



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

Pretoria, 3rd June 2018

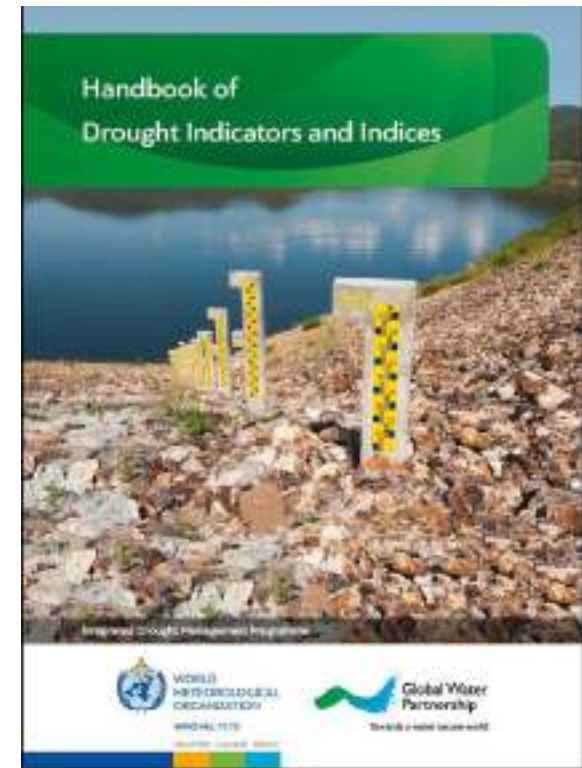


1. Remote Sensing for Drought Hazard Monitoring
2. EVIDENZ Approach
3. Data and Methods
4. Drought Hazard Assessment
5. Hazard Approach: Potential / Limitations
6. Discussion and Outlook

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

Name	Acronym	Category	Inputs	Sensor(s)
Enhanced Vegetation Index	EVI	Vegetation	Sat	MODIS (+/- AVHRR)
Normalized Difference Vegetation Index	NDVI	Vegetation	Sat	AVHRR
Vegetation Condition Index	VCI	Vegetation	Sat	AVHRR
Vegetation Health Index	VHI	Vegetation	Sat	AVHRR
Soil Adjusted Vegetation Index	SAVI	Vegetation	Sat	MODIS
Temperature Vegetation Dryness Index	TVDI	Vegetation	Sat	MODIS
Optimized Vegetation Drought Index	OVDI	Vegetation/ Drought		
Vegetation Drought Response Index		Vegetation/ Drought	Sat+	
Evaporative Stress Index	ESI	Vegetation/ Water	Sat+	AVHRR
Water Requirement Satisfaction Index	WRSI	Vegetation/ Water	Sat+	NOAA Rainfall Estimates (RFE)+
Normalized Difference Water Index	NDWI	Vegetation/ Water	Sat	MODIS
Land Surface Water Index	LSWI	Vegetation/ Water	Sat	MODIS
Combined Drought Indicator	CDI	Drought	Sat+	MODIS (fAPAR)+
Perpendicular Drought Index	PDI	Drought		
Modified PDI	MPDI	Drought		
Precipitation Condition index	PCI	Water		MODIS, TRMM
Soil Moisture Condition Index	SMCI	Water		
Optimized Meteorological Drought Index	OMDI	Water		
Temperature Condition Index	TCI	Temperature	Sat	AVHRR

1. Reviews of remote sensing vegetation indices remind us that there are quite a lot to choose from...

Table 1. Summary of vegetation index expression.			Table 1. Continued.			Table 1. Continued.			
Index	Definition	Index	Definition	Index	Definition	Index	Definition	Index	
AGVI	$GVI - (1 + 0.018GVI) + YVI - \frac{NSI}{2}$	AGVI	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}$	ARI	$\frac{R_{21}}{R_{22}}$	ARI	$\frac{R_{21}}{R_{22}}$	ARI	$\frac{R_{21}}{R_{22}}$
ARI	$\left(\frac{1}{R_{21}}\right) - \left(\frac{1}{R_{22}}\right)$	GEMI	$\eta(1 - 0.25\eta) - \frac{(R - 0)}{(1 - 0.05AGVI)}$	ARI2	$\frac{R_{21}}{R_{22}}$	OSAVI	$0.5 \times [2R_{21} + 1 - \sqrt{4R_{21}^2 - 1}] - 0.06(1 - R)$	ARI2	$\frac{R_{21}}{R_{22}}$
ARI2	$R_{21} \left[\left(\frac{1}{R_{21}}\right) - \left(\frac{1}{R_{22}}\right) \right]$	GLI	$\eta = \frac{2(NIR^2 - R^2) + 1.5N}{(NIR + R + 0.1)}$	ARI3	$\frac{R_{21}}{R_{22}}$	PRI	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}$	ARI3	$\frac{R_{21}}{R_{22}}$
ARVI	$\frac{(NIR - RB)}{(NIR + RB)}$	GMI	$\frac{(2R_p - R_s - R_b)}{(2R_p + R_s + R_b)}$	ARI4	$\frac{R_{21}}{R_{22}}$	PSR1	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}$	ARI4	$\frac{R_{21}}{R_{22}}$
ASBI	0.2YVI	GMI	$\frac{R_{21}}{R_{22}}$	ARI5	$\frac{R_{21}}{R_{22}}$	PSR2	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}$	ARI5	$\frac{R_{21}}{R_{22}}$
ATSAVI	$\frac{[a(NIR - aRed - b)]}{[a(NIR + Red) - ab + X(1 + a^2)]}$	GMI	$\frac{R_{21}}{R_{22}}$	ARI6	$\frac{R_{21}}{R_{22}}$	PSR3	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}$	ARI6	$\frac{R_{21}}{R_{22}}$
AVI	2.0MSS _s - MSS _s	GMI	$\frac{R_{21}}{R_{22}}$	ARI7	$\frac{R_{21}}{R_{22}}$	PSR4	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}$	ARI7	$\frac{R_{21}}{R_{22}}$
AVI	$\tan^{-1} \left[\left(\frac{R_1 - R_2}{R_1 + R_2} \right) \right] + \tan^{-1} \left[\left(\frac{R_3 - R_4}{R_3 + R_4} \right) \right]$	GMI	$\frac{R_{21}}{R_{22}}$	ARI8	$\frac{R_{21}}{R_{22}}$	PSR5	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}$	ARI8	$\frac{R_{21}}{R_{22}}$
BGI	$\frac{R_{21}}{R_{22}}$	GRABS	$GVI - 0.091768SBI + 5$	ARI9	$\frac{R_{21}}{R_{22}}$	PSR6	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}$	ARI9	$\frac{R_{21}}{R_{22}}$
BGI2	$\frac{R_{21}}{R_{22}}$	GRVI	$\frac{NIR}{Green}$	ARI10	$\frac{R_{21}}{R_{22}}$	PSR7	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}$	ARI10	$\frac{R_{21}}{R_{22}}$
BB1	$\frac{R_{21}}{R_{22}}$	Greenness index (G)	$\frac{R_{21}}{R_{22}}$	ARI11	$\frac{R_{21}}{R_{22}}$	PVI	$\sqrt{\frac{(R_{21} - R_{22})^2}{(R_{21} + R_{22})^2} - \frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}}$	ARI11	$\frac{R_{21}}{R_{22}}$
BB2	$\frac{R_{21}}{R_{22}}$	GVI	$(-0.283MSS_s - 0.66MSS_s + 0.577)$	ARI12	$\frac{R_{21}}{R_{22}}$	PVI	$\frac{(NIR - aR - b)}{\sqrt{c^2 + 1}}$	ARI12	$\frac{R_{21}}{R_{22}}$
CAI	$0.5(R_{201} + R_{202}) - R_{203}$	GVSBI	$\frac{GVI}{SBI}$	ARI13	$\frac{R_{21}}{R_{22}}$	RARS	$\frac{R_{21}}{R_{22}}$	ARI13	$\frac{R_{21}}{R_{22}}$
CARI	$CAR + \frac{R_{21}}{R_{22}}$	LICI	$\frac{R_{21}}{R_{22}}$	ARI14	$\frac{R_{21}}{R_{22}}$	RDVI	$\frac{(R_{21} - R_{22})}{[SQRT(R_{21} + R_{22})]}$	ARI14	$\frac{R_{21}}{R_{22}}$
CCCI	$\frac{(NDRE - NDRE_{min})}{(NDRE_{max} - NDRE_{min})}$	HVI	$\frac{[2(R_{21} - R_{22})]}{(R_{21} + 9R_{22} - 7.5R_{23})}$	ARI15	$\frac{R_{21}}{R_{22}}$	RDVI	$\frac{(R_{21} - R_{22})}{\sqrt{NDVI - DVI}}$	ARI15	$\frac{R_{21}}{R_{22}}$
CRCWD	$\frac{(1/R_{21})}{(1/R_{22})}$	HI	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})} - 0.5$	ARI16	$\frac{R_{21}}{R_{22}}$	RENDVI	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}$	ARI16	$\frac{R_{21}}{R_{22}}$
CR150	$\frac{(1/R_{21})}{(1/R_{22})}$	IAVI	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})} - \gamma(R_{21} - R_{22})$	ARI17	$\frac{R_{21}}{R_{22}}$	RGR1	$\frac{(\sum_{i=1}^{20} R_i)}{(R_{21} + R_{22})}$	ARI17	$\frac{R_{21}}{R_{22}}$
CR170	$\frac{(1/R_{21})}{(1/R_{22})}$	II	$\frac{TM_2}{TM_1}$	ARI18	$\frac{R_{21}}{R_{22}}$	RI	$\frac{(R - G)}{(R + G)}$	ARI18	$\frac{R_{21}}{R_{22}}$
CWSI	$\frac{((T_s - T_a) - (T_s - T_{a,c}))}{((T_s - T_{a,c}) - (T_s - T_{a,b}))}$	IPVI	$\frac{TM_2}{(TM_1 + TM_2)}$	ARI19	$\frac{R_{21}}{R_{22}}$	EVI	$\frac{R}{NIR}$	ARI19	$\frac{R_{21}}{R_{22}}$
DII	$\frac{R_{201} - R_{202}}{R_{201} + R_{202}}$	MCARI	$\frac{((R_{201} - R_{202}) - 0.2(R_{201} - R_{202}))}{\sqrt{(2R_{201} + 1)^2 - (8R_{201} - 5)}}$	ARI20	$\frac{R_{21}}{R_{22}}$	SAVI	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})} + (1 + L)$	ARI20	$\frac{R_{21}}{R_{22}}$
DVI	$\int_{R_{21}}^{\lambda} \left(\frac{dR}{d\lambda} \right) d\lambda$	MCARI	$\frac{1.5 + 12.5(R_{201} - R_{202}) - 1.3}{\sqrt{(2R_{201} + 1)^2 - (8R_{201} - 5)}}$	ARI21	$\frac{R_{21}}{R_{22}}$	SIPI	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}$	ARI21	$\frac{R_{21}}{R_{22}}$
DVI	2.0MSS _s - MSS _s	MGVI	$(-0.386MSS_s - 0.53MSS_s + 0.535)$	ARI22	$\frac{R_{21}}{R_{22}}$	SBI	$(-0.283MSS_s - 0.66MSS_s + 0.577MSS_s + 0)$	ARI22	$\frac{R_{21}}{R_{22}}$
EVI	$\frac{[(TM_1 - TM_2) + L]}{(TM_1 - C_1 TM_2 + C_2 TM_1 + L)}$	MNT1	$\frac{[(NIR^2 - Red)(1 + 0.1)]}{(NIR^2 + Red + L)}$	ARI23	$\frac{R_{21}}{R_{22}}$	SBI	$MSS_s - 2.4MSS_s$	ARI23	$\frac{R_{21}}{R_{22}}$
ERG	$\frac{NIR - [Green - \gamma(Blue - Red)]}{NIR + [Green - \gamma(Blue - Red)]}$	MNSI	$(0.404MSS_s - 0.039MSS_s - 0.505MSS_s + 0.762MSS_s)$	ARI24	$\frac{R_{21}}{R_{22}}$	SDr	$\sum_{i=1}^N (L_i)$	ARI24	$\frac{R_{21}}{R_{22}}$
GARI	$\frac{NIR - Green}{NIR + Green}$	MRENDVI	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22}) - 2 \times (R_{22})}$	ARI25	$\frac{R_{21}}{R_{22}}$	SGI	$\frac{R_{21}}{Red}$	ARI25	$\frac{R_{21}}{R_{22}}$
GDVI	$\frac{(R_{21} - R_{22})}{(R_{21} + R_{22})}$			ARI26	$\frac{R_{21}}{R_{22}}$	SR	$\frac{R_{21}}{R_{22}}$	ARI26	$\frac{R_{21}}{R_{22}}$
				ARI27	$\frac{R_{21}}{R_{22}}$	SR2	$\frac{R_{21}}{R_{22}}$	ARI27	$\frac{R_{21}}{R_{22}}$

