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India's Experience of using Earth Observation for Drought Management

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INDRODUCTION OF DROUGHT

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"Drought is a deficiency in precipitation over an extended period, usually a season or more, resulting in a water shortage causing adverse impacts on vegetation, animals, and/or people."

As a result, the climatological community has defined four types of drought

1. **METEOROLOGICAL DROUGHT**

It is the lack of precipitation over a region with respect to normal precipitation.

2. **HYDROLOGICAL DROUGHT**

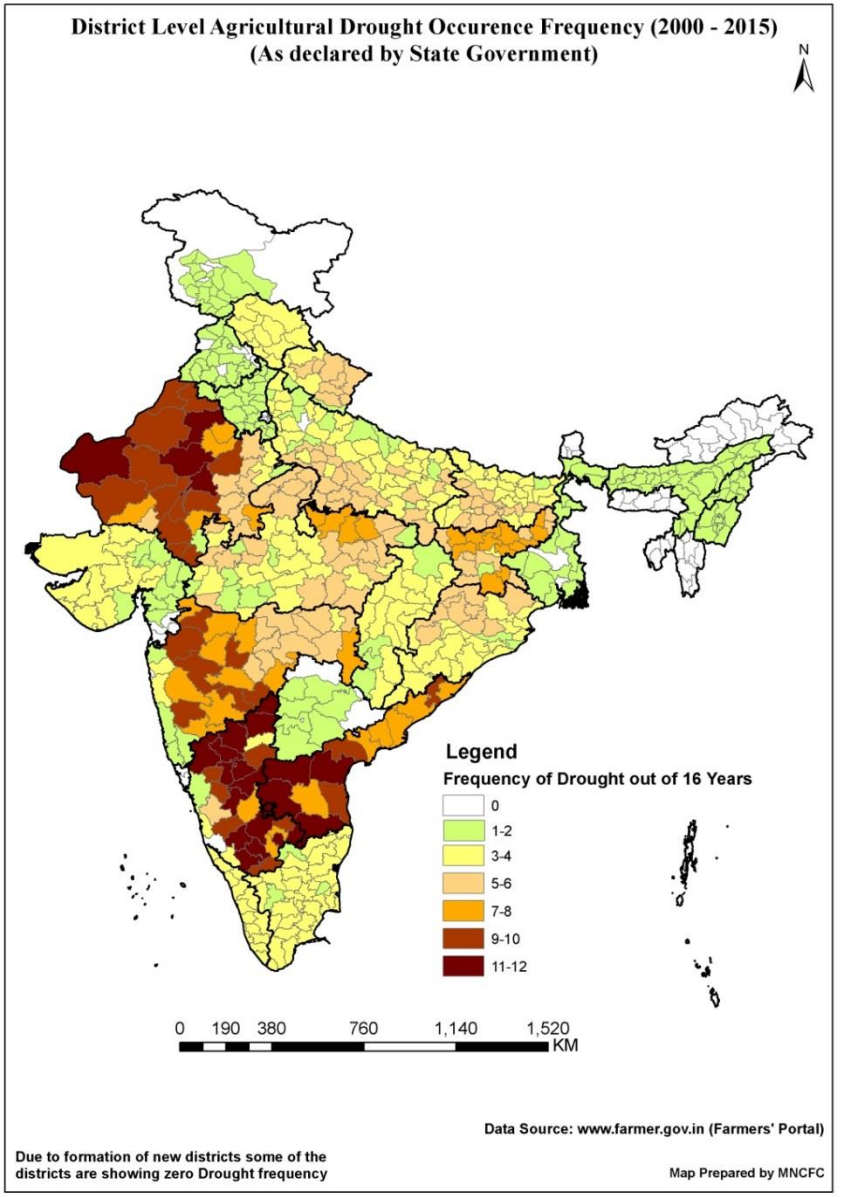
It is the shortfall in surface and subsurface water supply due to lack of precipitation.

3. **AGRICULTURAL DROUGHT**

It is largely the result of soil moisture deficiencies, or it is the difference between
the actual and potential evapotranspiration.

4. **SOCIO-ECONOMIC DROUGHT**

It occurs when the demand (eg. Drinking water, hydroelectric power) exceeds supply as a result of weather related supply shortfall.

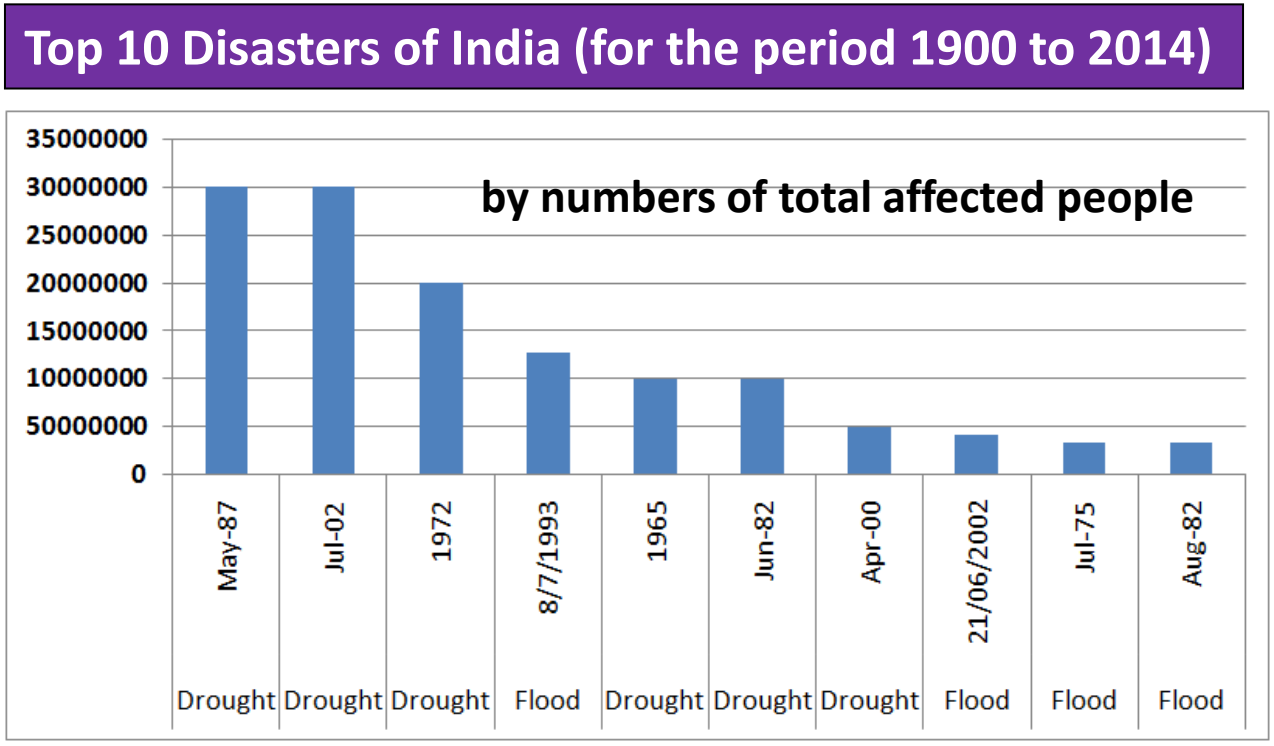


Drought in India

During 1871–2015, there were 25 major drought years, defined as years with All India Summer Monsoon Rainfall (AISMR) less than one standard deviation below the mean (i.e. anomaly below –10 percent): 1873, 1877, 1899, 1901, 1904, 1905, 1911, 1918, 1920, 1941, 1951, 1965, 1966, 1968, 1972, 1974, 1979, 1982, 1985, 1986, 1987, 2002, 2009, 2014 and 2015. (Source: Drought Manual)

- Drought is a perennial feature; 16 percent of India's total area is drought prone and approximately, 50 million people are annually affected by droughts.

- Over 68-70% of total sown are India is vulnerable to drought.



(Source: "EM-DAT: The OFDA/CRED International Disaster Database)

Drought Occurrence Frequency As declared by State Government

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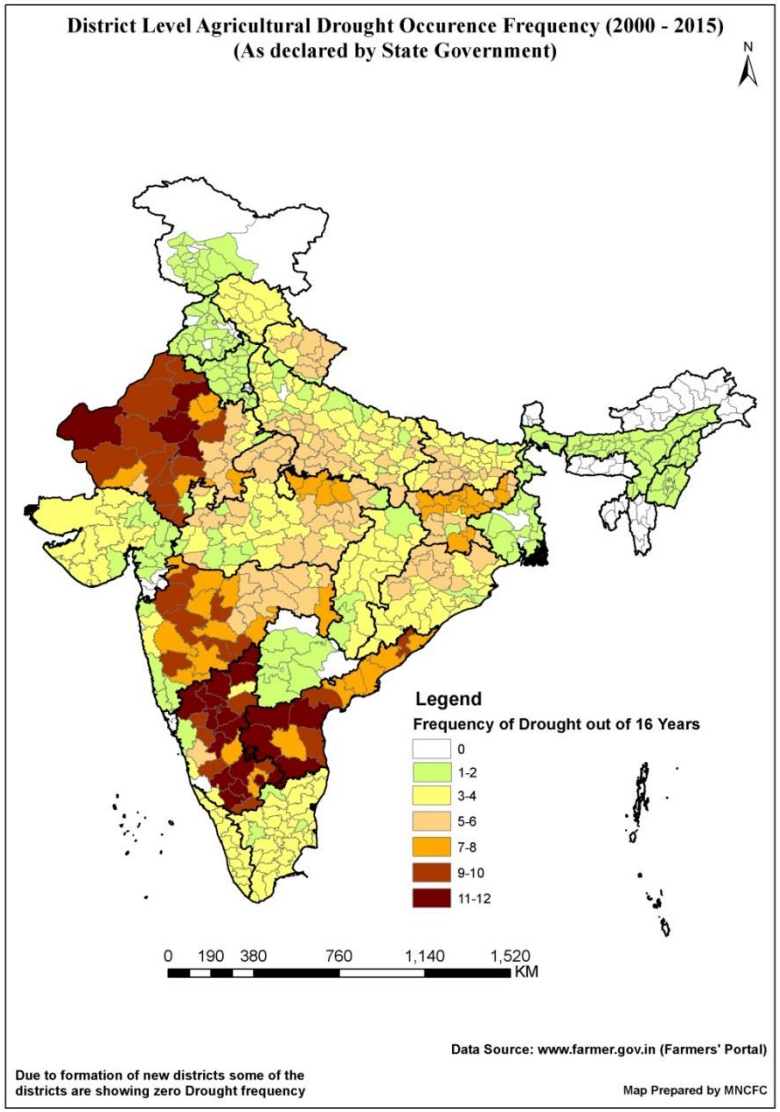
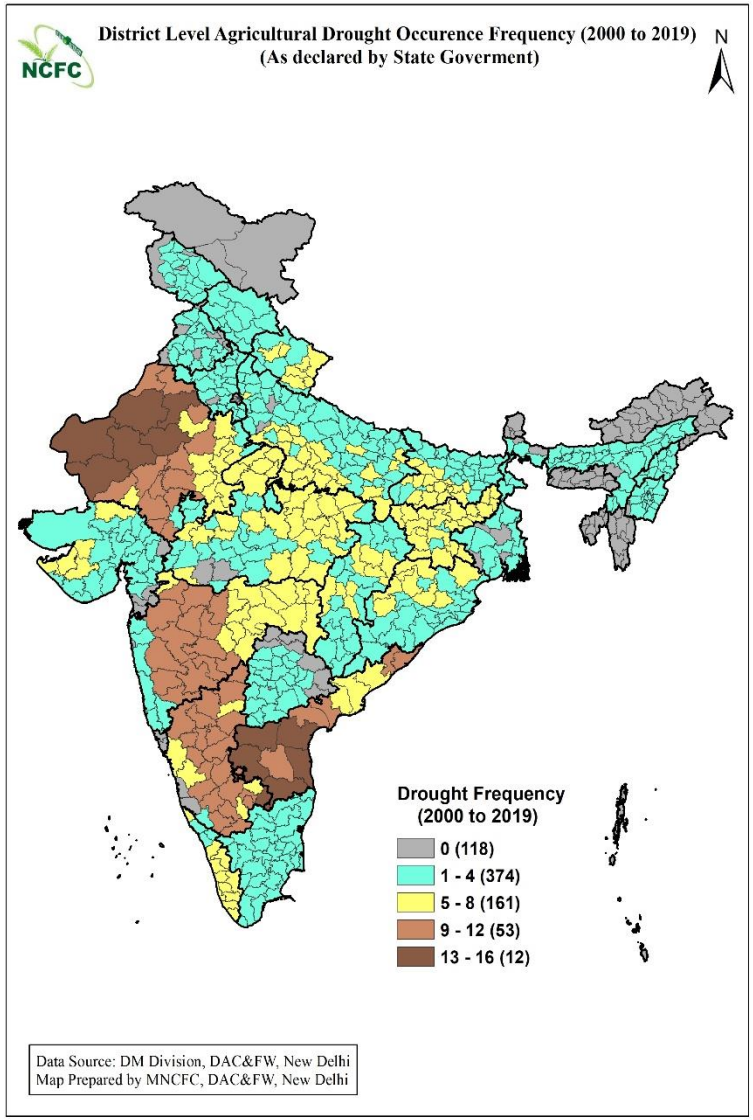


2000-2015 (Year)



2000-2019 (Year)

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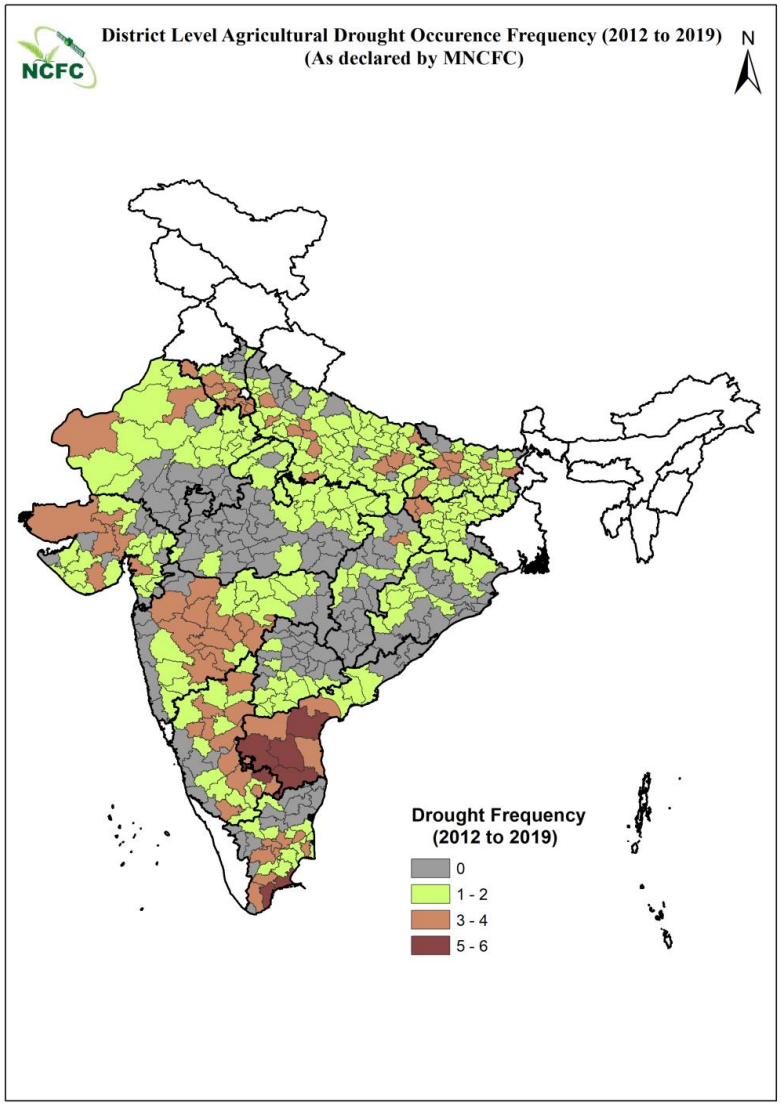
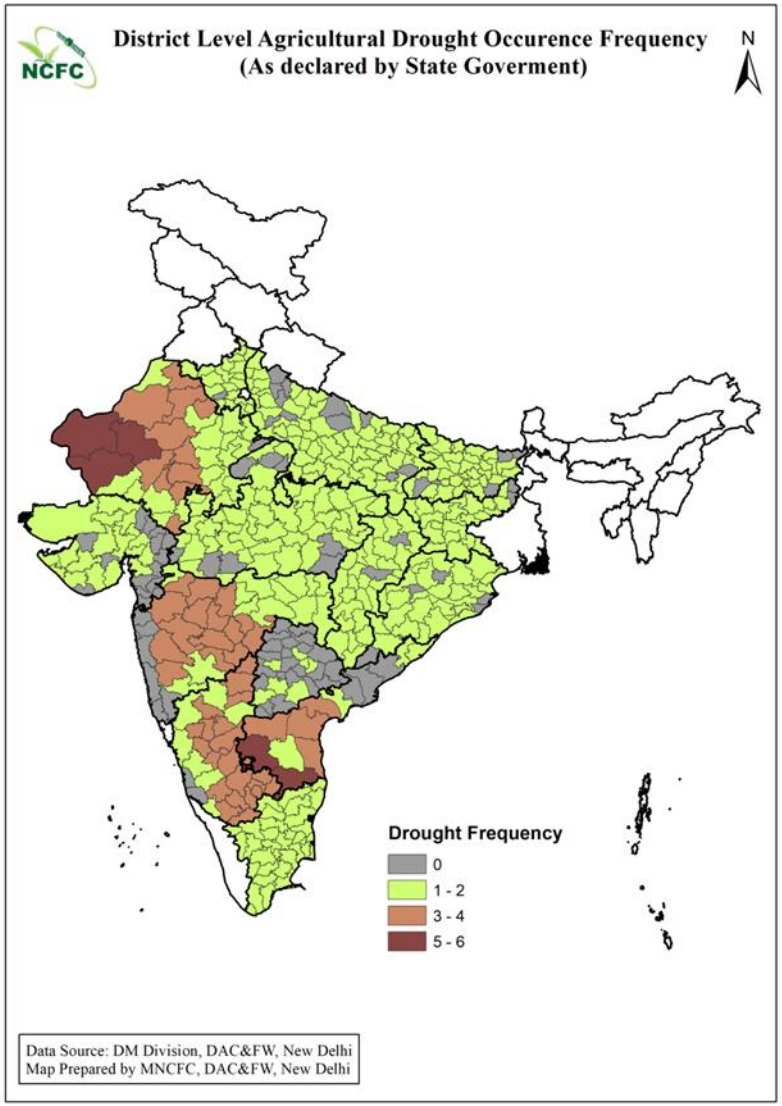
Drought Occurrence Frequency As assessed by MNCFC and declared by State Govt.





2012-2019 (Year)

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Central Agencies involved with Drought Monitoring/Management in India

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Ministry of Agriculture & Farmers' Welfare

- Overall coordination, Inter-Ministerial Crop Weather Watch Group (CWWG), Leading IMCT for Drought Assessment

India Meteorological Department

- Weather Forecasting, Rainfall Data

Central Water Commission

- Monitoring Storage situation in Major Reservoirs

DAC&FW (MNCFC) and ISRO

- Space technology based drought assessment (NADAMS)

ICAR- CRIDA

- Contingency planning

DOLR/ MOWR/DAC&FW

- PMKSY-Watershed Development-Water Harv. Str. /Irrigation/Water Use efficiency

National Institute of Disaster Management

- Capacity Building

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Crop Weather Watch Group

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Partners	Function
Additional Secretary, DAC&FW & Central Drought Relief Commissioner	Chairperson of the Group: overall coordination
Economics & Statistical Advisor, DAC&FW	Report behavior of agro-climatic and market indicators
Agriculture Commissioner	Crop conditions: Availability of Inputs; Contingency Planning
Animal Husbandry Commissioner	Livestock health; Fodder availability
India Meteorological Department	Rainfall forecast and monsoon conditions.
Central Water Commission & Central Ground Water Board	Monitoring data on Important reservoirs / groundwater.
Crop specialists	Report on crop conditions.
Ministry of Power	Availability of power
Indian Council of Agricultural Research	Technical input and contingency planning
National Centre for Medium Range Weather Forecasting	Provide medium-term forecasts
Mahalanobis National Crop Forecast Centre	Agricultural Drought Information

National Agricultural Drought Assessment and Monitoring System (NADAMS)

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Under NADAMS project drought assessment has been carried out for 17 states (553 Districts) namely (A.P., Assam, Bihar, Chhattisgarh, Haryana, Gujarat, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh and West Bengal)

- **Regularly under NADAMS project District-wise drought condition assessment as per the Drought Manual 2016.**

Details of Five Products generated from basic dataset are as follow.

1. IMD District wise Rainfall Deviation Data.

a). District wise Rainfall Deviation Map for Weekly and Cumulative
b). Dry Spell map
c). Scanty Rainfall map
d). Trigger 1 (Yes/No) map

2. MODIS 250m Data (mod13q1)

a). NDVI and NDWI fortnightly.
b). District wise and sub-district wise statistics generation (mean value of district/sub-district)
c). NDVI and NDWI Deviation from Average of 3 Normal years. (District wise and Pixel wise)
d). VCI of NDVI and NDWI district wise and pixel wise.

3. CPC rainfall and PET data.

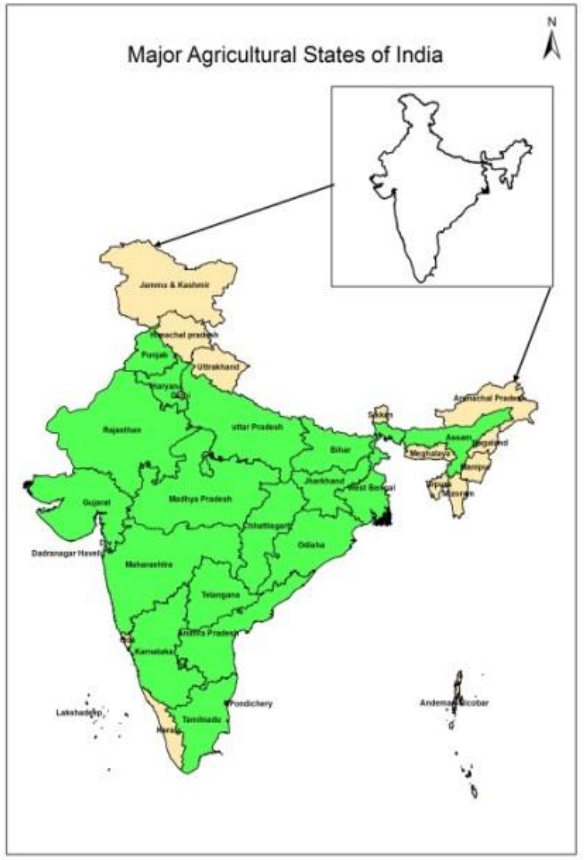
a). Available Soil Moisture percent (SMI) daily map.
b). District wise statistics generation (mean value of District)
c). District wise cumulative PASM map (from normal onset to end of each kharif month).

