

Drought monitoring experiences of India

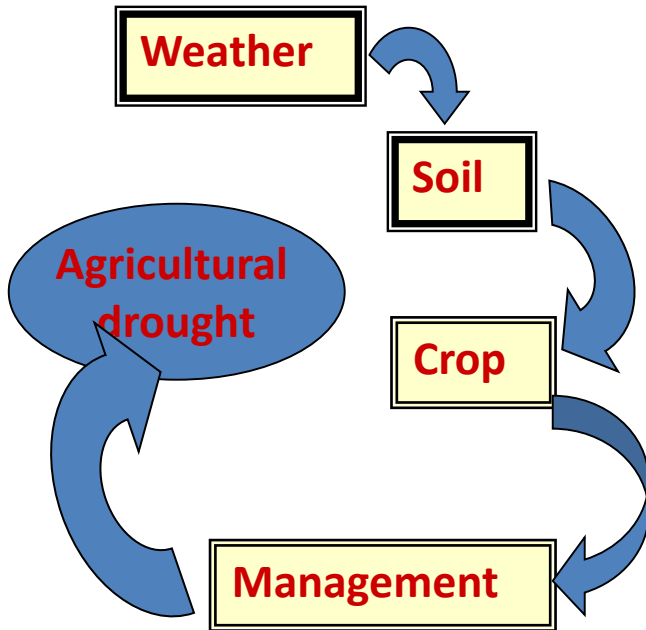
Dr. C.S. Murthy

Head, Agricultural Sciences and Applications

National Remote Sensing Centre, Hyderabad

murthy_cs@nrsc.gov.in, csmurthy09@gmail.com

Understanding Drought



- Complex nonlinear interactions
- Slow process with multi dimensional impact
- No single index
- Different states adopt different norms

Drought - Indian Agriculture

- Agriculture - mainstay of Indian economy
- Diverse weather and cropping patterns
- Net cropped area – 142 M ha, 60 % depends on rains
- Three Crop Seasons
 - Kharif (June to November) main crop season with 105 M ha of cropped area, mostly rainfed, corresponds to prime monsoon season (South west monsoon)
 - Rabi (Oct/Nov to Mar/April) with cropped area of about 50 M ha, mostly irrigated
 - Summer (March to June)

Drought Management in India

Short term Management

- ❖ **Monitoring & Assessment**
- ❖ **Prediction & Early warning**
- ❖ **Agro-advisories**
- ❖ **Crop damage assessment**

Long term Management

- ❖ **Vulnerability/risk assessment**
- ❖ **Prioritization**
- ❖ **Structural and Management measures for drought proofing (soil and water conservation)**
- ❖ **Impact monitoring**

Stake holders

- Ministries of Agriculture and Rural Development
- State Departments of Agriculture, Revenue, Disaster Management
- Science and Technology institutions

Department of Agriculture, Cooperation and Farmers Welfare (DACFW), Govt. of India is the Nodal agency for drought management

Guidelines to states

- National Drought Manual 2009
- **National Drought Manual 2016**
(www.agricoop.nic.in)

Manual provides

- Indices for drought monitoring
 - Meteorological
 - Hydrological
 - Agriculture
- Drought declaration protocols
- Relief management
- Long term measures
- Training to states

MANUAL FOR DROUGHT MANAGEMENT

DECEMBER 2016



Department of Agriculture, Cooperation & Farmers Welfare
Ministry of Agriculture & Farmers Welfare
Government of India
New Delhi

Rainfall deviation from normal

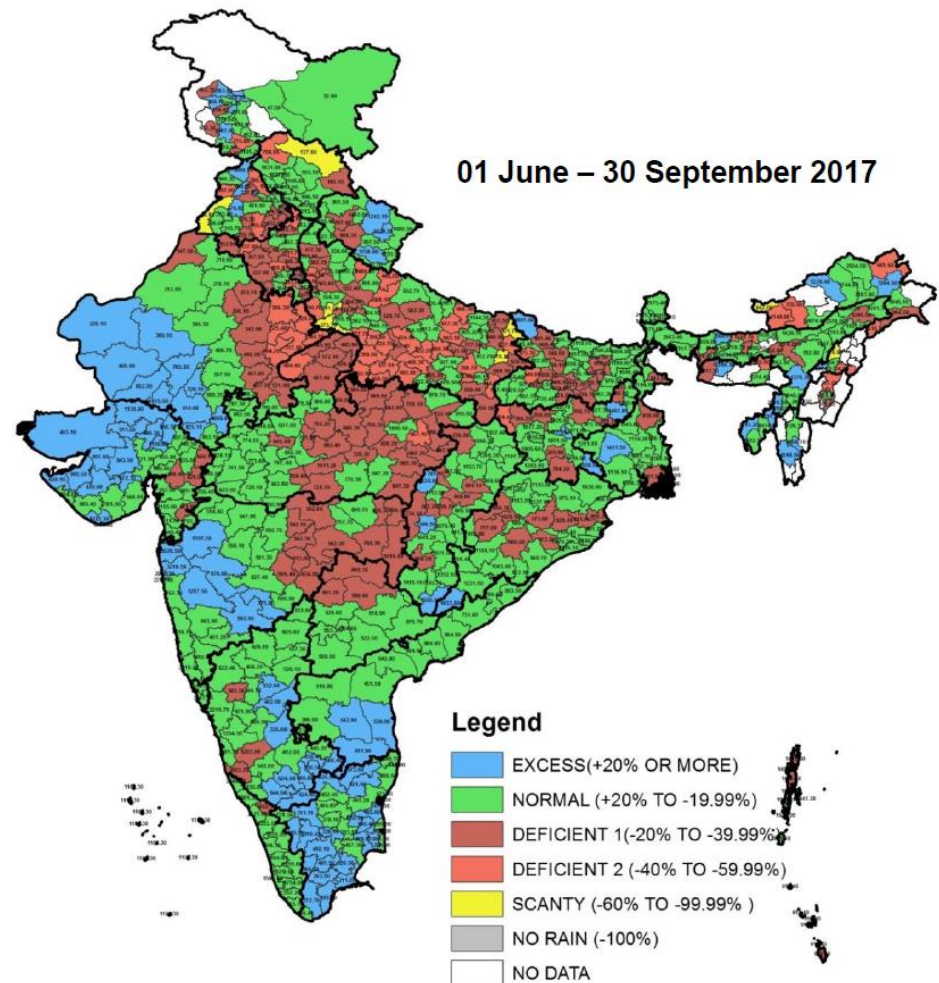
Normal rainfall: long term mean

Deviation = $(\text{Current rainfall} - \text{Normal rainfall}) / \text{Normal rainfall}$

Extent of negative deviation is directly related to drought

Limitation of rainfall deviation as drought indicator

Rainfall deviation – June to September 2017

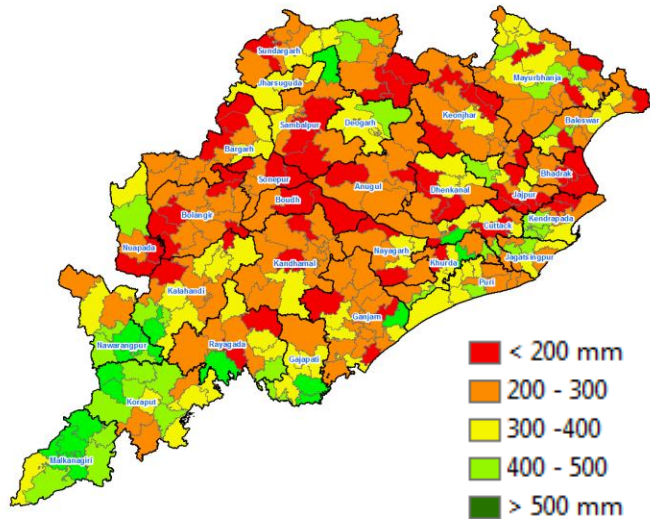


Source MNCFC, Ministry of Agriculture

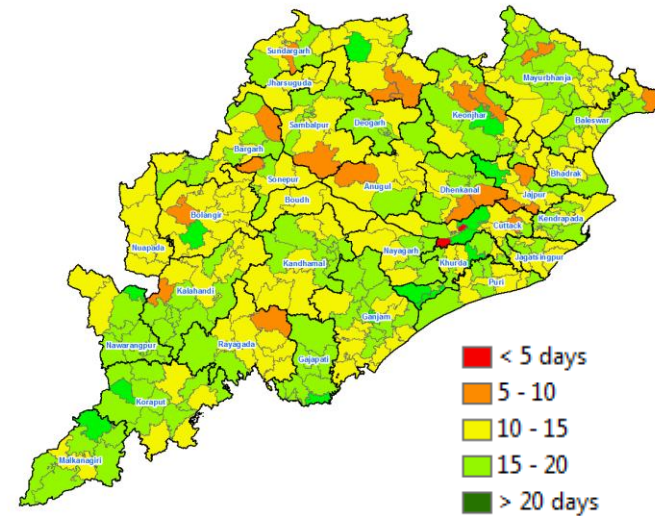
Block-wise rainfall status of Odisha state (Aug 2017)

