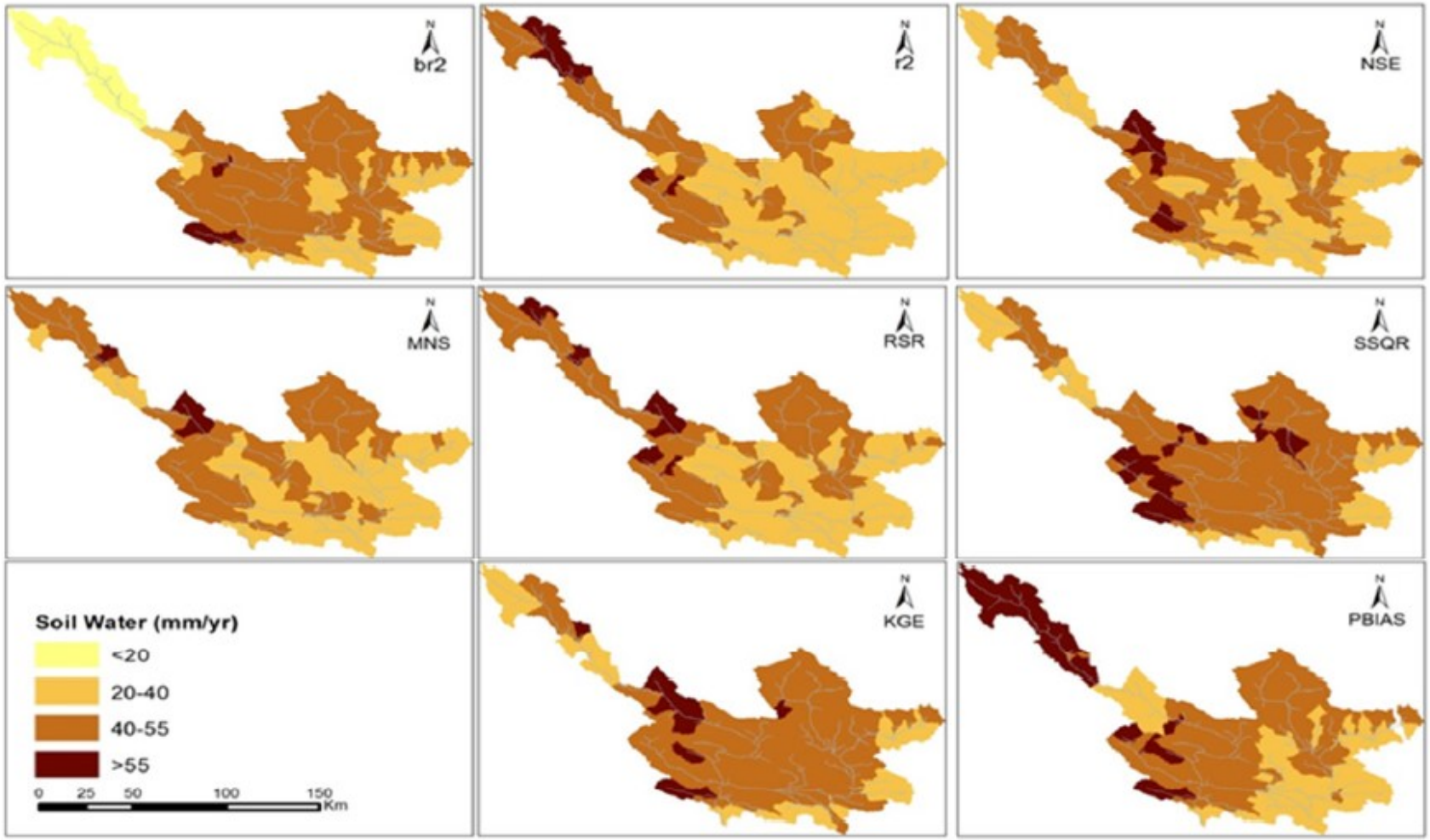
Objective Function	Reference	Formulation *
Modified Coefficient of determination (bR^2)	[26]	$bR^2 = \begin{cases} \lvert b\rvert . R^2 \text{ for } b \le 1 \\ \lvert b\rvert^{-1} . R^2 \text{ for } b > 1 \end{cases}$
Coefficient of determination (R^2)	-	$R^2 = \frac{\left[\sum_i (Q_{i,o} - \bar{Q}_o)(Q_{i,s} - \bar{Q}_s)\right]^2}{\sum_i (Q_{i,o} - \bar{Q}_o)^2 \sum_i (Q_{i,s} - \bar{Q}_s)^2}$
Nash-Sutcliffe efficiency (NSE)	[14]	$NSE = 1 - \left[\frac{\sum_{i=1}^{n} (Q_{i,o} - Q_{i,s})^2}{\sum_{i=1}^{n} (Q_{i,o} - \bar{Q}_o)^2}\right]$
Modified Nash- Sutcliffe efficiency (MNS)	[26]	$MNS = 1 - \frac{\sum_{i=1}^{n} \lvert Q_{i,o} - Q_{i,s}\rvert^j}{\sum_{i=1}^{n} \lvert Q_{i,o} - \overline{Q_o}\rvert^j}$ with $j \in N$
Ratio of standard deviation of observations to root mean square error (RSR)	[15]	$RSR = \frac{RMSE}{STDEV_o} = \frac{\left[\sqrt{\sum_{i=1}^{n} (Q_{i,o} - Q_{i,s})^2}\right]}{\left[\sqrt{\sum_{i=1}^{n} (Q_{i,o} - Q_m)^2}\right]}$
Ranked sum of squares ($SSQR$)	[27]	$SSQR = \frac{1}{n} \sum_{i=1,n} [Q_{i,o} - Q_{i,s}]^2$
Kling-Gupta efficiency (KGE)	[16]	$KGE = 1 - \sqrt{(R-1)^2 + (\alpha - 1)^2 + (\beta - 1)^2}$
Percent bias ($PBIAS$)	[28]	$PBIAS = 100 * \left[\frac{\sum_{i=1}^{n} (Q_{i,o} - Q_{i,s})}{\sum_{i=1}^{n} Q_{i,o}}\right]$

