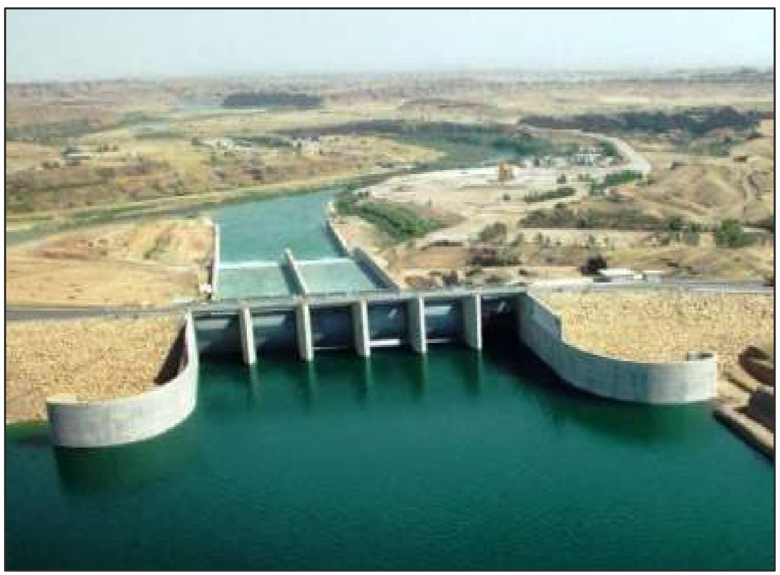
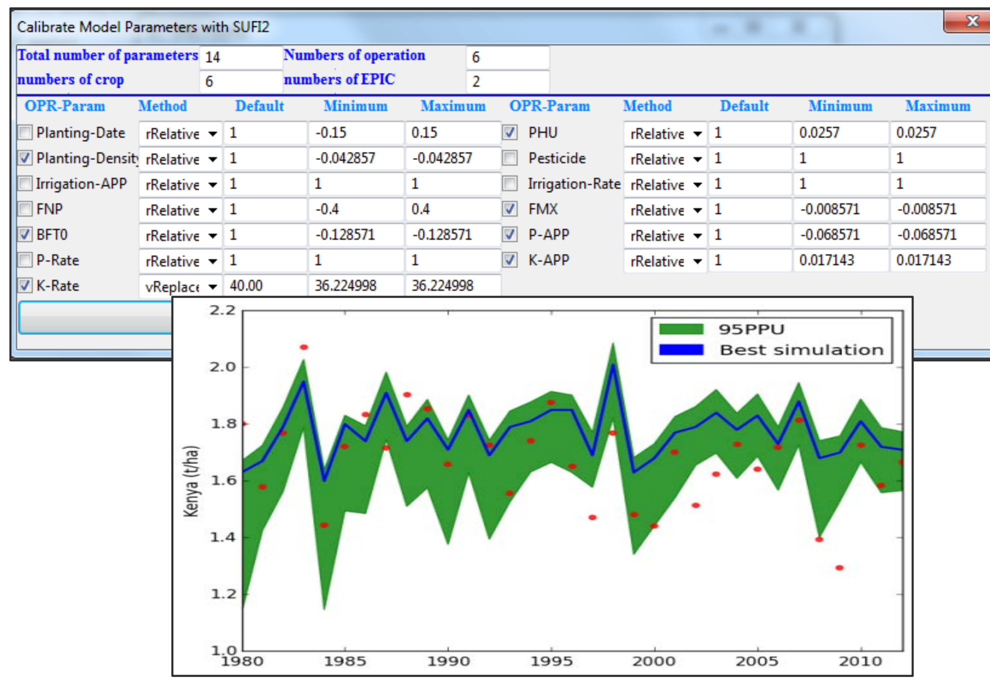
Climate change impacts on crop yield and meteorological, hydrological and agricultural droughts in semi-arid regions.

Application of SWAT and EPIC model for drought and drought vulnerability assessment

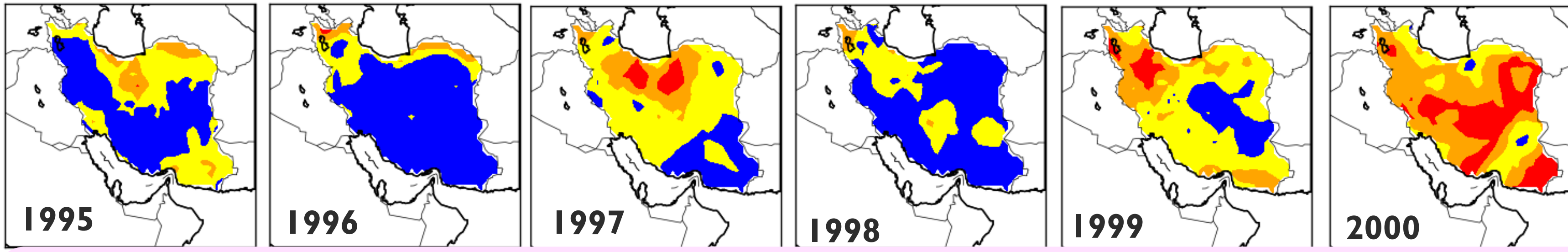
Bahareh Kamali , Karim C. Abbaspour, Hong Yang





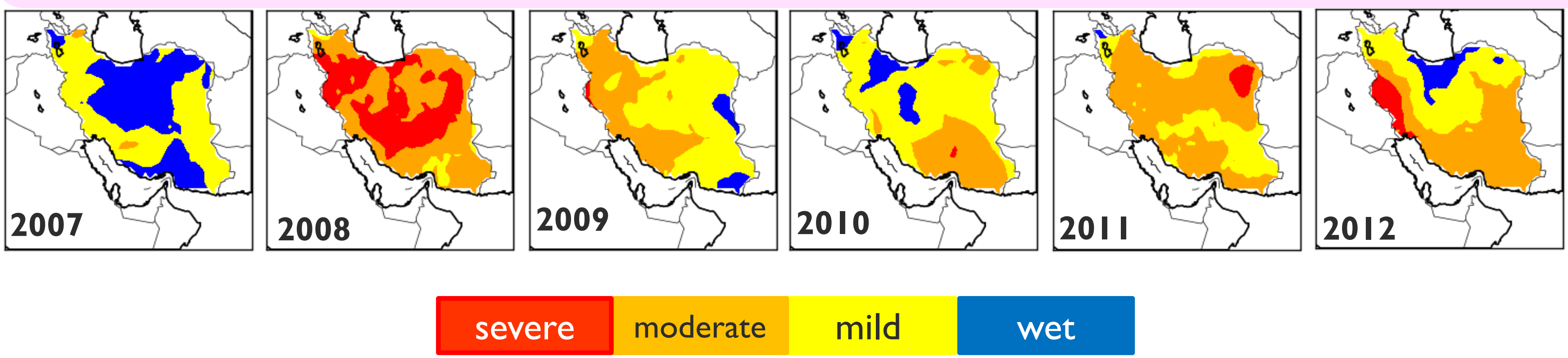
Soil & Water Assessment Tool SWAT

Historical evolution of drought in Iran



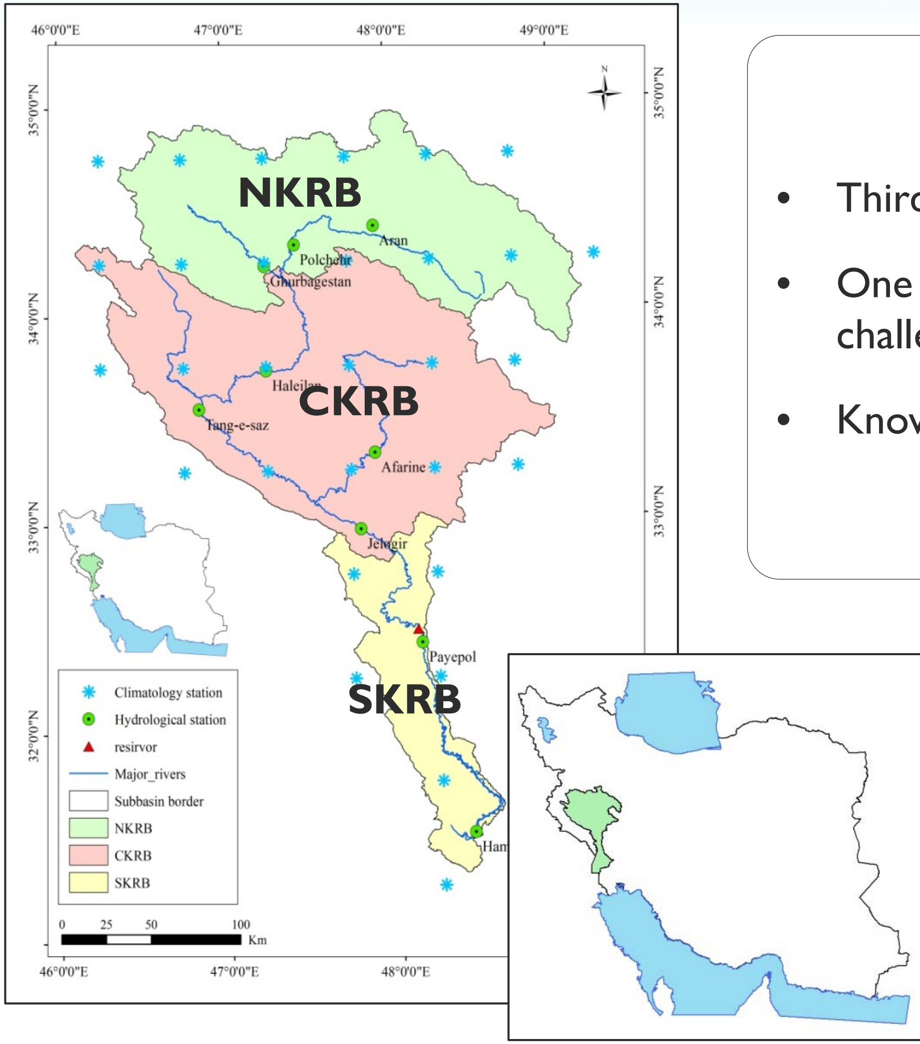
In 2007, Iran exported nearly 600,000 t of wheat while producing15 million t

In 2009, it was reported that Iran purchased 6 million t of wheat because of the drought in 2008



SPI-12

Karkheh River Basin (KRB)



- Third largest basin in Iran with area of 51,000 km^2
- One of the nine benchmark watershed of the CGIAR challenge program on water and food
- Known as the food basket of country

