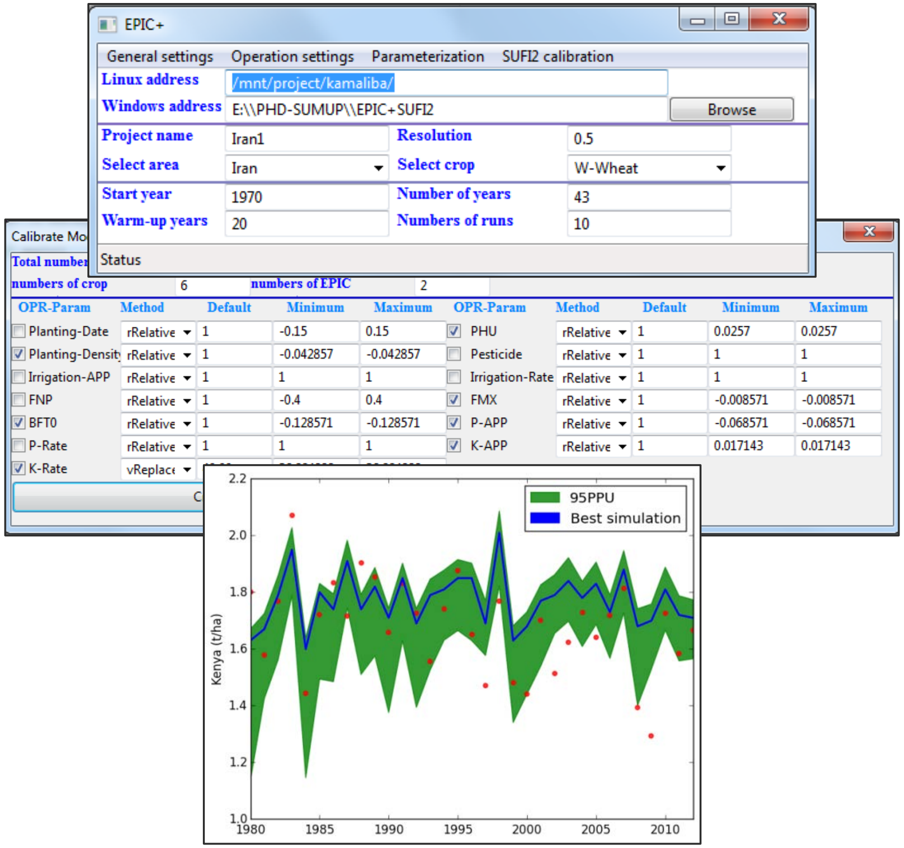
# An introduction to EPIC+SUFI2 for calibrating EPIC crop growth model at different scales

**Bahareh Kamali**, Karim C. Abbaspour, Hong Yang



# EPIC Structure

EPIC
Environmental Policy Integrated Climate model

- One of the most widely used crop models that simulate crop-related processes at a specific site
- Operates on daily time step
- Offers different options for agricultural operations

EPIC0810.exe
Read EPICRUN
**Line by line**

Controls the execution process

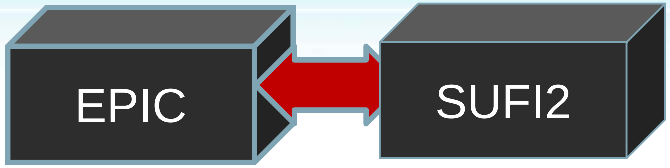
Climate data

Agricultural operation

Physiographic data

| | | | |
|---|---|---|---|
| fort.51 | 8/6/2015 1:51 PM | 51 File | 676 KB |
| EPIC0810 | 6/9/2011 10:40 AM | Application | 3,824 KB |
| AYEAR | 4/4/2005 1:33 PM | DAT File | 1 KB |
| CMOD0810 | 9/10/2001 12:42 PM | DAT File | 1 KB |
| CROPCOM | 5/26/2015 1:10 PM | DAT File | 66 KB |
| EPICCONT | 6/1/2015 6:24 PM | DAT File | 1 KB |
| EPICERR | 9/27/2010 9:16 AM | DAT File | 1 KB |
| epicfile | 6/9/2011 10:01 AM | DAT File | 1 KB |
| EPICRUN | 6/2/2015 2:52 PM | DAT File | 1 KB |
| FERTCOM | 5/4/2011 12:28 PM | DAT File | 8 KB |
| MLRN0810 | 3/24/2008 10:18 AM | DAT File | 1 KB |
| OPSCCOM | 7/2/2015 6:46 PM | DAT File | 1 KB |
| PARM0810 | 4/4/2011 10:14 AM | DAT File | 2 KB |
| PESTCOM | 6/1/2007 10:14 AM | DAT File | 21 KB |
| PRNT0810 | 7/2/2015 6:46 PM | DAT File | 2 KB |
| RTSOIL | 3/21/2011 9:08 AM | DAT File | 1 KB |
| SITECOM | 6/2/2015 2:54 PM | DAT File | 1 KB |
| SOILCOM | 6/2/2015 2:58 PM | DAT File | 1 KB |
| TILLCOM | 7/12/2015 5:24 PM | DAT File | 60 KB |
| TR55COM | 11/6/2007 10:30 AM | DAT File | 6 KB |
| WDLSTCOM | 6/3/2015 10:24 AM | DAT File | 1 KB |
| WIDXCOM | 9/14/2005 2:27 PM | DAT File | 8 KB |
| WINDUSEL | 12/2/2014 8:50 AM | DAT File | 1 KB |
| WORKSPACE | 6/3/2015 10:24 AM | DAT File | 1 KB |
| WPM1USEL | 6/3/2015 10:24 AM | DAT File | 1 KB |
| WPM5US | 10/12/2004 9:38 AM | DAT File | 393 KB |
| TEMP | 6/3/2015 10:24 AM | DLY File | 953 KB |
| log | 5/27/2015 8:42 AM | File | 1 KB |
| TEMP | 7/2/2015 6:29 PM | OPS File | 2 KB |
| Default_SIT | 7/6/2015 5:08 PM | SIT File | 1 KB |
| TEMP | 7/6/2015 5:08 PM | SIT File | 1 KB |
| TEMP | 6/3/2015 10:24 AM | SOL File | 1 KB |
| RUN0810.SUM | 8/6/2015 1:51 PM | SUM File | 1 KB |
| TEMP.WND | 4/14/2015 10:52 PM | WND File | 2 KB |
| TEMP | 6/3/2015 10:24 AM | WP1 File | 2 KB |