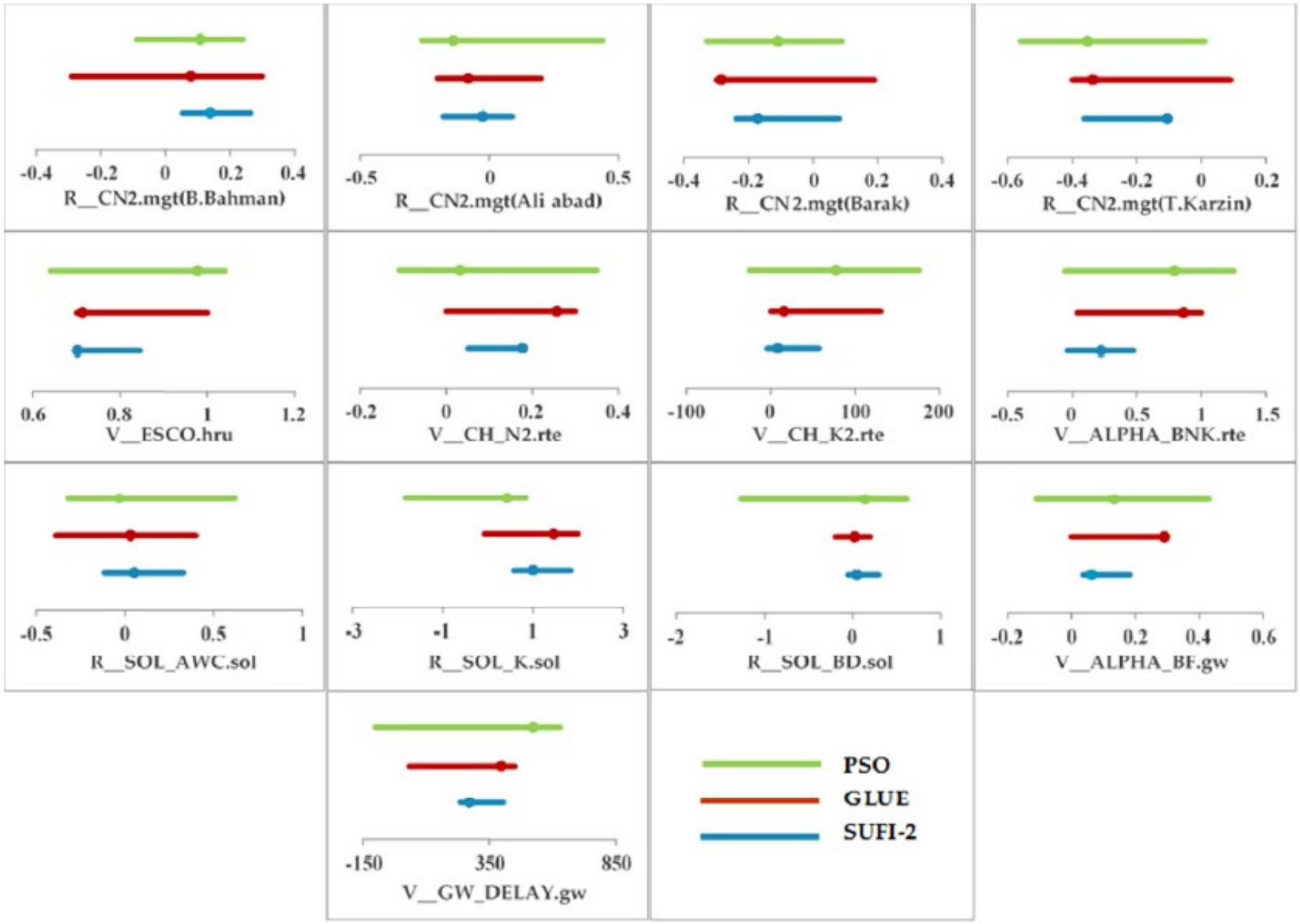
SUFI-2, Abbaspour et al., 2004, 2007
GLUE, Beven et al., 1992
PSO, Eberhart et al., 1995


