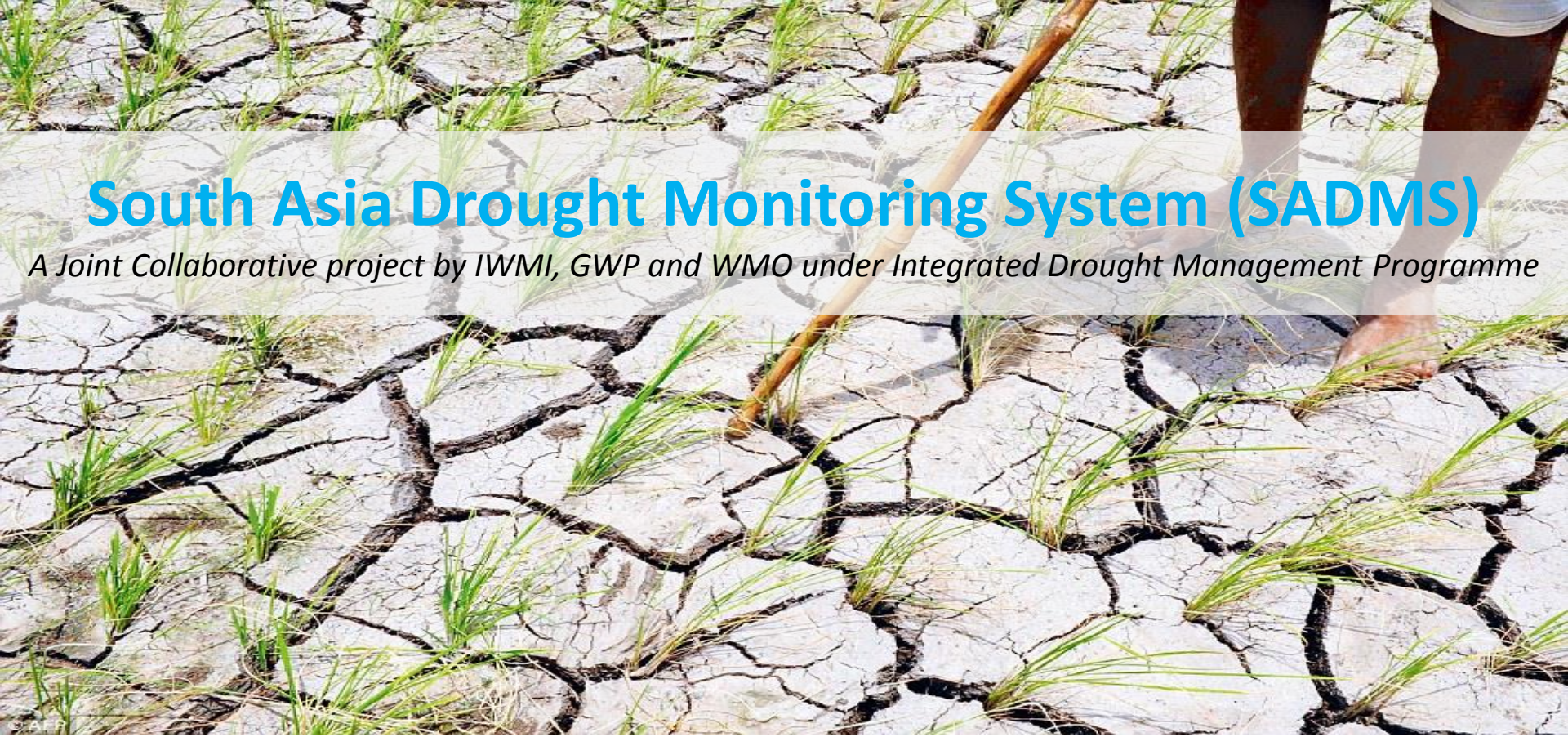


South Asia Drought Monitoring System (SADMS)

A Joint Collaborative project by IWMI, GWP and WMO under Integrated Drought Management Programme

Giriraj Amarnath, Niranga Alahacoon, Peejush Pani, Vladimir Smakhtin
International Water Management Institute (IWMI), Sri Lanka

Jegananthan C., Kirti A.
Birla Institute of Technology, India

Overarching Goal

- To build climate resilience, reduce economic and social losses, and alleviate poverty in drought-affected regions in SA through an integrated approach to drought management;
- To support stakeholders at all levels by providing policy and management guidance and by sharing scientific information, knowledge and best practices for IDM;
- To promote the evolution of the drought knowledge base and to establish a mechanism for sharing knowledge and providing services to stakeholders across sectors at all levels;
- To build capacity of various stakeholders at different levels.

Specific objectives

- Better scientific understanding and inputs for drought monitoring and management;
  - Drought monitoring, early warning and risk assessment;
  - Development of operational online drought monitoring system;
- Capacity building, customization for national needs and dissemination of the monitoring product;
- Policy and planning for drought preparedness and mitigation across sectors; and
- Drought risk reduction and response.

Partners

Donors

World Meteorological Organization

Global Water Partnership

CLIMATE CHANGE AGRICULTURE AND FOOD SECURITY

CGIAR RESEARCH PROGRAM ON Water, Land and Ecosystems

Technical Partners

BIRLA INSTITUTE OF TECHNOLOGY RANCHI

SYMBIOSIS INTERNATIONAL UNIVERSITY PUNE

End Users

महाराष्ट्र शासन

SAARC

UNITED NATIONS Office for Outer Space Affairs

Historical Drought Trends

- Drought an important disaster, and its impact on agriculture, ecological and social and economic consequences worldwide;

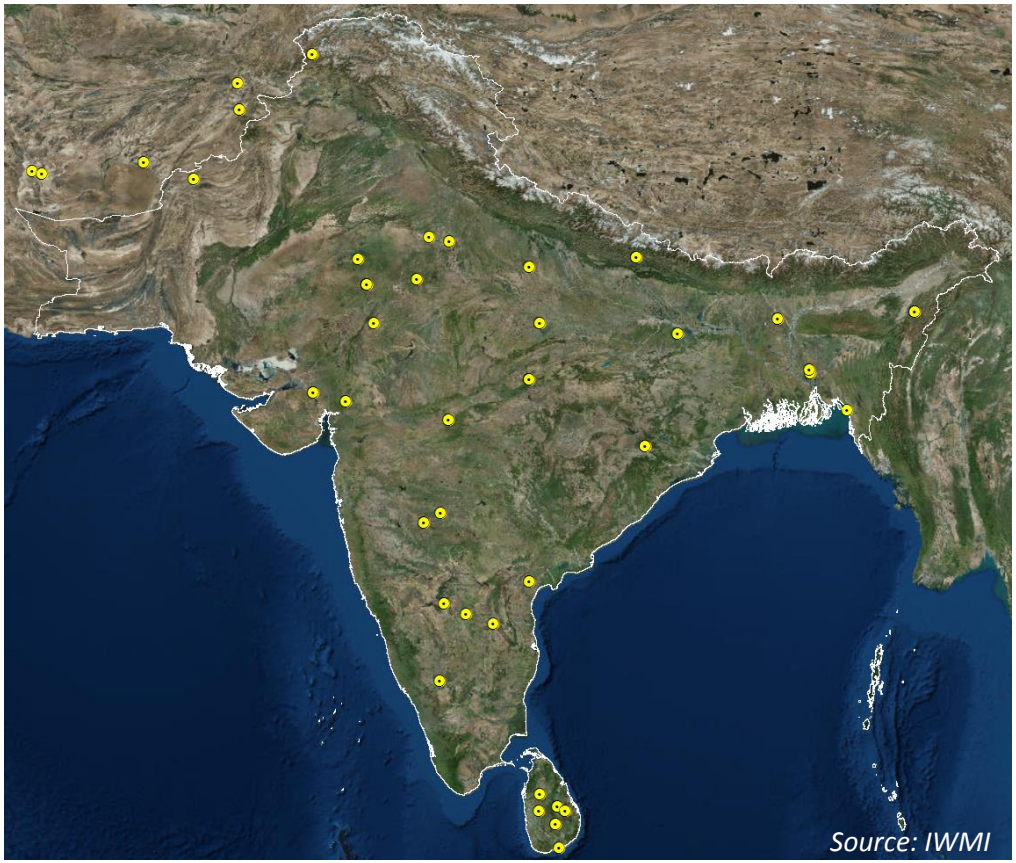
- Since 2000's 14 major drought occurrences were reported in SA countries
  - 305 death mortality
  - 360 million people affected
  - 1.6 billion economic losses in damages

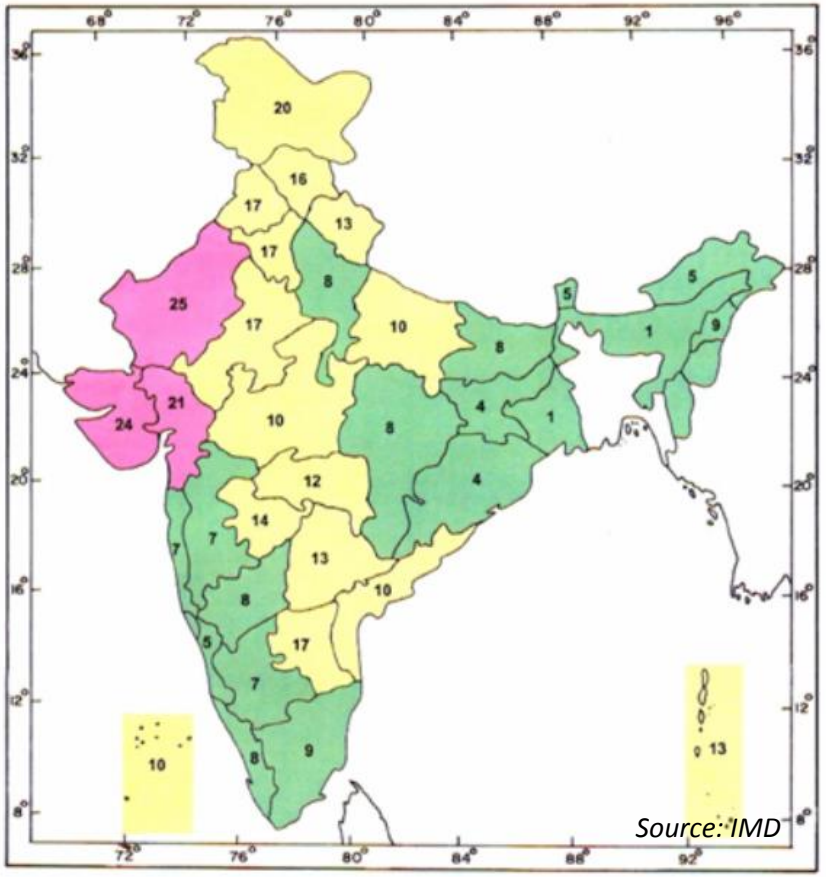
- SA regions have been among the perennially drought-prone regions of the world.

- Afghanistan, India, Pakistan and Sri Lanka have reported droughts at least once in every three year period in the past five decades, while Bangladesh and Nepal also suffer from drought frequently.

- The frequent occurrence of drought, coupled with the impact of global warming, poses an increasingly severe threat to the SA agricultural production.

Historical Drought Trends





PROBABILITY OF OCCURRENCE OF DROUGHT (%) AND DROUGHT PRONE AREAS 1875 - 2004

CRONICALLY DROUGHT PRONE ARE A
(PROBABLITY OF OCCURRENCE OF DROUGHT MORE THAN 20%)

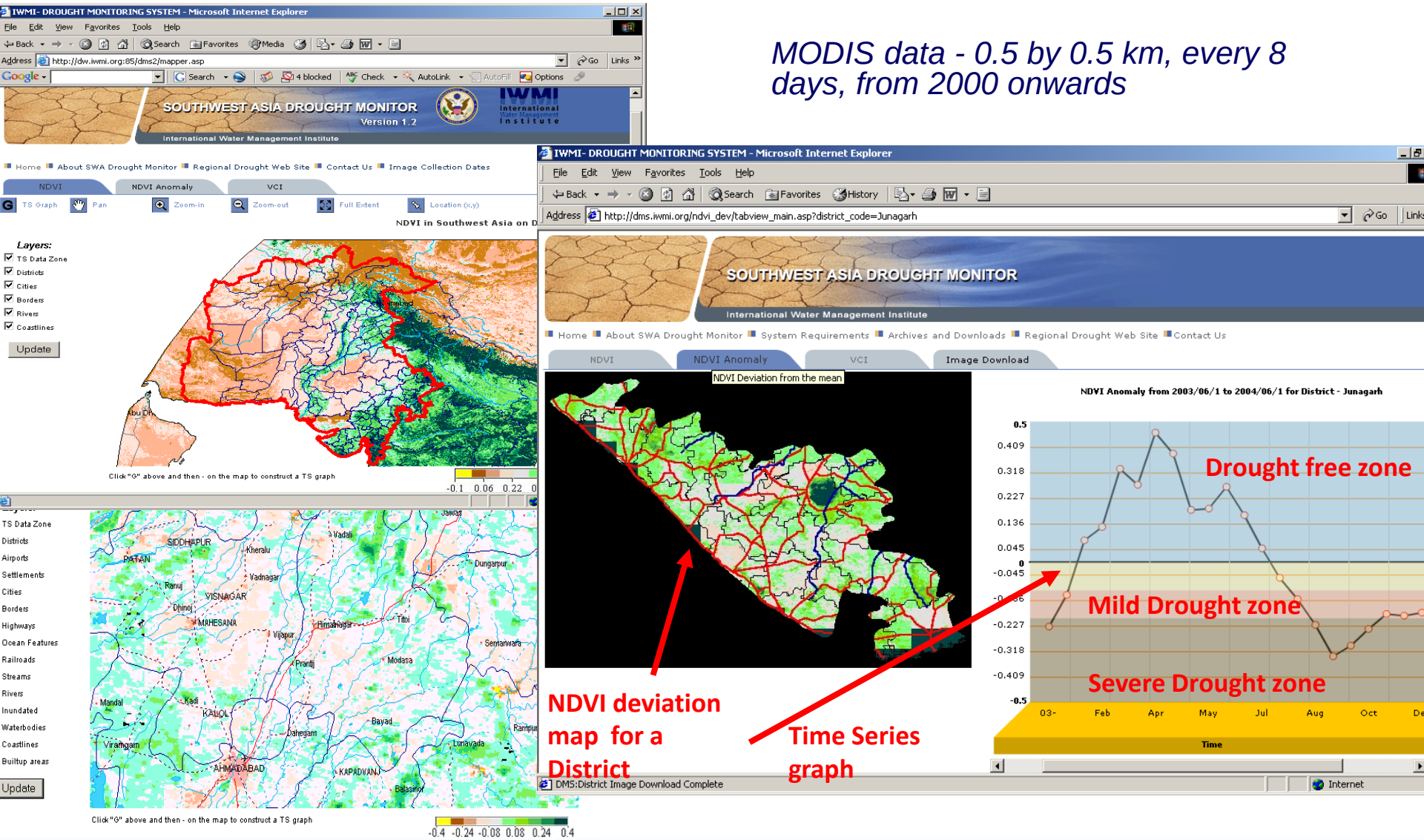
FREQUENT LY DROUGHT PRONE AREA
(PROBABILITY OF OCCURRENCE OF DROUGHT 10% TO 20%)

LEAST DROUGHT PRONE AREA
(PROBABILITY OF OCCURRENCE OF DROUGHT LESS THAN 10%)

- Annual occurrence of drought over 50years;
- Increasing trend in occurrences, both in magnitude and frequency;
- Knowledge on the spatial distribution across SA is limited;
- Currently developing comprehensive database from multi-data sources

PREVIOUS ONLINE DMS – South West Asia

MODIS data - 0.5 by 0.5 km, every 8 days, from 2000 onwards



SOUTH ASIA DROUGHT MONITORING SYSTEM (DMS): OVERVIEW

- Builds on IWMI's expertise and previous DMS in SW Asia
- Will feature historical and near-real time weekly high-spatial resolution drought severity maps
- Integrates remote sensing and ground truth data (vegetation indices, rainfall data, soil information, hydrological data)
- Supports regionally coordinated drought mitigation efforts that can be further tailored to analysis at the national level
- Will be part of regional, national and local decision making – working with WMO partners and GWP South Asia as well as the Water Partnerships in Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka to generate ownership by Governments and communities.

SOUTH ASIA DROUGHT MONITORING SYSTEM: NEEDS ASSESSMENT SURVEY

- Carried out by the GWP South Asia and the Country Water Partnerships in Bhutan, Bangladesh, Nepal, India, Pakistan and Sri Lanka in collaboration with IWMI
- Full report available at: *http://www.droughtmanagement.info/literature/GWP_SA_Summary_Report_Need_Assessment_Survey_2014.pdf*

	1 Existence of Drought Early Warning System	2 Capability to contribute to Drought Monitor/ Early Warning	3 Requirement for infrastructural support	4 Rating of usefulness of Drought Monitor/Early Warning System
Afghanistan	No	Very Low – No prediction capability	Very High – Technical and Training Support needed	"Very essential"
Bhutan	No	Very low – daily and seasonal rainfall prediction	Very high – satellite images of moisture contents, hydrological models, forecast products	"Important"
Bangladesh	No	Medium – experience in flood warning, usage of drought prediction tools	High – Technical support and training needed	"Very essential to ensure food security"
Maldives	No	Medium – Experience in flood & rainfall early warning	High – Technical support and training needed	"Very essential to ensure drinking w
Nepal	No	Low – experience in collecting post-drought information	Very high – more hydro-met stations required	"One of the best initiatives in the region and my country"
India	Yes – especially powerful in certain regions	Very high – experience in usage of different drought indices	Medium – nationalized institution needed who can run a Drought Early Warning System	"Extremely useful and essential"
Pakistan	Yes	Very high – weather radar and GIS spatial integration systems capability to identify drought	Medium – information for specific drought prone areas needed	"Moderate in own country" / "Strong in South Asia"
Sri Lanka	No	Low – capacities exist, but need improvement	Very high – information tailored to the area is needed	"Very useful"

Table: Overview of the responses. Colour scale indicating country capacity: min → max

Drought Monitoring Approach

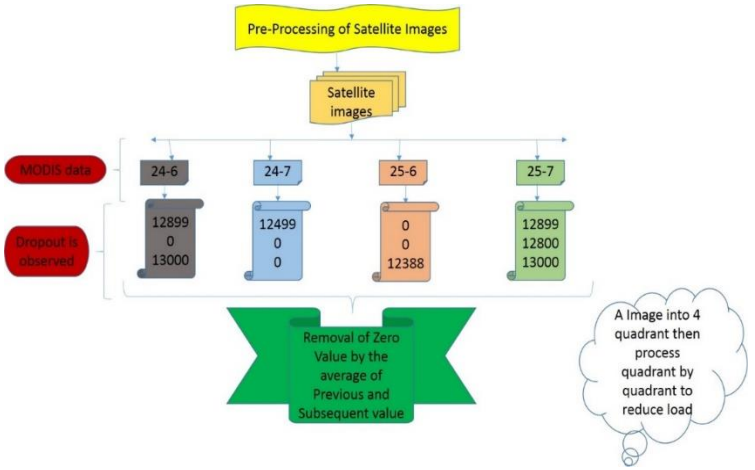
Correction of Vegetation Time Series for Long Term Monitoring

Step 1: Cloud Removal using LDOPE tool

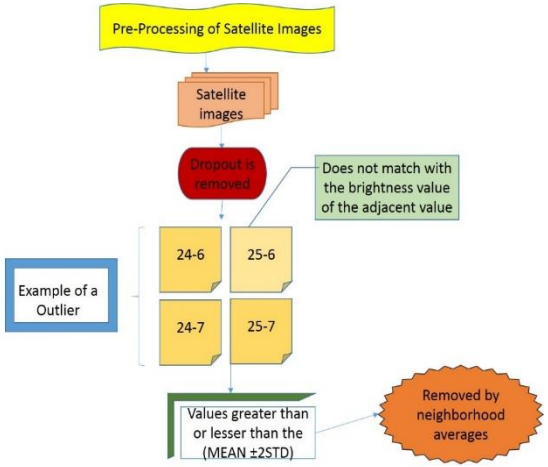
Step 2: Additional Filter using Blue reflectance band >0.2 threshold

Step 3: Drop out removal using Statistical Outlier with ± 2 STD by neighborhood method

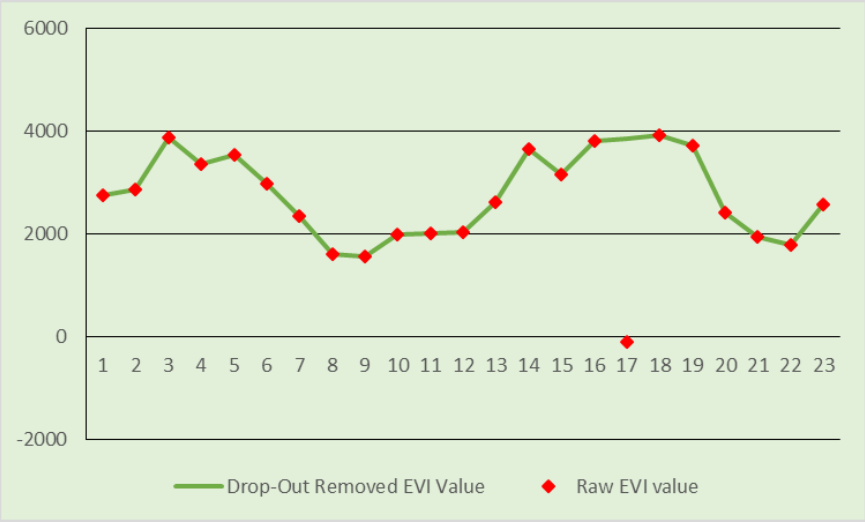
Step 4: Fourier time series analysis to determine seasonal changes in vegetation growth, Crop anomaly and Extraction of Peak growth time