# Why EPIC+SUFI2?




## Main Goals

**Objective 1:** Extending its application from site-based to different scales (regional, county and continent)

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

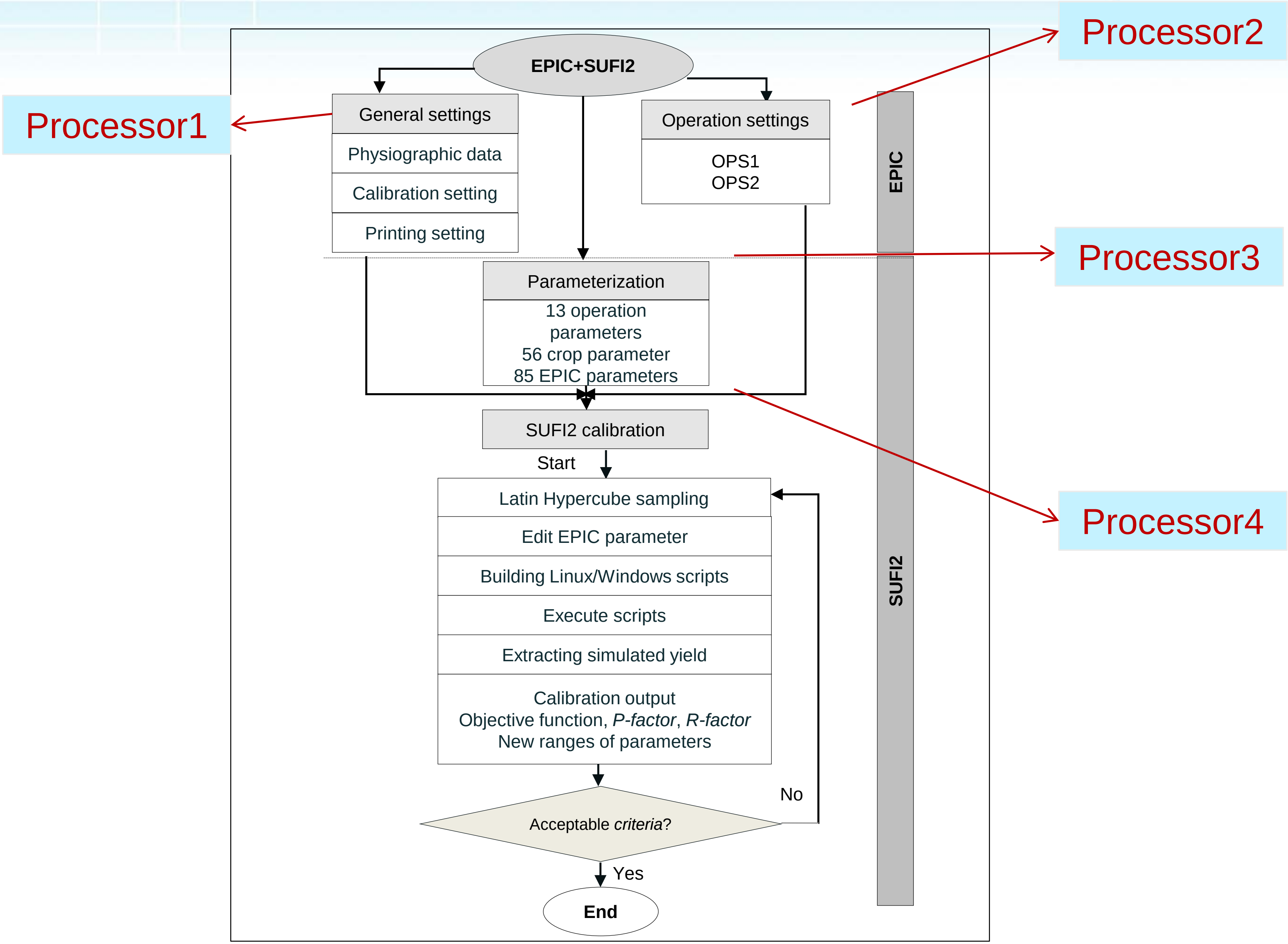
Drought vulnerability assessment

## Other objectives

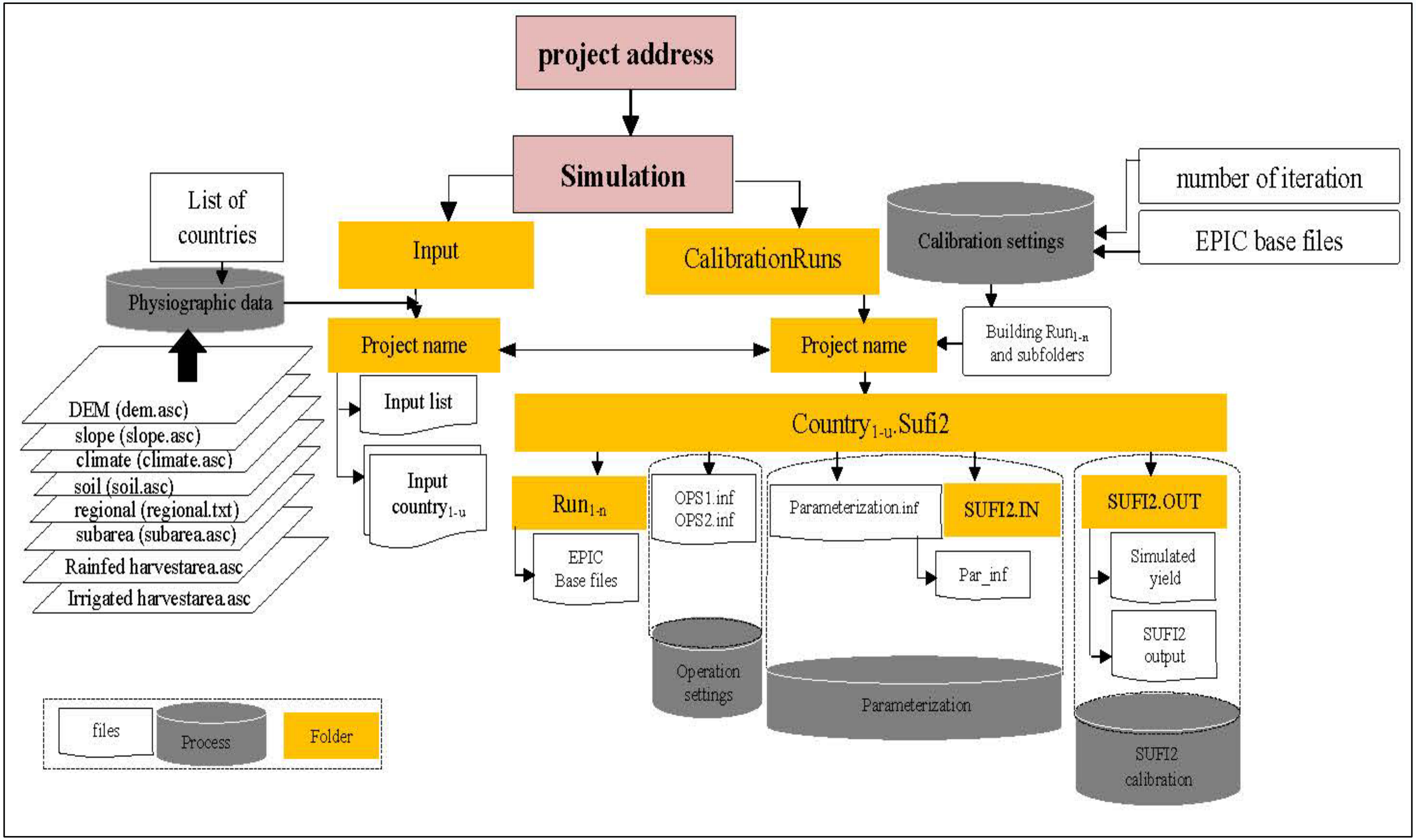
- A **user-friendly workspace** where the user manage settings of input data systematically;
- **Setting agricultural operations** in different ways;
- Setting of **printing outputs**;