4. Precipitation Daily data for Standardized Precipitation Index.

a). download precipitation data daily and prepare fortnightly and monthly SPI.

5. CWC reservoir storage data.

a). Prepare Reservoir Storage Position (Departure % from 10 year Average) Map.



Key Parameters for Assessing Drought

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Rainfall Based

- Rainfall Amount and Deviation
- Rainfall Distribution (Dry Spell)
- Standardized Precipitation Index

Crop Based

- Sowing Progression
- Crop Damage/ Crop Yield
- Moisture Availability (Moisture Adequacy Index, Plant Available Water Content, etc.)

Satellite Based

- Normalized Difference Vegetation Index
- Normalized Difference Wetness Index
- Vegetation Condition Index
- Soil Moisture

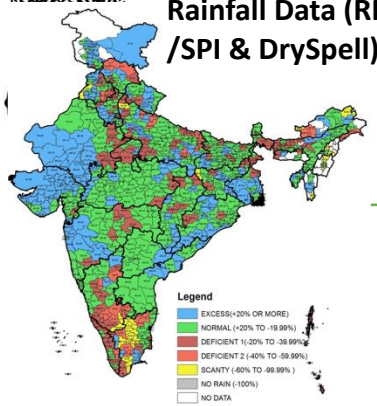
Hydrological Parameters

- Stream flow
- Reservoir level
- Ground water level

Other Socio-economic parameters such as Availability Food, Fodder & Water; Demand for Work; Migration etc.

Drought Assessment as per New Drought Manual 2016

Rainfall Data (RFDev /SPI & DrySpell)



Drought Trigger 1

No

Drought Assessment

No Drought

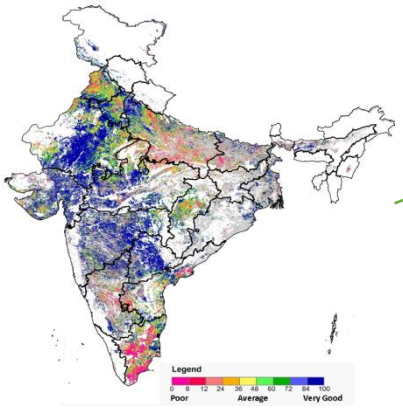
Yes

Socio-Economic Indicators.

Drought Assessment

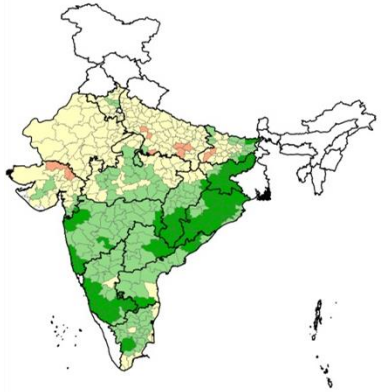
Drought Category (Severe, Moderate, Normal)

Remote Sensing Data

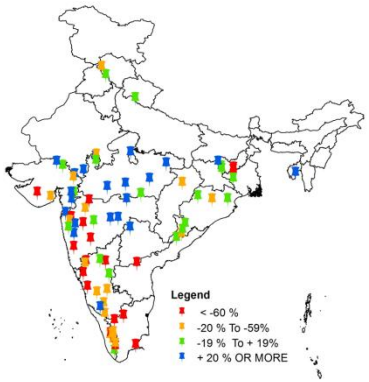


Asses any 3 impact indicators

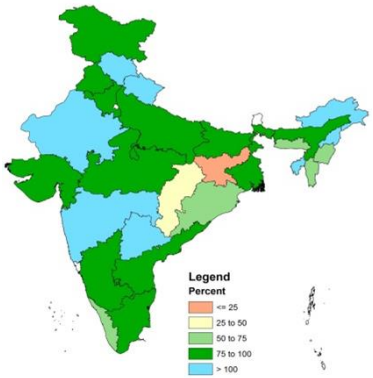
Soil Moisture



Hydrological data



Crop Sown Area



Drought Trigger 2

Yes

Ground Truthing

Parameters for Drought Declaration

(Drought Manual, 2016)

Levels	Category	Parameters
Trigger 1 (Mandatory Indicator)	Rainfall Based	1. RF Deviation or SPI 2. Dry Spell
Trigger 2 (Impact Indicator) *Need to Select 3 out of 4 type of Indicators*	1. Remote Sensing 2. Crop Situation 3. Soil Moisture 4. Hydrological	1. NDVI & NDWI Deviation or VCI 2. Area under sowing 3. PASM or MAI 4. RSI/GWDI/SFDI
Verification	Field Data	GT in 5 sites, each, of 10% of Villages

RF – Rainfall
SPI – Standardized Precipitation Index
NDVI – Normalized Difference Vegetation Index
NDWI –Normalized Difference Wetness Index
PASM – Plant Available Soil Moisture
MAI – Moisture Adequacy Index
RSI – Reservoir Storage Index
GWDI – Ground Water Drought Index
SFDI – Stream Flow Drought Index
GT – Ground Truth

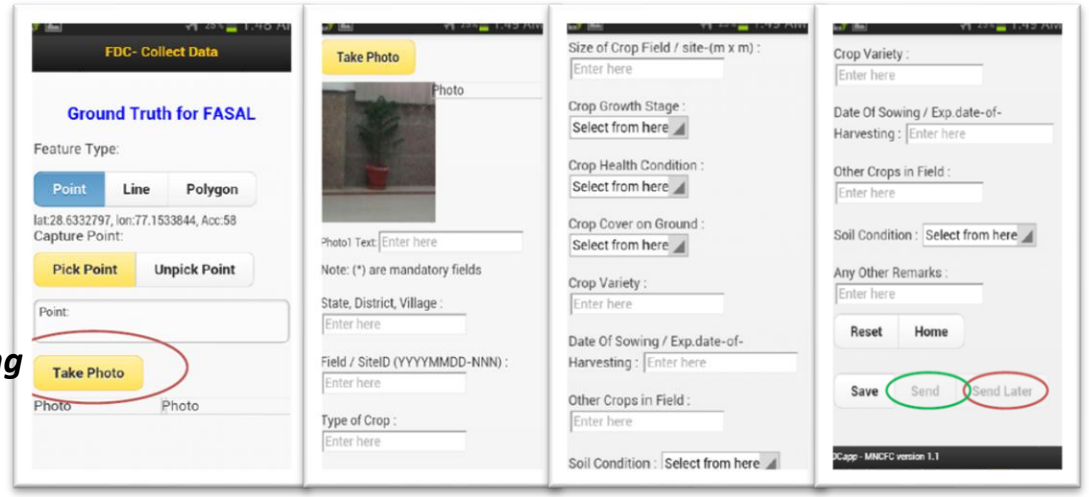
- ***Severe drought:*** *if two of the selected 3 impact indicators are in Severe category and 1 is in Moderate category*
- ***Moderate drought:*** *(i) if two of the selected 3 impact indicators are in 'Moderate' class. (ii) if two of th selected 3 impact indicators are in severe and 1 is in Normal category*
- ***Normal:*** *for all other cases.*
- *Trigger 2 will be set off in the event of a finding of 'severe' or 'moderate' drought.*
- *The State has an option to reduce the drought category by one rank (i.e. Severe to Moderate) if the irrigation percentage of the administrative region (District/Taluk/Block/Mandal), for which drought is being declared is more than 75%.*
- *Finally the drought assessed using impact indicators needs to be validated through ground truth.*

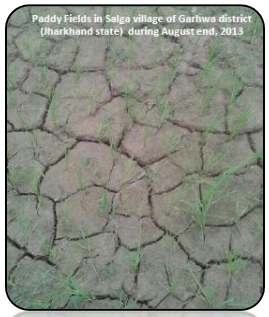
Field Assessment and Verification

- *MNCFC conducts field visits in the affected districts during the monsoon season (August end to September month) to assess the agricultural condition on the field. Also, State agriculture departments regularly collect Ground truth data for MNCFC during the season.*

- *The Ground truth data is collected through a smartphone using Android based application developed by NRSC, Hyderabad. Ground Data is uploaded to BHUVAN server in the real time. While collecting field data various information regarding the crop is collected through a form in the android application.*

  - ***Photograph of the crop***
  - ***Latitude and longitude of the field***
  - ***State, District and Village***
  - ***Type of Crop***
  - ***Size of the field***
  - ***Crop Variety***
  - ***Date of sowing/expected Harvesting***
  - ***Soil condition Crop health***
  - ***Any other information etc.***





Normalized Difference Vegetation Index (NDVI)

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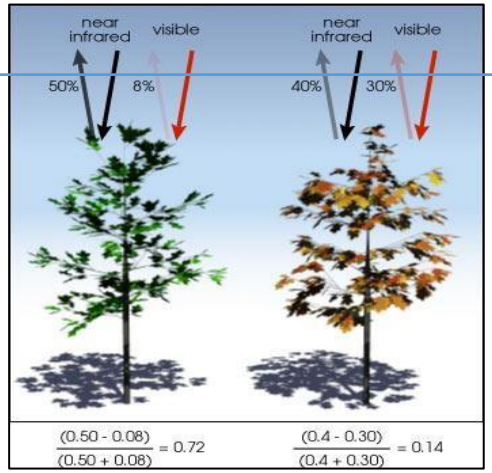
Ratio of difference and sum of surface reflectance in NIR and red spectral bands

Most successful indicator for describing vegetation

- ✓ Normalization - reduces the effect of sensor degradation
- ✓ Sensitive to changes in vegetation
- ✓ Easy to compute and interpret
- ✓ Available from most of the sensor systems
- ✓ Limitations – soil back ground, saturation, time lag etc.



Spectral response of vegetation

Red – more absorption due to chlorophyll
Near Infra red – more reflection due to leaf structure

Normalized Difference Vegetation Index (NDVI)

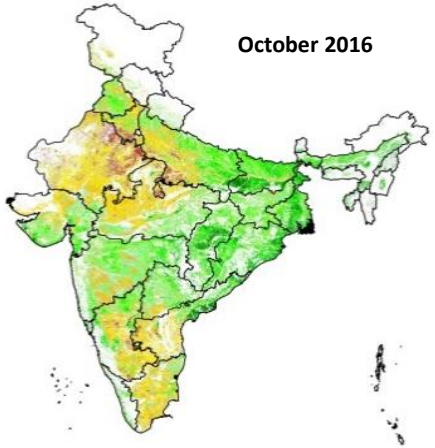
NIR - Red / NIR + Red

Reflected radiation in Near infrared and red bands.
NDVI ranges from -1 to +1
Water – negative NDVI
Clouds – zero NDVI
Vegetation – positive NDVI represents density, vigor

NDWI = (NIR-Red) / (NIR+Red)

Normalized Difference Wetness Index/ Land Surface Wetness Index

- ✓ Shortwave Infrared (SWIR) band is sensitive to moisture available in soil as well as in crop canopy.
- ✓ Reflectance in 0.9 – 2.5 microns dominated by liquid water absorption
- ✓ Sensitive to surface wetness/ vegetation moisture
- ✓ Less affected by atmosphere
- ✓ SWIR availability – AWiFS, LISS-III, MODIS
- ✓ MODIS – 3 SWIR bands – 1240 nm, 1640 nm, 2100 nm
- ✓ Sensitive to surface wetness during sowing period



NDWI = (NIR-SWIR) / (NIR+SWIR)

<u>NDWI/LSWI use</u>

Agriculture – crop stress detection, crop yield, classification of succulent crops, surface moisture

NDVI/NDWI Deviation

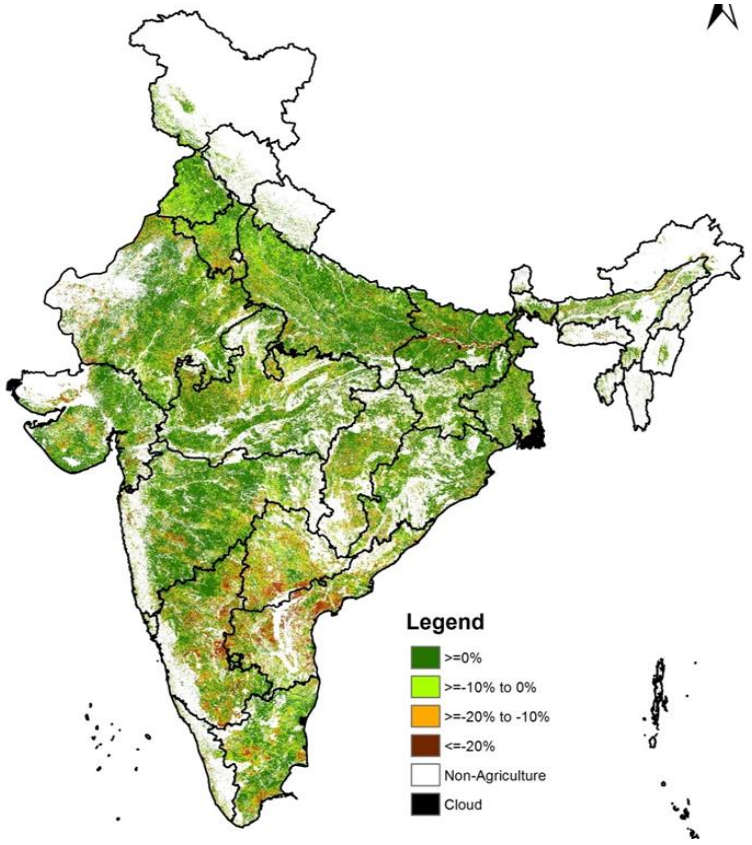
NDVI/NDWI anomaly

% deviation from normal

- *((actual NDVI-normal NDVI)/normal NDVI)*100*
- *Normal NDVI – average of recent past normal years/year*
- *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



Reduction in NDVI is caused by;

- ***Crop moisture stress***
- ***Flooding/excess rainfall***
- ***Crop and crop stage differences between the two years under comparison***

Vegetation Condition Index

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Vegetation Condition Index (VCI)

- *Derivative of NDVI/NDWI*
- *Substitute to NDVI/NDWI deviation*

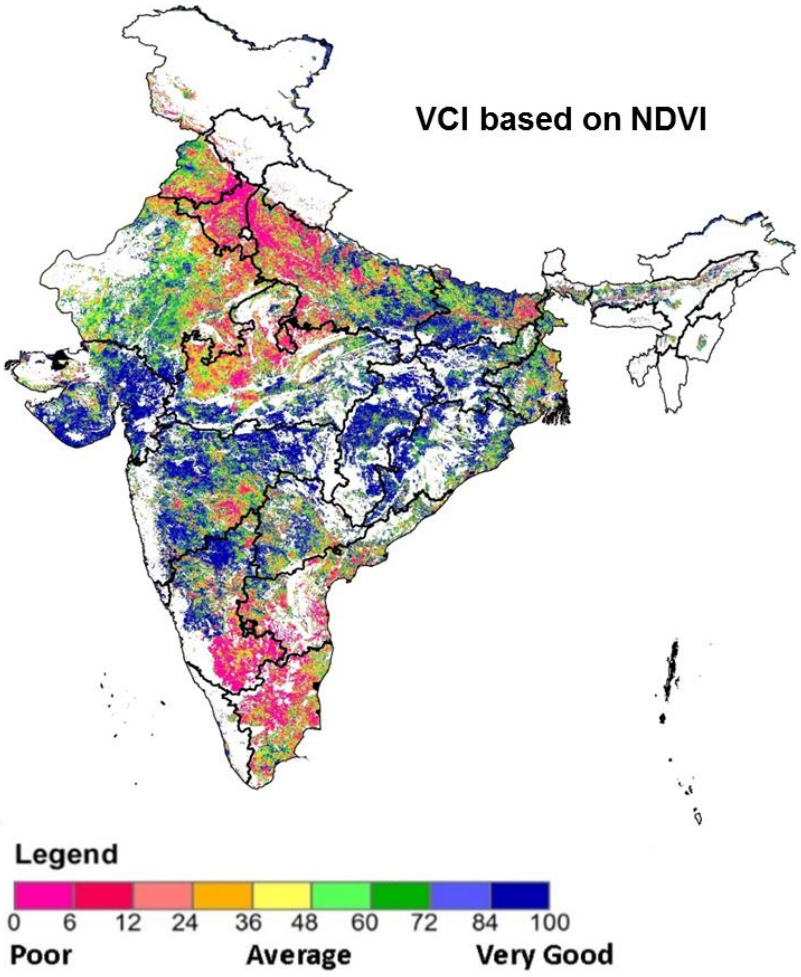
*VCI = (NDVIcurr - NDVImin) / (NDVImax - NDWImin)*100*

Range 0-100%

0-40 % moderate to severe drought
40-60 % mild drought
60-100 % good

Some critical issues:

- *Time series data base (at least 10-12 years)*
- *Differences due to cropping pattern, crop calendar to be normalised*



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Agricultural Drought Assessment – September 2020

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- Agricultural Drought Indicator assessment of 18 states of the country for the month of September 2020 is done as per Drought Manual 2016
- Based on Rainfall, Trigger1 was checked for the month of September 2020. If Trigger1 was YES, the impact Indicators were checked.
- One has to check 3 out of 4 impact indicators (Remote Sensing, Soil Moisture, Crop Sown area and Hydrology) for Trigger 2.
- In this assessment , 3 impact Indicators (Remote Sensing Vegetation Index & Soil Moisture and Sown Area) were assessed under Trigger-2.
- Satellite based Crop sown area assessed using temporal MODIS NDVI dataset
- Based on above analysis, all districts of 18 states were classified into following categories.
    - Trigger 1 is NO (*382 districts*)
    - Trigger 1 is YES (187 districts)
        - Normal (166), Moderate (17), Severe (4)

***Disclaimer** : This is an intermediate drought indicator assessment, must not be used for final drought declaration by states*

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District wise Weekly Rainfall Deviations - September 2020

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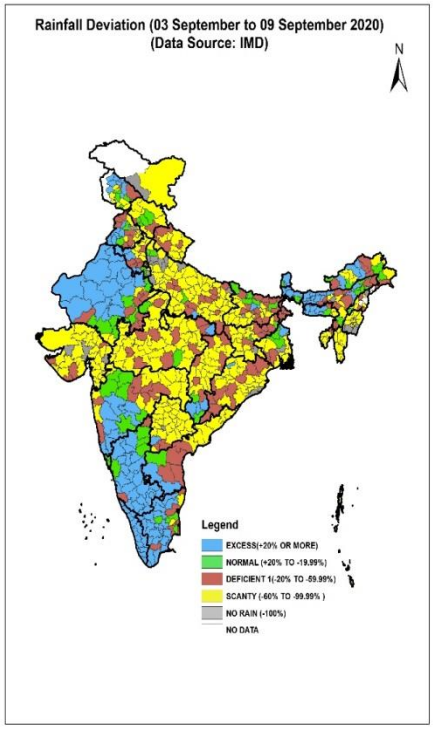

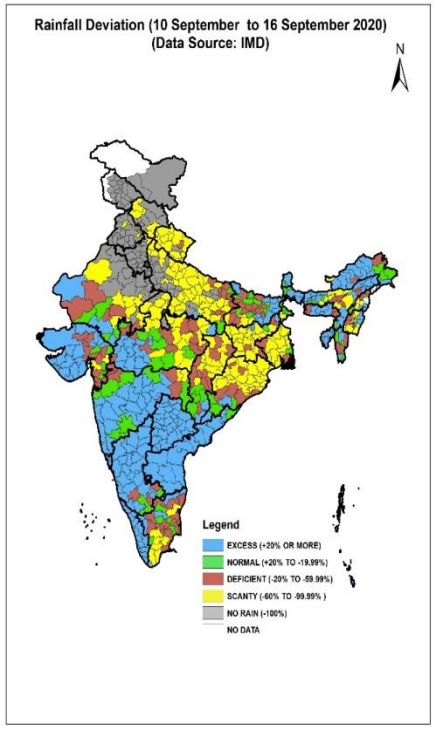

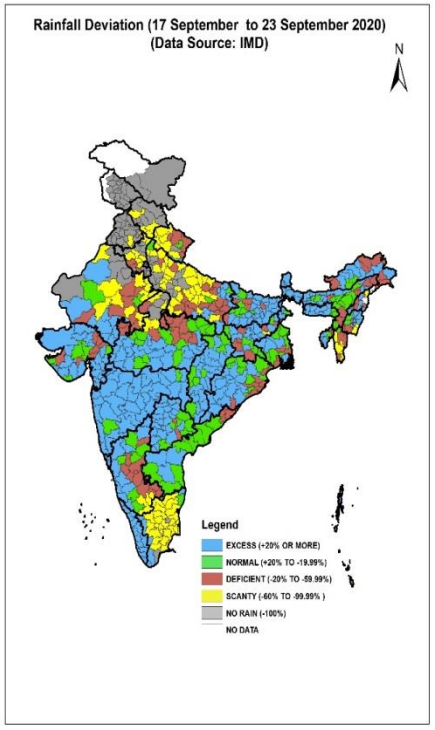

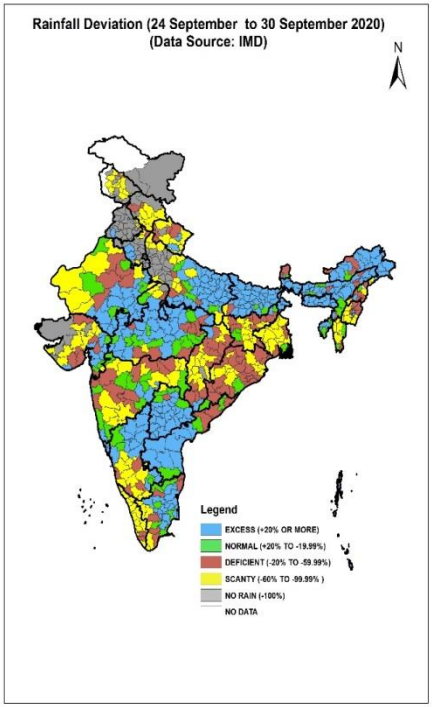

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Cumulative Rainfall Deviation - September 2020

