Agricultural Drought; Assessment and Monitoring using Geospatial technologies

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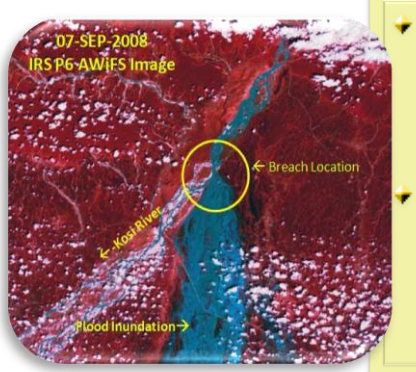
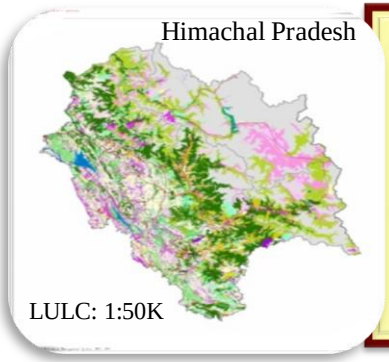
NATIONAL REMOTE SENSING CENTRE (NRSC), ISRO
Key Performance Areas

- End-to-end operations of Ground Segment for IRS Satellite Constellation
- Exclusive entity for Remote Sensing Data Dissemination in India for Civilian Sector



- Providing Space-based Disaster Management Support
- Primary responsibility for National Database for Emergency Management



- Lead organization in the country for National Remote Sensing Application Missions
- Responsible for NR Mgmt Information Products and Value Added Services

- Capacity Building and outreach in Geospatial Technologies
- Hosting a UN Regional Centre for Asia-Pacific (CSSTE-AP)

- Sole civilian Aerial Remote Sensing Data and Services Provider in India
- Dedicated Aircraft System for Disaster Management Support

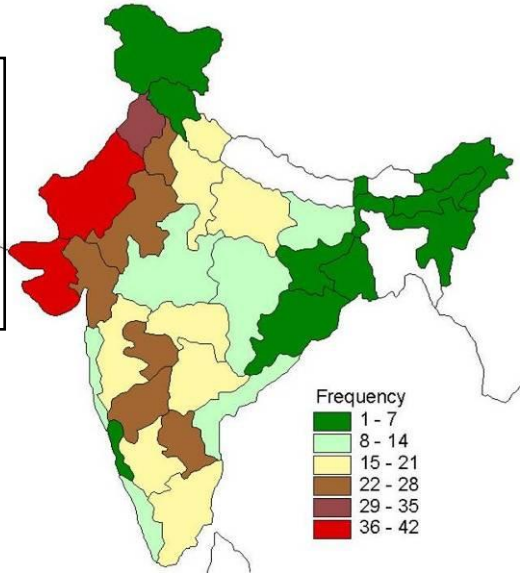
- R&D : ISRO-GBP, RESPOND, TDP
- EOAM: RISAT, MOP
- Outreach: Web Enabled Services (INFFRAS, WALIS, iBIN, VRC)
- Promotional Activities

Drought – a silent threat to rural economy

Agriculture – the immediate victim of drought

- 70% of population depend on agril.
- 68% of net sown area(142.2 M ha) is drought prone
- 50% of drought prone is severe in nature

Geographical Area
328.7 M ha
Net Sown Area
142.2 M ha
Net Irrigated Area
55.10 M ha



Consequences of crop failure

unemployment

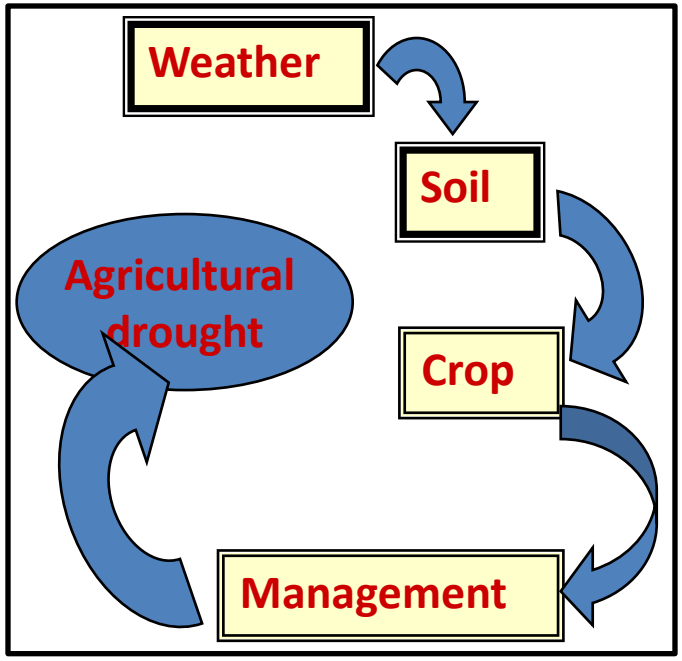
Cattle - starvation

Fodder shortage

Non agricultural impact:
Drinking water shortage

Understanding Drought

Meteorological drought:	reduced rainfall	met. indicators
Hydrological drought:	reduced surface water	hydrological indicators
Agricultural drought:	reduced soil moisture	crop stress indicators



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

Drought Management

Short term Management

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

Long term Management

- Vulnerability maps
- Risk maps
- Prioritization
- Impact monitoring

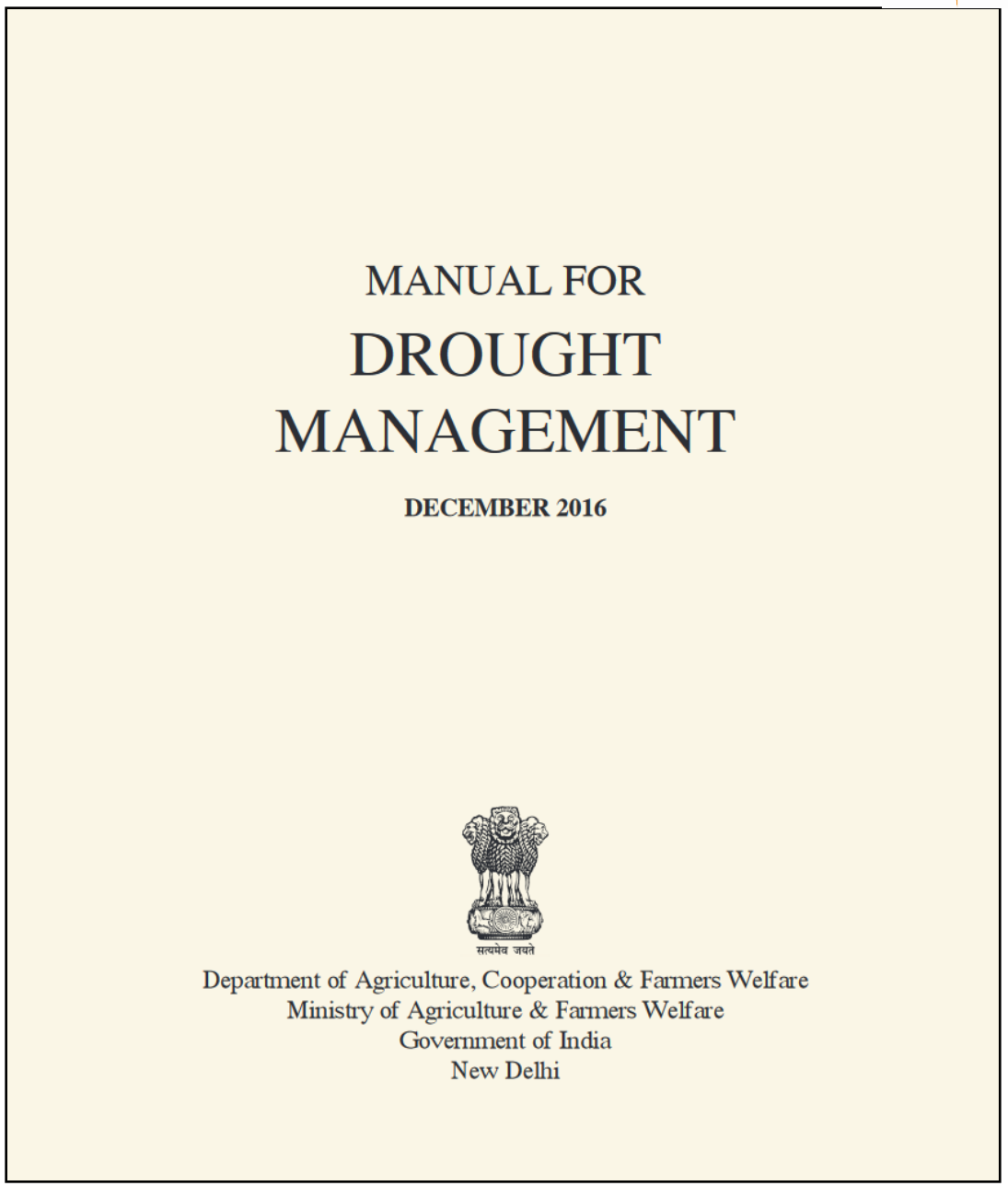
Guidelines for drought management in India

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
- Drought declaration protocols
- Relief management
- Long term measures
- Training to states


MANUAL FOR

DROUGHT MANAGEMENT

DECEMBER 2016

सत्यमेव जयते

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

Agricultural Drought

Causative factors

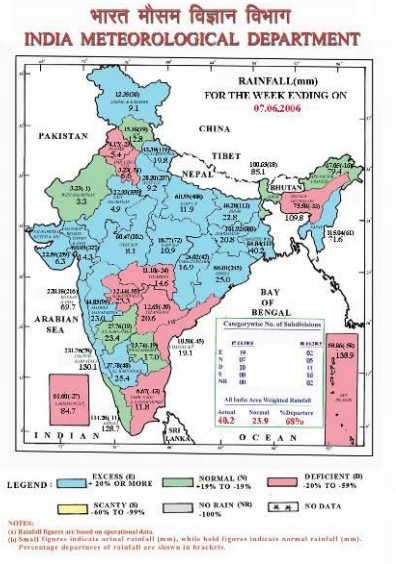
- Deficit rainfall
- Deficit Soil moisture
- Rise in temperature
- Rise in water demand

Effect on agriculture

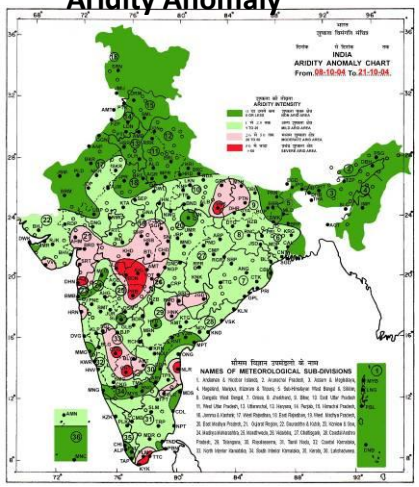
- Delayed sowings
- Reduced sown area
- Poor germination
- Stressed crops
- Loss of crop yield

Indian Meteorological Department

Met. Drought season – if rainfall is less than 75 % of normal



Aridity Anomaly



- Sparse observations
- Sharp variability in weather
- Physical nature of parameters partly related to biological nature of crops.

State Depts. of Agriculture/Revenue/Relief

Weekly reporting of information

- Rainfall
- Crop sown areas (delay in sowings/reduction in sown area)
- Reservoir levels
- Manually observed agricultural situation at district/sub district level

- Non spatial and subjective manual observations.
- Inconsistency w.r.t to data collection and availability among the states.
- No uniform criteria for drought assessment/drought declaration

Meteorological indicators

Rainfall – in season

+/- 20 % dev. Normal

-20 to -60 % Deficit

<-60 % dev. Scanty

SPI Values	
2.0+	extremely wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

Rainfall – most common indicator

Standardized Precipitation index (SPI)

Indicators based on water balance

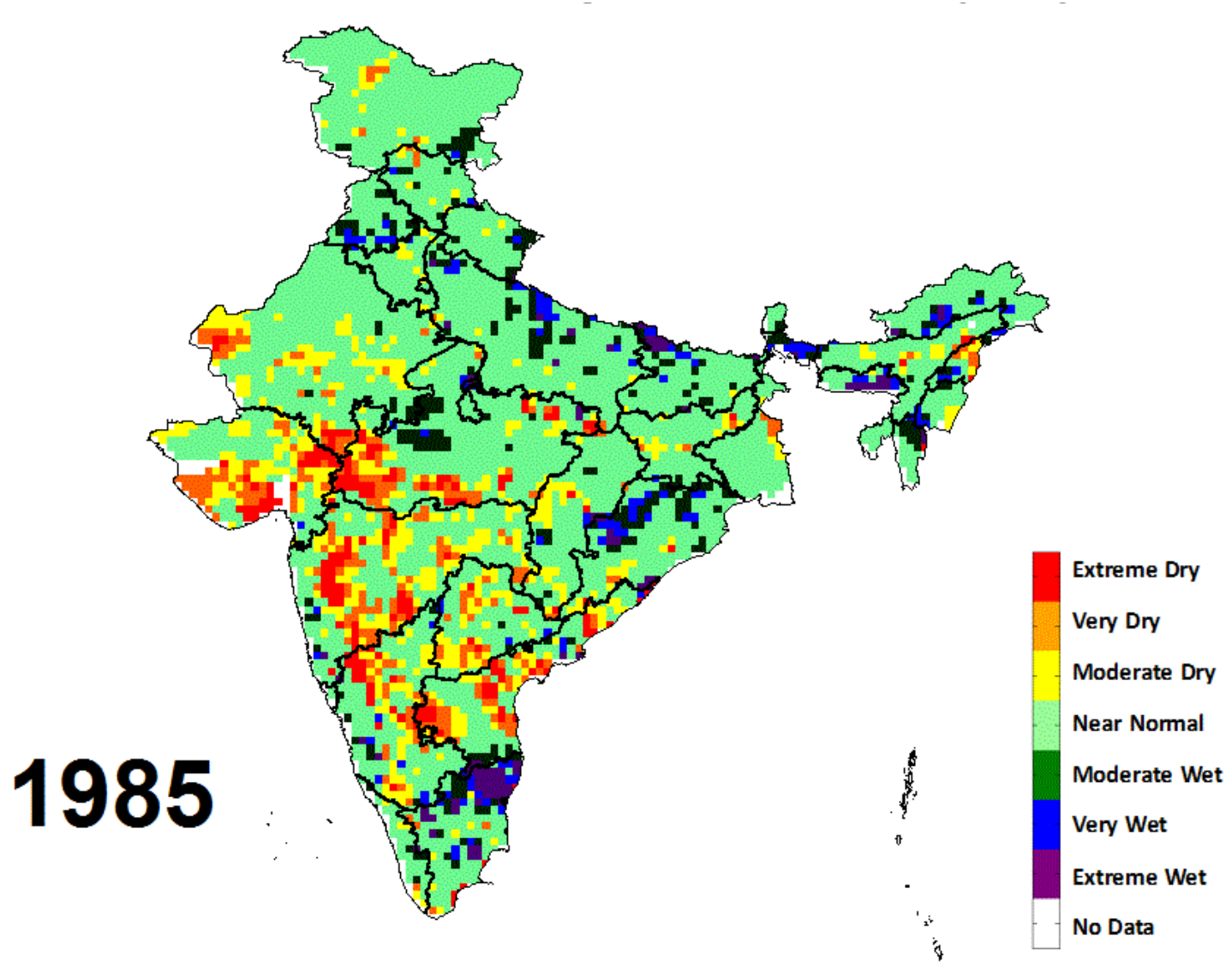
- **Palmer drought severity index**
- **Moisture Adequacy Index (MAI)**
- **Aridity Index and its anomaly**