- Different options for **EPIC parameterization**;
- Considering uncertainties in **operational data**, *PHU*, *N-P-K* application rate, Planting date;
- Considering **sensitivity analysis**
- Evaluating **model performance** based on different objective function;
- **Speed up** simulations on large scales;

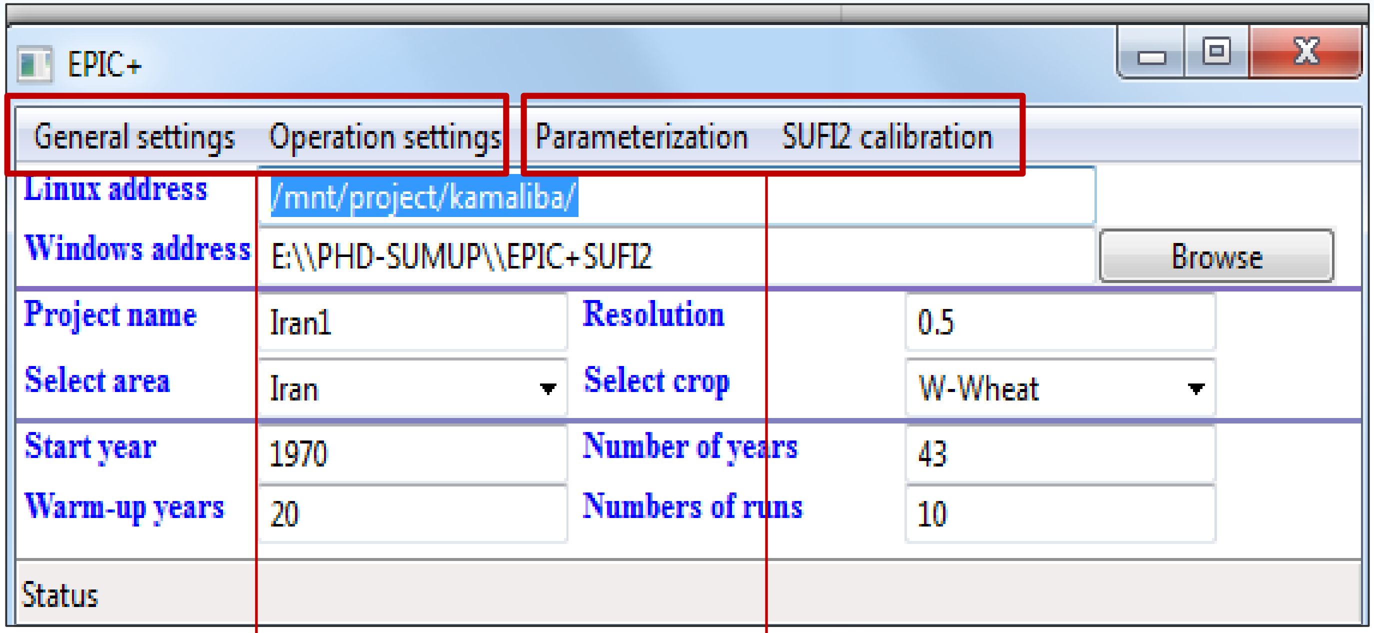
# EPIC+SUFI2 structure



# EPIC+SUFI2 architecture



# EPIC+SUFI2 main window

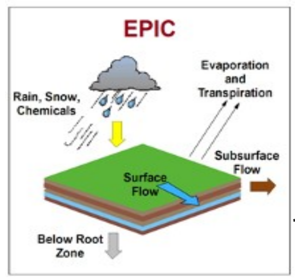


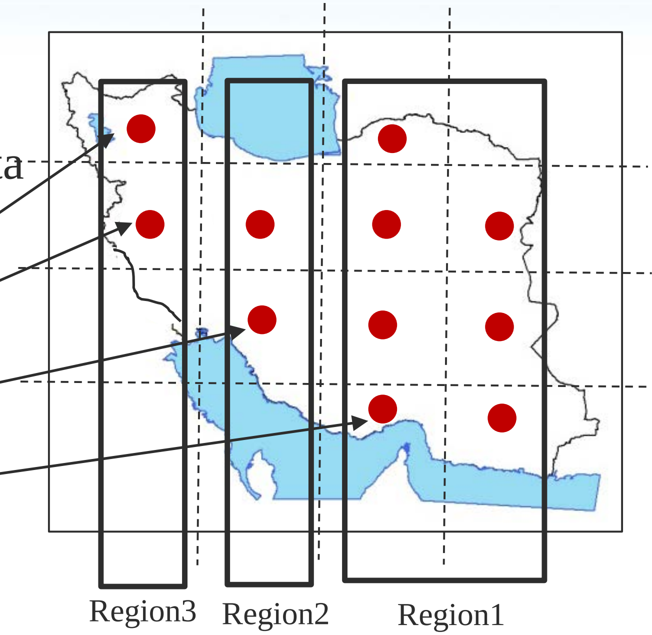

Objective-1

Objective-2

# Objective 1:Extending its application to different scale

- Country level is the core scale
- The user can define different resolution depending on data

