An index to quantifying the impacts of agricultural drought and its application in China

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Drought is a recurring and stochastic natural hazard.

It is a primary option to develop and apply drought indices for drought monitoring and characterization.

- **Drought types:**

  Drought can be classified into four types: meteorological, agricultural, hydrological, and socio-economic (Mishra and Singh, 2010).
  - Meteorological ()
  - Agricultural ()
  - Hydrological ()
  - Socio-economic ()
Recent drought events in China

- 2009–2010: SW China
- 2011: China
- 2013: E China
- 2009–2014: SW China
- 2015: N China

Under the global warming in 1.5°C, the direct economic loss by drought will reach 46 billion US dollars in China (market value in 2015). Under the global warming in 2.0°C, the direct economic loss will be 1.8 times of 1.5°C (Su et al., 2019)

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Methods

- Drought and the crop water production functions (CWPF)
  - Agricultural drought care about the crop growth and production.
  
  - The response of crops to drought:
    - stress response - active adaptation - passive adaptation
    -(mild drought - moderate drought - severe drought - extreme drought).
  
- Crop water production functions (CWPF) generally refer to the functional relationship between crop yield (y) and evapotranspiration (ET).

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Methods

- Drought and the crop water production functions (CWPF)

  Linear CWPF
  \[ \frac{Y_a}{Y_m} = \frac{ET_a}{ET_m} \]
  \[ \frac{Y}{Y_m} = \frac{T}{T_m} \]

  Nonlinear CWPF
  \[ Y_a = a + b \left[ 1 - \left( 1 - \frac{ET_a}{ET_m} \right)^2 \right] \]

  Addition CWPF
  \[ \frac{Y_a}{Y_m} = \sum_{i=1}^{n} B_i \left[ 1 - \left( 1 - \frac{ET_a}{ET_{m_i}} \right)^2 \right] \]

  Multiplication CWPF
  \[ \frac{Y_a}{Y_m} = \prod_{i=1}^{n} \left[ 1 - \left( 1 - \frac{ET_a}{ET_{m_i}} \right)^2 \right]^{\delta_i} \]

- Many CWPF rely on the ET.

- It is more reliable to use the new relationship: \( Y \sim ET \times P/PET \).
Methods

A new index for drought monitoring

Crop Water Related Index of drought

\[ CWRI = P \frac{AET}{PET} \]

Level | SPI | SPEI | SEDI | CI | CWRI
--- | --- | --- | --- | --- | ---
Extreme | ≤-2 | ≤-2 | ≤-4 | ≤-2.4 | ≤-2
Serious | -2～-1.5 | -2～-1.5 | -4～-3 | -2.4～-1.8 | -2～-1.5
Medium | -1.5～-1 | -1.5～-1 | -3～-2 | -1.8～-1.2 | -1.5～-1
Mild | -1～-0.5 | -1～-0.5 | -2～-1 | -1.2～-0.6 | -1～-0.5
Normal | -0.5～0.5 | -0.5～0.5 | -1～1 | ≥-0.6 | -0.5～0.5
Wet | ≥0.5 | ≥0.5 | ≥1 | | ≥0.5

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Results

❖ Validation with drought events in 2013

➢ CWRI can reflect the drought in spring of 2013.

➢ Among monthly, quarterly, semi-annual, and annual scales, we chose the SPI6, SPEI6, CWRI6, and CI for comparison.
Other indices have the problem of unreasonable drought aggravation.

Such as, CI fluctuates violently especially in the time period without precipitation.
Results

- **Trends of drought**

 Among the four indexes, SPI shows a downward trend, which is quite different from the actual situation.

- The change of SPEI is non significant.

- CWRI and CI show a phased characterize.
Several drought indexes reflect the increasing trend of drought in Southwest China, especially in Yunnan Province.

CWRI is reasonable, and suitable for drought monitoring.
The R tool named “RMEP”, developed by our team for ET calculation and be available in R platform using the following code:

```
install_github("Yangyonghust/RMEP")
```

Github access: [https://github.com/Yangyonghust/RMEP](https://github.com/Yangyonghust/RMEP)

A VIC model in R, developed by our team:

```
install_github("MomentVon/EDHM")
```