EvIDENz – Drought Hazard

Multi-Scale Drought Hazard Assessment

Cooperation: ZFL, UNU-EHS

Affiliated Partners: United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER), Space Research Institute of Ukraine & University of the Free State, South Africa

East London, 8th June 2018
1. Remote Sensing for Drought Monitoring

**RS-based Drought Indices**

- Normalized Difference Vegetation Index (NDVI)
- Enhanced Vegetation Index (EVI)
- Vegetation Drought Response Index (VegDRI)
- Temperature Condition Index (TCI)
- Normalized Difference Water Index (NDWI)
- Vegetation Health Index (VHI)
- Absolute Difference Normalized Difference Vegetation Index (ADVI)
- Standardized Vegetation Index (SVI)

- Satellite RS-based methods achieve much higher added value
  - good spatial resolution
  - temporal dynamic
  - consistent data
# 1. Remote Sensing for Drought Monitoring

<table>
<thead>
<tr>
<th>Name</th>
<th>Acronym</th>
<th>Category</th>
<th>Inputs</th>
<th>Sensor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced Vegetation Index</td>
<td>EVI</td>
<td>Vegetation</td>
<td>Sat</td>
<td>MODIS (+/- AVHRR)</td>
</tr>
<tr>
<td>Normalized Difference Vegetation Index</td>
<td>NDVI</td>
<td>Vegetation</td>
<td>Sat</td>
<td>AVHRR</td>
</tr>
<tr>
<td>Vegetation Condition Index</td>
<td>VCI</td>
<td>Vegetation</td>
<td>Sat</td>
<td>AVHRR</td>
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<tr>
<td>Vegetation Health Index</td>
<td>VHI</td>
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<td>Sat</td>
<td>AVHRR</td>
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<tr>
<td>Soil Adjusted Vegetation Index</td>
<td>SAVI</td>
<td>Vegetation</td>
<td>Sat</td>
<td>MODIS</td>
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<tr>
<td>Temperature Vegetation Dryness Index</td>
<td>TVDI</td>
<td>Vegetation</td>
<td>Sat</td>
<td>MODIS</td>
</tr>
<tr>
<td>Optimized Vegetation Drought Index</td>
<td>OVDI</td>
<td>Vegetation/Drought</td>
<td>Sat+</td>
<td>AVHRR</td>
</tr>
<tr>
<td>Vegetation Drought Response Index</td>
<td>ESI</td>
<td>Vegetation/Water</td>
<td>Sat+</td>
<td>AVHRR</td>
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<tr>
<td>Evaporative Stress Index</td>
<td>WRSI</td>
<td>Vegetation/Water</td>
<td>Sat+</td>
<td>NOAA Rainfall Estimates (RFE)+</td>
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<tr>
<td>Water Requirement Satisfaction Index</td>
<td>NDWI</td>
<td>Vegetation/Water</td>
<td>Sat</td>
<td>MODIS</td>
</tr>
<tr>
<td>Land Surface Water Index</td>
<td>LSWI</td>
<td>Vegetation/Water</td>
<td>Sat</td>
<td>MODIS</td>
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<tr>
<td>Combined Drought Indicator</td>
<td>CDI</td>
<td>Drought</td>
<td>Sat+</td>
<td>MODIS (fAPAR)+</td>
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<tr>
<td>Perpendicular Drought Index</td>
<td>PDI</td>
<td>Drought</td>
<td></td>
<td></td>
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<tr>
<td>Modified PDI</td>
<td>MPDI</td>
<td>Drought</td>
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<tr>
<td>Precipitation Condition index</td>
<td>PCI</td>
<td>Water</td>
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<td>MODIS, TRMM</td>
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<tr>
<td>Soil Moisture Condition Index</td>
<td>SMCI</td>
<td>Water</td>
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<td>Optimized Meteorological Drought Index</td>
<td>OMDI</td>
<td>Water</td>
<td></td>
<td></td>
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<tr>
<td>Temperature Condition Index</td>
<td>TCI</td>
<td>Temperature</td>
<td>Sat</td>
<td>AVHRR</td>
</tr>
</tbody>
</table>
1. Reviews of remote sensing vegetation indices remind us that there are quite a lot to choose from...