Palmer Classifications	
4.0 or more	extremely wet
0.5 to 0.99	incipient wet spell
0.49 to -0.49	near normal
-0.5 to -0.99	incipient dry spell
-1.0 to -1.99	mild drought
-2.0 to -2.99	moderate drought
-3.0 to -3.99	severe drought
-4.0 or less	extreme drought

MAI Values	
76-100	No drought
50-75	mild
25-49	moderate
< 25	severe

Aridity anomaly	
0	Non arid
1-25	mild
25-50	moderate
>50	severe

Standardized Precipitation Index (SPI)



Hydrology indicators

Reservoir Storage Index

- Water levels in reservoirs in different years
- Surface water bodies mapping – water spread area
- Runoff index using hydrological models

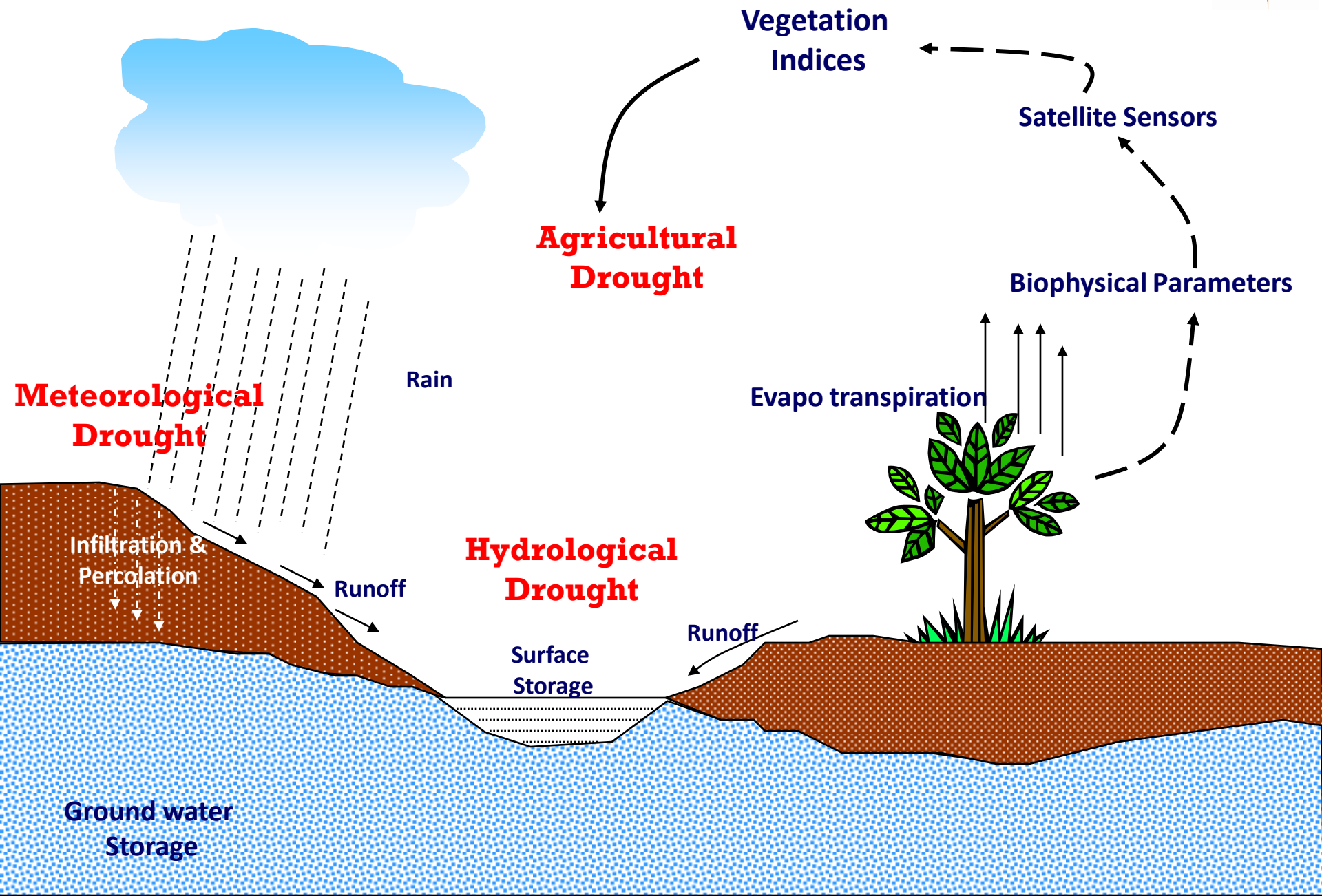
Ground water index

- Observation wells – water level data

Agricultural drought indicators

- Extent of reduction in crop planted area
- Extent of delay in crop planted area
- Crop stress at different growth states
- Crop yield loss

AGRICULTURAL DROUGHT – Satellite indices



National Agricultural Drought Assessment and Monitoring Systems (NADAMS)

Conceptualisation, development, operational services and institutionalisation of a remote sensing application project

Trajectory of NADAMS project- Development and operational services

Institutionalisation phase

2012+

2009+
- New approach for sowing-period drought assessment
- Geospatial products on soil mositure and rainfall
- New Indices – Shortwave Angle Slope Index

2004+
- Use of multiple indices
- IRS AWiFS based sub-district level assessment
- Decision rules for drought warning & declaration
- Enhanced content & frequency of reporting
- Institutional participation & Capacity building

2002+
- Supplementation of WiFS with MODIS
- Agricultural area monitoring
- Increased number of indices

1998+
- IRS WiFS based district / subdistrict level assessment
- Participation of user departments

1989 +
- Operational Services from NRSC
- NOAA AVHRR
- Regional/district level assessment
- Prevalence, intensity and persistence of agricultural

1988
- Conceptualization of NADAMS project at NRSC
- Development of Methodology

NADAMS Project
A success story of Institutionalization

- Institutional Arrangement at Ministry of Agriculture, GOI
- Creation of MNCFC
- Transfer of NADAMS project to MNCFC April 2012
- Enhanced end-use of NADAMS project

NADAMS)

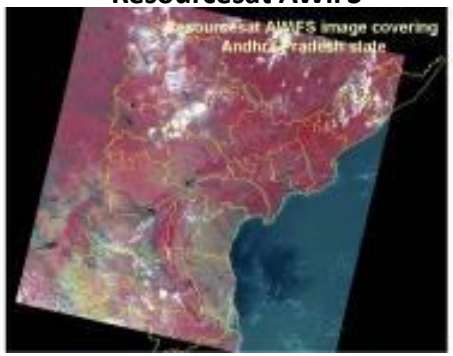
Coverage

Satellite data analysis – Resourcesat, Oceansat, NOAA, Terra, Aqua

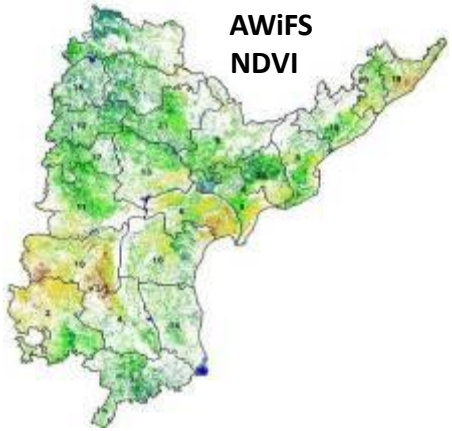
Agricultural drought assessment

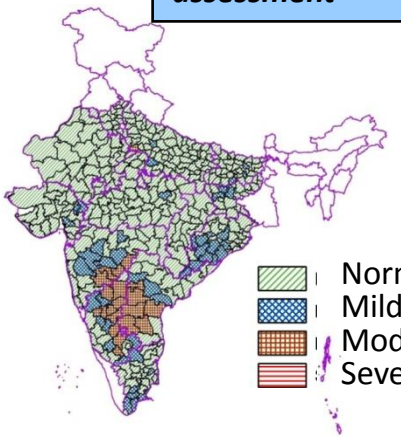
- District level
- Sub-district level

Resourcesat AWiFS

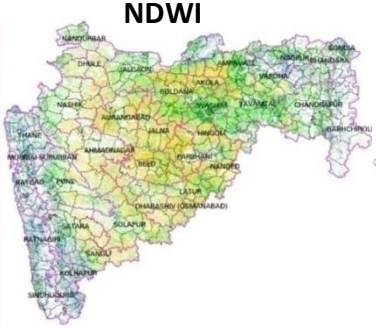


AWiFS NDVI

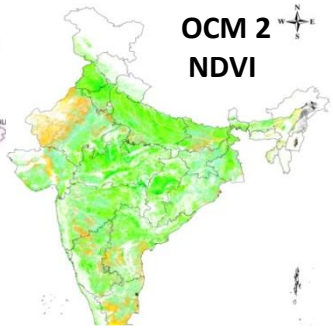




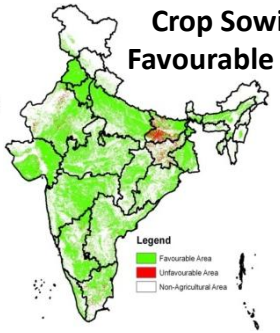
NDWI



OCM 2 NDVI



Crop Sowing Favourable Area



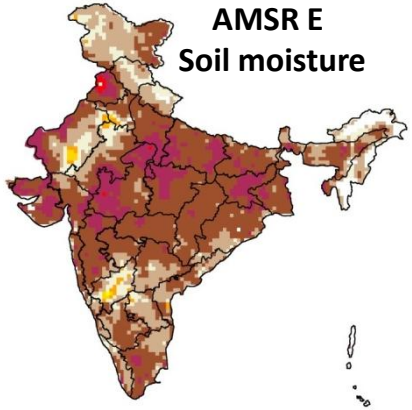
Satellite derived Indicators/information

- NDVI
- NDWI/LSWI
- EVI
- SASI
- AMSR E soil moisture

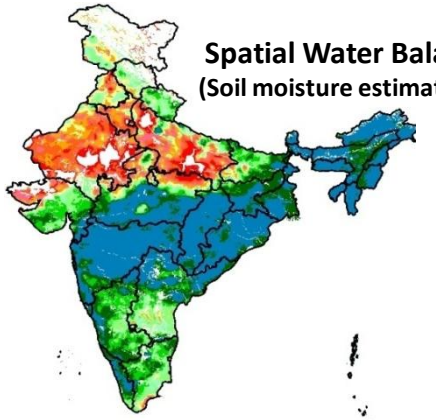
Ground data

- Soil
- Rainfall
- Sown area
- Cropping pattern
- Irrigation support

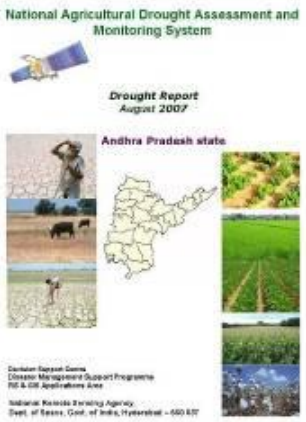
AMSR E Soil moisture



Spatial Water Balance (Soil moisture estimation)



Information reporting



- Ministry of Agriculture
- State Depts. of Agril and Relief
- Scientific Organizations

End use:

- Crop contingency plans
- Drought declaration

Strengths of NADAMS project

- Data from multiple satellites
- Combination of indices for assessment
- Strong ground data base
- Sub-district level assessment
- Objective and user friendly information
- Positive feedback from the User departments

Commonly used satellite indices

- ✓ Spectral response in V, NIR region
- ✓ Spectral response in the SWIR region
- ✓ Thermal response
- ✓ Mainly using data from polar orbiting satellites
- ✓ Process based indices – not operational
- ✓ Weak forewarning and preparedness capability

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.

LSWI/NDWI

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

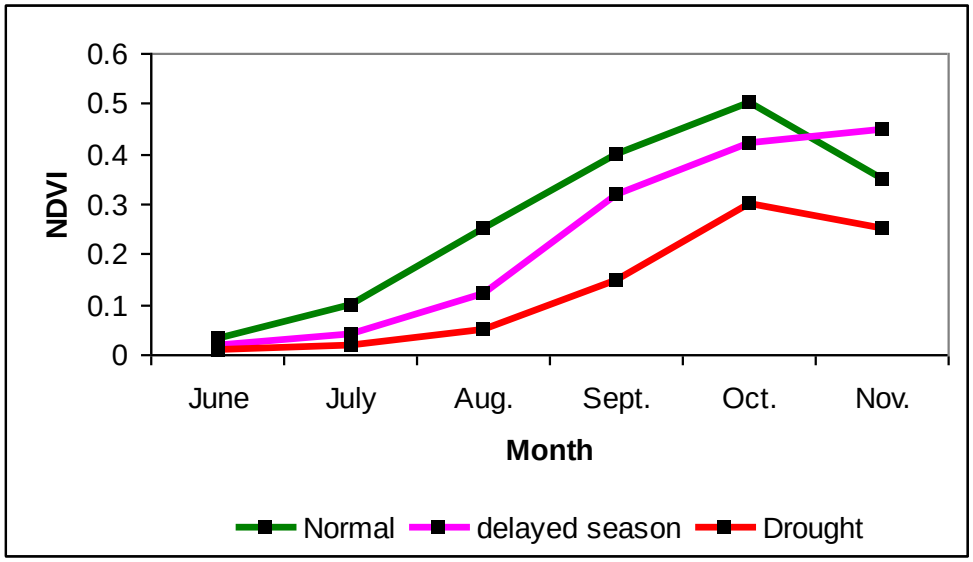
a) Overcomes limitations of either one
b) amplifies anomalies and
c) more responsive to ground situation

NDVI response to Agricultural Drought

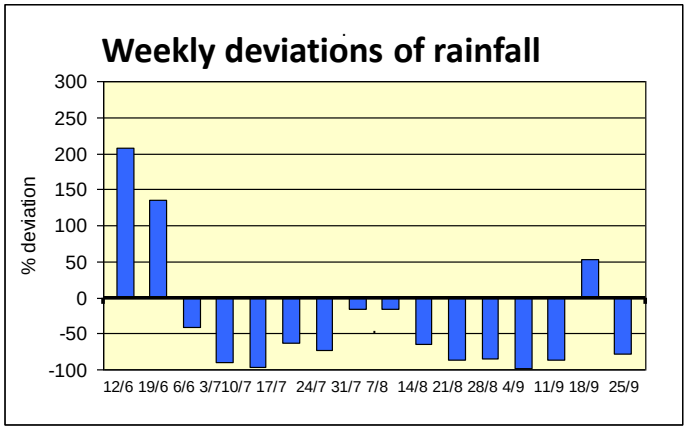
Integration with ground data

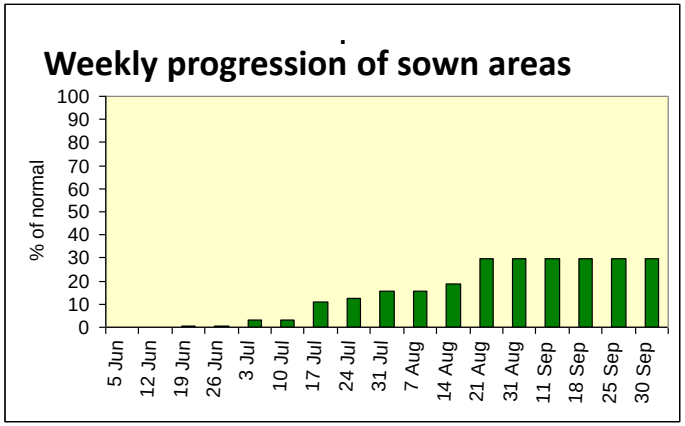
Tie up with ground depts.