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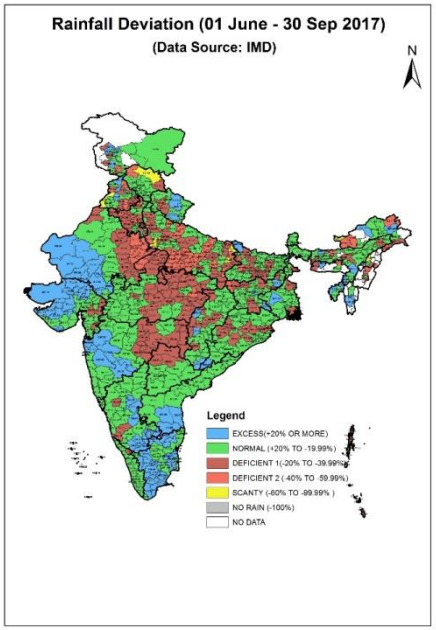
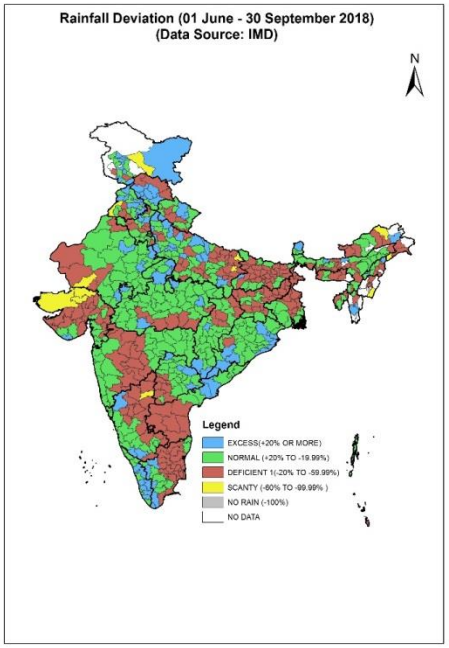
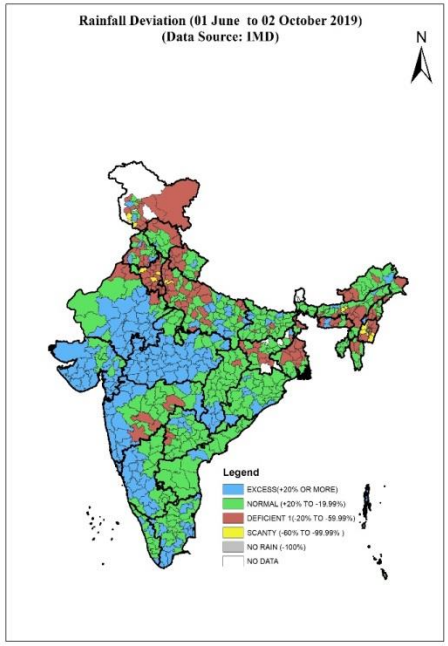
Cumulative 1 June -30 September 2017



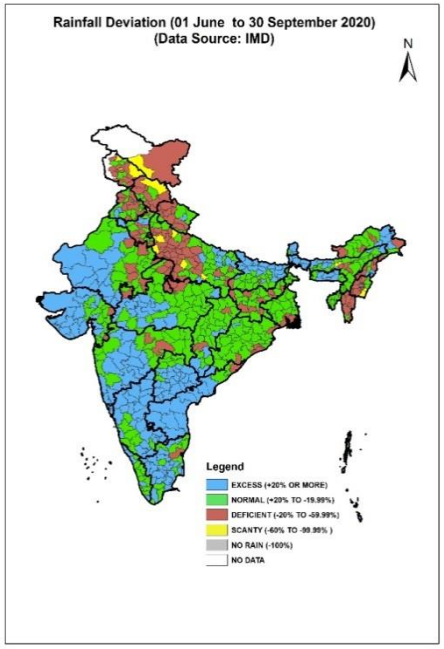
Cumulative 1 June - 30 September 2018



Cumulative 1 June - 2 October 2019



Cumulative 1 June - 30 September 2020



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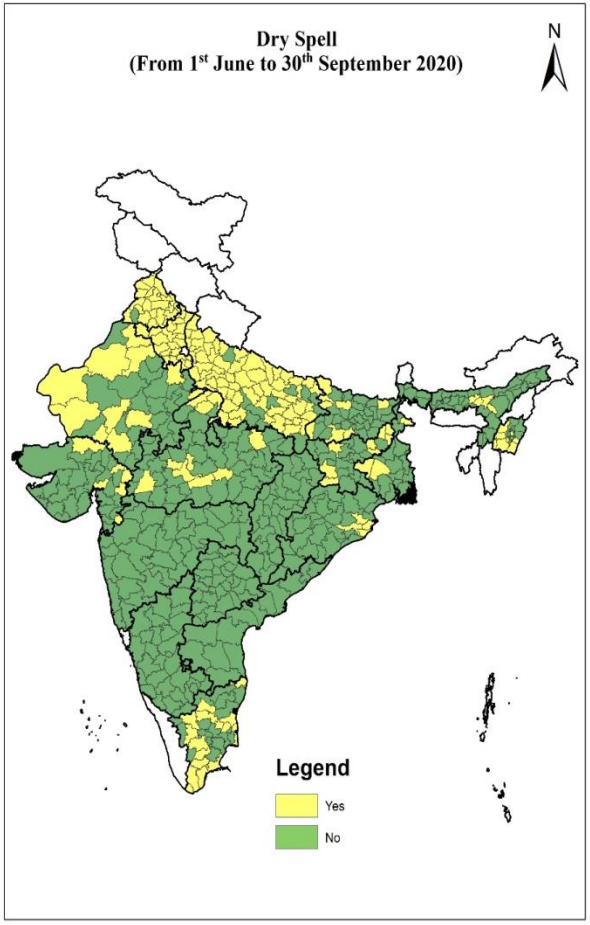
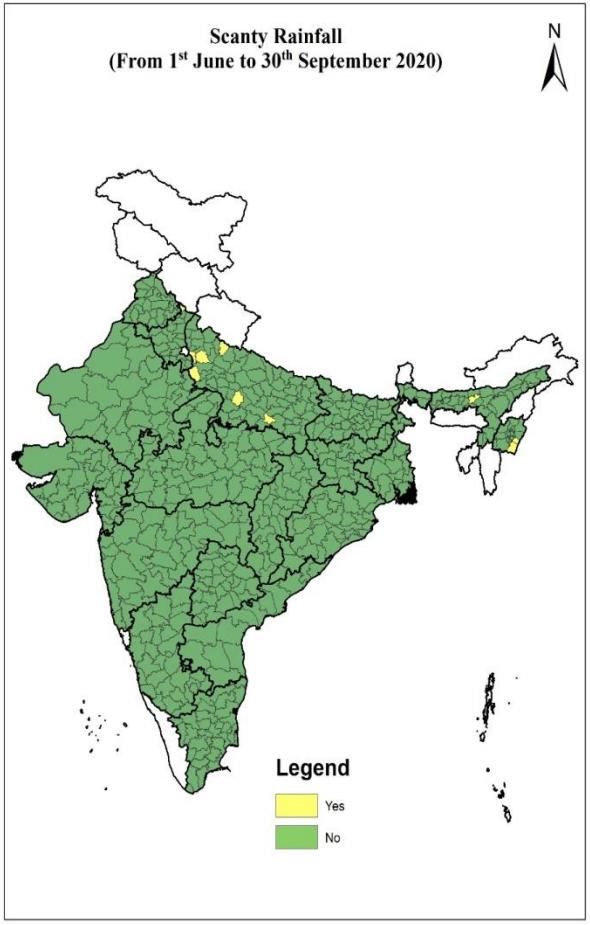
Dry Spell and Scanty Rainfall





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Trigger 1 Based on Scanty Rainfall and Dry Spell

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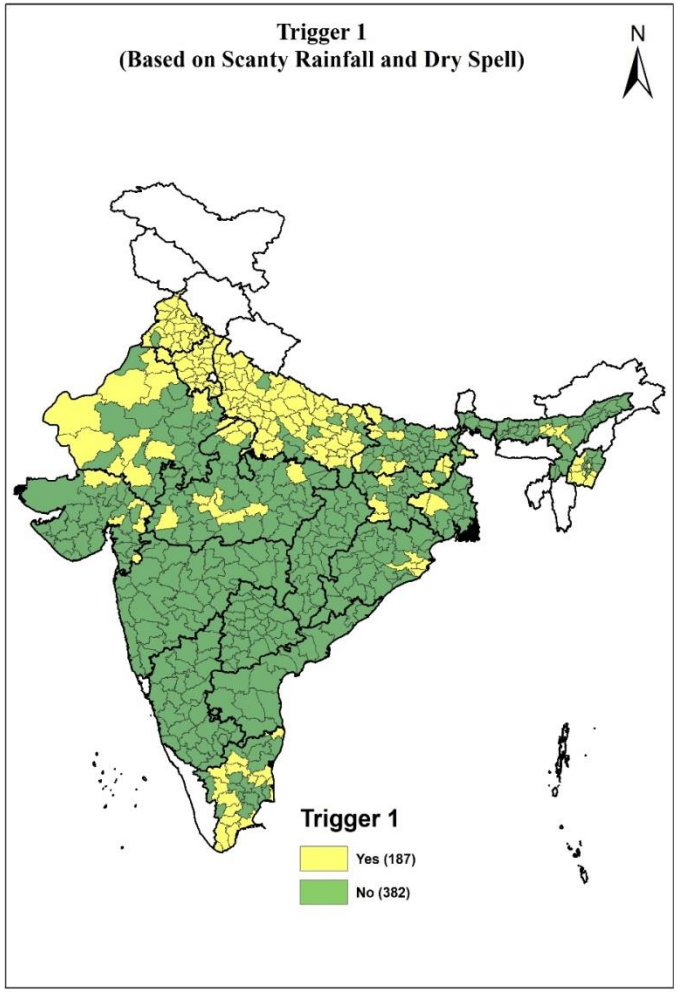
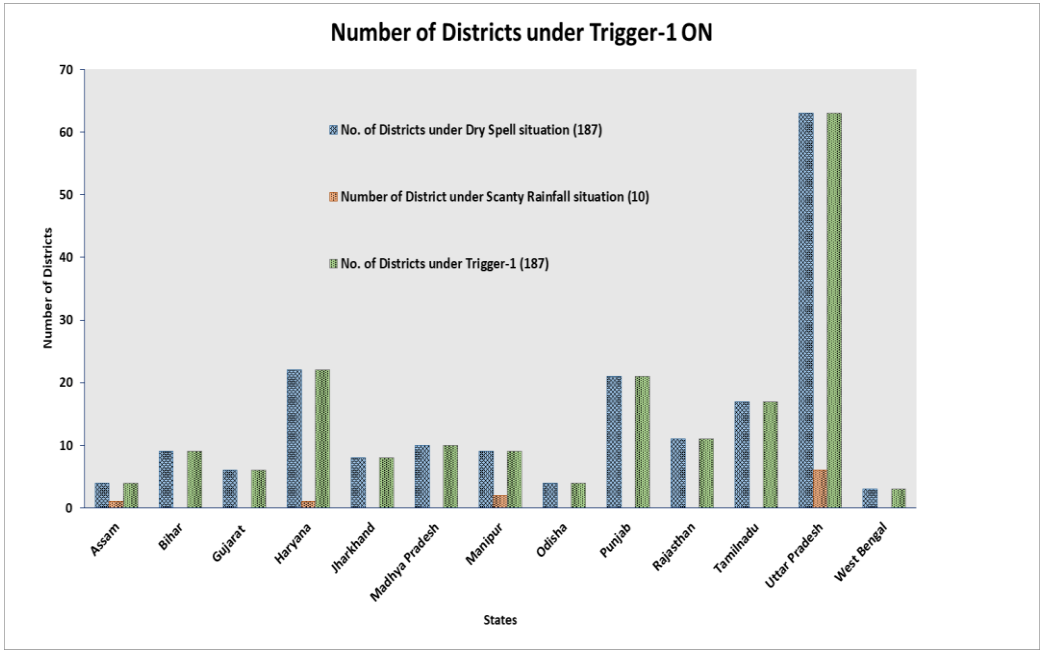


State	No. of Districts under Dry Spell situation (187)	Number of District under Scanty Rainfall situation (10)	No. of Districts under Trigger-1 (187)
Assam	4	1	4
Bihar	9	0	9
Gujarat	6	0	6
Haryana	22	1	22
Jharkhand	8	0	8
Madhya Pradesh	10	0	10
Manipur	9	2	9
Odisha	4	0	4
Punjab	21	0	21
Rajasthan	11	0	11
Tamilnadu	17	0	17
Uttar Pradesh	63	6	63
West Bengal	3	0	3
Total	187	10	187



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AWiFS NDVI - September 2019 & 2020

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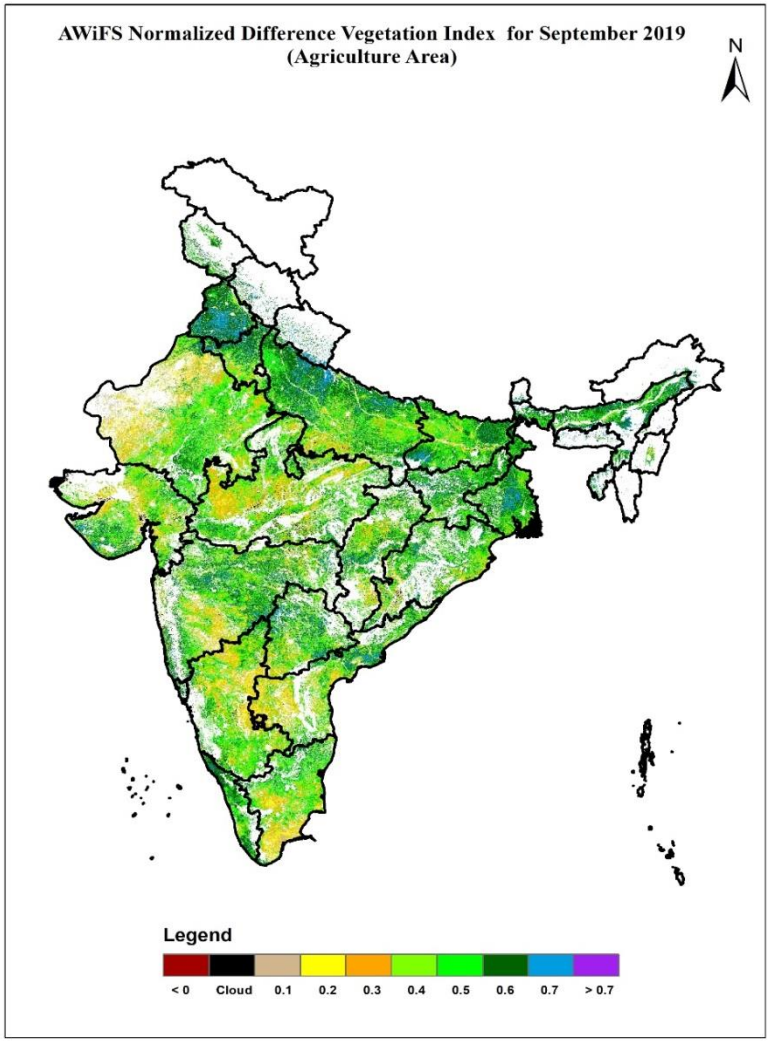
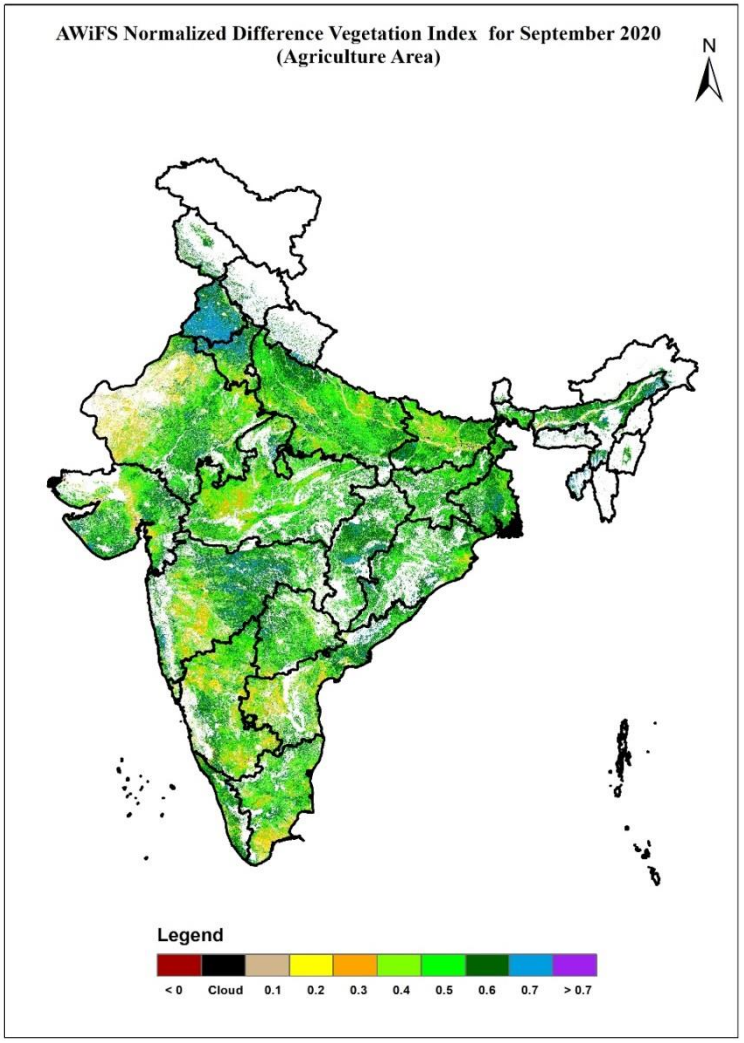
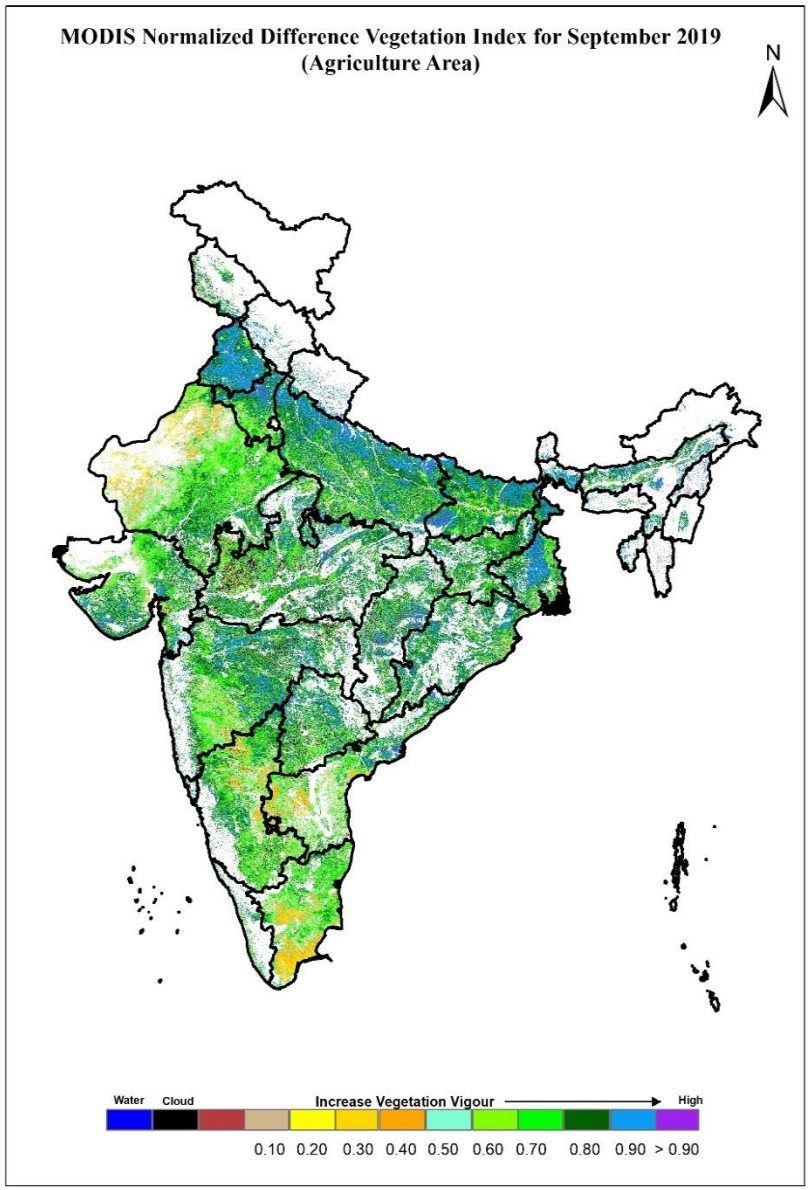
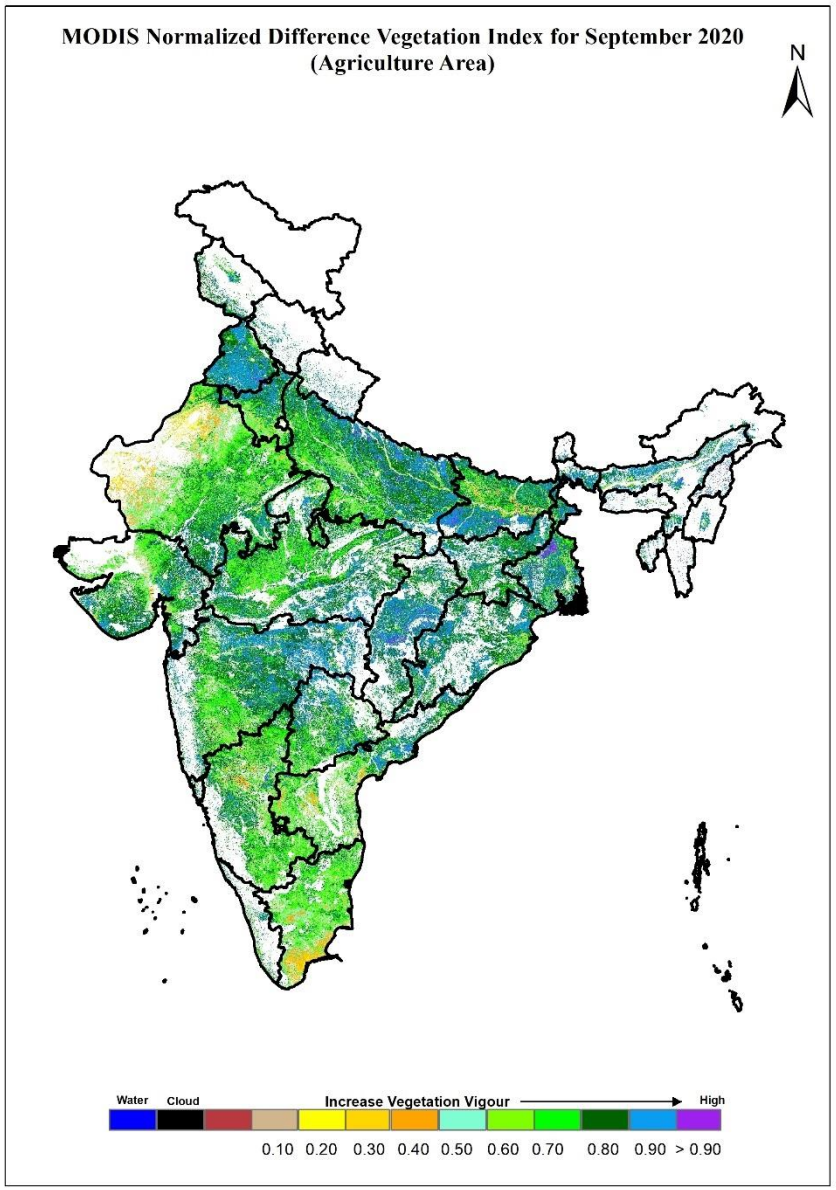