Drought references
EMDAT vs. Literature/ Reporting

Source: <https://doi.org/10.1155/2017/1353691>

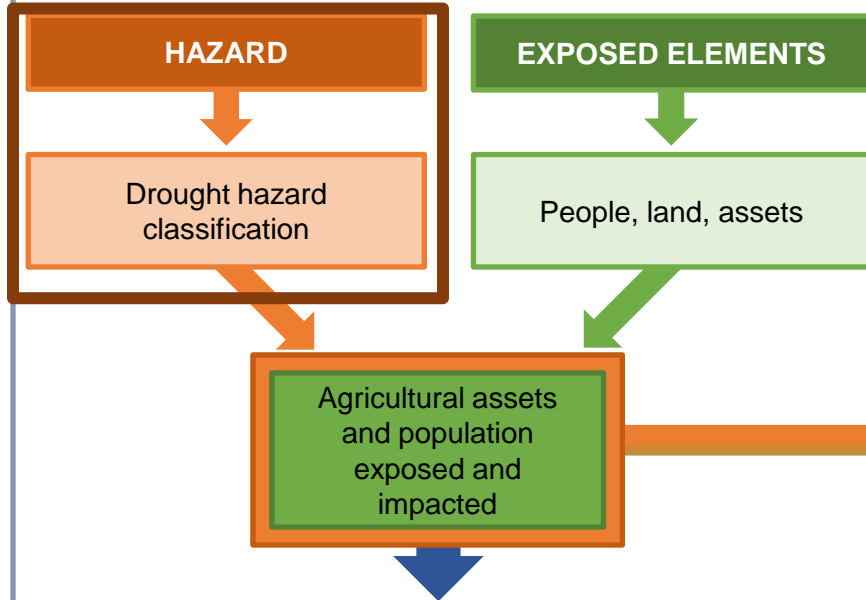


1. Drought Event Database

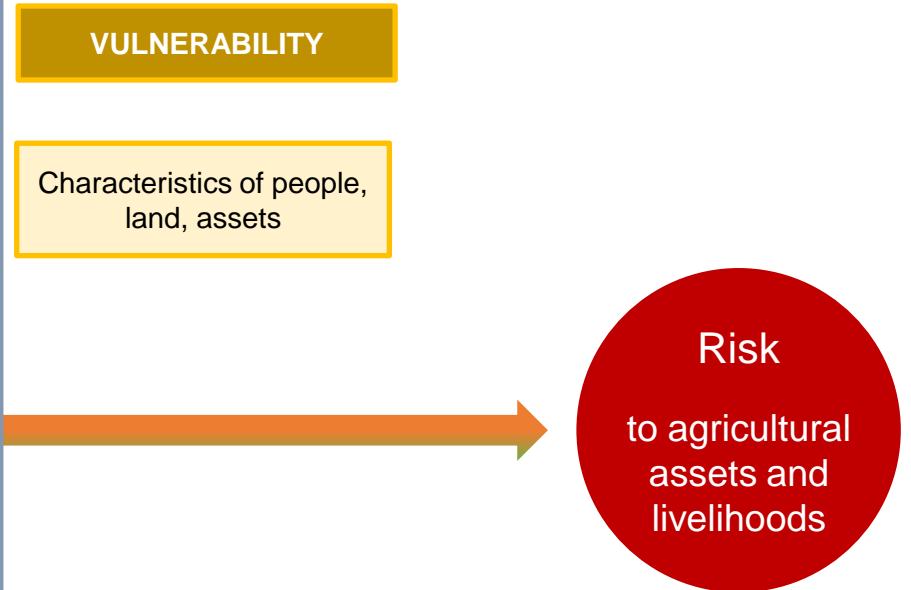


2. EVIDENZ approach

Objective II: Assessment of Sendai targets



Objective I: Understanding risk



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

2. Analysis

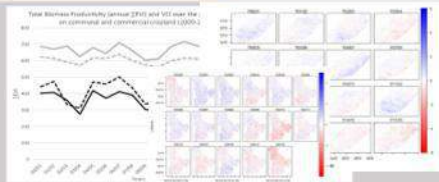
Moderate Resolution Data
(MODIS 250m, NOAA AVHRR 4km)

Vegetation

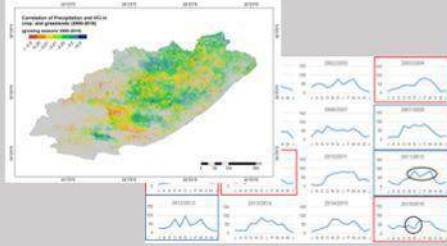
Temperature

Water

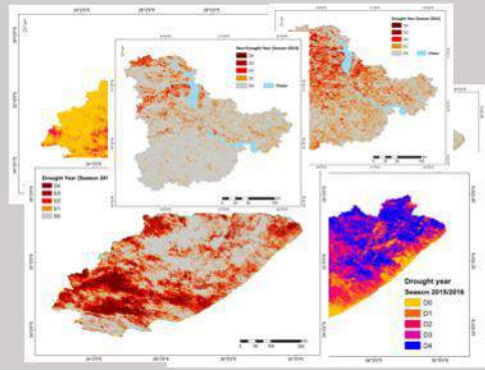
Productivity & Anomalies
(Detecting Drought Events)



Variable Complexity
Correlation, Cross-Correlation, Time Lags



Drought Classification
(Predefined vs. Weighted classification)



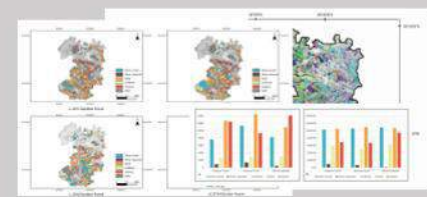
High-Resolution Data
(Sentinel 1- 20m, Sentinel 2- 10-20m)

Vegetation

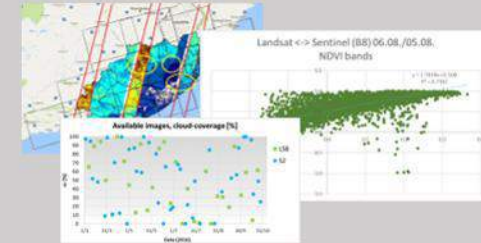
Temperature

Water

Crop Classification
(Drought Stress)



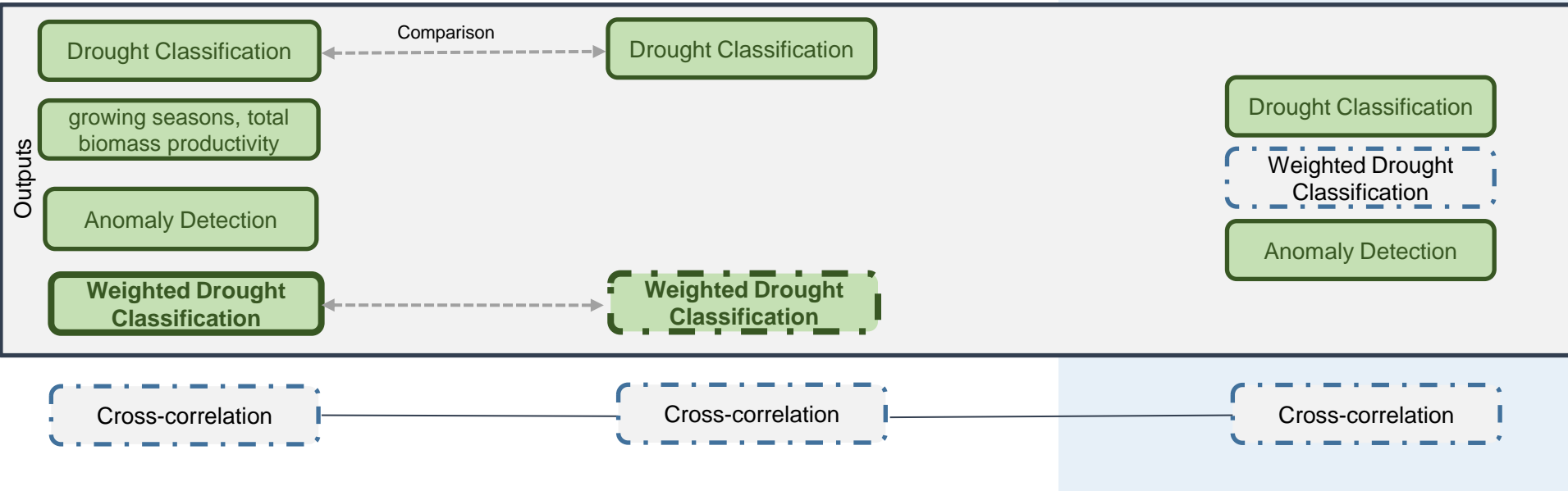
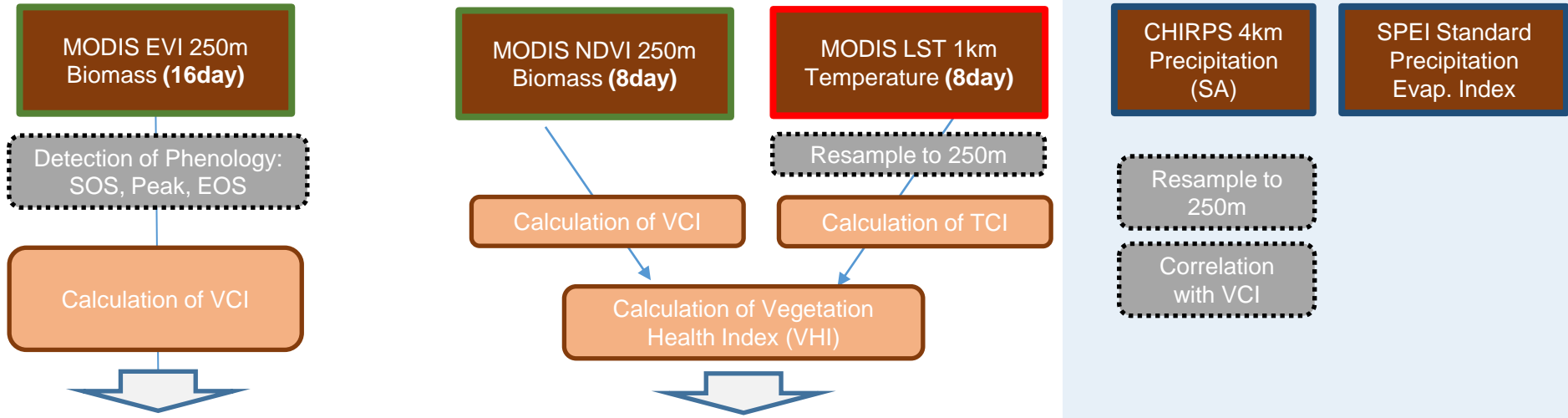
Variable Complexity