Seasonal NDVI profiles for drought assessment



(1) relative deviation from normal,
(2) vegetation Condition Index,
(3) in season rate of transformation





Data availability

Satellites	Sensor	Spatial resolution	Temporal resolution	Swath
Resourcesat	AWiFS	56 m	5 days	750 km
	LISS III	23 m	26 days	140 km
LANDSAT 8	OLI	30 m	16 days	185 km

Satellite/ Sensor	Indices
NOAA AVHRR (1km)	NDVI
Oceansat 2- OCM (360m)	NDVI, ARVI
Terra MODIS (500 m)	SASI, NDWI
Terra AMSRE (25 km)	Soil moisture
INSAT 3A CCD (1 km)	NDVI

Data in public domain for drought assessment

- Rainfall –

IMD, INSAT, CPC, TRMM

- Soil Moisture – AMSR2
- PET – NOAA
- Temperature – MODIS LST
- Vegetation Indices –

MODIS, OCM, SPOT, AVHRR etc

- Satellite data free downloads – Resourcesat, MODIS..

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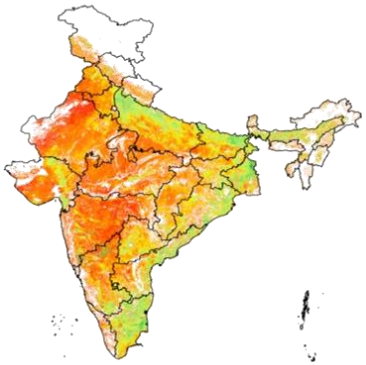
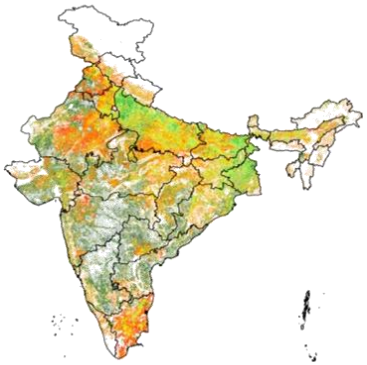
Fortnightly NDVI Composites of Resourcesat-2 AWiFS over kharif crop area

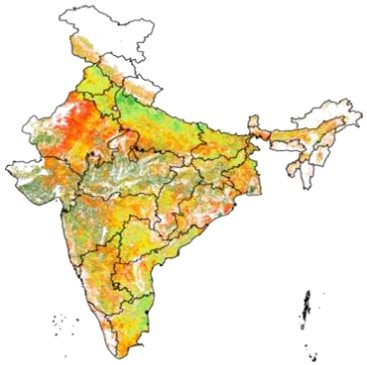
Jun 01-15, 2016



Jun 16-30, 2016



Jul 01-15, 2016



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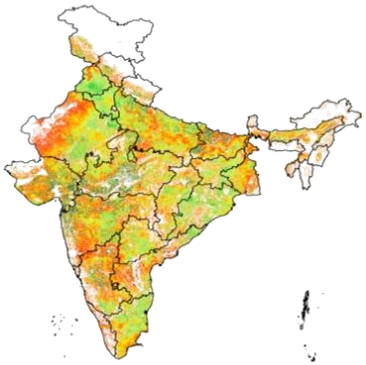

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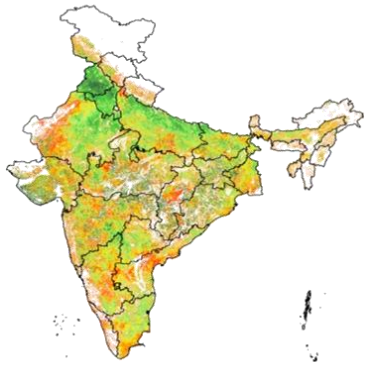
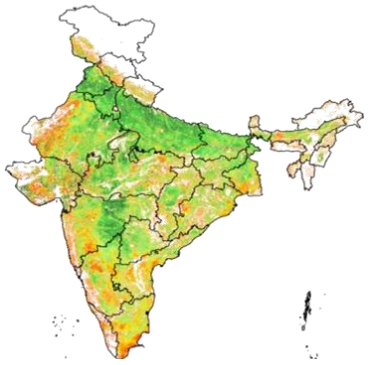
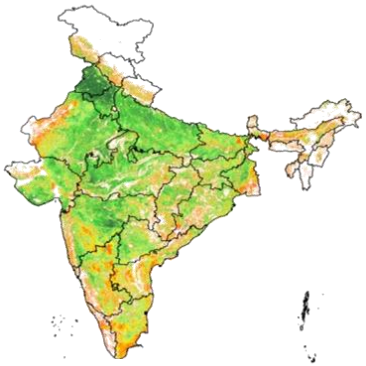


Aug16-30, 2016



Sep 01-15, 2016



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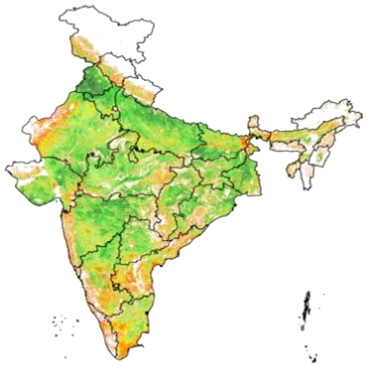

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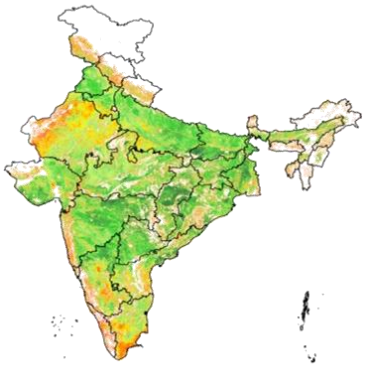
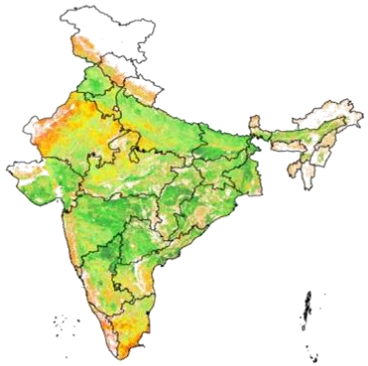
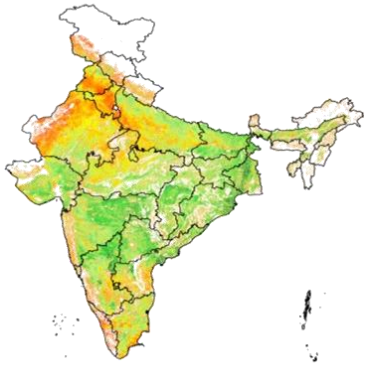


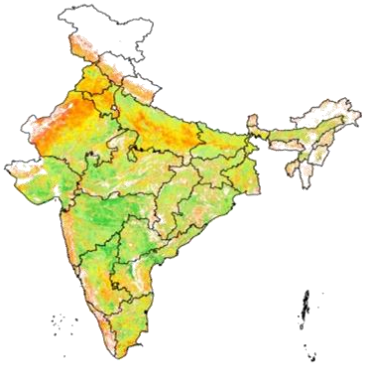
Oct 15-31, 2016



Nov 01-15, 2016



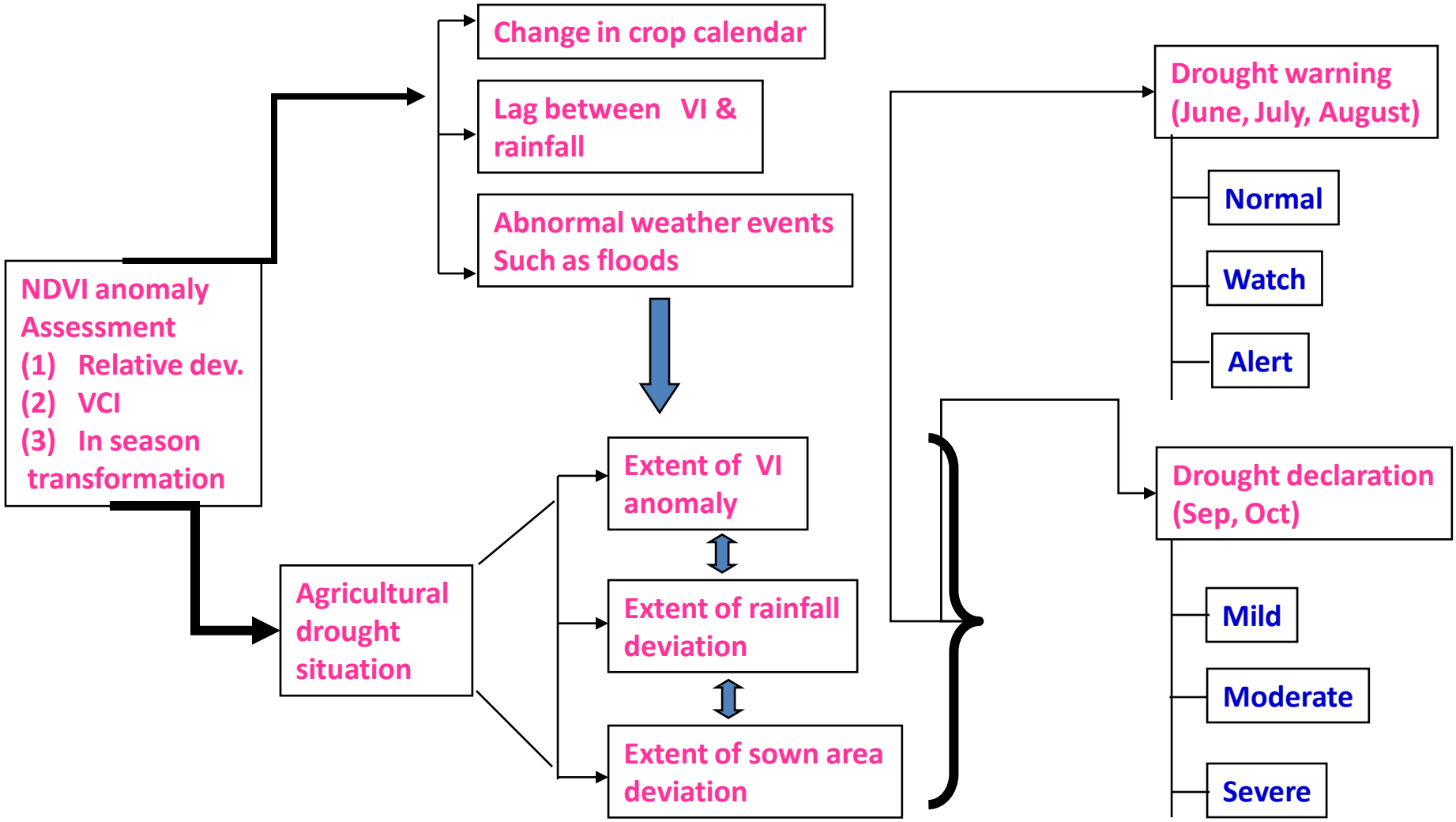
Nov15-31, 2016



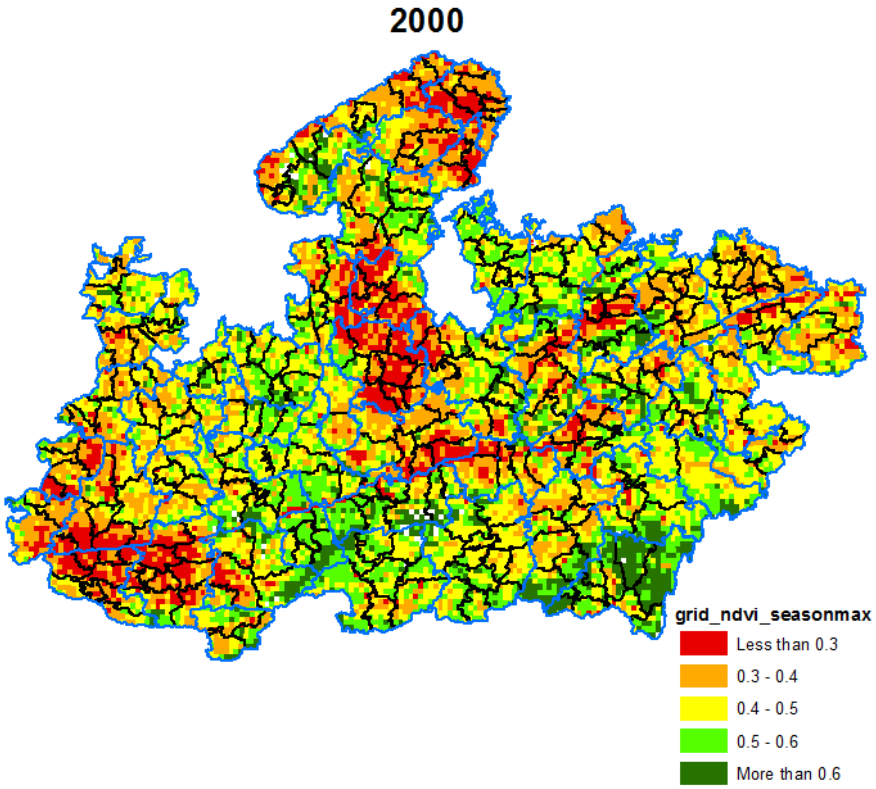
Increasing NDVI (greenness)