MODIS NDVI - September 2019 & 2020





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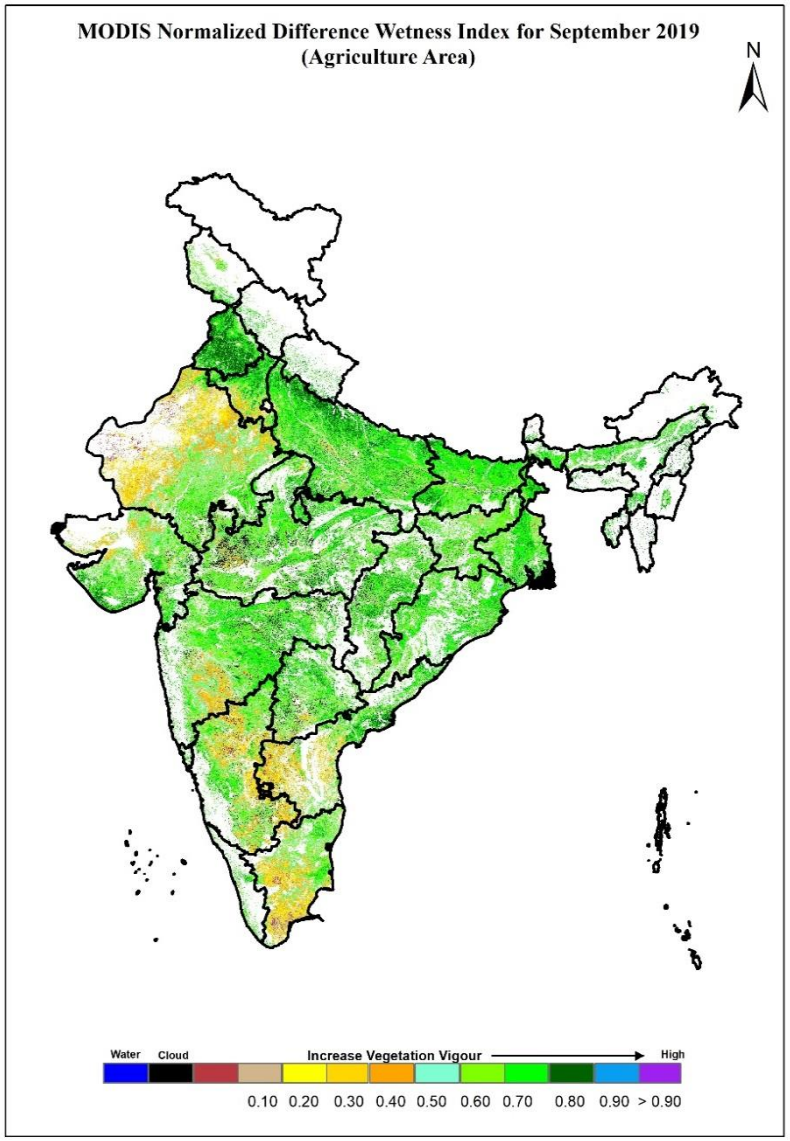
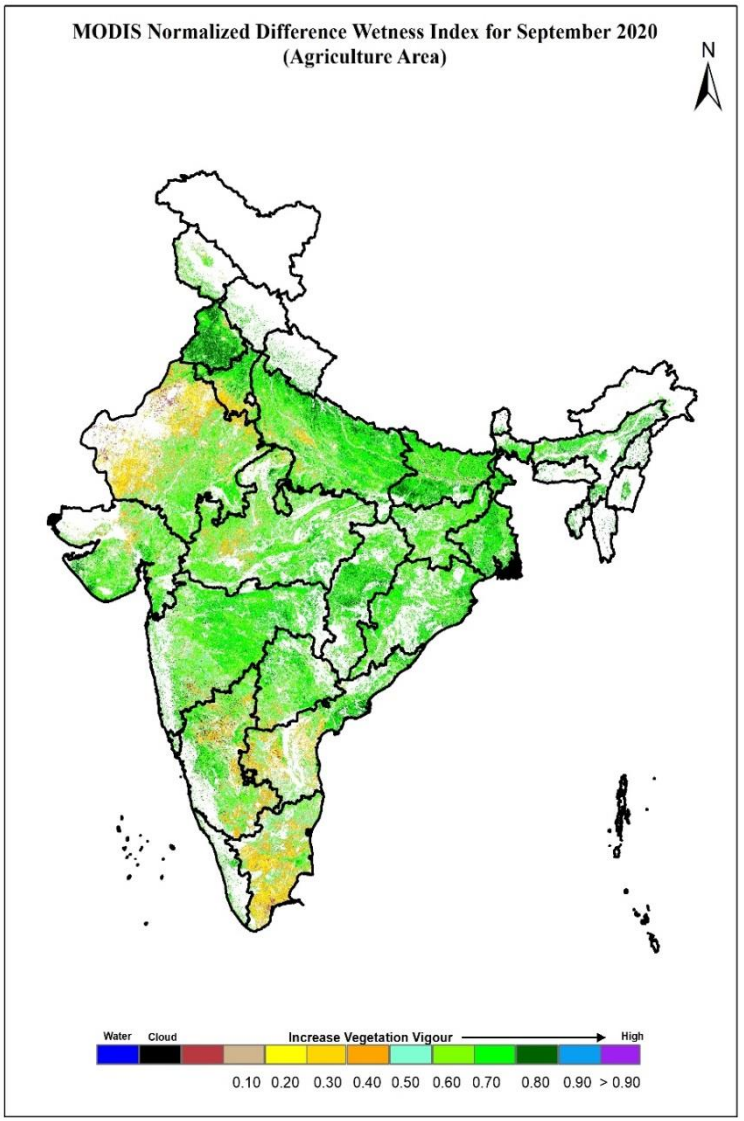
MODIS NDWI - September 2019 & 2020





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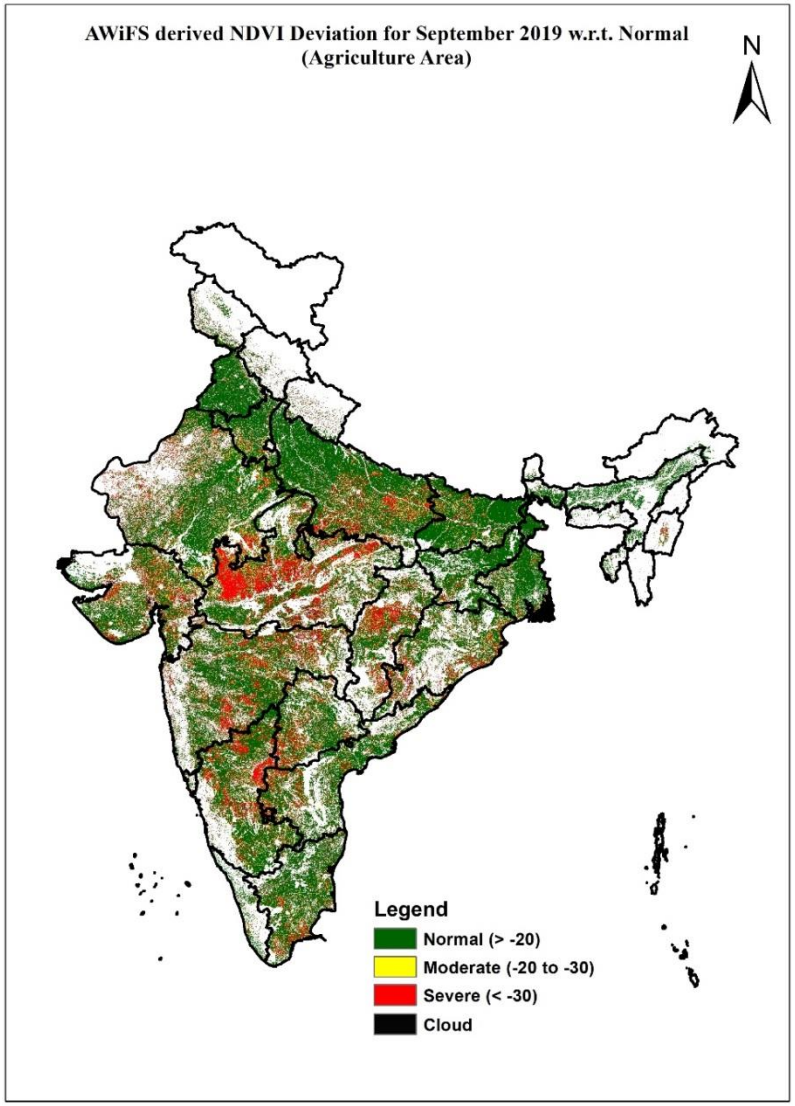
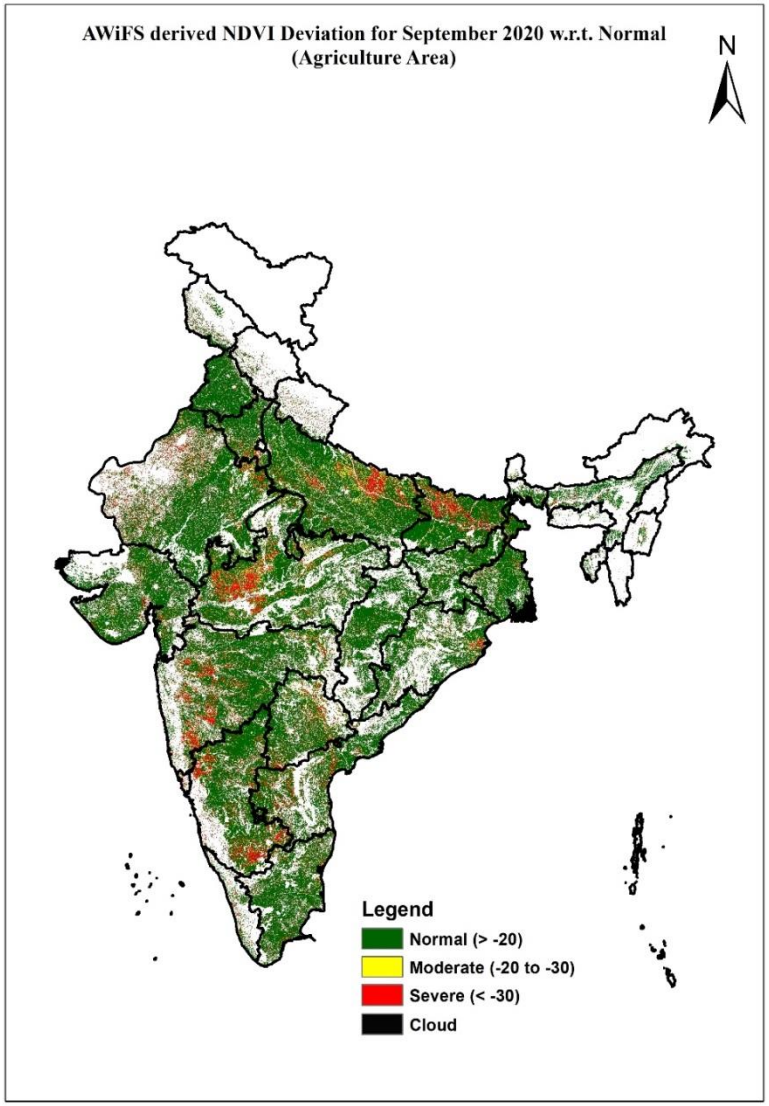
AWiFS NDVI Deviation for September 2019 & 2020 w.r.t. Normal

NCFC





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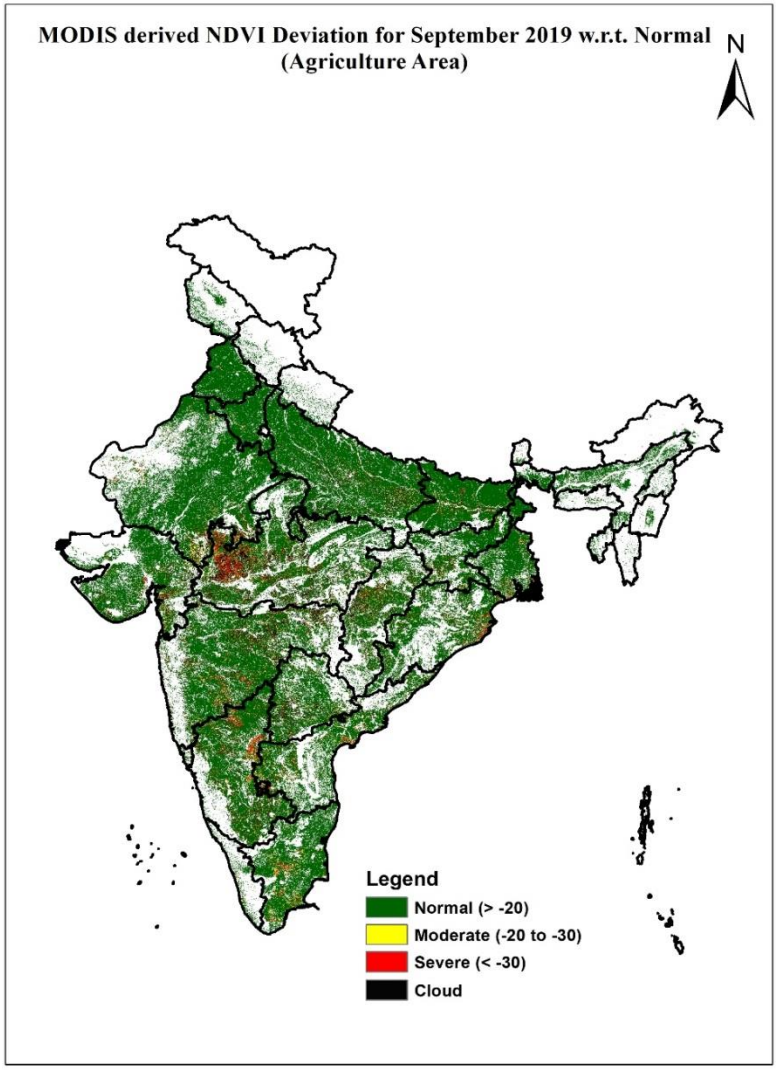
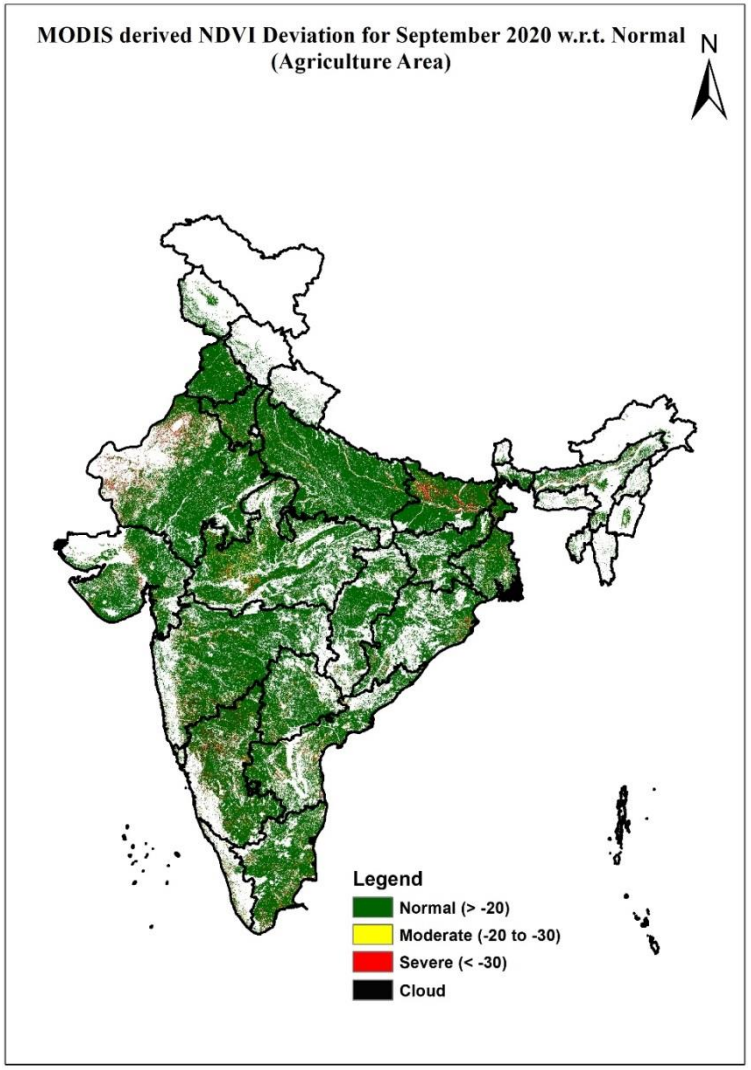
MODIS NDVI Deviation for September 2019 & 2020 w.r.t. Normal

NCFC





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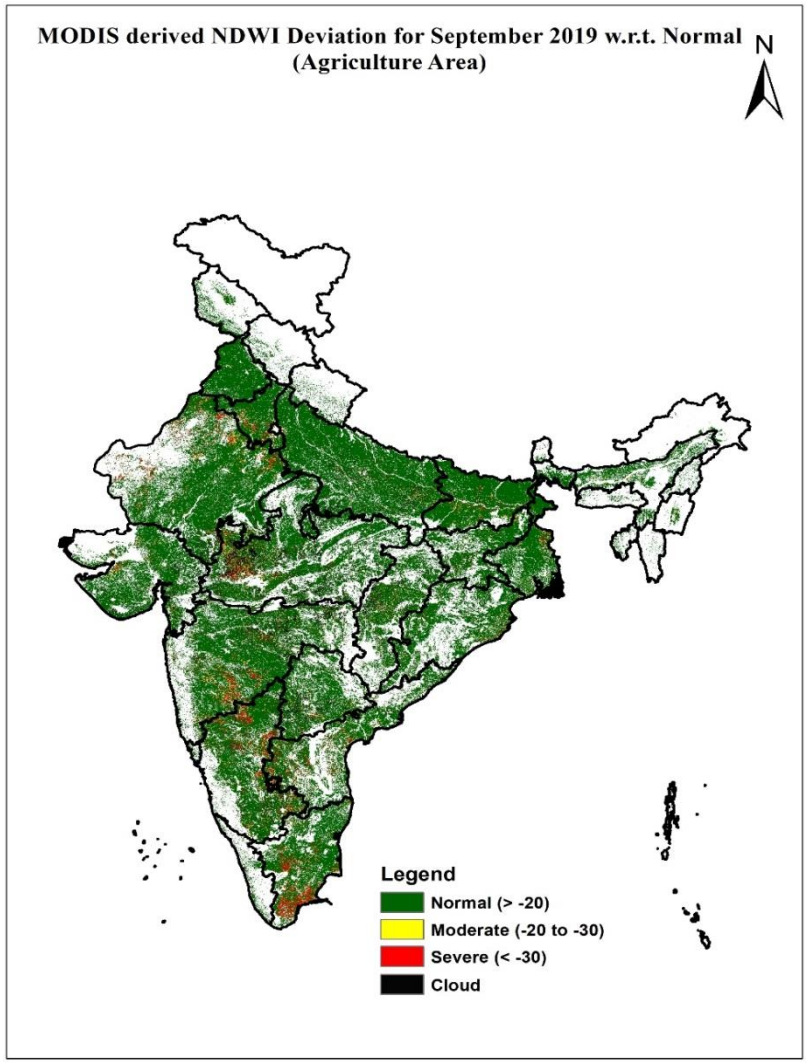
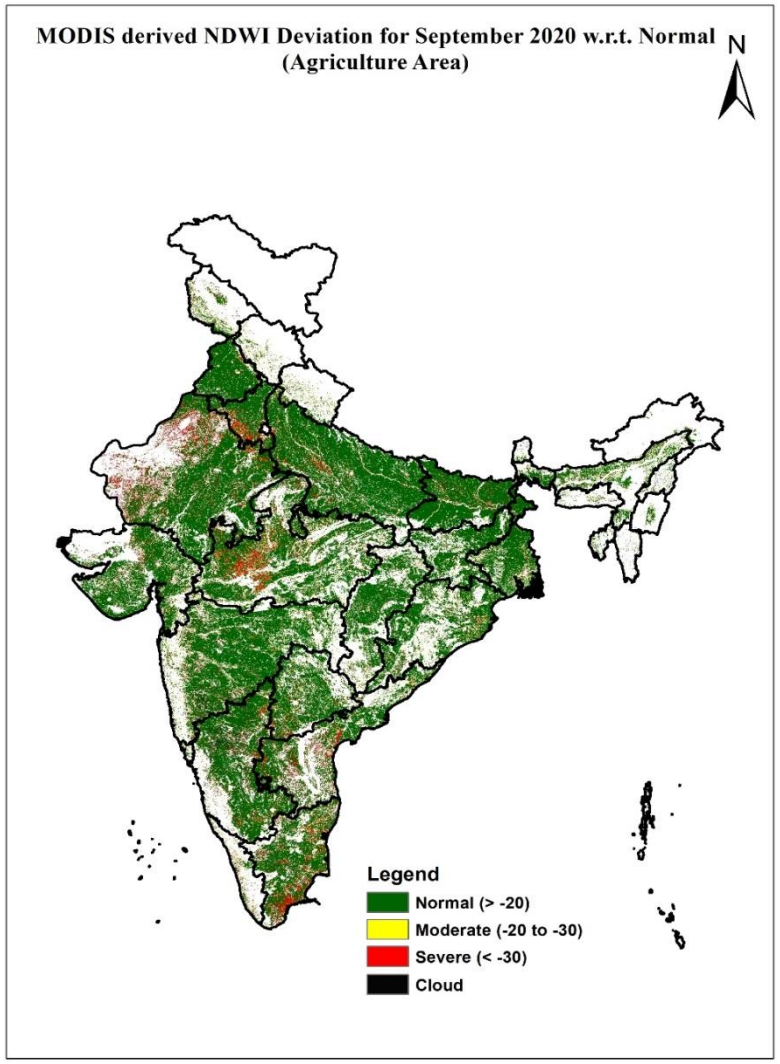
MODIS NDWI Deviation for September 2019 & 2020 w.r.t. Normal