Drought Stress Detection



3. Data and Methods – moderate resolution



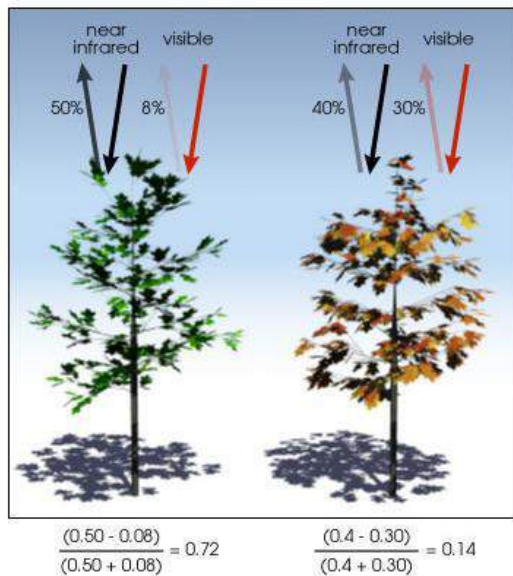
3. Data and Methods – Drought Indices

Response of Vegetation

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

EVI

Measuring Vegetation Performance with Remote Sensing (EVI/NDVI)



<https://earthobservatory.nasa.gov/Features/MeasuringVegetation/>

VCI

Vegetation Condition Index (VCI)

$$= \frac{EVI - EVI_{min}}{EVI_{max} - EVI_{min}} * 100$$

Classification for VCI (and VHI)

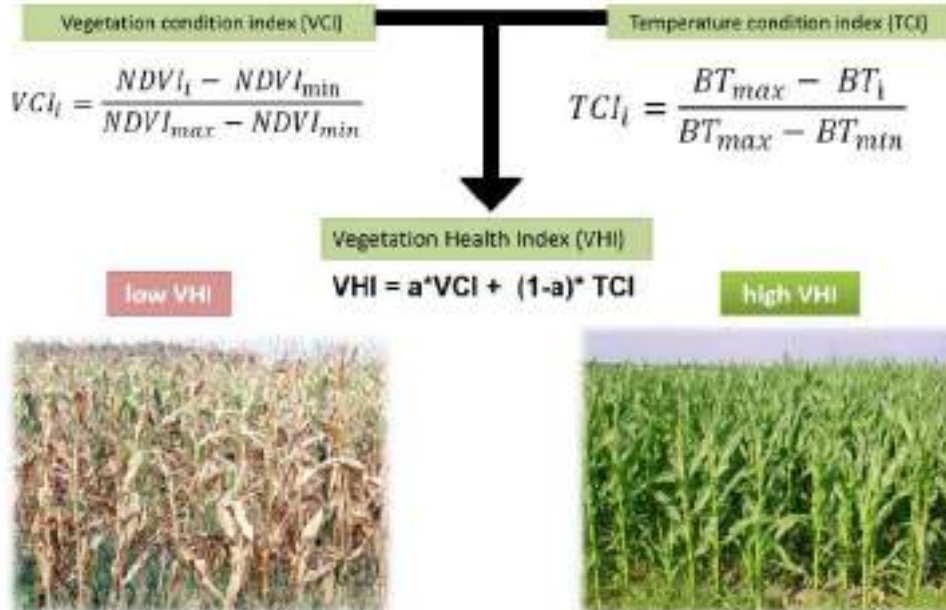
Drought hazard severity classes	VCI/VHI Values
No Drought	> 40
Mild Drought	30 - 40
Moderate Drought	20 - 30
Severe Drought	10 - 20
Extreme Drought	< 10

Kogan, 1998

3. Data and Methods – Drought Indices

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

Agricultural Stress Index System is based on the Vegetation Health Index (VHI) (Kogan et al. 1995)



Classification for VCI (and VHI)

Drought hazard severity classes	VCI/VHI Values
No Drought	> 40
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Moderate Drought	20 - 30
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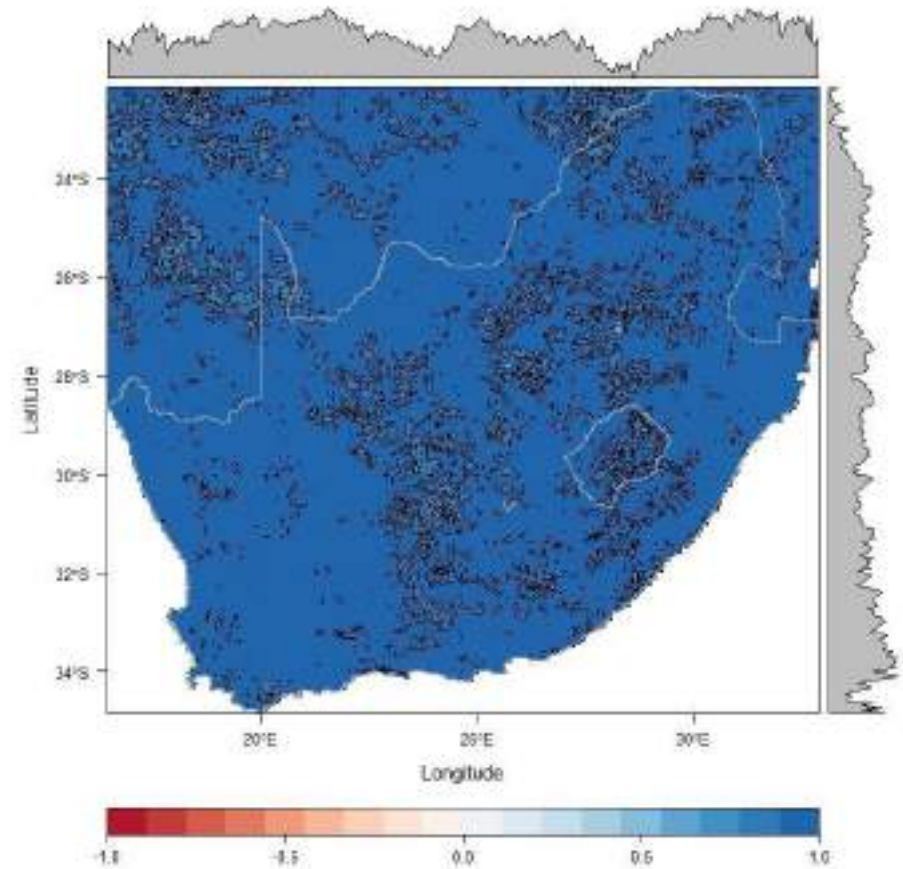
Kogan, 1998

Does remote sensing of vegetation support the detection of drought conditions?

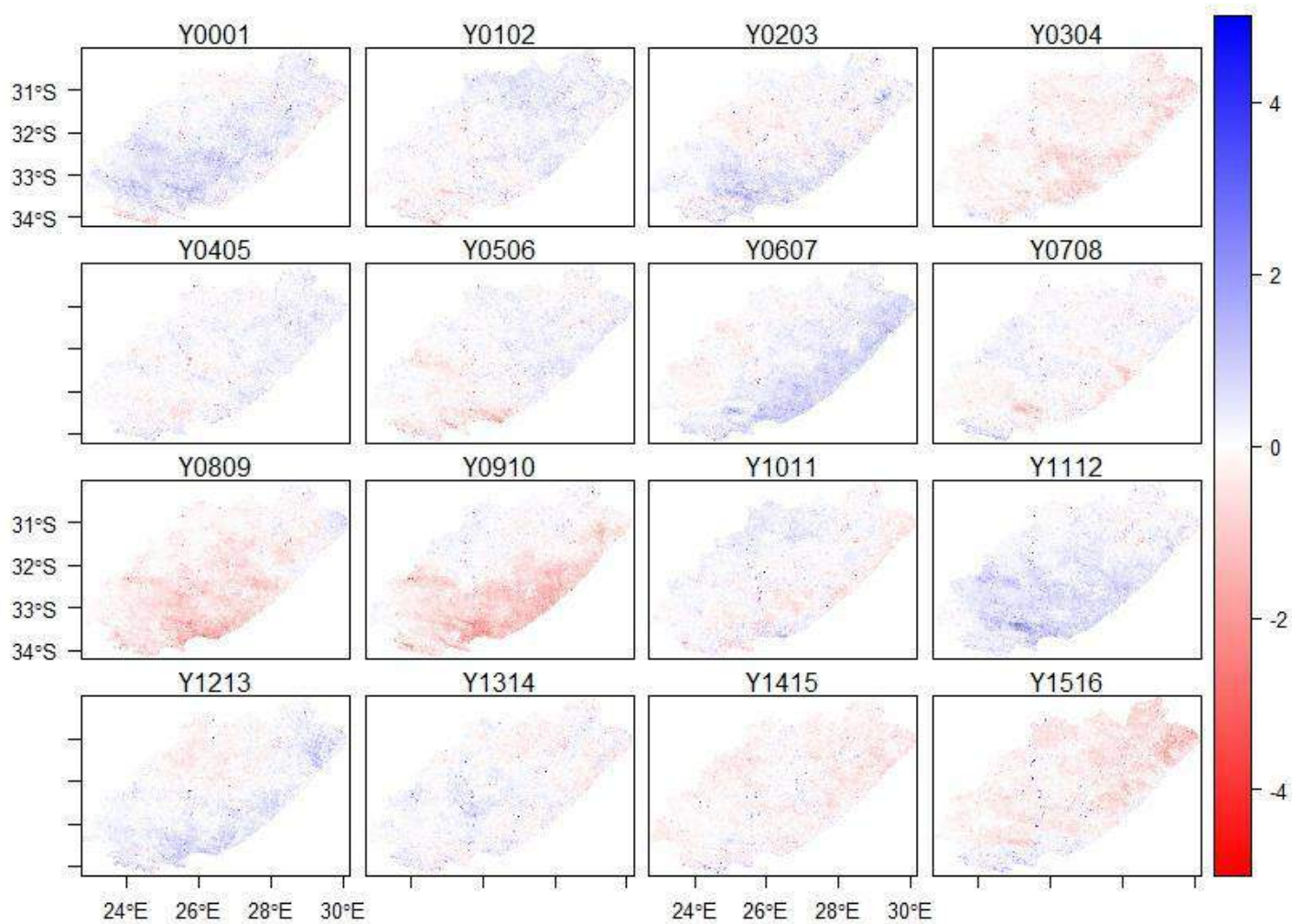
4. Drought Hazard Assessment

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

- VHI integrates also Temperature
- Two most common used indices
- Same drought classifications