Non-crop area

Methodology for agricultural drought assessment



Interpretation of NDVI changes to a Agricultural drought



NDVI anomaly

% dev. from normal

(actual NDVI-normal NDVI)/normal NDVI*100

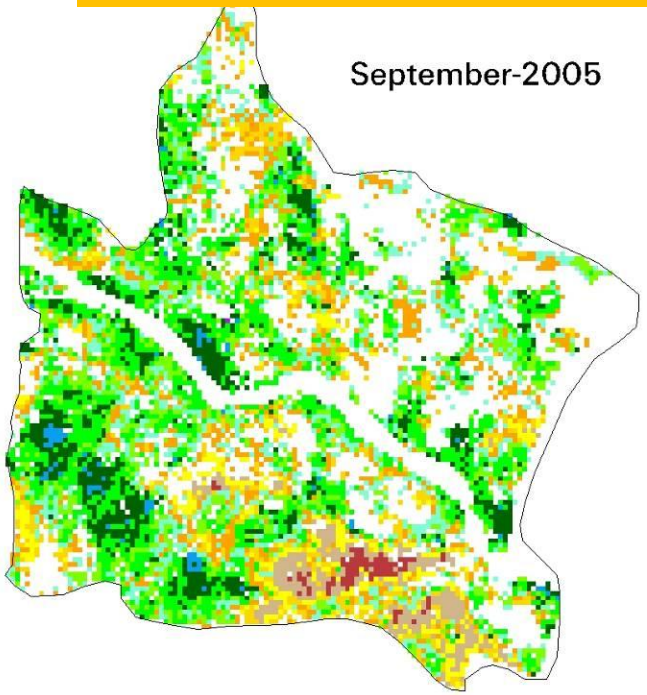
Selection of normal year – average of recent past normal years

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

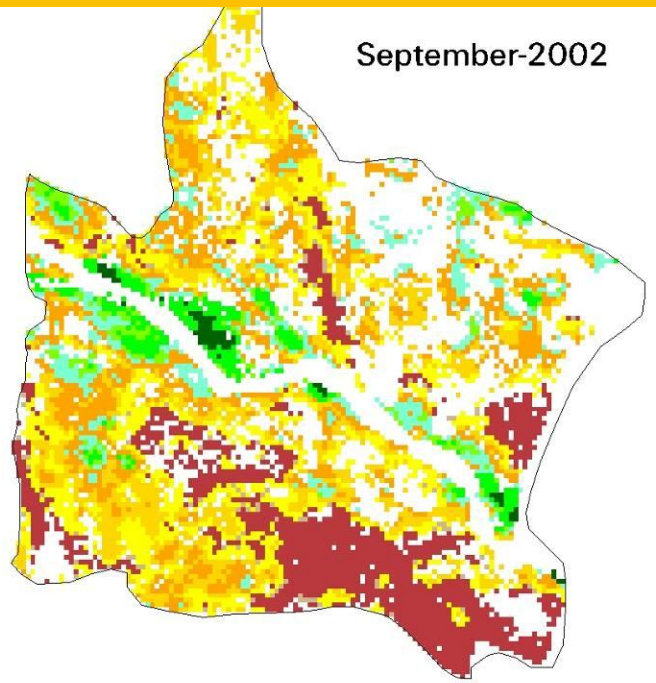
Thumb rule:
> 20% reduction in NDVI – drougt conditions

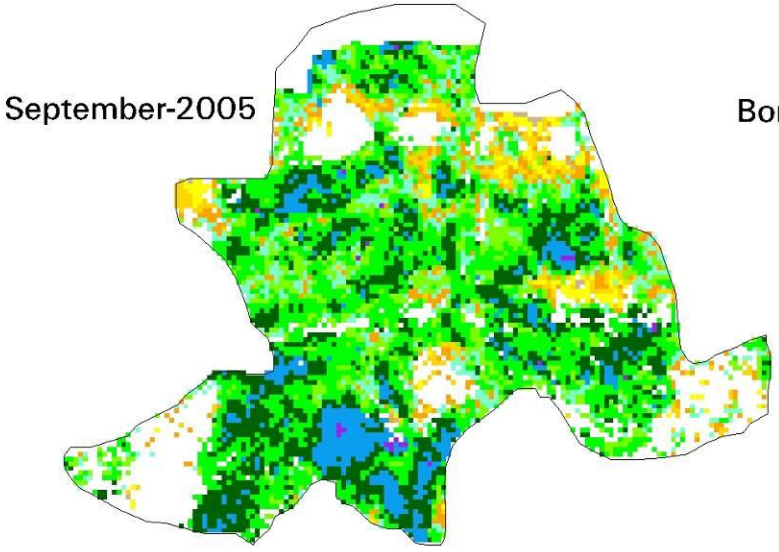
>30% reduction indicate moderate to severe drought conditions

Block level crop condition – Anantpur district
Comparison between normal year (2005) and drought year (2002)

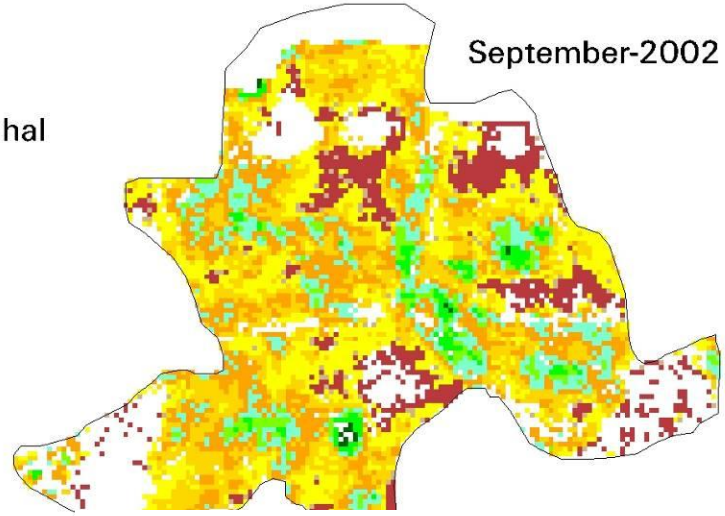


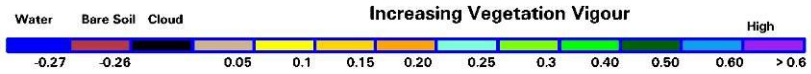
Tadpatri





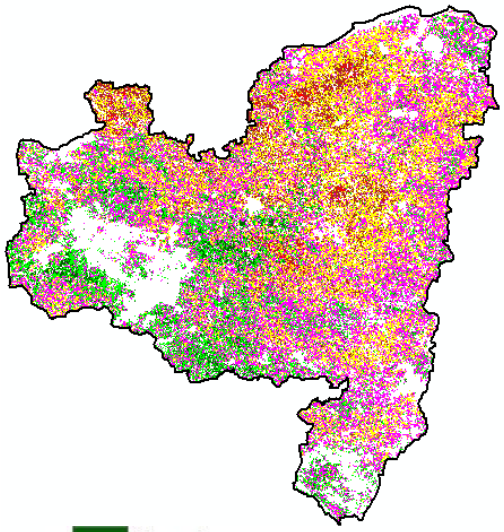
Bommanahal

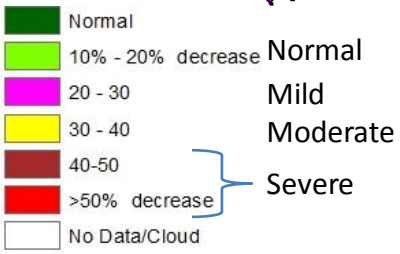


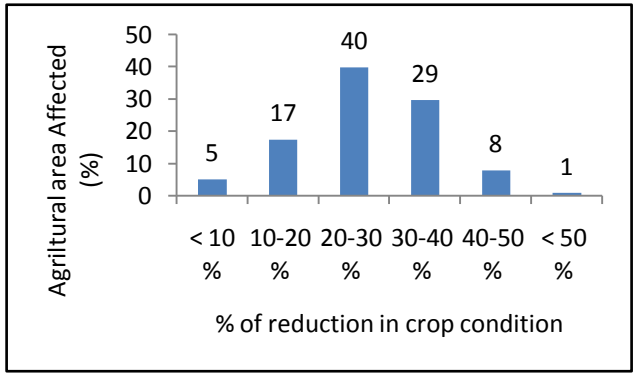


Crop area affected by drought in kharif 2015, West Bengal

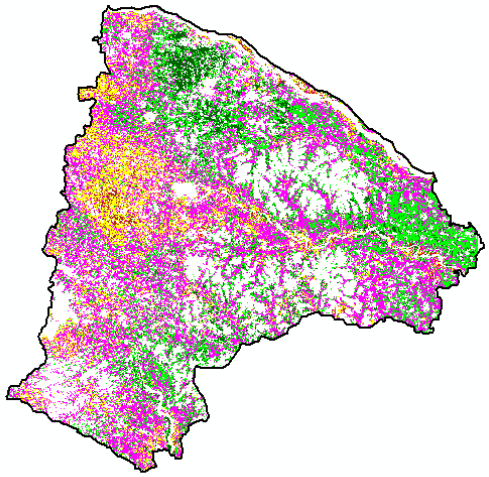
Purulia district

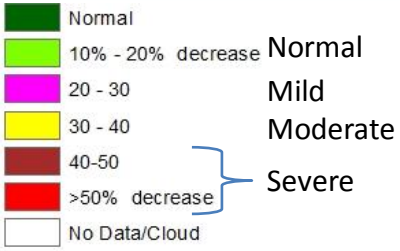


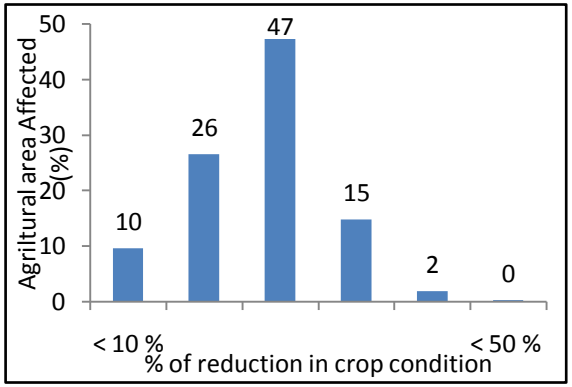




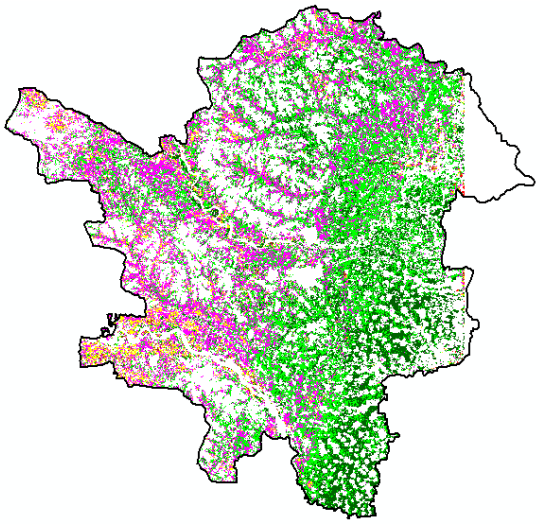
Bankura district

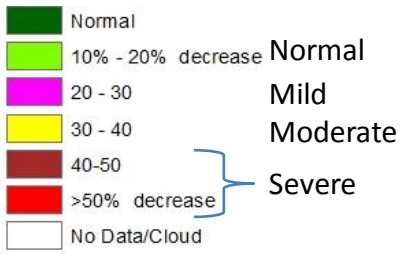


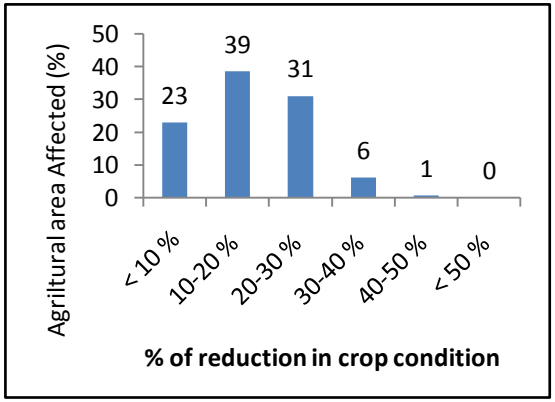




West Midnapur district

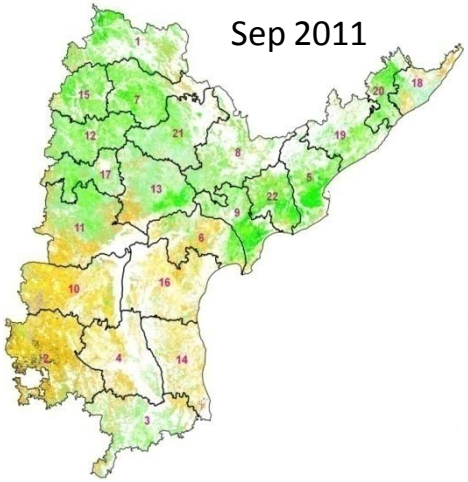




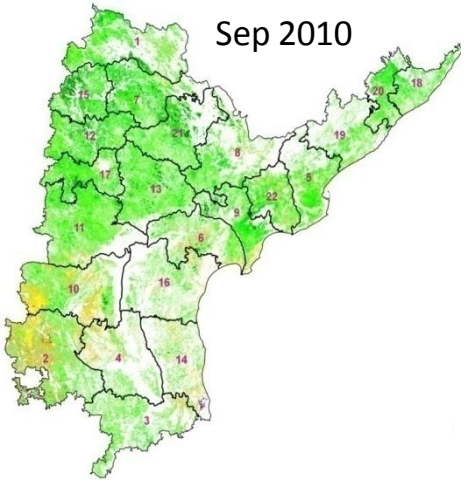


AWiFS derived crop condition anomalies showing agricultural drought situation in Andhra Pradesh, kharif 2011