CGIAR: **Consultative Group for International Agricultural Research**

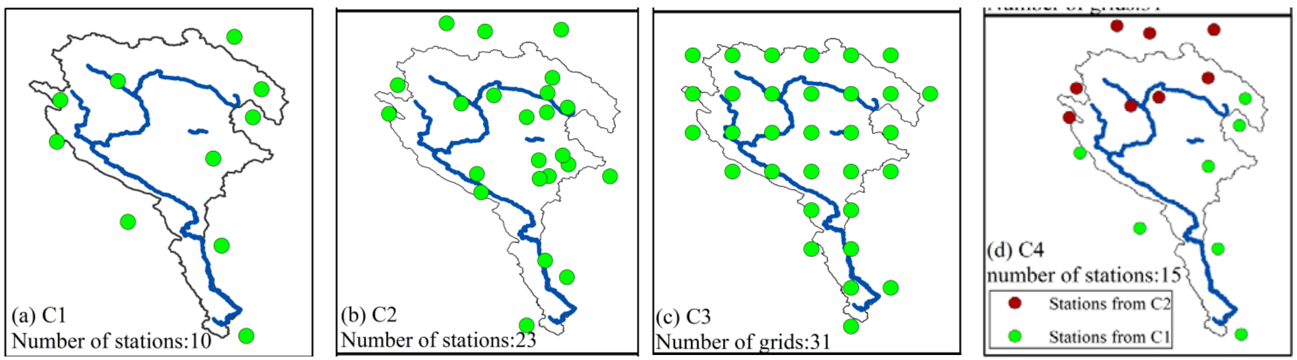
Outlines

Uncertainty in hydrological modeling of the study area

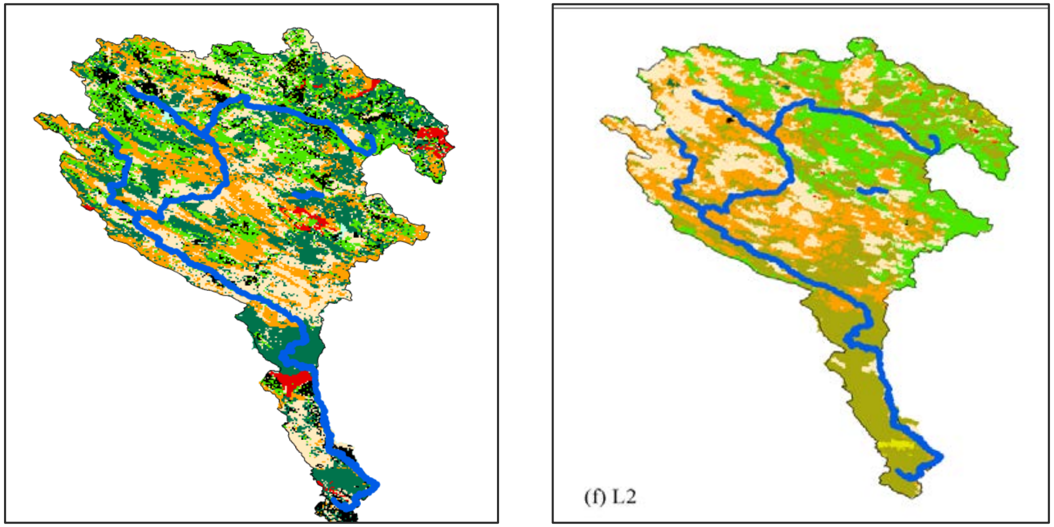
Multi level drought identification in KRB