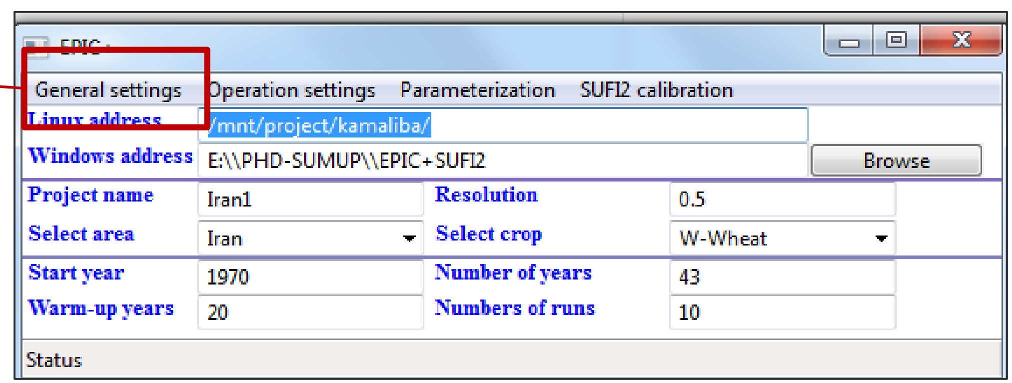


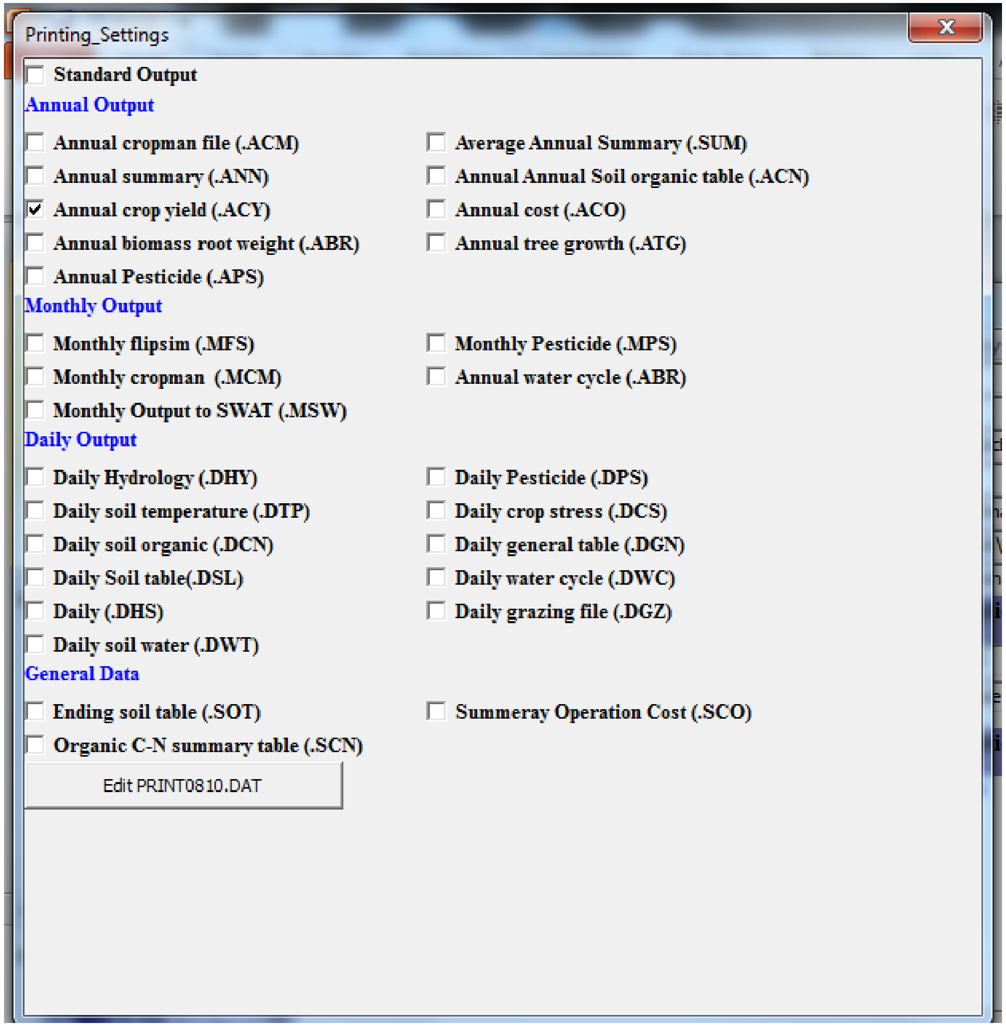

**Smaller scale,** each country can be divided into regions

**Larger scale,** selecting a group of countries

Initial Settings

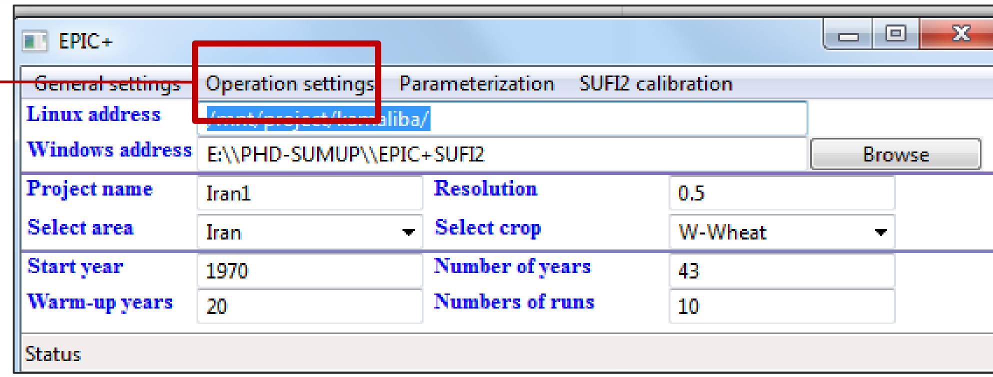


# Printing options



# Agricultural operation

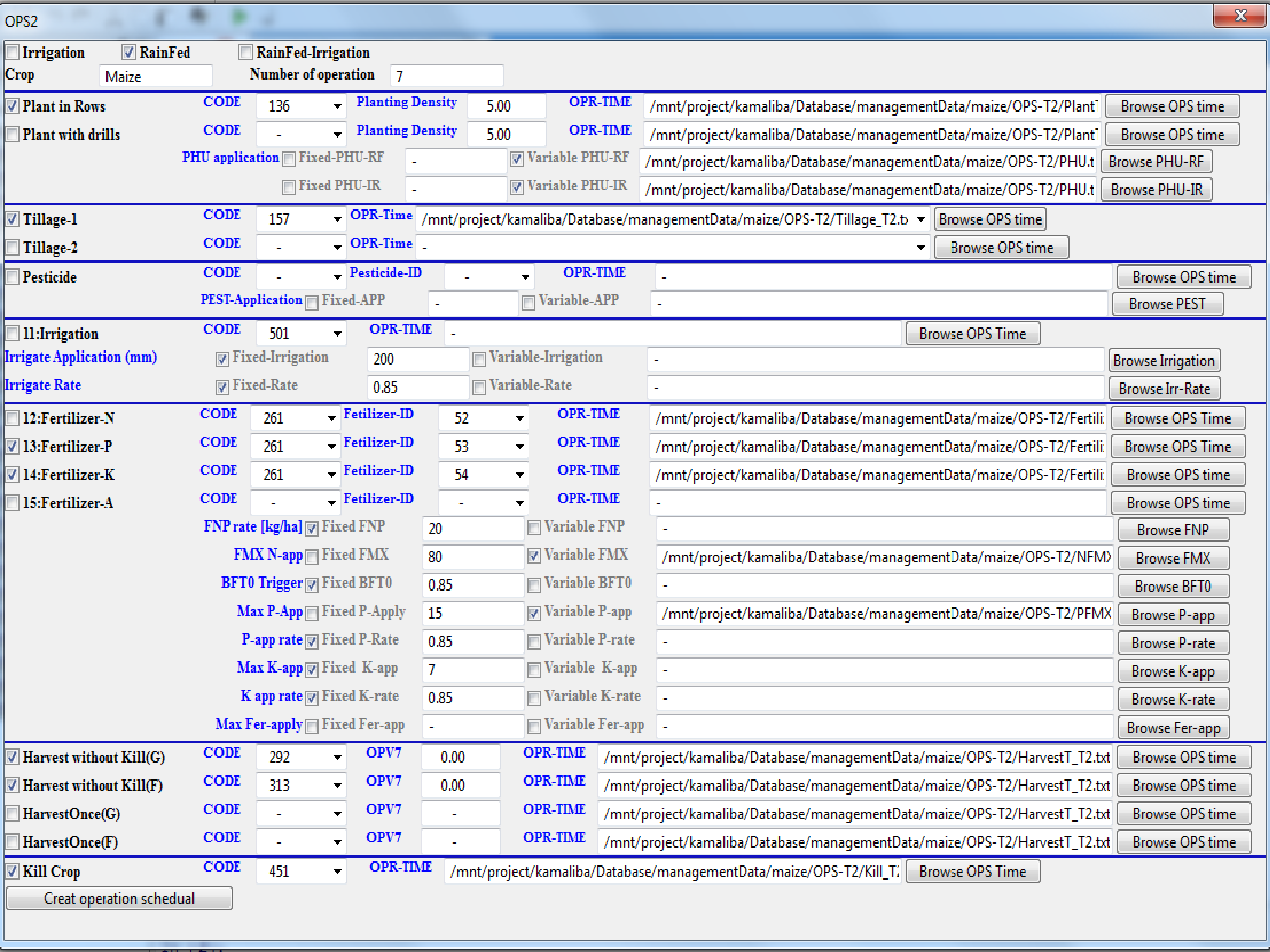
Agricultural operation settings




- Select the sets of operations from planting date to harvesting date;
- Two options are available:

**OPS1** → planting date is considered as calibrating parameters

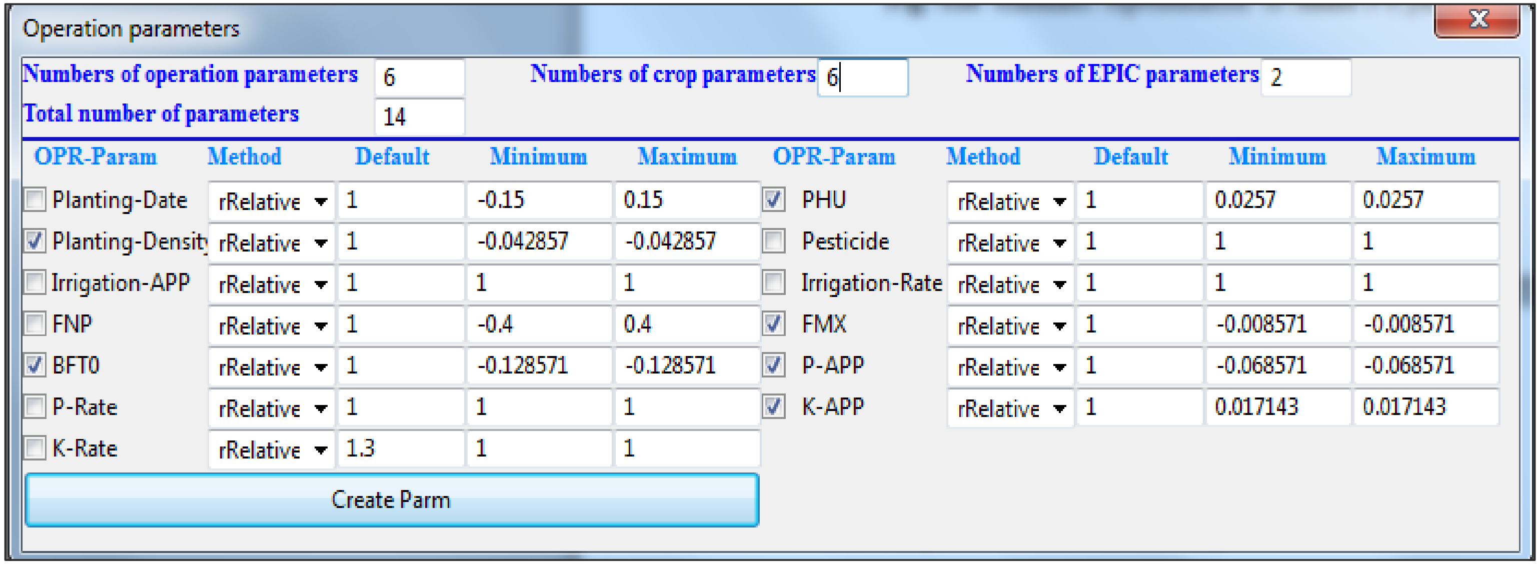
**OPS2** → planting date is not a calibrating parameter, but can change from one grid to another


OPS2
Irrigation
RainFed
RainFed-Irrigation
Crop
Maize
Number of operation
7
Plant in Rows
CODE
136
Planting Density
5.00
OPR-TIME
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/Plant
Browse OPS time
Plant with drills
CODE
-
Planting Density
5.00
OPR-TIME
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/Plant
Browse OPS time
PHU application
Fixed-PHU-RF
-
Variable PHU-RF
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/PHU.t
Browse PHU-RF
Fixed PHU-IR
-
Variable PHU-IR
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/PHU.t
Browse PHU-IR
Tillage-1
CODE
157
OPR-Time
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/Tillage_T2.t
Browse OPS time
Tillage-2
CODE
-
OPR-Time
-
Browse OPS time
Pesticide
CODE
-
Pesticide-ID
-
OPR-TIME
-
Browse OPS time
PEST-Application
Fixed-APP
-
Variable-APP
-
Browse PEST
11:Irrigation
CODE
501
OPR-TIME
-
Browse OPS Time
Irrigate Application (mm)
Fixed-Irrigation
200
Variable-Irrigation
-
Browse Irrigation
Irrigate Rate
Fixed-Rate
0.85
Variable-Rate