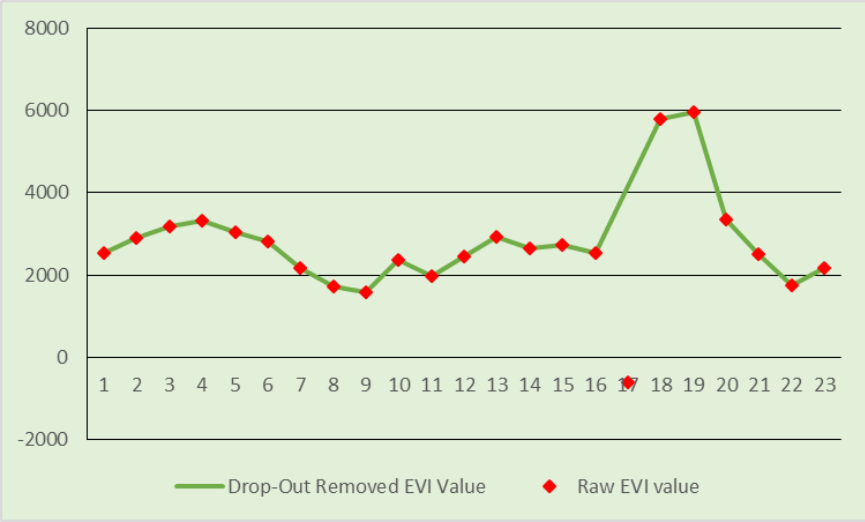


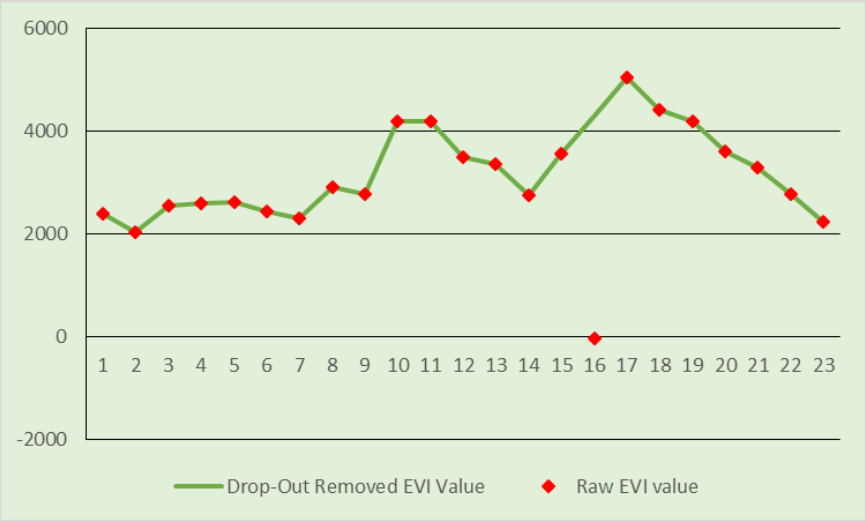
Whereas statistical outliers is also removed from yearly dataset. The values which are greater than or less than the (MEAN + - 2STD) will be treated as OUTLIERS and it will removed by neighbourhood averages.

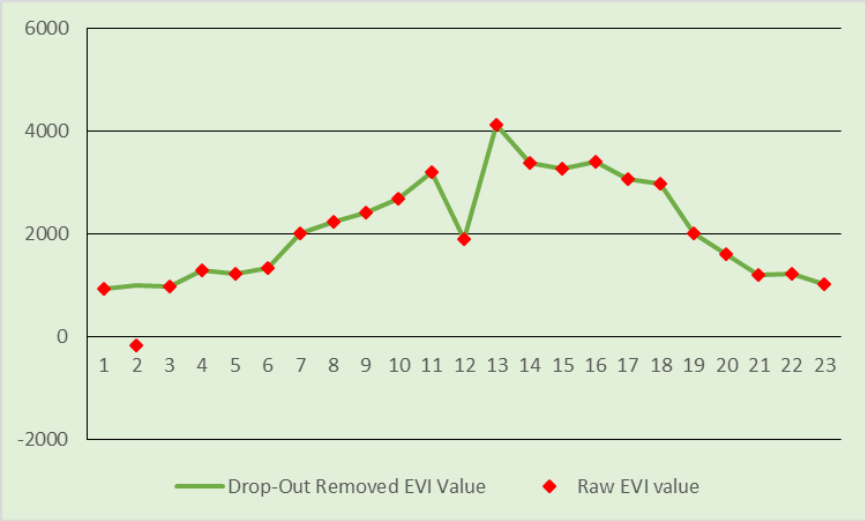


Drop-Out Removal



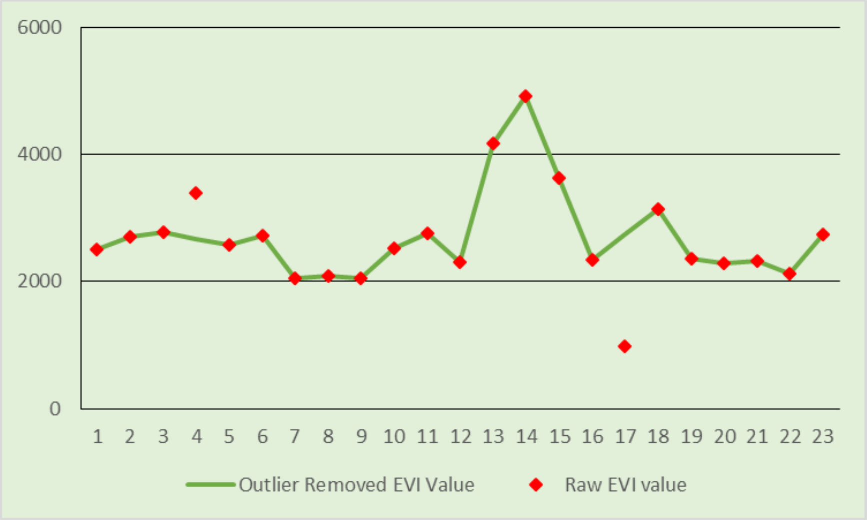


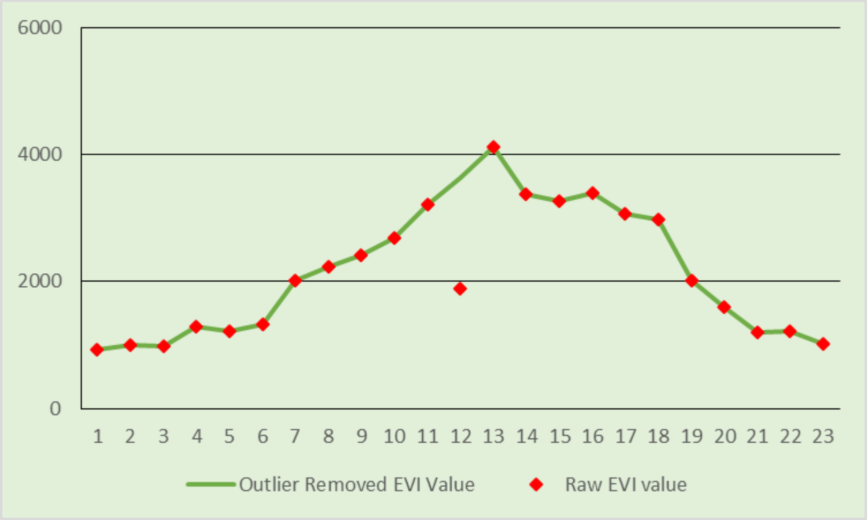


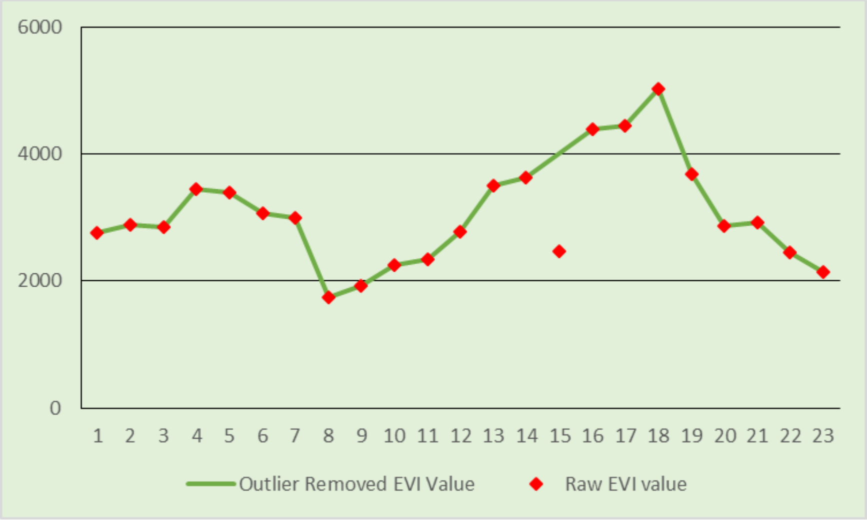


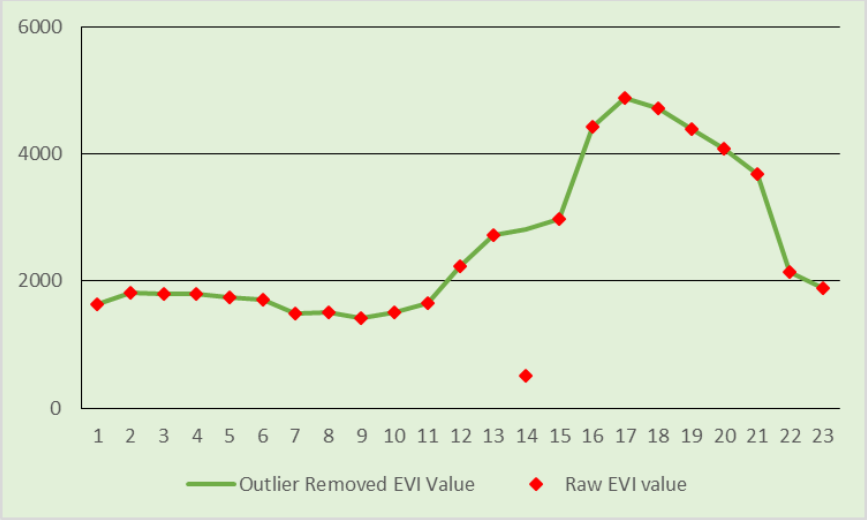
Correction of Vegetation Time Series for Long Term Monitoring

Outlier Removal



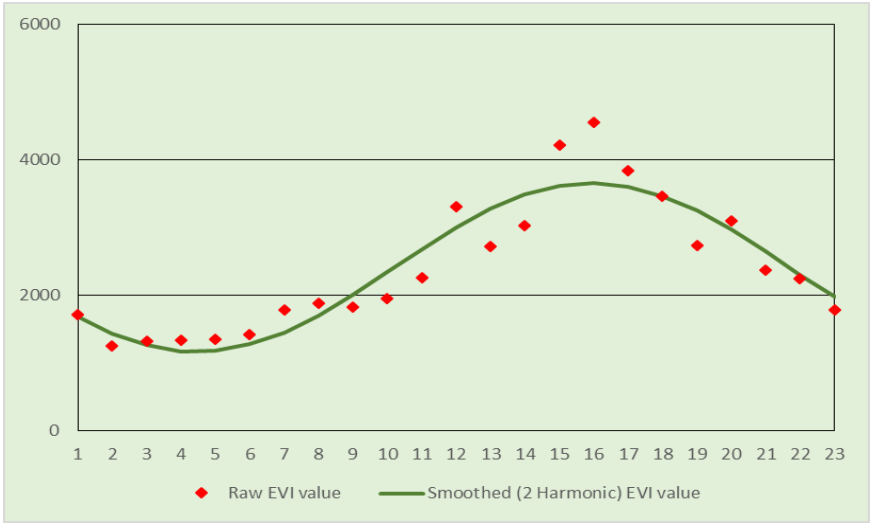


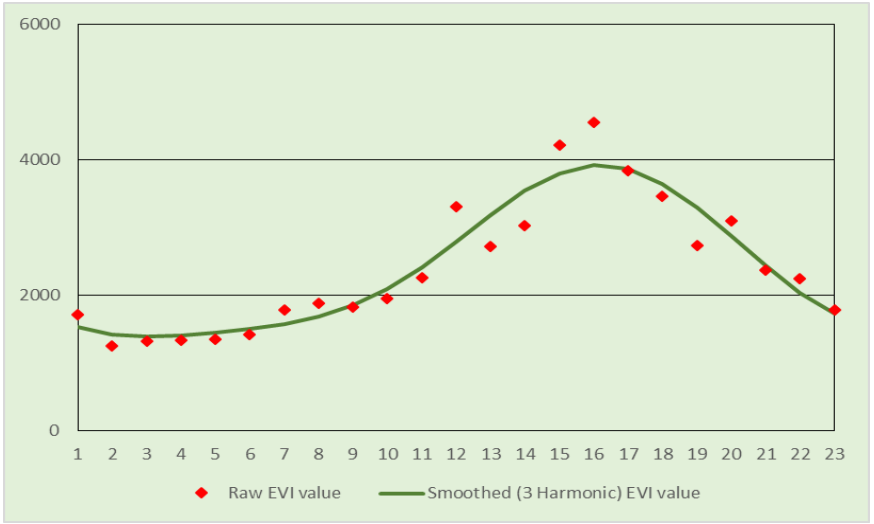


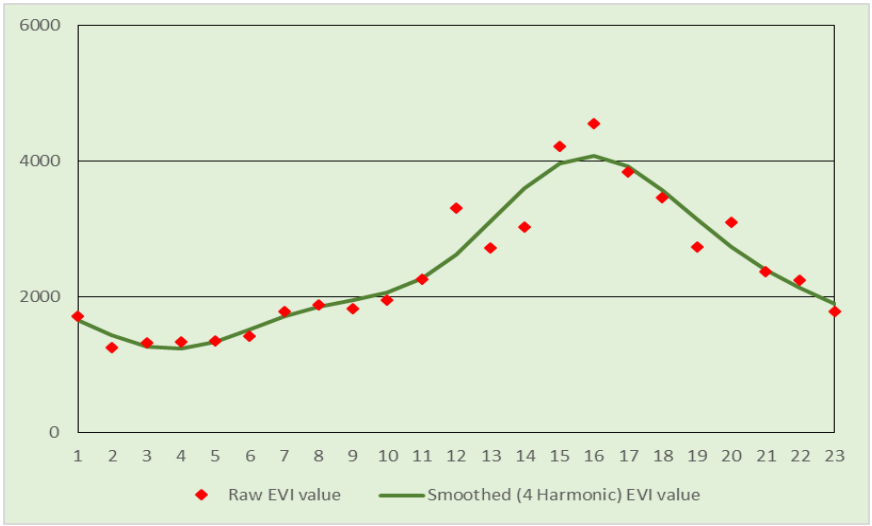


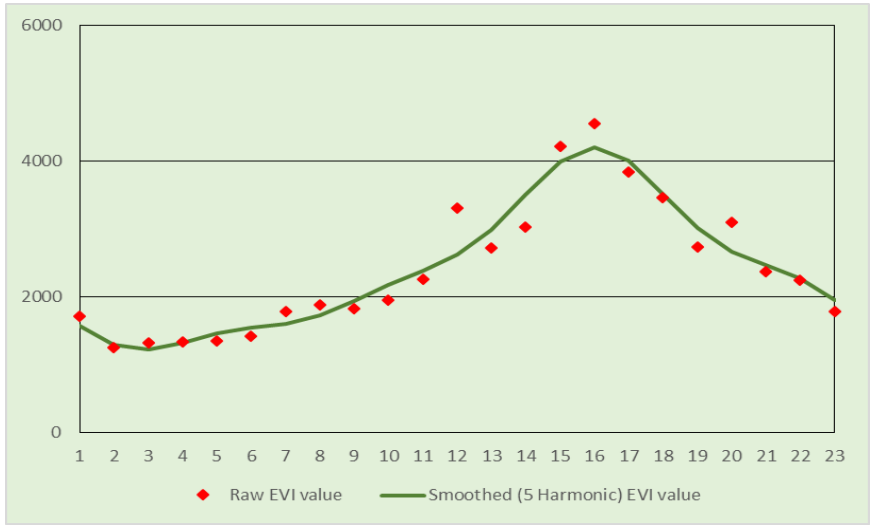
Correction of Vegetation Time Series for Long Term Monitoring

Fourier Smoothing in 1 peak



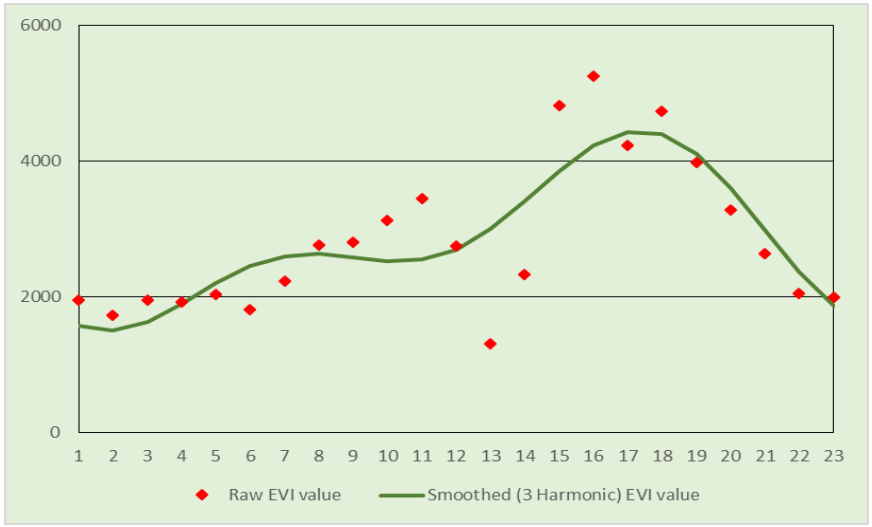


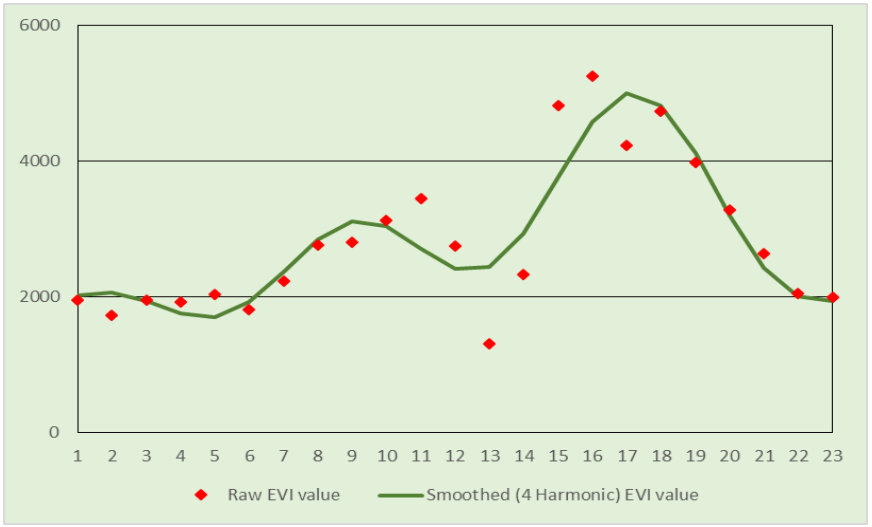


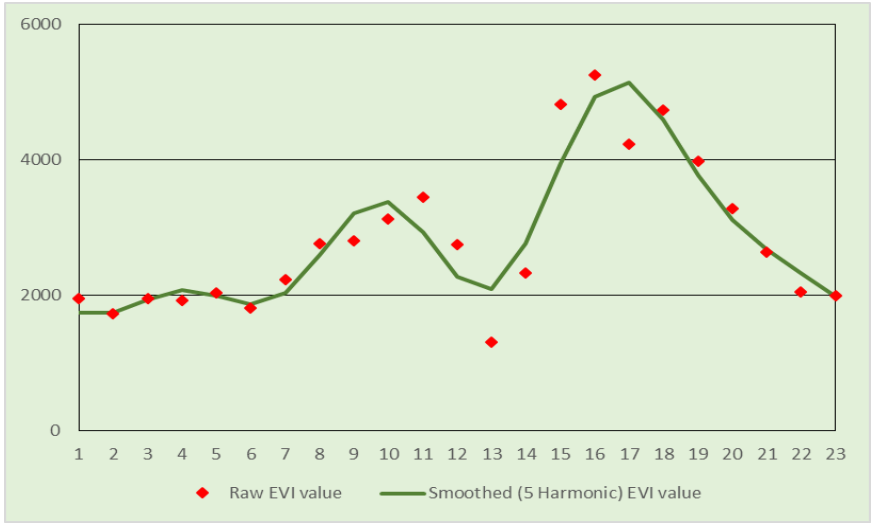


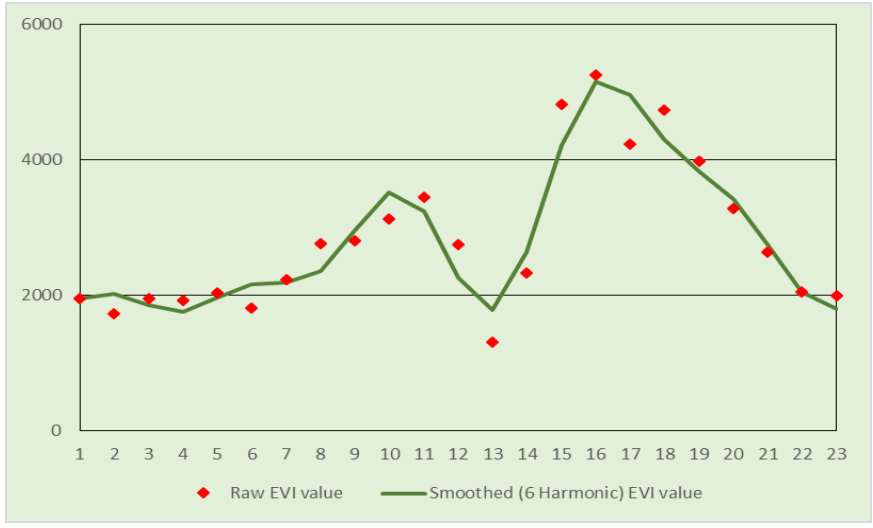
Correction of Vegetation Time Series for Long Term Monitoring