Rainfall

Cumulative Rainfall Aug2017

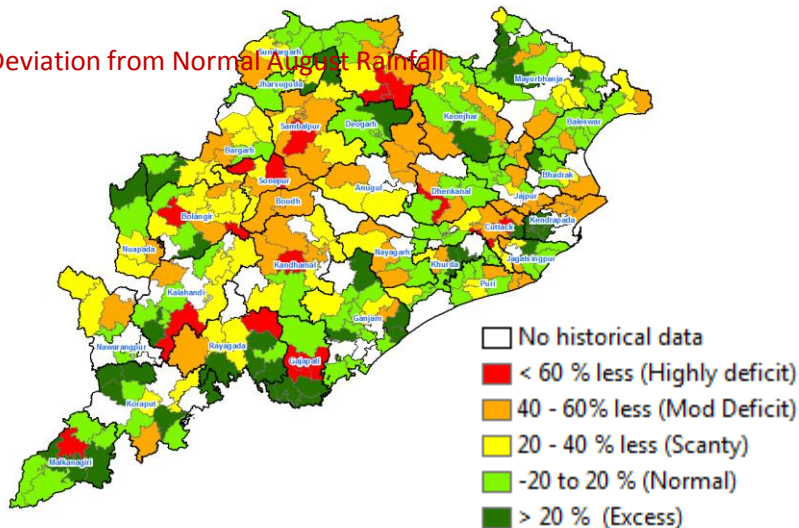


Rainydays

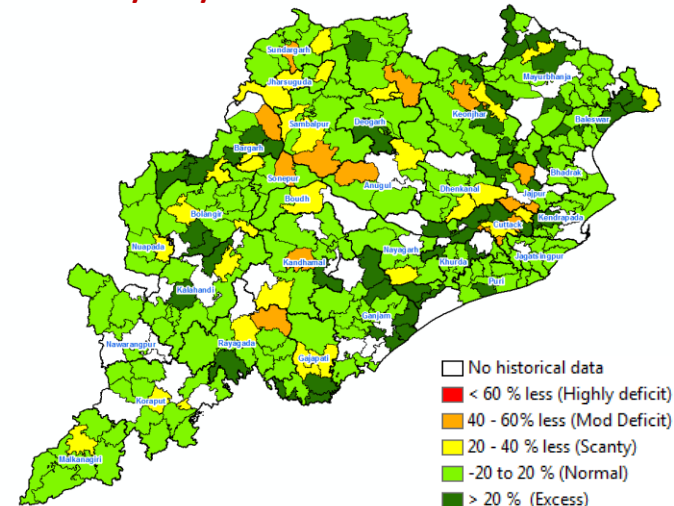


Rainfall deviation from the Normal

Deviation from Normal August Rainfall

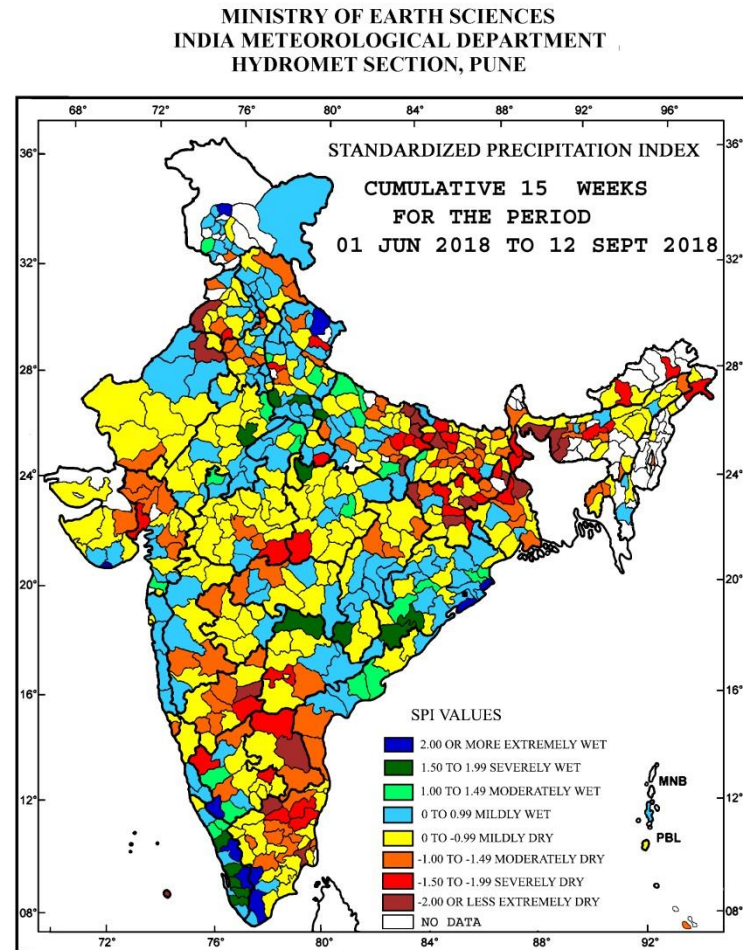


Rainydays deviation from the Normal

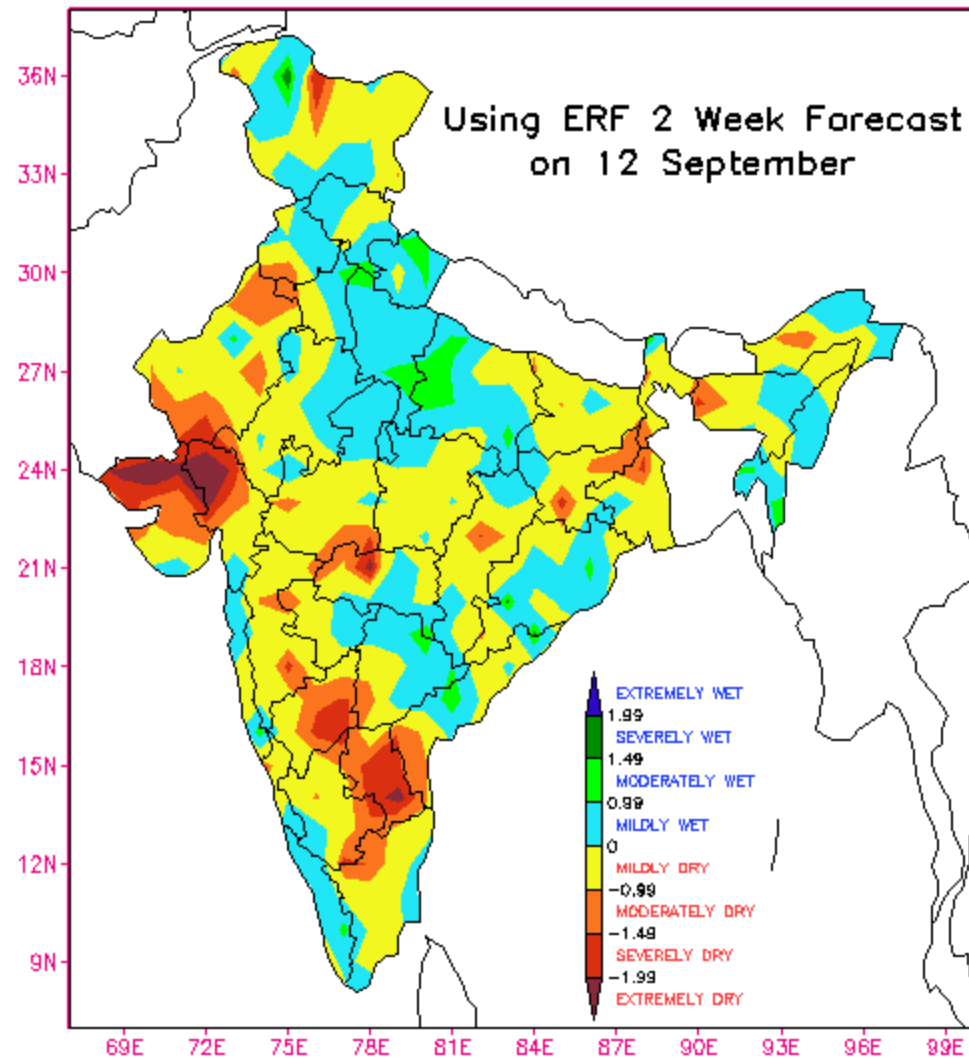


Standardized Precipitation index (SPI)

- Based on precipitation alone
- Detection of dryness or wetness
- Versatile indicator
- Data transformation
- Gamma probability density function
- Needs long term data base



STANDARDIZED PRECIPITATION INDEX OUTLOOK SPI Condition From 1 June To 26 September 2018

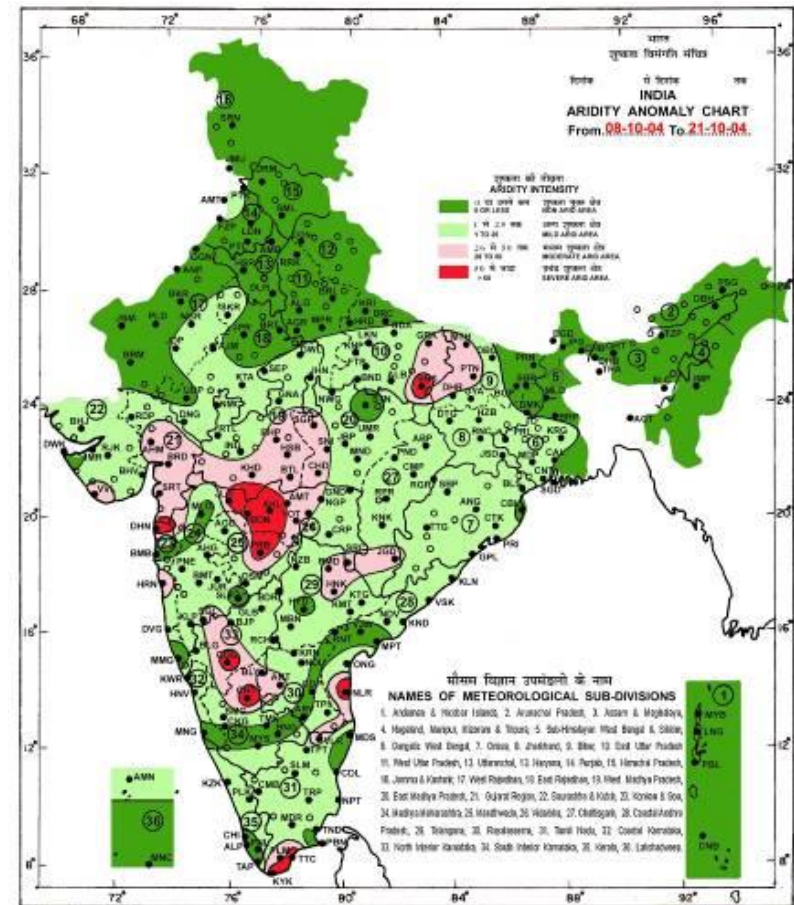


Aridity Anomaly

Aridity = AET/PET

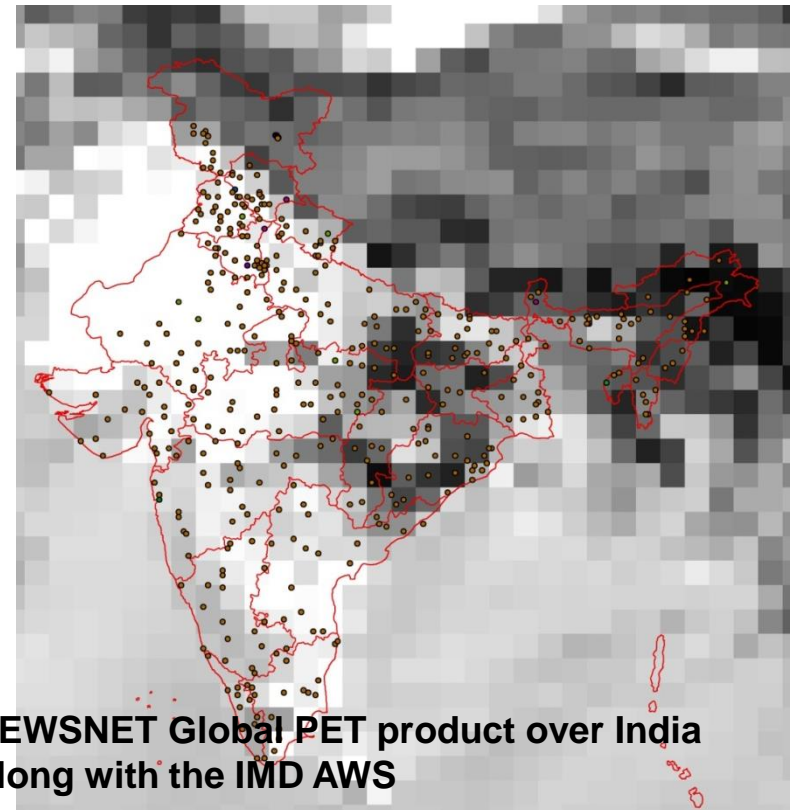
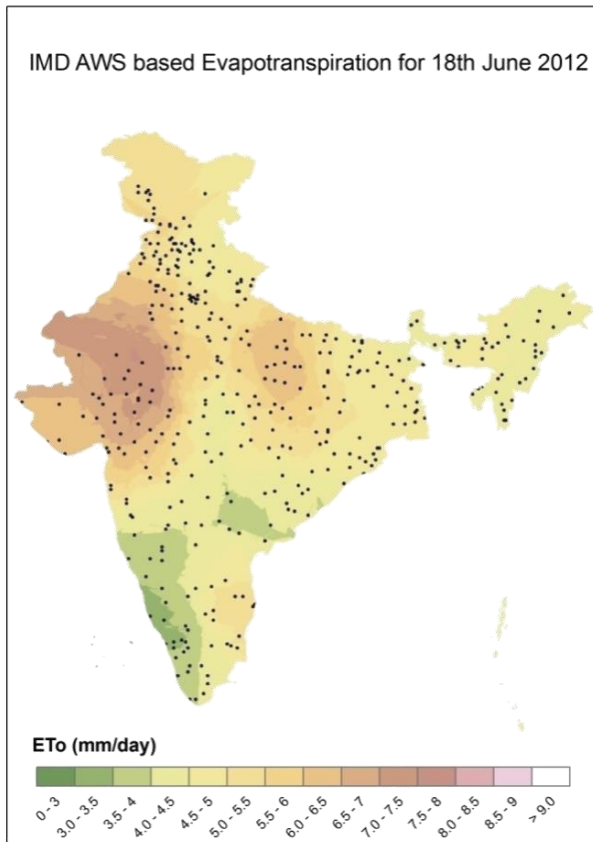
Climatic water balance