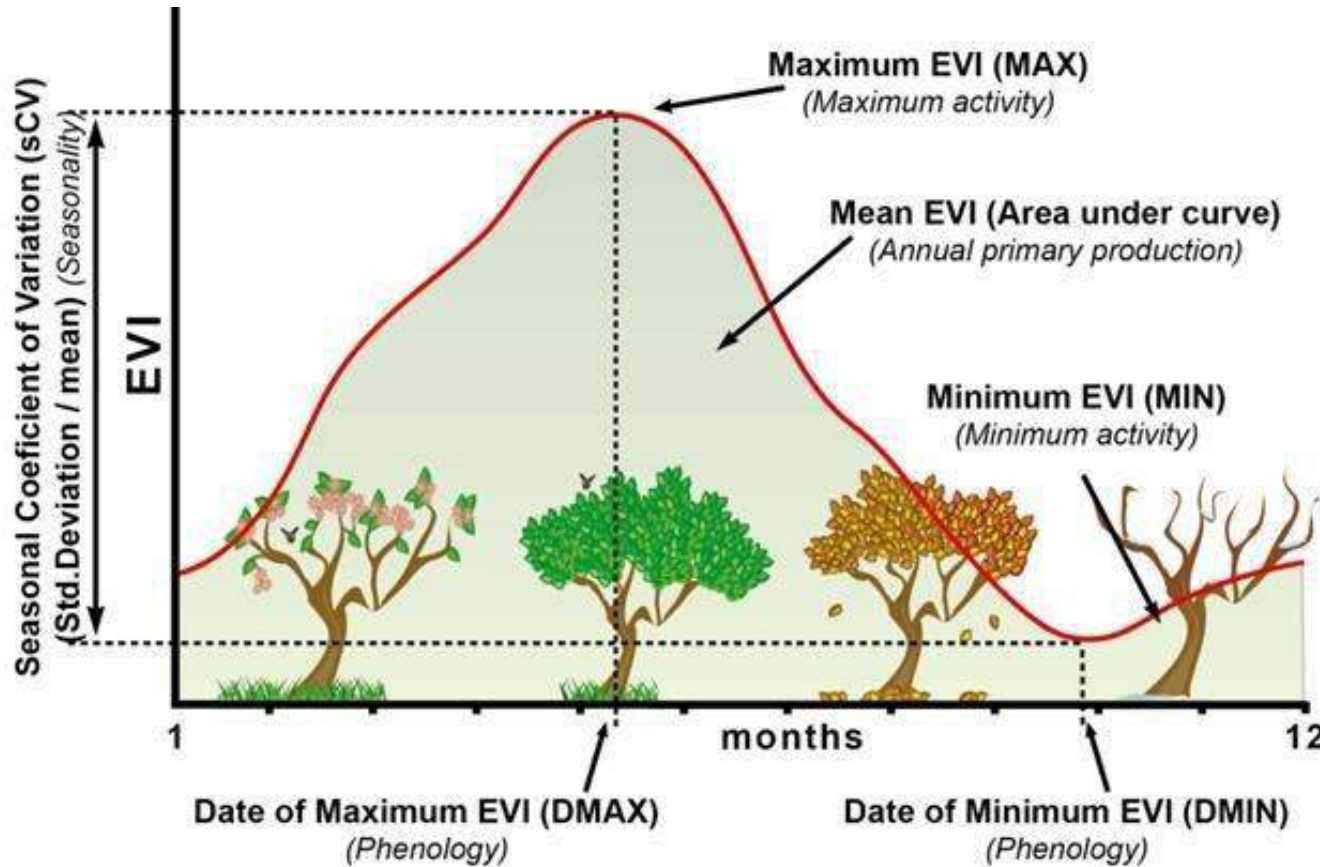


4. Drought Hazard Assessment – Anomalies in Productivity



4. Drought Hazard – the phenological stages

Seasonality Parameters – Vegetation Phenology

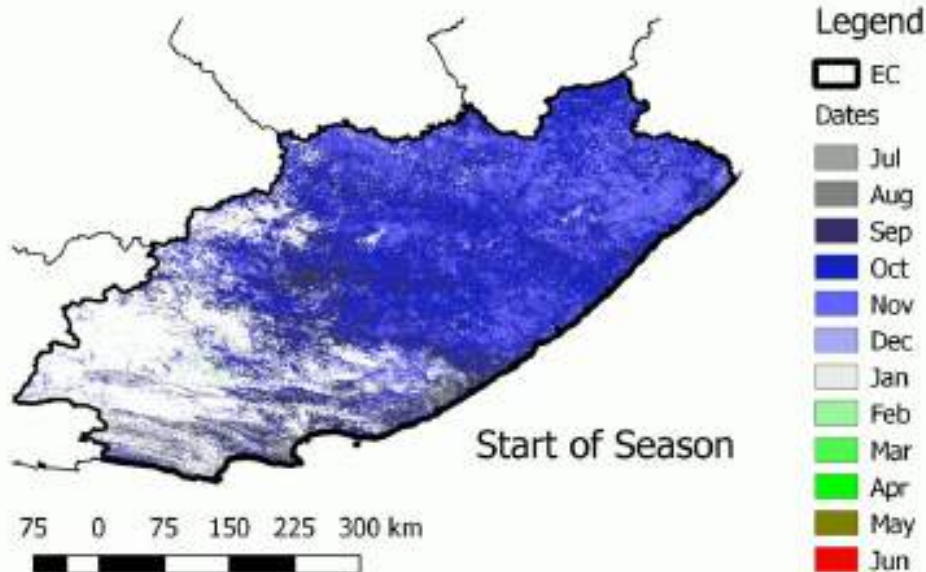


Lourenço (2015)

4. Drought Hazard – Timing matters ...

When crops start to grow...

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



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

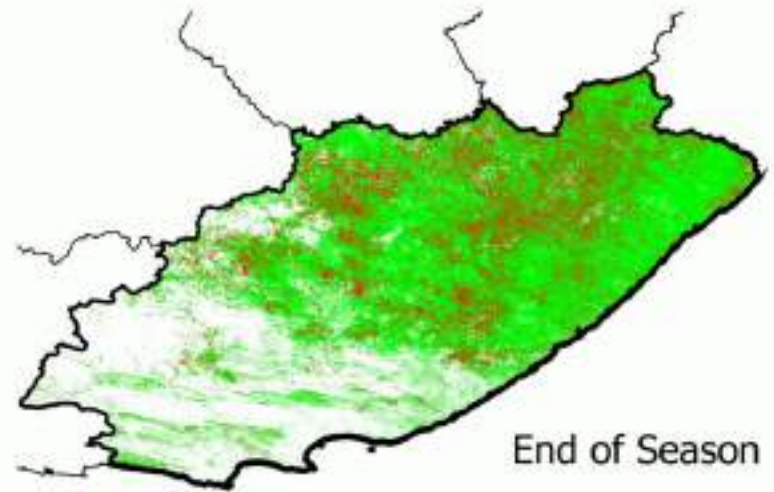
Feb

Mar

Apr

May

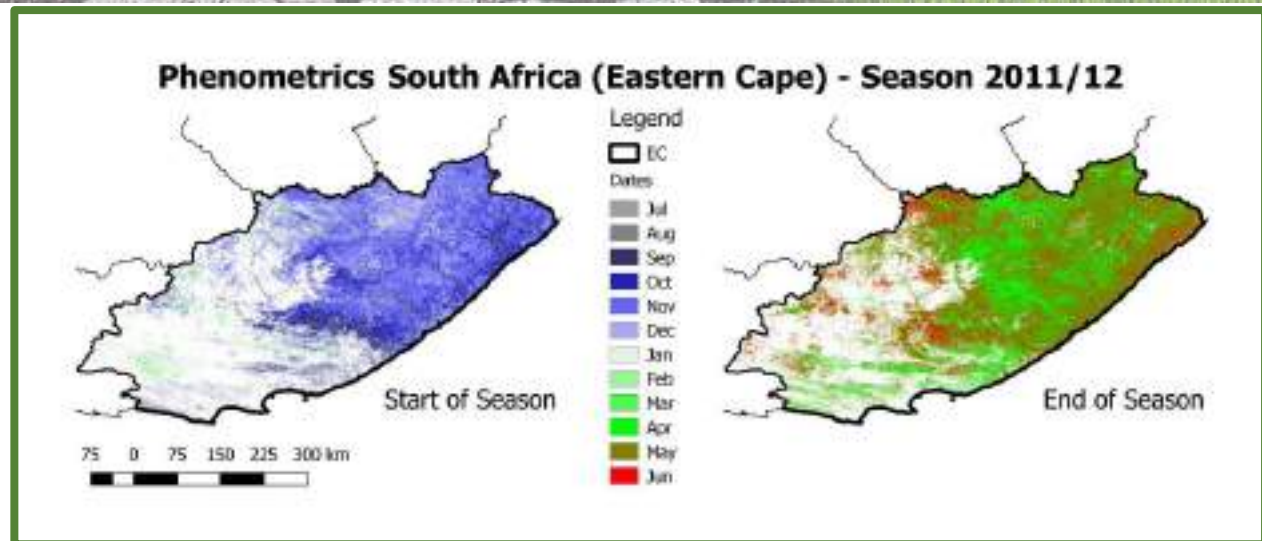
Jun



4. Timing matters: Drought vs. Non Drought Year

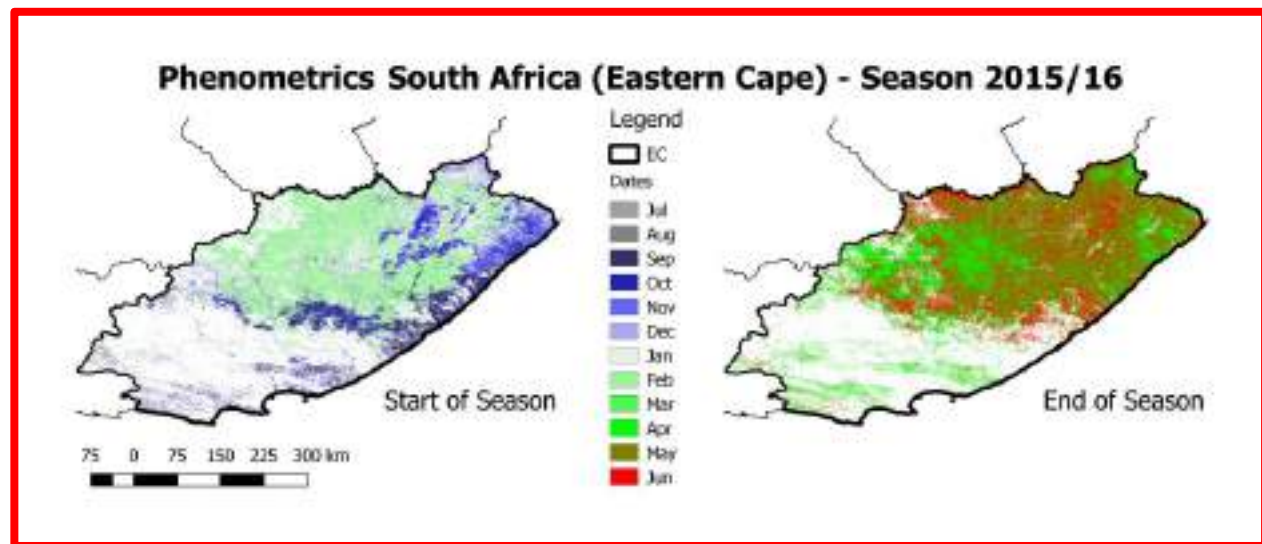
Start of Season (SOS)

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



End of Season (EOS)

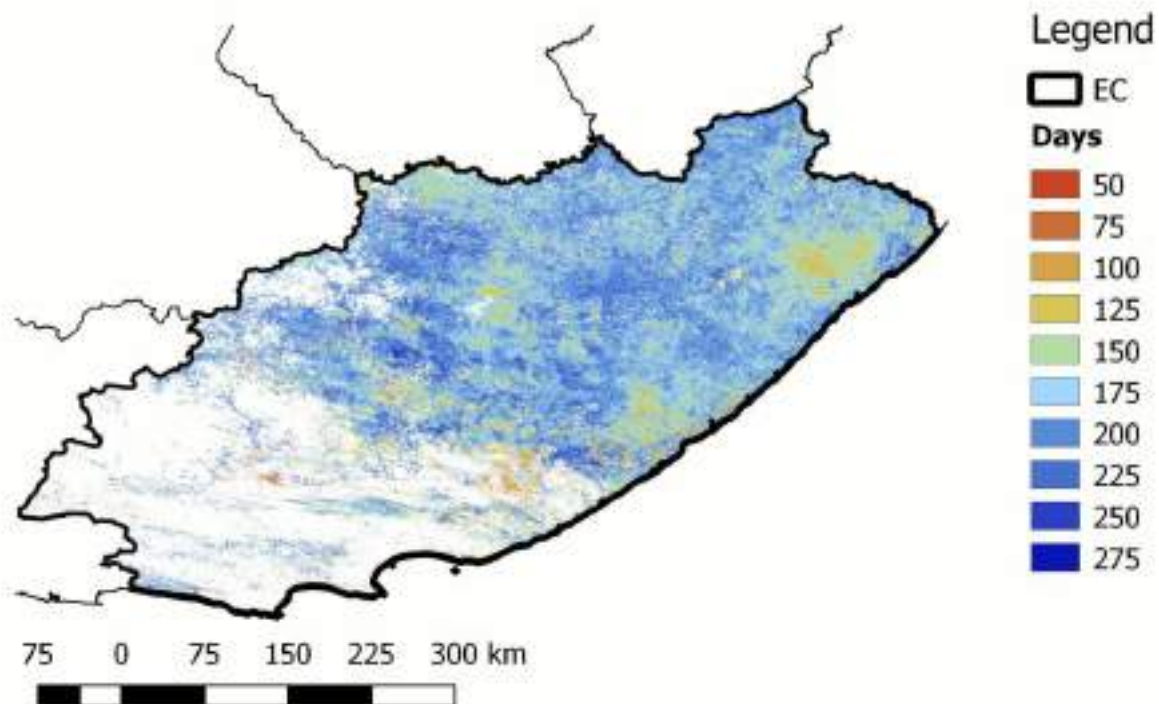
- effect not as different comparing different years