NCFC





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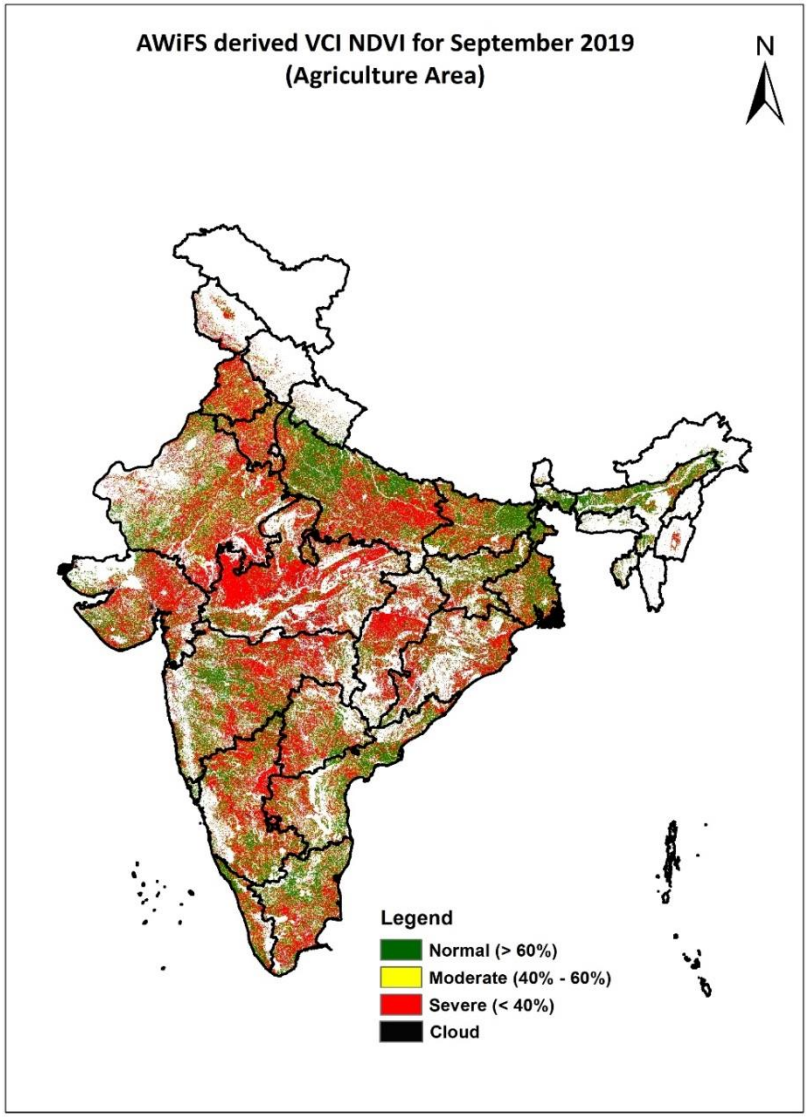
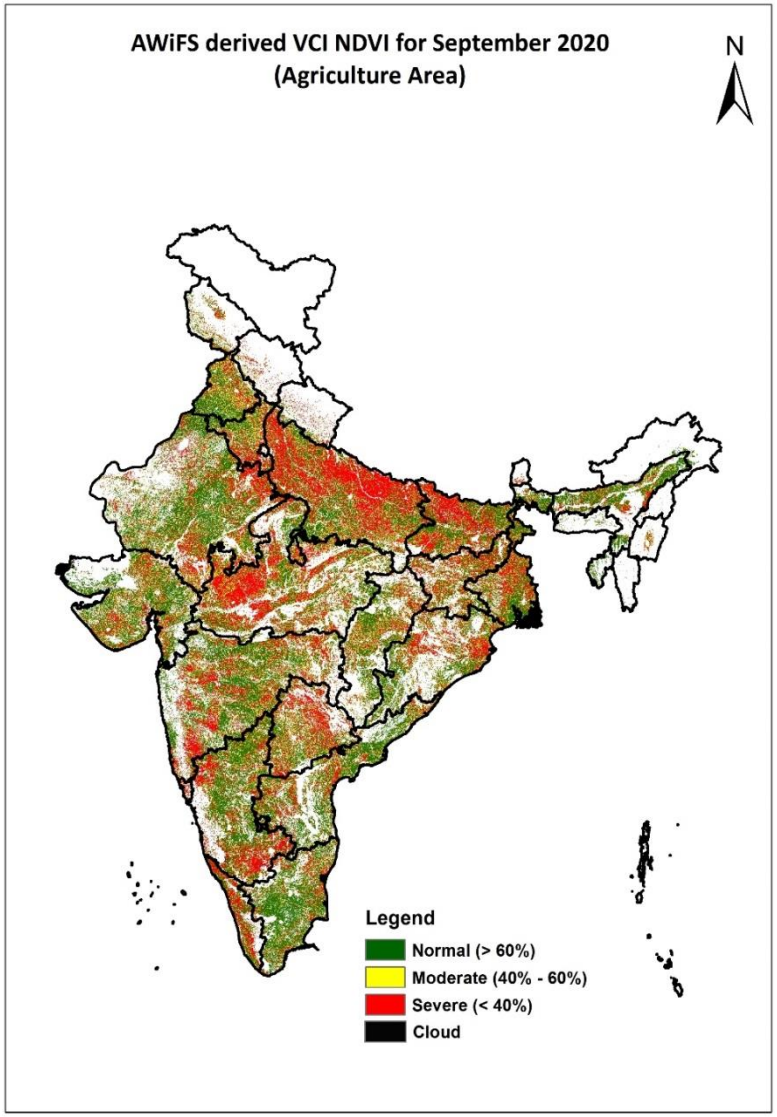
AWiFS Vegetation Condition Index (NDVI)- September 2019 & 2020

NCFC





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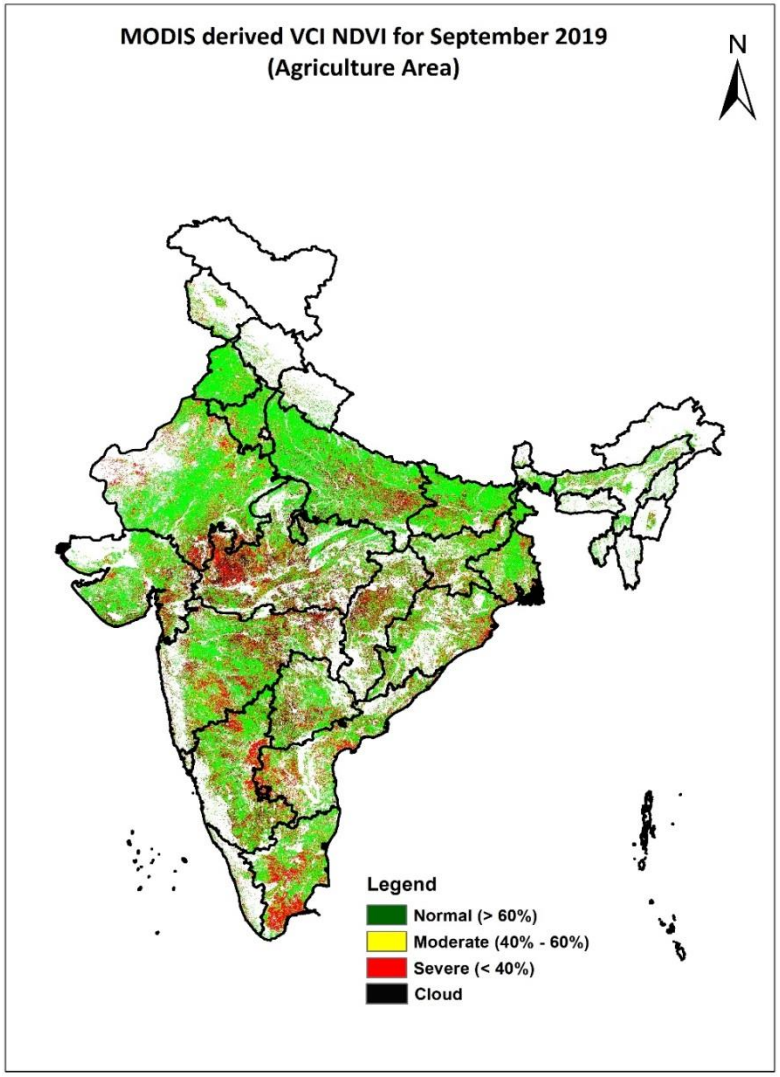
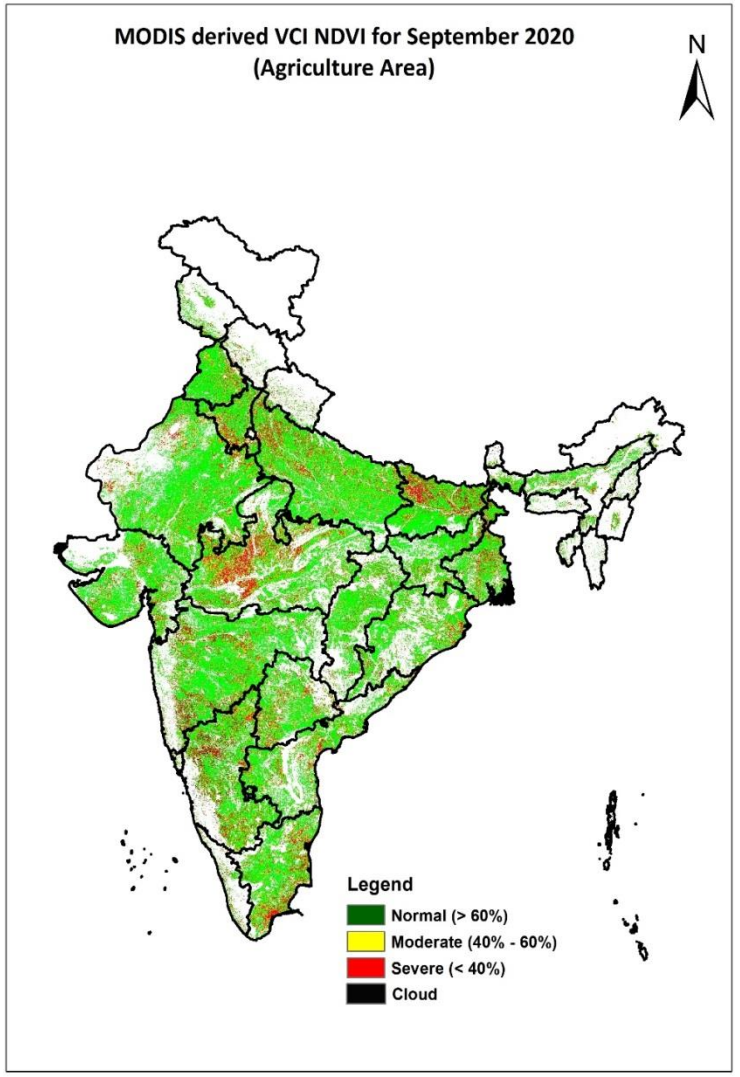
MODIS Vegetation Condition Index (NDVI)- September 2019 & 2020

NCFC





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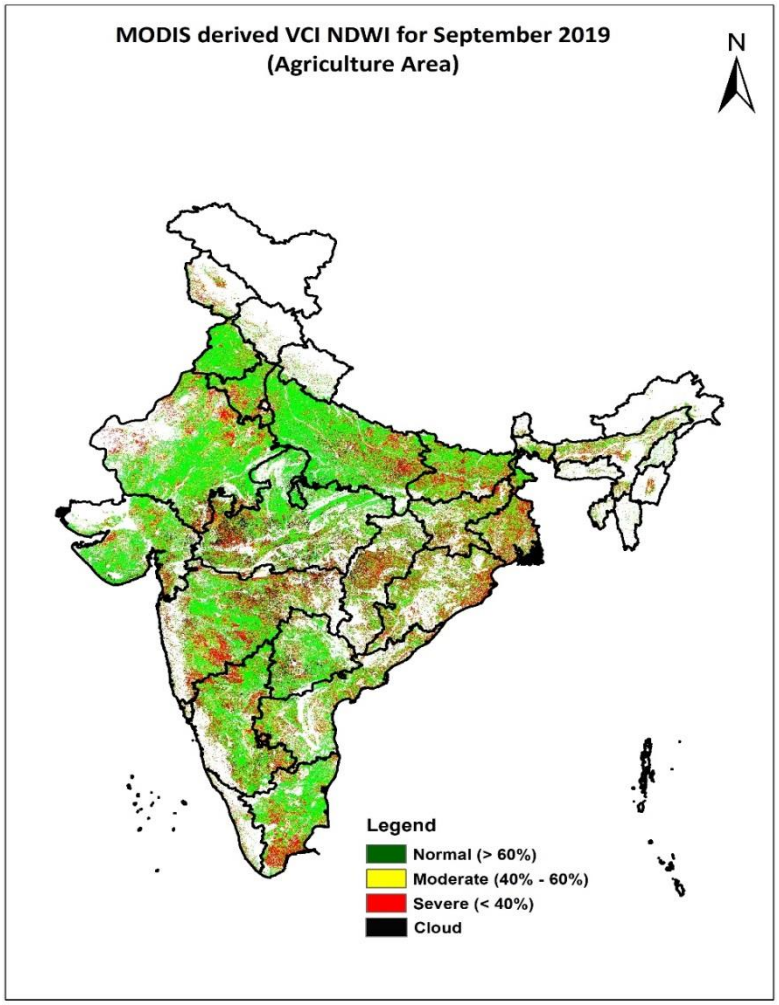
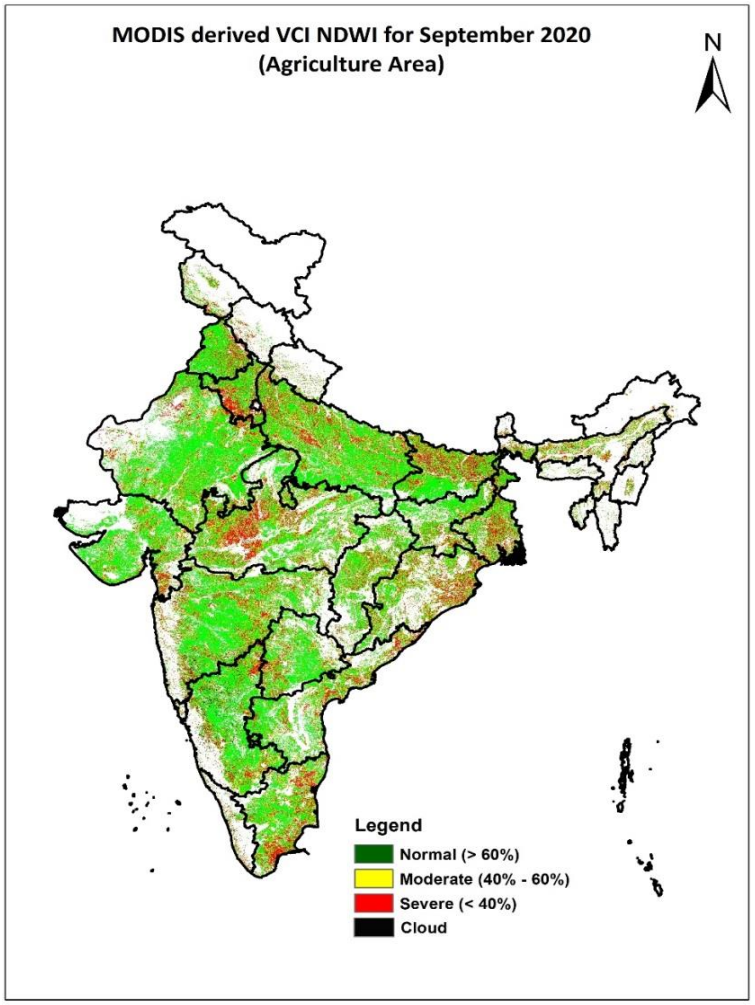
MODIS Vegetation Condition Index (NDWI)- September 2019 & 2020

NCFC





Percent Available Soil Moisture (PASM) up to 31st September 2020

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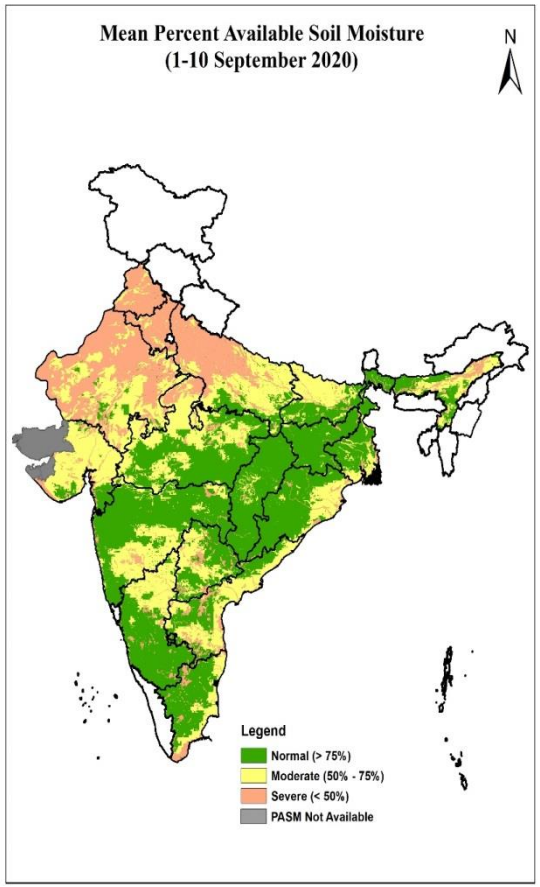
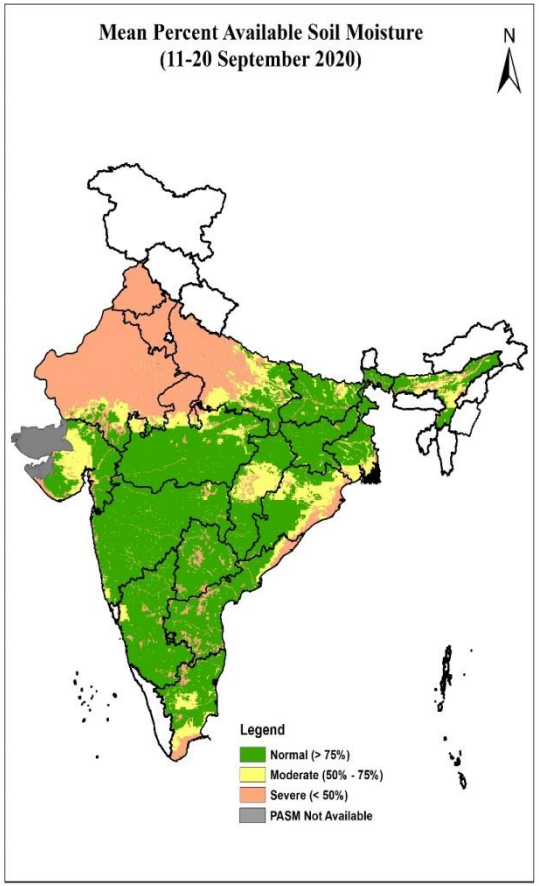
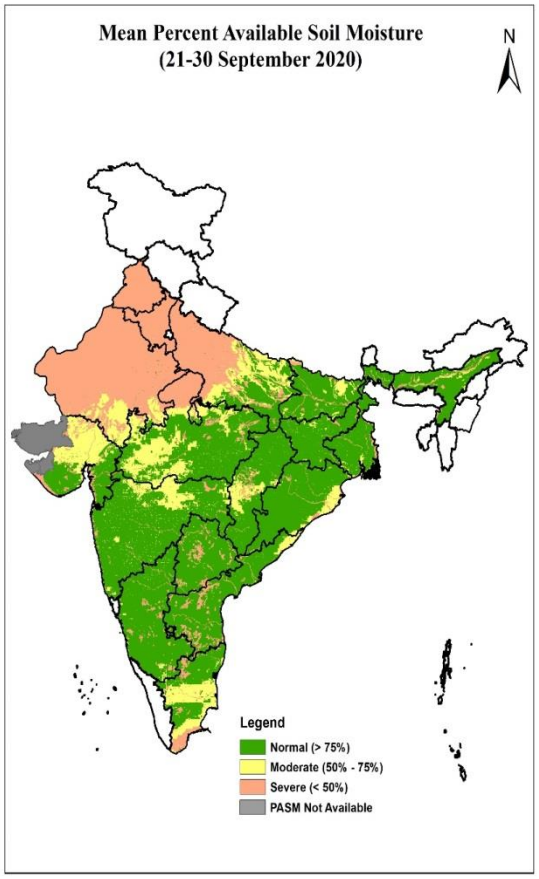
Mean Percent Available Soil Moisture (1st September to 10th September 2020)



Mean Percent Available Soil Moisture (11th September to 20th September 2020)



Mean Percent Available Soil Moisture (21st September to 31st September 2020)



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District level NDVI/NDWI deviation & Soil Moisture – September 2020