Soil water balance

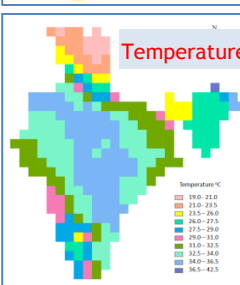
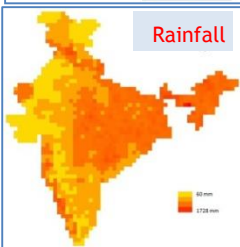
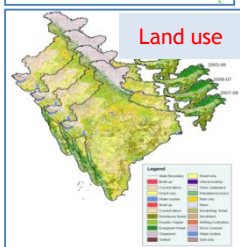
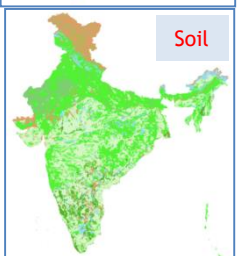
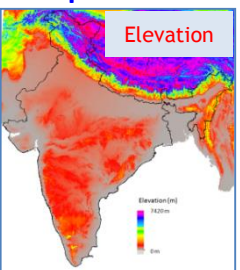


- IMD AWS provides data on near real time basis on
(Temperature, Pressure, Dew Point, Wind speed, Wind direction, Sun Shine hours, Rainfall)
- Total number of station over India is approximately 588
- Total number of station usable after quality check are approx. 400.

Comparative study of FEWSNET global PET product and IMD AWS based ET_0



Input dataset



Hydrological Modeling Framework

Variable Infiltration Capacity Hydrological Model

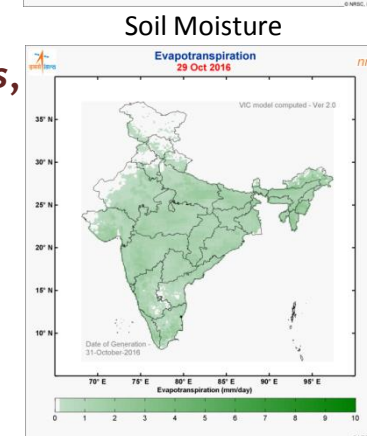
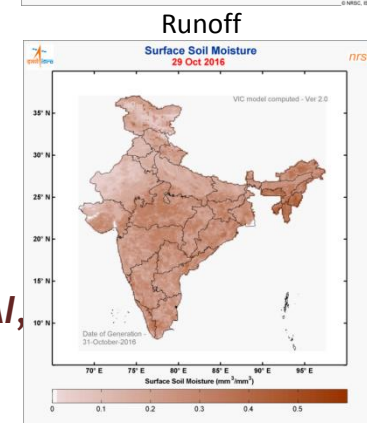
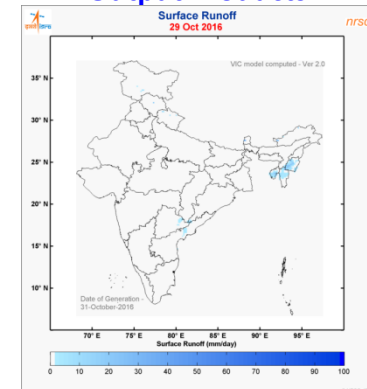
- Open source; Grid-wise water and energy balance
- Sub-grid heterogeneity of Land cover
- Soil depth-wise hydrological response
- Vegetation phenological changes
- Daily / sub-daily time step

9 min (~16.5km), 3 min (~ 5.5km) Grid-wise data base

Geo-spatial data

- Terrain - Topographic, Soil (NBSSLUP), LULC (NRC-250k), LAI, Albedo
- Meteorological - Rainfall, Temperature, ... (IMD & CPC)
- Hydrological - River discharge, Reservoir Storage/Releases, GW levels, ...

Output Products



Data Sources and related info.

Meteorological Data Source	Parameter	Resolution	Latency
IMD Gridded data	Rainfall, Min, Max Temperature	0.5 degree	1 day
IMD AWS data	Rainfall, Min, Max Temperature	Point data (interpolated to 9min/3min)	1 day
IMD high density data (Godavari & Mahanadi)	Rainfall	Point data (interpolated to 3min)	1 day
CPC	Rainfall	0.1 degree	2 days
GEFS	Rainfall, Min, Max Temperature	0.5 degree (interpolated to 9min/3min)	Daily forecast data
APSDPS AWS data	Rainfall, Min, Max Temperature	Point data (interpolated to 3min)	1 day

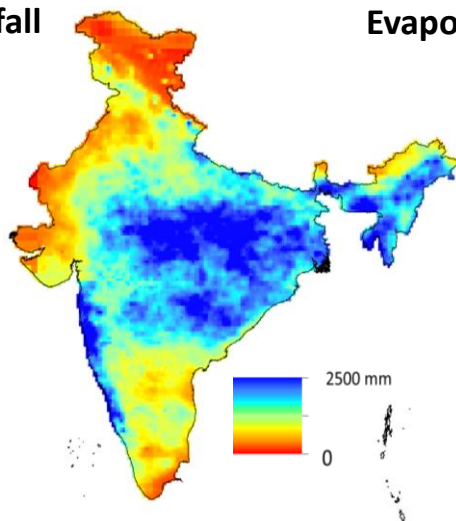
Web Published VIC Model Derived Products

Product	Resolution	Frequency
Water Balance Components for entire India	3min (~5.5km), 9min (~16.5km)	Daily
Forecast Surface Runoff (d*+3)	9min (~16.5km)	Daily
Accumulated Surface Runoff	9min (~16.5km)	Daily
Climate Indices – SPI , SRI (1, 3, 6, 12 Months)	9min (~16.5km)	Daily
River Basin Wise Statistics	-	Weekly
WBC's for Godavari, Mahanadi River	3min (~5.5km)	Daily

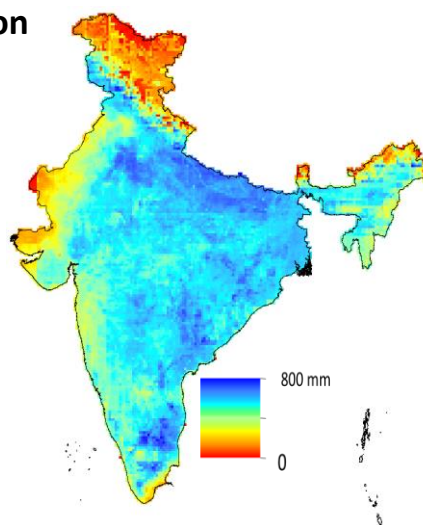
Seasonal Water Balance Components Estimation