Fourier Smoothing in 2 Peaks



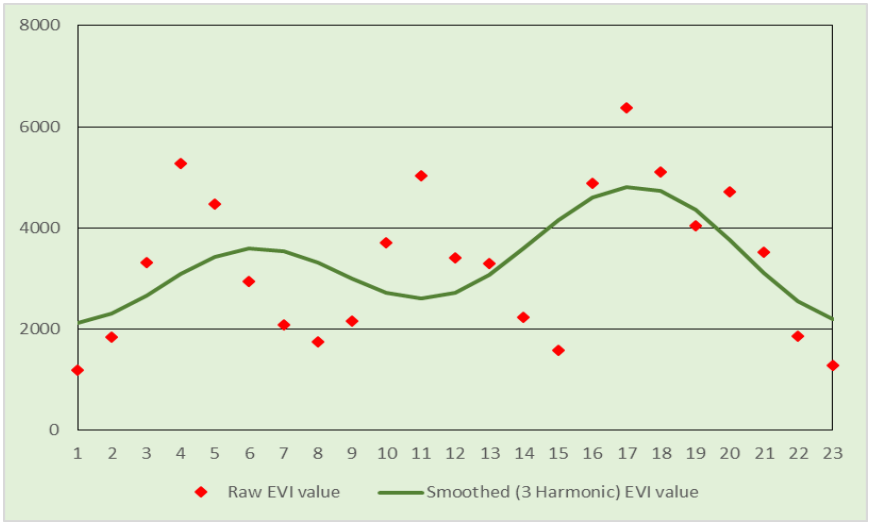


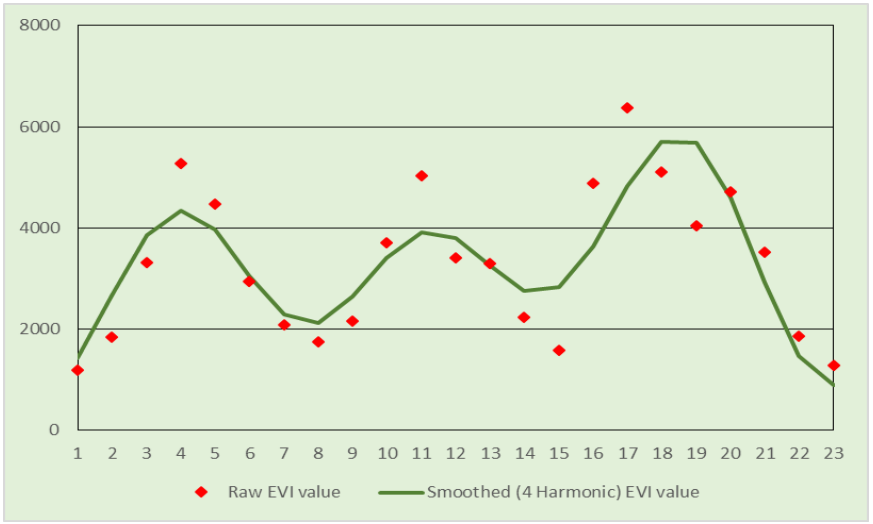


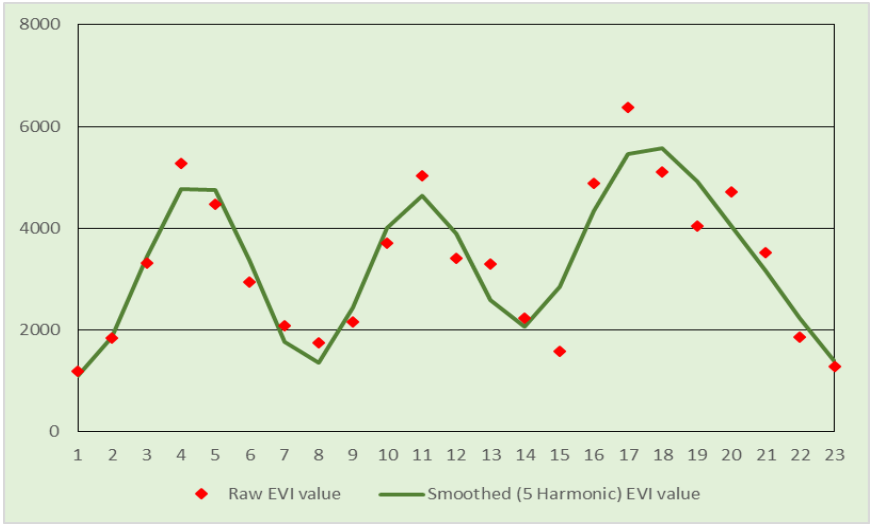


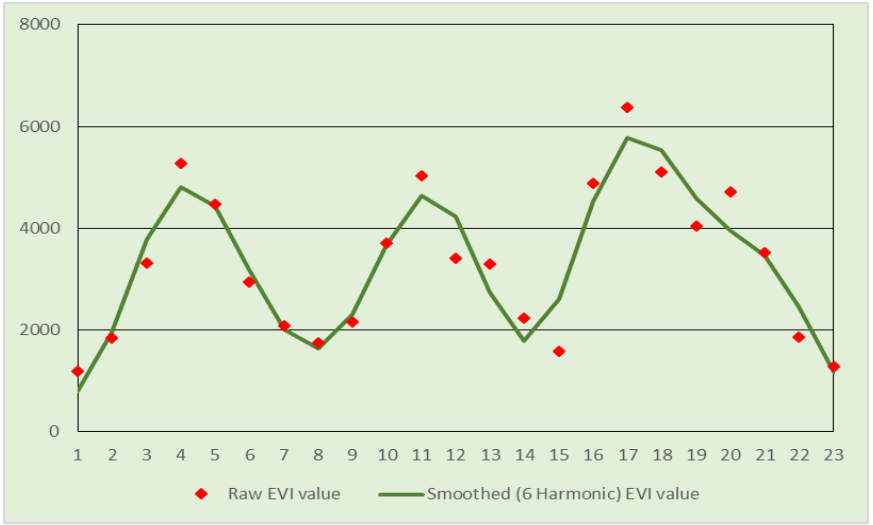
Correction of Vegetation Time Series for Long Term Monitoring

Fourier Smoothing in 3 Peak

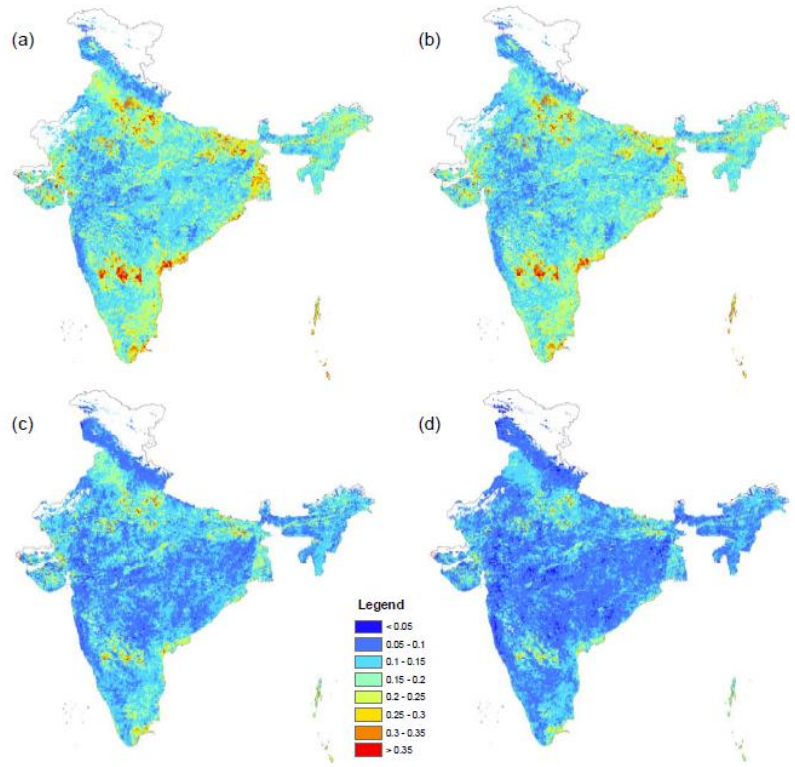








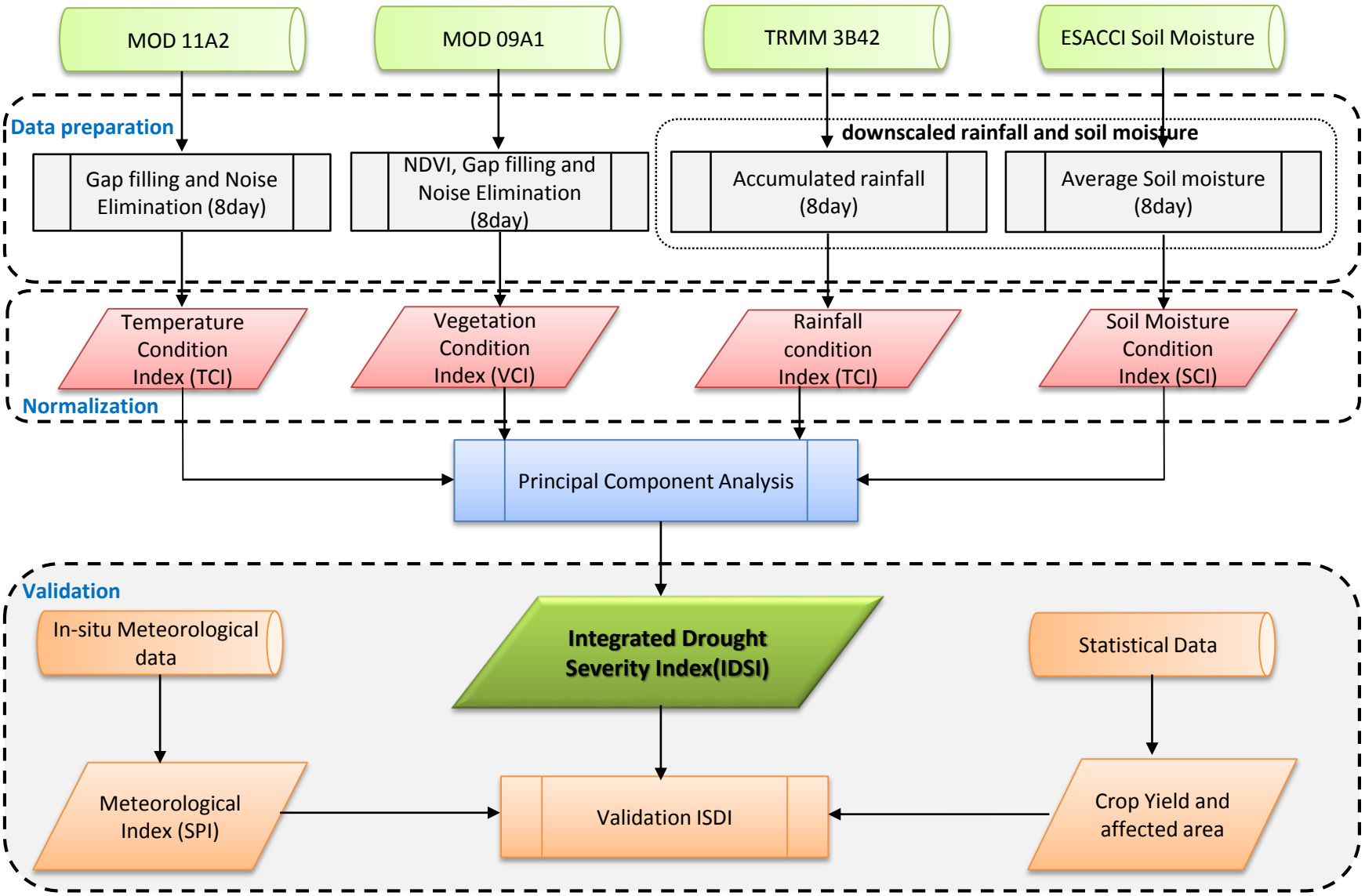
Correction of Vegetation Time Series for Long Term Monitoring



RMSE (Year 2008) from four smoothing functions to fit crop growth

Corrected NDVI images will be used for calculation of vegetation indices

Drought Monitoring Approach



Calculation of Drought Monitoring Indices

Index: Vegetation Condition Index (VCI)

Data : MODIS Surface Reflectance Spatial: 500m Temporal: Every 8-day

$$VCI_n = \frac{NDVI_n - NDVI_{LT\_min}}{NDVI_{LT\_max} - NDVI_{LT\_min}}$$

Where,

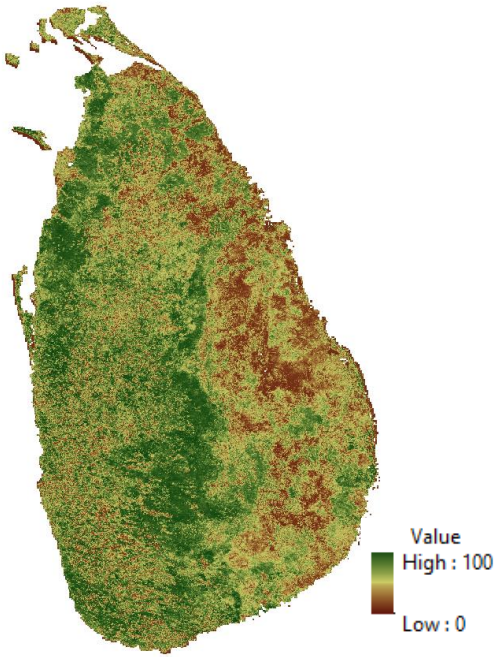
VCI_n = Vegetation Condition Index of an 8 days composite

$NDVI_n$ = Mean Normalized Difference Vegetation Index off current and previous composite

n = 8 days composite

$NDVI_{LT\_max}$ & $NDVI_{LT\_min}$ = Long term (2001-2014) max & min of $NDVI_n$

- VCI is an indicator on the status of the vegetation cover as a function of the NDVI minimum and maximum.
- Also, VCI values indicate how much the vegetation has progressive or declined in response to weather. It was concluded that VCI has provided an assessment of spatial characteristics of drought.
- The 8-day NDVI is been layer stacked and used in the study. April, May, June, July, August and September of every year from 2001 to 2014 is been grouped in mean, then each pixel's minimum and maximum can be used to derive the vegetation conditional index



Calculation of Drought Monitoring Indices

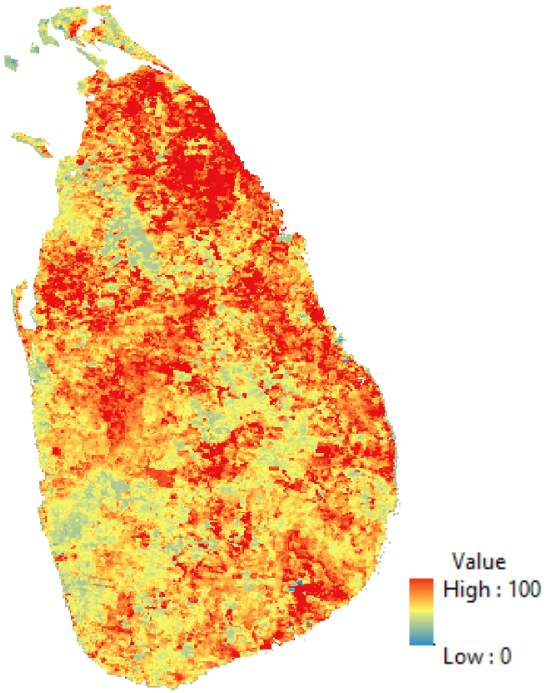
Index: Temperature Condition Index (TCI)

Data : MODIS Land Surface Temperature Spatial: 1000m Temporal: Every 8-day

$$TCI_n = \frac{LST_{max} - LST}{LST_{max} - LST_{min}}$$

Where, T is brightness temperature. Maximum and minimum T values are calculated from the long-term record of remote sensing images for a period of 2002-2014. Low TCI values indicate very hot weather.

- TCI, a remote sensing based thermal stress indicator is proposed to determine temperature-related drought phenomenon
- TCI assumes that drought event will decrease soil moisture and cause land surface thermal stress;
- TCI algorithm is similar to the VCI one and its conditions were estimated relative to the maximum/minimum temperature in a given time series. However, opposite to the NDVI, high LST in the vegetation growing season indicates unfavorable conditions while low LST indicates mostly favorable condition



Calculation of Drought Monitoring Indices

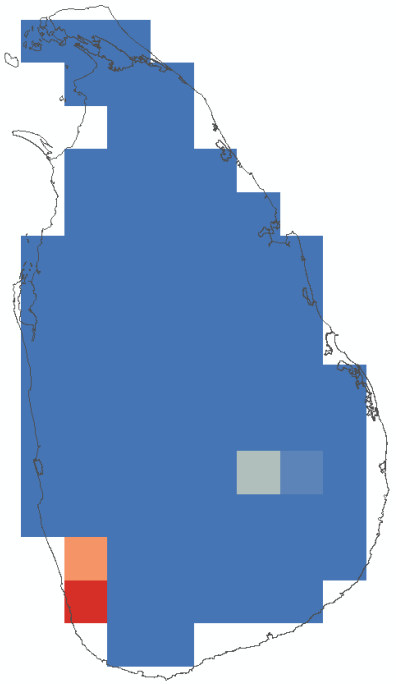
Index: Precipitation Condition Index (PCI)

Data : TRMM 3B42 Spatial: 0.25degree Temporal: Daily (accumulated rainfall rate)

$$TCI_n = \frac{TRMM - TRMM_{min}}{TRMM_{max} - TRMM_{min}}$$

Where, TRMM, $TRMM_{max}$ and $TRMM_{min}$ are the pixel values of precipitation and maximum, minimum of it respectively in daily during 2000 – 2014.

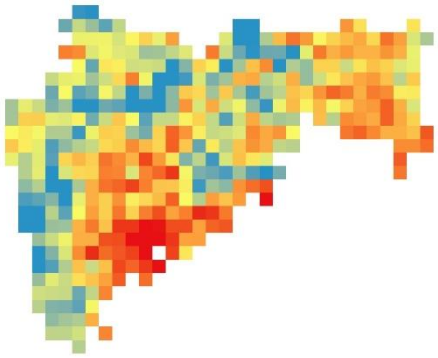
- TRMM data provides meteorological drought information and has spatial and temporal climate component but it cannot be directly analyzed with VCI and TCI.
- PCI was normalized by the TRMM 3B42 data using a similar algorithm of VIC to detect the precipitation deficits from climate signal.
- PCI also changes from 0 to 1, corresponding to changes in precipitation from extremely unfavorable to optimal.
- In case of meteorological drought which has an extremely low precipitation, the PCI is close or equal to 0, and at flooding condition, the PIC is close to 1.