-
Browse Irr-Rate
12:Fertilizer-N
CODE
261
Fetilizer-ID
52
OPR-TIME
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/Fertil
Browse OPS Time
13:Fertilizer-P
CODE
261
Fetilizer-ID
53
OPR-TIME
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/Fertil
Browse OPS Time
14:Fertilizer-K
CODE
261
Fetilizer-ID
54
OPR-TIME
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/Fertil
Browse OPS time
15:Fertilizer-A
CODE
-
Fetilizer-ID
-
OPR-TIME
-
Browse OPS time
FNP rate [kg/ha]
Fixed FNP
20
Variable FNP
-
Browse FNP
FMX N-app
Fixed FMX
80
Variable FMX
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/NFM
Browse FMX
BFT0 Trigger
Fixed BFT0
0.85
Variable BFT0
-
Browse BFT0
Max P-App
Fixed P-Apply
15
Variable P-app
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/PFMX
Browse P-app
P-app rate
Fixed P-Rate
0.85
Variable P-rate
-
Browse P-rate
Max K-app
Fixed K-app
7
Variable K-app
-
Browse K-app
K app rate
Fixed K-rate
0.85
Variable K-rate
-
Browse K-rate
Max Fer-apply
Fixed Fer-app
-
Variable Fer-app
-
Browse Fer-app
Harvest without Kill(G)
CODE
292
OPV7
0.00
OPR-TIME
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/HarvestT_T2.txt
Browse OPS time
Harvest without Kill(F)
CODE
313
OPV7
0.00
OPR-TIME
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/HarvestT_T2.txt
Browse OPS time
HarvestOnce(G)
CODE
-
OPV7
-
OPR-TIME
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/HarvestT_T2.txt
Browse OPS time
HarvestOnce(F)
CODE
-
OPV7
-
OPR-TIME
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/HarvestT_T2.txt
Browse OPS time
Kill Crop
CODE
451
OPR-TIME
/mnt/project/kamaliba/Database/managementData/maize/OPS-T2/Kill_T
Browse OPS Time
Creat operation schedual