Jun-Oct, 2016

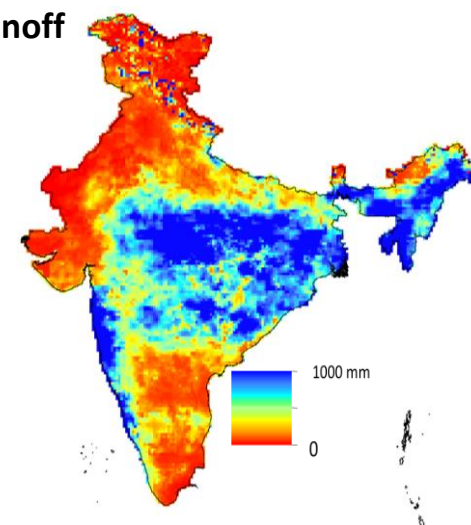
Rainfall



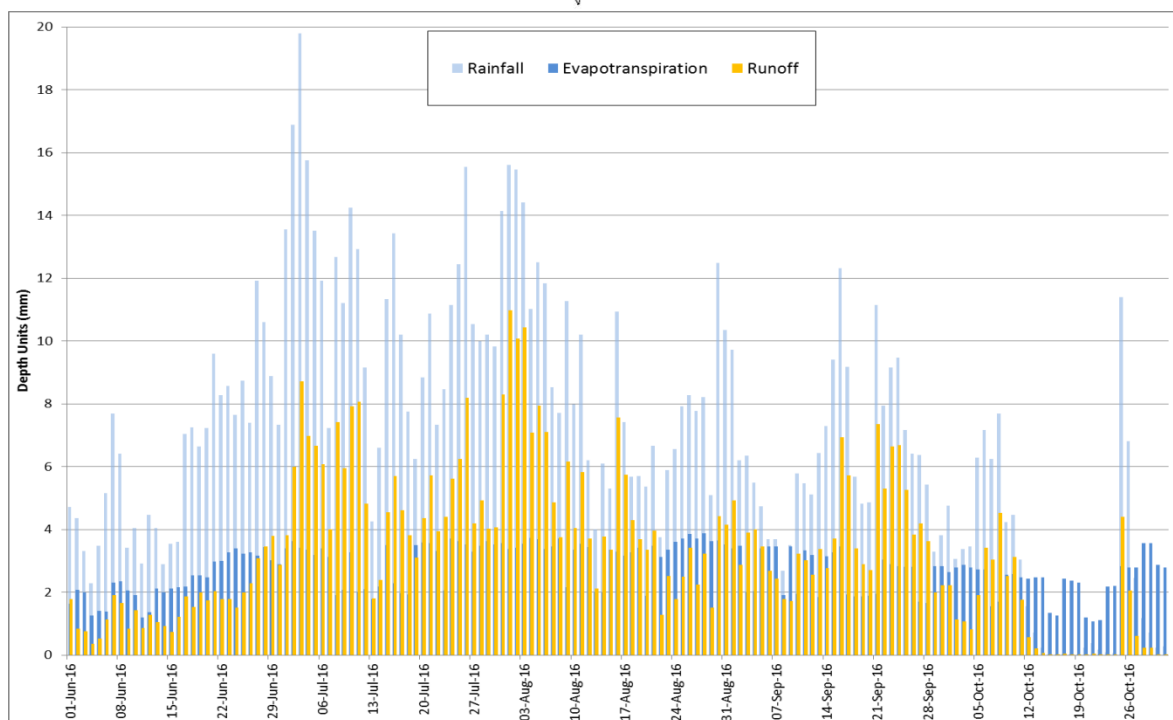
Evapotranspiration



Runoff



Daily Mean (India) Water Balance Components

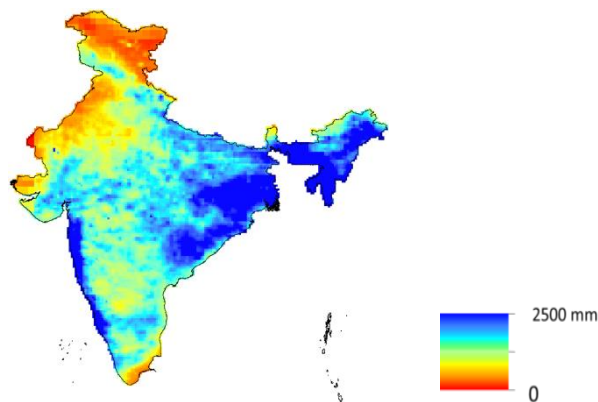


Seasonal Water Balance Components Estimation

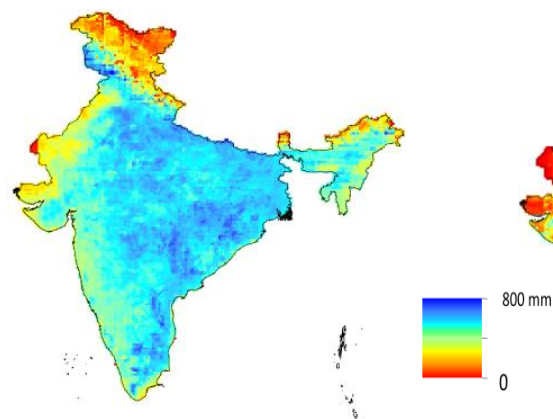
Jun-Oct, 2017

nrsc

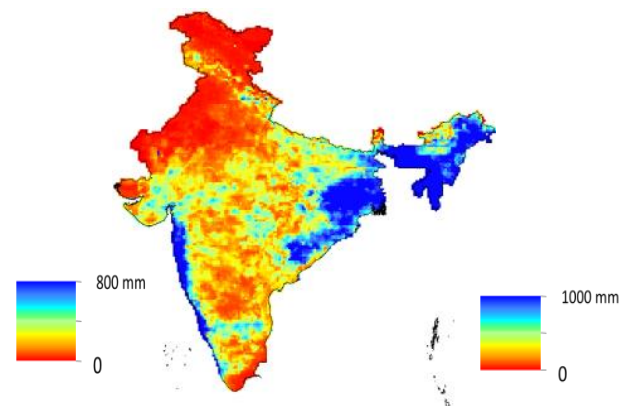
Rainfall



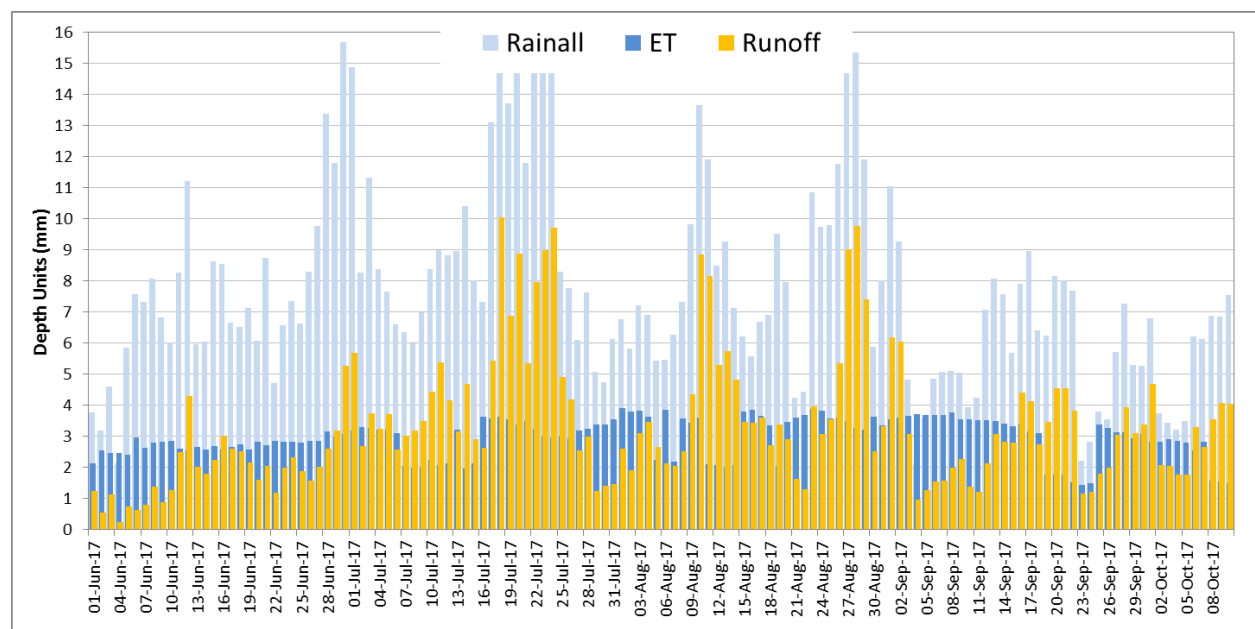
Evapotranspiration



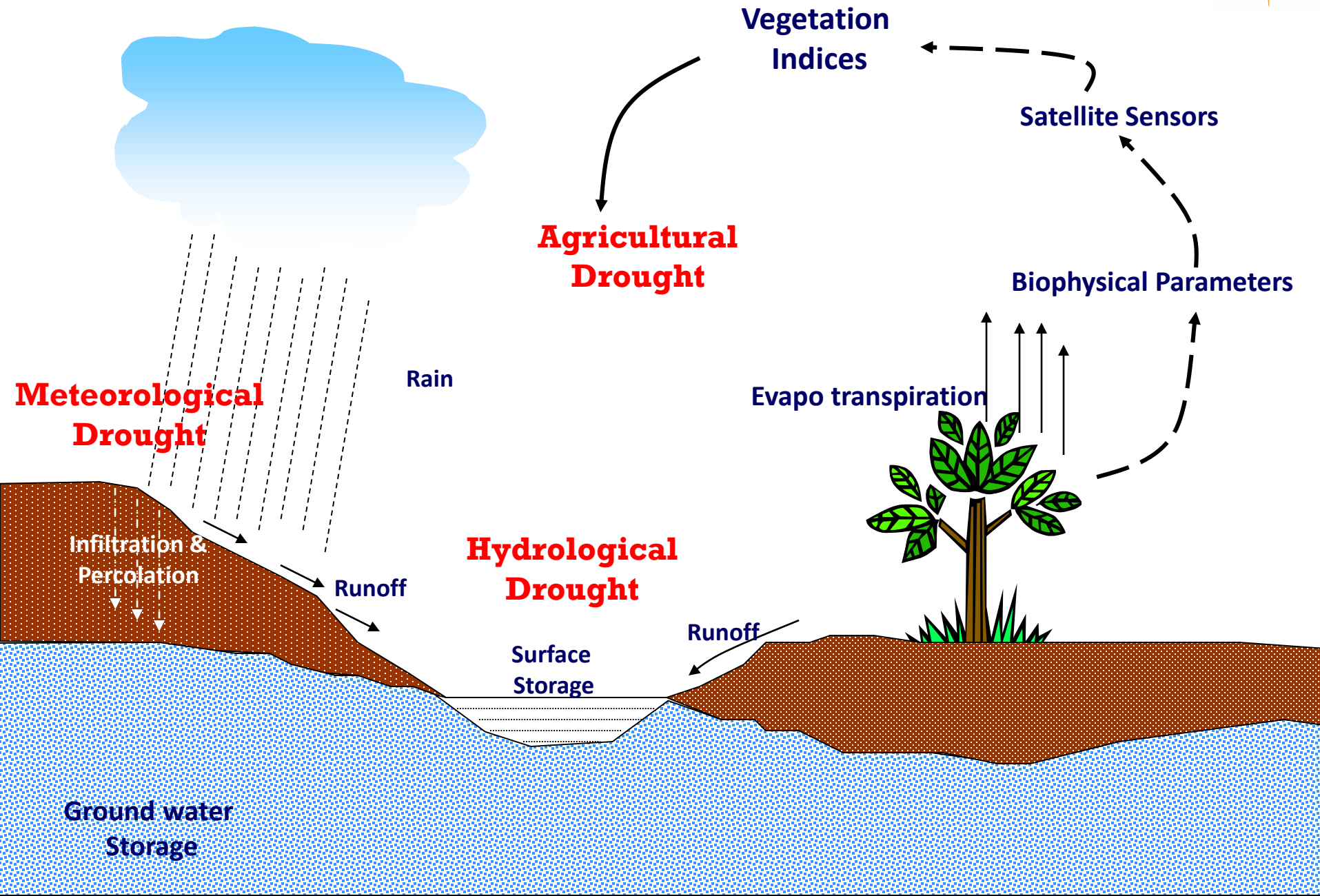
Runoff



Daily Mean (India) Water Balance Components



SATELLITE MONITORING OF AGRICULTURAL DROUGHT



National Agricultural Drought Assessment & Monitoring System

NADAMS Project

INPUTS

Multiple indices

VI anomaly

Rainfall deviation

Sown area deviation

2012+

- ❖ Institutionalization – transfer to MNCFC
- ❖ Country wide monitoring with high resolution AWiFS data
- ❖ Support from geo-stationary systems
- ❖ Utilization of microwave data
- ❖ Process based indicators (energy balance)

2004+

- Use of multiple indices
- IRS AWiFS based sub-district level assessment
- AVHRR based regional/district level assessment
- Integration with ground data/multiple indices
- Decision rules for drought warning & declaration
- Enhanced content & frequency of reporting
- Institutional participation & Capacity building

2002

- IRS WiFS based district / sub district level assessment
- Supplementation of WiFS with MODIS
- AVHRR based regional/district level assessment
- Agricultural area monitoring

1998

- IRS WiFS based district / subdistrict level assessment
- AVHRR based regional/district level assessment
- Participation of user departments

1988

- NOAA AVHRR
- Regional/district level assessment

Drought warning:
June, July, Aug.

- * Normal
- * Watch
- * Alert

Drought declaration:
Sept, Oct., Nov.