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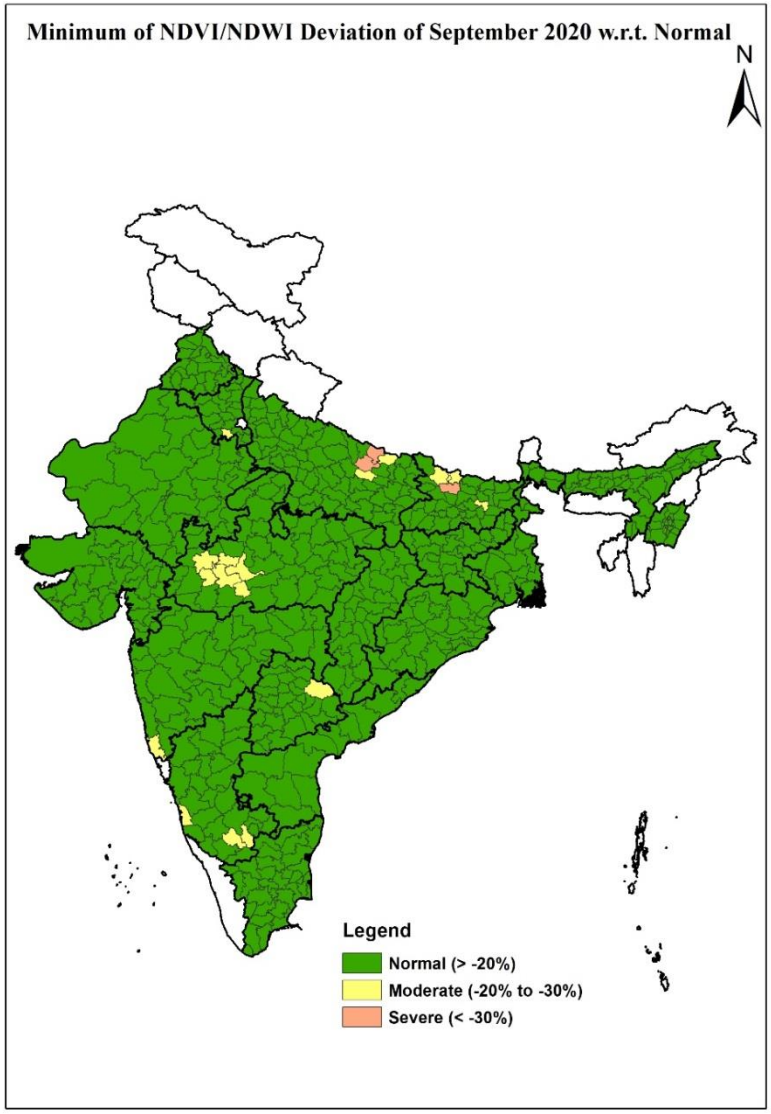

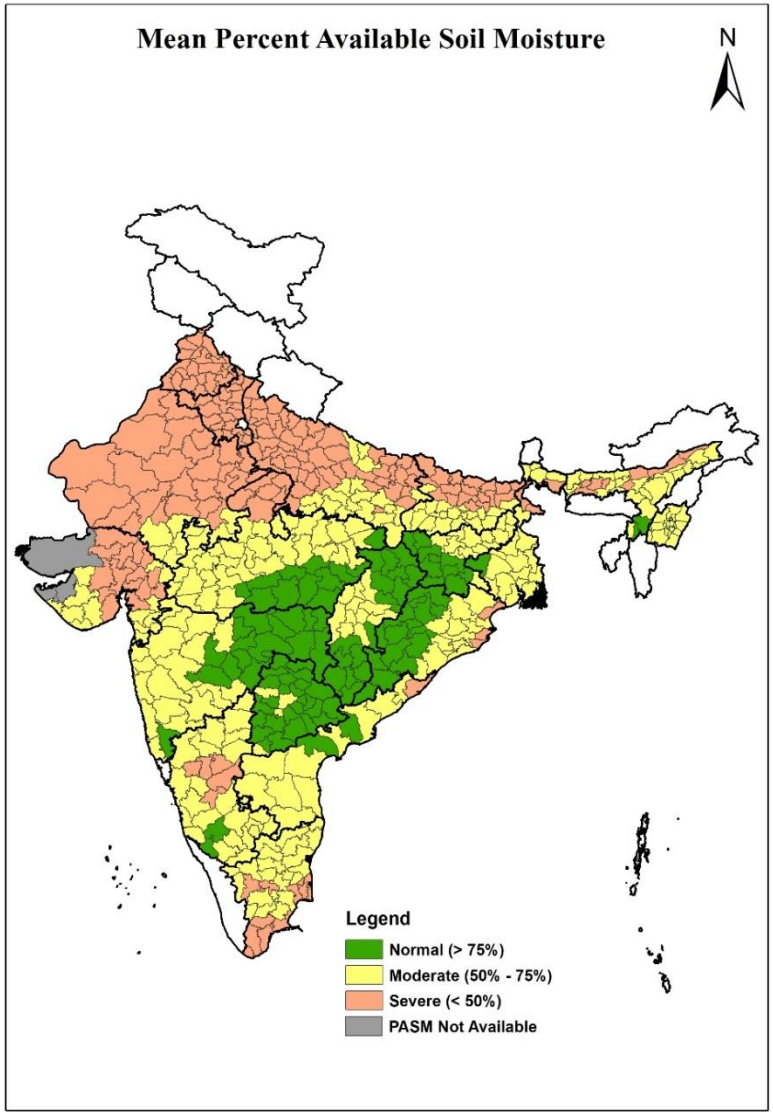

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Crop Sown Area: June to September 2020

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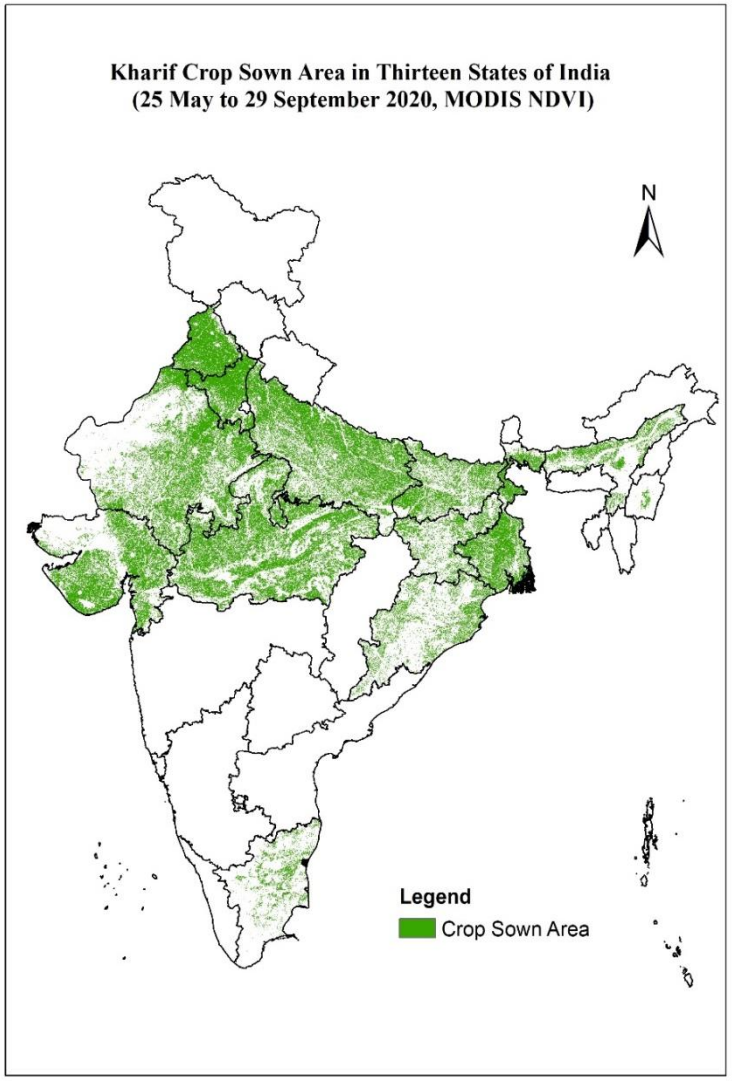

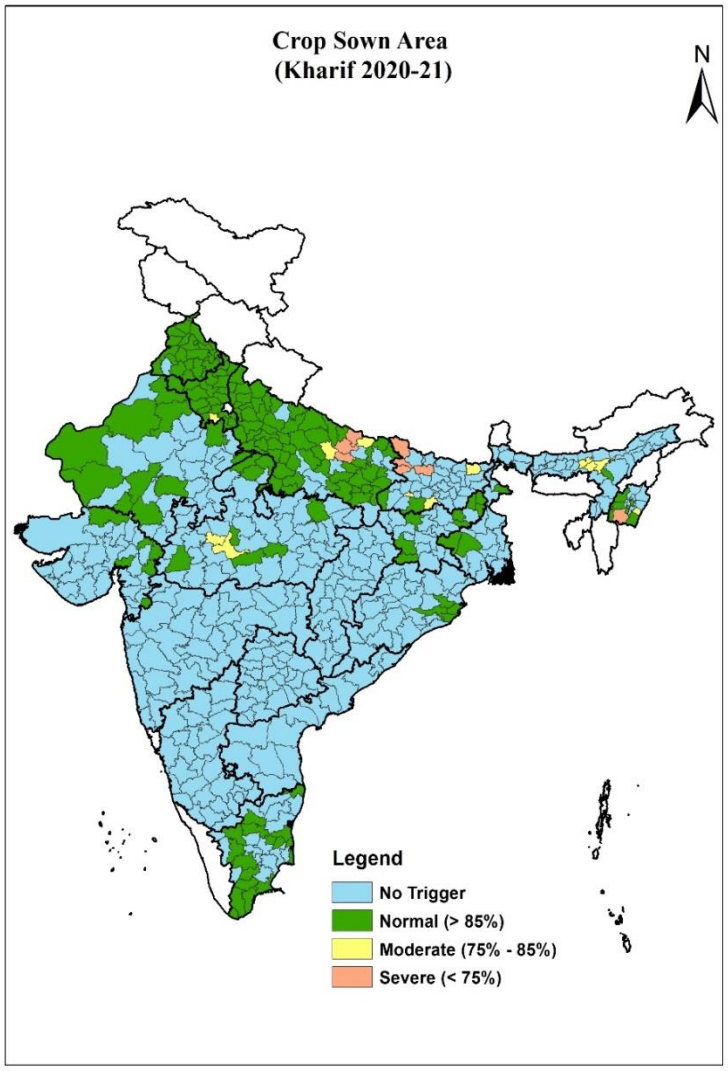

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Reservoir Storage Position

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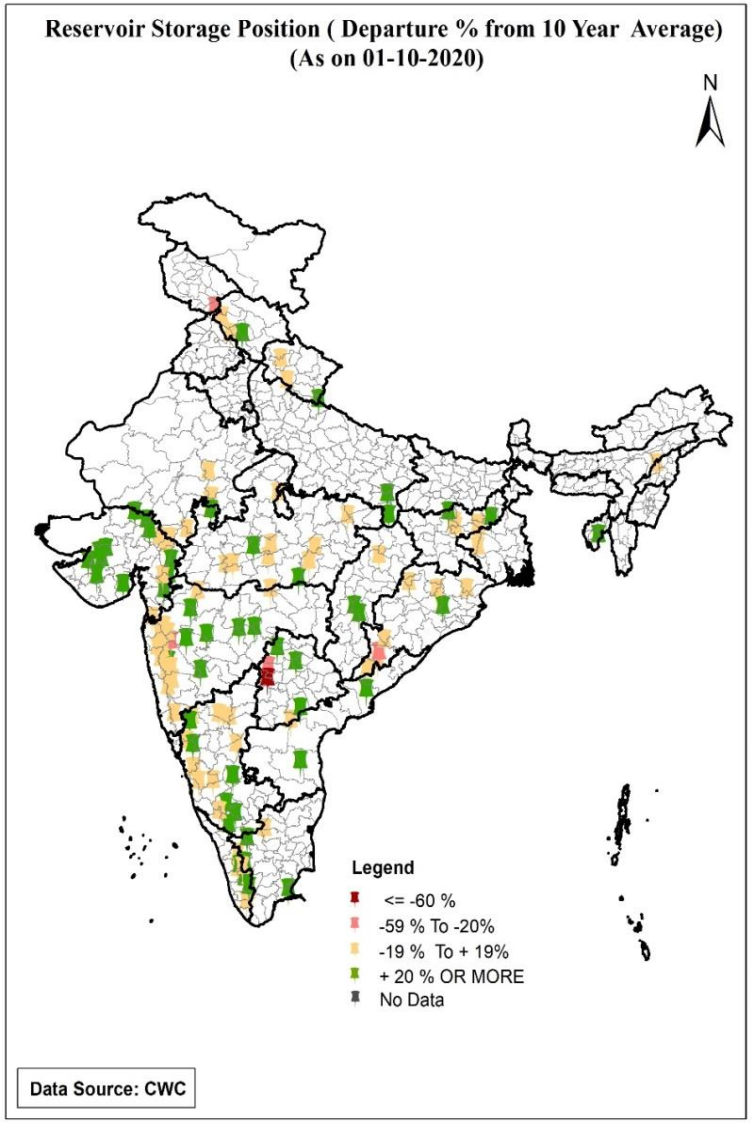

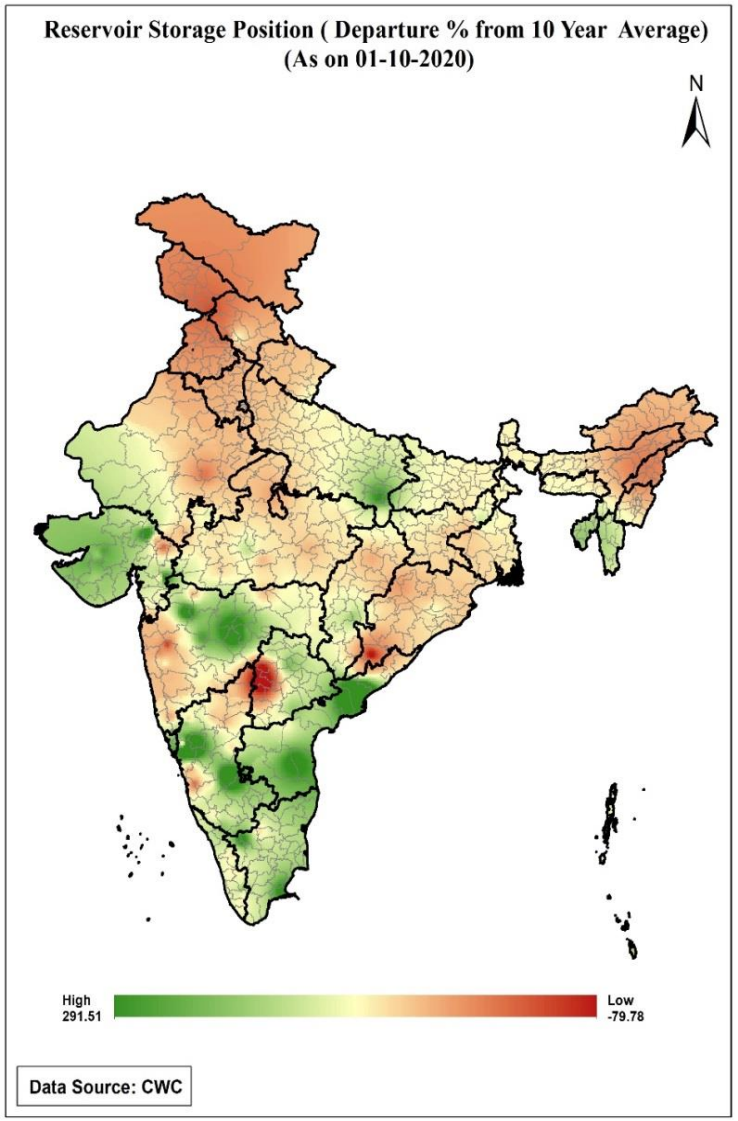

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Agricultural Drought Indicators – September 2020

(Based on rainfall, Remote sensing, Soil Moisture and Crop Sown Area)

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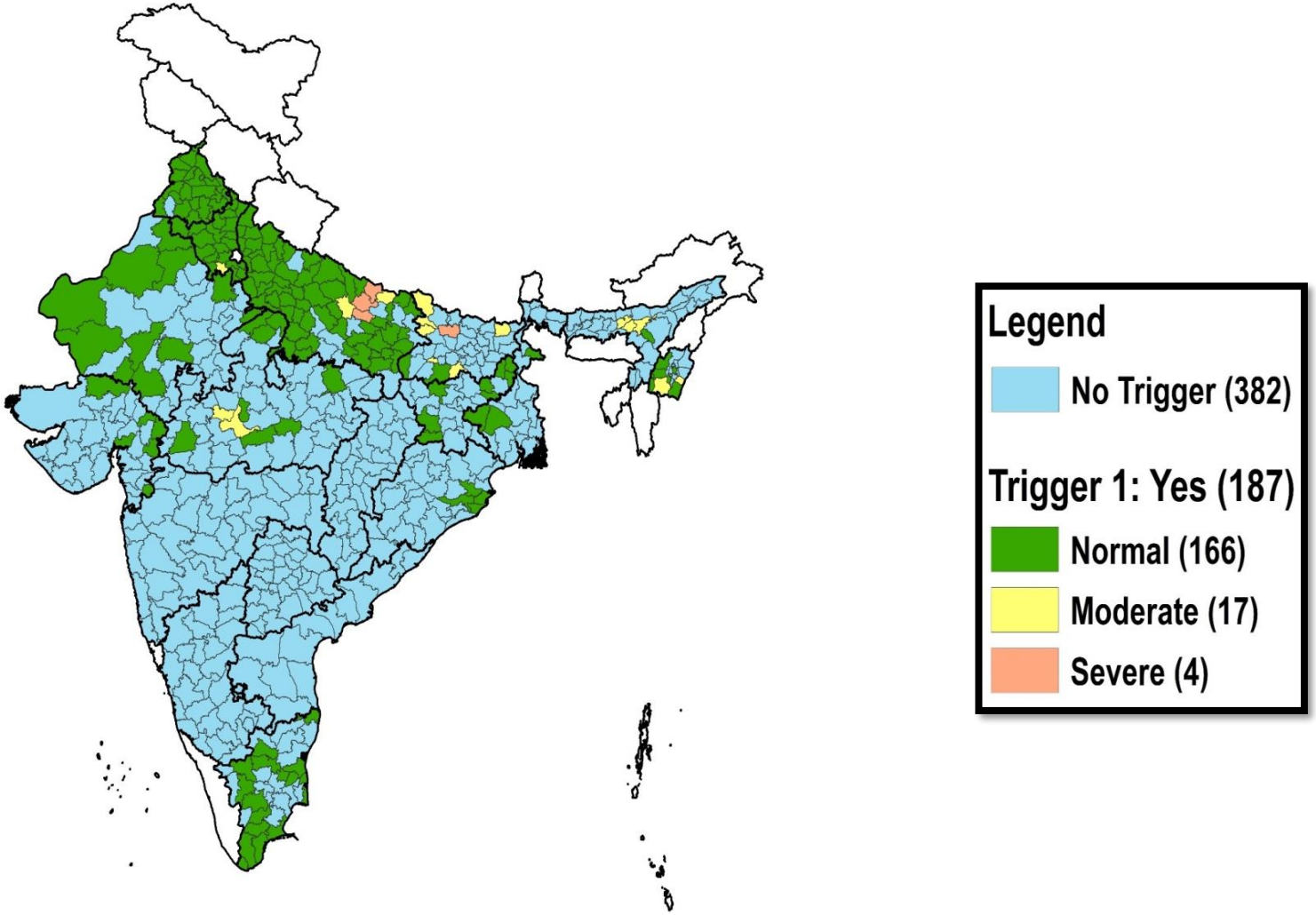

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Assessment of *Rabi* Drought Indicators 2019-20

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- Rabi drought Assessment is a typical procedure, where the districts have to be first classified into different Cropping Situations (NE Monsoon, Rainfed, Surface Irrigated and Ground water Irrigated). The Drought Indicators and Assessment criteria are different for different cropping situations (Annexure I).

- Initially, the districts were categorized into four different cropping situations. NE Monsoon districts were identified based on IMD Report. (Situation 4).
- Rainfed districts were categorized using climate based on Moisture Index (Thornthwaite and Mather, 1995) and guidelines provided by Hanumantha Rao Committee (1994) (Annexure II). (Situation 1). The rest irrigated districts were classified into Surface (Situation 2) or Ground water irrigated (Situation 3), based on source wise Irrigation percentage (From DES Data).

- The Assessment was carried out for Rainfed, Ground Water Irrigated area and NE Monsoon districts. For Surface irrigated Districts, Reservoir Storage position was checked from CWC data.

- Assessment was carried out for 15 major Agricultural states of the Country.