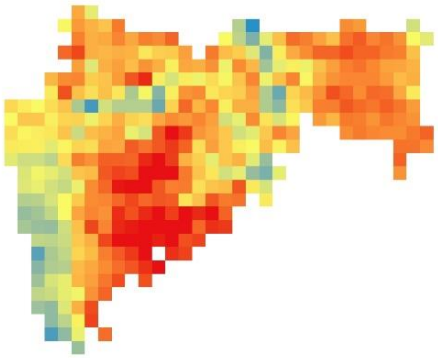
Calculation of Precipitation Condition Index (PCI)

PCI based on the Cumulative sum from the monsoon – (June 2011)

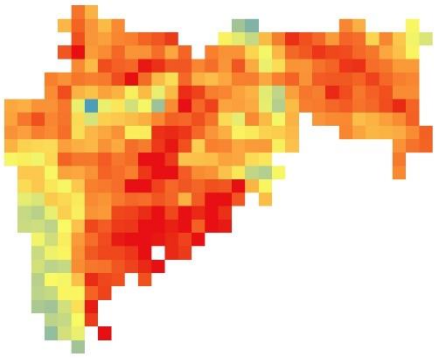
I - week



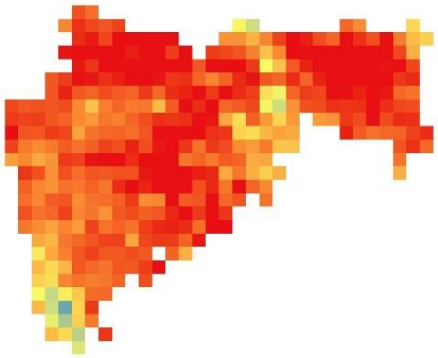
II - week



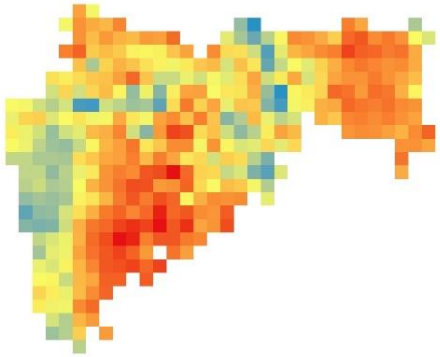
III - week

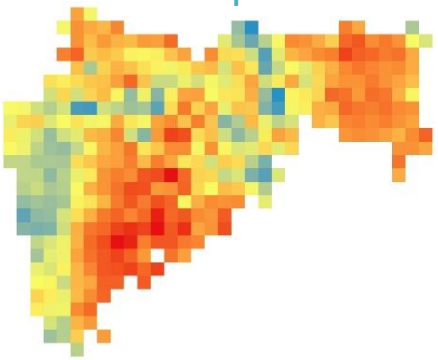


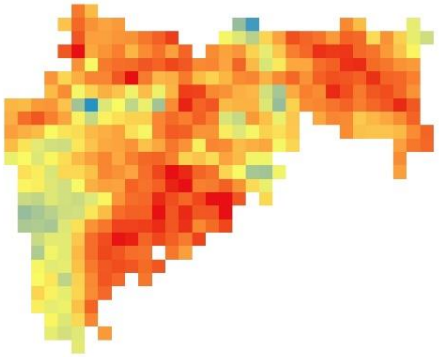
IV - week

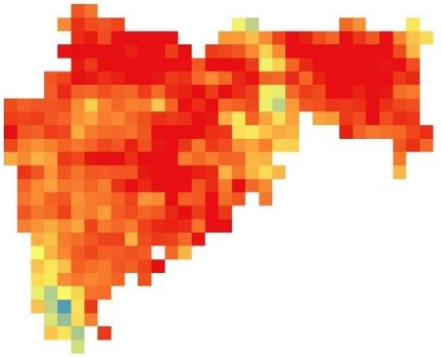


PCI based on the Cumulative sum for past three weeks

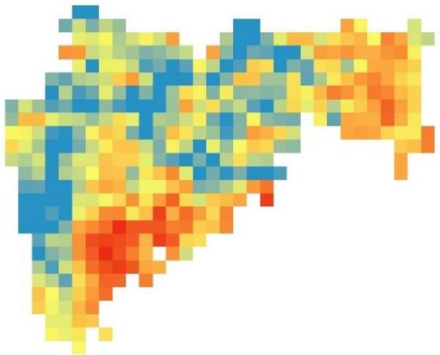


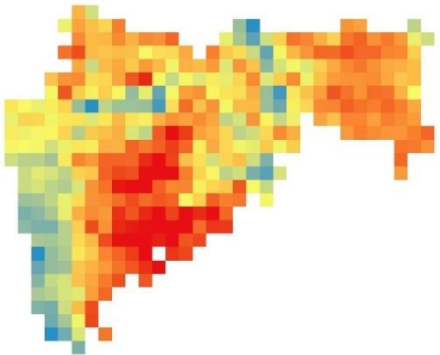


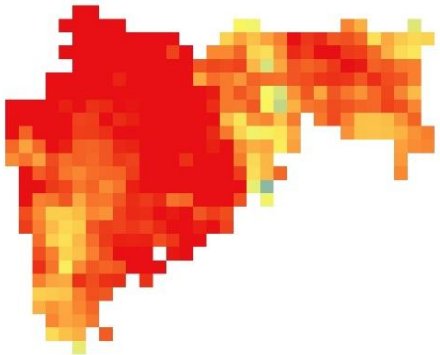


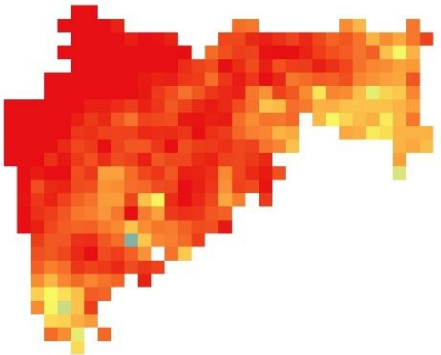


PCI based on the Cumulative sum of pervious week only

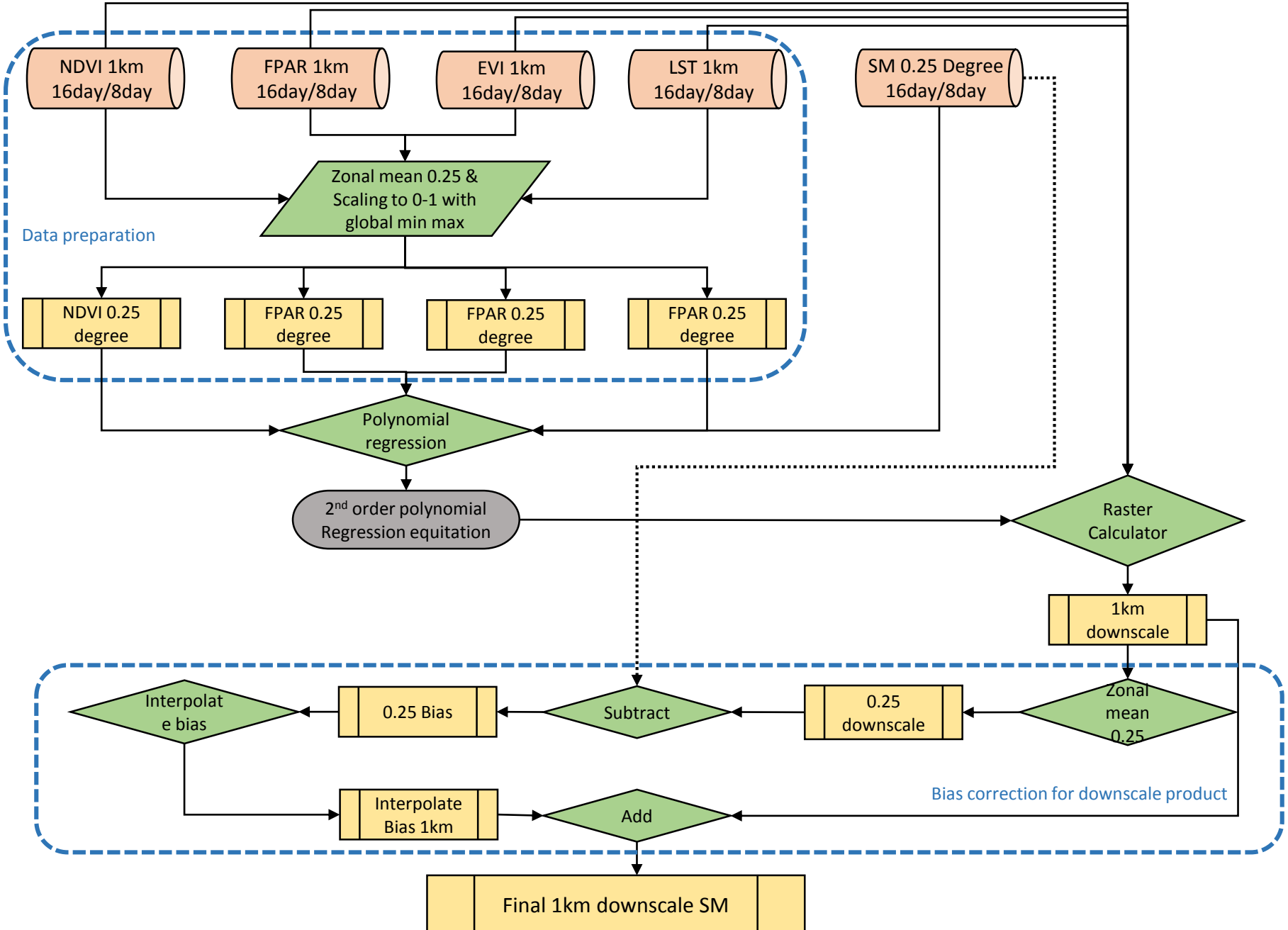






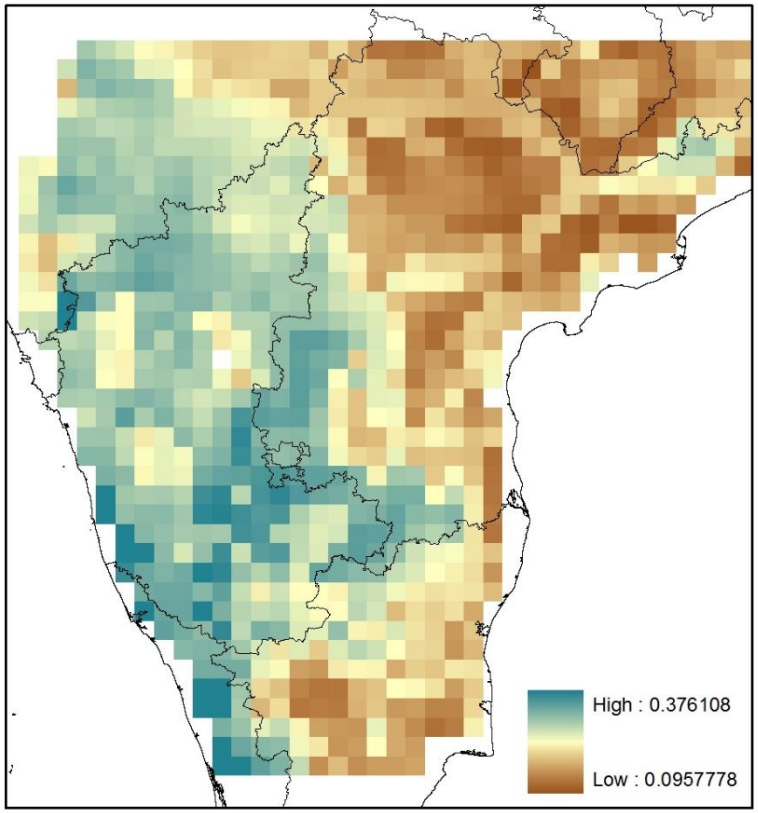


Spatial Downscaling of Soil Moisture

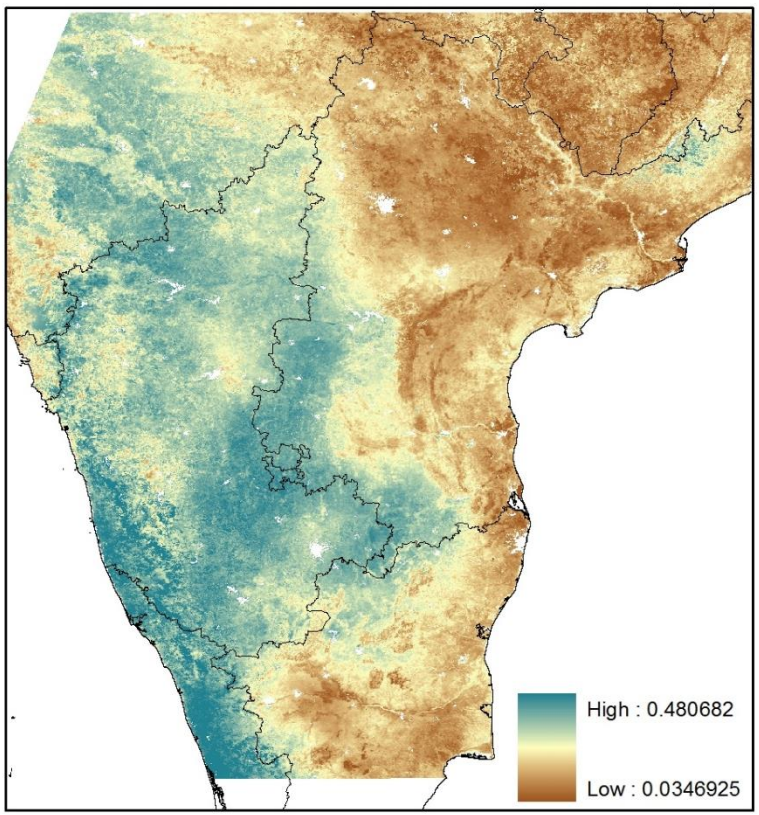


Spatial Downscaling of Soil Moisture

Example from South India



2009_177_Soil Moisture ESA Product (27 KM)



2009_177_Soil Moisture ESA Product (1 KM)

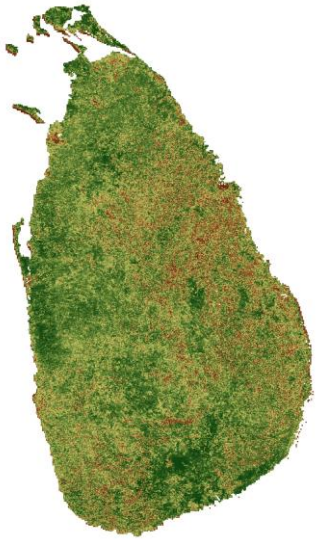
- Good Correlation with observed and predicted Soil Moisture product
- NDVI, LST and fPAR are critical variables in downscaling process
- Useful input in drought monitoring process and weekly product can be generated

Examples of Drought Monitoring Products

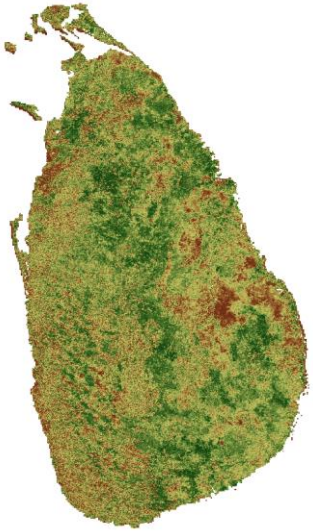
Vegetation Condition Index (VCI) for Sri Lanka

Weekly composite

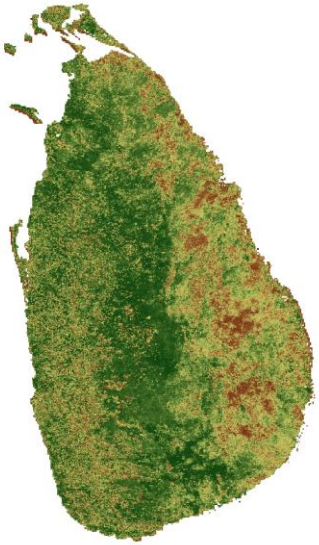
June 2, 2013



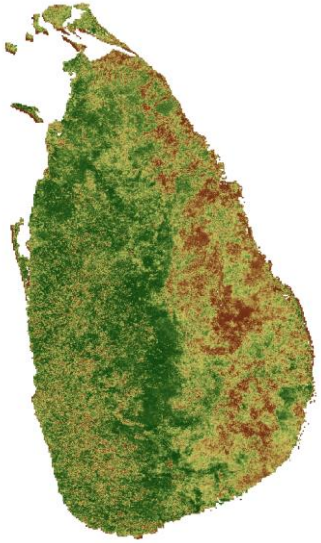
June 4, 2013



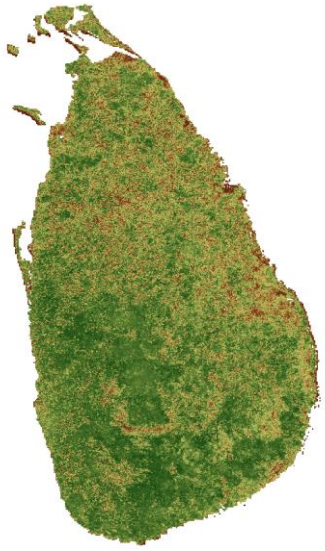
July 2, 2013



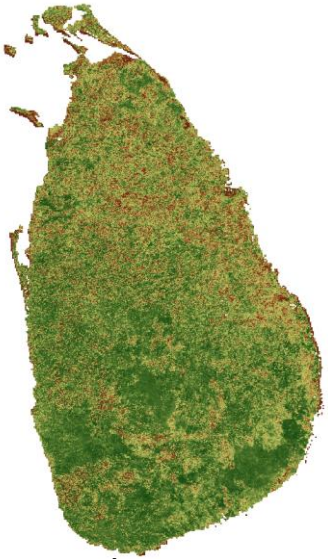
July 4, 2013



August 3, 2013

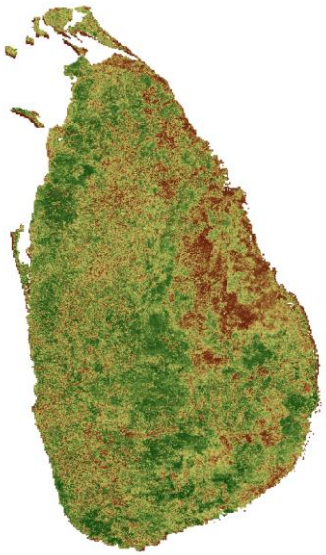


November 1, 2013

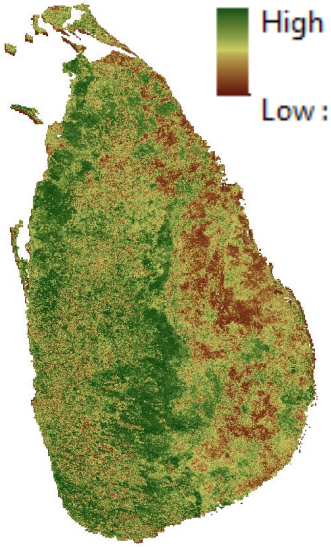


October 3, 2013

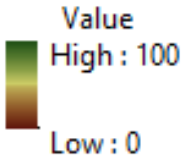
October 1, 2013



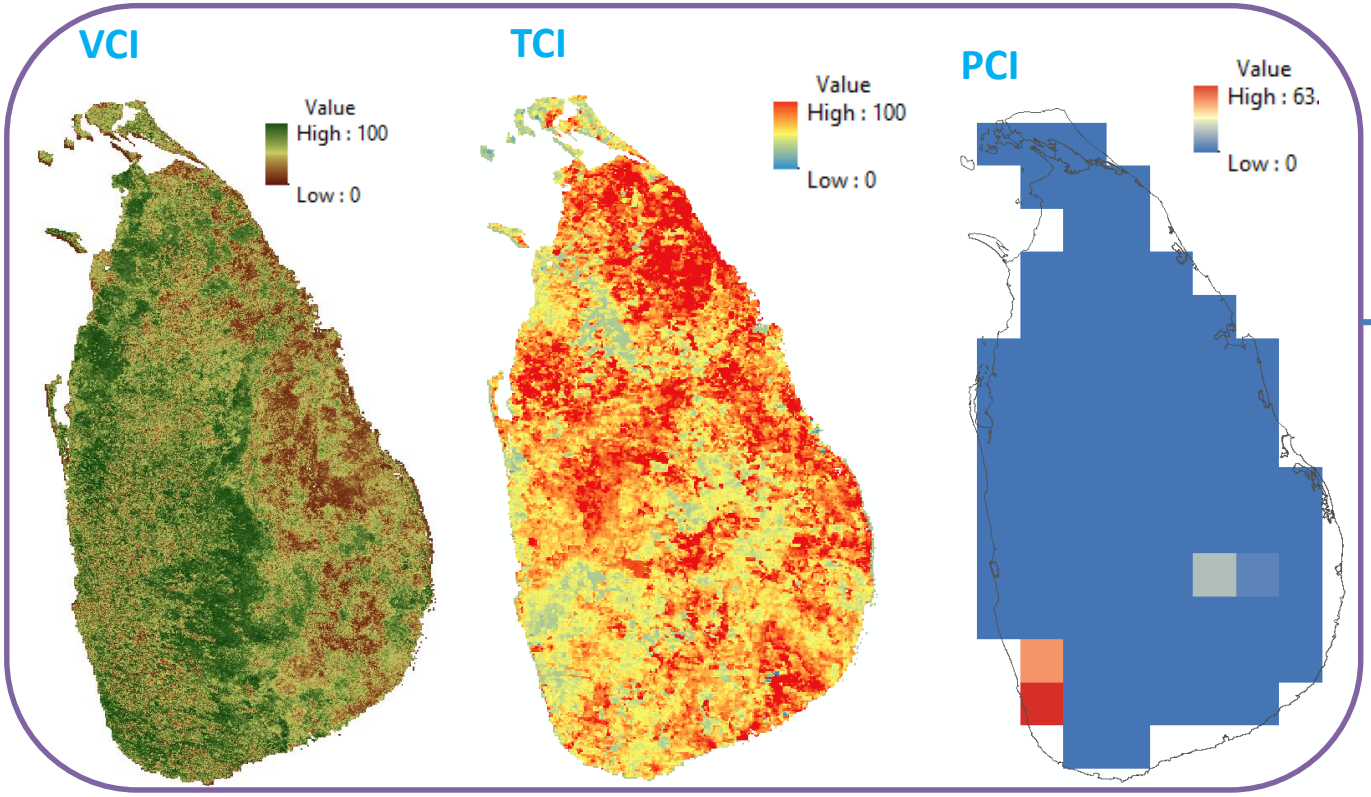
September 3, 2013



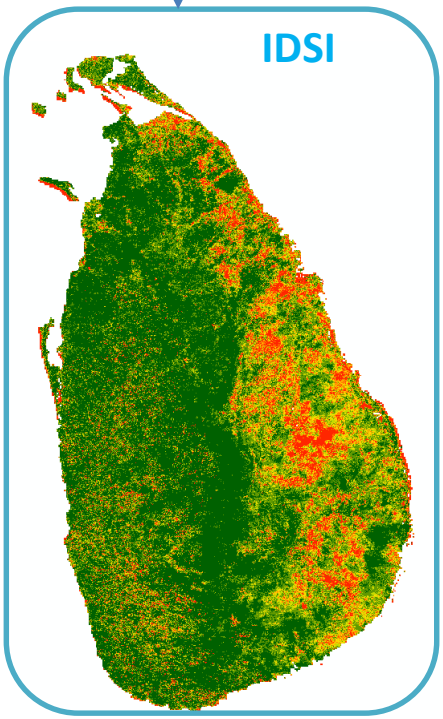
September 1, 2013



Integrated Drought Response Index (IDSI) – Example for Sri Lanka



1st Week – September 2013

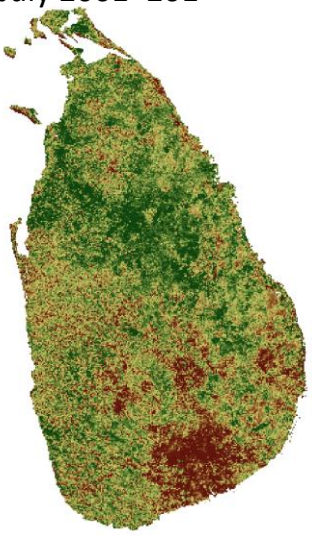


VCI – Vegetation Condition Index; TCI – Temperature condition Index; PCI – Precipitation condition Index; IDSI – Integrated Drought Severity index