eawag aquatic research

# Parameterization

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



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aquatic research

# Other parameters

## 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 |
| [ ] PARM29 | rRelative | .01 | 1 | 1 | [ ] PARM30 | rRelative | 1. | 1 | 1 |
| [ ] PARM31 | rRelative | 1.5 | 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

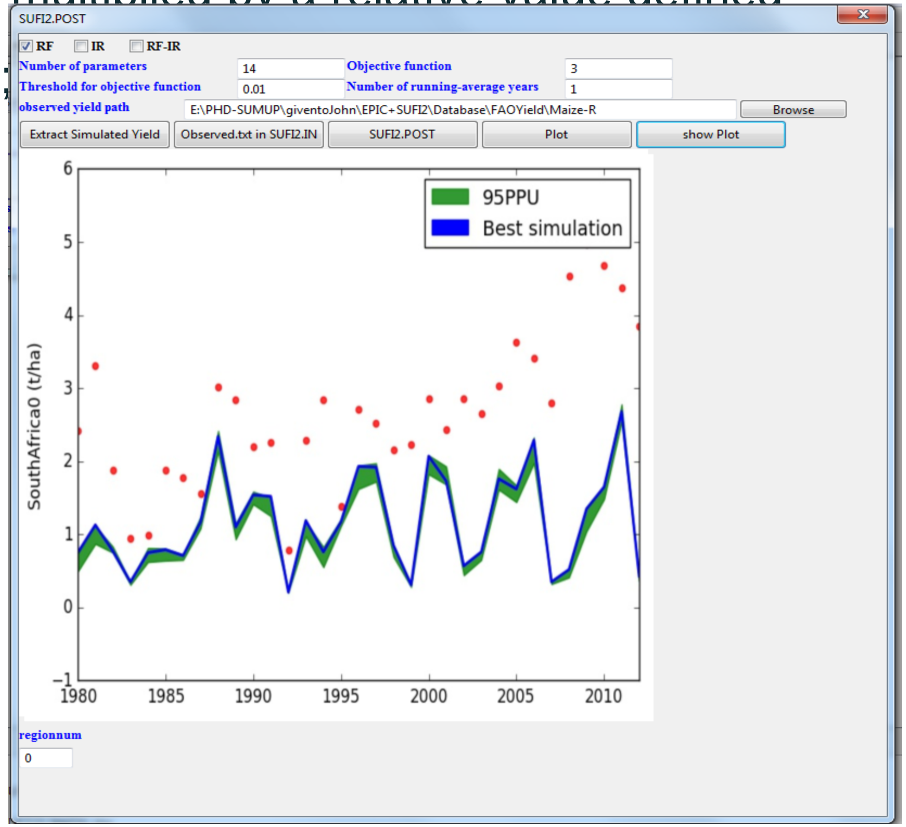
Crop parameters

| 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

# 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

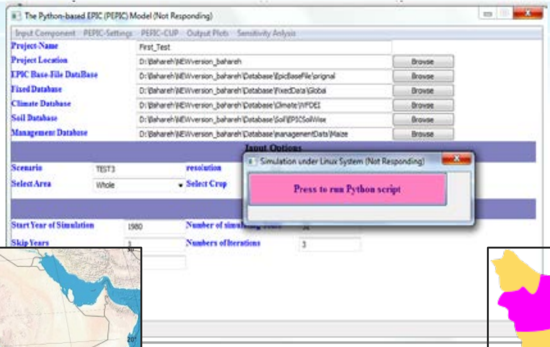


# Speed up Simulations

- The Linux scripts were prepared.
  - Splitting each iteration in one cluster to do parallel processing