- * Mild
- * Moderate
- * Severe

OUTPUTS

USER DEPARTMENTS
(Union & State Govts.):
Agriculture Ministry
Relief Commissioners

NADAMS

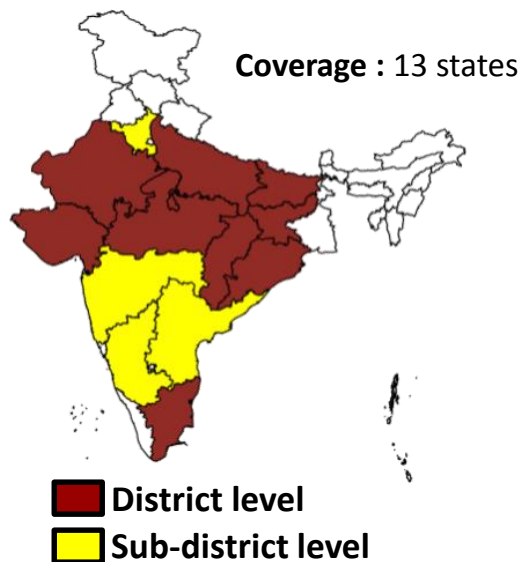
- **Meteorological drought:**
reduced rainfall
- **Hydrological drought:**
reduced surface water
- **Agricultural drought:**
reduced soil moisture

NADAMS

Operational service

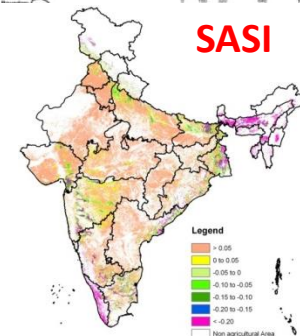
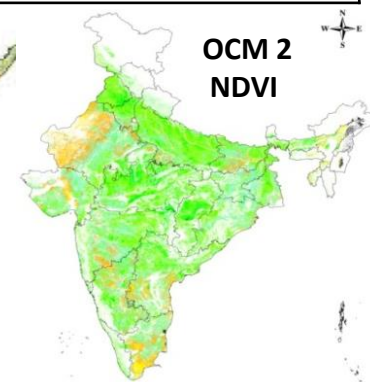
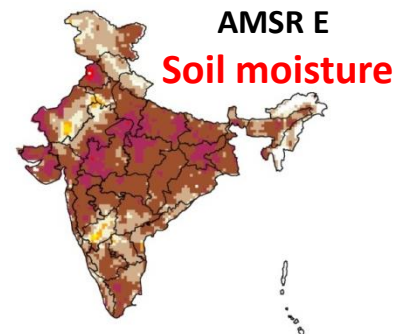
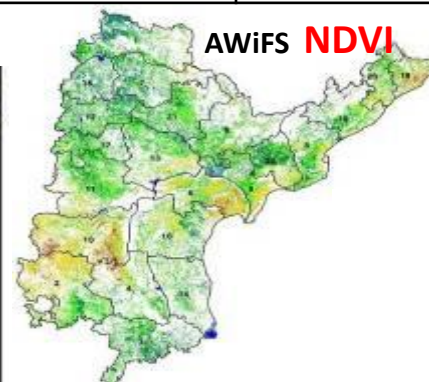
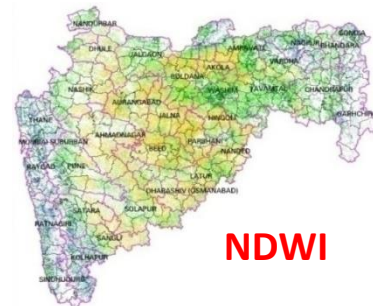
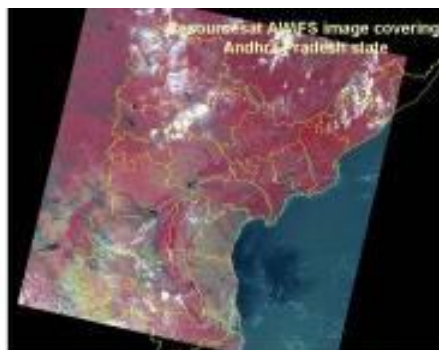
Season : kharif

Objective: prevalence, intensity and persistence of agricultural drought at district/sub-district level



Satellite/ Sensor	Indices	Relevant Parameter
Resourcesat AWiFS (60m)	NDVI, NDWI	Crop condition, surface wetness
NOAA AVHRR (1km)	NDVI	Crop condition
Oceansat 2- OCM (360m)	NDVI, ARVI	Crop condition
Terra MODIS (500 m)	SASI, NDWI	Surface wetness/sown area discrimination
Terra AMSRE (25 km)	Soil moisture	Surface wetness/ sown area discrimination
INSAT 3A CCD (1 km)	NDVI	Crop condition

FCC of R2 AWiFS



Legend



Most commonly adopted index – NDVI

- a) chlorophyll based index
- b) plant vigour and density
- c) easy to compute and interpret
- d) robust index
- e) Limitations – soil back ground, saturation, time lag etc.

Recently popularized index – LSWI

- a) Plant moisture based index
- b) NIR and SWIR based
- c) No saturation issues
- d) Immediate response
- e) Sensitive to surface wetness during sowing period

Combination of NDVI and LSWI

- a) Overcomes limitations of either one
- b) amplifies anomalies and
- c) more responsive to ground situation

NDVI anomaly

% dev. from normal

$$\frac{(\text{actual NDVI} - \text{normal NDVI})}{\text{normal NDVI}} \times 100$$

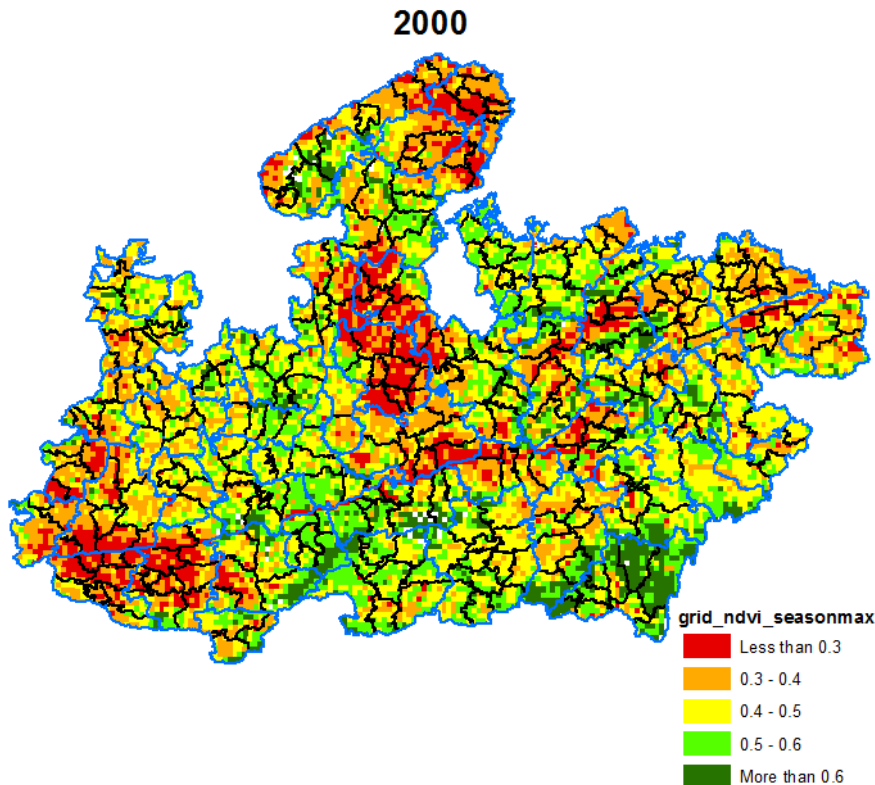
Selection of normal year –
average of recent past normal
years

NDVI is a conservative indicator
and hence anomalies are not
very high

Thumb rule:

> 20% reduction in NDVI – drought
conditions

>30% reduction indicate moderate
to severe drought conditions



Sep 2017
(partly under
drought)

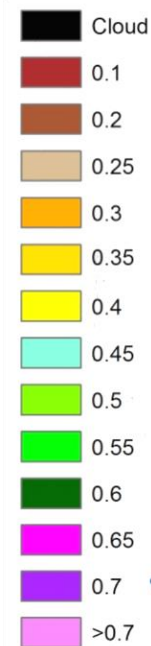
**AWiFS derived
Agril. area NDVI
- the main
dataset for
drought
assessment**

