Multi-sensor Integrated Agricultural Drought Monitoring and Assessment

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1. Current Drought Research
2. New Drought Index: PADI
3. Experiment of PADI in China and US
4. Conclusions
1. Current Drought Research

- Drought is a complex extreme hydrometeorology event
- 2012 Midwest US drought: 35 states and 35 billion USD
1. Current Drought Research

- Multiple variables, insidious development, high requirements for accuracy and timeliness

Rainfall

Ground initial condition

Requirement

Three Determinants of Drought

Characteristics of Drought Disaster

- Insidious
- High frequency
- Wide Area
- Accumulative
- Anthropogenic
- Long term
1. Current Drought Research

- Meteorological, Agricultural, Hydrological, and Socioeconomic Drought
1. Current Drought Research

- Drought variable $\rightarrow$ Drought Index $\rightarrow$ Quantification and Integration

**Typical Drought Variables**

- Precipitation
- Cloud
- Air Temperature
- Runoff
- Evapotranspiration
- Relative Humidity
- Vegetation
- Land Surface Temperature
- Soil Moisture

Typical Drought Variables
## 1. Current Drought Research

### Common Drought Index/Method

<table>
<thead>
<tr>
<th>Approach</th>
<th>Input</th>
<th>Model/Method</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation Anomaly (Pa)</td>
<td>Precipitation</td>
<td>$Pa_i = \frac{P_i - \overline{P}}{\overline{P}} \times 100%$</td>
<td>&lt;-40</td>
</tr>
<tr>
<td>Standardized Precipitation Index (SPI)</td>
<td>Precipitation</td>
<td>$SPI_i = \frac{P_i - \overline{P}}{\sigma}$</td>
<td>&lt;-0.5</td>
</tr>
<tr>
<td>Vegetation Condition Index (VCI)</td>
<td>Vegetation</td>
<td>$VCI_i = \frac{NDVI_i - NDVI_{\text{min}}}{NDVI_{\text{max}} - NDVI_{\text{min}}}$</td>
<td>&lt;0.35</td>
</tr>
<tr>
<td>Standardized Precipitation Evapotranspiration Index (SPEI)</td>
<td>Precipitation, Temperature</td>
<td>$SPEI_i = f(P_i - PET_i)$</td>
<td>&lt;-0.84</td>
</tr>
<tr>
<td>Palmer Drought Severity Index (PDSI)</td>
<td>Precipitation, Temperature</td>
<td>$PDSI_i = PDSI_{i-1} + Z$</td>
<td>&lt;-2</td>
</tr>
<tr>
<td>Vegetation Drought Response Index (VegDRI)</td>
<td>Eight variables from climate, hydrology and ecology</td>
<td>Data mining</td>
<td>&lt;96</td>
</tr>
<tr>
<td>United States Drought Monitor (USDM)</td>
<td>Dozens of variables</td>
<td>Expert decision</td>
<td>D1</td>
</tr>
</tbody>
</table>
1. Current Drought Research

**Q1:** Is there any limitation in current drought index?

(SPEI&PDSI: water-balance model; MIDI: Linear weighting; VegDRI: data mining; USDM: expert decision)

**Answer:** With regard to agricultural drought index, no development process of drought and crop was taken into account; Periodic refresh.

**Q2:** Which index is better?

**Answer:** With regard to agricultural drought, the index should be evaluated by its correlation with crop yield loss due to drought stress.
2. New Drought Index: PADI

- **PADI**: Process-based Accumulated Drought Index
2. New Drought Index: PADI

- Process of an agricultural drought

Phase 1: Latency
- Precipitation (PCI-GPCC)
  \[
  \text{PCI} = \frac{P - P_{\text{min}}}{P_{\text{max}} - P_{\text{min}}}
  \]

Phase 2: Onset
- Root Zone Soil Moisture (SMCI-GLDAS)
  \[
  \text{SMCI} = \frac{\text{SM} - \text{SM}_{\text{min}}}{\text{SM}_{\text{max}} - \text{SM}_{\text{min}}}
  \]