Crop drought vulnerability assessment based on crop modeling using EPIC model

Data for building SWAT model of the region

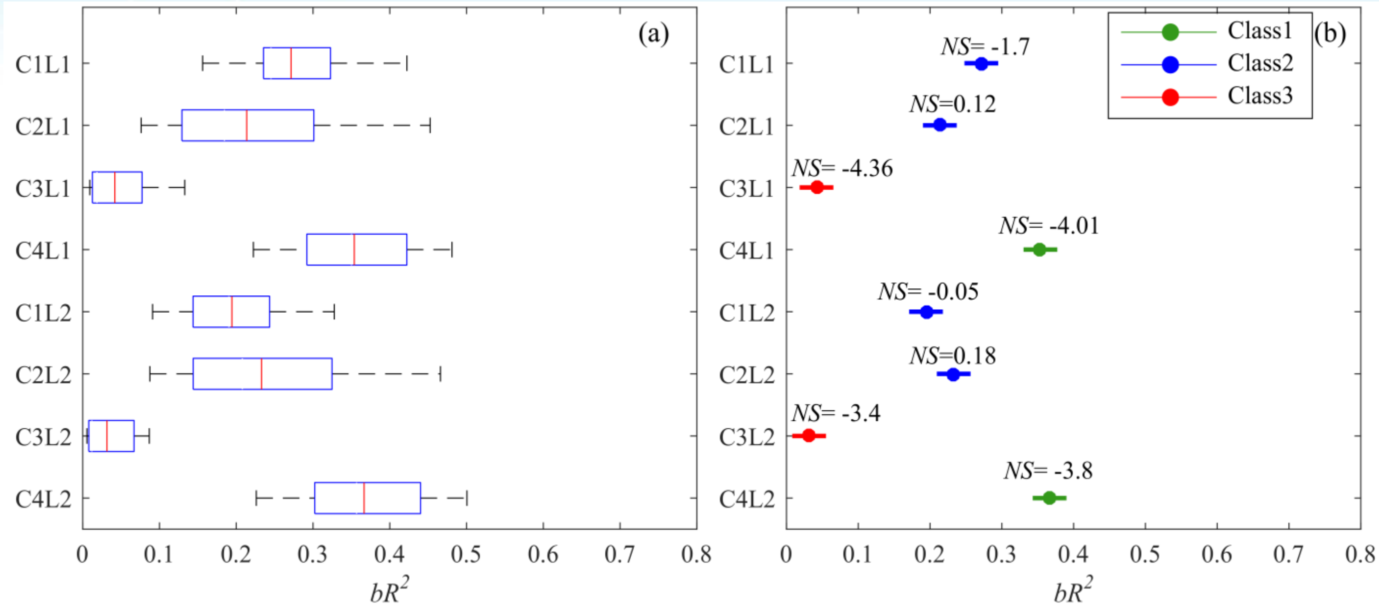


Climate data

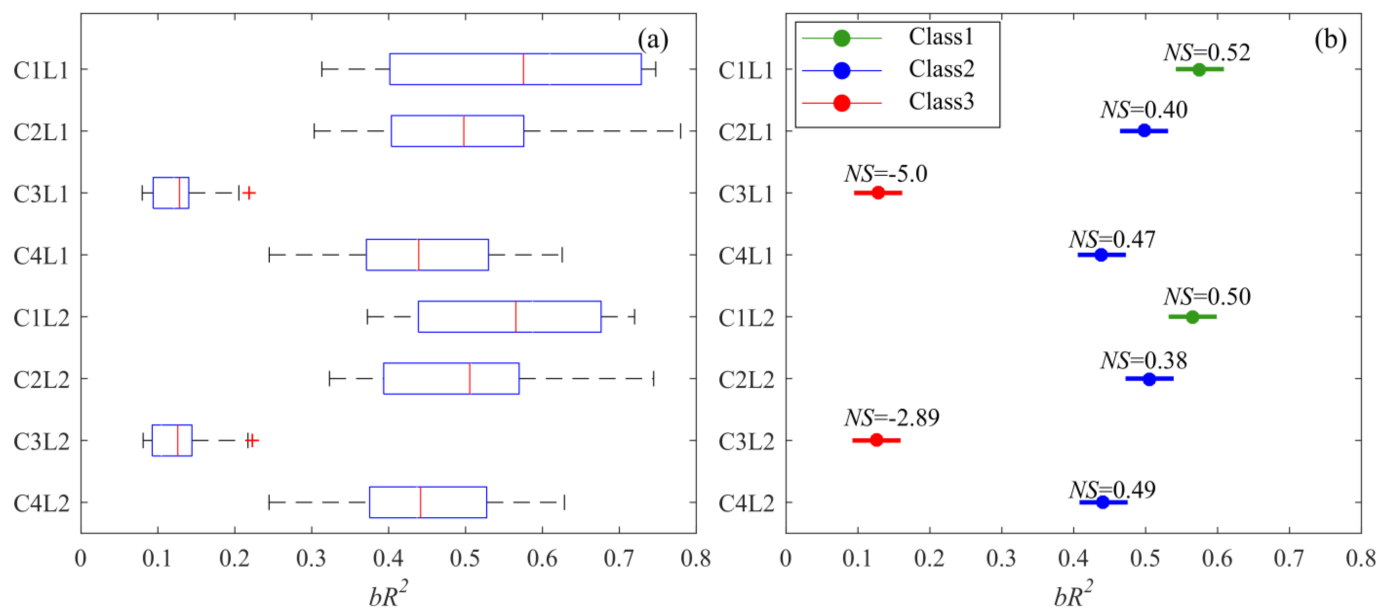


Landuse data

Model performance before and after calibration

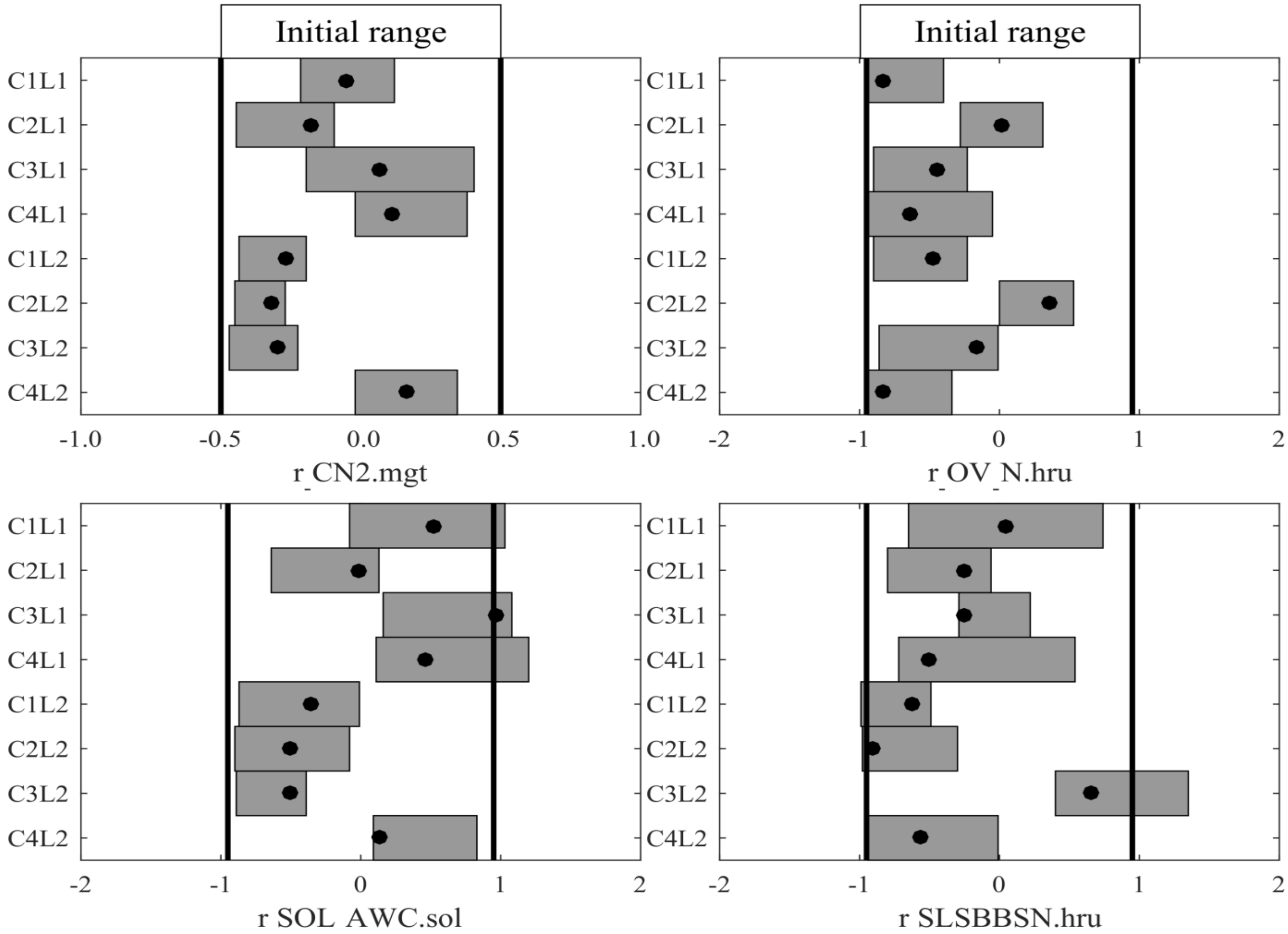


Before calibration



After calibration

Final ranges of parameter after calibration



The impact of different input data on different water resources components

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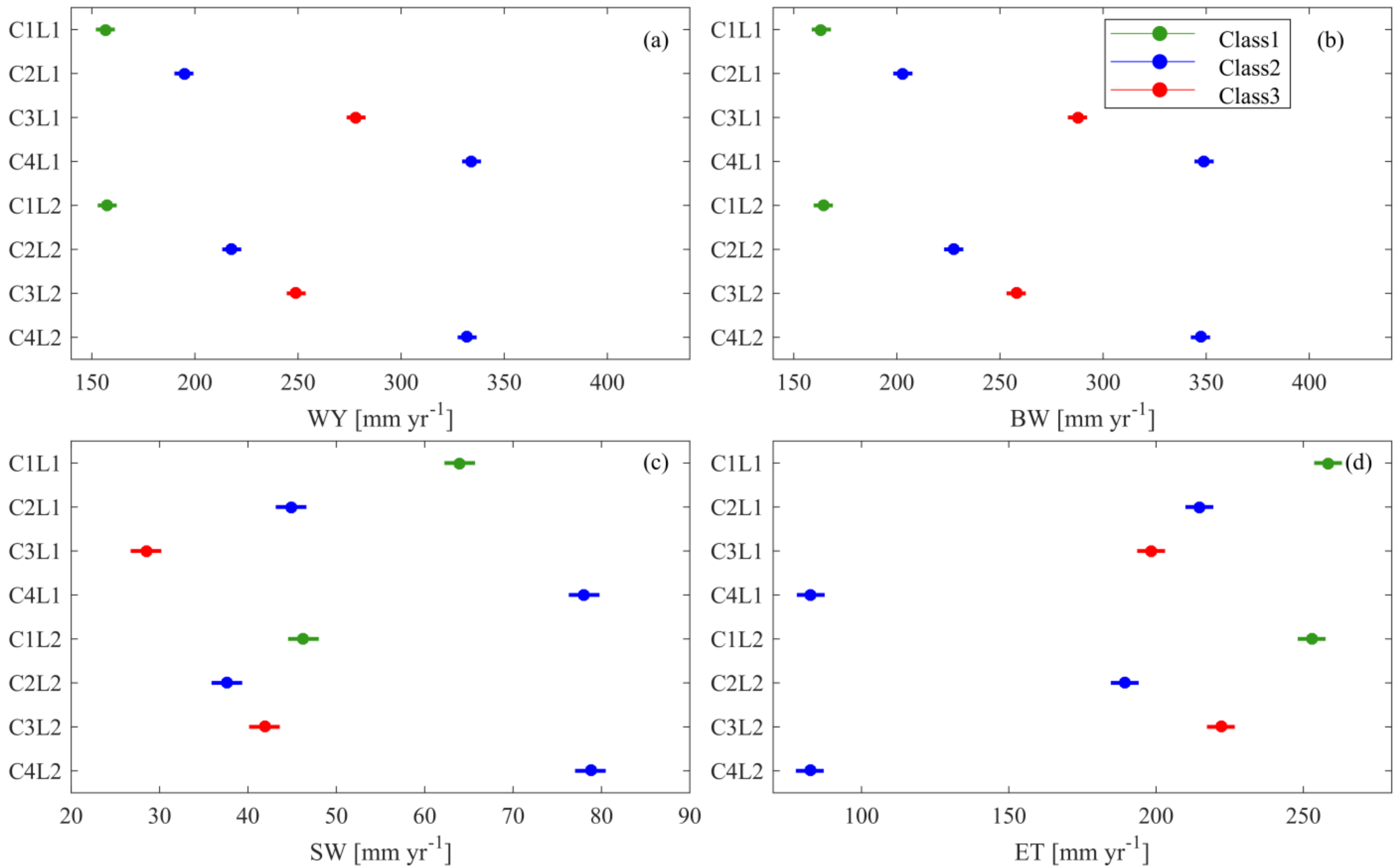
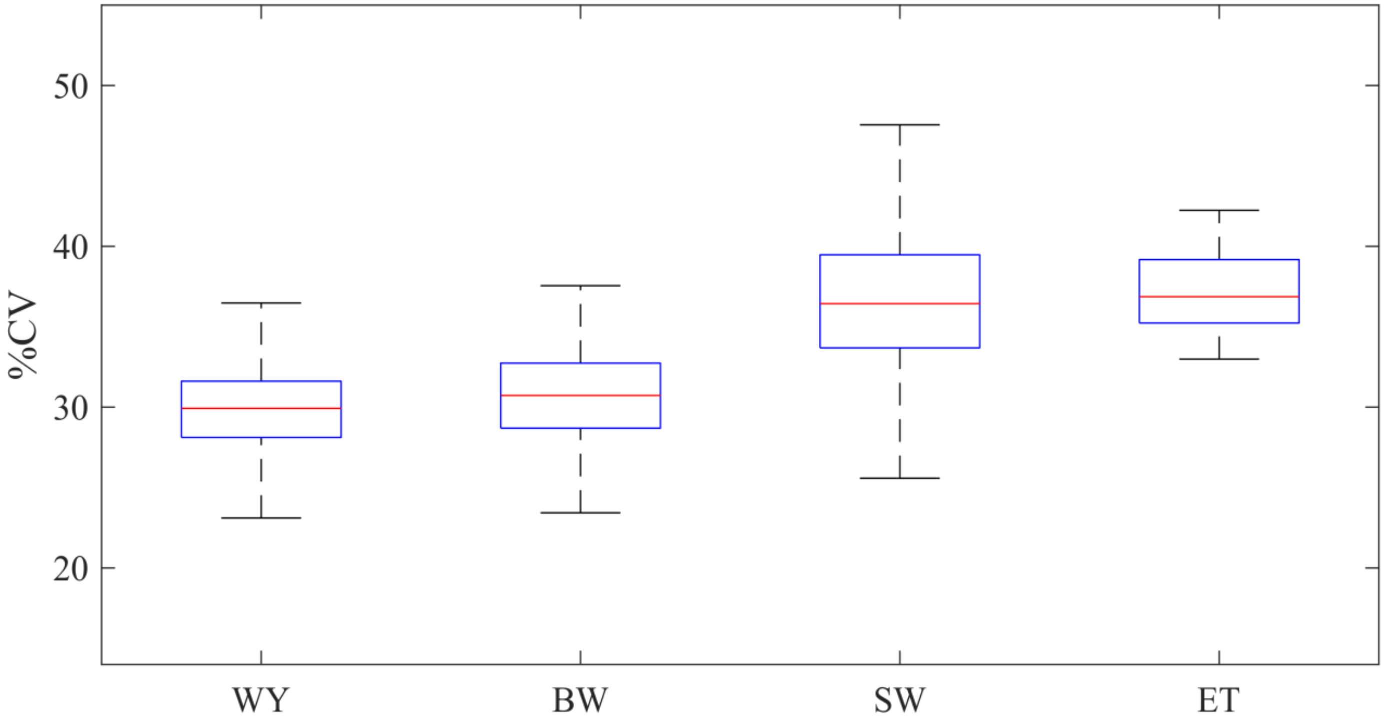
water resources components are significantly different for different configurations,



Kamali, Yang, Karim C. Abbaspour, "Assessing the Uncertainty of Multiple Input Datasets in Prediction of Water Resources Components", 2017

The impact of input data uncertainty on different water resource components



it is prudent for modelers to pay more attention to the selection of input data.

Kamali, Yang, Karim C. Abbaspour, "Assessing the Uncertainty of Multiple Input Datasets in Prediction of Water Resources Components", 2017

Multi level drought assessment in KRB

Meteorological droughts	Standardized precipitation index (SPI) using Precipitation
Hydrological droughts	Standardized runoff Index (SRI) using Discharge
Agricultural droughts	Standardized Soil Water index (SSWI) using soil moisture data

Kamali, B.; Houshmand Kouchi, D.; Yang, H.; Abbaspour, K.C. Multilevel drought hazard assessment under climate change scenarios in semi-srid regions—A case study of the Karkheh River Basin in Iran. *Water*. **2017**, 9, 241.

Multi-level drought identification in KRB

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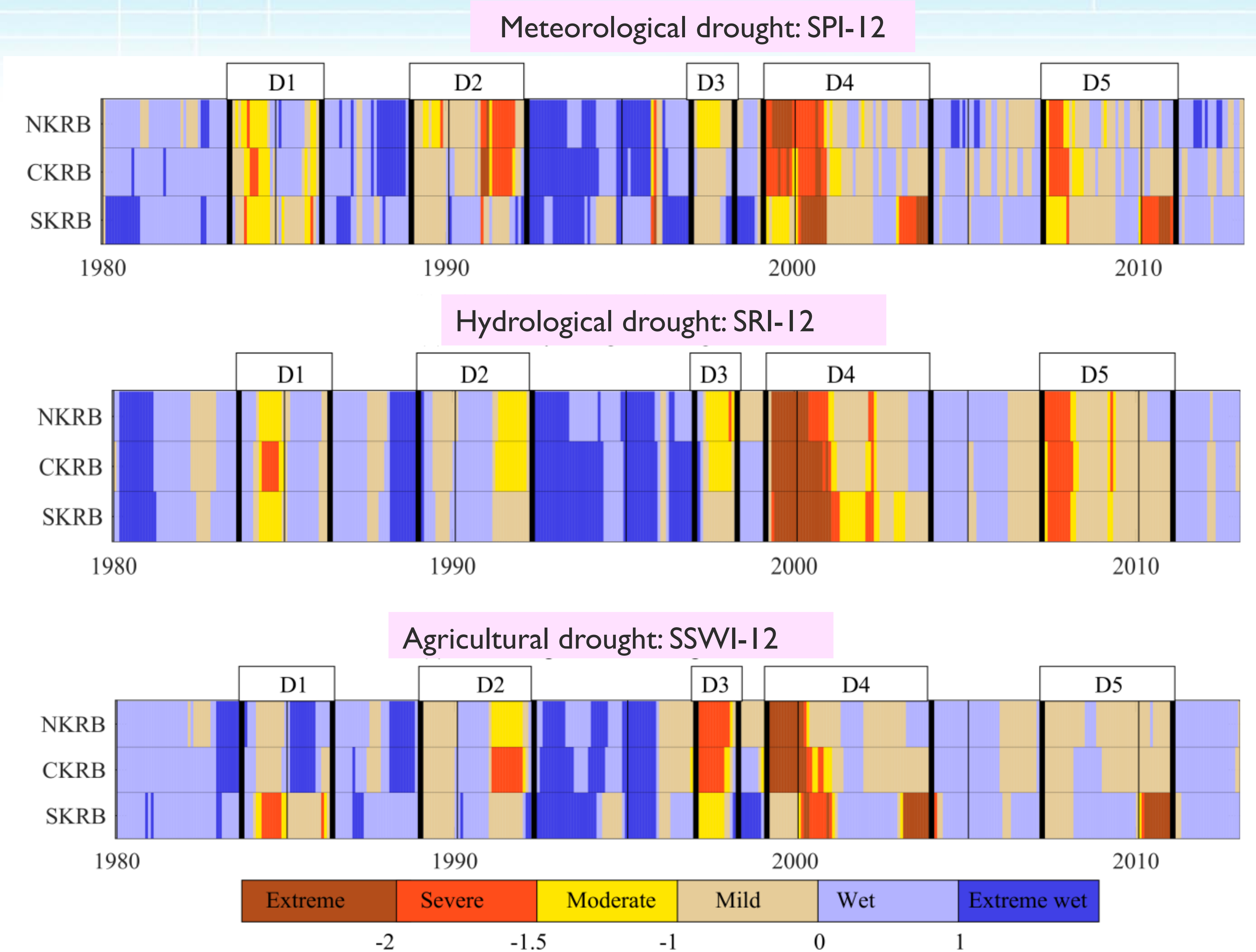

Multi level drought assessment in KRB

- There was 3-month lag between hydrological and meteorological droughts

  In the northern region, it is due to snow melt

  In the southern regions due to routing method

Kamali, B.; Houshmand Kouchi, D.; Yang, H.; Abbaspour, K.C. Multilevel drought hazard assessment under climate change scenarios in semi-srid regions—A case study of the Karkheh River Basin in Iran. *Water.* **2017**, *9*, 241.