4. Drought Hazard – Timing matters ...

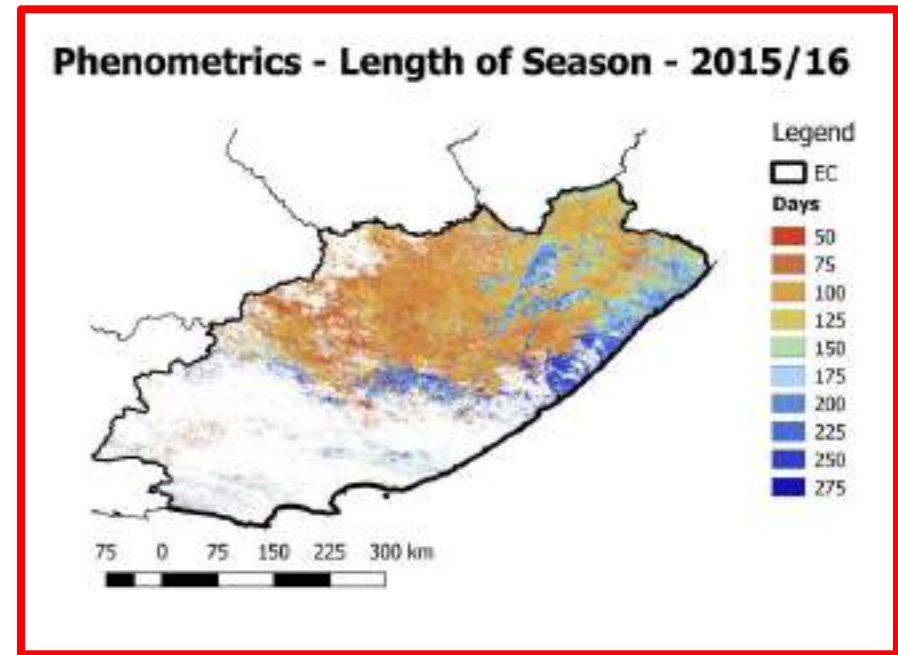
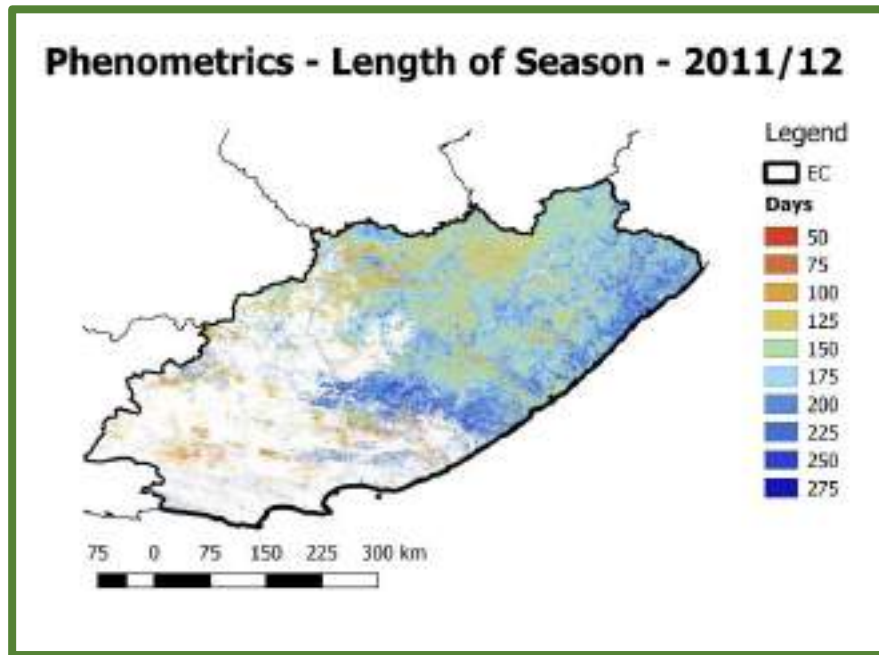
How much time is there for growing ...

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 appEARS platform for data preparation

Data: EVI: Enhanced Vegetation Index

Extract Area Sample

Start a new request

Enter a name to identify your sample

My_study_area **1) Enter a name for your sample**

Upload a file or draw a polygon using the or or . Drop a vector polygon file containing the shape to extract or click here to select the file. Supported file formats: • ESRI Shapefile (.shp including .prj, .dbf, .shx) • GeoJSON (.json or .geojson)

2) Enter start and end date for your sample

Start Date: 01-01-2001 End Date: 12-31-2010

Is Date Recurring?

3) Select your shape-to-extract

Select the layers to include in the sample

Selected layers

- 250m_16_days_ndvi 250m_16 day
- 250m_16_days_ndvi_reliability 250m_16 day

Output Options

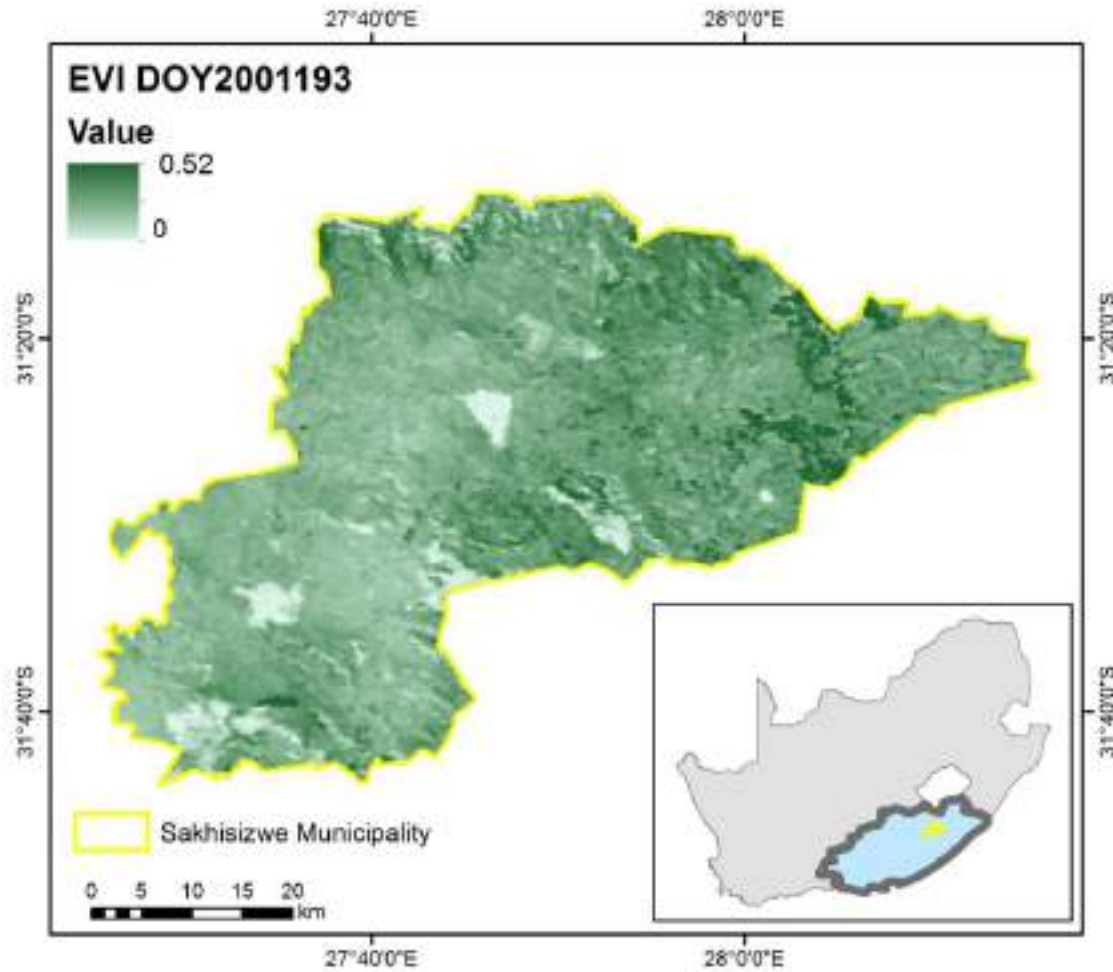
File Format: GeoTIFF

Projection: Geographic

Download Cancel

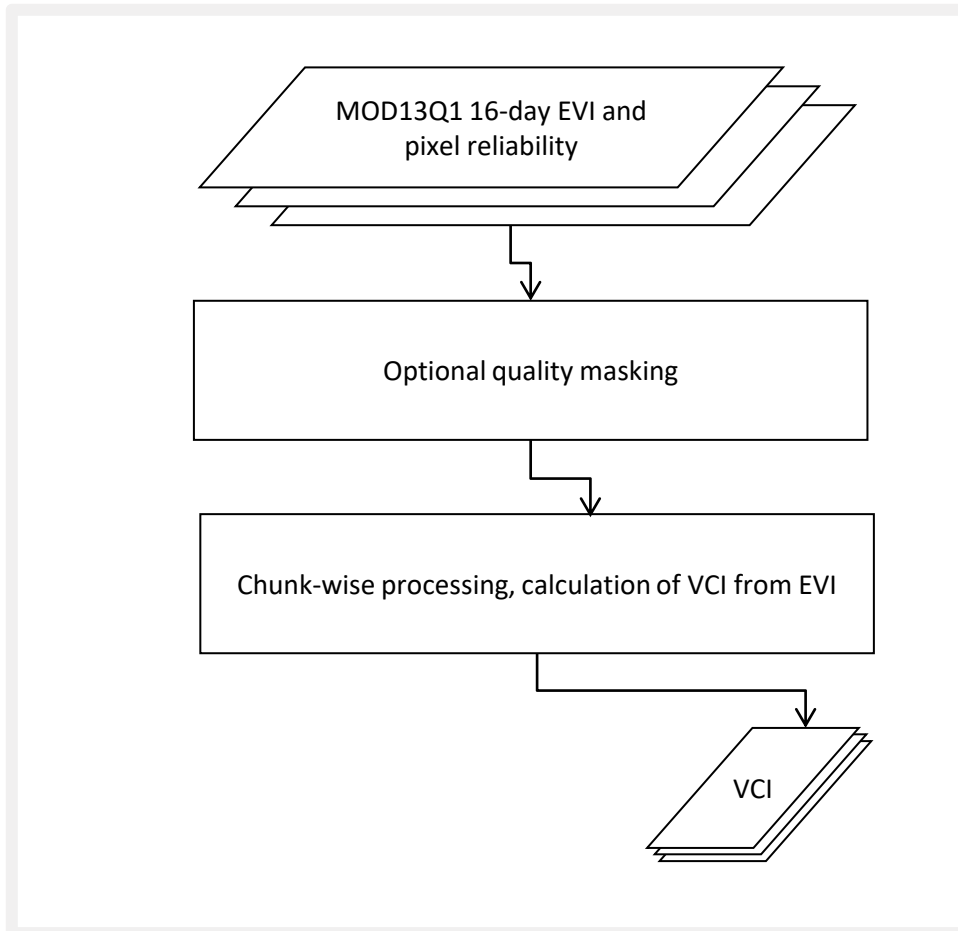
4. Drought Hazard – Study Site for Training