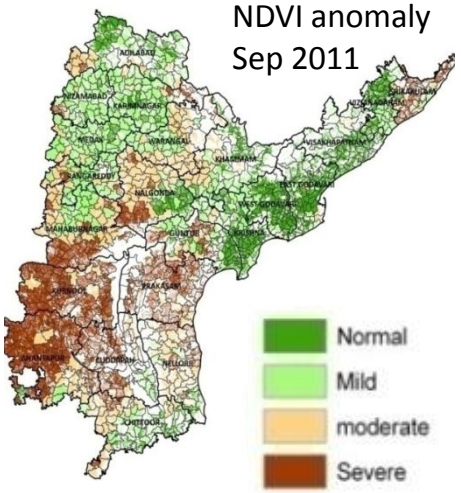
Sep 2011



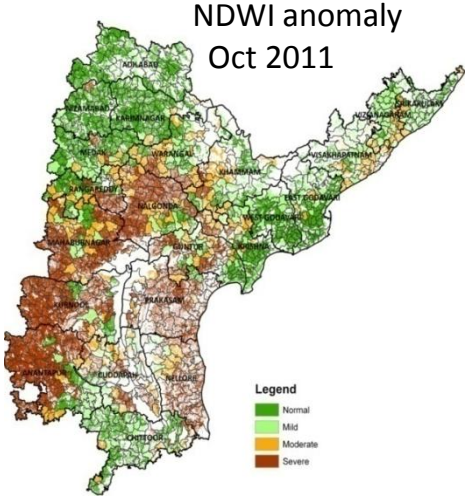
Sep 2010

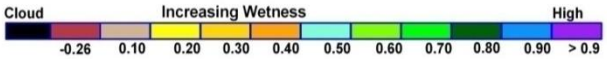


NDVI anomaly Sep 2011

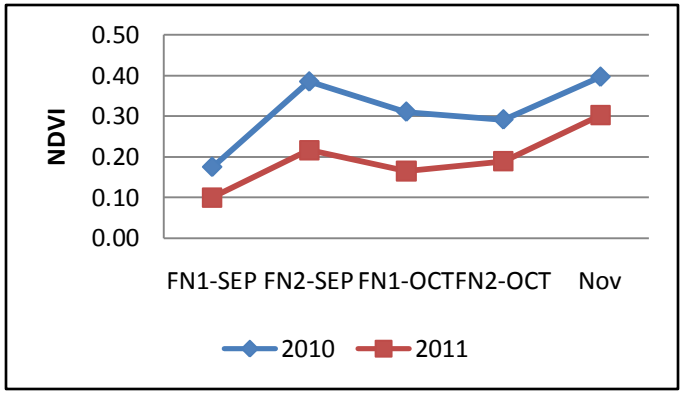


NDWI anomaly Oct 2011

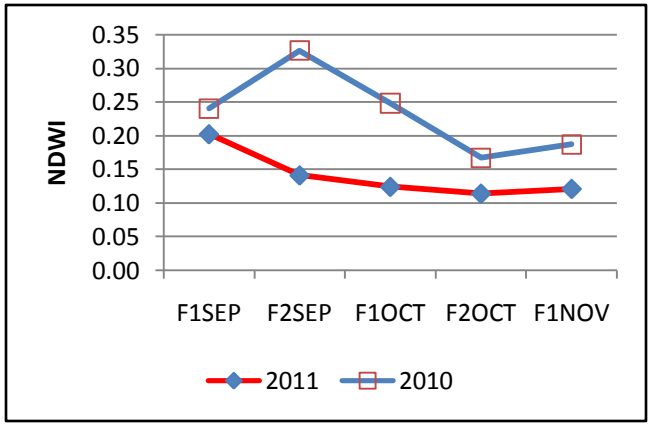




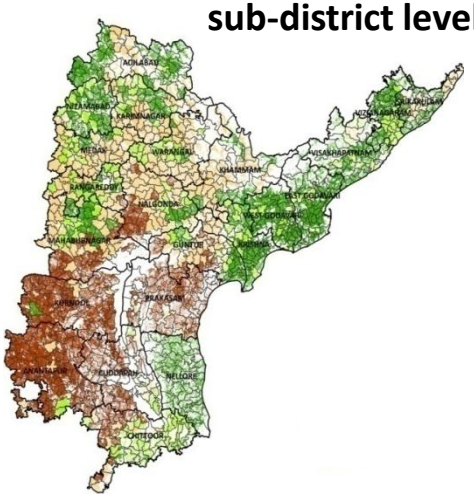
NDVI - Roddam mandal, Anantpur

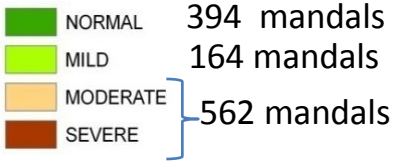


NDWI - Roddam mandal, Anantpur

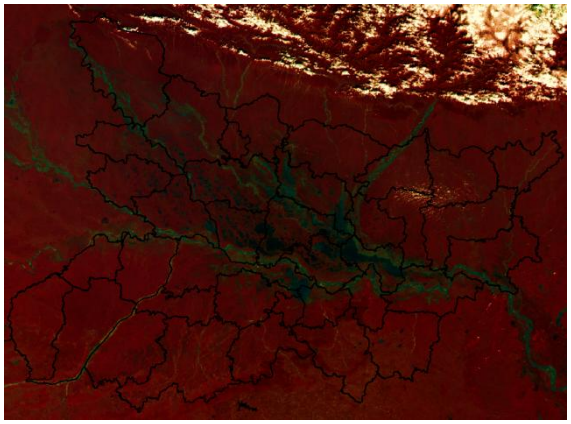


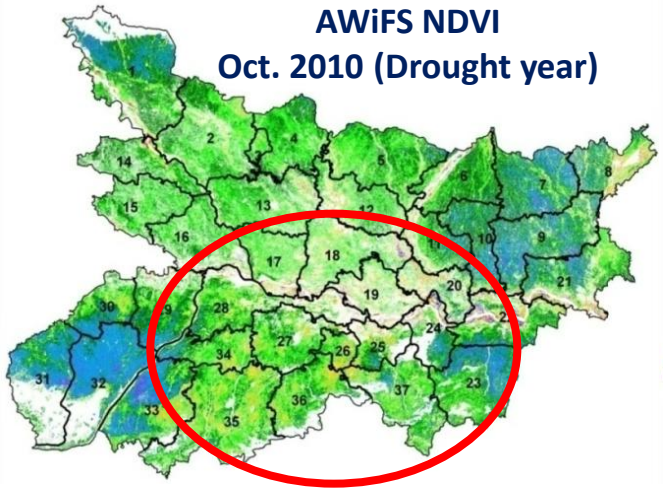
Assessment at sub-district level

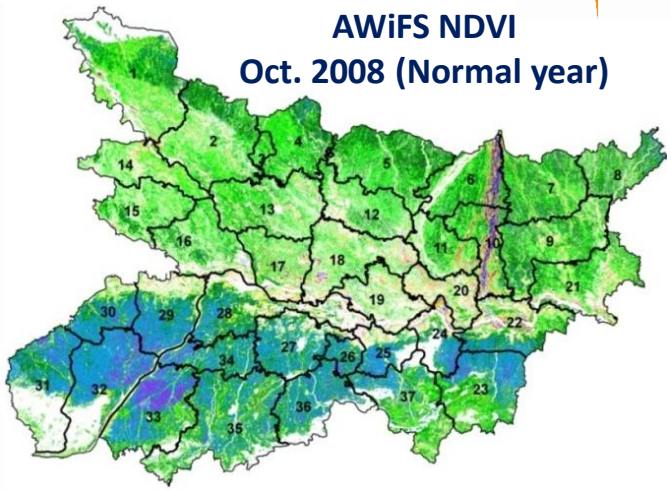


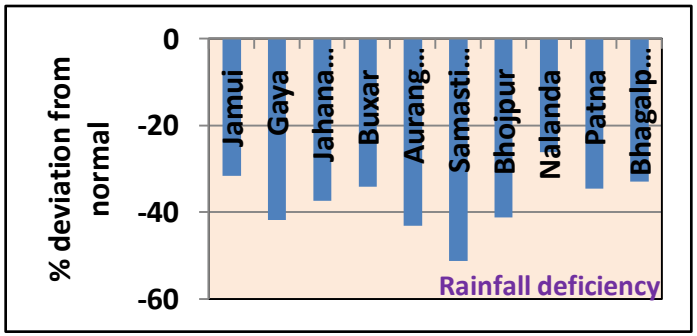


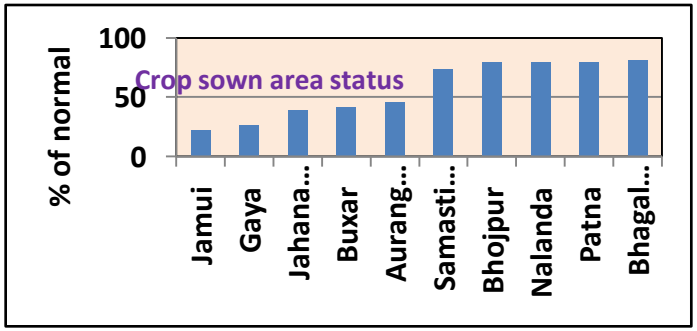
Resourcesat AWiFS – A work-horse for monitoring Agriculture





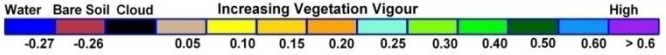






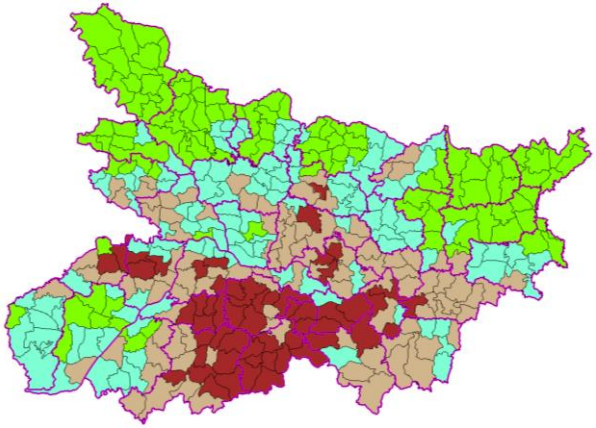
Satellite derived Area Favourable for Crop Sowing/Crop Sown Area (AFCS) , Lakh ha.

Kharif Nromal Area	AFCS Jul-10	AFCS Aug-10	Unfavourable area
37	19	23	14



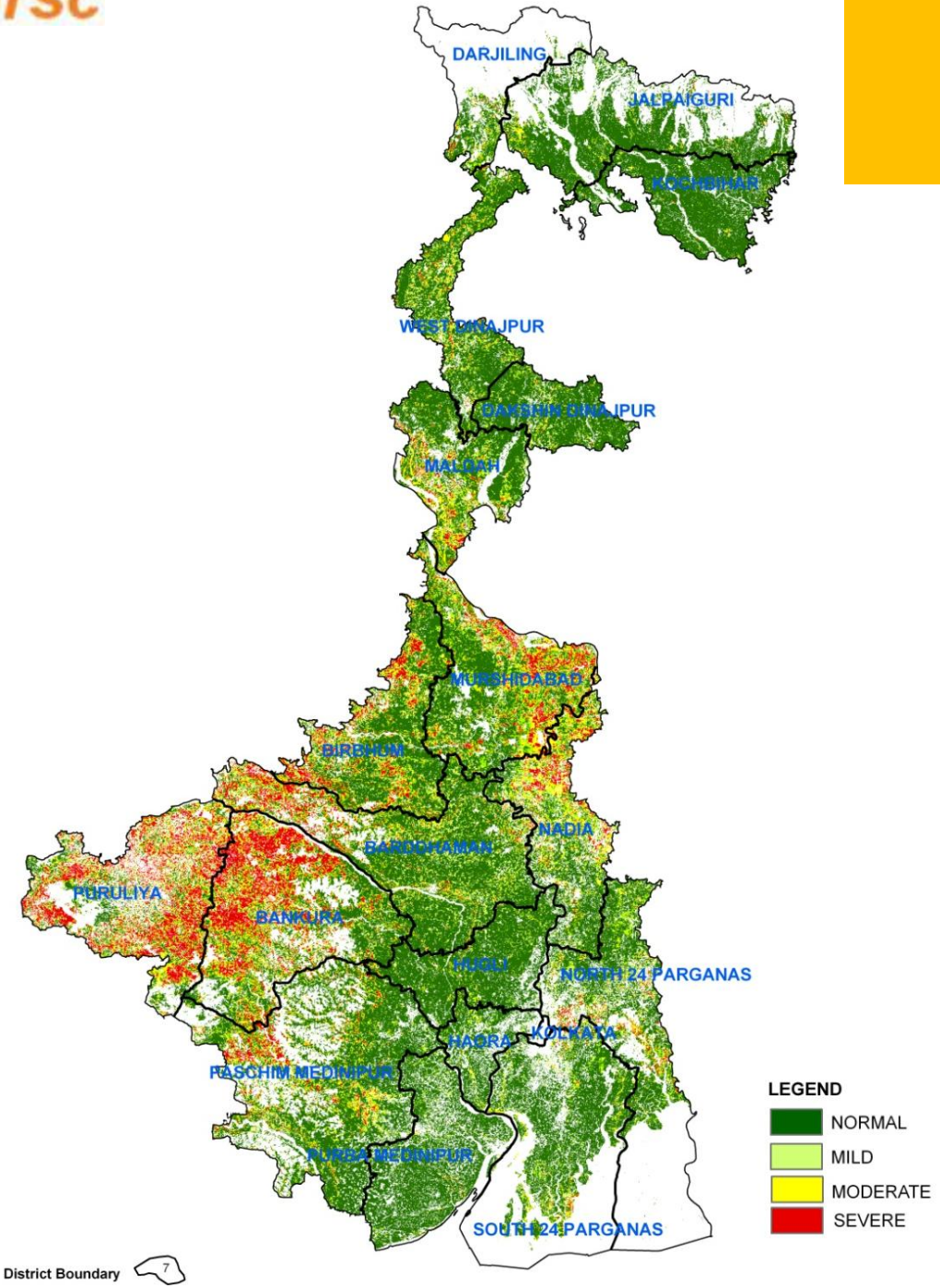
Crop areas affected by agricultural drought situation are showing lower NDVI compared to normal, in kharif 2010 in Bihar state.