<table>
<thead>
<tr>
<th>Index</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVWI</td>
<td>$\frac{(\frac{1}{K_{NI}}) - (\frac{1}{K_{MI}})}{2}$</td>
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<tr>
<td>AVW2</td>
<td>$\frac{K_{NI} - K_{MI}}{(NI - MI)(NI + MI)}$</td>
</tr>
<tr>
<td>AVW3</td>
<td>$\frac{K_{NI} - K_{MI}}{2(NI + MI)}$</td>
</tr>
<tr>
<td>AVI</td>
<td>$\frac{1}{(\frac{1}{K_{NI}}) - (\frac{1}{K_{MI}})}$</td>
</tr>
<tr>
<td>AV2</td>
<td>$2(NI + MI)$</td>
</tr>
<tr>
<td>AV3</td>
<td>$NI - MI$</td>
</tr>
<tr>
<td>AV4</td>
<td>$\frac{K_{NI}}{K_{MI}}$</td>
</tr>
<tr>
<td>GA1</td>
<td>$CWI - (0.048 + 0.095 \times AVWI)$</td>
</tr>
<tr>
<td>GA2</td>
<td>$CWI + (0.048 + 0.095 \times AVWI)$</td>
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<tr>
<td>GA3</td>
<td>$CWI + (0.048 + 0.095 \times AVWI)$</td>
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<td>GA4</td>
<td>$CWI + (0.048 + 0.095 \times AVWI)$</td>
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<td>GA6</td>
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<td>GA18</td>
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<td>GA29</td>
<td>$CWI + (0.048 + 0.095 \times AVWI)$</td>
</tr>
<tr>
<td>GA30</td>
<td>$CWI + (0.048 + 0.095 \times AVWI)$</td>
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</table>

Source: https://doi.org/10.1155/2017/1353691
1. Drought Event Database
2. EvI DENz approach

Objective II: Assessment of Sendai targets
- **HAZARD**
  - Drought hazard classification

Objective I: Understanding risk
- **EXPOSED ELEMENTS**
  - People, land, assets
- **VULNERABILITY**
  - Characteristics of people, land, assets

Risk to agricultural assets and livelihoods

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Sendai Framework Targets
- **Affected people**: global population 2030-2050 Average <= 2005-2015 Average
- **Economic loss**: global GDP 2030 Ratio <= 2015 Ratio

! Rely on open, accessible data sets that are representative for the national level!
2. Analysis

Moderate Resolution Data
(MODIS 250m, NOAA AVHRR 4km)

- Vegetation
- Temperature
- Water

Productivity & Anomalies
(Detecting Drought Events)

Variable Complexity
(Correlation, Cross-Correlation, Time Lags)

Drought Classification
(Predefined vs. Weighted classification)

High-Resolution Data
(Sentinel 1-20m, Sentinel 2-10-20m)

- Vegetation
- Temperature
- Water

Crop Classification
(Drought Stress)

Variable Complexity

Drought Stress Detection
3. Data and Methods – moderate resolution

- MODIS EVI 250m Biomass (16day)
- MODIS NDVI 250m Biomass (8day)
- MODIS LST 1km Temperature (8day)
- CHIRPS 4km Precipitation (SA)
- SPEI Standard Precipitation Evap. Index

Detection of Phenology: SOS, Peak, EOS

Calculation of VCI

Calculation of Vegetation Health Index (VHI)

Calculation of TCI

Resample to 250m

Drought Classification
- growing seasons, total biomass productivity
- Anomaly Detection
- Weighted Drought Classification

Comparison

Drought Classification

Weighted Drought Classification

Correlation with VCI

Outputs

Cross-correlation

Cross-correlation

Drought Classification

Weighted Drought Classification

Anomaly Detection
SPEI vs. VCI – Water vs. Vegetation? Hazard?

SPEI correlation with MODIS based vegetation index (here VCI), seasonal seasonal values
Response of Vegetation

- Agricultural productivity measured with Vegetation Condition
- How can we classify drought hazard?