Climate change impact on drought frequency and duration in KRB

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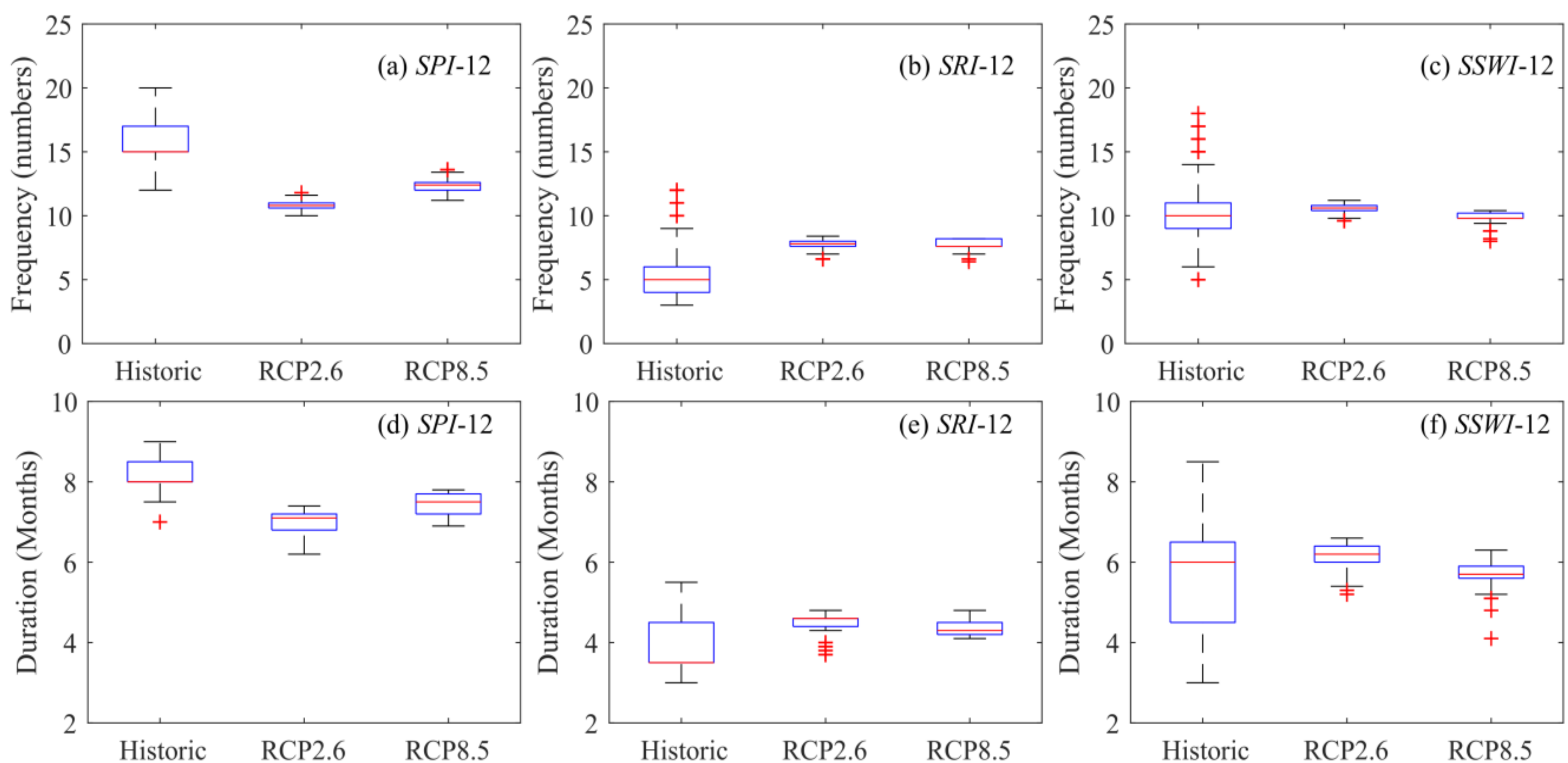

GCM Name	Institute Full Name
HadGEM2-ES	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)
IPSL-CM5A-LR	Institute Pierre-Simon Laplace
GFDL-ESM2M	NOAA Geophysical Fluid Dynamics Laboratory-Earth System Model
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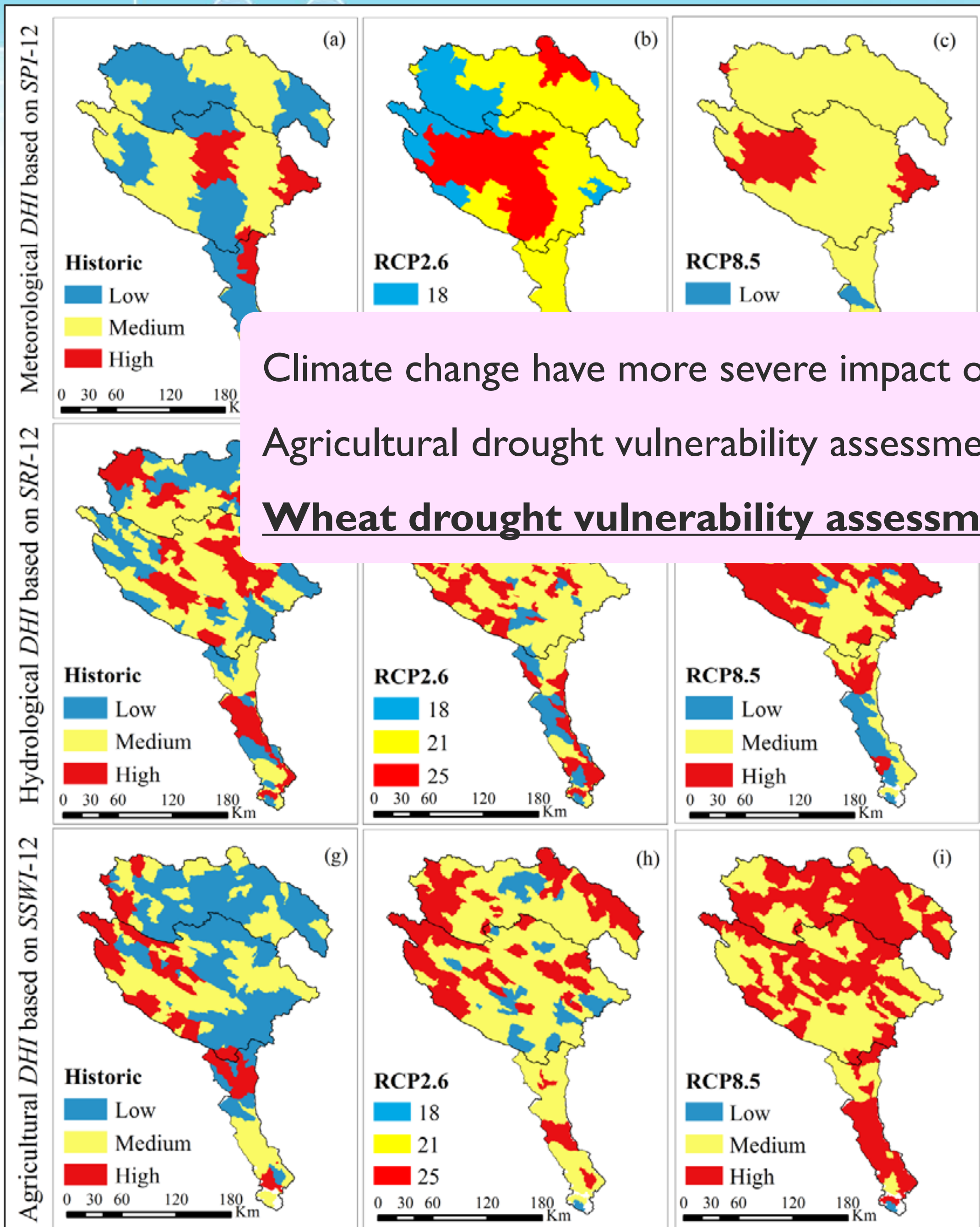

Climate change have more severe impact on agricultural sector

Agricultural drought vulnerability assessment is becoming an important issue

Wheat drought vulnerability assessment

EPIC: Crop yield simulator

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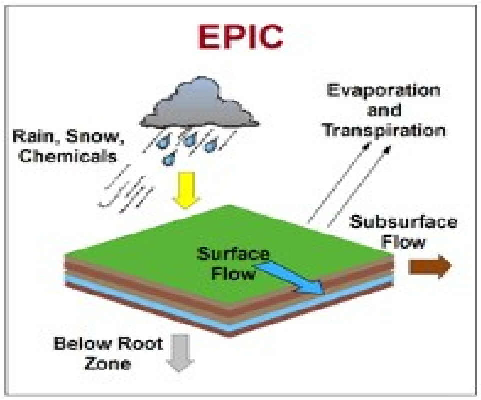
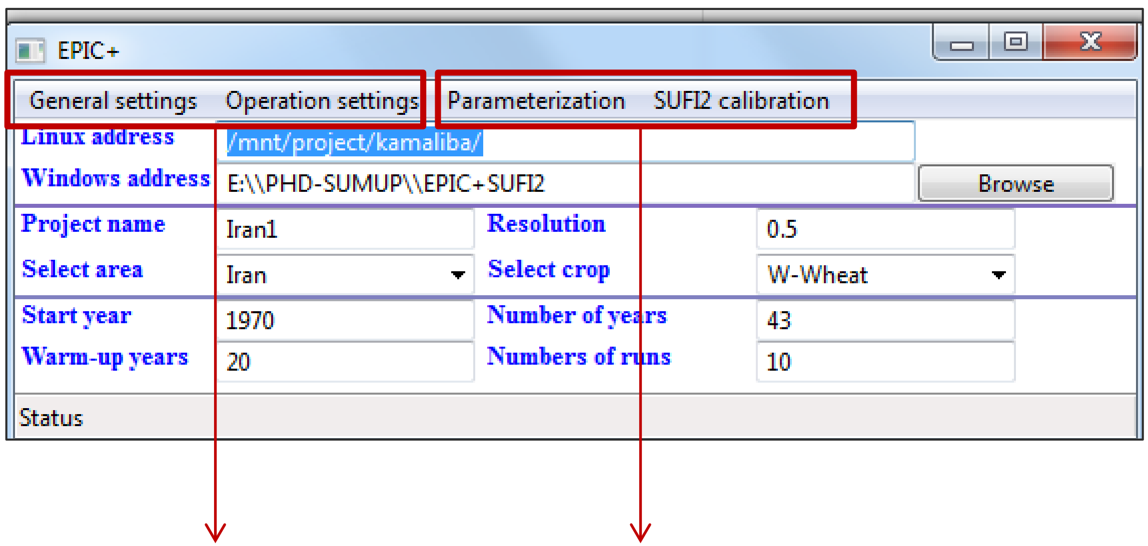


EPIC is originally a site-based model

Objective1: Extending its application from site-based to large scales using a user-friendly workspace

Objective 2: Model calibration to validate that crop model is replicating historic period