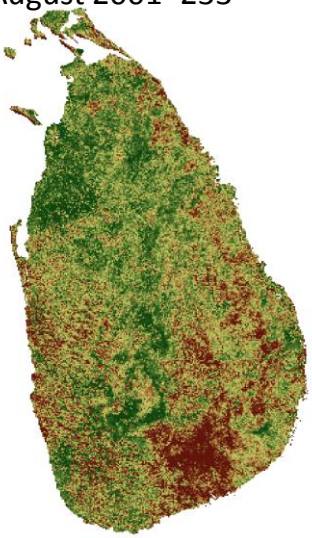
2001 Drought Evaluation – IDSI Vs. UN-WFP Field Assessment Report

Jun 2001 -153

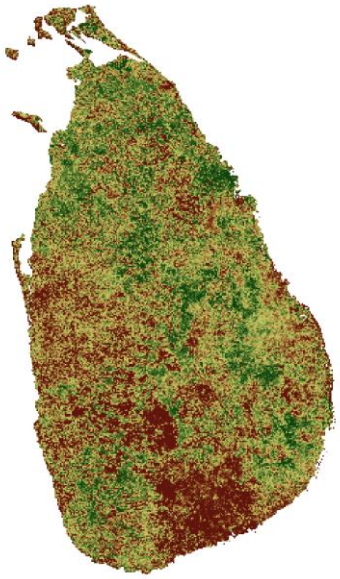
July 2001 -201



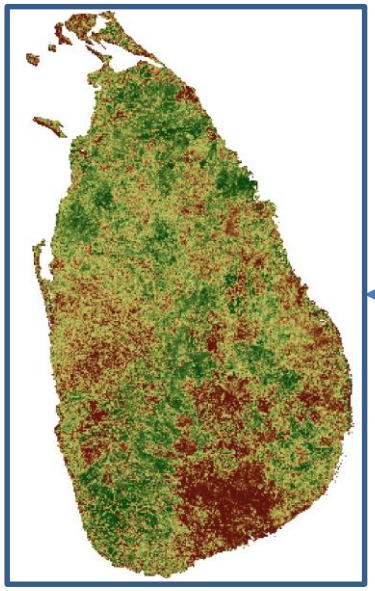
August 2001 -233



November 2001 -313

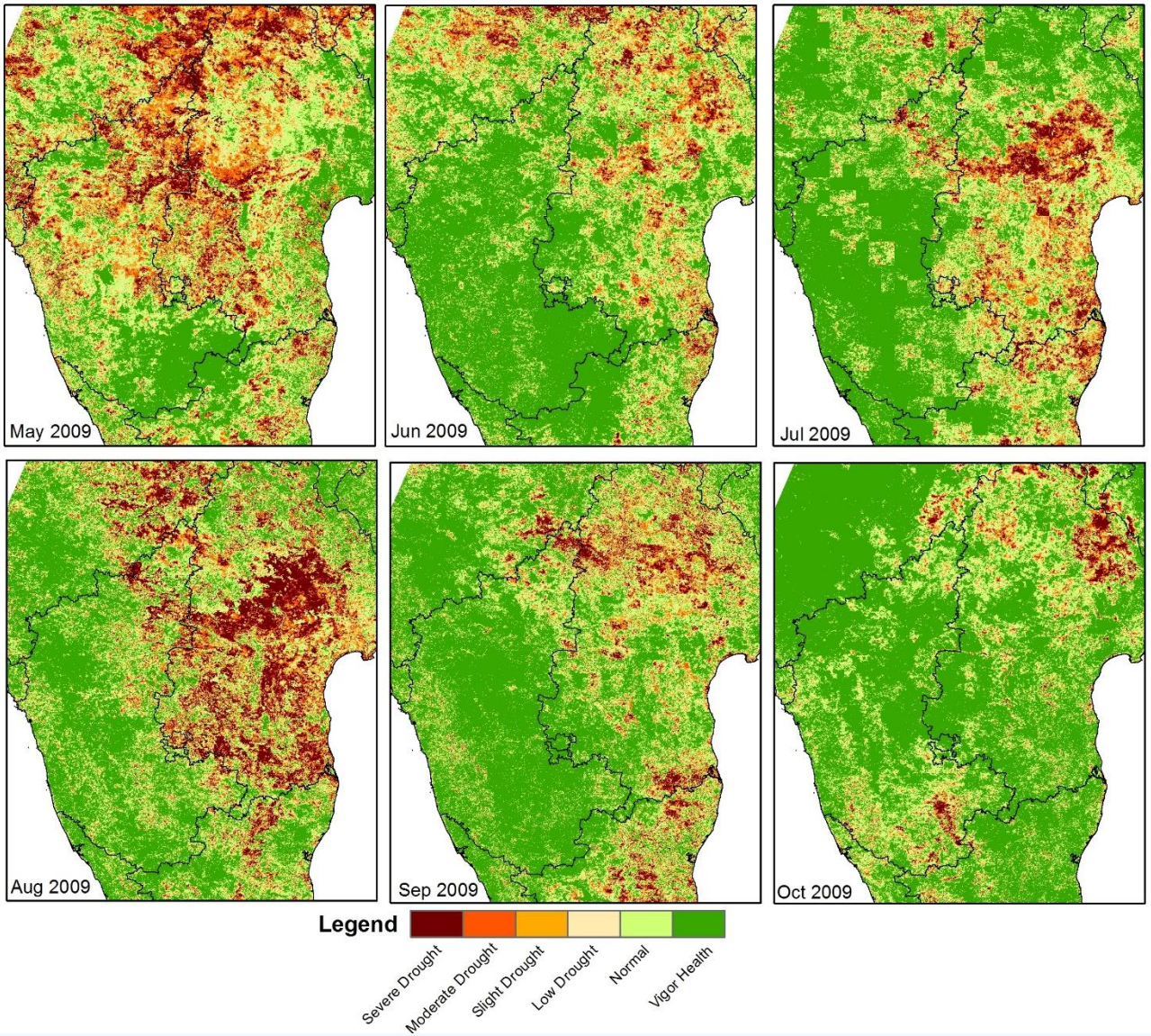


October 2001 -281

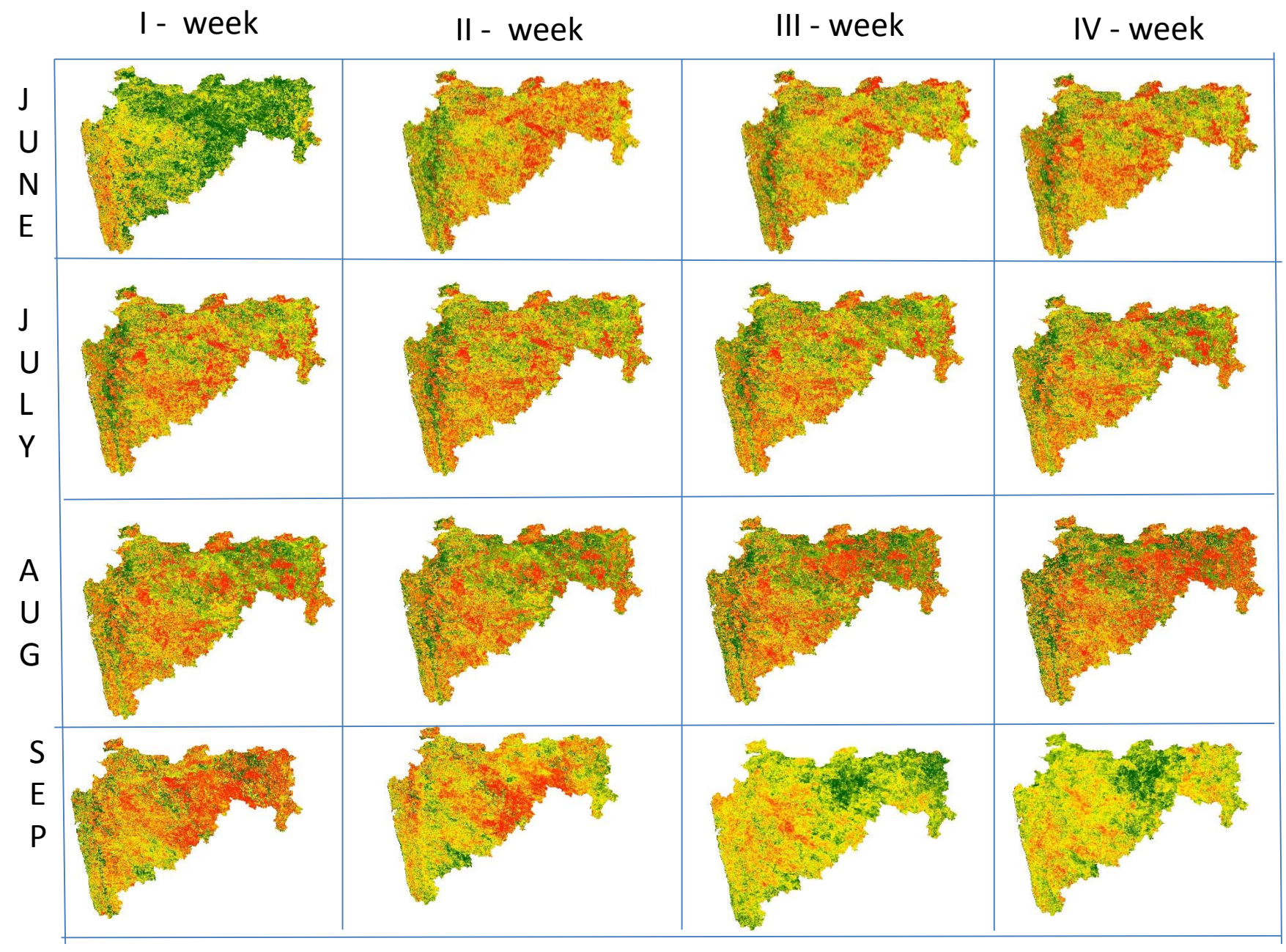


September 2001 -257

Integrated Drought Response Index (IDSI) – Example for South India

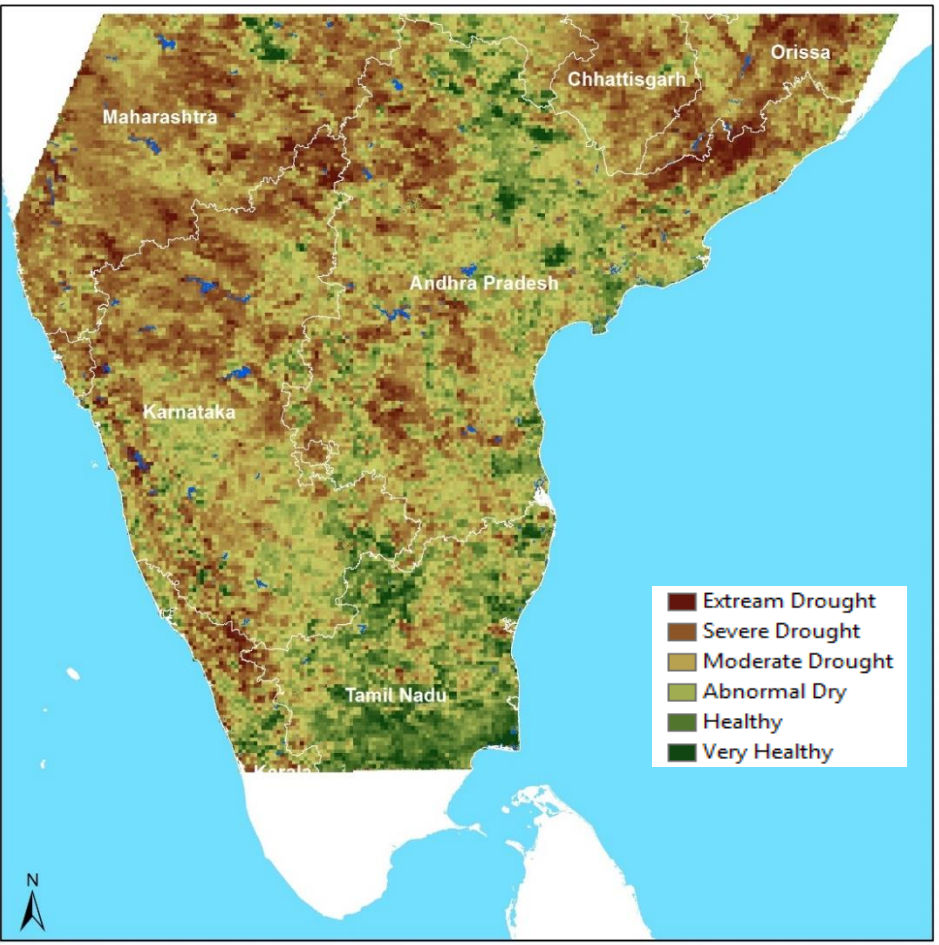


2011 Drought Product - Maharashtra

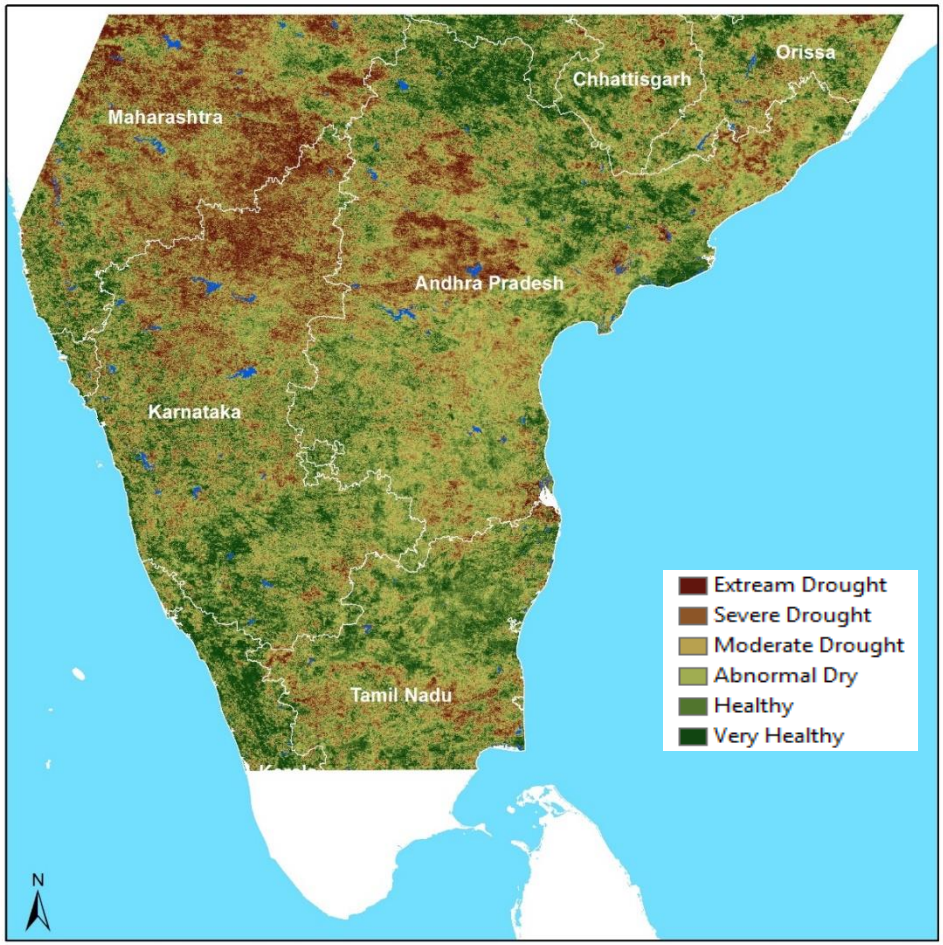


Comparison of Global Drought product Vs. SADMS

DSI – University of Montana



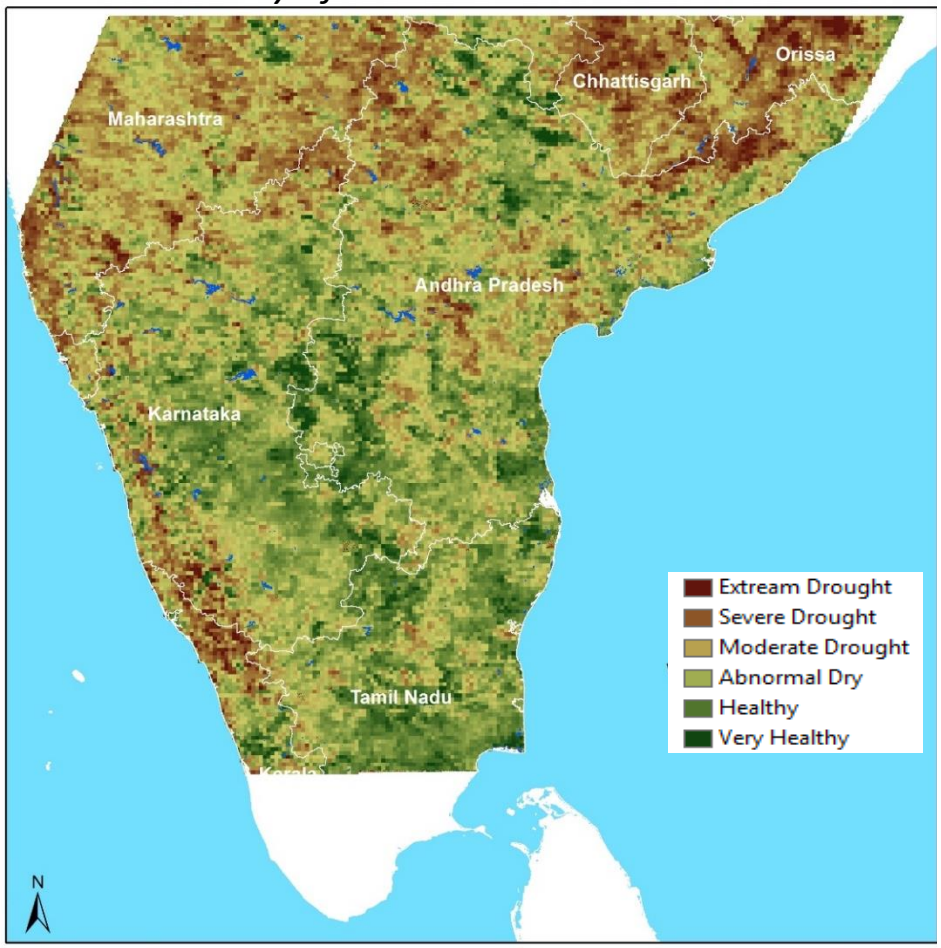
SADMS New Product



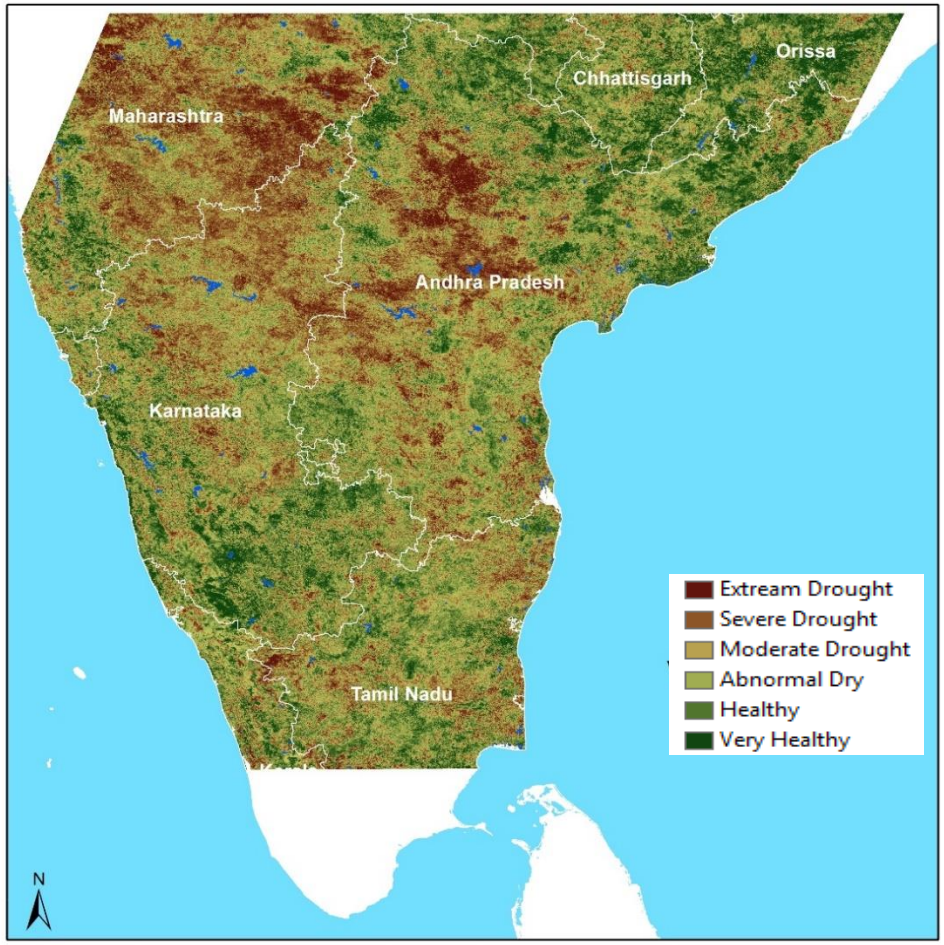
12 July 2008

Comparison of Global Drought product Vs. SADMS