Sep 2016
(partly cloud
Normal year

Sep 2015

Drought year

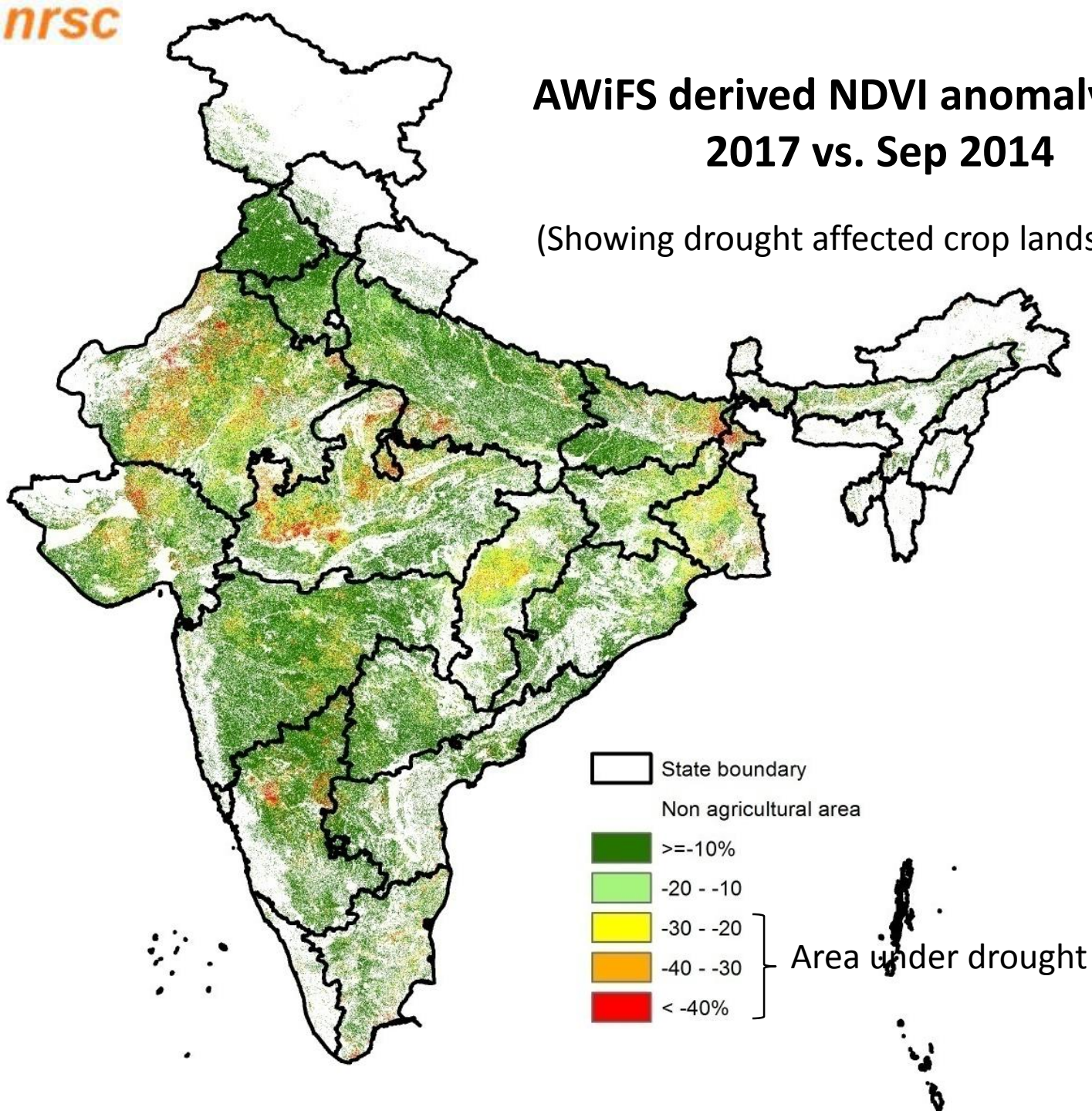
Sep 2014
Normal year



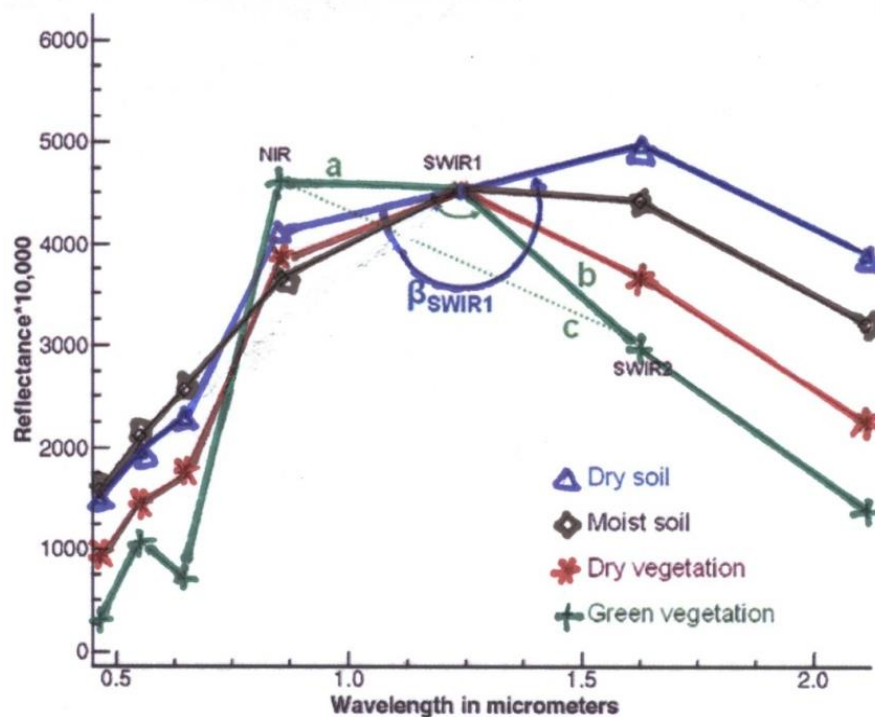
Increasing vegetation vigour

AWiFS derived NDVI anomaly – Sep 2017 vs. Sep 2014

(Showing drought affected crop lands in kharif 2017)



Shortwave Angle Slope Index (SASI)



$$\beta_{SWIR1} = \cos^{-1} \left[\frac{(a^2 + b^2 - c^2)}{(2 * a * b)} \right]$$

$$\text{Slope} = (\text{SWIR2} - \text{NIR})$$

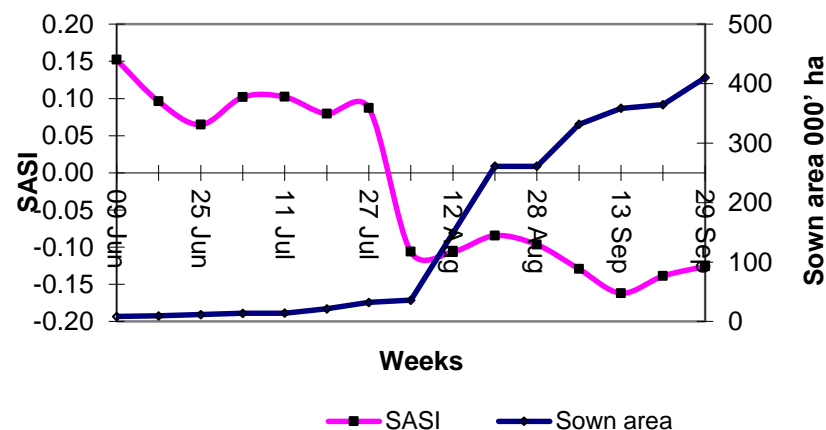
$$\text{SASI} = \beta_{SWIR1} * \text{Slope (radians)}$$

where a, b and c are Euclidian distances between vertices NIR and SWIR1, SWIR1 and SWIR2, and NIR and SWIR2, respectively

Features	SASI value
Dry soil	highly positive
Wet soil	low positive

Features	SASI value
Dry vegetation	low negative
Moist veg.	high negative

Response of SASI to crop sown area



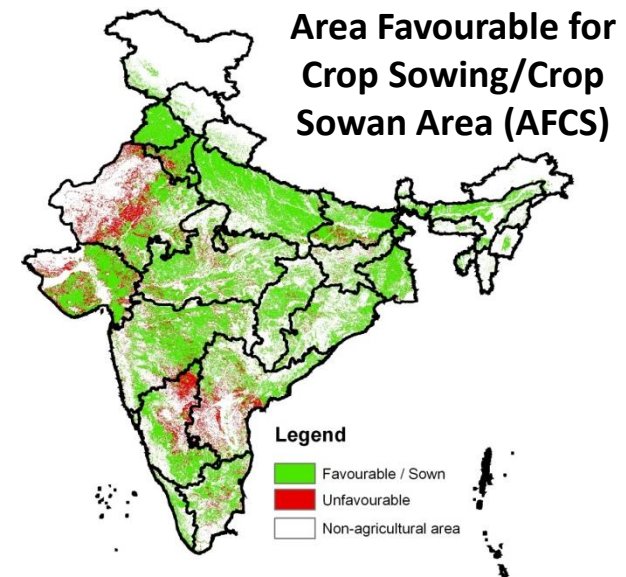
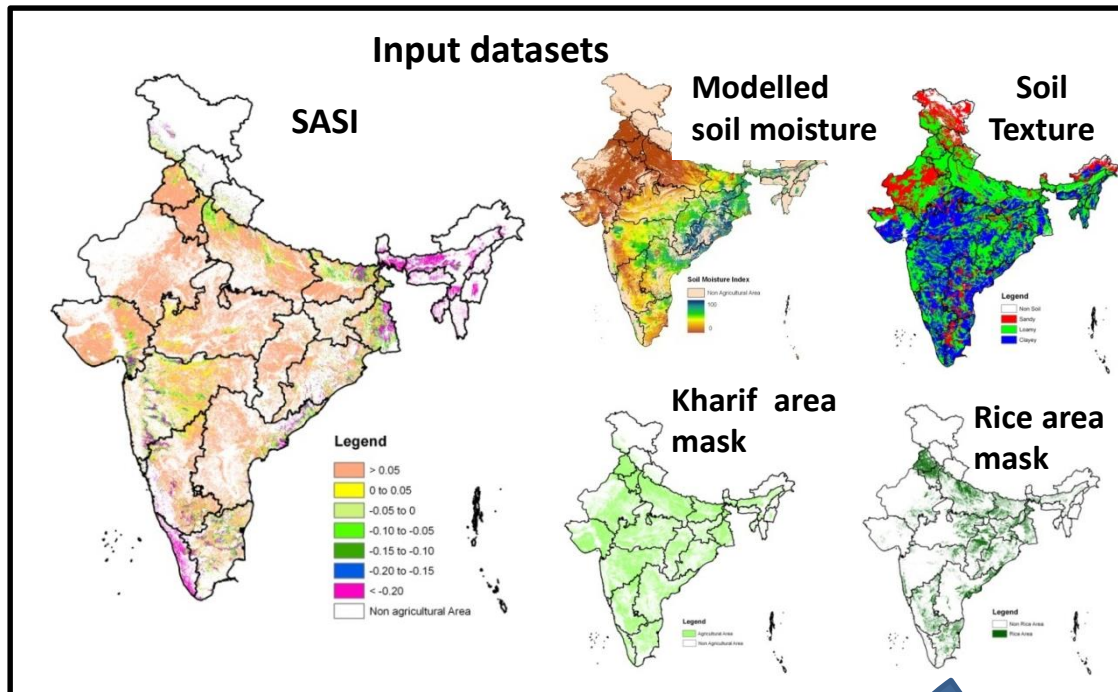
Chronological synchronization between

- (a) Decrease in SASI
- (b) Increase in rainfall
- (c) Increase in sown area

NADAMS project

Conceptually and computationally simple procedures to discriminate the crop sowing favorable areas at state level

Geospatial product on Area Favourable for Crop Sowing (AFCS) using multi-criteria approach



Soil moisture important data for hydrology, agriculture, environment, climate system etc.

Sources of soil moisture data

Non-spatial data

I. Insitu measurements

non-spatial data

Manual

- accurate
- inadequate coverage

Automatic systems

- calibration related issues
- large area coverage is expensive

Spatial data

Hydrological models

- Mass balance approach
- Profile level moisture
- Parameterisation of models – challenge

Satellite based

- Large area, daily coverage
- 25-50 km resolution
- Increasing popularity

Several microwave sensors

- SMRR – 1978-1987
- TRMM – TMI since 1997
- Scatterometer – ERS 1 & 2
- ASCAT – MetopA
- AMSRE – 2002-2011
- SMOS – 2009
- SMAP - 2015