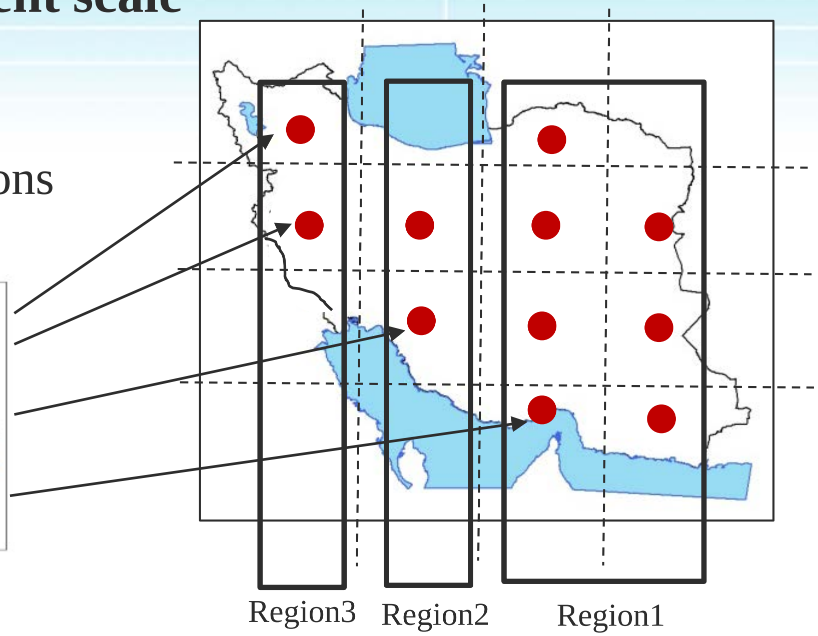
Objective-1 Objective-2

EPIC: Environmental Policy Integrated Crop Model

Objective 1:Extending its application to different scale

- Country level is the core scale

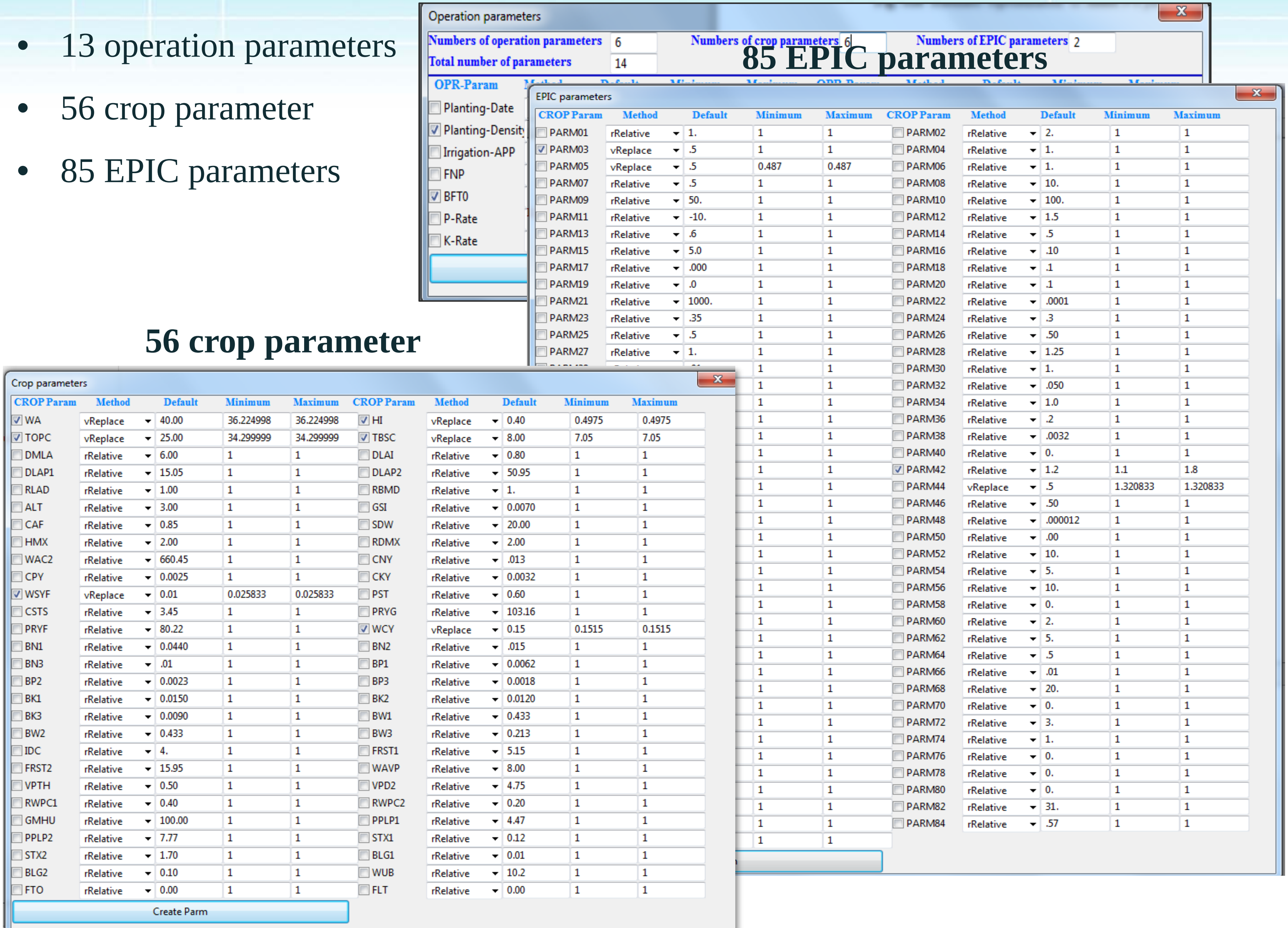
Smaller scale, each country can be divided into regions
Larger scale, selecting a group of countries



- Selecting different operations from planting to harvesting dates through the interface

Parameterization

- 13 operation parameters
- 56 crop parameter
- 85 EPIC parameters



Operation parameters

Numbers of operation parameters: 6 | Numbers of crop parameters: 6 | Numbers of EPIC parameters: 2

Total number of parameters: 14

OPR-Param
Planting-Date
[x] Planting-Density
Irrigation-APP
FNP
[x] BFTO
P-Rate
K-Rate

85 EPIC parameters

EPIC parameters

CROP Param	Method	Default	Minimum	Maximum	CROP Param	Method	Default	Minimum	Maximum
PARM01	rRelative	1.	1	1	PARM02	rRelative	2.	1	1
[x] PARM03	vReplace	.5	1	1	PARM04	rRelative	1.	1	1
PARM05	vReplace	.5	0.487	0.487	PARM06	rRelative	1.	1	1
PARM07	rRelative	.5	1	1	PARM08	rRelative	10.	1	1
PARM09	rRelative	50.	1	1	PARM10	rRelative	100.	1	1
PARM11	rRelative	-10.	1	1	PARM12	rRelative	1.5	1	1
PARM13	rRelative	.6	1	1	PARM14	rRelative	.5	1	1
PARM15	rRelative	5.0	1	1	PARM16	rRelative	.10	1	1
PARM17	rRelative	.000	1	1	PARM18	rRelative	.1	1	1
PARM19	rRelative	.0	1	1	PARM20	rRelative	.1	1	1
PARM21	rRelative	1000.	1	1	PARM22	rRelative	.0001	1	1
PARM23	rRelative	.35	1	1	PARM24	rRelative	.3	1	1
PARM25	rRelative	.5	1	1	PARM26	rRelative	.50	1	1
PARM27	rRelative	1.	1	1	PARM28	rRelative	1.25	1	1
			1	1	PARM30	rRelative	1.	1	1
			1	1	PARM32	rRelative	.050	1	1
			1	1	PARM34	rRelative	1.0	1	1
			1	1	PARM36	rRelative	.2	1	1
			1	1	PARM38	rRelative	.0032	1	1
			1	1	PARM40	rRelative	0.	1	1
			1	1	[x] PARM42	rRelative	1.2	1.1	1.8
			1	1	PARM44	vReplace	.5	1.320833	1.320833
			1	1	PARM46	rRelative	.50	1	1
			1	1	PARM48	rRelative	.000012	1	1
			1	1	PARM50	rRelative	.00	1	1
			1	1	PARM52	rRelative	10.	1	1
			1	1	PARM54	rRelative	5.	1	1
			1	1	PARM56	rRelative	10.	1	1
			1	1	PARM58	rRelative	0.	1	1
			1	1	PARM60	rRelative	2.	1	1
			1	1	PARM62	rRelative	5.	1	1
			1	1	PARM64	rRelative	.5	1	1
			1	1	PARM66	rRelative	.01	1	1
			1	1	PARM68	rRelative	20.	1	1
			1	1	PARM70	rRelative	0.	1	1
			1	1	PARM72	rRelative	3.	1	1
			1	1	PARM74	rRelative	1.	1	1
			1	1	PARM76	rRelative	0.	1	1
			1	1	PARM78	rRelative	0.	1	1
			1	1	PARM80	rRelative	0.	1	1
			1	1	PARM82	rRelative	31.	1	1
			1	1	PARM84	rRelative	.57	1	1
			1	1					

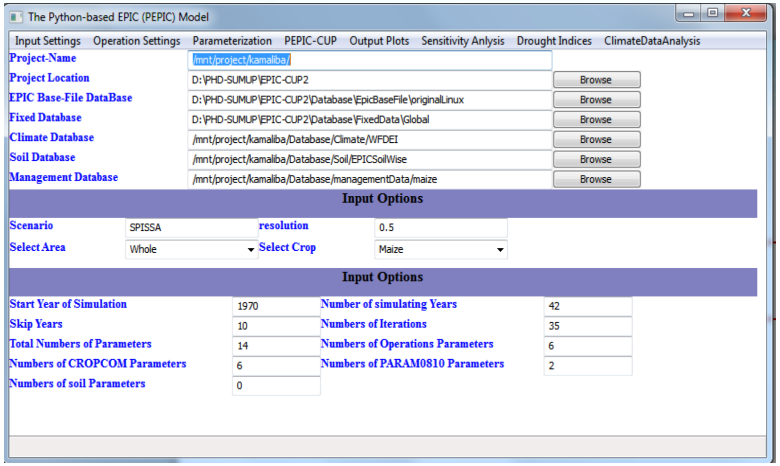
56 crop parameter

Crop parameters

CROP Param	Method	Default	Minimum	Maximum	CROP Param	Method	Default	Minimum	Maximum
[x] WA	vReplace	40.00	36.224998	36.224998	[x] HI	vReplace	0.40	0.4975	0.4975
[x] TOPC	vReplace	25.00	34.299999	34.299999	[x] TBSC	vReplace	8.00	7.05	7.05
DMLA	rRelative	6.00	1	1	DLAI	rRelative	0.80	1	1
DLAP1	rRelative	15.05	1	1	DLAP2	rRelative	50.95	1	1
RLAD	rRelative	1.00	1	1	RBMD	rRelative	1.	1	1
ALT	rRelative	3.00	1	1	GSI	rRelative	0.0070	1	1
CAF	rRelative	0.85	1	1	SDW	rRelative	20.00	1	1
HMX	rRelative	2.00	1	1	RDMX	rRelative	2.00	1	1
WAC2	rRelative	660.45	1	1	CNY	rRelative	.013	1	1
CPY	rRelative	0.0025	1	1	CKY	rRelative	0.0032	1	1
[x] WSYF	vReplace	0.01	0.025833	0.025833	PST	rRelative	0.60	1	1
CSTS	rRelative	3.45	1	1	PRYG	rRelative	103.16	1	1
PRYF	rRelative	80.22	1	1	[x] WCY	vReplace	0.15	0.1515	0.1515
BN1	rRelative	0.0440	1	1	BN2	rRelative	.015	1	1
BN3	rRelative	.01	1	1	BP1	rRelative	0.0062	1	1
BP2	rRelative	0.0023	1	1	BP3	rRelative	0.0018	1	1
BK1	rRelative	0.0150	1	1	BK2	rRelative	0.0120	1	1
BK3	rRelative	0.0090	1	1	BW1	rRelative	0.433	1	1
BW2	rRelative	0.433	1	1	BW3	rRelative	0.213	1	1
IDC	rRelative	4.	1	1	FRST1	rRelative	5.15	1	1
FRST2	rRelative	15.95	1	1	WAVP	rRelative	8.00	1	1
VPTH	rRelative	0.50	1	1	VPD2	rRelative	4.75	1	1
RWPC1	rRelative	0.40	1	1	RWPC2	rRelative	0.20	1	1
GMHU	rRelative	100.00	1	1	PPLP1	rRelative	4.47	1	1
PPLP2	rRelative	7.77	1	1	STX1	rRelative	0.12	1	1
STX2	rRelative	1.70	1	1	BLG1	rRelative	0.01	1	1
BLG2	rRelative	0.10	1	1	WUB	rRelative	10.2	1	1
FTO	rRelative	0.00	1	1	FLT	rRelative	0.00	1	1

Create Parm

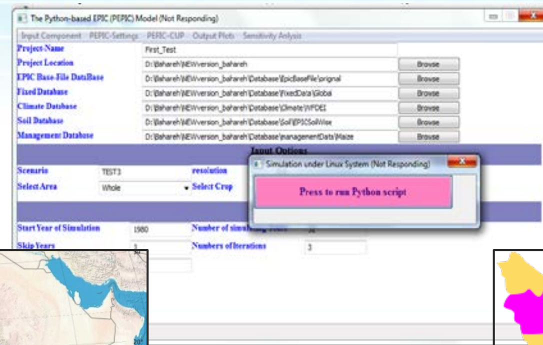
Automatic calibration: Linking EPIC with SUFI2 (EPIC+)