Identification of District wise Rabi cropping situation

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Total Districts (497) of 15 States

IMD's North-East Monsoon Report

NE Monsoon
(Situation 4)
(61 Districts)

Others
(436 Districts)

Irrigation% (NAI/NAS) Statistics from DES

(≤30% of Irrigation dependable areas)*

(>30% of Irrigation dependable areas)

Rainfed Districts
(Situation 1)
(178 Districts)

Irrigated Districts
(254 Districts)

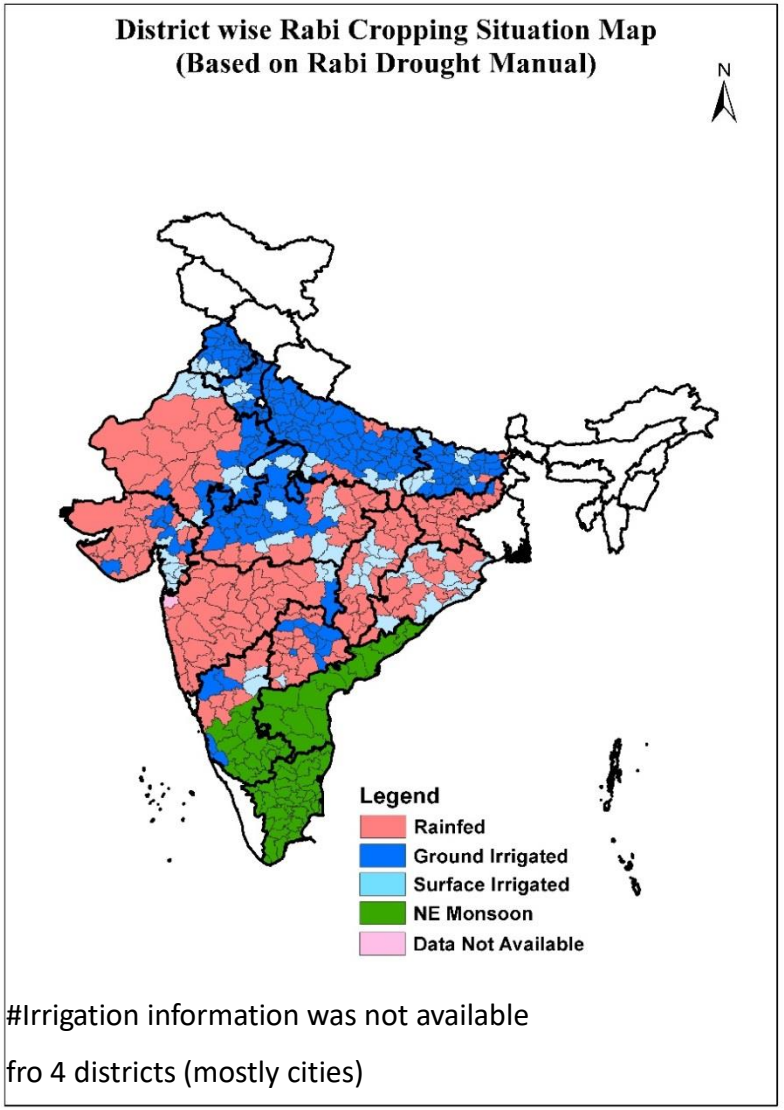
Source of Irrigation

>50% Well Irrigated

>50% Canal Irrigated

Ground Water
(Situation 3)
(183 Districts)

Surface Irrigated
(Situation 2)
(71 Districts)



#Irrigation information was not available fro 4 districts (mostly cities)

*The Approach for identifying Rainfed Districts is given in Annexure II

Data and Sources

Parameter	Data/ Approach Used
Rainfall Deviation (%), Dry spell	IMD Rainfall Data
NDVI Deviation (%)	Resourcesat 2 AWiFS (56 m)
Sown Area Deviation (%)	Analysis of Multi-year and Multi-date satellite data of Proba V (300 m) and Resourcesat 2 AWiFS (56 m); Data from State Agriculture Department
Soil Moisture Index (PASM)	Soil Water Balance Model
Groundwater Drought Index (GWDI)	Post Monsoon Groundwater Data form Central Ground Water Board
Reservoir Storage Position	CWC
Irrigated Area and Sources	DES

Approach for Drought Assessment

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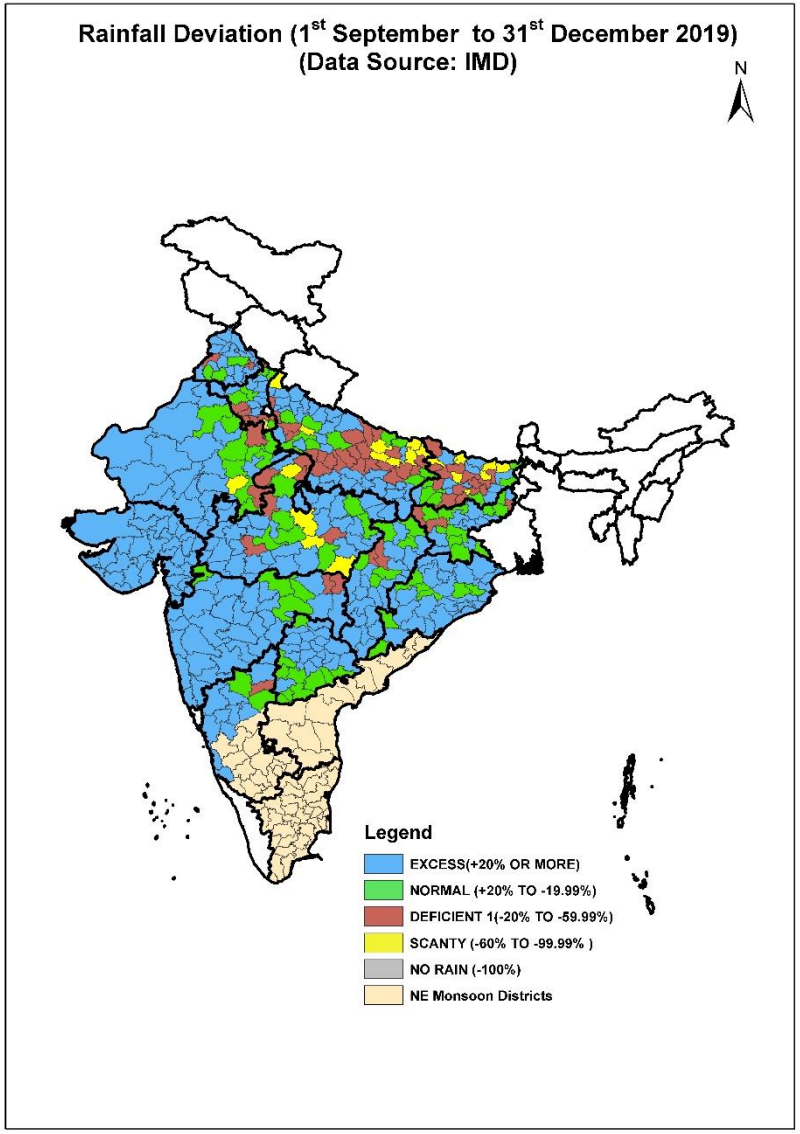
Cropping Situations

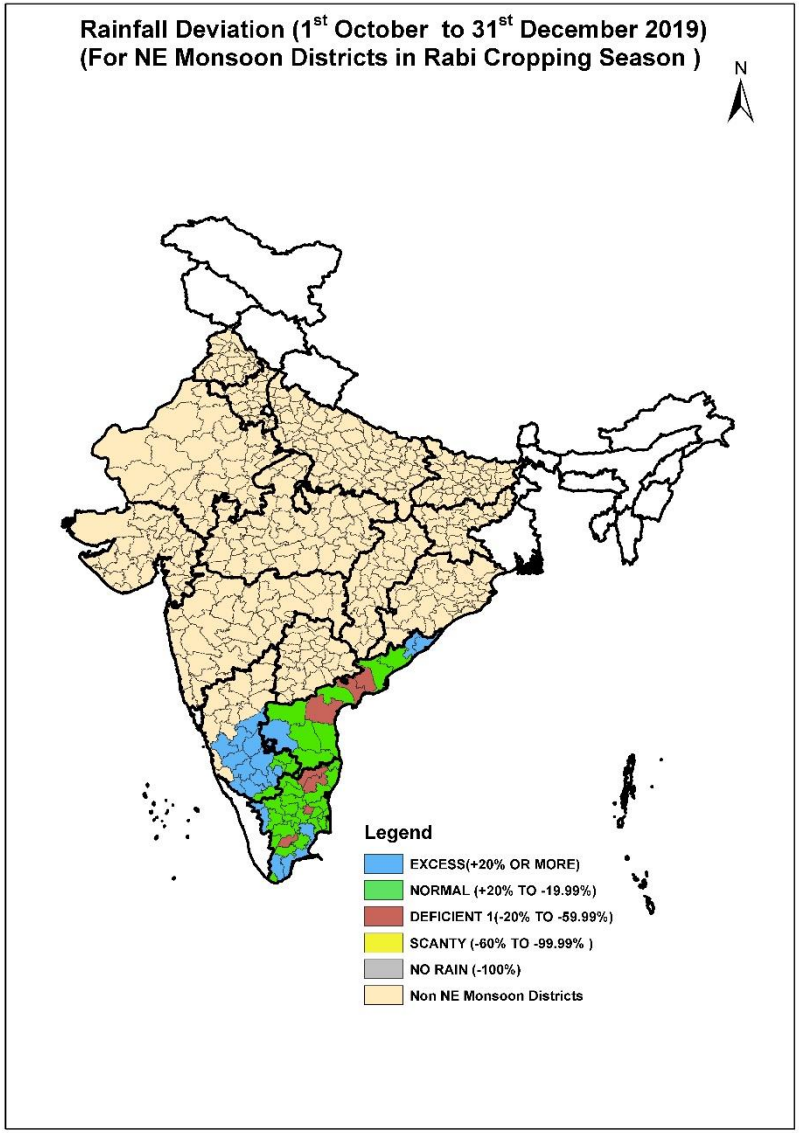
	1. Rainfed	2. Surface Irrigated	3. Ground Water Irrigated	4. NE Monsoon
Trigger 1	RF Dev (%) & Dry Spell (Sep-Dec)	Reservoir Storage Index (RSI)	Ground Water Drought Index (GWDI), Post monsoon	RF Dev (%) & Dry Spell (Oct-Dec)
Trigger 2	Crop Sown Area (%) Soil Moisture (PASM) NDVI Dev (%)	Crop Sown Area (%) NDVI Dev (%) GWDI	Crop Sown Area (%) NDVI Dev (%)	Crop Sown Area (%) Soil Moisture (PASM) NDVI Dev (%)

Rainfall Deviations – up to December 2019

Situation 1 (Rainfed Area)

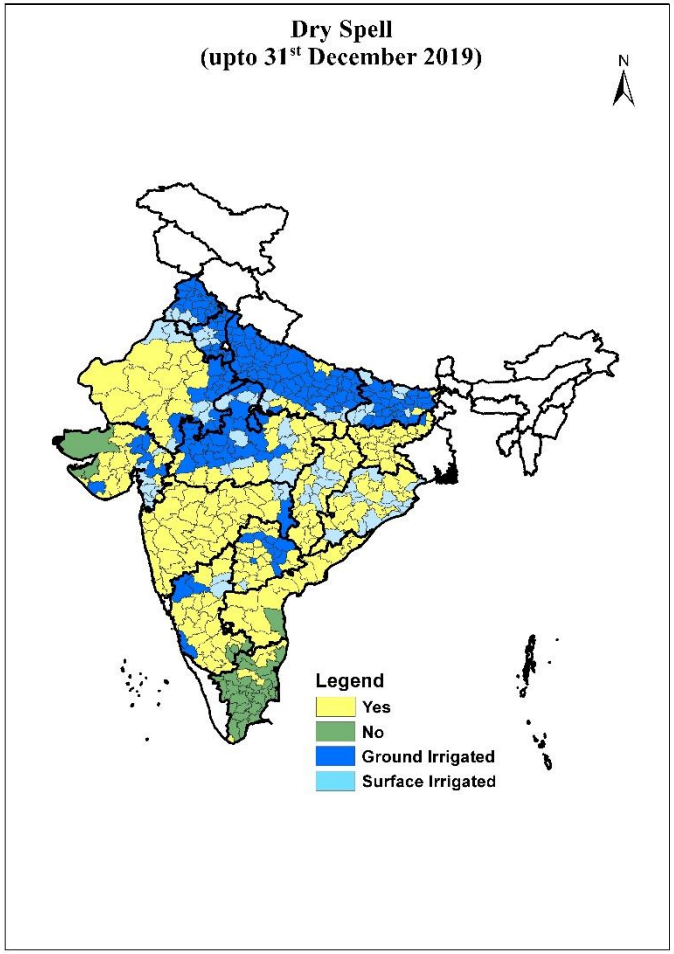


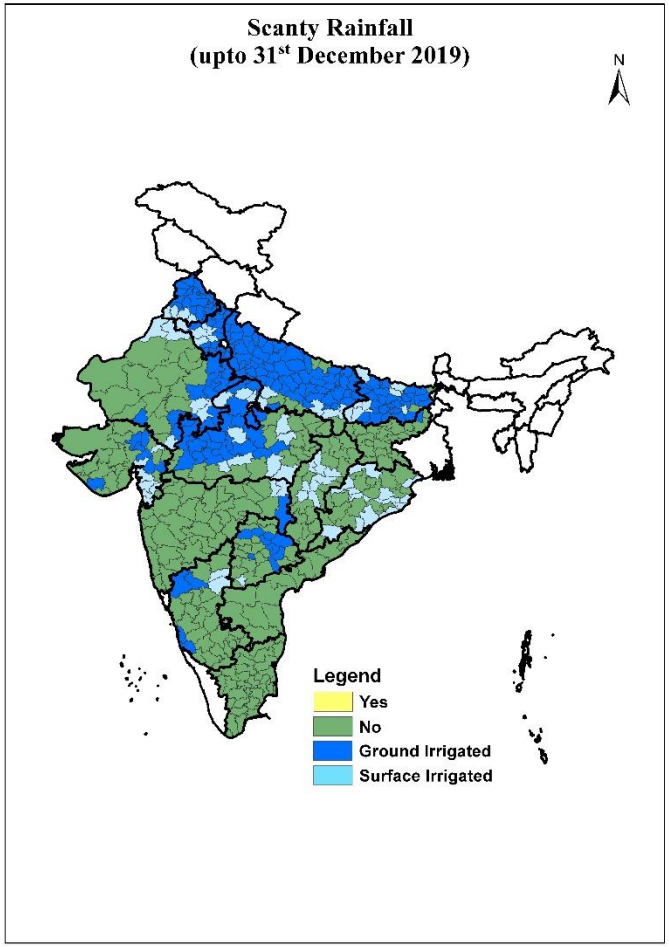
Situation 4 (NE Monsoon)



Data Source: IMD

Dry Spell and Scanty Rainfall – up to 31st December 2019

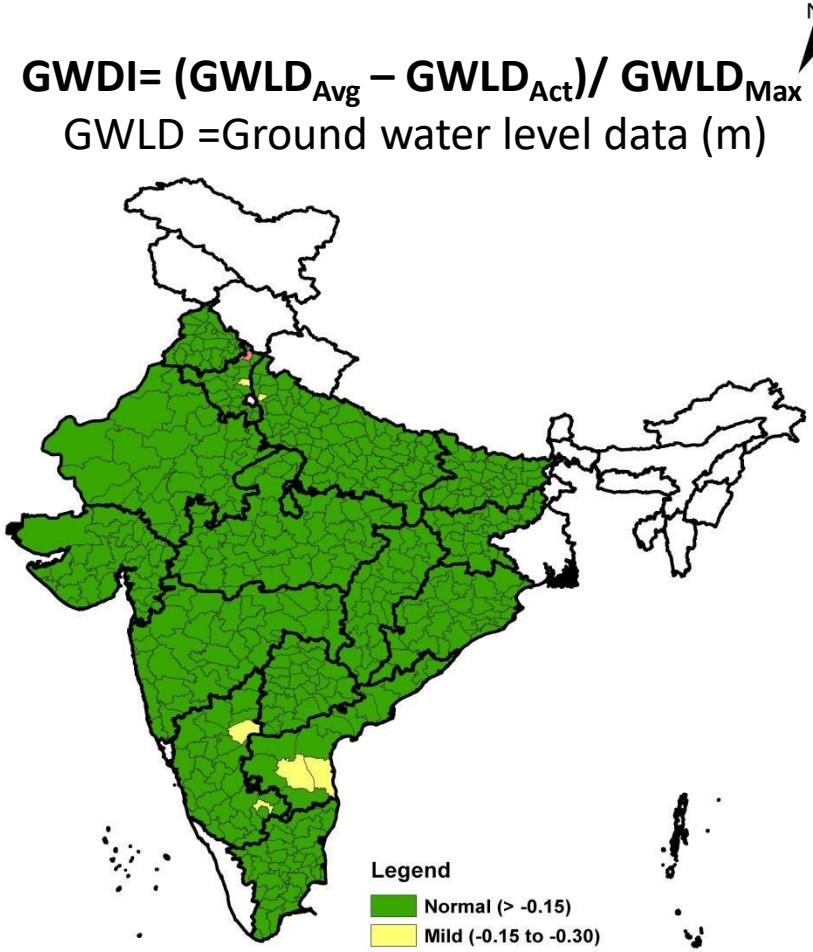




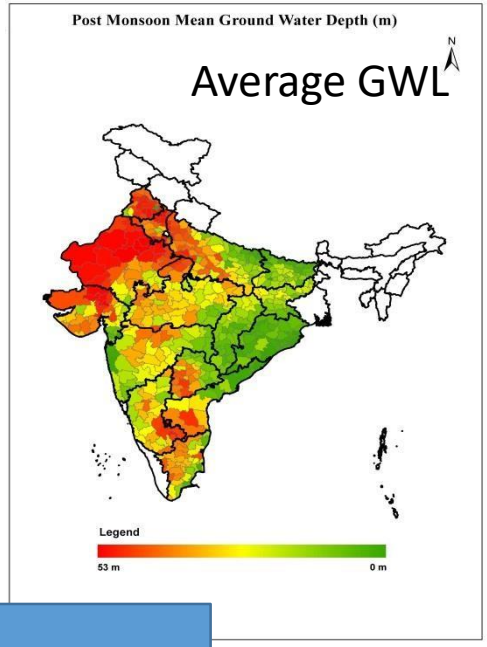
- **Dry spell is 'yes' for the Districts which have received more than 50% deficient rainfall during Two Consecutive weeks for Arid Soil region, Three Consecutive weeks for light soil region and Four weeks for Heavy soil region.**
- **Scanty rainfall is 'Yes' for the Districts which have received rainfall with more than 60% deficiency, up to December Month.**
- **Cumulative Rainfall from 1st September to 31st December for District under rainfed Condition & from 1st October to 31st December for remaining districts.**

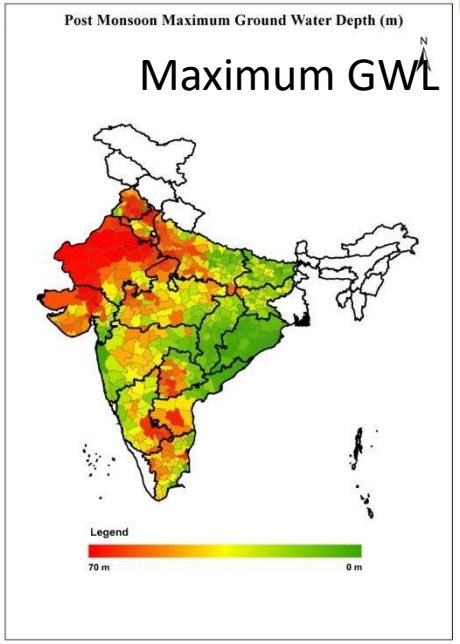
(Data Source: IMD)

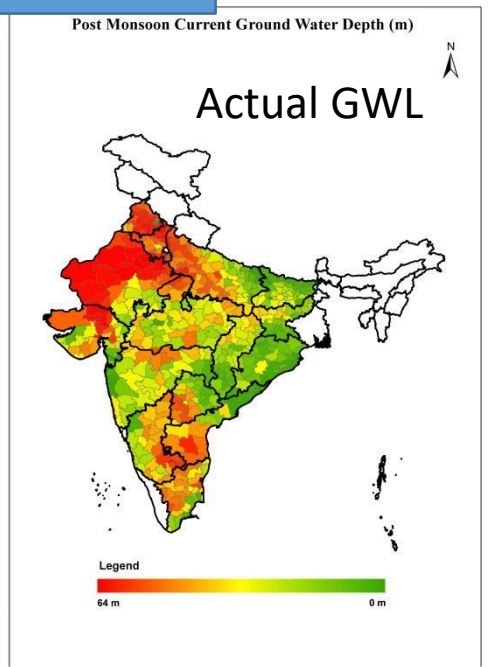
Ground Water Drought Index Map (Situation 3)



Data Source: Central Ground Water Board





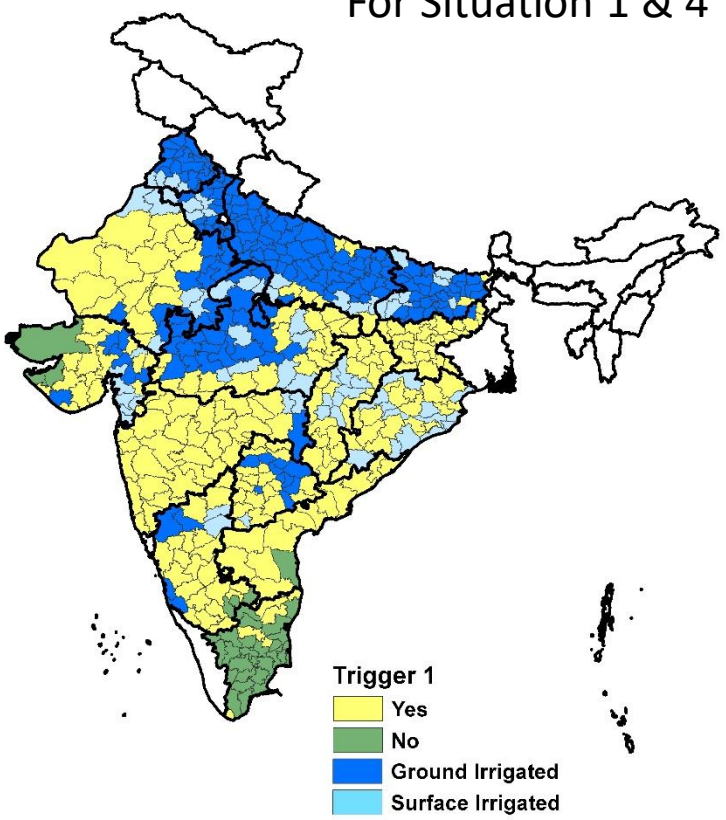


All the Data are Post-monsoon values

Drought Trigger-1 based on Rainfall Deviation & Dry Spell, up to December 2019

Trigger1: Rainfall
(upto 31st December 2019)

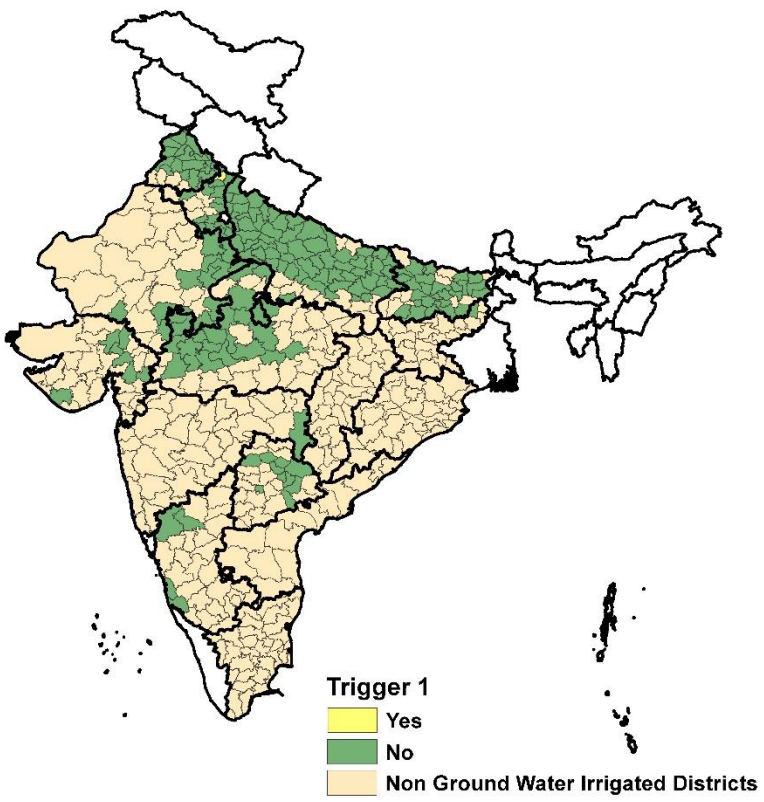
For Situation 1 & 4



Trigger-1 is mainly due to Dry Spell

Trigger1: Based on Ground Water Drought Index
(For Ground Water Irrigated Districts)

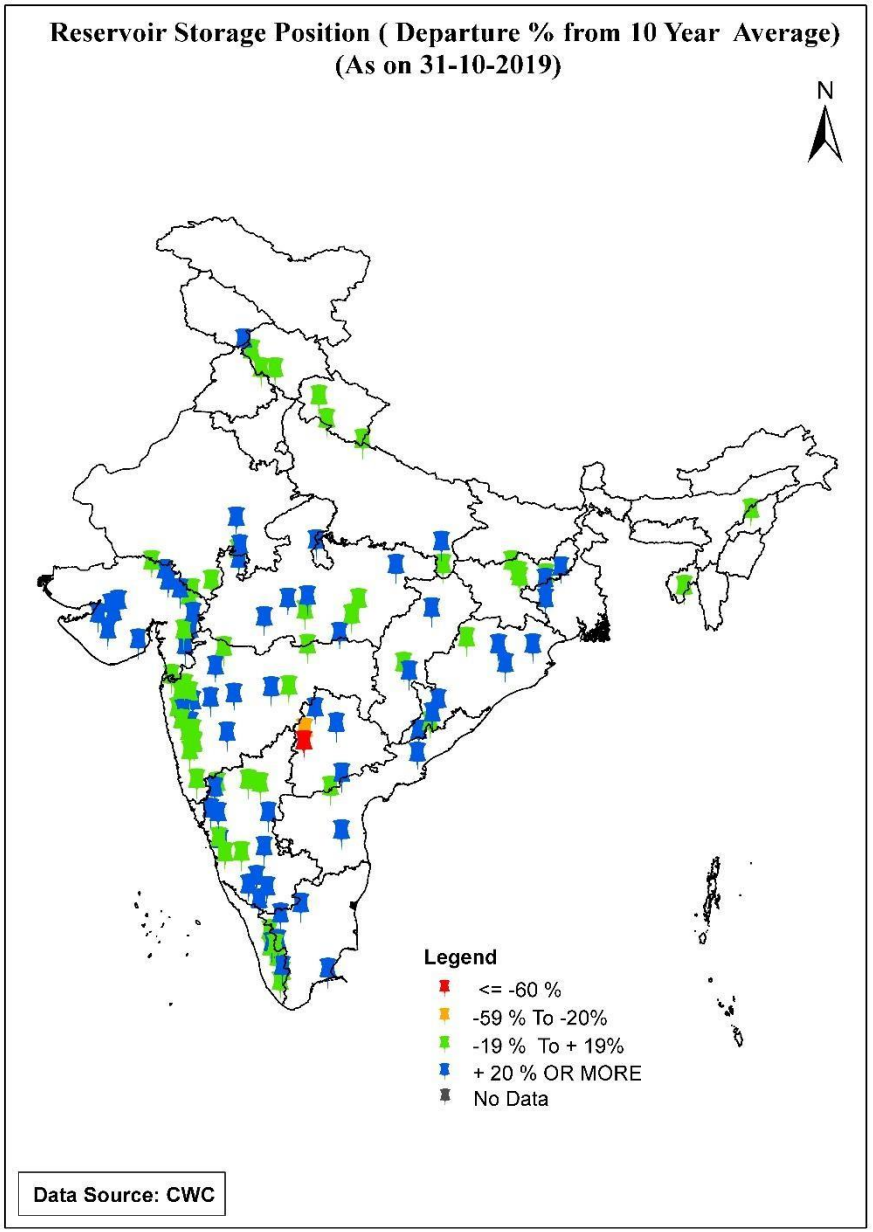
For Situation 3



- **Trigger 1 (rainfall) was decided as per the matrix given in amended *rabi* Drought Declaration**

Reservoir Storage Position for Situation 2 (Surface Irrigated Area)

As most of the reservoirs do not have much negative deviations, it was assumed that the Situation 2, for which Reservoir Storage Index is the Mandatory Indicator, does not satisfy Trigger 1. Hence, the districts under Situation 2 were not further considered for drought assessment.