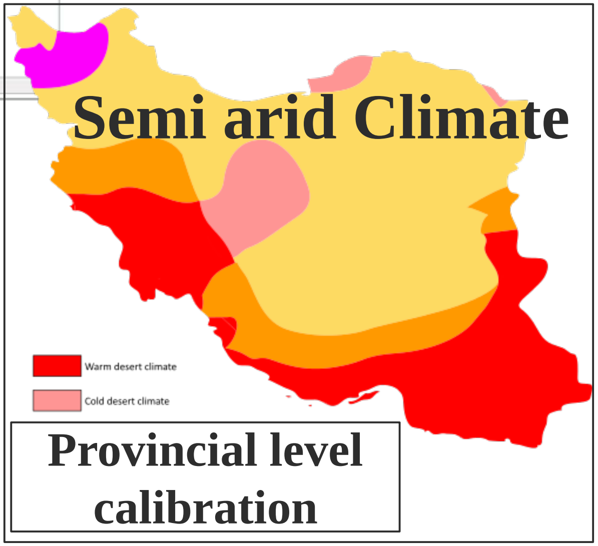
Microsoft Windows

# Case Studies




Tropical Climate

Country level calibration




Semi arid Climate

Provincial level calibration

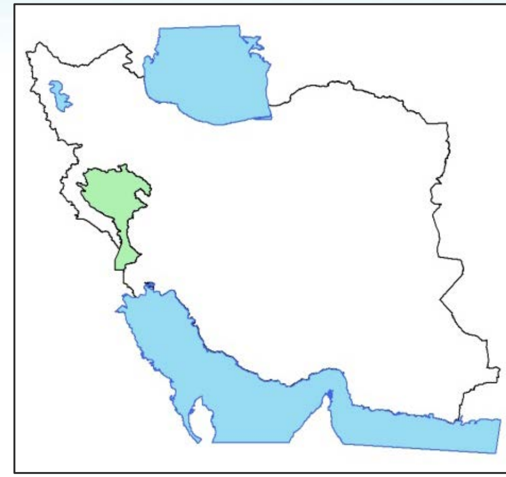
Maize

Sorghum

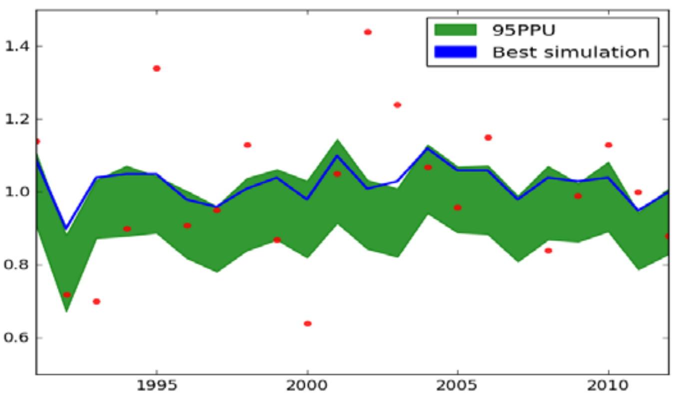
Wheat

# Model calibration on provincial level and based on wheat yield

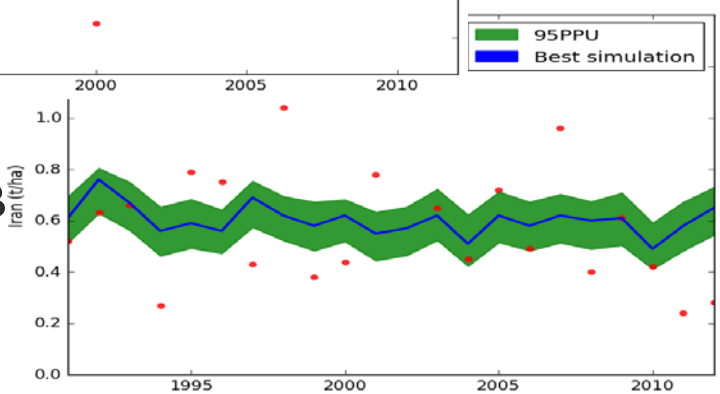
| region | Mean Square Error | P-factor | R-factor |
|---|---|---|---|
| NKRB | 0.13 | 0.52 | 1.1 |
| CKRB | 0.073 | 0.45 | 1.04 |
| SKRB | 0.096 | 0.55 | 1.17 |