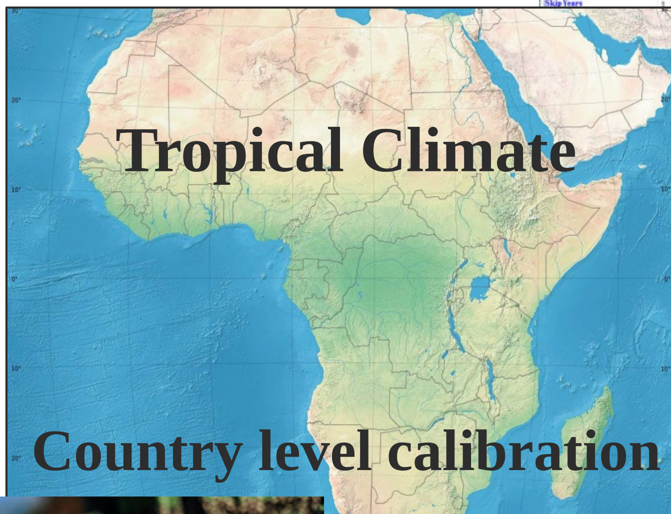


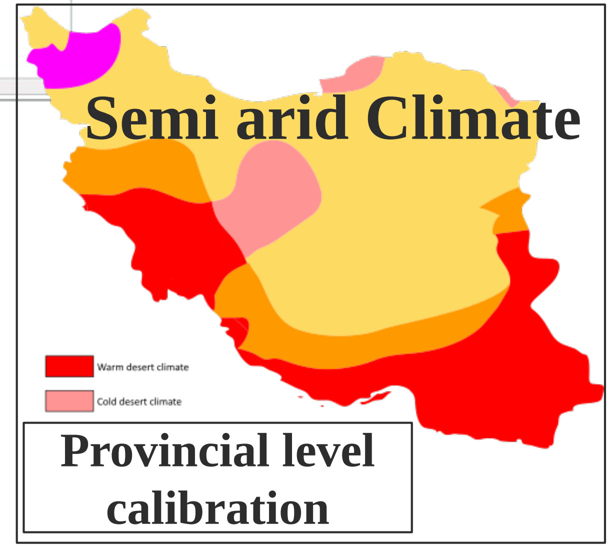
Microsoft Windows

- Parallel processing
- Running under windows and linux

Case Studies





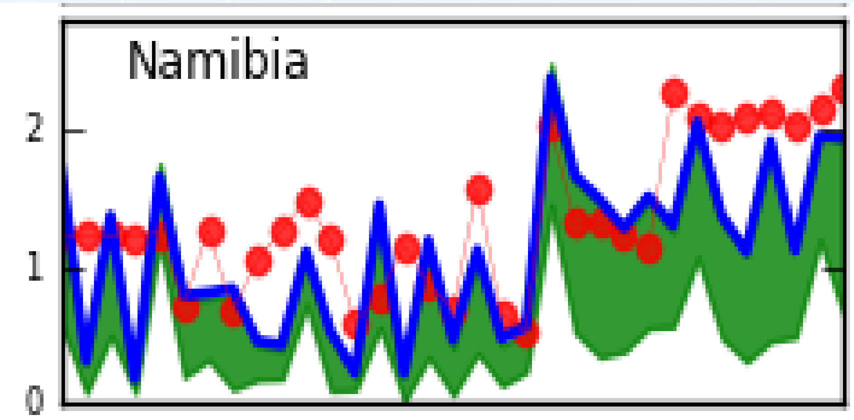


Maize

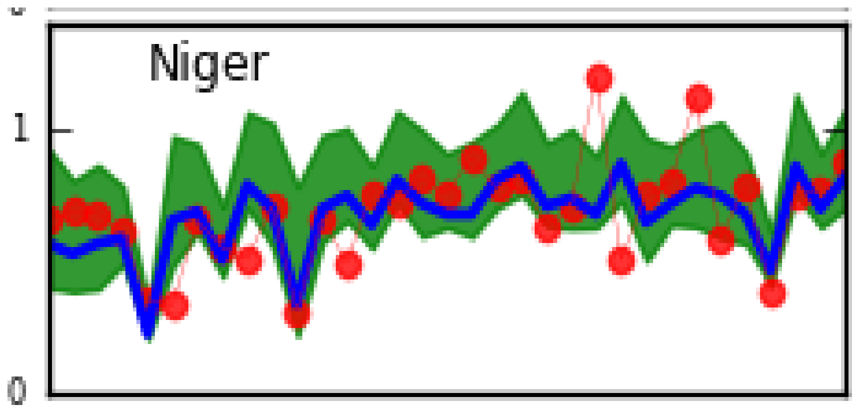
Sorghum

Wheat

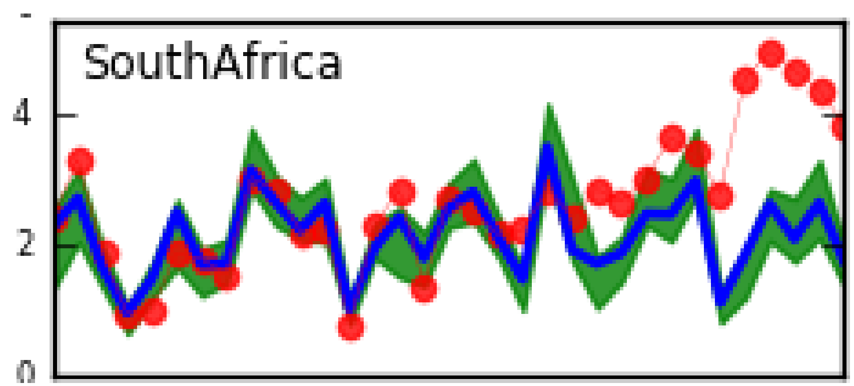
Sub-Saharan Africa



R2	P-factor	R-factor
0.42	0.60	1.3



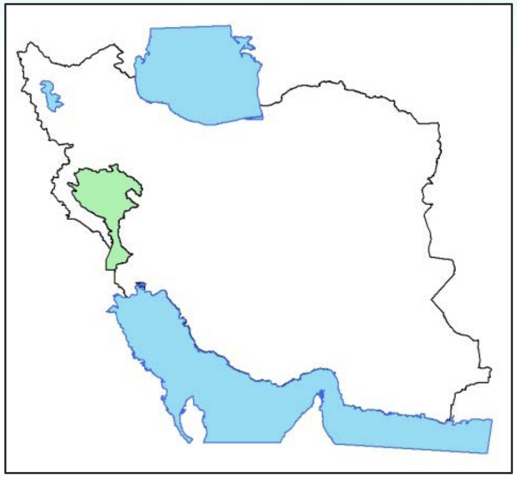
R2	P-factor	R-factor
0.32	0.55	1.1

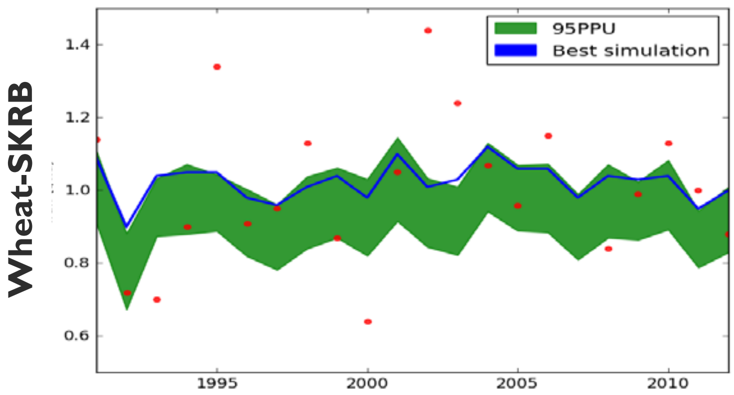


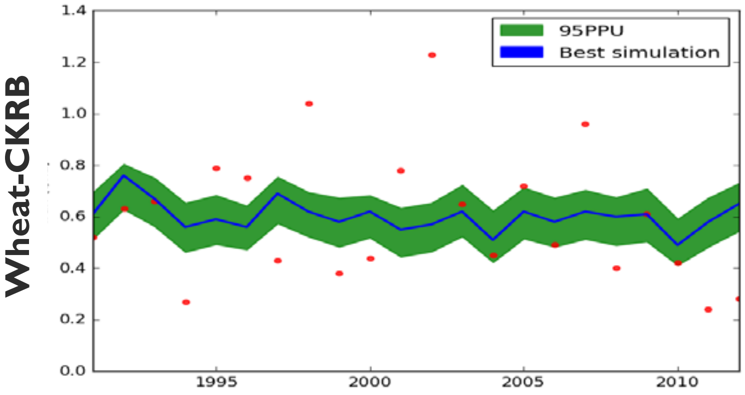
R2	P-factor	R-factor
0.28	0.68	1.2

Model calibration on provincial level and based on wheat yield

region	Mean Square Error	P-factor	R-factor
NKRB	0.13	0.52	1.1
CKRB	0.073	0.45	1.04
SKRB	0.096	0.55	1.17