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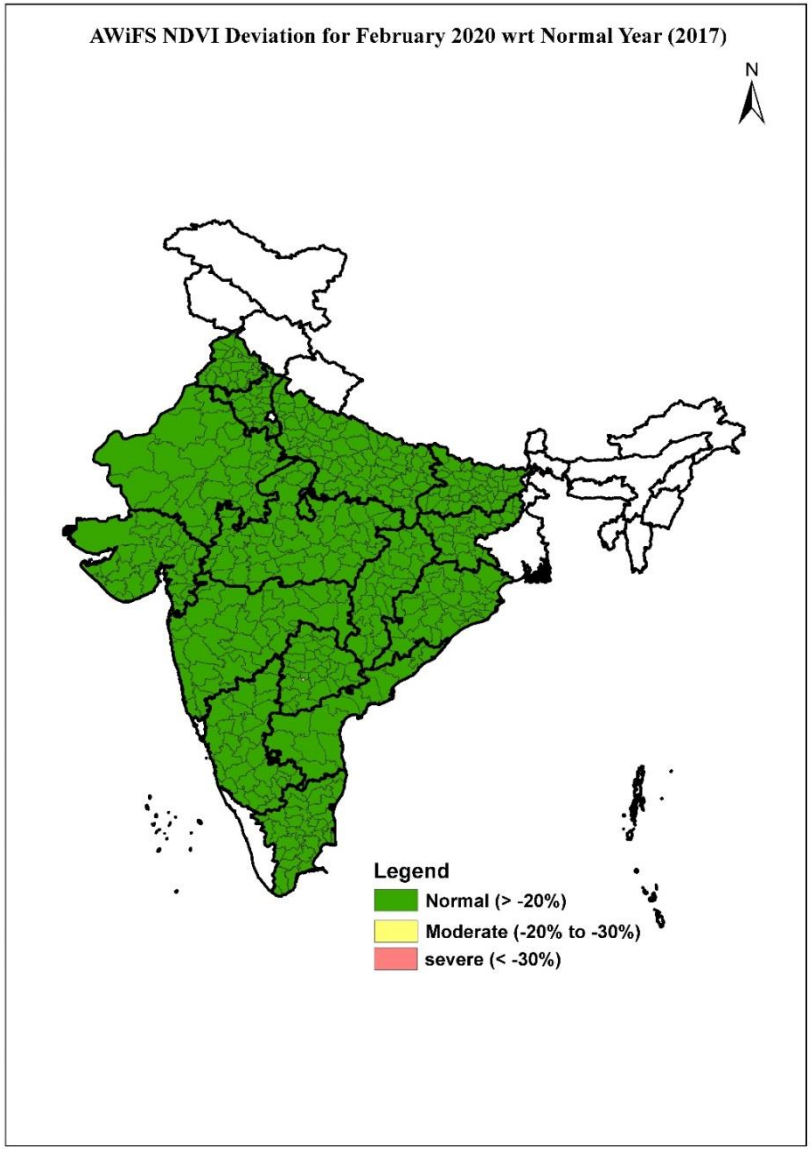
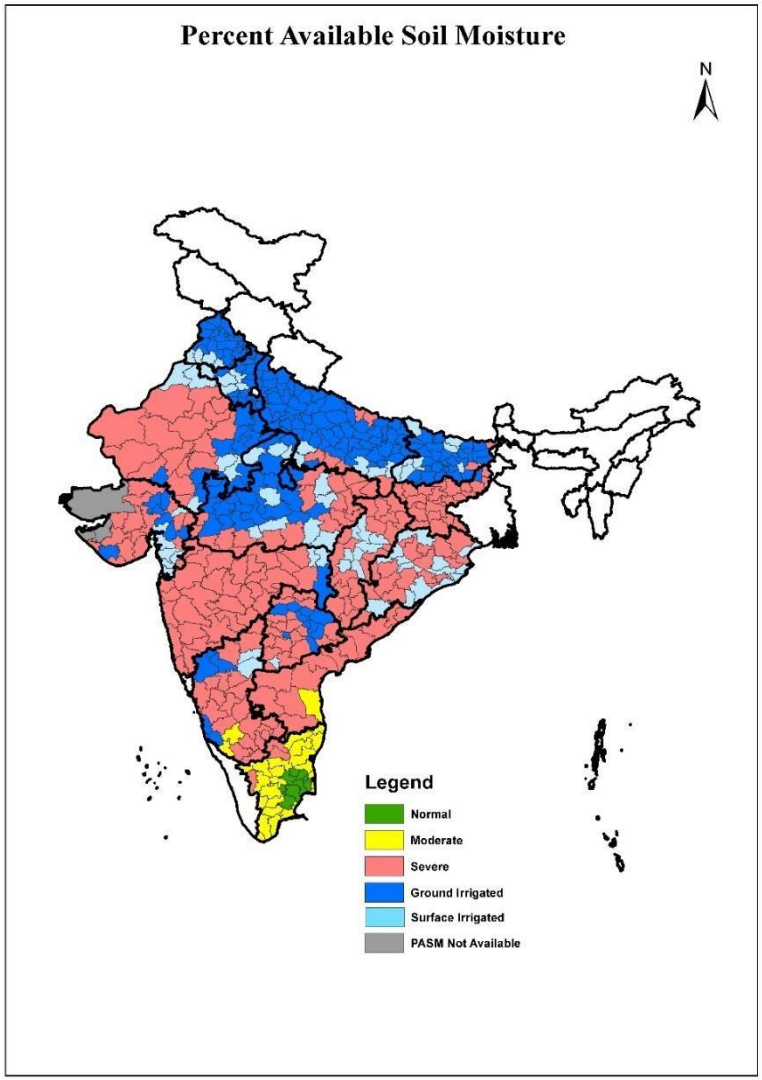
Resourcesat-2 AWiFS NDVI and District wise NDVI Deviation for February 2020

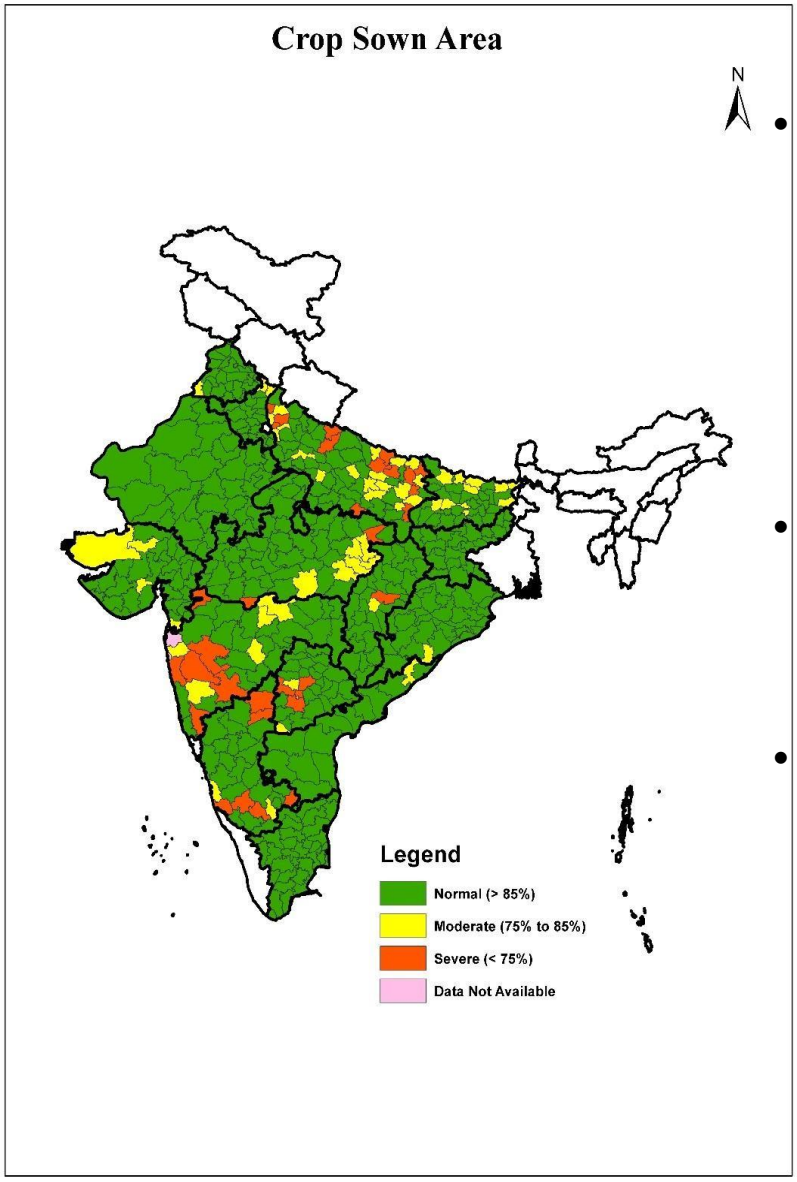


District Level Percent Available Soil Moisture (PASM)



PASM has been computed for the period of December 2019 to 1st Fortnight of January 2020, the period of critical stages for moisture for rabi season crops. Soil Water Balance Model was used for computing PASM.

District wise Sown Area Deviation Map



- PROBA-V (300 m) NDVI data from 1st Nov 2019 to 20th Feb 2020 and that of 2016-17 (as normal) were used to estimate sown area deviation (%) for 07 states i.e. Bihar, Punjab, Haryana, Rajasthan, Gujarat, Madhya Pradesh and Uttar Pradesh.
- Resourcesat-2 AWiFS data from 1st Dec 2019 to 15th Mar 2020 and that of 2016-17 (as normal) were used for 02 states i.e. Tamil Nadu and Jharkhand.
- State Agriculture Department's rabi sowing data were used for 06 states i.e. Karnataka, AP, Telangana, Maharashtra, Odisha and Chhattisgarh.

Annexure I. Rabi Drought Assessment Procedure, as per Drought Manual

- As per drought manual, for drought assessment the region has to be divided into four cropping situations,
- The drought assessment indicators are different for different cropping situations, as given below.

Situation	Cropping Situations*	Indicative Regions	Cropping season	Mandatory Indicators	Impact Indicators
1	Rainfed crops depending on residual moisture	Malwa region of MP, northern Karnataka, Madhya Maharashtra, parts of Andhra Pradesh, Telangana, Odisha, Chhattisgarh, etc	September/October to January	• Rainfall during September to December (Rainfall deviation/SPI & Dry Spell)	• Crop sown area. • Soil Moisture based (PASM/MAI) • Remote Sensing based NDVI/NDWI or VCI
2	Surface irrigated command areas	Parts of Indo Gangetic Plains, Canal Command Areas of Tamil Nadu, AP, Telangana, Rajasthan, Gujarat, Karnataka, etc.	October to April	• Reservoir Storage Index (RSI) at the end of September/October	• Crop sown area • Remote Sensing based NDVI/ NDWI or VCI • GWDI
3	Ground water irrigated areas (Outside the command areas)	Parts of Telangana, AP, Maharashtra, Karnataka, Bihar, West Bengal, Odisha, UP, etc.	October to April	• Standardized Ground Water Level Index/ Ground Water Level Index (Post Monsoon)	• Crop sown area • Remote Sensing based(NDVI/NDWI)
4	North-East monsoon dependent areas	Major Parts of Tamil Nadu and Southern AP	October to February	• Rainfall during N-E Monsoon (October to December), Rainfall deviation/SPI & Dry Spell	• Crop sown area • Soil Moisture based (PASM/MAI) • Remote Sensing based NDVI/NDWI or VCI • Hydrological based(RSI/GWDI)

**The Drought Manual requires the states to identify the dominant cropping situation in the drought declaration unit i.e., Taluk, block etc. and adopt the suitable set of indicators and decision rules.*

Drought Condition

Situation 1,2 and 4	**Severe:** if any two indicators are in Severe category	**Moderate:** (a) If one indicator in Severe category and one in Moderate category or (b) If any two indicators in Moderate category
Situation 3	**Severe**: if any one indicator is in Severe category	**Moderate**: If both the indicators are in Moderate category

Annexure II: Approach for Identifying Rainfed Districts

- Situation 1 i.e. Rainfed districts are categorised based on climate based on Moisture Index (Thornthwaite and Mather,1995) guidelines provided by Hanumantha Rao Committee (1994).
- District wise normal average precipitation (IMD) and Potential evapotranspiration (IMD) was used to calculate Moisture Index (MI),

$$MI = \frac{(P - PET)}{PET}$$

- **MI wa**s used to identify the different climatic zones and dependable irrigated areas to get the Rainfed areas

Value of MI	Climatic Zone
<-66.7	Arid
-66.6 to -33.3	Semi-arid
-33.3 to 0	Dry sub-humid
0 to +20	Moist sub-humid
+20.1 to +99.9	Humid
100 or more	Per-Humid

Source: Thornthwaite and Maither,1995

- Dependable /Assured Irrigated area and rainfed districts were identified based on the guidelines provided by Hanumantha Rao Committee (1994). The area under tanks and other wells in non-command areas were adjusted in relation to agro climatic situations to arrive at dependable/assured irrigated areas as given below:

Moisture Index	Dependable/Assured Irrigated Area
-66 to -50	Canal and Command Area wells +25% tanks and wells
-49.9 to 0.0	Canal and Command Area wells +50% tanks and wells
0.0 to 99.9	Canal and Command Area wells +75% tanks and wells
<100	Canal and Command Area wells +100% tanks and wells

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Annexure II: (contd.)

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- The districts are having <30 of dependable Irrigation are considering under Rainfed districts and districts are having >30 of dependable Irrigation are considering under Irrigated areas.

- In those districts where the > 50 % Agriculture land is irrigated by canal was identified as surface irrigated districts and where the > 50 % land is being irrigated by well & tanks were categorized under ground water irrigated districts.

- GDWI is the mandatory Indicator for Ground Water Irrigated Areas, which was calculated using the post monsoon ground water data provided by Central Ground Water Board.

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Rabi Drought Assessment Map – February 2020

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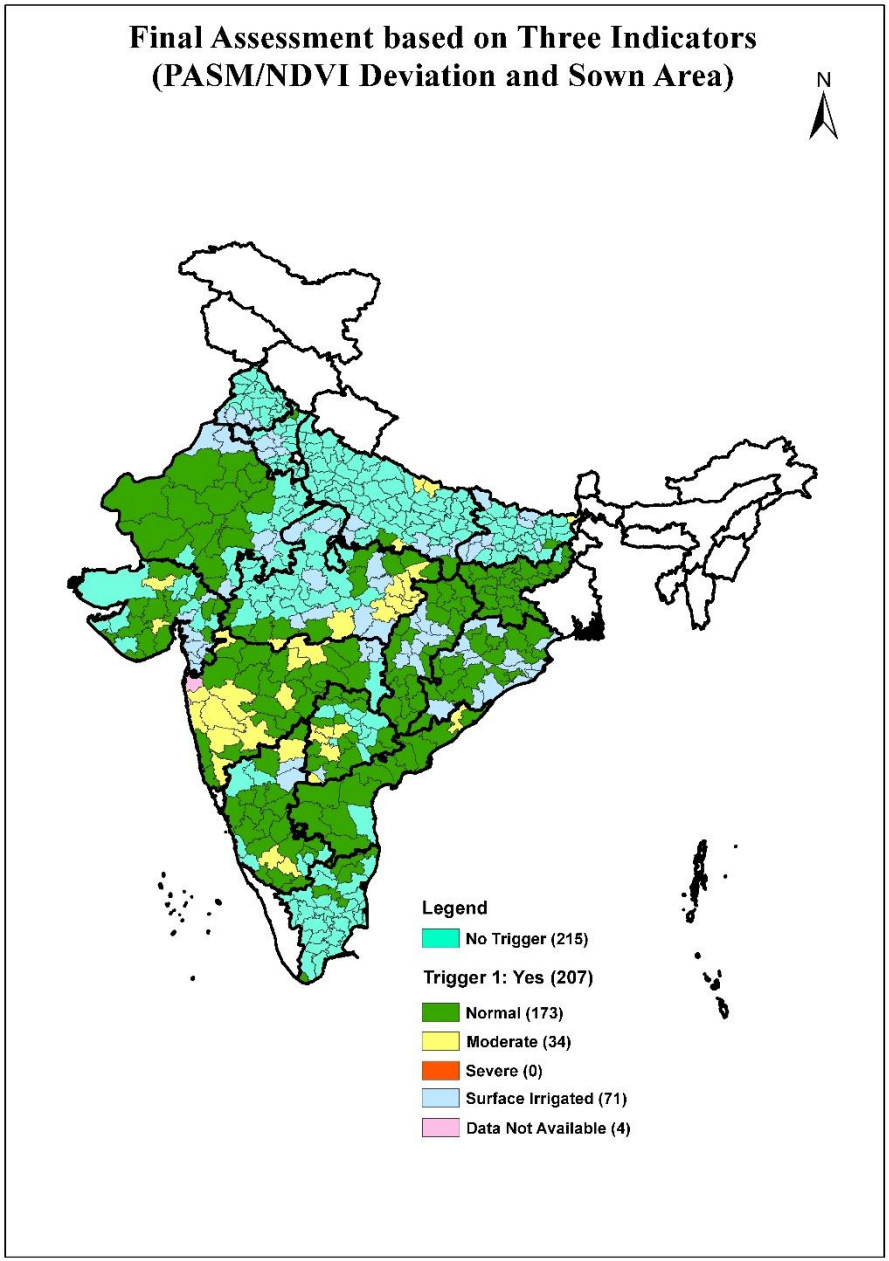
(Based on rainfall, Remote sensing based vegetation indices and Soil Moisture)



Districts under Moderate Category of Rabi Drought 2019-20

S.No	State	Districts	S.No	State	Districts
1	Andhra Pradesh	Vizianagaram	18	Maharashtra	Amaravati
2	Bihar	Kishanganj	19	Maharashtra	Kolhapur
3	Gujarat	Botad	20	Maharashtra	Nandurbar
4	Gujarat	Patan	21	Maharashtra	Parbhani
5	Karnataka	Gulbarga	22	Maharashtra	Pune
6	Karnataka	Hassan	23	Maharashtra	Raigarh1
7	Karnataka	Mandhya	24	Maharashtra	Satara
8	Madhya Pradesh	Anuppur	25	Maharashtra	Solapur
9	Madhya Pradesh	Burhanpur	26	Maharashtra	Thane
10	Madhya Pradesh	Chhindwara	27	Telangana	Jogulamba Gadwal
11	Madhya Pradesh	Dindori	28	Telangana	Medak
12	Madhya Pradesh	Mandla	29	Telangana	Ranga Reddy
13	Madhya Pradesh	Shahdol	30	Telangana	Sangareddy
14	Madhya Pradesh	Sidhi	31	Telangana	Siddipet
15	Madhya Pradesh	Umaria	32	Uttar Pradesh	Balrampur
16	Maharashtra	Ahmadnagar	33	Uttar Pradesh	Sahuji Maharaj Nagar
17	Maharashtra	Akola	34	Uttar Pradesh	Shrawasti

There was no district under Severe Category.

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Future Needs

- Monitoring at dis-aggregated level (Block/GP)
- Early Warning of Droughts
- Composite Indicator: *Integrated, Implementable, Acceptable*
- Vulnerability Assessment – *towards drought mitigation*
- Development of products (long-term, calibrated and real-time) for drought monitoring
- Assessment Climate Change Impacts vis-à-vis drought vulnerability

Thank You