Retrieval algorithms from passive systems

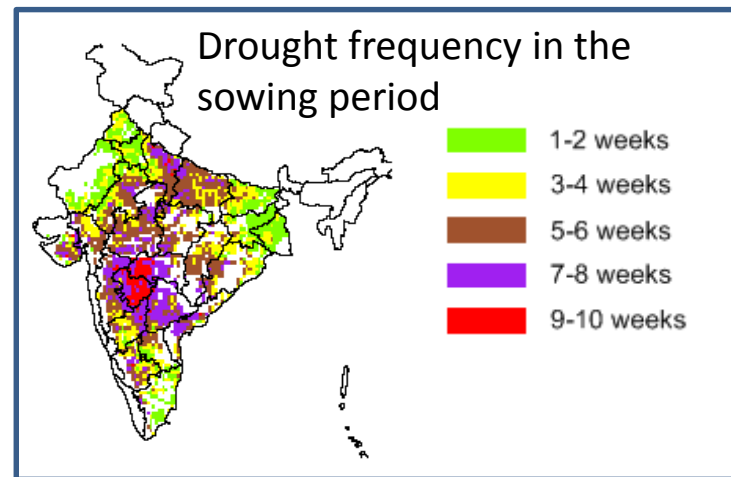
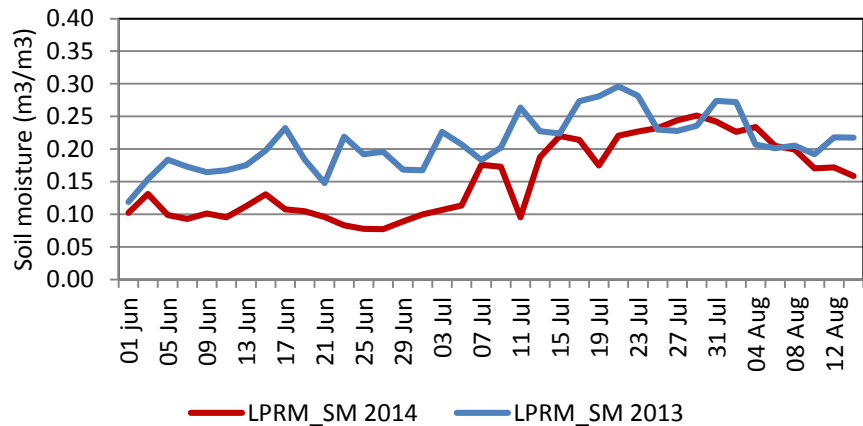
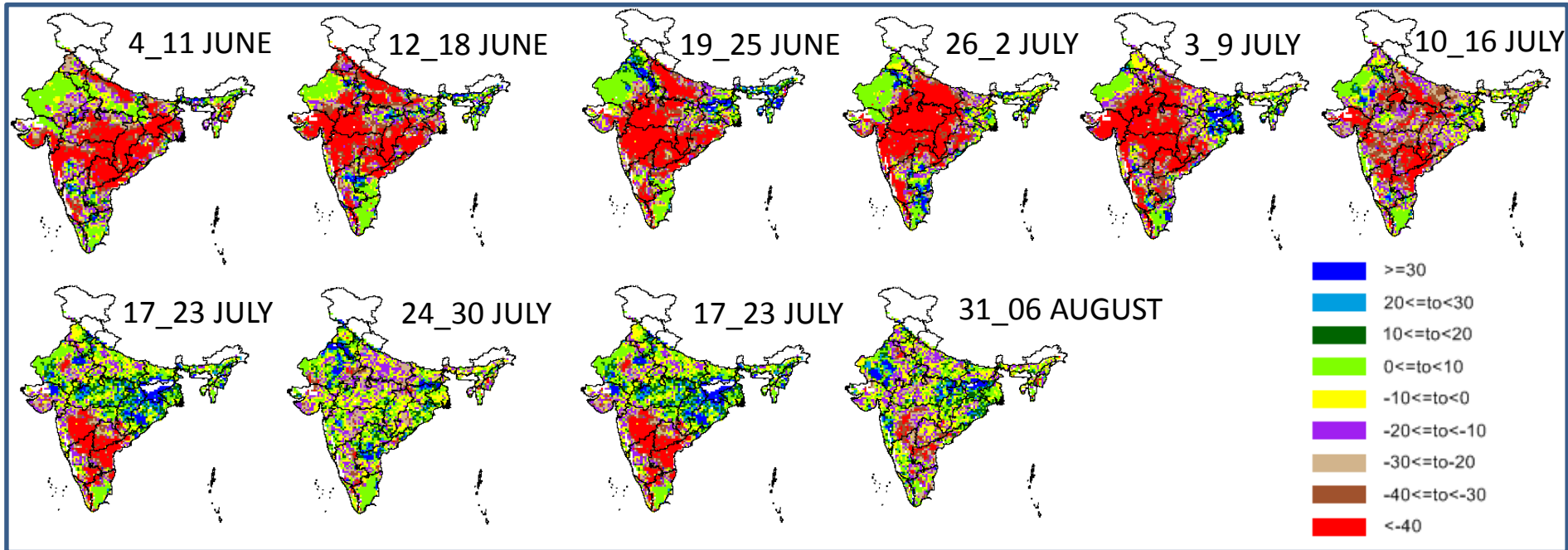
- NASA
- LPRM
- PRI

Soil moisture products from NRSC

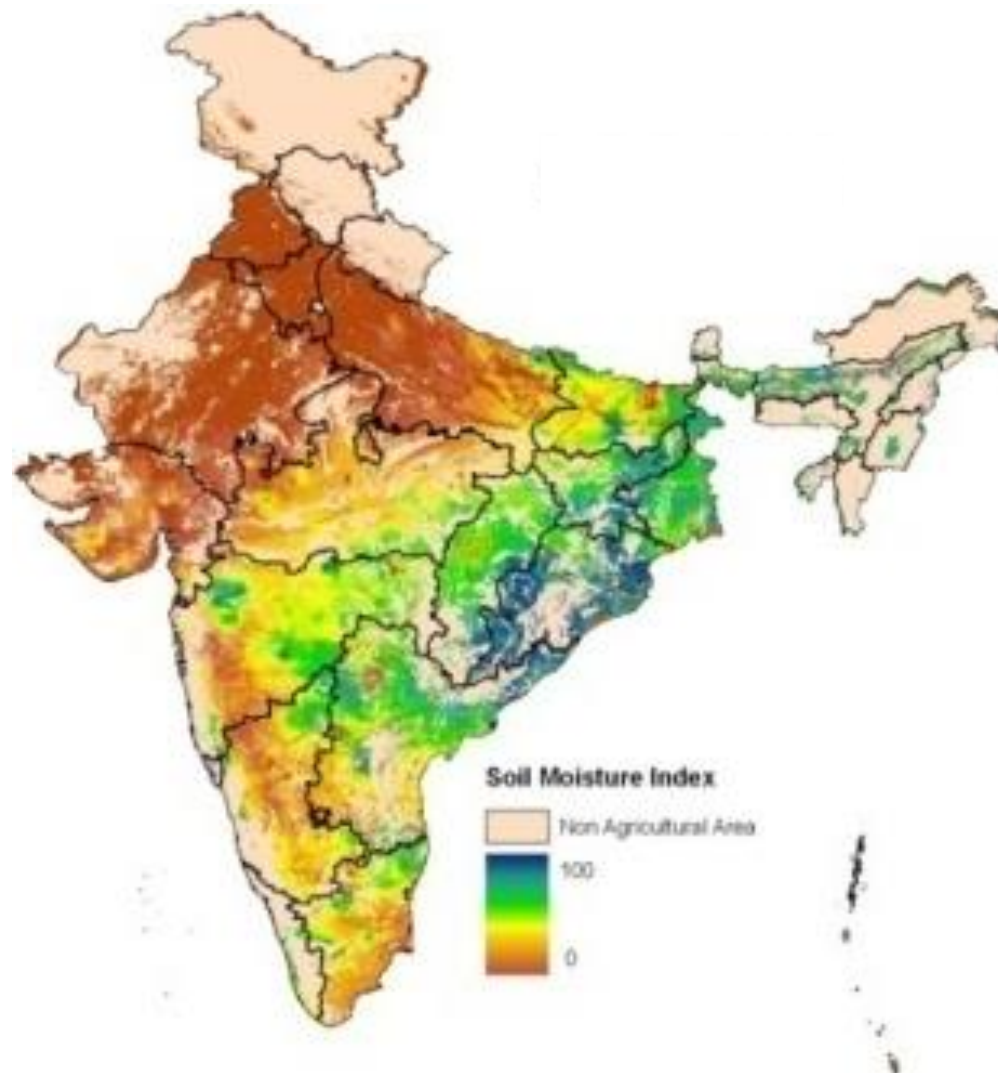
- VIC hydrological models – daily soil moisture images
- AMSR 2 LPRM soil moisture 25 km, 2 day frequency

Tracking the drought conditions of 2014 using LPRM Soil Moisture datasets of NRSC

Soil moisture deviations from normal in 2014



Soil moisture Index (Derived from Hydrological Model)



Integrated approach with multiple criteria

Mandatory indicator – rainfall reduction

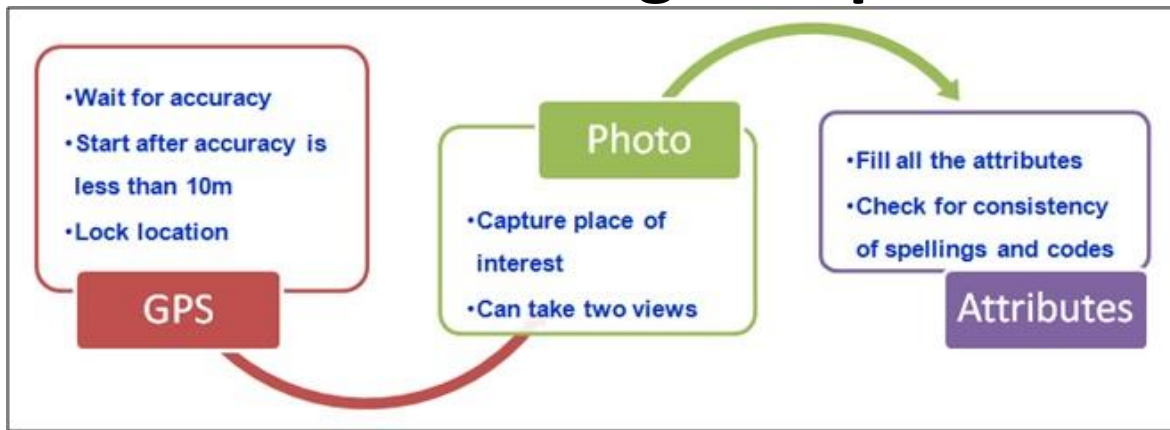
Impact indicators

- Soil moisture
- Crop condition
- Surface water storage
- Ground water levels

Drought impact assessment for relief management

- Drought declaration
- Notification of affected areas
- Field enumeration
- Relief assessment and distribution

Mobile Apps for crop field data collection for drought impact assessment



Improved field data collection system

- Real-time field data collection, robust & versatile system, automation etc.
- Surveillance of events, automated alerts generation and dissemination
- Objective enumeration system

Field Data Collection using Geo-ICT

Observation

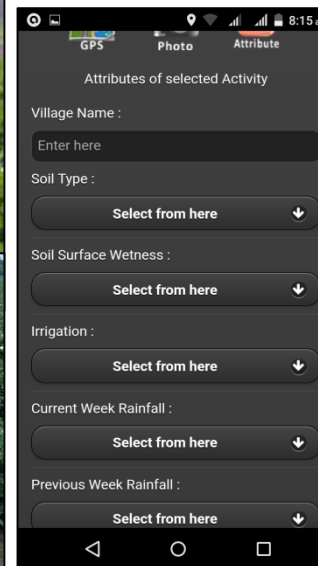
Information

Transmission

Decision

Action

Value addition and information products from field data



Agricultural drought vulnerability assessment

for long term drought management

- A quantitative and multi-dimensional approach for measuring crop-generic agricultural drought vulnerability status at sub-district level