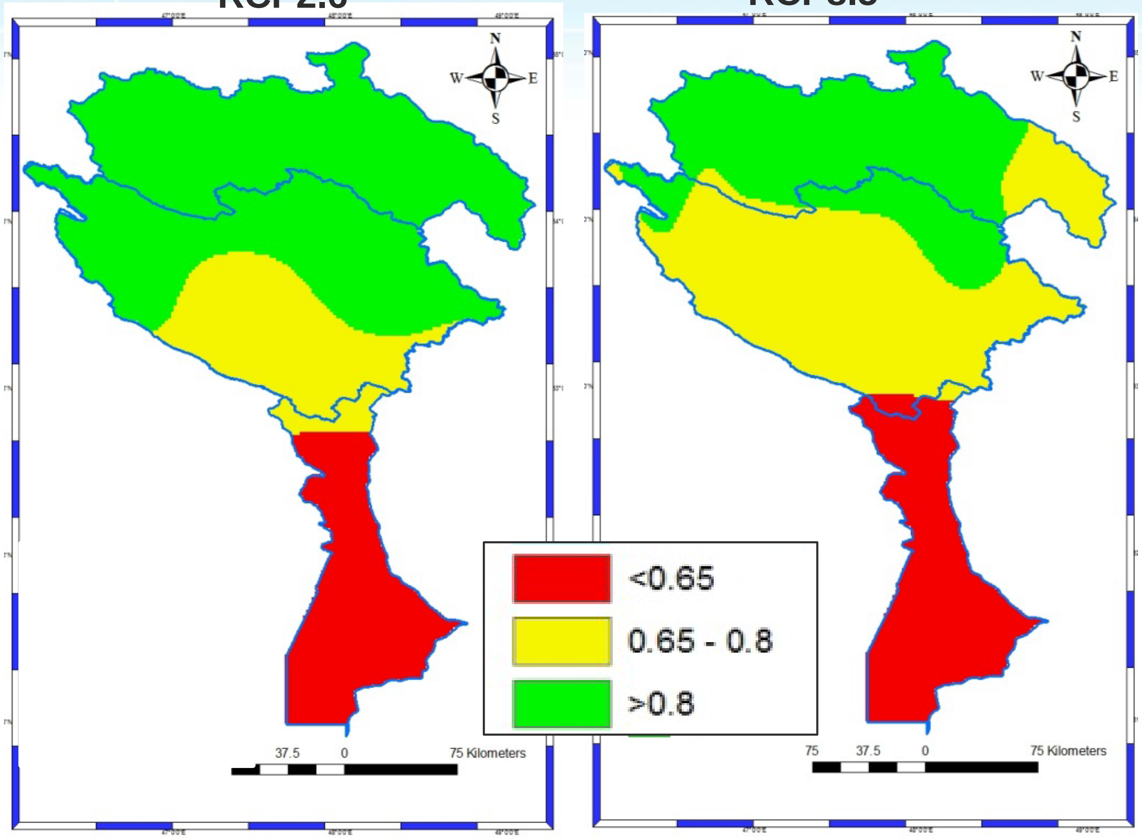






The impact of climate change on rainfed wheat in KRB

RCP2.6 | RCP8.5



$$\text{Relative Change} = \frac{\text{Future Yield}}{\text{Historic yield}}$$

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MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo) and National Institute for Environmental Studies
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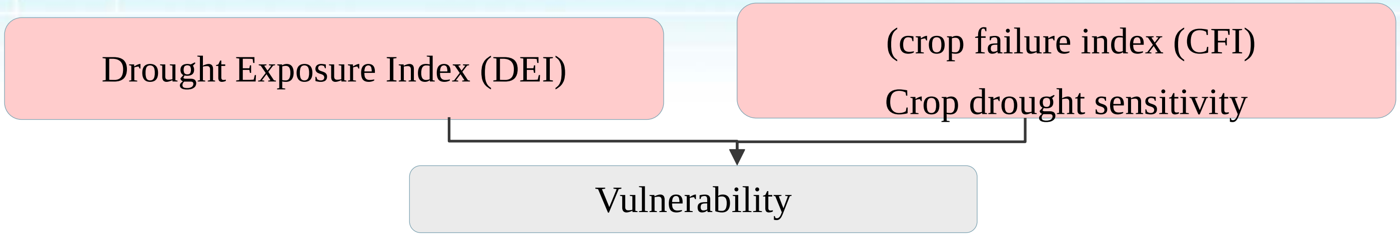
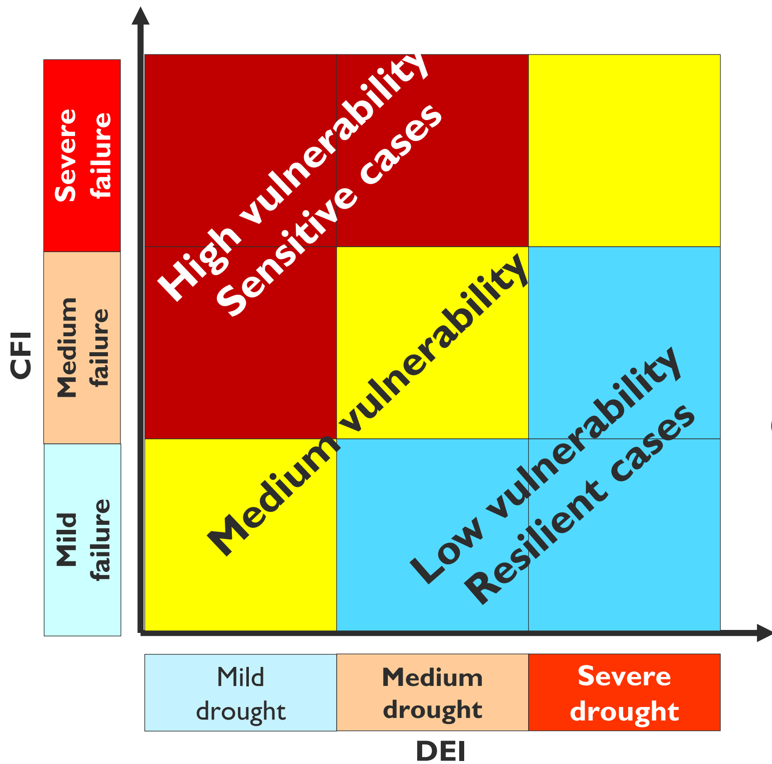
Step 2: Definition of crop drought vulnerability index (CDVI)





A high value of *DVI* :
identifies years and/or regions where the crop failure is larger compare to the magnitude of drought

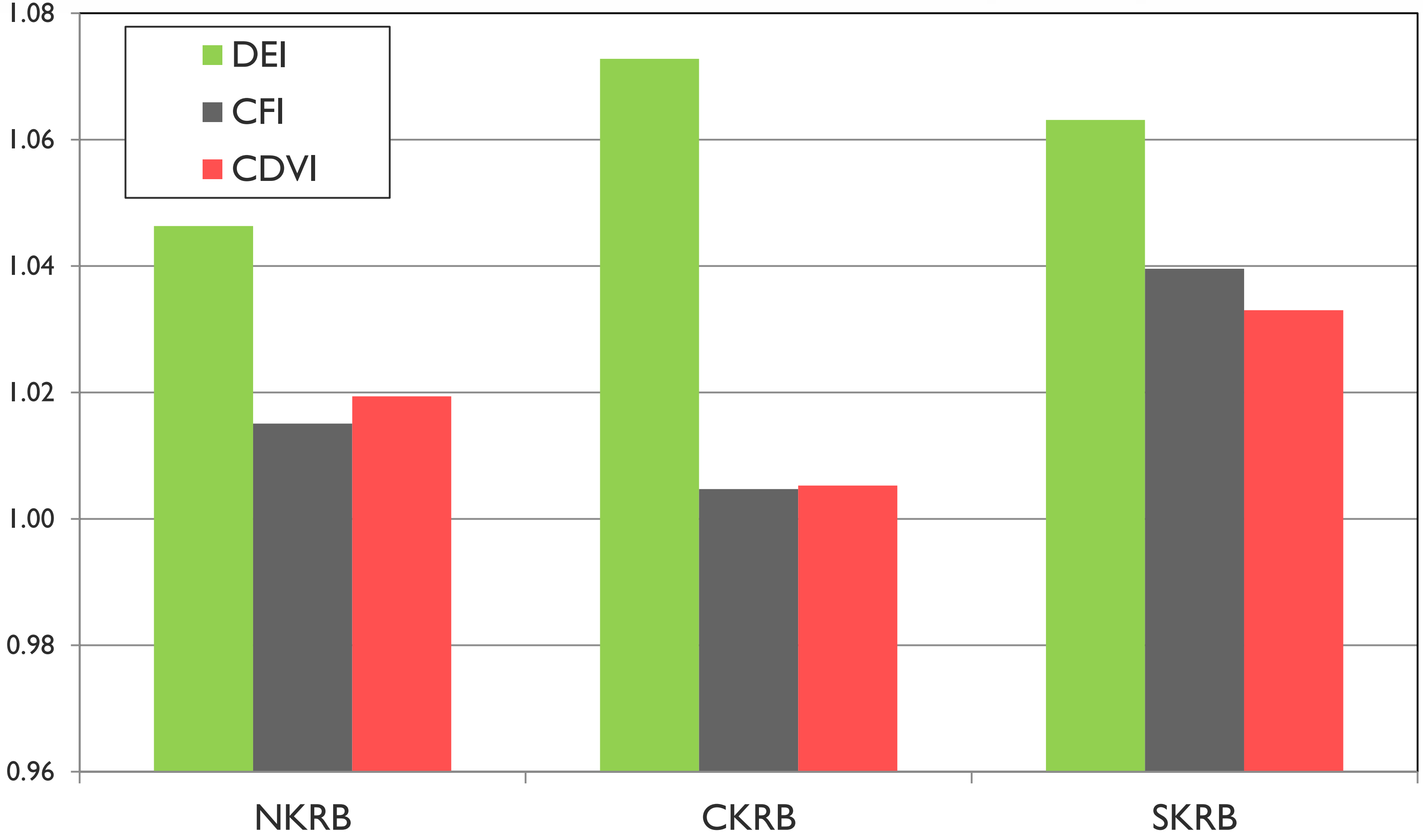
$$CDVI = \frac{CFI}{DEI}$$

$$CFI_t = \frac{\text{Expected-yield}_{historic}}{\text{Actual-yield}_t}$$

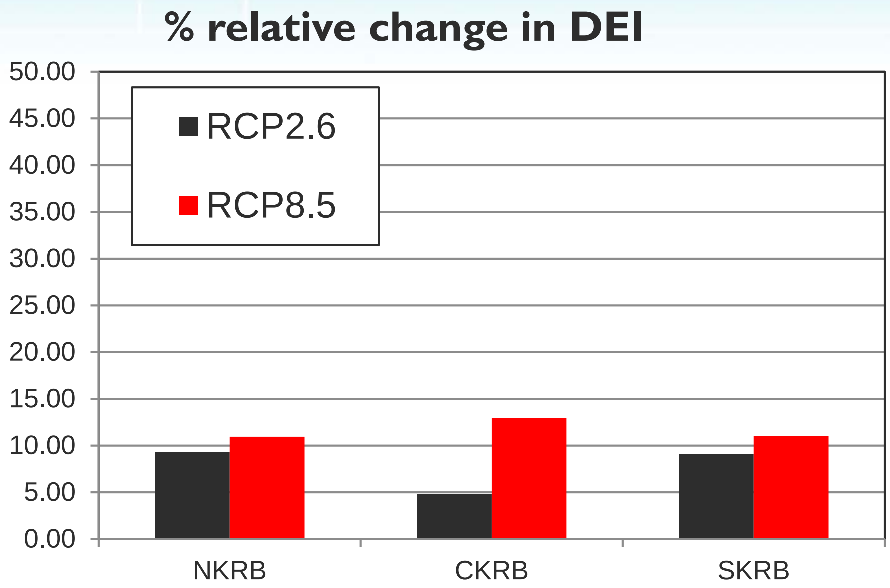
$$DEI_t = \frac{\text{Expected-PCP}_{historic}}{\text{Growing season-PCP}_t}$$

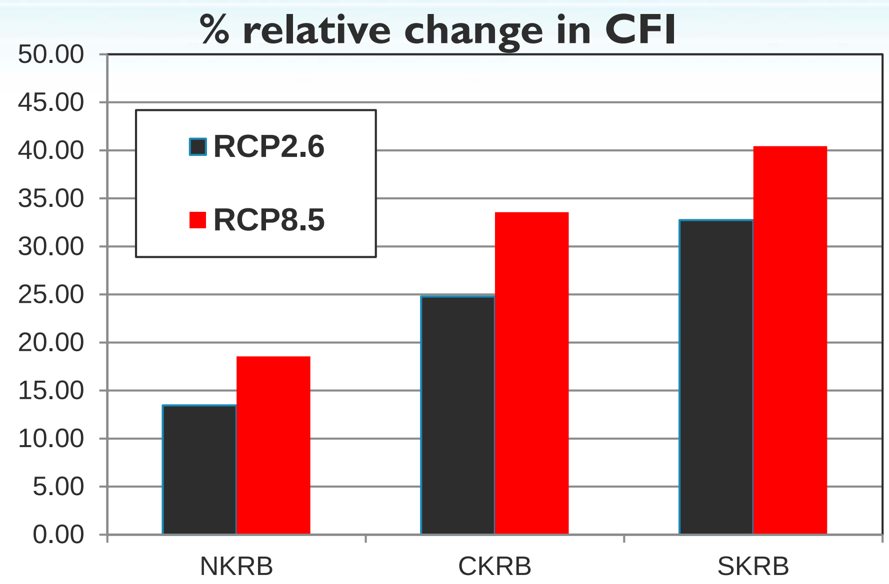
Simelton, E., E. D. G. Fraser, M. Termansen, P. M. Forster, and A. J. Dougill, 2009: Typologies of crop-drought vulnerability: an empirical analysis of the socio-economic factors that influence the sensitivity and resilience to drought of three major food crops in China (1961-2001). *Environ Sci Policy*, **12,** 438-452.