Vegetation Condition Index (VCI)

\[ \text{VCI} = \frac{\text{EVI} - \text{EVI}_{\text{min}}}{\text{EVI}_{\text{max}} - \text{EVI}_{\text{min}}} \times 100 \]

Classification for VCI (and VHI)

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<thead>
<tr>
<th>Drought hazard severity classes</th>
<th>VCI/VHI Values</th>
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<td>10 - 20</td>
</tr>
<tr>
<td>Extreme Drought</td>
<td>&lt; 10</td>
</tr>
</tbody>
</table>

Kogan, 1998

Measuring Vegetation Performance with Remote Sensing (EVI/NDVI)

https://earthobservatory.nasa.gov/Features/MeasuringVegetation/
3. Data and Methods – Drought Indices

Example: Agricultural Stress Index System (ASIS): Global and Local Analysis

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<td>Extreme Drought</td>
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</tr>
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</table>

Kogan, 1998

Does remote sensing of vegetation support the detection of drought conditions?
4. Drought Hazard Assessment

**Vegetation Condition Index (VCI) vs. Vegetation Health Index (VHI)**

- VHI integrates also Temperature
- Two most common used indices
- Same drought classifications
4. Drought Hazard Assessment – Anomalies in Productivity

Anomalies using annual $\Sigma\text{EVI}$
4. Drought Hazard – the phenological stages

Seasonality Parameters – Vegetation Phenology

Lourenço (2015)
4. Drought Hazard – Timing matters ...

When crops start to grow...

**Phenometrics South Africa (Eastern Cape) - Season 2001/02**

Legend:
- EC
- Dates:
  - Jul
  - Aug
  - Sep
  - Oct
  - Nov
  - Dec
  - Jan
  - Feb
  - Mar
  - Apr
  - May
  - Jun

Start of Season

Scale: 75 0 75 150 225 300 km
4. Drought Hazard – Timing matters ...

When crops start to grow...

**Phenometrics South Africa (Eastern Cape) - Season 2001/02**

Legend
- EC
- Dates
- Jul
- Aug
- Sep
- Oct
- Nov
- Dec
- Jan
- Feb
- Mar
- Apr
- May
- Jun

End of Season
4. Timing matters: Drought vs. Non Drought Year

Start of Season (SOS)
- Can have huge impact – e.g. much later in 2015/2016 (drought year)

End of Season (EOS)
- Effect not as different comparing different years
4. Drought Hazard – Timing matters ...

How much time is there for growing ...

Phenometrics - Length of Season - 2001/02
4. Timing matters: Drought vs. Non Drought Year

- SOS changes (later) – EOS stays almost the same = growing period much shorter
- Less time to provide harvests as expected
4. Drought Hazard

To be questioned
- Can a RS-based drought indicator represent agricultural drought conditions?
- What about drought conditions within different observation periods?

Characteristics
- to be operatable: it should be an index that could represent drought conditions
- No complicated index calculation but rather simple and representative
- Approach that can be adjusted for defined needs

Our Approach
- VCI – an index that does not need a complex setting of input data but is still representative
- detect drought characteristics and drought severity
4. Drought Hazard – Insights in the workflow

Data acquisition

USGS appEEARS platform for data preparation

Data: EVI: Enhanced Vegetation Index
4. Drought Hazard – Study Site for Training

EVI Data 16 day, 250 m resolution
4. Drought Hazard – The Drought Index

Calculating Vegetation Condition Index (VCI)

MOD13Q1 16-day EVI and pixel reliability

Optional quality masking

Chunk-wise processing, calculation of VCI from EVI

VCI – Drought Index Calculation

Pixel reliability: Quality of the data
4. Preliminary Output

VCI

Monthly Compositing

Mean / Median Calculation
- growing season and full years –

Drought Classification
(D0 - D4)

Hazard Classification
(H0 – H4)
4. Preliminary Output – Conditions for a full year and for a season

Drought classifications South Africa (Eastern Cape) - Season 2000/01

Legend
- EC
- Drought Cl.
- D0
- D1
- D2
- D3
- D4

July to June

November to May

(Based on median VCI-Values)
4. Preliminary Output – Conditions for a full year and for a season