Agricultural drought assessment
(based on multiple indices; NDVI, NDWI, SASI)

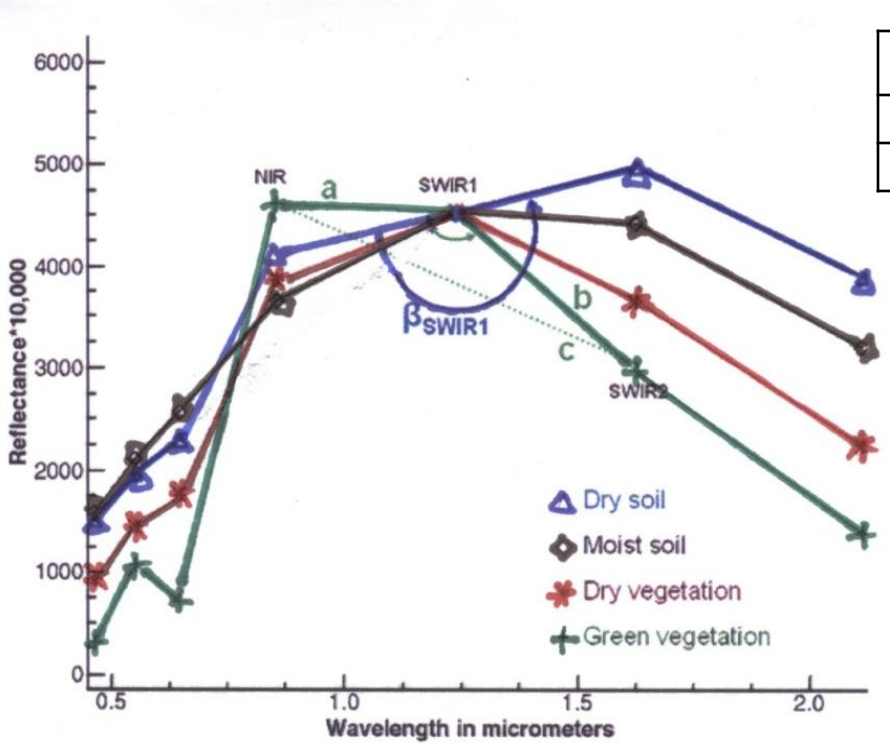


1. Pas. Champaran
2. Pur. Champaran
3. Sheohar
4. Sitamarhi
5. Madhubani
6. Supal
7. Ararai
8. Kishanganj
9. Purnia
10. Madhepura
11. Saharsa
12. Darbhanga
13. Muzaffarpur
14. Gopalganj
15. Siwan
16. Saran
17. Vaishali
18. Samastipur
19. Begusarai
20. Khagaria
21. Katihar
22. Bhagalpur
23. Banka
24. Munger
25. Lackeesarai
26. Sheikhpura
27. Nalanda
28. Patna
29. Bhojpur
30. Buxar
31. Bhabua
32. Rhotas
33. Aurangabad
34. Jahanabad
35. Gaya
36. Nawada
37. Jamui

Satellite based agricultural drought assessment kharif 2010, West Bengal

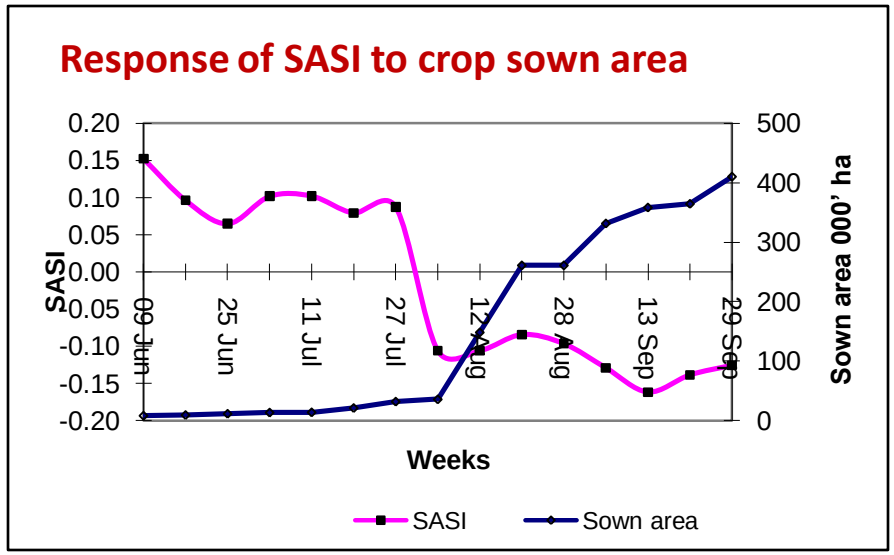


Shortwave Angle Slope Index (SASI)



Features	SASI value
Dry soil	highly positive
Wet soil	low positive

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



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

Slope = (SWIR2 – NIR)

SASI = β_{SWIR1} * Slope (radians)

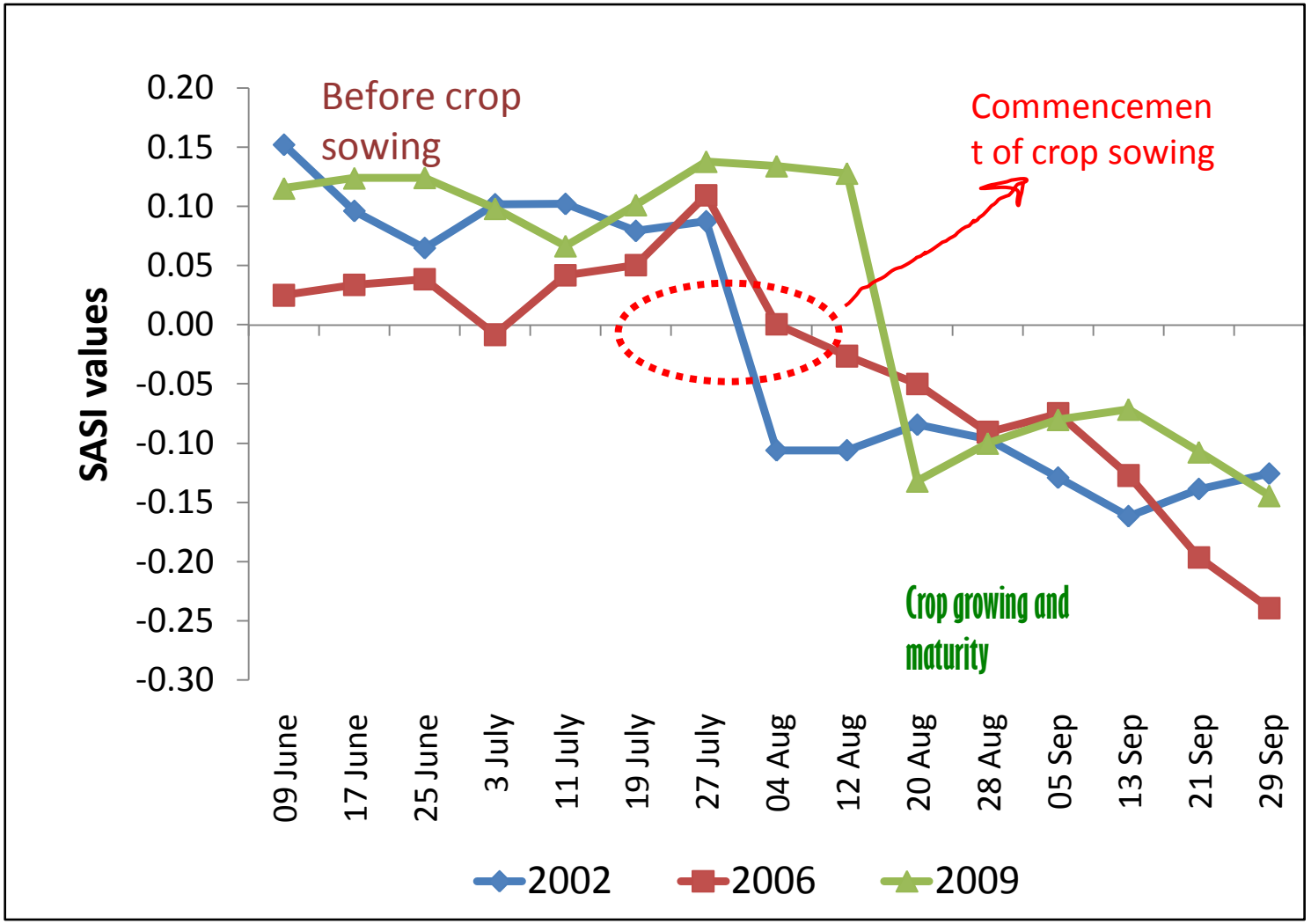
where a, b and c are Euclidian distances between vertices NIR and SWIR1, SWIR1 and SWIR2, and NIR and SWIR2, respectively

Chronological synchronization between
(a) Decrease in SASI
(b) Increase in rainfall
(c) Increase in sown area