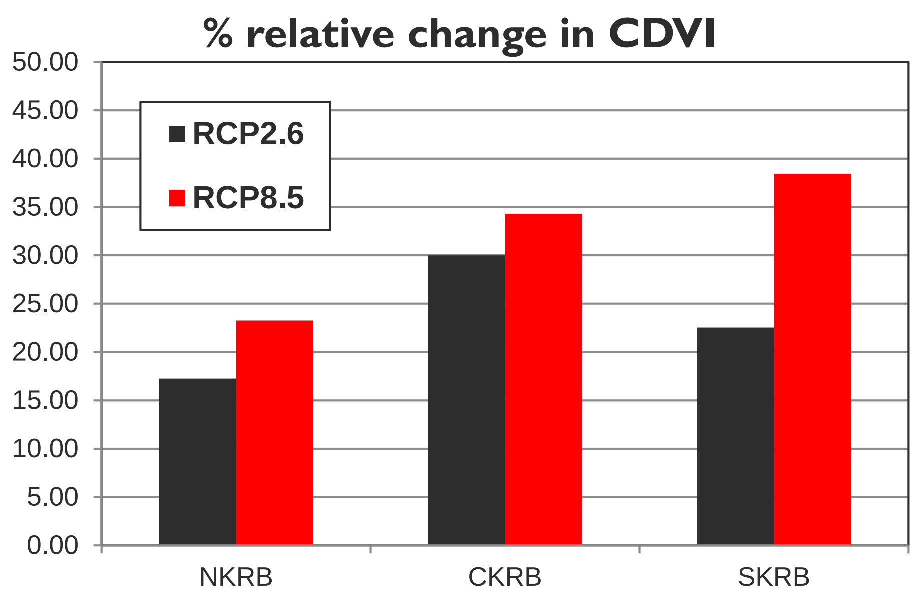
Interaction of DEI-CFI –CDVI during historic period



Climate change impact on CDVI and its components



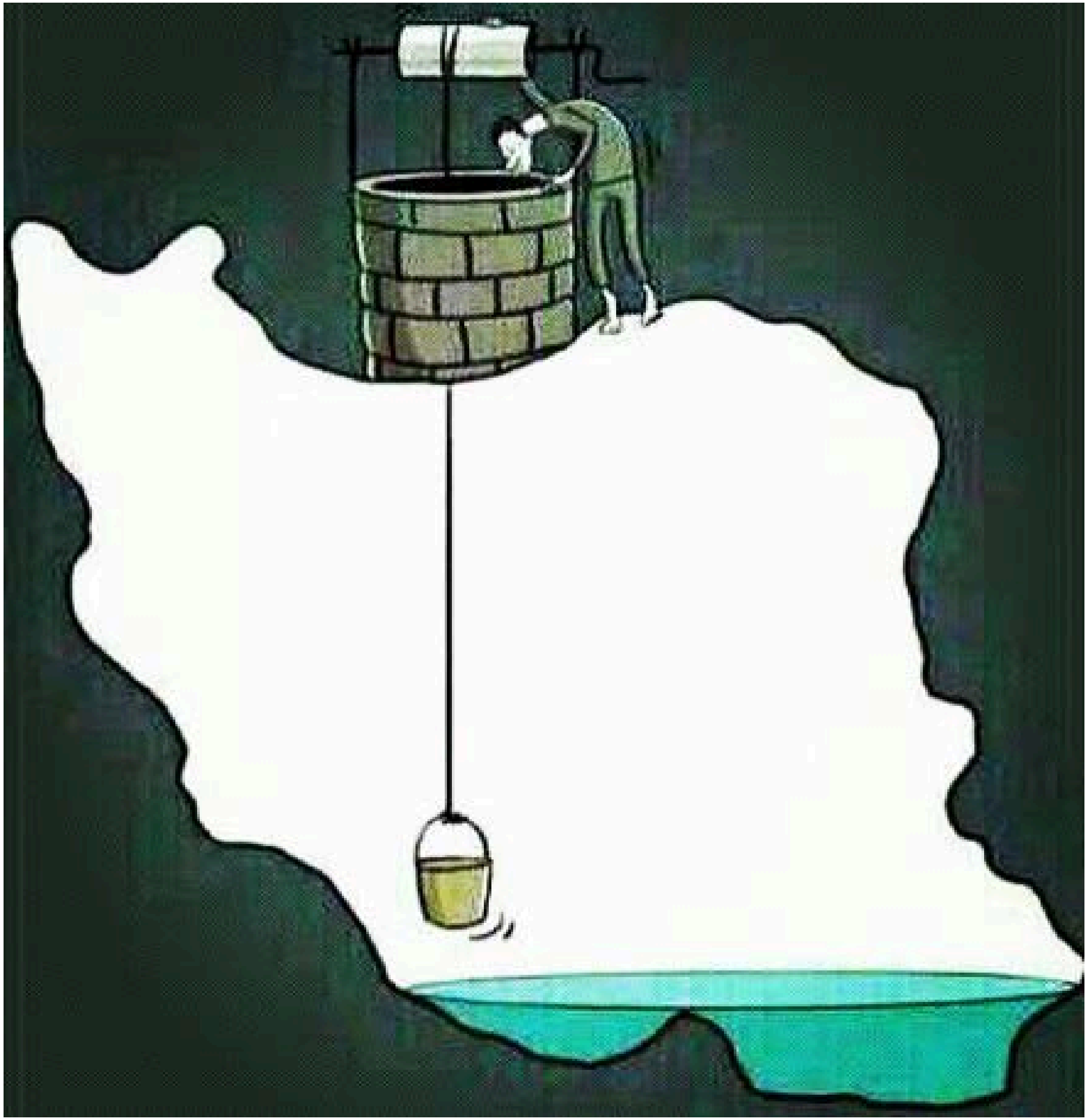




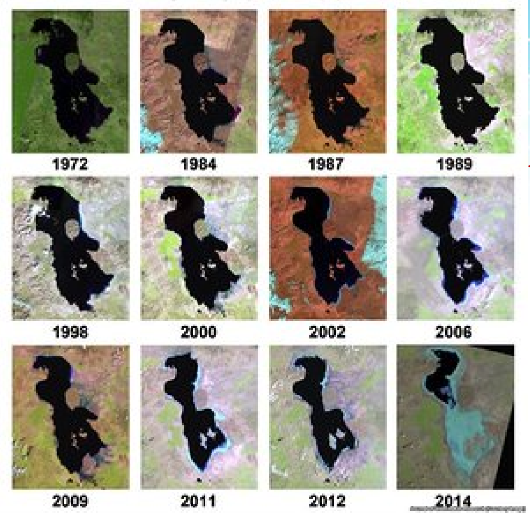
Summary and conclusion

- Iran has been experiencing extreme drought events over that last two decades;
- Climate change had more severe impacts on agricultural sectors and yield production;
- Agricultural sector is more exposed to drought;
- EPIC+SUFI2 is a practical for crop yield calibration on different scales;
- The results for Sub Saharan Africa and Iran were satisfactory;
- SKRB is more exposed to yield reduction;
- CKRB and SKRB are more vulnerable to drought;

Thanks for your attention



Droughts in Iran



Urmia Lake

Zayandehrood Basin

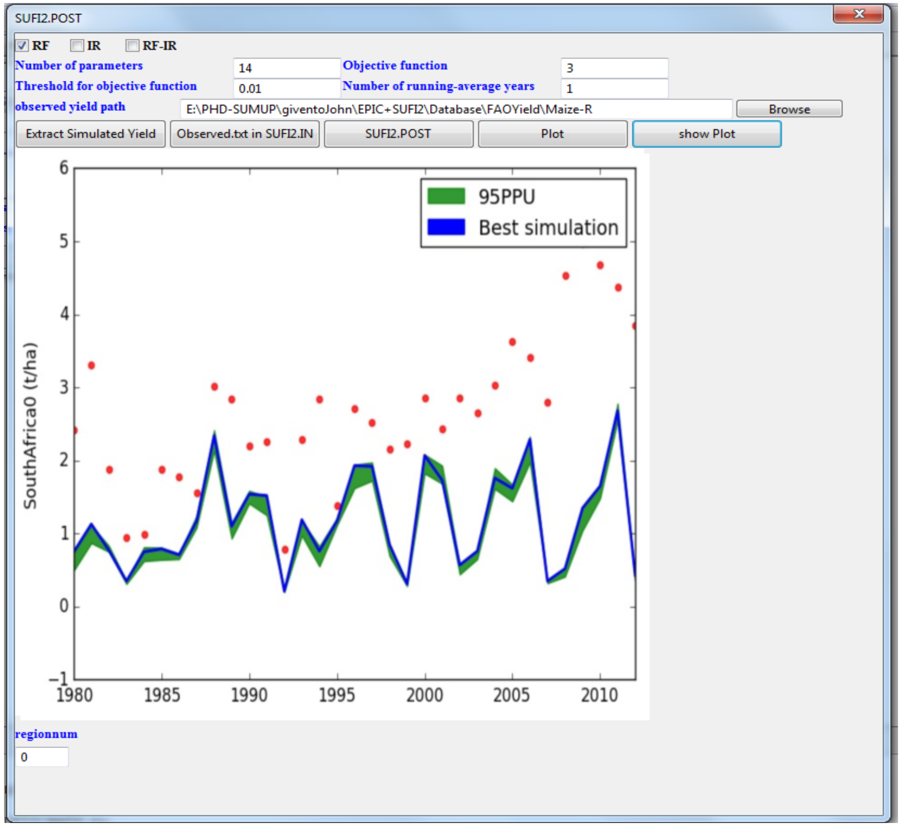
Karun Basin

ISNA/PHOTO:HADI JAFARZADEH

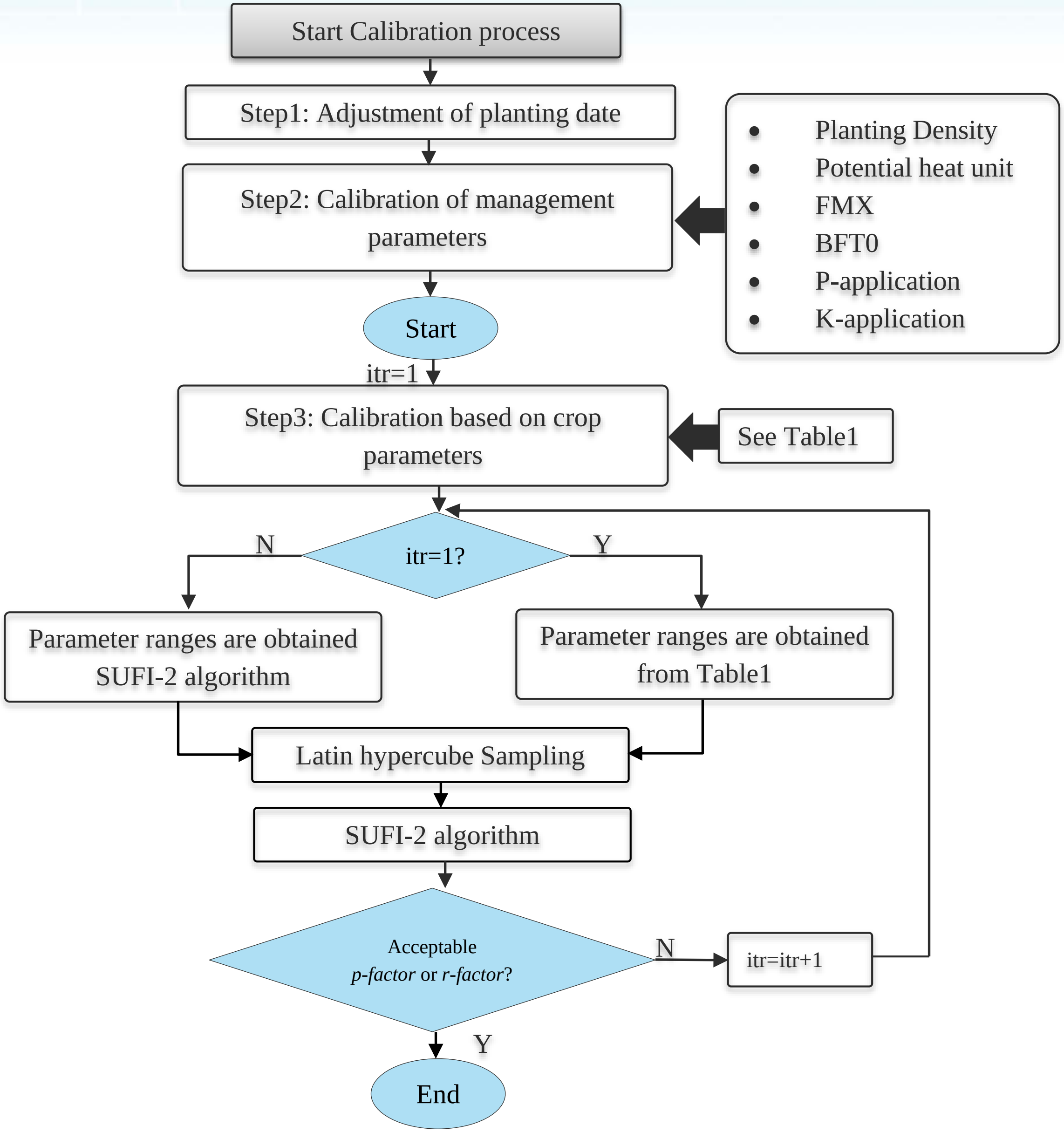
Calibration

- Similar structure to SUFI2 in SWAT-CUP
- Latin hypercube sampling
  - **Replacement**: Parameters are changed between maximum and minimum;
  - **Relative:** An existing parameter is multiplied by a relative value defined between a maximum and minimum;

- A python script is prepared for each iteration;
- Considering different objective functions



General procedure performed for calibration



General procedure followed to perform calibration