EVI Data 16 day, 250 m resolution



4. Drought Hazard – The Drought Index

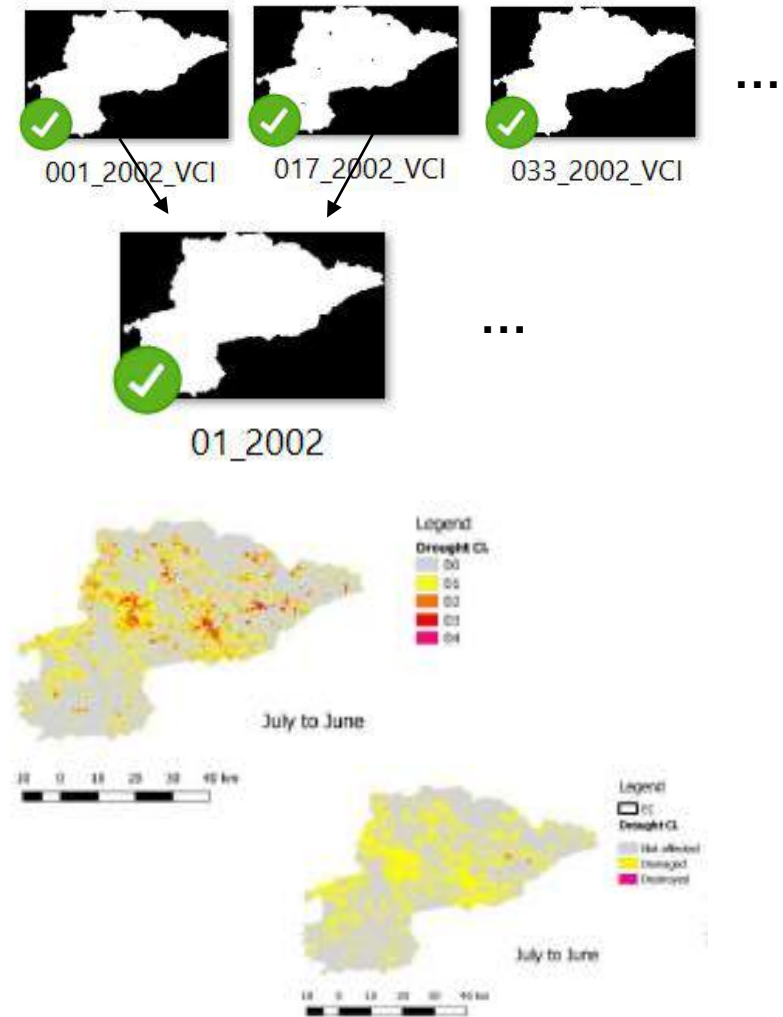
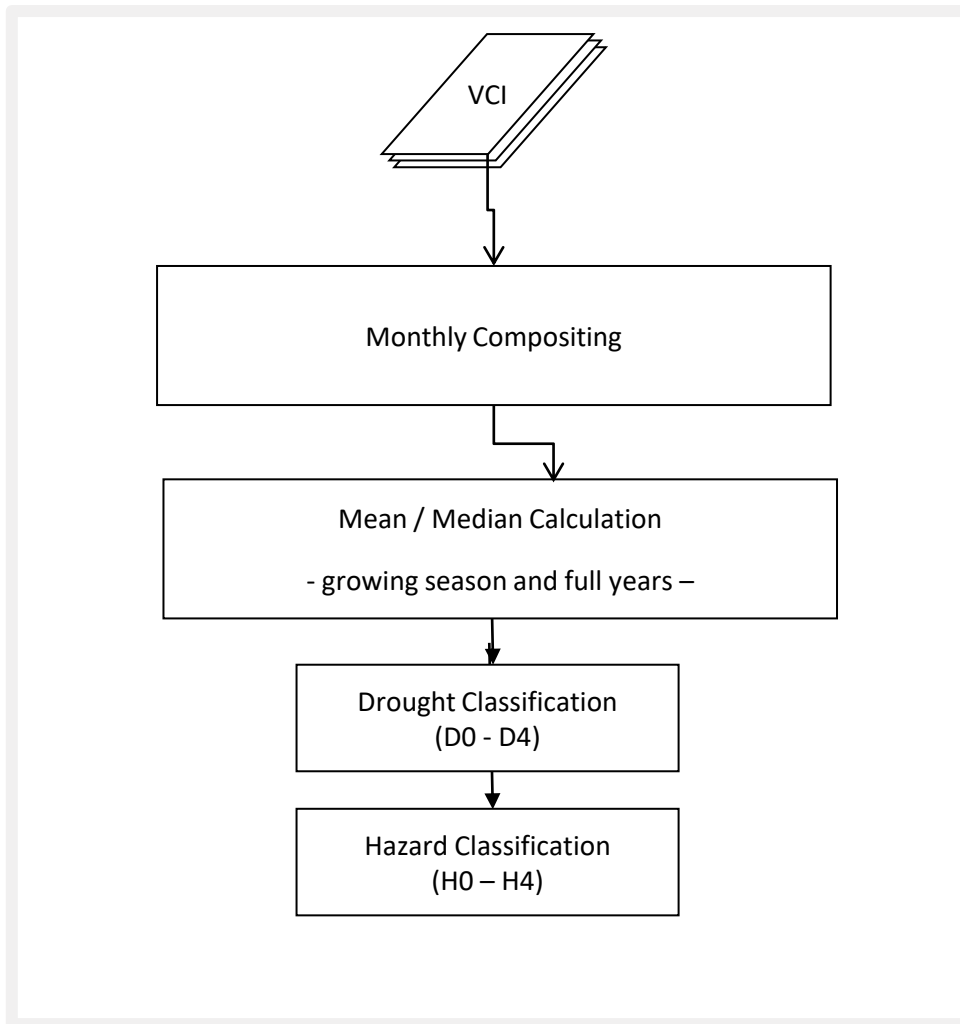
Calculating Vegetation Condition Index (VCI)



Pixel reliability: Quality of the data

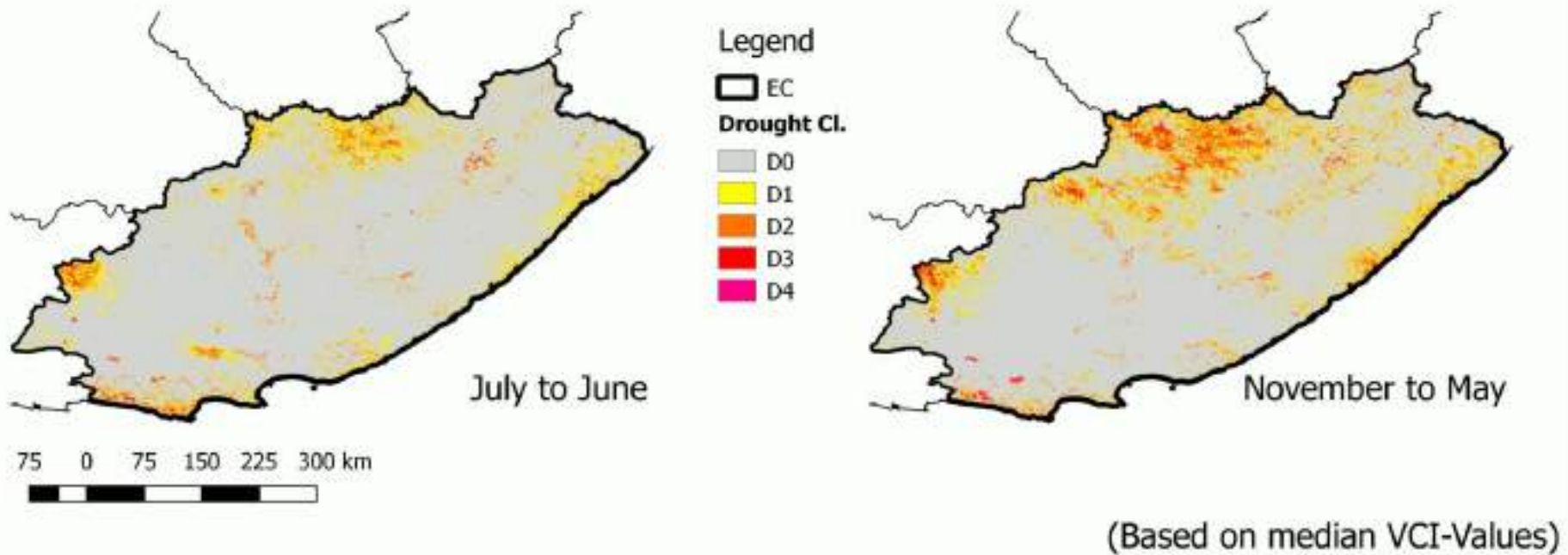
VCI – Drought Index Calculation

4. Preliminary Output



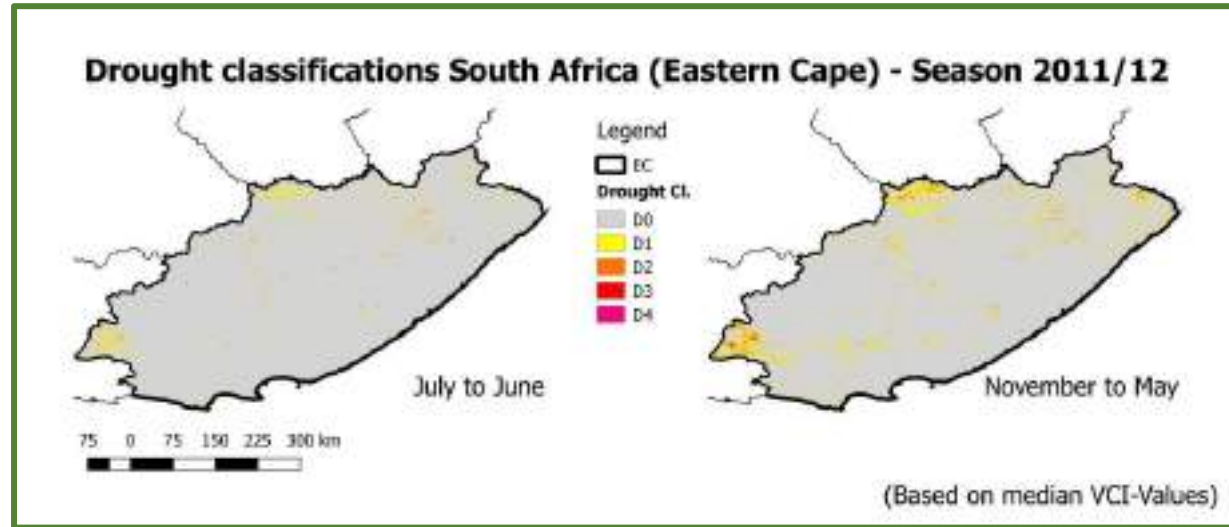
4. Preliminary Output – Conditions for a full year and for a season