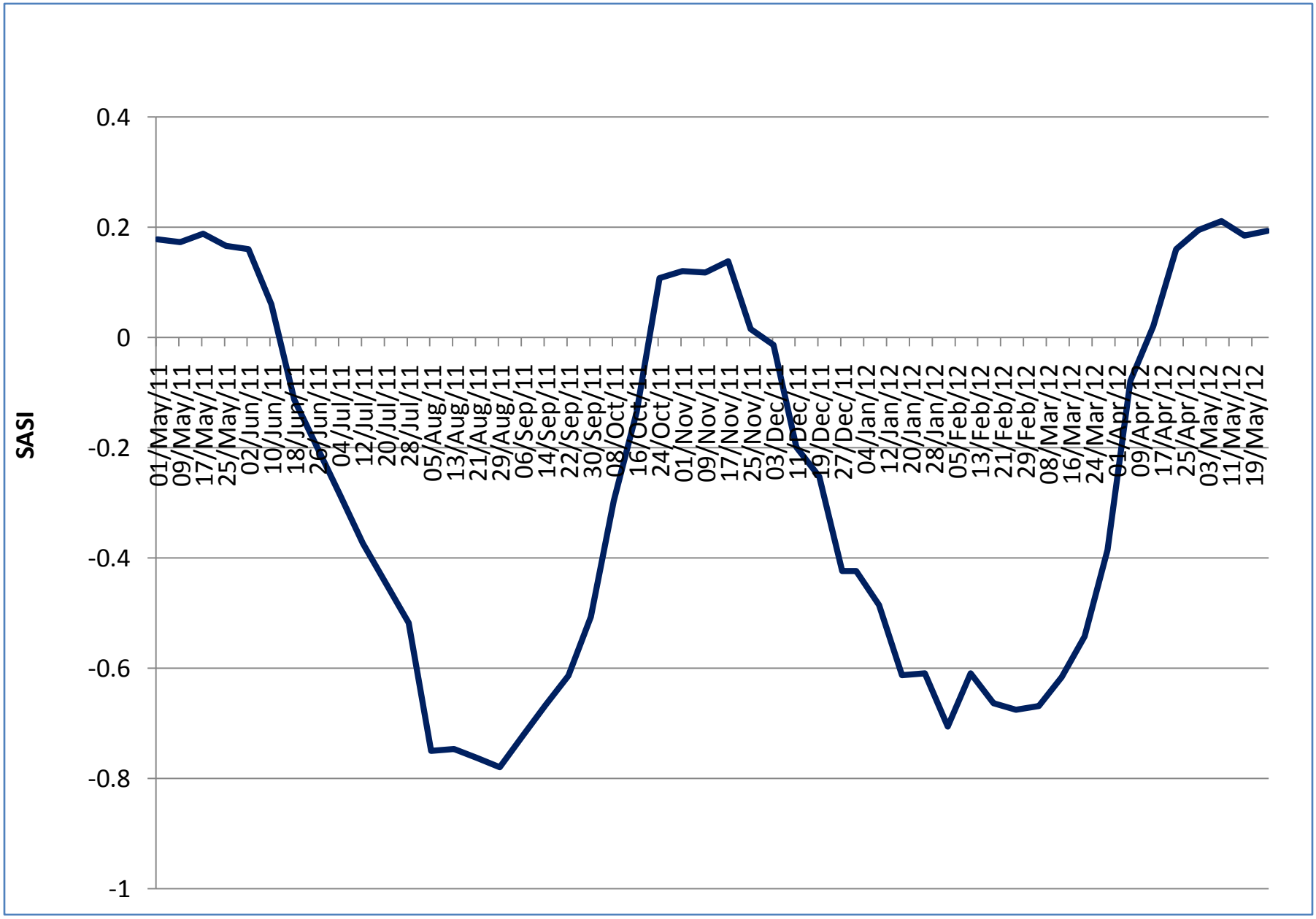
NADAMS project

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

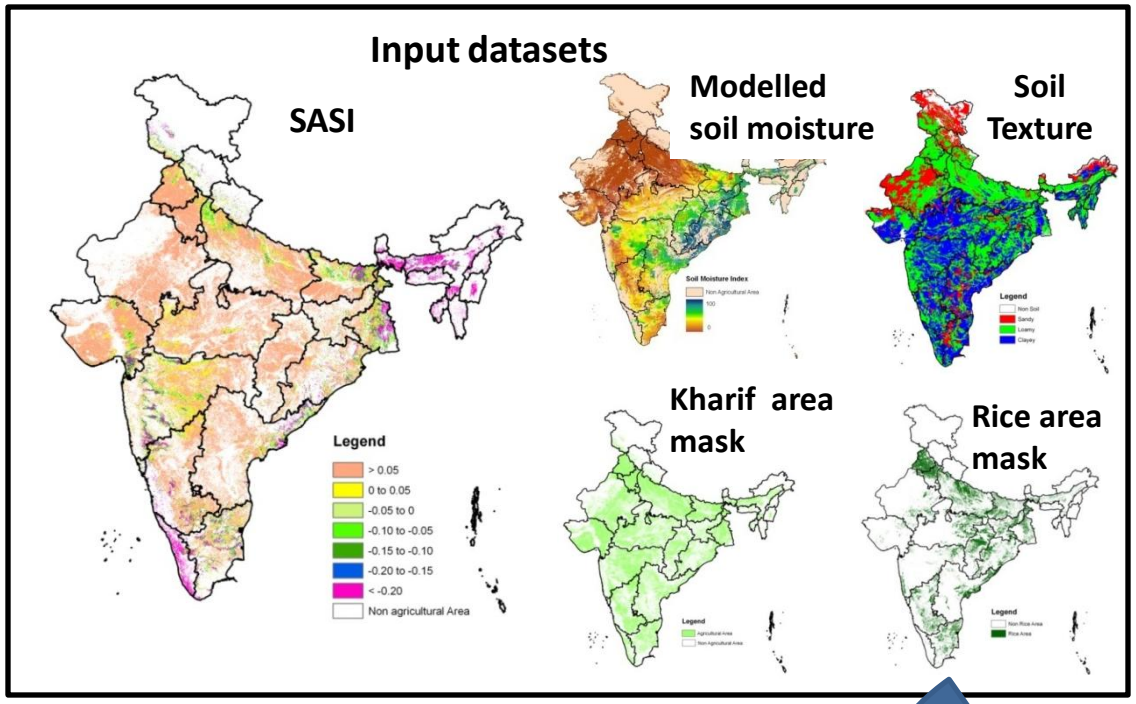
Seasonal dynamics of SASI

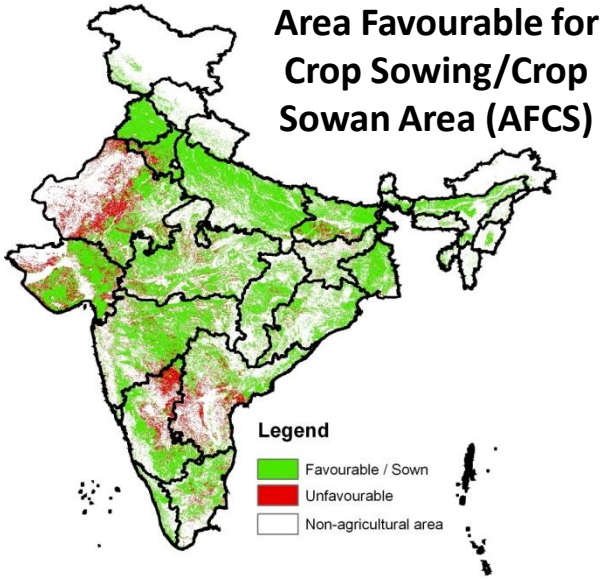


Seasonal SASI profile

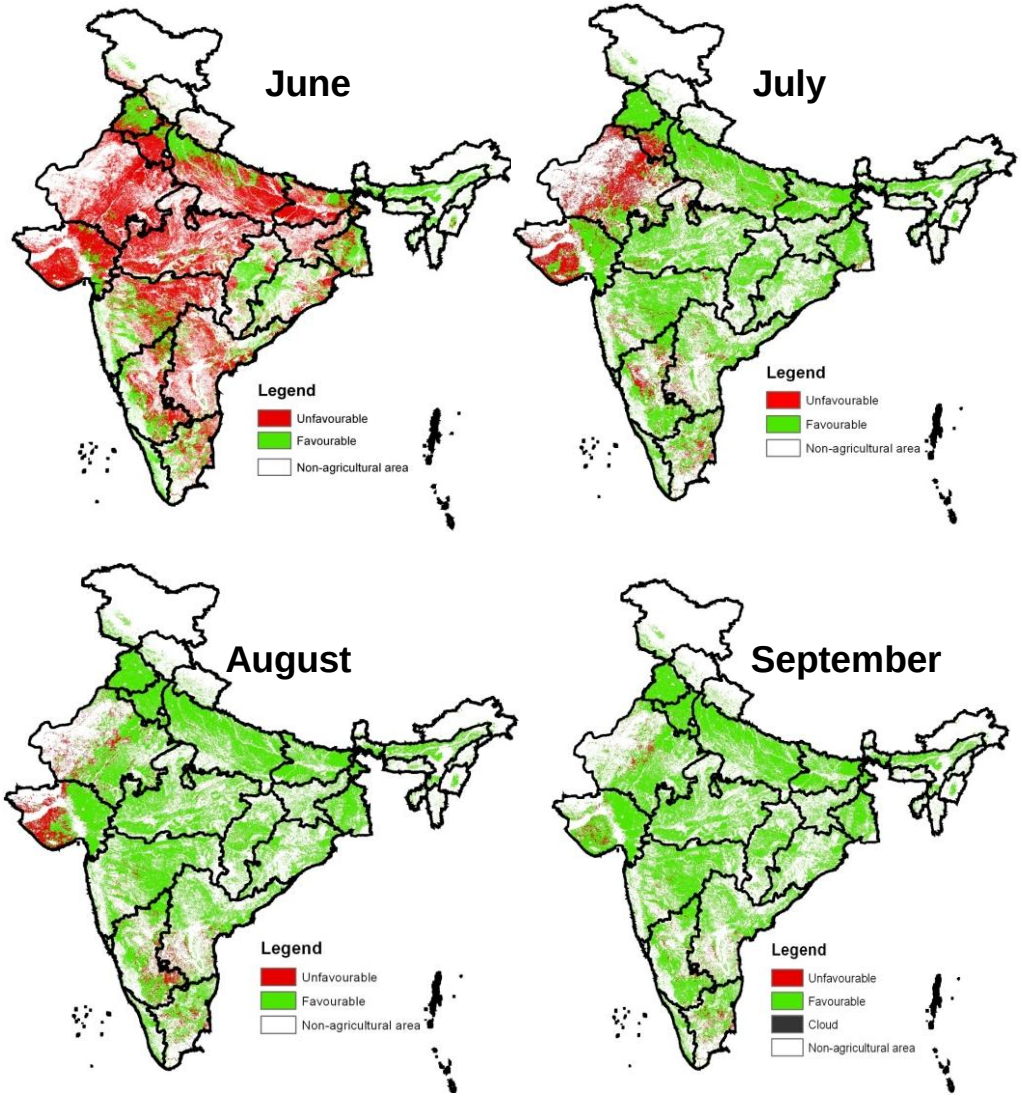


Geospatial product on Area Favourable for Crop Sowing (AFCS) using multi-criteria approach





Area Favourable for Crop Sowing (AFCS) derived from SASI and water balance methodology, Kharif 2012



State	Kharif normal	AFCS M ha.				Unfavorable area
state		June	July	Aug	Sep	
Andhra Pradesh	7.8	2.0	6.8	6.9	7.3	0.4
Bihar	3.7	0.7	3.6	3.7	3.7	0
Chhattisgarh	4.8	3.2	4.8	4.8	4.8	0
Gujarat	8.7	1.3	5.0	5.8	8.1	0.6
Haryana	2.8	0.6	1.6	2.8	2.8	0
Jharkhand	2.5	0.3	2.4	2.5	2.5	0
Karnataka	7.5	3.5	6.0	6.0	7.0	0.5
Madhya Pradesh	10.4	0.7	9.7	10.3	10.4	0
Maharashtra	14.0	5.5	13.2	13.8	13.8	0.2
Odisha	6.3	3.9	6.1	6.2	6.3	0
Rajasthan	14.3	0.2	4.4	11.7	13.6	0.8
Tamil nadu	2.4	1.1	1.8	2.0	2.0	0.4
Uttar Pradesh	9.3	2.8	8.7	9.2	9.3	0
Sub-Total	**94.5**	**25.8**	**74.2**	**85.7**	**91.7**	**2.9**
All India	**108.6**	**34.2**	**87.0**	**97.7**	**105.5**	**3.1**

Soil moisture

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

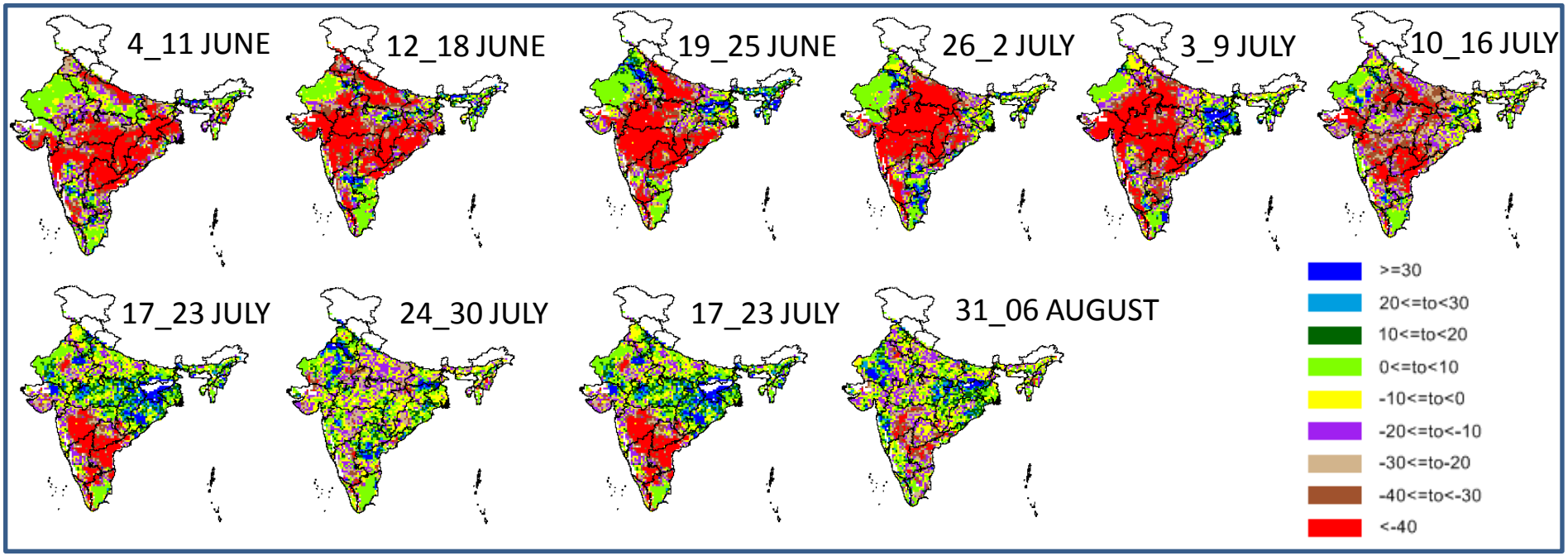
- NASA
- LPRM
- PRI

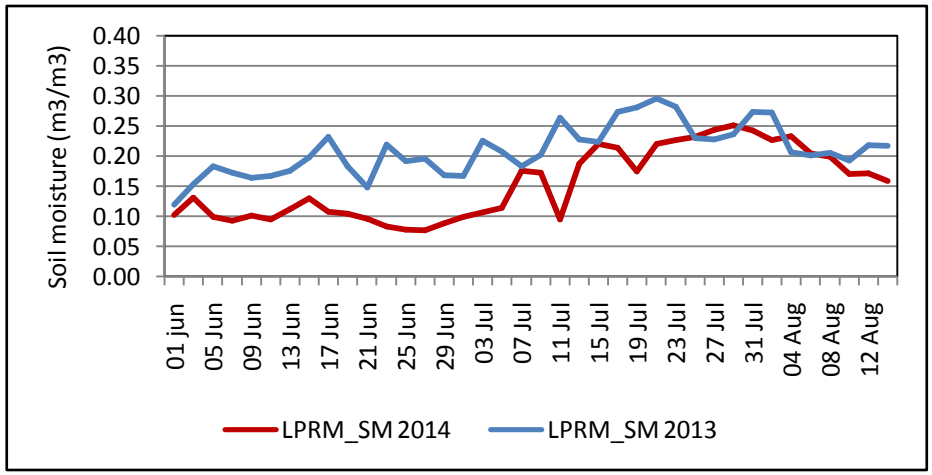
Soil moisture products from NRSC

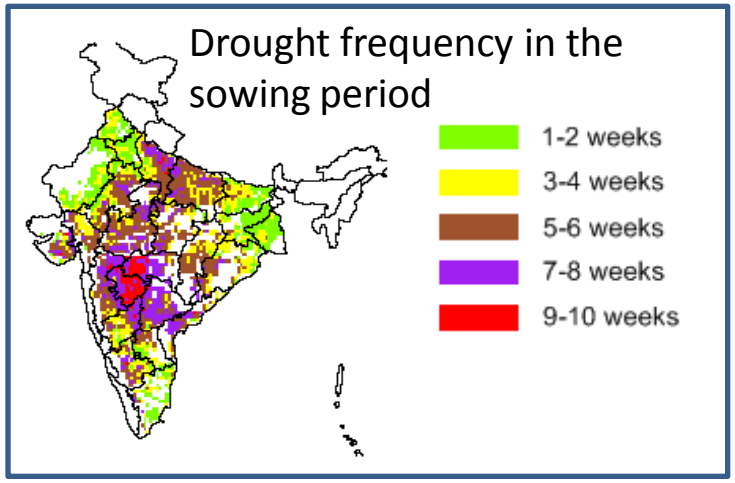
- VIC hydrological models – daily soil moisture images
- AMSR 2 LPRM soil moisture 25 km, 2 day frequency

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

Soil moisture deviations from normal in 2014







Field enumeration for drought impact assessment and relief management

Mobile Apps. Technology

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
- Localised crop damages

Field Data Collection using Geo-ICT

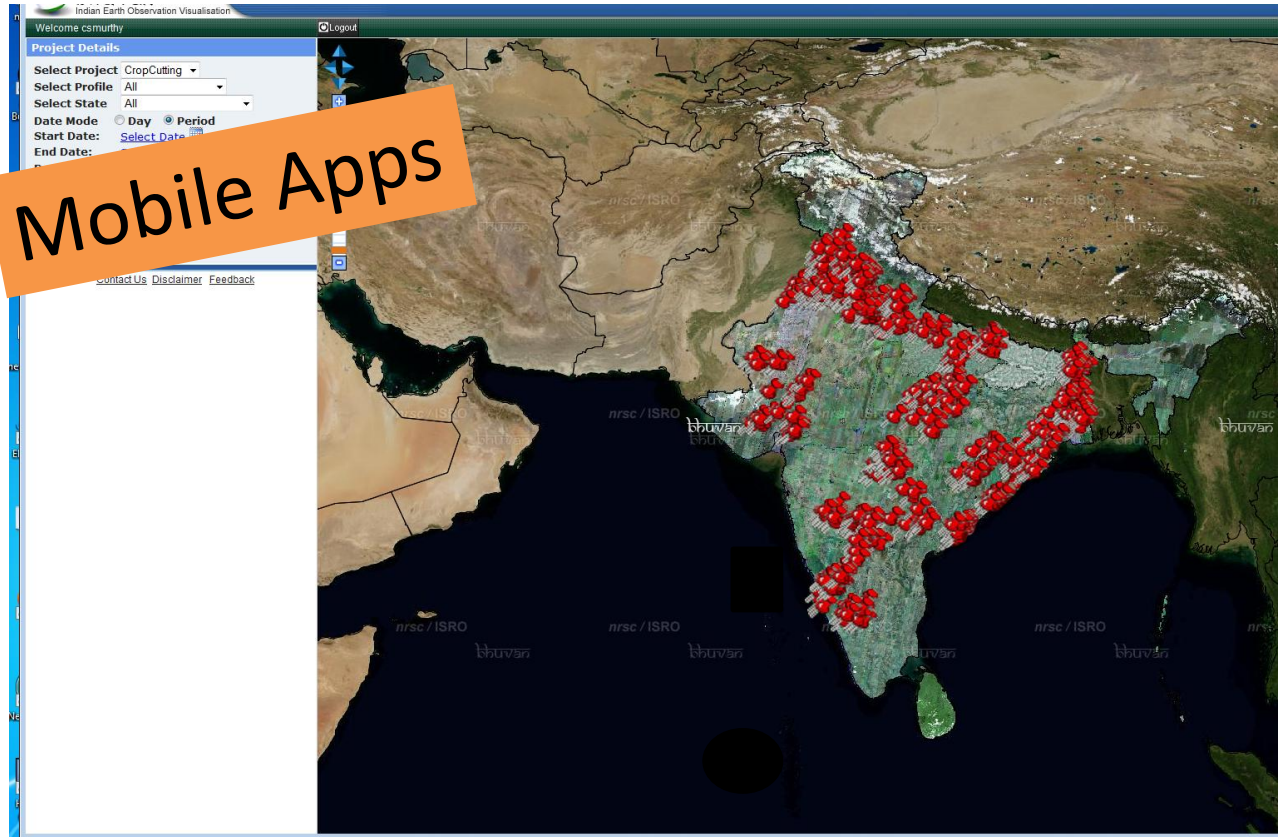
Observation → Transmission → Information → Decision → Action

Field Data Collection using Geo-

Observation → Transmission → Information → Decision → Action

e app. from NRSC/ISRO that allows users to share, access and upload natural resources information on a near real time basis, with Bhuvan serving as the platform

- Crowd sourcing approach with open source tools like Open layers, PHP, Geoserver and Mapserver, etc. for visualization and uploading
- Immense use for agricultural information collection/analysis
- Provision to upload the information through internet or customized mobile which will be geo-tagged for visualization through Bhuvan Portal
- Geo-tagged in-season field data enables developing a repository of agriculture/crop related data



Successful and On-going applications of FDC

- **Crop mapping**
- **Pest/disease surveillance**
- **Crop Insurance**
- **Crop damage assessment enumerations**
- **Disaster**
- **Drought impact enumeration.**

Agricultural drought vulnerability

- **Degree of susceptibility of an area to agricultural drought due to variable exposure and coping abilities, Vulnerability map helps visualize the hazard and act before potential damage**
- **Vulnerability information is crucial for long term drought management**
- **A quantitative and multi-dimensional approach for measuring crop-generic agricultural drought vulnerability status at sub-district level**

Vulnerability framework

Exposure

Sensitivity

Adaptive Capacity

- Identification of factors
- Collection of data
- Analysis of data
- Construction of composite Index

Exposure Index (EI)