DSI – University of Montana

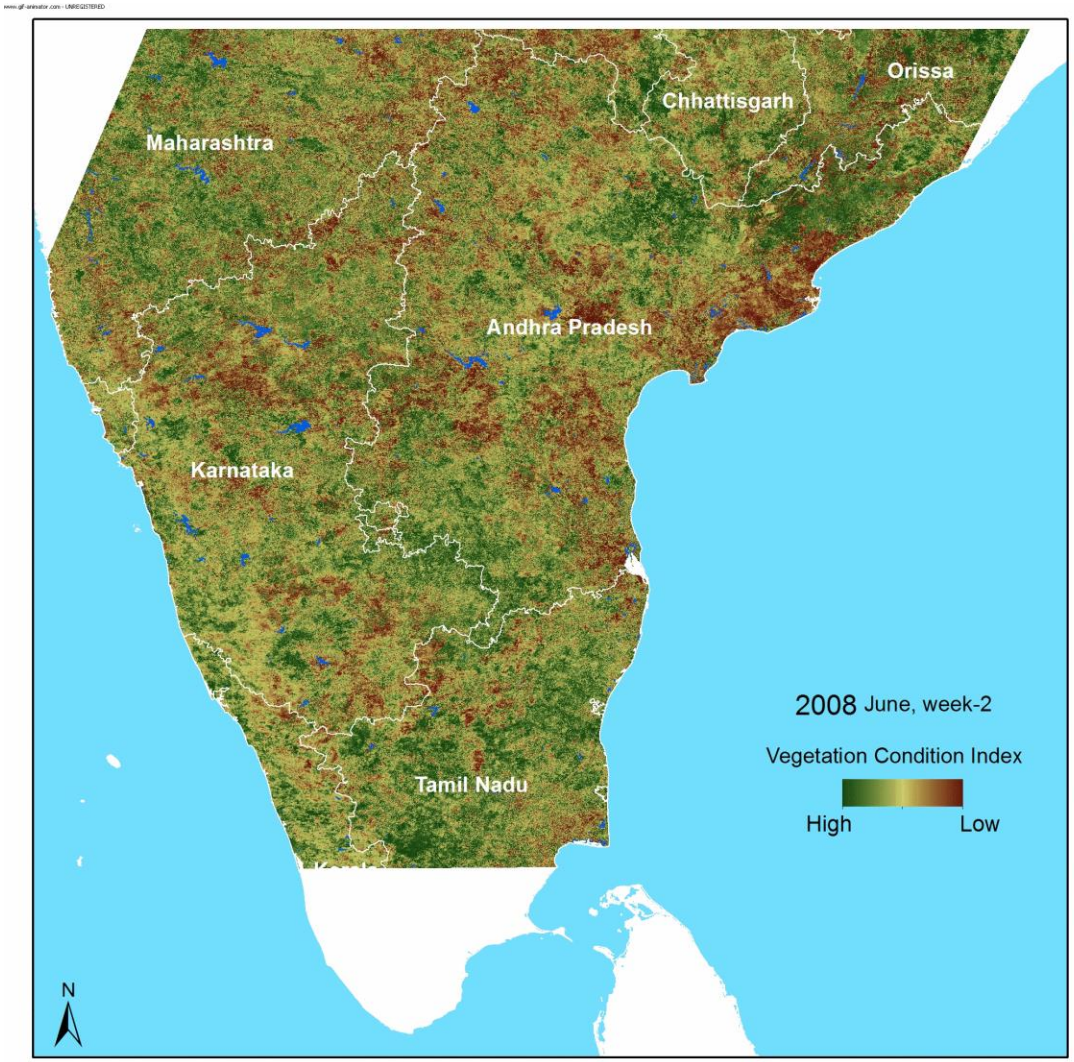


SADMS New Product

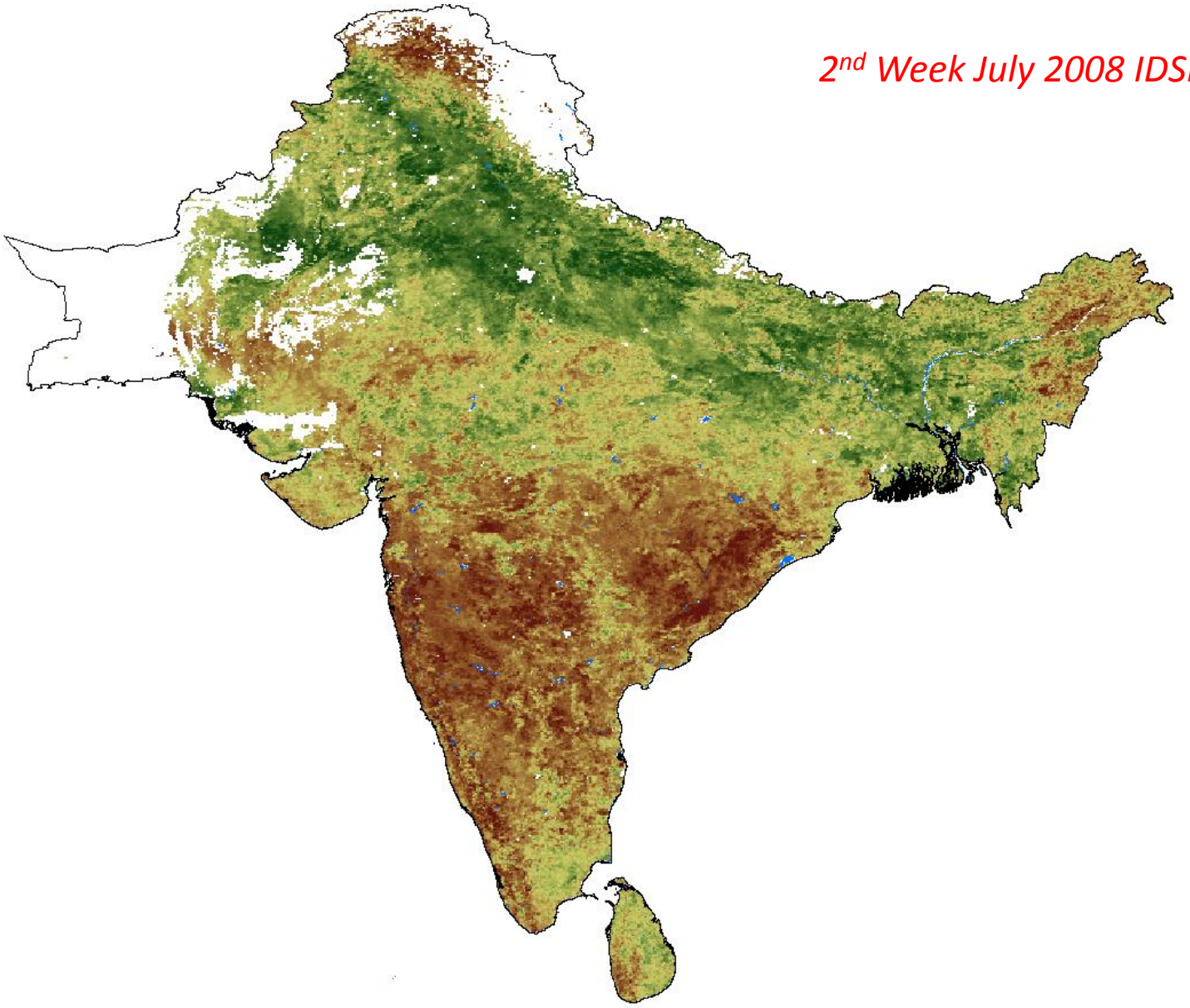


20 July 2008

Time Series drought mapping

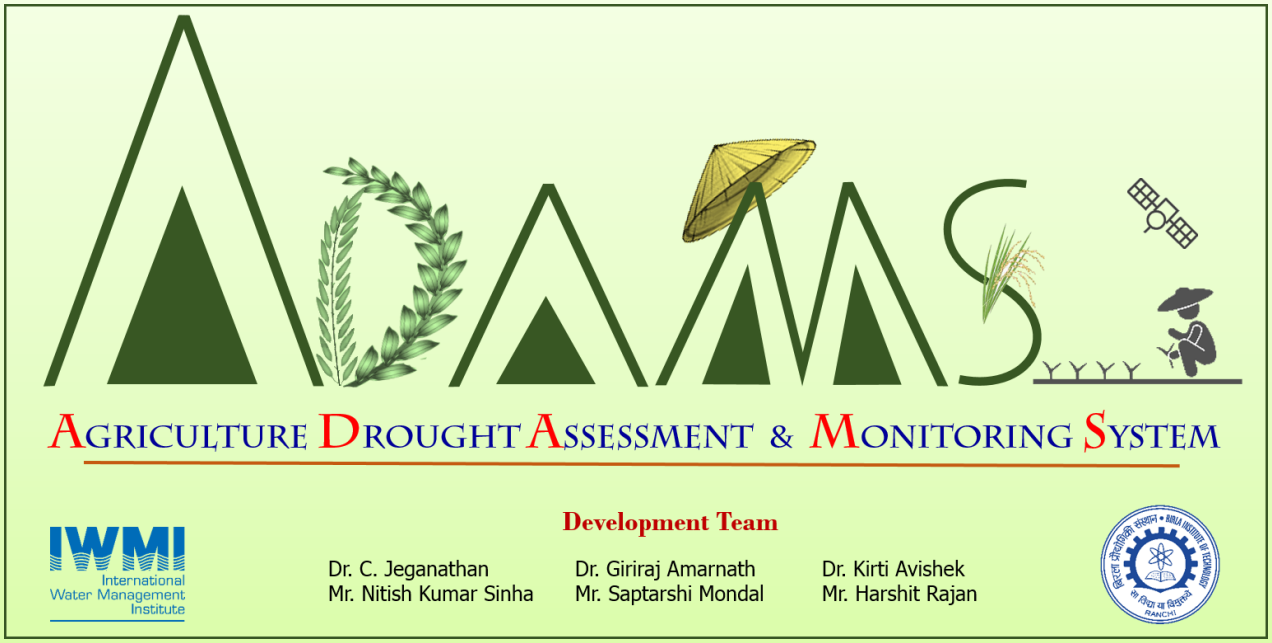


South Asia Drought Severity Product



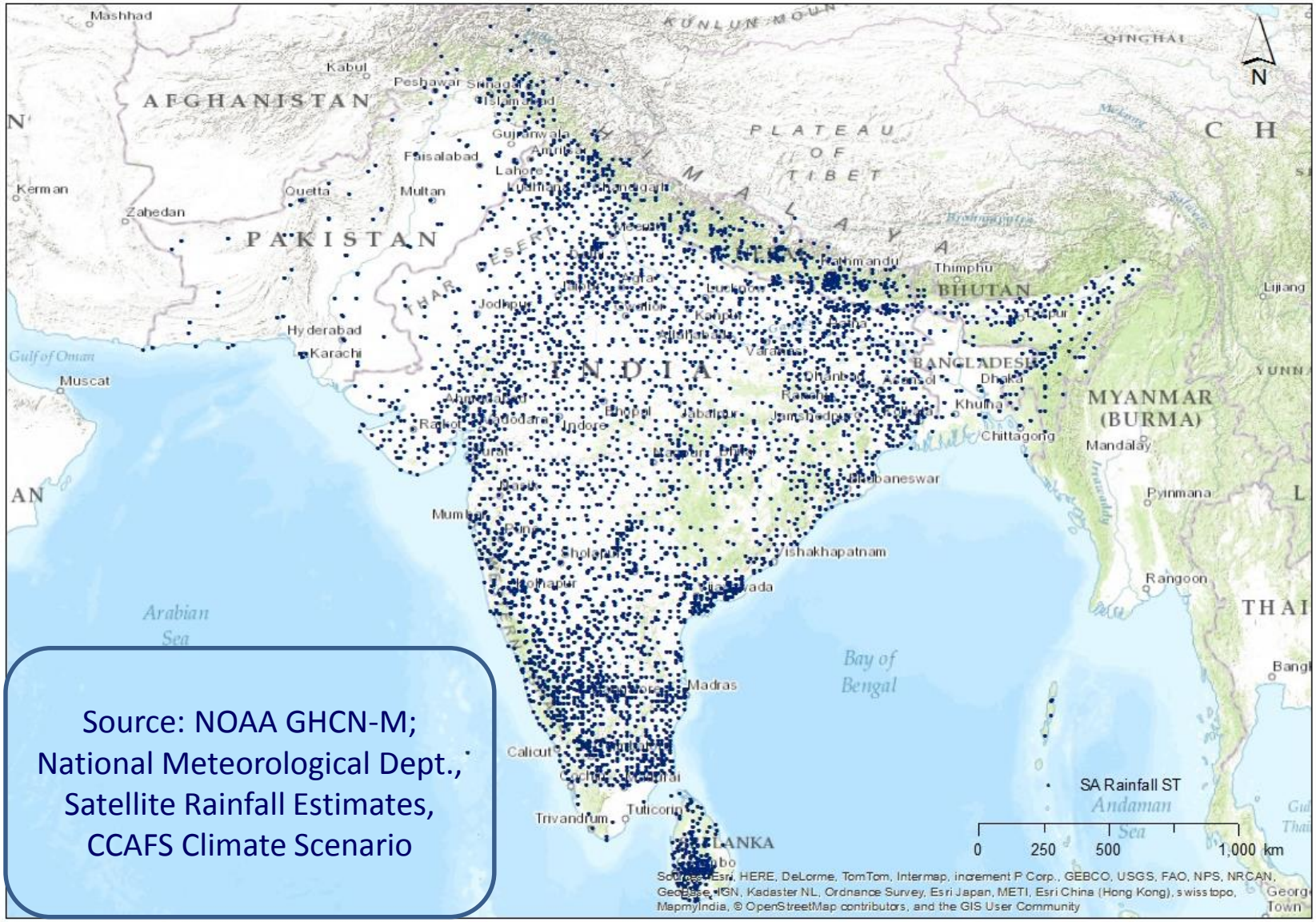
2nd Week July 2008 IDSI

Drought Monitoring System Tool



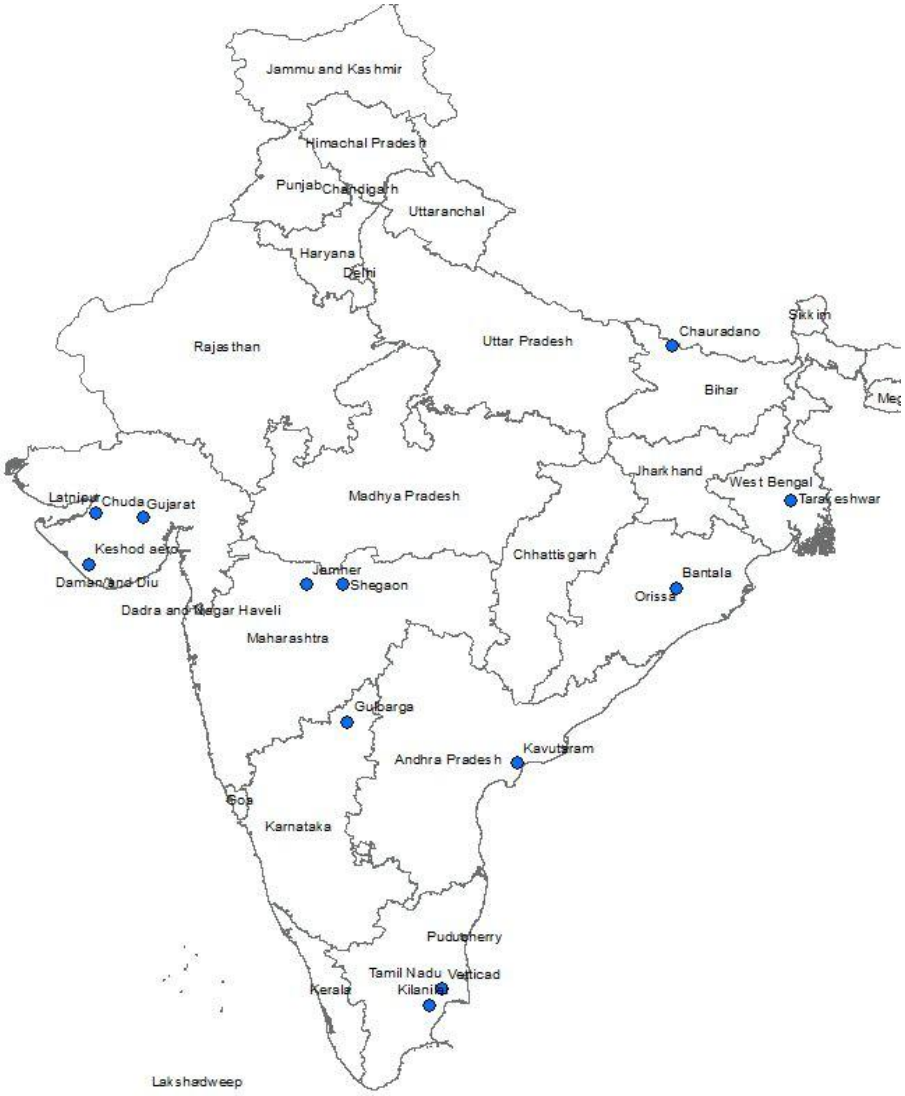
- DMS tool allows automated image processing, calculation of drought monitoring indices
- Tool is being developed using ArcGIS ArcObject and Visual Basic
- Drought Management Scenario for early warning process and Impact analysis

Meteorological Drought Assessment



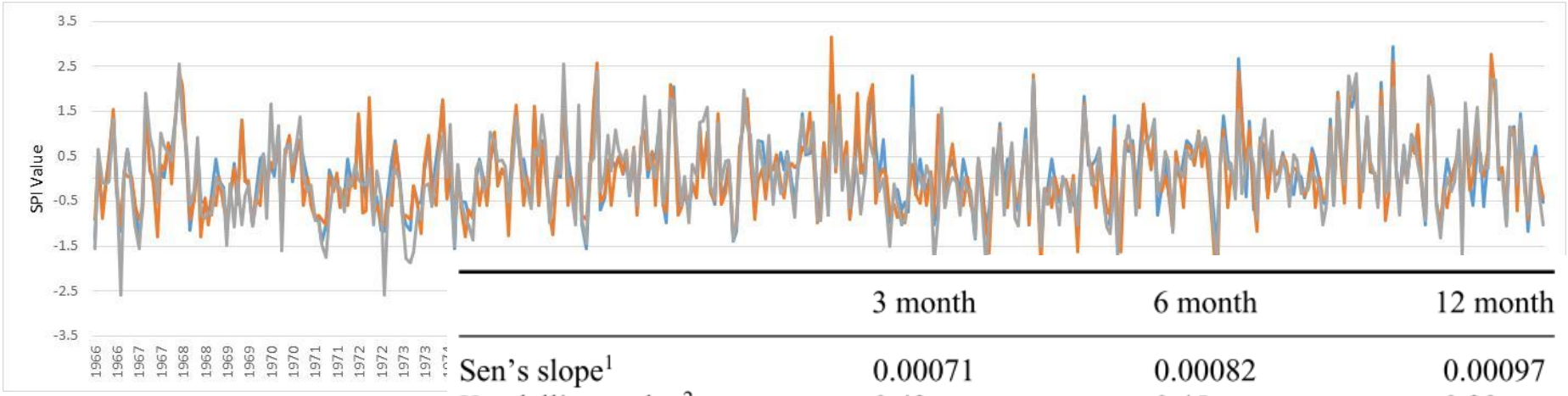
Source: NOAA GHCN-M; National Meteorological Dept., Satellite Rainfall Estimates, CCAFS Climate Scenario