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

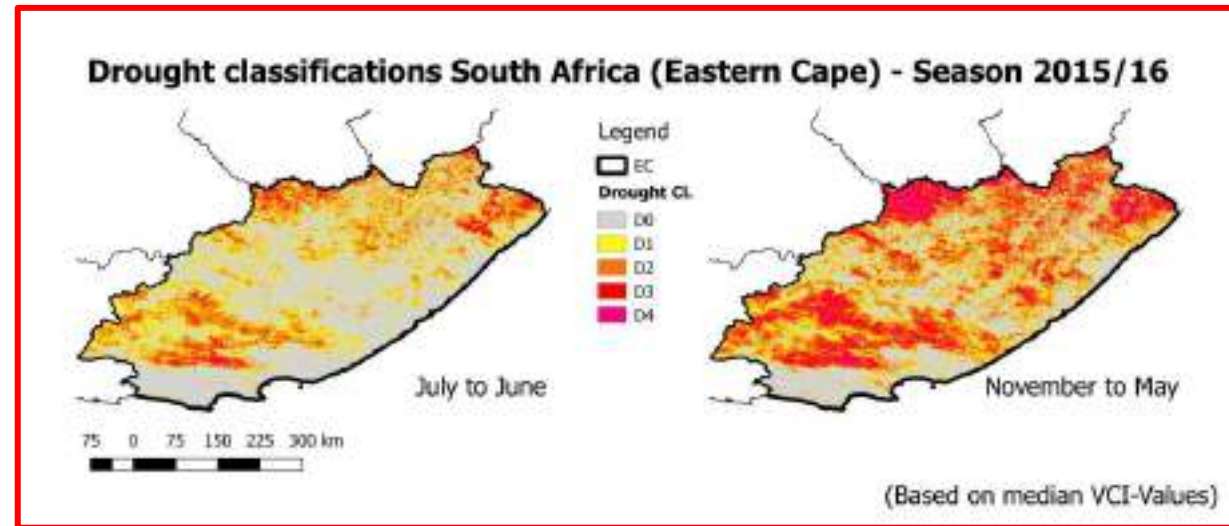


4. Preliminary Output – Conditions for a full year and for a season

Normal/Non-Drought Year

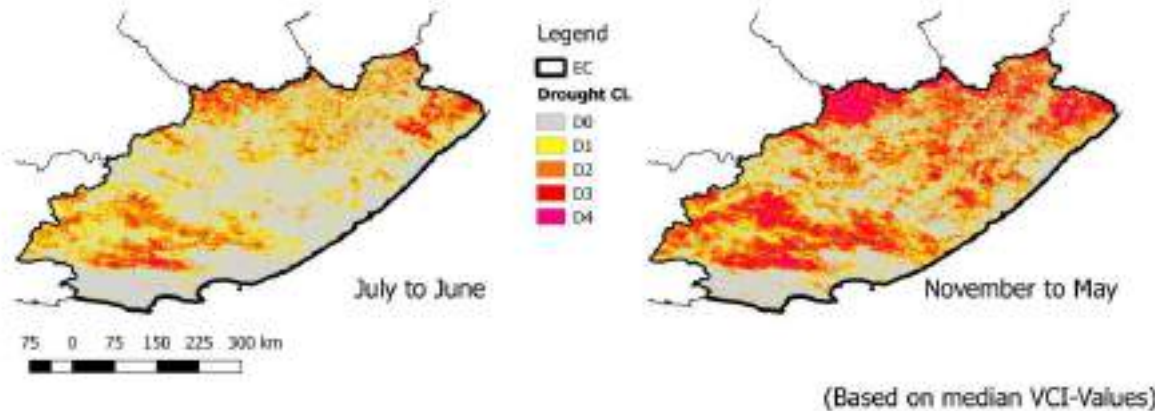


Drought Year



4. Drought Classification – Hazard Classification

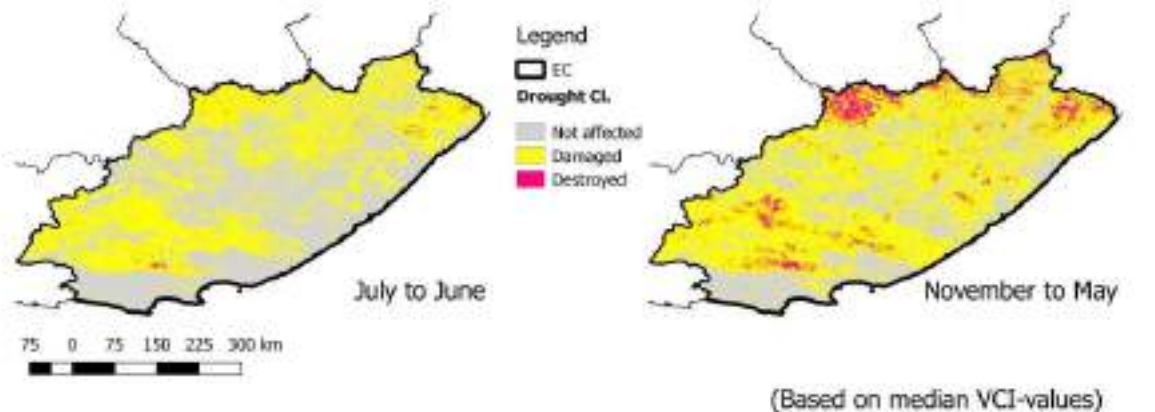
Drought classifications South Africa (Eastern Cape) - Season 2015/16



Drought Hazard Severity Classes	Value in final output	VCI Values (weighted over season)
No Drought (D0)	0	>40
Mild Drought (D1)	1	30–40
Moderate Drought (D2)	2	20–30
Severe Drought (D3)	3	10–20
Extreme Drought (D4)	4	<10

Global Classification

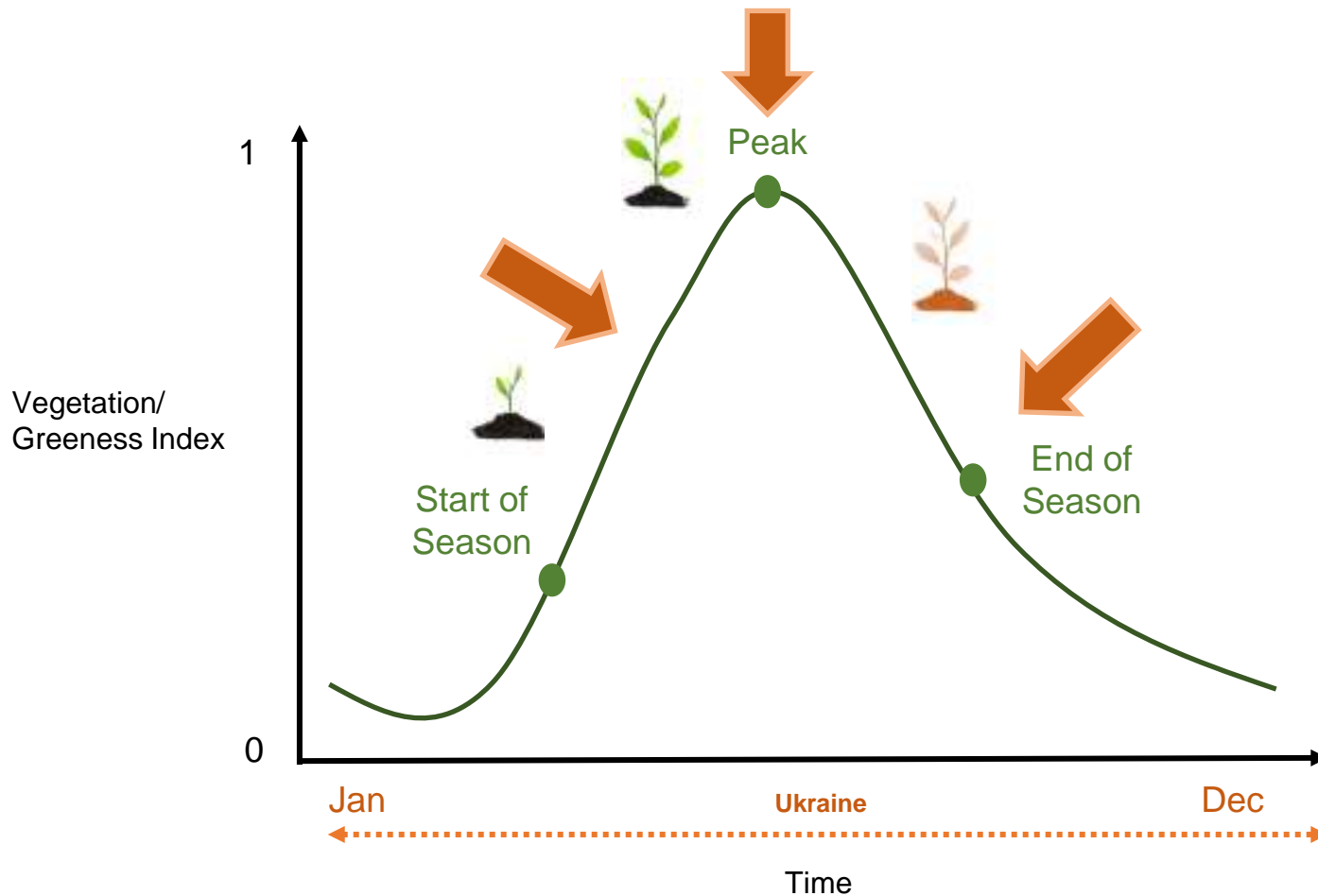
Drought classifications South Africa (Eastern Cape) - Season 2015/16



Vegetation condition	Value in final output	VCI Values (weighted over season)
Not affected (H0)	0	>40
Damaged (H1)	1	10–40
Destroyed (H2)	2	<20

5. Hazard Approach – Potential

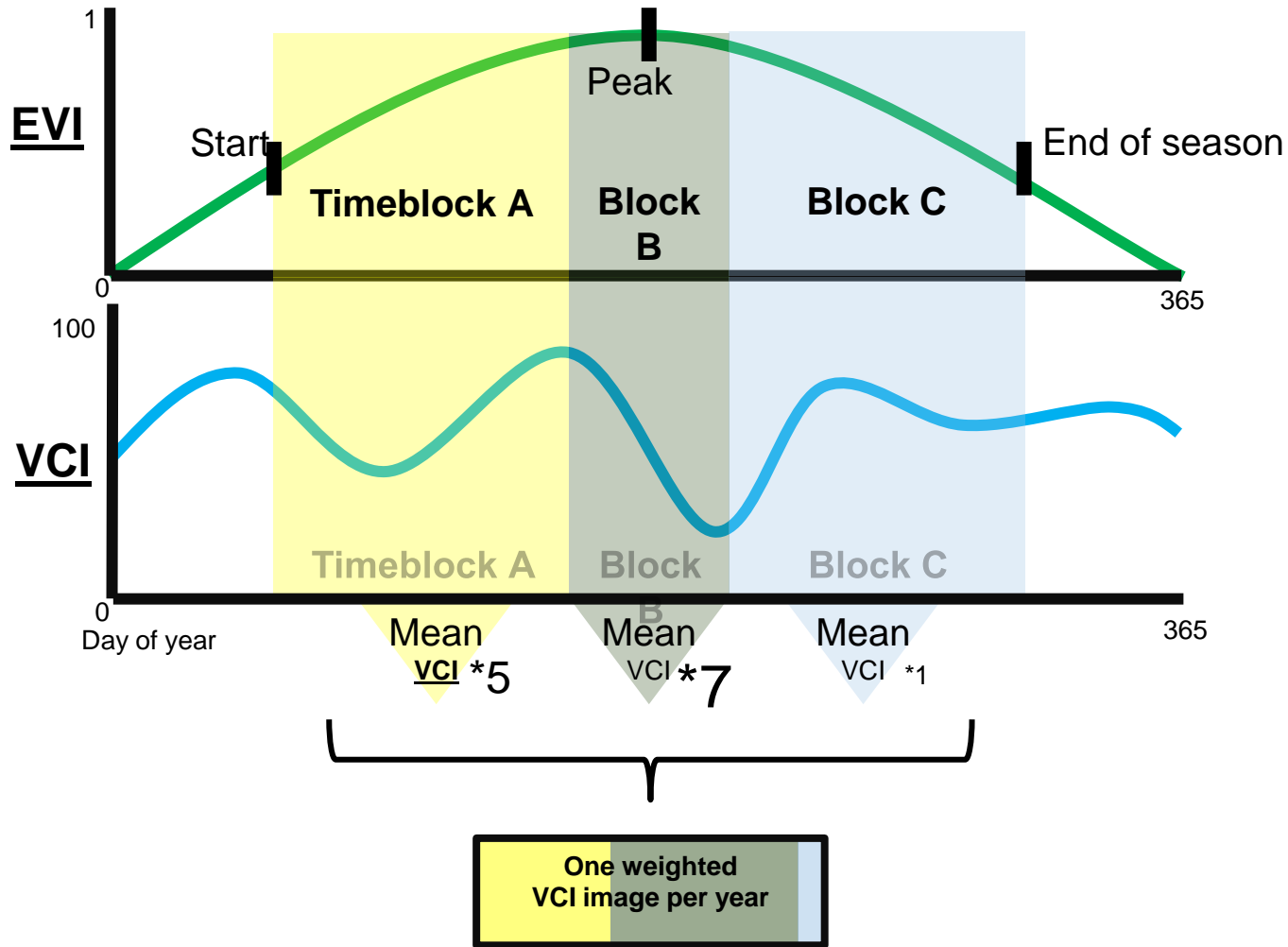
Seasonality Parameters – Vegetation Phenology



Drought Event

Timing
When does a drought occur?