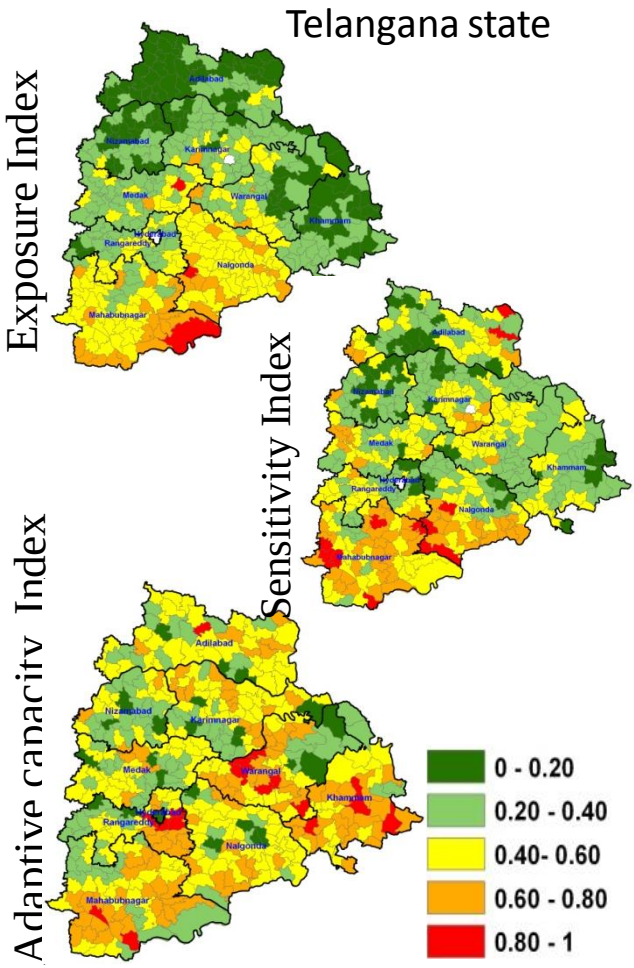
Sensitivity Index (SI)

Adaptive Capacity Index (AI)

Agricultural Drought Vulnerability Index (ADVI)

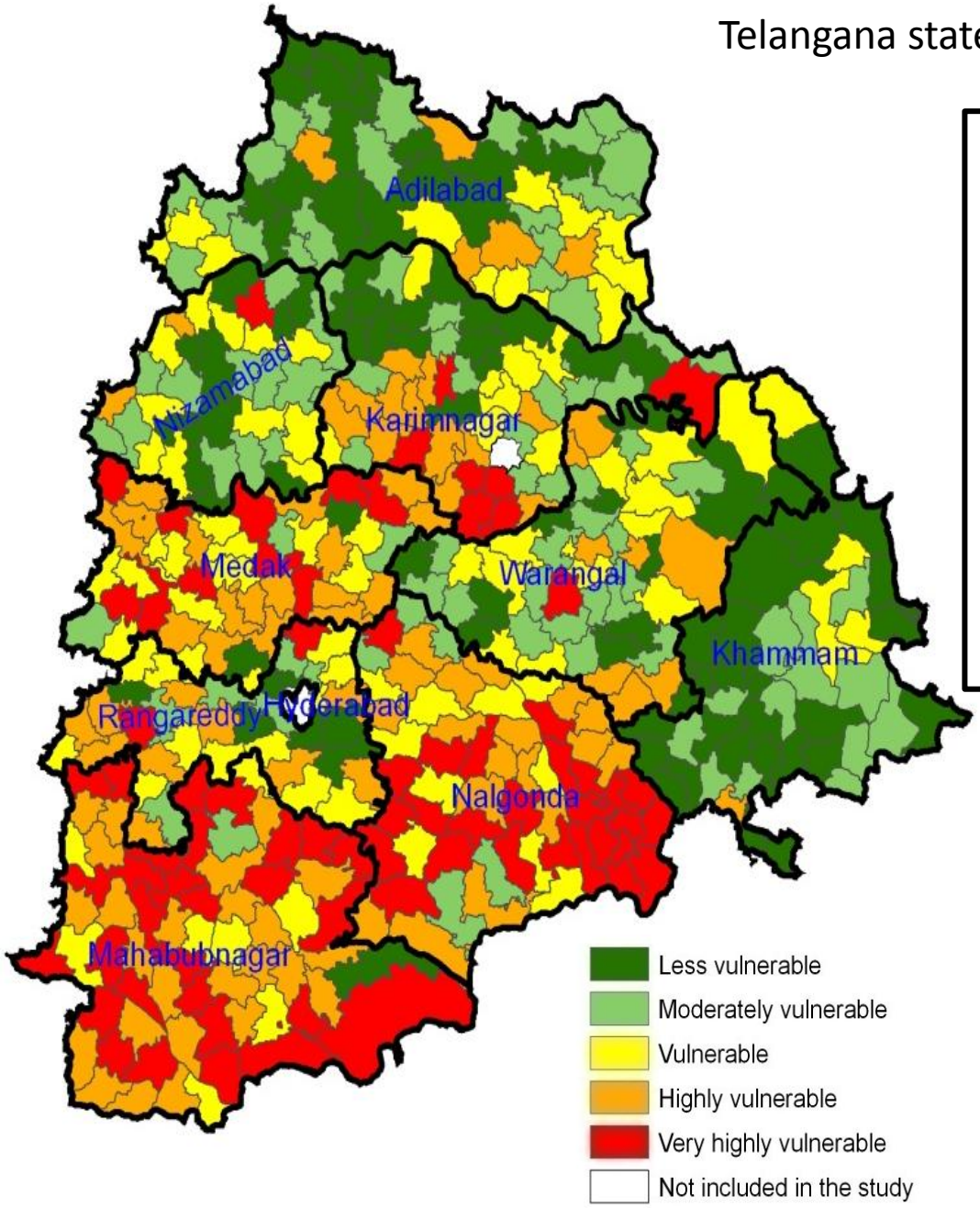
ADVI = EI+SI-AI

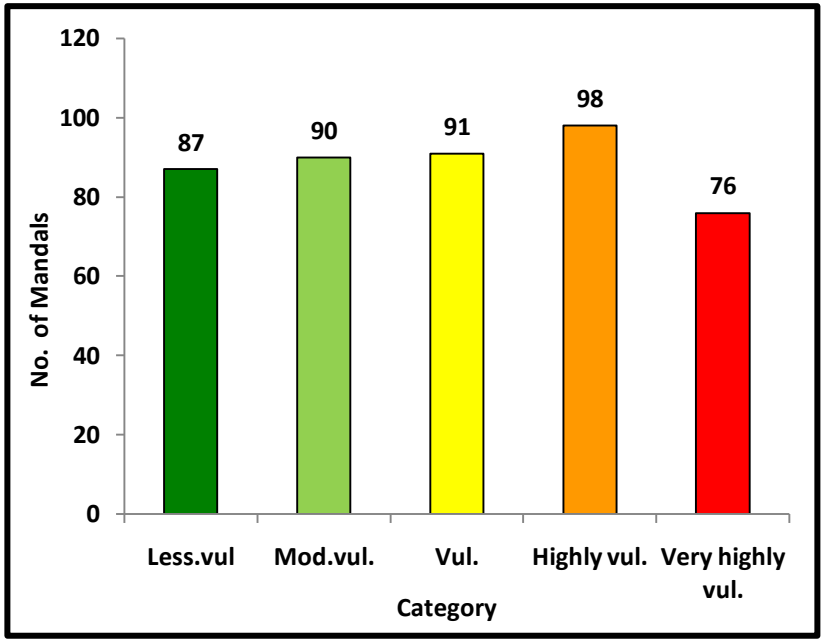
A. Exposure component
1. Total season rainfall
2. Sowing period rainfall
3. Total season rainy days
4. Sowing period rainy days
B. Sensitivity component
1. Season's Integrated NDVI
2. Season's Maximum NDVI
3. August NDVI
4. Cropping pattern
C. Adaptive capacity component
1. Soil
2. Irrigation support
3. Land holdings



Agricultural Drought Vulnerability Index

Telangana state



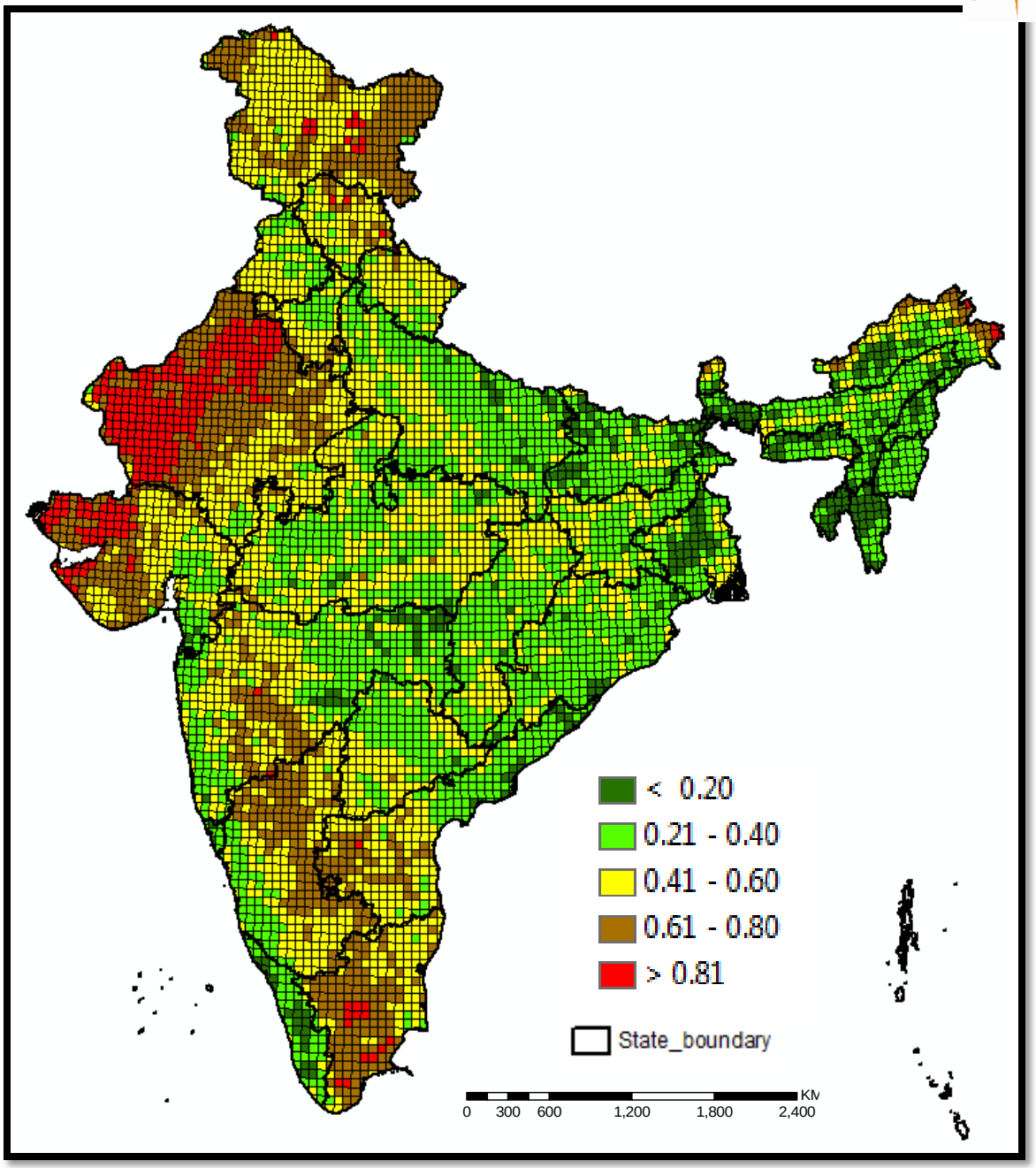


Agricultural Drought Vulnerability Index – all India

Regional analysis

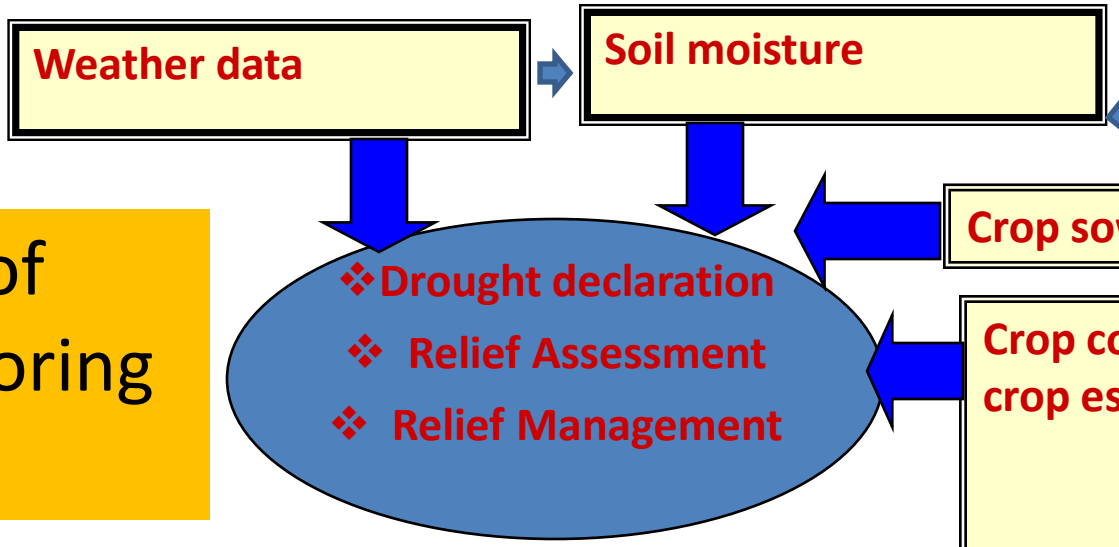
Grid scale – 25*25 km

Scope for improvement with additional indicators



Establishment of Drought Monitoring System

Integrated Approach



Institutional participation

Development of an integrated approach with data from multiple sources

Scientific Organizations

Meteorology | Agriculture | Hydrology | Environmental | Socioeconomic

Integrated Geospatial Data base on drought related parameters (Spatial and non spatial)

Drought Monitoring | Drought Early warning | Drought Impact Assessment

Federal Government | State Government | District Administration | Farmers

Training/Capacity building to other countries - Initiatives at NRSC

Trained UN ESCAP countries

Developed drought monitoring system for Srilanka and Myanmar 2015 and 2016

Trained the Officials of Srilanka in 2015

Conclusion

- Development of drought manuals
- Strengthen the drought monitoring and declaration systems
- Adopt integrated approach
- Satellite indices have the potential to capture drought conditions
- Satellite data – free access, easy computations
- Immense scope for automation
- Technology support for drought resilient agriculture

Other applications in Agriculture at NRSC

- Crop insurance
- Crop intensification
- Crop mapping and modelling
- Horticulture assessment
- Plantations – rubber, coffee and tea
- Crop loss assessment due to natural calamities
- Drought vulnerability and risk assessment

THANKYOU

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