Phase 3: Development
- Vegetation (VCI-AVHRR)
  \[
  \text{VCI} = \frac{\text{NDVI} - \text{NDVI}_{\text{min}}}{\text{NDVI}_{\text{max}} - \text{NDVI}_{\text{min}}}
  \]

Phase 4: Recovery
- Precipitation + Root Zone Soil Moisture (PCI + SMCI)
3. Experiment of PADI in US and China

- Process of the agricultural drought event in Hubei China 2011
3. Experiment of PADI in US and China

- Process of the agricultural drought event in Midwest US 2012

![Graph showing the process of the agricultural drought event in Midwest US 2012](image)

**Legend:**
- PCI
- SMCI
- VCI
- Inflection
- Date line for planting and harvest
- Threshold line for PCI, SMCI, and VCI
- Latency phase
- Onset phase
- Development phase
- Recovery phase
### 2. New Drought Index: PADI

- **Process of crop growth:** previous literature and statistical data (*water-deficit coefficient*)

<table>
<thead>
<tr>
<th>Growth stage</th>
<th>Wheat in Hubei China</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>start</td>
</tr>
<tr>
<td>Tillering</td>
<td>22 Oct.</td>
</tr>
<tr>
<td>Booting</td>
<td>7 Jan.</td>
</tr>
<tr>
<td>Florescence</td>
<td>10 Apr.</td>
</tr>
<tr>
<td>Pustulation</td>
<td>20 Apr.</td>
</tr>
</tbody>
</table>
2. New Drought Index: PADI

- How to calculate PADI value?

\[
PADI_t = PADI_{t-1} \sum_{i=1}^{n} \left[ (T_i \cap S_i \cap p_2) \times \lambda_i \times (1 - SMCI_i) + (T_i \cap S_i \cap p_3) \times (1 - VCI_i) \right] \frac{1}{PADI_{\text{max}}}
\]

- Calculate PADI once a week
- Calculation start from the drought onset during crop growth period
- Calculation end when drought end during crop growth or crop harvest
- PADI ranges from 0 to 1
- Higher PADI \(\rightarrow\) More severe drought
3. Experiment of PADI in US and China

Drought Assessment based on PADI in 2011 Hubei Drought
3. Experiment of PADI in US and China

Drought Assessment based on PADI in 2011 Hubei Drought

- a) PADI in Region A
- b) PADI in Region B
- c) PADI in Region C
- d) PDSI in Region A
- e) PDSI in Region B
- f) PDSI in Region C

PADI Legend:
- Mild drought
- Severe drought
- Exceptional drought

SPI Legend:
- Moderate drought
- Extreme drought
- Mid-range
- Severe drought
- Extreme drought
3. Experiment of PADI in US and China

- Drought Assessment based on PADI in 2012 Midwest Drought
3. Experiment of PADI in US and China

Drought Assessment based on PADI in 2012 Midwest Drought
3. Experiment of PADI in US and China

- **Correlation analyses between drought indices and yield loss**

![Correlation plots](image)

(a) Yield and Precipitation

\[ y = -3.52x + 77.50 \]

\[ \rho = -0.54 \]

(b) Yield and Soil Moisture

\[ y = -0.03x + 30.76 \]

\[ \rho = 0.01 \]

(c) Yield and Vegetation

\[ y = -1.41x + 114.95 \]

\[ \rho = -0.64 \]

(d) Yield and PADI

\[ y = 186.07x - 43.10 \]

\[ \rho = 0.70 \]
3. Experiment of PADI in US and China

- Correlation analyses between drought indices and yield loss
3. Experiment of PADI in US and China

- Correlation analyses between drought indices and yield loss
3. Experiment of PADI in US and China

- Performance of PADI upgrades as drought evolving
4. Conclusions

Based on the basic principle of drought development and impact, precipitation, root zone soil moisture, and vegetation condition have been integrated to the proposed PADI model.

Experiments in China and US demonstrated PADI can accurately and stably calculated accumulated drought impacts on crops, which is better than other indices when assessing an agricultural drought disaster.

Future: operational monitoring system, real-time assessment, and accurate drought reports for the government and public.


Thank you for your attention!

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