- Vulnerability map helps visualize the hazard and act before potential damage

Agricultural Drought Vulnerability

Index (ADVI) $ADVI = EI + SI - AI$

A. Exposure component

1. Total season rainfall

2. Sowing period rainfall

3. Total season rainy days

4. Sowing period rainy days

B. Sensitivity component

1. Season's Integrated NDVI

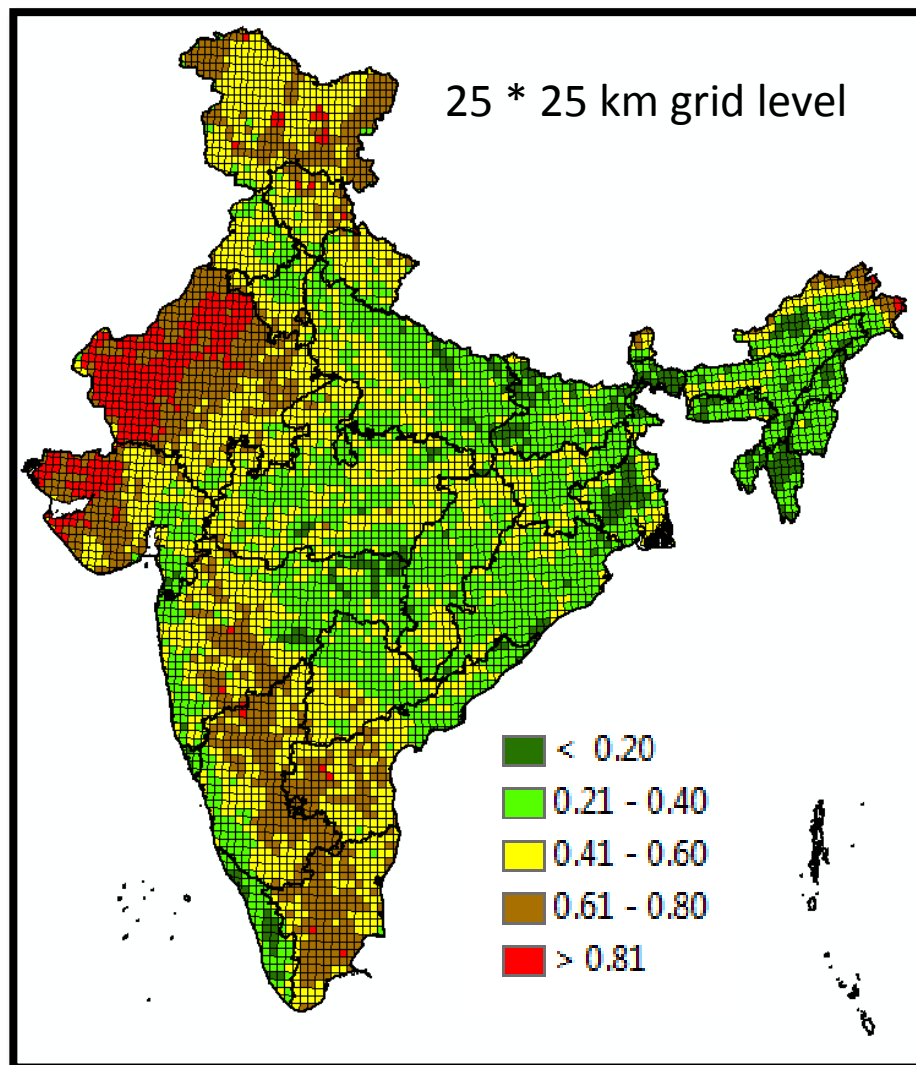
2. Season's Maximum NDVI

3. Sowing period NDVI

C. Adaptive capacity component

1. Soil

2. Irrigation support



**Visualization (22 TB) and
Free Download (110 GB)**

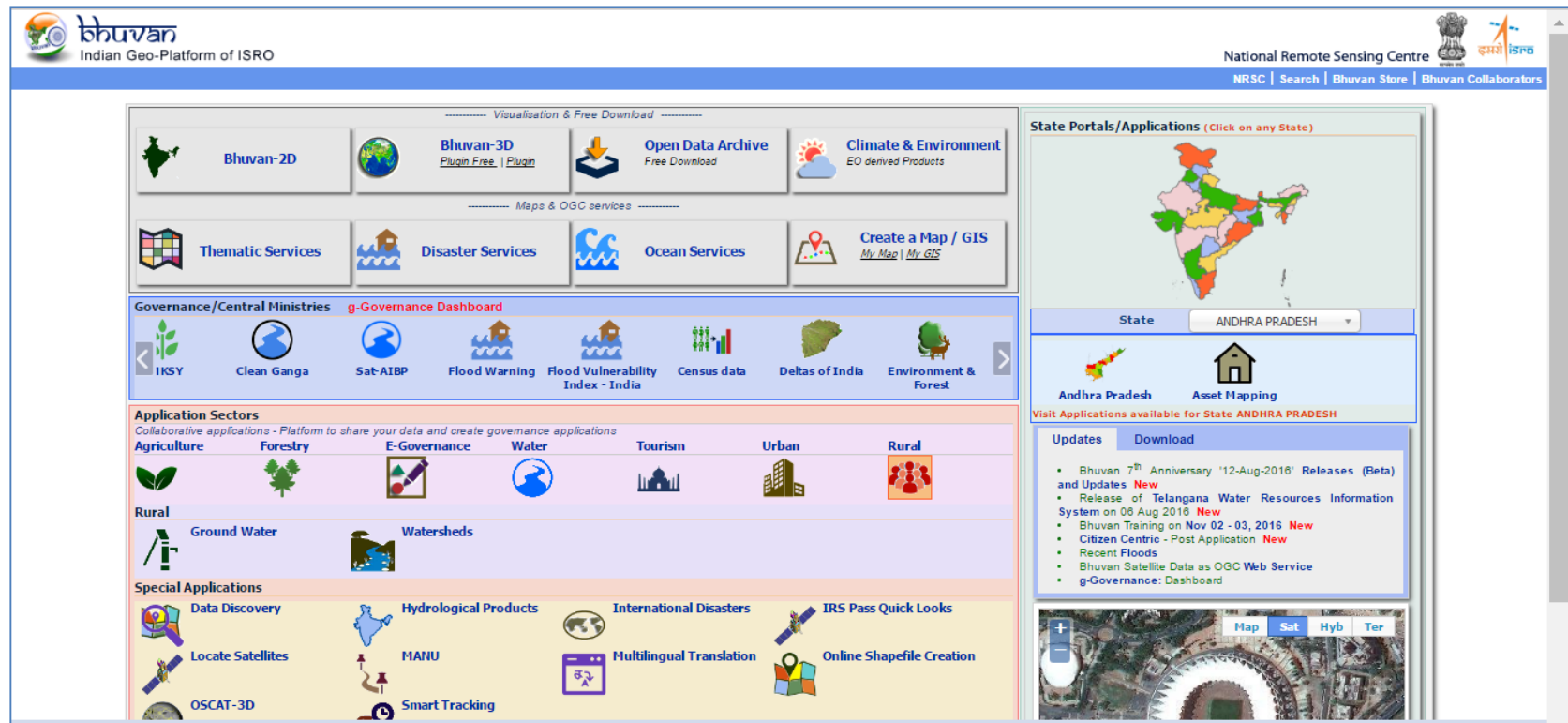
**Maps & OGC Services
(~7000+)**

Applications (200+)

State Portals (30)

**Crowd Sourcing
(25 M)**

**Mobile Apps
(61+)**



The screenshot shows the Bhuvan Indian Geo-Platform interface. At the top, it features the Bhuvan logo and the text 'Indian Geo-Platform of ISRO'. On the right, it displays the 'National Remote Sensing Centre' logo and the text 'NRSC | Search | Bhuvan Store | Bhuvan Collaborators'. The main content area is divided into several sections:

- Visualization & Free Download:** Includes links for Bhuvan-2D, Bhuvan-3D (Plugin Free, | Plugin), Open Data Archive (Free Download), and Climate & Environment (EO derived Products).
- Maps & OGC services:** Includes links for Thematic Services, Disaster Services, Ocean Services, and Create a Map / GIS (My Map | My GIS).
- Governance/Central Ministries g-Governance Dashboard:** Includes links for IKS, Clean Ganga, Sat-AIBP, Flood Warning, Flood Vulnerability Index - India, Census data, Deltas of India, and Environment & Forest.
- Application Sectors:** Includes links for Agriculture, Forestry, E-Governance, Water, Tourism, Urban, and Rural.
- Rural:** Includes links for Ground Water and Watersheds.
- Special Applications:** Includes links for Data Discovery, Hydrological Products, International Disasters, IRS Pass Quick Looks, Locate Satellites, MANU, Multilingual Translation, OSCAT-3D, Smart Tracking, and Online Shapefile Creation.
- State Portals/Applications:** Includes a map of India and a dropdown menu for selecting a state (currently set to ANDHRA PRADESH). It also includes links for Andhra Pradesh and Asset Mapping.
- Updates:** Includes a list of recent updates and releases, such as 'Bhuvan 7th Anniversary '12-Aug-2016' Releases (Beta) and Updates New', 'Release of Telangana Water Resources Information System on 08 Aug 2016 New', 'Bhuvan Training on Nov 02 - 03, 2016 New', 'Citizen Centre - Post Application New', 'Recent Floods', 'Bhuvan Satellite Data as OGC Web Service', and 'g-Governance: Dashboard'.

**2009
Visualisation**

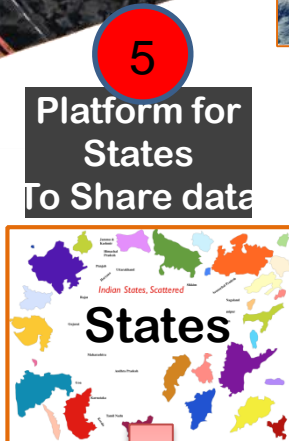
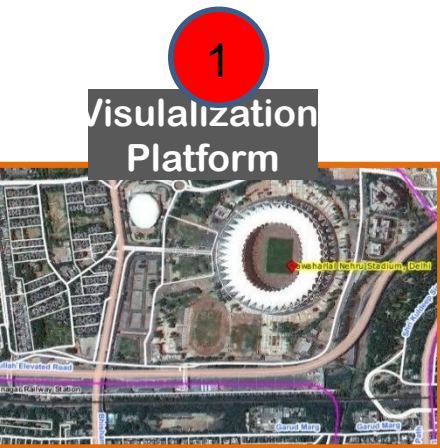
**2012
Mashups**

**2015
Platform**

**2017
1m Data**



Bhuvan : The Platform with Diverse Application Potential



Registered users : > 1.5 lakhs
Download: > 1 TB per month

Unique visitor : 7.0 lakhs / month
Location info. : > 10 million



- Adopting an integrated approach with multiple indices
- Satellite indices are part of the system
- States establishing Drought Monitoring Centres
- Enhancing the density of weather stations
- Institutional participation
- R & D efforts are in parallel