5. Hazard Approach – Potential



5. Hazard Approach – Strengths and Weaknesses

Strengths

- free and open data
- simple index calculation
- addressing seasonality and allow focus on the growing season
- considering vulnerability stages during the phenological stages
- aiming at more accurate severity detection

Weaknesses

- Validation missing – drought event database
- Phenology detection needs to consider land cover – so far only distinction between crop- and grasslands
- Drought characteristics – individual measurements needed

6. Discussion and Outlook

Until the end of the project:

- Finalize Phenology detection and WLC
- Stress detection with actual temperature threshold passing

Ongoing

- Drought Monitoring with remote sensing on higher resolution scales (Sentinel 1 and 2 analysis currently under development for integration)
- Understanding rs-based drought indices better by also expanding to other regions:

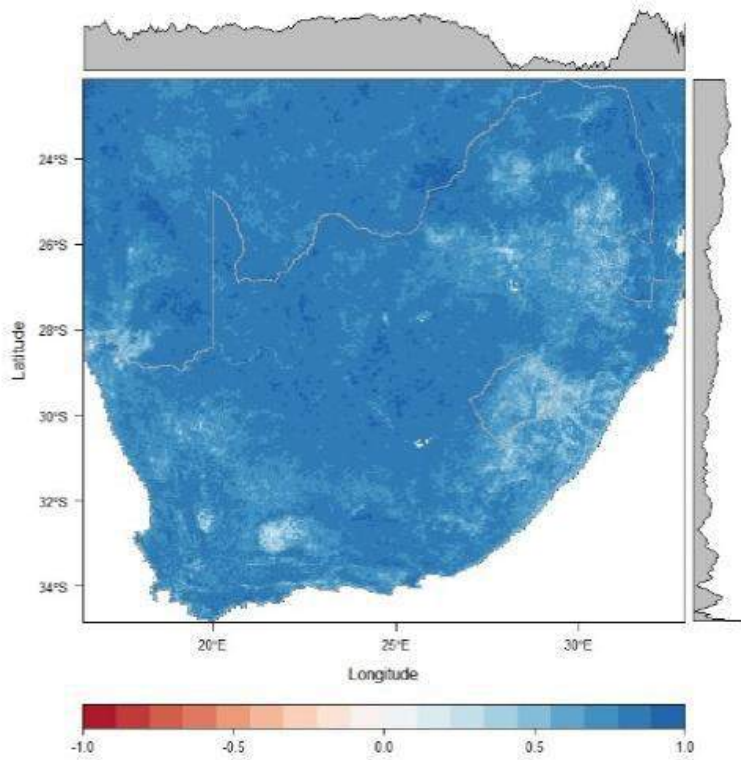
ongoing/new project activities



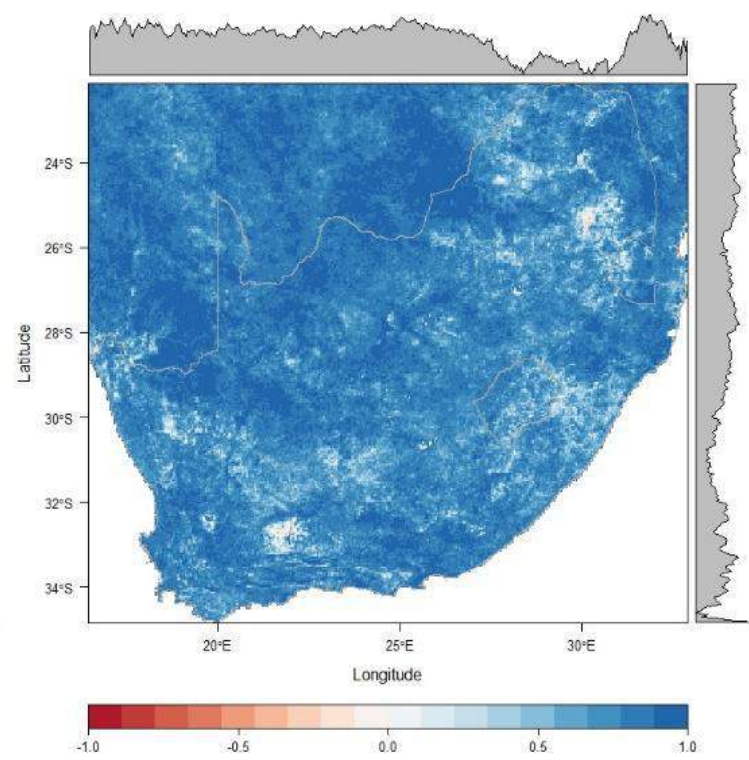


**Thank you very much for
your attention!**

VCI (median) and Σ EVI Anomalies

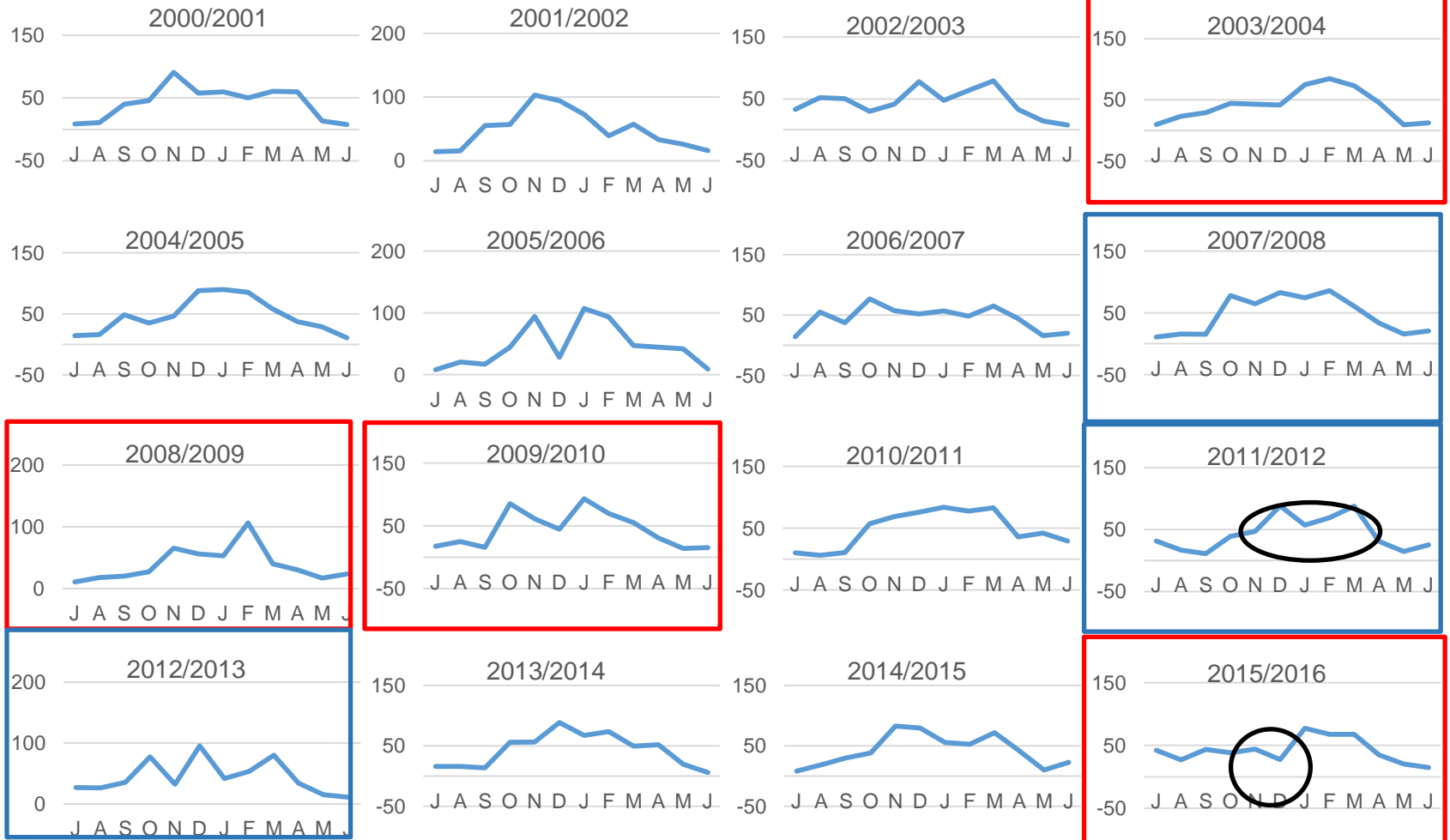


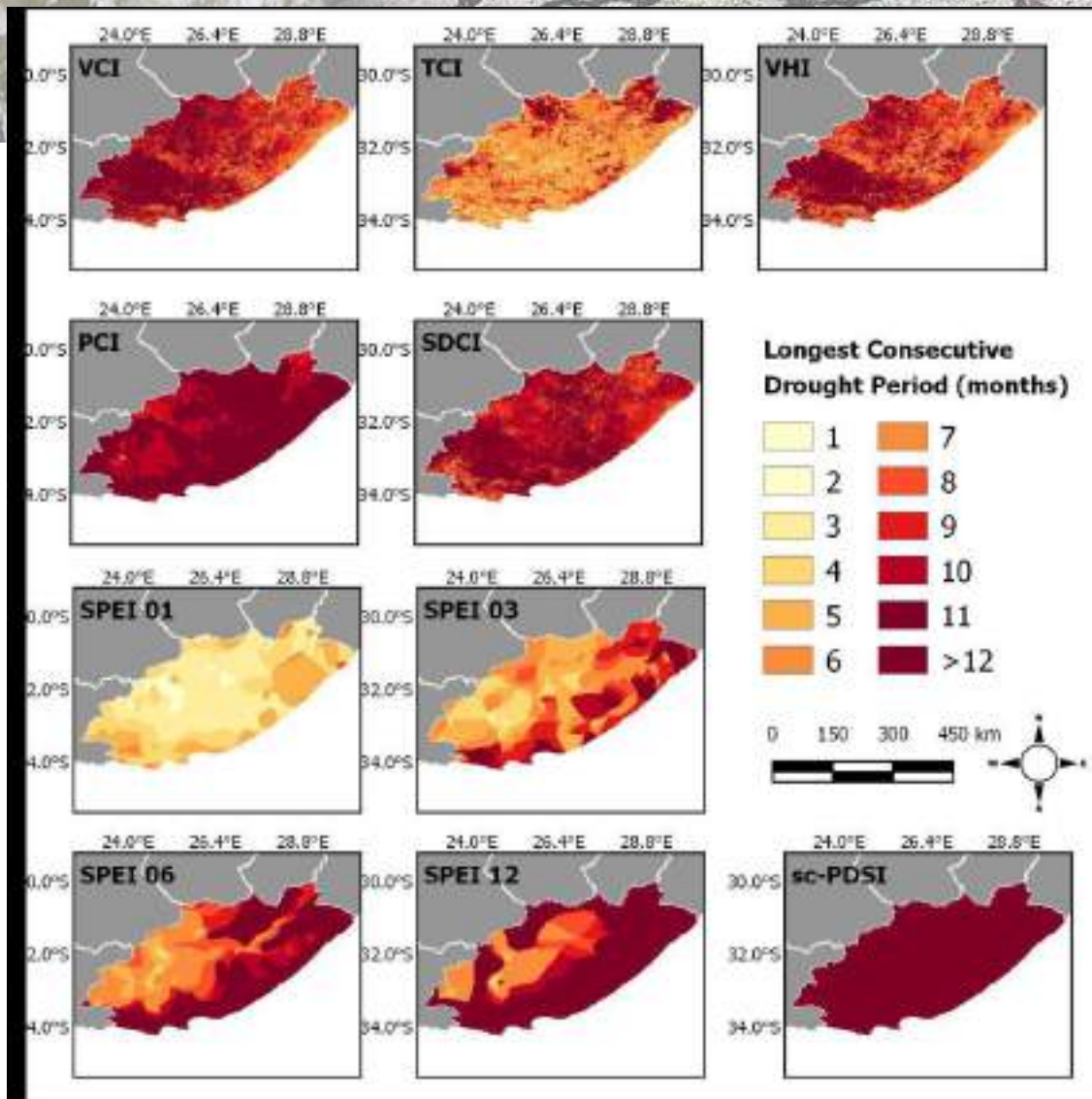
VHI (median) and Σ EVI Anomalies



4. Precipitation Profiles 2000-2016 – example Eastern Cape

Getting a better understanding ...





“A project is never truly finished, you simply run out of time” (Peter Jackson)