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
In 2007, Iran exported nearly 600,000 t of wheat while producing 15 million t. In 2009, it was reported that Iran purchased 6 million t of wheat because of the drought in 2008.
Karkheh River Basin (KRB)

- Third largest basin in Iran with area of 51,000 km²
- 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**
  - (a) C1: Number of stations: 10
  - (b) C2: Number of stations: 23
  - (c) C3: Number of grids: 31
  - (d) C4: Number of stations: 15

- **Landuse data**
  - (f) L2
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

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

<table>
<thead>
<tr>
<th>Type of Drought</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meteorological droughts</td>
<td>Standardized precipitation index (SPI) using Precipitation</td>
</tr>
<tr>
<td>Hydrological droughts</td>
<td>Standardized runoff Index (SRI) using Discharge</td>
</tr>
<tr>
<td>Agricultural droughts</td>
<td>Standardized Soil Water index (SSWI) using soil moisture data</td>
</tr>
</tbody>
</table>

Multi-level drought identification in KRB

Meteorological drought: SPI-12

Hydrological drought: SRI-12

Agricultural drought: SSWI-12

Legend:
- Extreme: -2
- Severe: -1.5
- Moderate: -1
- Mild: 0
- Wet: 1
- Extreme wet: 2
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

Climate change impact on drought frequency and duration in KRB

<table>
<thead>
<tr>
<th>GCM Name</th>
<th>Institute Full Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>HadGEM2-ES</td>
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</table>
Climate change have more severe impact on agricultural sector

Agricultural drought vulnerability assessment is becoming an important issue

**Wheat drought vulnerability assessment**
Objective 1: 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: 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

85 EPIC parameters

56 crop parameter
Automatic calibration: Linking EPIC with SUFI2 (EPIC+)

- Parallel processing
- Running under windows and linux
Case Studies

Tropical Climate

Country level calibration

Semi arid Climate

Provincial level calibration

Maize

Sorghum

Wheat
Sub-Saharan Africa

<table>
<thead>
<tr>
<th>Country</th>
<th>R2</th>
<th>P-factor</th>
<th>R-factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Namibia</td>
<td>0.42</td>
<td>0.60</td>
<td>1.3</td>
</tr>
<tr>
<td>Niger</td>
<td>0.32</td>
<td>0.55</td>
<td>1.1</td>
</tr>
<tr>
<td>South Africa</td>
<td>0.28</td>
<td>0.68</td>
<td>1.2</td>
</tr>
</tbody>
</table>
Model calibration on provincial level and based on wheat yield

<table>
<thead>
<tr>
<th>region</th>
<th>Mean Square Error</th>
<th>P-factor</th>
<th>R-factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>NKRB</td>
<td>0.13</td>
<td>0.52</td>
<td>1.1</td>
</tr>
<tr>
<td>CKRB</td>
<td>0.073</td>
<td>0.45</td>
<td>1.04</td>
</tr>
<tr>
<td>SKRB</td>
<td>0.096</td>
<td>0.55</td>
<td>1.17</td>
</tr>
</tbody>
</table>
The impact of climate change on rainfed wheat in KRB

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

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Step 2: Definition of crop drought vulnerability index (CDVI)

- **Drought Exposure Index (DEI)**
- **Crop failure index (CFI)**

**Vulnerability**

A high value of $DVI$ identifies years and/or regions where the crop failure is larger compared to the magnitude of drought.

**Formulae**

\[
CDVI = \frac{CFI}{DEI}
\]

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

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

Interaction of DEI-CFI –CDVI during historic period
Climate change impact on CDVI and its components

% relative change in DEI

- RCP2.6
- RCP8.5

% relative change in CFI

- RCP2.6
- RCP8.5

% relative change in CDVI

- RCP2.6
- RCP8.5
Summary and conclusion

- Iran has been experiencing extreme drought events over the last two decades;
- Climate change had more severe impacts on agricultural sectors and yield production;
- Agricultural sector is more exposed to drought;
- EPIC+SUF12 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

Karun Basin

Zayandehrood Basin

Persian Gulf

Gulf of Oman

Arabian Sea

1972 1984 1987 1989


2008 2011 2012 2014

Droughts in Iran
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

Start Calibration process

Step 1: Adjustment of planting date

Step 2: Calibration of management parameters

 itr=1

Parameter ranges are obtained from Table 1

Latin hypercube Sampling

SUFI-2 algorithm

Acceptable p-factor or r-factor?

itr=itr+1

Y

End

• Planting Density
• Potential heat unit
• FMX
• BFT0
• P-application
• K-application

General procedure followed to perform calibration