KRB
SDB
IRAN
N
0 500 1,000 Km
Salman Dam Basin
(a)
SDB
B.Bahman
Al Abad
Barak
T-Karzin
DEM(m)
High : 3172
Low : 674
Resirvor
Outlet
Stream
0 25 50 100 Km
Karkheh River Basin
(b)
KRB
Aran
Potchehr
Ghorbagestan
Haleilan
Tang saz
Afa qneh
Jelogir
Payepol
DEM(m)
High : 3615
Low : -1
Resirvor
Outlet
Stream
0 45 90 180 Km


-0.2 0 0.2 0.4 0.6
r__CN2.mgt (B.Bahman)
-0.4 -0.2 0 0.2 0.4
r__CN2.mgt (Ali abad)
-0.6 -0.4 -0.2 0 0.2 0.4
r__CN2.mgt (Barak)
-0.7 -0.5 -0.3 -0.1 0.1
r__CN2.mgt (T.Karzin)
0.4 0.6 0.8 1
v__ESCO.hru
-0.2 0 0.2 0.4 0.6
v__CH_N2.rte
-100 0 100 200 300
v__CH_K2.rte
-0.5 0 0.5 1 1.5 2
v__ALPHA_BNK.rte
-0.5 0 0.5 1 1.5
r__SOL_AWC.sol
-1 0 1 2
r__SOL_K.sol
-1 0 1 2
r__SOL_BD.sol
-0.2 0 0.2 0.4 0.6
v__ALPHA_BF.gw
0 200 400 600 800
v__GW_DELAY.gw


-1.00
-0.75
-0.50
-0.25
0.00
r__CN2mgt
0.00
0.15
0.30
0.45
v__CH_N2rte
0.00
0.20
0.40
0.60
0.80
v__ALPHA_BF.gw
-0.75
0.00
0.75
1.50
r__SOL_BD.sol
0.00
0.05
0.10
0.15
v__GW_REVAP.gw
0.00
2000.00
4000.00
6000.00
v__GWQMN.gw
-2.50
-1.50
-0.50
0.50
r__OV_N.hru
0.00
200.00
400.00
600.00
v__GW_DELAY.gw
bR²
R²
NSE
MNS
RSR
SSQR
KGE
PBIAS


br2
r2
NSE
MNS
RSR
SSQR
KGE
PBIAS
N
Soil Water (mm/yr)
<20
20-40
40-55
>55
0 25 50 100 150
Km


-0.4 -0.2 0 0.2 0.4
R__CN2.mgt(B.Bahman)
-0.5 0 0.5
R__CN2.mgt(Ali abad)
-0.4 -0.2 0 0.2 0.4
R__CN2.mgt(Barak)
-0.6 -0.4 -0.2 0 0.2
R__CN2.mgt(T.Karzin)
0.6 0.8 1 1.2
V__ESCO.hru
-0.2 0 0.2 0.4
V__CH_N2.rte
-100 0 100 200
V__CH_K2.rte
-0.5 0 0.5 1 1.5
V__ALPHA_BNK.rte
-0.5 0 0.5 1
R__SOL_AWC.sol
-3 -1 1 3
R__SOL_K.sol
-2 -1 0 1
R__SOL_BD.sol
-0.2 0 0.2 0.4 0.6
V__ALPHA_BF.gw
-150 350 850
V__GW_DELAY.gw
PSO
GLUE
SUFI-2

Conclusion

Scientific community needs to pay more attention to calibration issues