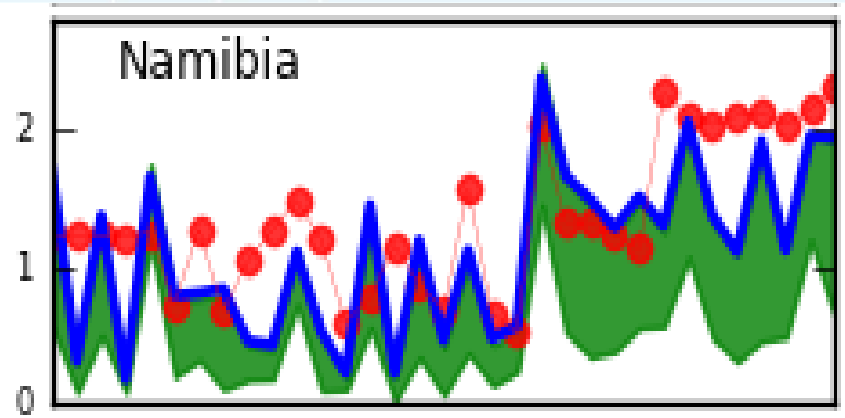
SKRB



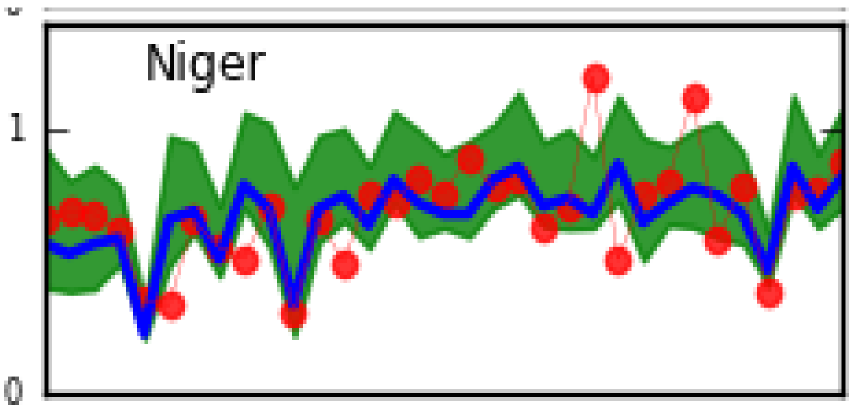

CKRB



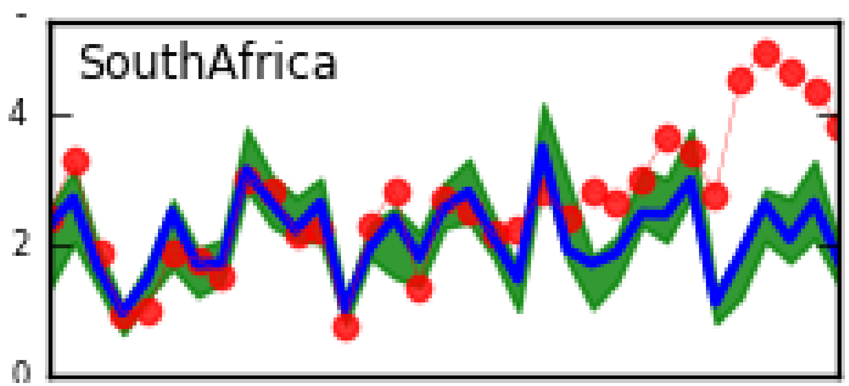
# Sub-Saharan Africa




| R2 | P-factor | R-factor |
|---|---|---|
| 0.42 | 0.60 | 1.3 |

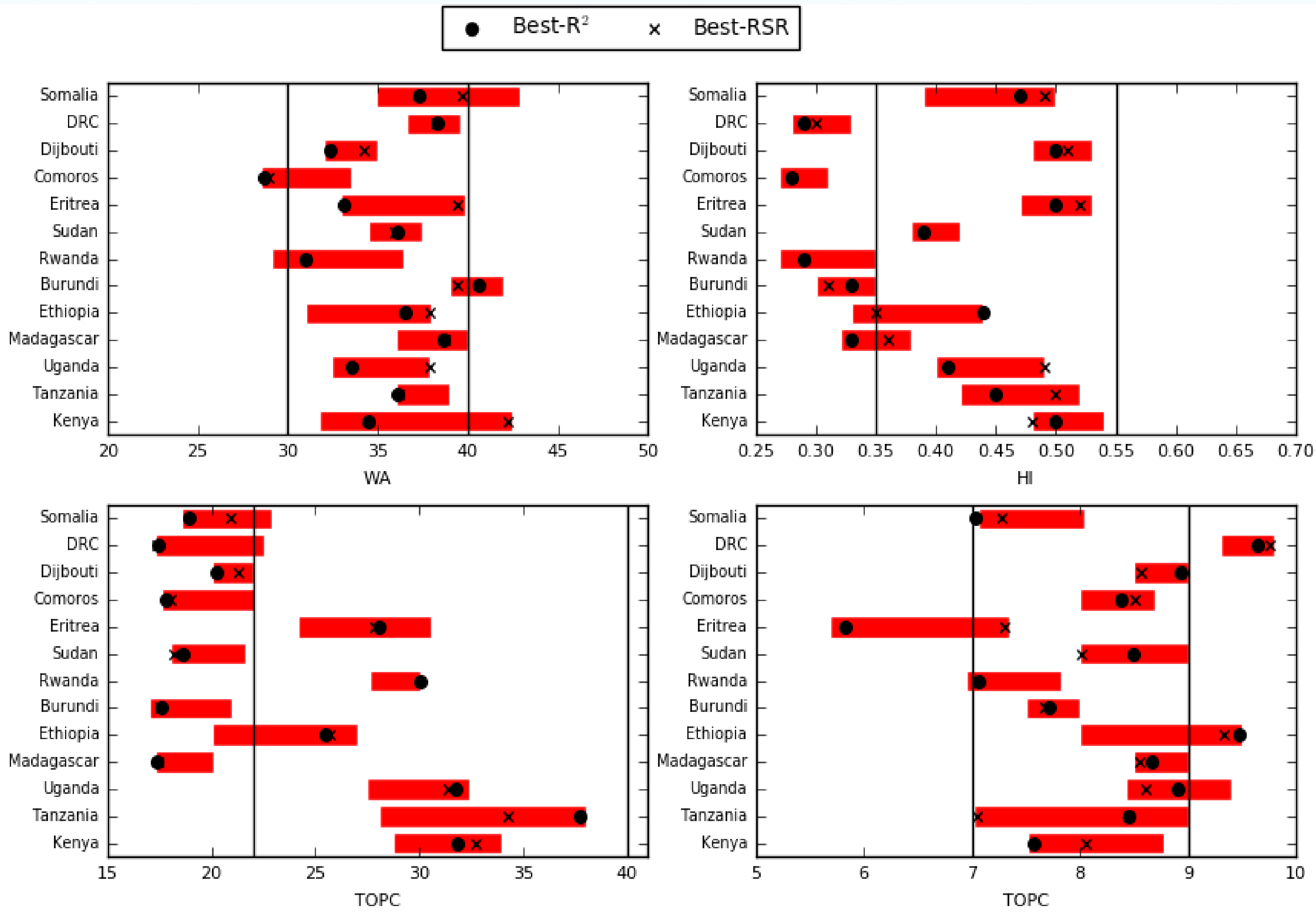



| R2 | P-factor | R-factor |
|---|---|---|
| 0.32 | 0.55 | 1.1 |




| R2 | P-factor | R-factor |
|---|---|---|
| 0.28 | 0.68 | 1.2 |

# Final ranges of parameters



# Sensitivity Analysis

**One at once sensitivity analysis:** Model calibration to validate that crop model is replicating historic period

$$S = \frac{\Delta X}{\Delta b}\frac{b}{X}$$

**Global sensitivity analysis:** Long-term model calibration and validation were needed to

$$g = \alpha + \sum_{i=1}^{m} \beta_i b_i$$

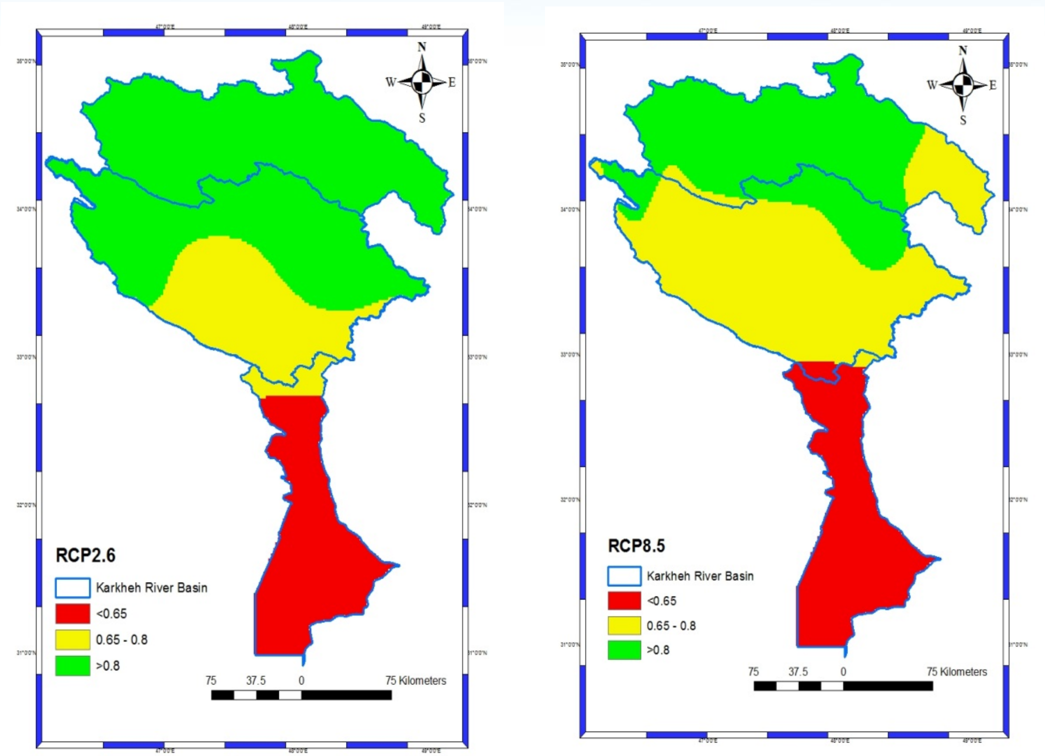
# Summary

- EPIC+SUFI2 is a practical for crop yield calibration on different scales
- The results for Sub Saharan Africa and Iran were satisfactory;
- The final ranges of parameters will always need user's interpretation, so that they are physically meaningful;
- This is the first version of the model, improvement in different perspective will certainly be needed.


Thanks for your attention
2015 International SWAT Conference / ITALY


2016 International SWAT Conference in Beijing, China

# The impact of climate change on rainfed yield in KRB




| GCM Name | Institute full name |
|---|---|
| HadGEM2-ES | Met Office Hadley Centre and Instituto Nacional de Pesquisas Espaciais |
| IPSL-CM5A-LR | Institute Pierre-Simon Laplace |
| GFDL-ESM2M | NOAA Geophysical Fluid Dynamics Laboratory |