South Asia – SPI Assessment



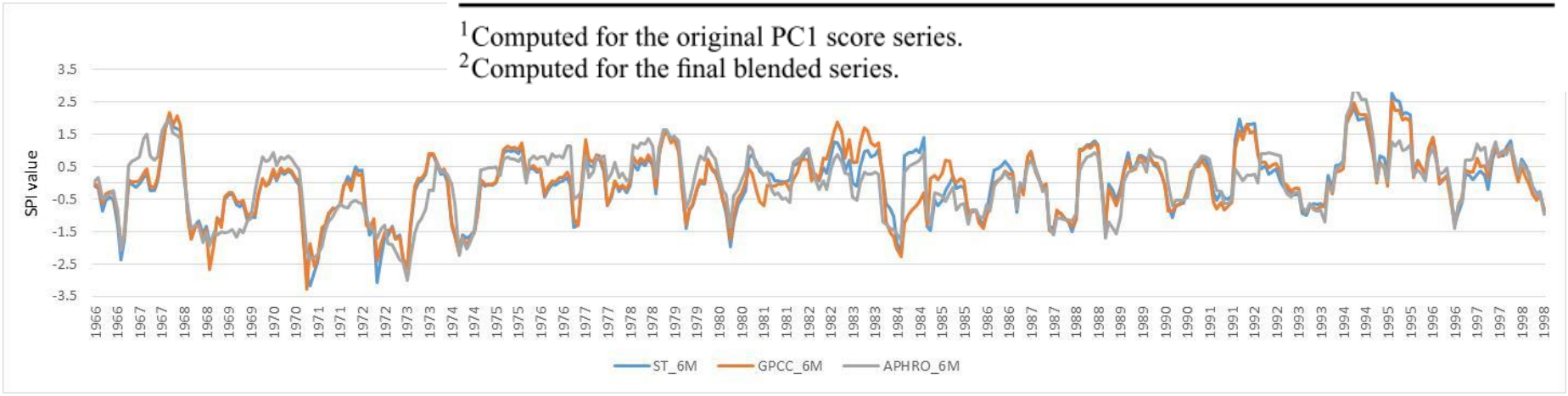
1. **Gulbarga**
2. Kilanilai
3. Bantala
4. Vetticad
5. Jamner
6. Shegaon
7. Keshod Aero
8. Chuda
9. Latnipur
10. Tarakeshv
11. Kavutara
12. Chauradano

SPI Inter comparison
GPCC vs. Aphrodite vs. Observed Stations



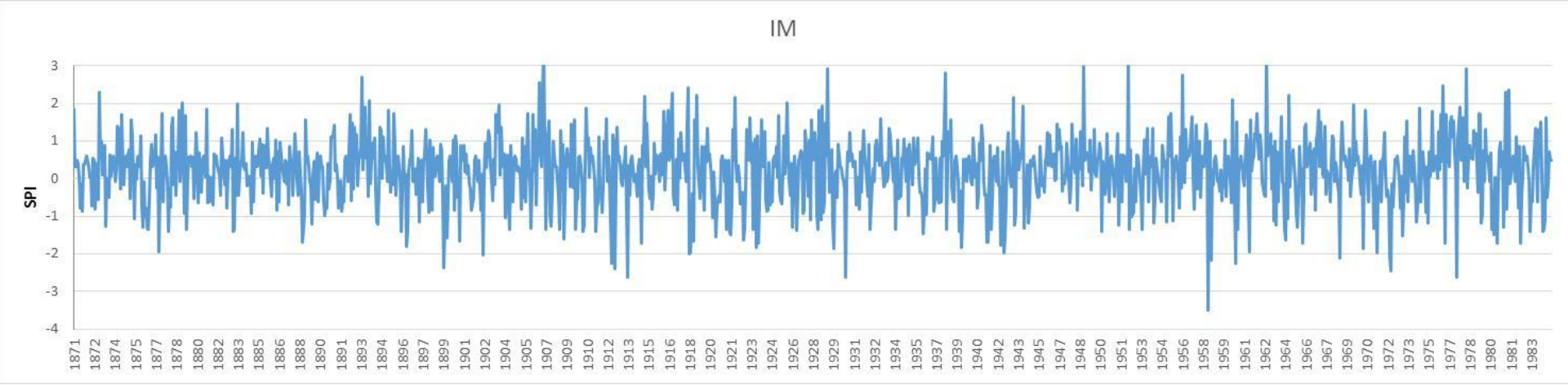
	3 month	6 month	12 month
Sen's slope[1]	0.00071	0.00082	0.00097
Kendall's *p*-value[2]	0.42	0.45	0.29

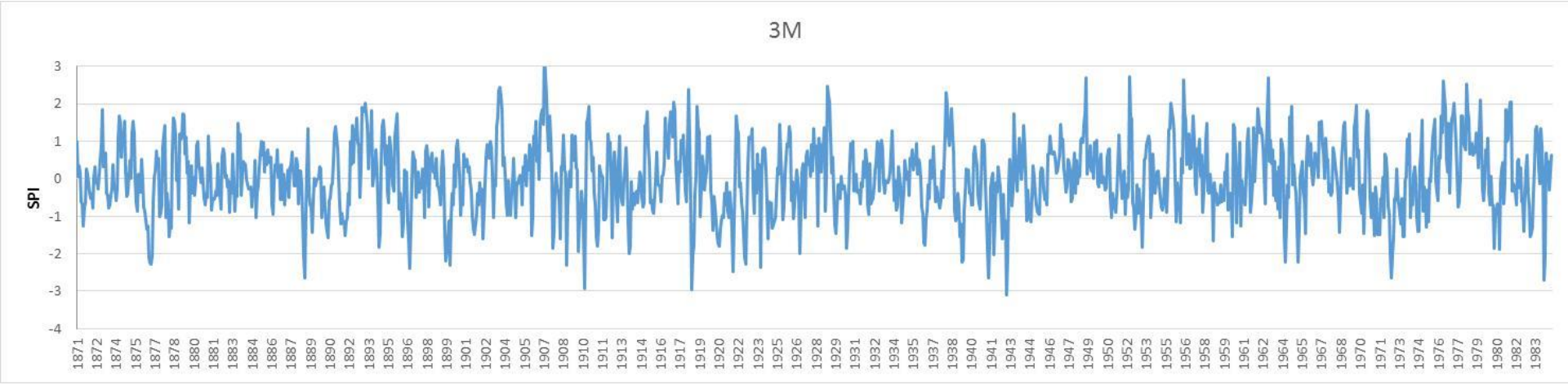
[1]Computed for the original PC1 score series.
[2]Computed for the final blended series.



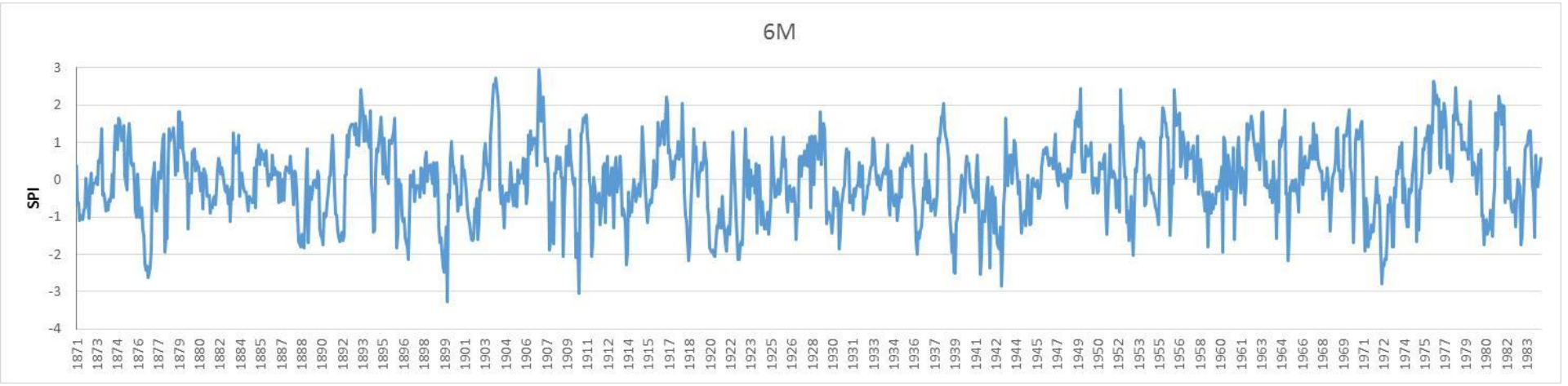
Khuzdar, Balochistan province, Pakistan

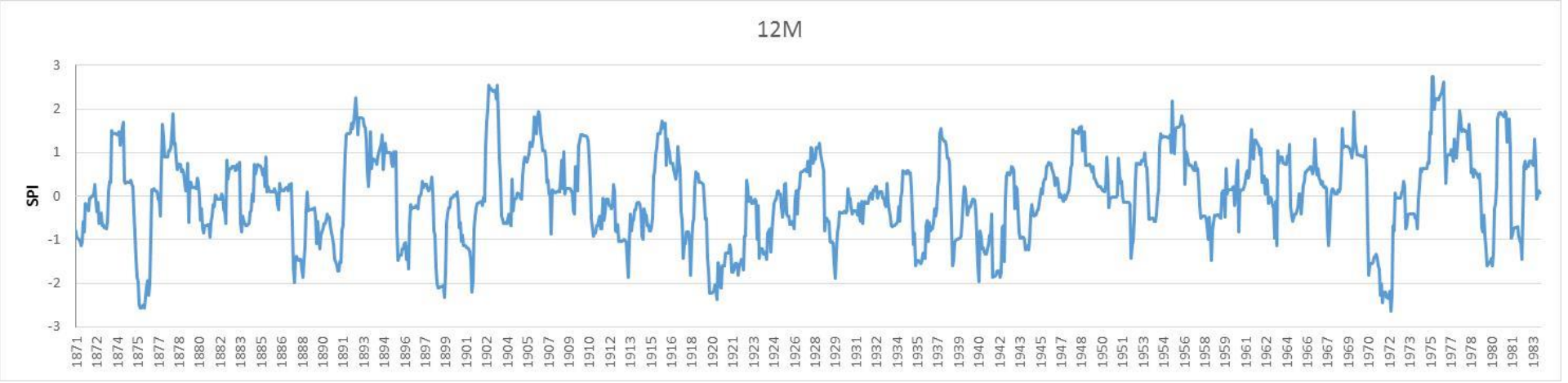
SPI Annual variation
Gulbarga, Karnataka (India)



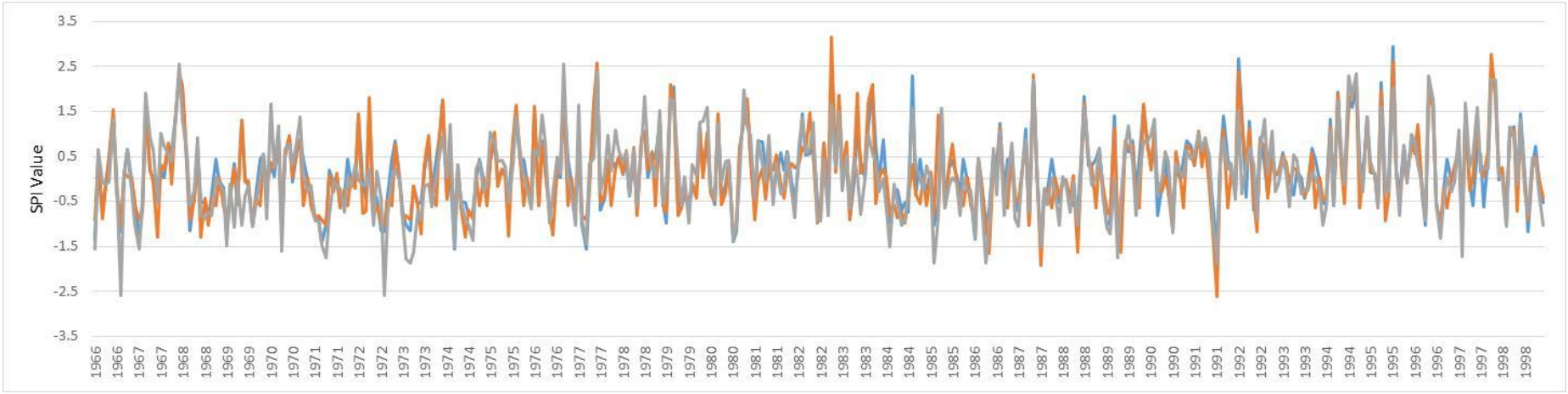


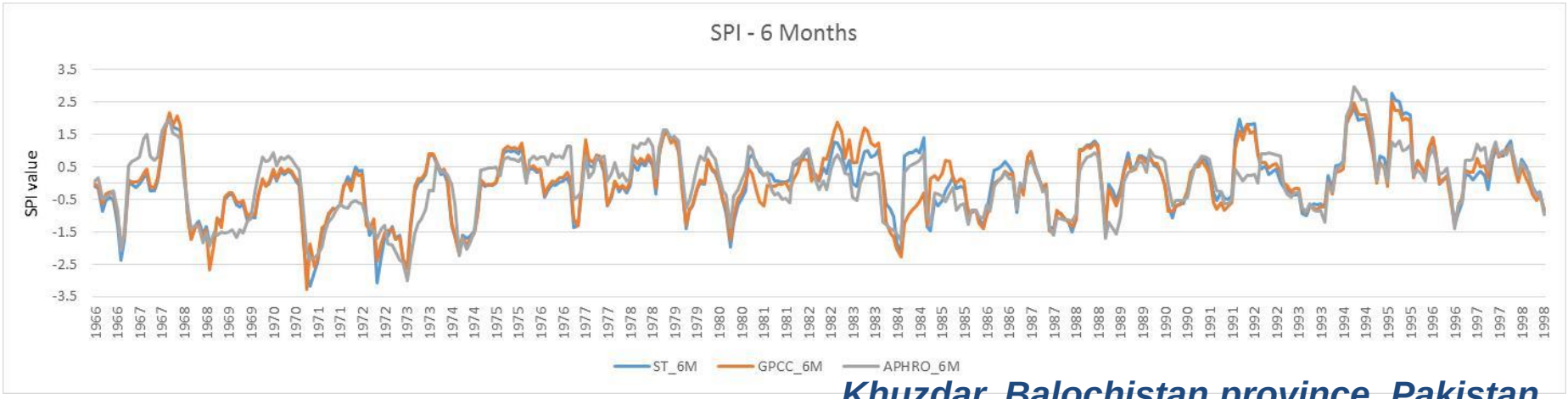
SPI Annual variation
Gulbarga, Karnataka (India)





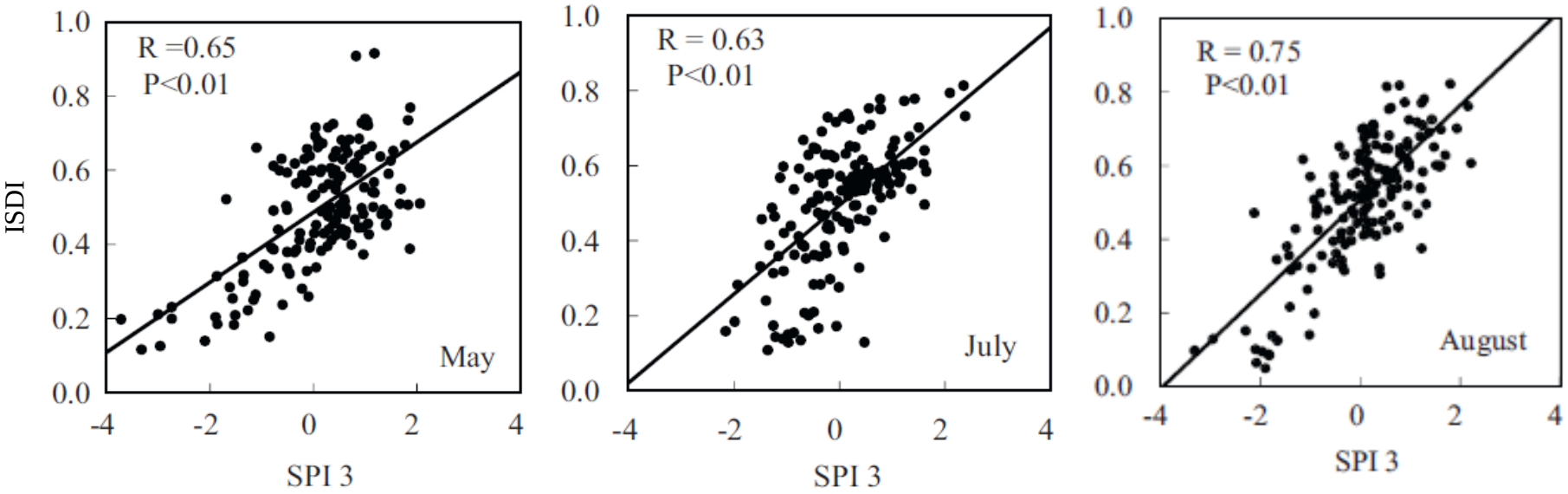
SPI INTER COMPARISON
GPCC VS. APHRODITE VS. OBSERVED STATIONS





Khuzdar, Balochistan province, Pakistan

Correlation Analysis for IDSI and SPI

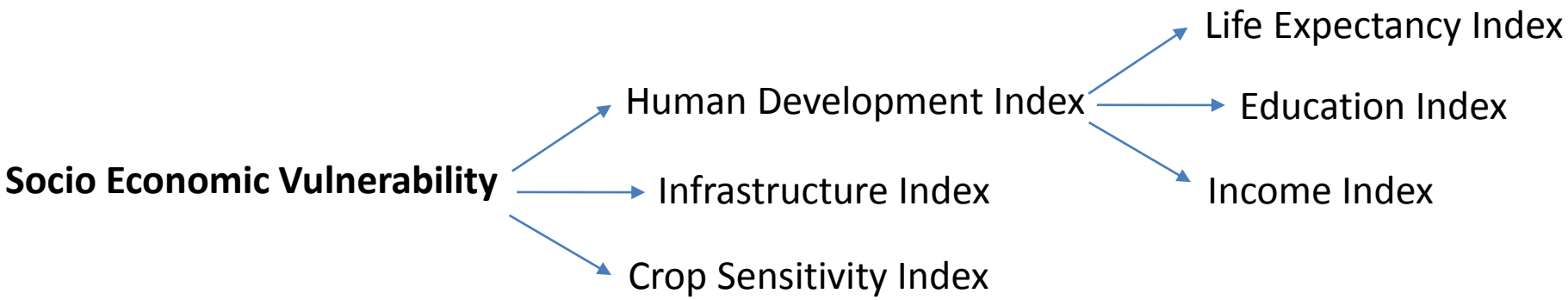


- For assessing the accuracy of SDI, a validation experiment was carried out using in situ meteorological drought index.
- Results showed that ISDI and SPI3 are highly correlated during the Kharif crops growing period

Drought Affected Crop Area in Maharashtra

MAHARASHTRA (INDIA)					
BEED		**Integrated Drought Severity Index**			
Year	**Production Tonnes**	Severe	Moderate	Abnormally Dry	Healthy
1998	1400				
1999	1700				
2000	2000			3	8
2001	1500				
2002	600				
2003	1000				
2004	600	7	3	1	
2005	900				
2006	1500				
2007	7	9	2		
2008	400	8	2	1	
2009	200	5	3	2	1
2010	300				

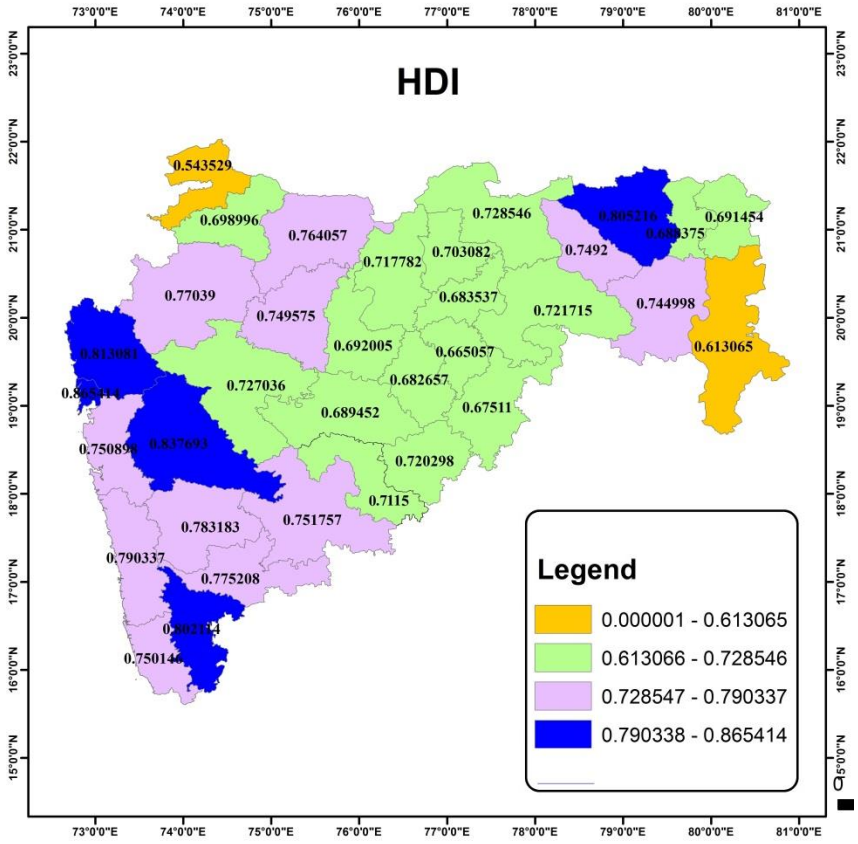
SOCIO ECONOMIC VULNERABILITY ASSESSMENT FOR MAHARASHTRA STATE (INDIA)