Normal/Non-Drought Year

Drought Year
## 4. Drought Classification – Hazard Classification

### Drought Hazard Severity Classes

<table>
<thead>
<tr>
<th>Drought Hazard Severity Classes</th>
<th>Value in final output</th>
<th>VCI Values (weighted over season)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Drought (D0)</td>
<td>0</td>
<td>&gt;40</td>
</tr>
<tr>
<td>Mild Drought (D1)</td>
<td>1</td>
<td>30–40</td>
</tr>
<tr>
<td>Moderate Drought (D2)</td>
<td>2</td>
<td>20–30</td>
</tr>
<tr>
<td>Severe Drought (D3)</td>
<td>3</td>
<td>10–20</td>
</tr>
<tr>
<td>Extreme Drought (D4)</td>
<td>4</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>

### Vegetation condition

<table>
<thead>
<tr>
<th>Vegetation condition</th>
<th>Value in final output</th>
<th>VCI Values (weighted over season)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not affected (H0)</td>
<td>0</td>
<td>&gt;40</td>
</tr>
<tr>
<td>Damaged (H1)</td>
<td>1</td>
<td>10–40</td>
</tr>
<tr>
<td>Destroyed (H2)</td>
<td>2</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>
5. Hazard Approach – Potential

Seasonality Parameters – Vegetation Phenology

Drought Event

Timing
When does a drought occur?

Vegetation/Greenness Index

Vegetation/Greenness Index

Start of Season

Peak

End of Season

Jul
South Africa
Jun

Time

Drought Event

When does a drought occur?
5. Hazard Approach – Potential

![Graph showing EVI and VCI over time]

- **EVI**: EVI graph shows the start, peak, and end of the season.
- **VCI**: VCI graph shows the mean VCI values over time.
- **Timeblocks**: Timeblock A, Block B, Block C.
- **Mean VCI**: Mean VCI values are calculated as $\text{Mean VCI} \times 5$, $\text{Mean VCI} \times 7$, and $\text{Mean VCI} \times 1$ for Blocks A, B, and C respectively.
- **One weighted VCI image per year**: One VCI image is generated per year.

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**Legend**

- **EVI**: Enhanced Vegetation Index
- **VCI**: Vegetation Condition Index
- **UN-SPIDER**: United Nations Office for Outer Space Affairs
- **IKO**: Institute for a Knowledge Society
- **ZFL**: Zentrum für Landesforschung
- **UFS**: University of the State of Lower Saxony
- **UNU-EHS**: United Nations University – Institute for Environment and Human Security
- **Bundesministerium für Wirtschaft und Energie**: German Federal Ministry for Economic Affairs and Energy

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**Notes**

- The graph illustrates the temporal variations in EVI and VCI across different timeblocks.
- The seasonal cycle is divided into three main sections: Start, Peak, and End of season.
- Mean VCI values are calculated for each block to provide a weighted average per year.
5. Hazard Approach – Preliminary Results
5. Hazard Approach – Strengths and Weaknesses

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• free and open data</td>
<td>• Validation missing – drought event database</td>
</tr>
<tr>
<td>• simple index calculation</td>
<td>• Phenology detection needs to consider land cover – and has weak detection abilities over some land covers (e.g. Forest)</td>
</tr>
<tr>
<td>• addressing seasonality and allow focus on the growing season</td>
<td>• Drought characteristics – move away from global approaches but locally applied ones needed</td>
</tr>
<tr>
<td>• considering vulnerability stages during the phenological stages</td>
<td></td>
</tr>
<tr>
<td>• aiming at more accurate severity detection</td>
<td></td>
</tr>
</tbody>
</table>
6. Discussion and Outlook

Final stage:
• Finalize Phenology detection and WLC
• Stress detection with actual temperature threshold passing
• Still in need of validation data

Ongoing
• Drought Monitoring with remote sensing on higher resolution scales (Sentinel 1 and 2 analysis currently under development for integration)
• We continue: ongoing /new project activity GlobeDrought → more impacts, more understanding, 5 countries → development of a drought information system
Thank you very much for your attention!
VCI (median) and $\Sigma$EVI Anomalies

VHI (median) and $\Sigma$EVI Anomalies
Getting a better understanding …
“A project is never truly finished, you simply run out of time” (Peter Jackson)