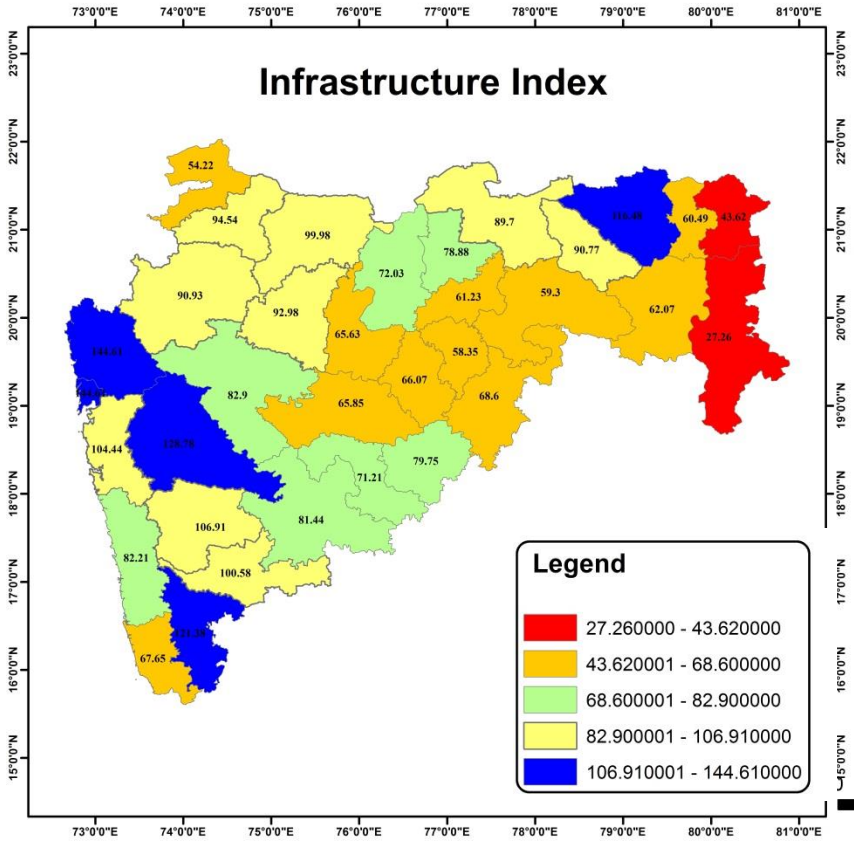
- For calculation of vulnerability several data sources were integrated and how often data is limited;
- SPSS tool was used with PCA factor analysis and ranking were obtained to identify most vulnerable areas

S.No	Range	Category
1.	Less than 0.500	Poor
2.	0.500-0.599	Less than average
3.	0.600-0.699	Average
4.	0.700 or More than 0.700	Good

SOCIO ECONOMIC VULNERABILITY ASSESSMENT FOR MAHARASHTRA STATE (INDIA)



Higher the HDI higher the development



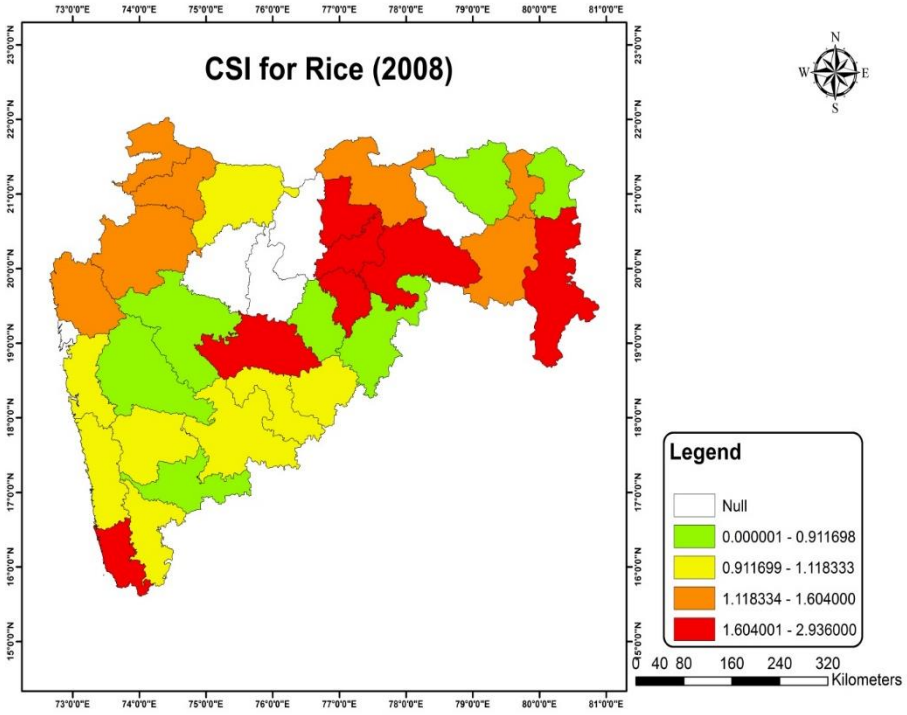
Higher the Infrastructure Index, Higher the development

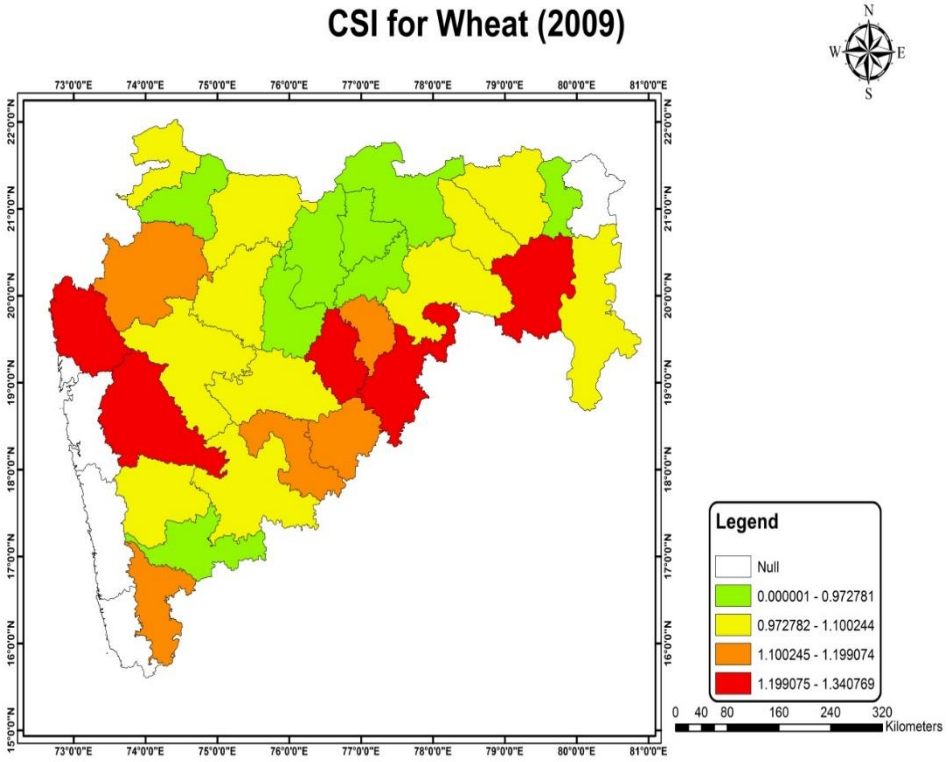
SOCIO ECONOMIC VULNERABILITY ASSESSMENT

Crop Sensitivity Index (CSI) was calculated using the below formula

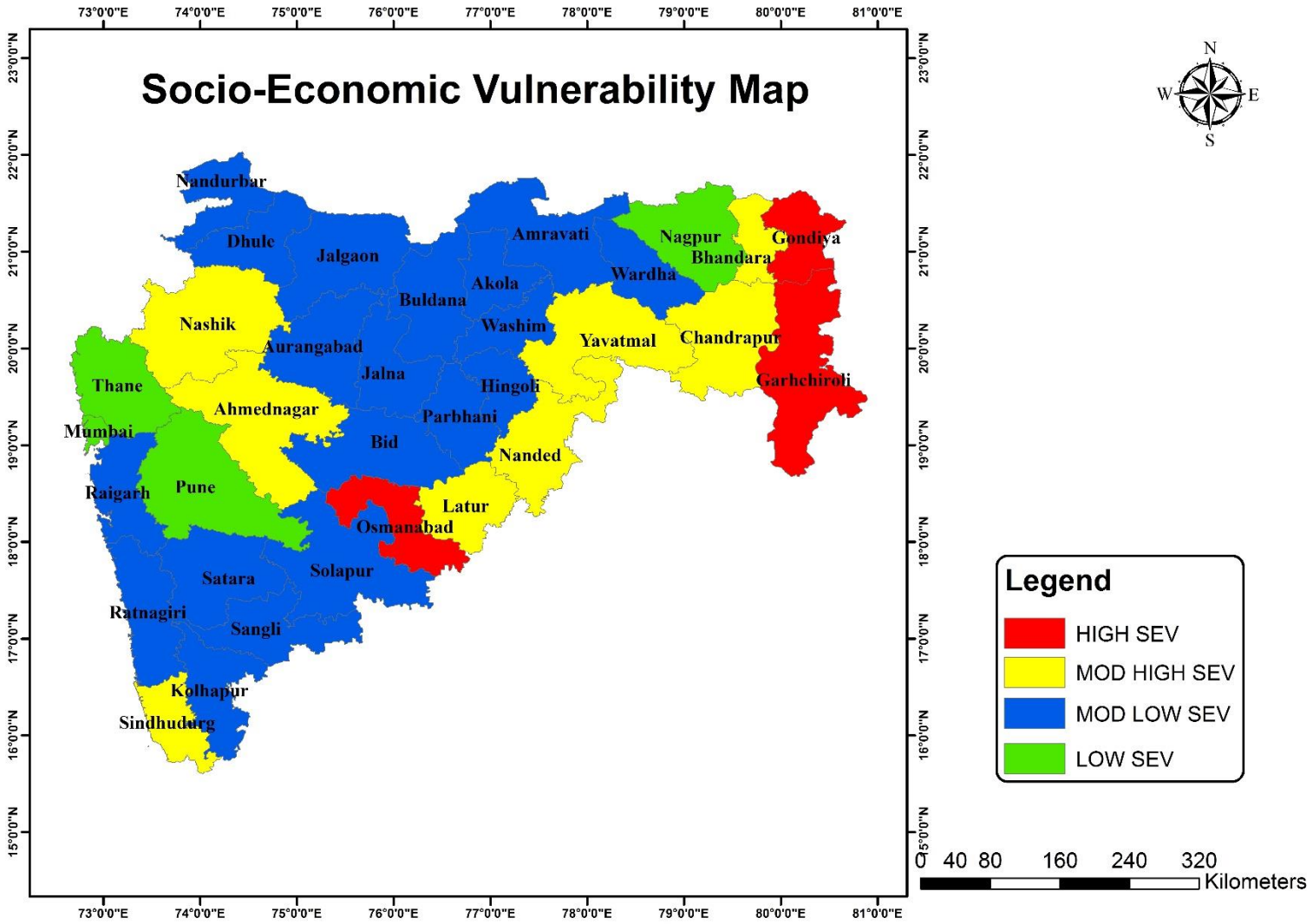
CSI = Expected yield/Actual Yield

To determine the crop yield sensitivity index, the linear trend for each yield for each region from 2003-2010 was calculated. The equation for this trend line was used to calculate the expected yield in each year as a linear model of the time series of the actual yield. The expected yield was then divided by the actual yield for each year to generate a crop yield sensitivity index.





SOCIO ECONOMIC VULNERABILITY ASSESSMENT



2014 DROUGHT IN INDIA AND SRI LANKA: RECONNAISSANCE SURVEY

An assessment of the response to the 2014 drought in Kurunagala (Sri Lanka)

The questionnaires for reconnaissance survey in selected drought affected districts of Kurunagala. Below are the checklists and questionnaires that will be used to collect the information while visiting various farmers/stakeholders at district level.

Respondent: Mr. W Ariyaratne

GENERAL INFORMATION:

Site Specific Details			
District	Kurunagala		
G S Division	48 Jayabima		
Village Name	Track 6		
Latitude / Longitude / Elevation	7.493088	80.320102	353ft
Major crops	Paddy & Cash Crops		
Soil type			
Note: Take picture in High resolution quality and tag the Photo ID No	12		

Drought Information

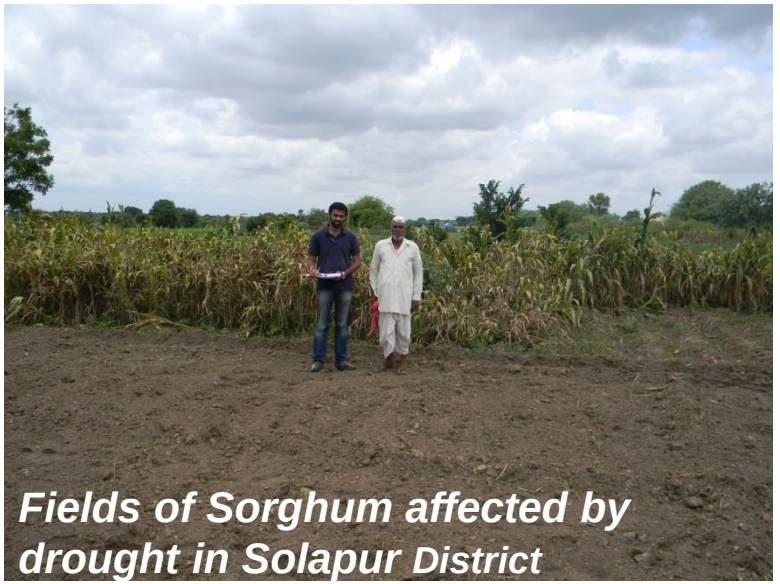
1. Ask the community/Stakeholders to explain the current drought situation and its impact?	In this "Yala Season", rain started on 10 April and lasted for 20 days until 10 May. But generally rain in "Yala Season" starts on 15 March & last until April end. Therefore, due to drought, there were not much fields cultivated in this "mass kanna". Farmer thinks this unusual weather pattern is due to climate change.
2. a) How and when do you notice the drought progress in your farm field? (example month, particular week). b) Do you also get any climate information services from agencies?	a) Delayed rain setting is an indication of less rain in this season. In addition to that, there are indigenous concepts of predicting the drought by examining the fruiting pattern of some trees in the area. b) [1]Business Committee meets every month and weather data are shared by officials with farmers.
3. What was the scale of drought? Low / Moderate / Severe	The present drought (2014) is very severe and it has been aggregated by strong, dry, warm wind leads to high temperature. According to the respondent, they are experiencing this uncertain weather during last 5 years. i.e. In 2012 – 5 month continuous rain and this is not normal.
4. Could you roughly tell us the extent/area of drought in your farm field?	No drinking water for farmers and animals in the area. Plants and paddy fields are being dying. Water level in wells is very low and whatever available is not drinkable.
5. Did you already sown seeds, expecting the monsoon will come in time, based on the past years weather condition?	The total cultivatable extent of this area is 2,250 Acres and only 50% of the area has been cultivated. This decision has been taken at the beginning of the season by the Farmer Leaders & Irrigation Department Officials since there is no sufficient water in the "Palukadawala Tank". So, others are growing Cowpea, Soya, Corn, Chillie, Gherkin and Melon. Therefore no seeds were sown expecting monsoon in "Yala". Sowing of "Maha' is not yet started.
6. In the failure of monsoon how do you shift /change the Kharif crop pattern and the delay in crop harvest affect your livelihood?	There is lot of unemployment in the area and most of them are working as laboures in the construction sites in Colombo and other who opted to stay back are engaged in brick making.
7. Do you get any compensation from the state / district government in the event of drought condition?	No compensation from the government for the crop loss other than the "Samurdi Benefit" of Rs. 200-300. To qualify for that, Farmer should attend two meetings and work voluntarily in the field.
8. Do you also engage in weather index insurance as it will help you in getting compensation in the event of crop failure?	No. For the subsidized 50Kg fertilizer Bag provides by the government charges Rs. 500 and Rs. 150 of that is for crop insurance. Crop loss compensation is Rs. 10,000 for one acre of mature field or pro-rata basis depending on the stage of the crop. The committee comprise of Grama Sevaka, Govi Jana Seva officer & Agriculture Research Assistant in the ares.

[1] BC is a statutory committee comprises of Farmer Leaders, officials from Agriculture Department, Govi Jana Seva & Irrigation Department and exchange technical details & take decision on releasing water to farm lands.

2014 DROUGHT IN SRI LANKA (KURUNAGALA DISTRICT)

2014 DROUGHT IN MAHARASHTRA STATE, INDIA

Groundnut and other crops impacted due to lack of water supply in OS District



Fields of Sorghum affected by drought in Solapur District

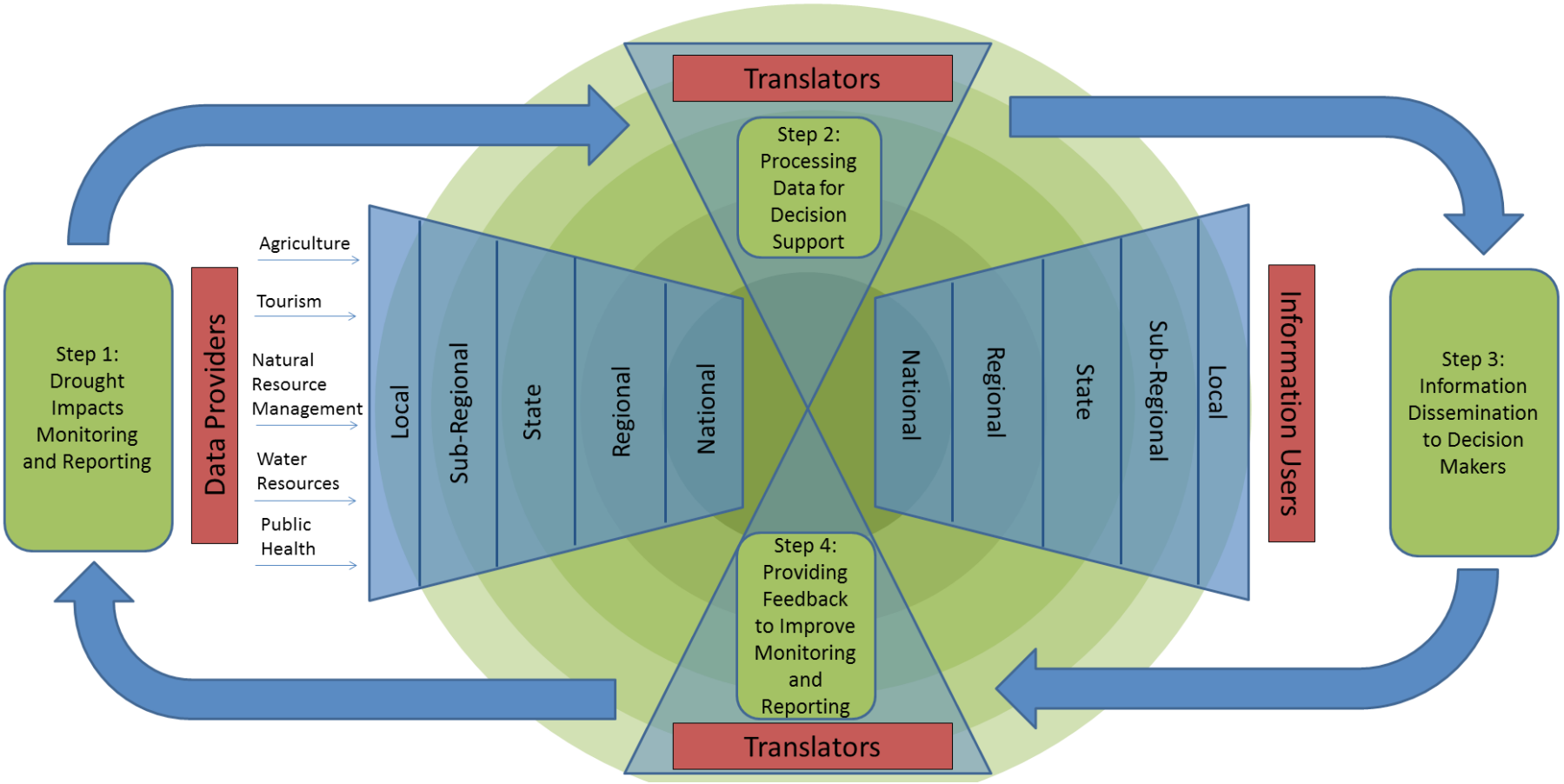
Drinking water supply in drought affected areas of Beed district

Grape fields affected by drought in Osmanabad District

SOUTH ASIA DMS OUTPUTS

- Enhanced understanding and quantification of drought's magnitude, spatial extent, and potential impact – through a combination of climate, vegetation and biophysical indicators
- On-line prototype drought monitoring tool – the basis for coordination of regional drought mitigation effort. Historical and current high spatial and temporal resolution drought risk and propagation mapping online
- Identified hot-spot areas – where droughts are more intense and frequent
- Operational drought monitoring system(s) installed in national center(s), or / and identified regional hub
- National capacity in drought monitoring built in all participating countries to address the gaps identified through needs assessment
- Regional sharing and dissemination of operational drought information to the users to download at country level for subsequent analysis;

COMPREHENSIVE DROUGHT IMPACTS REPORTING SYSTEM




THANK YOU