Drought monitoring and prediction for disaster risk reduction by IMD

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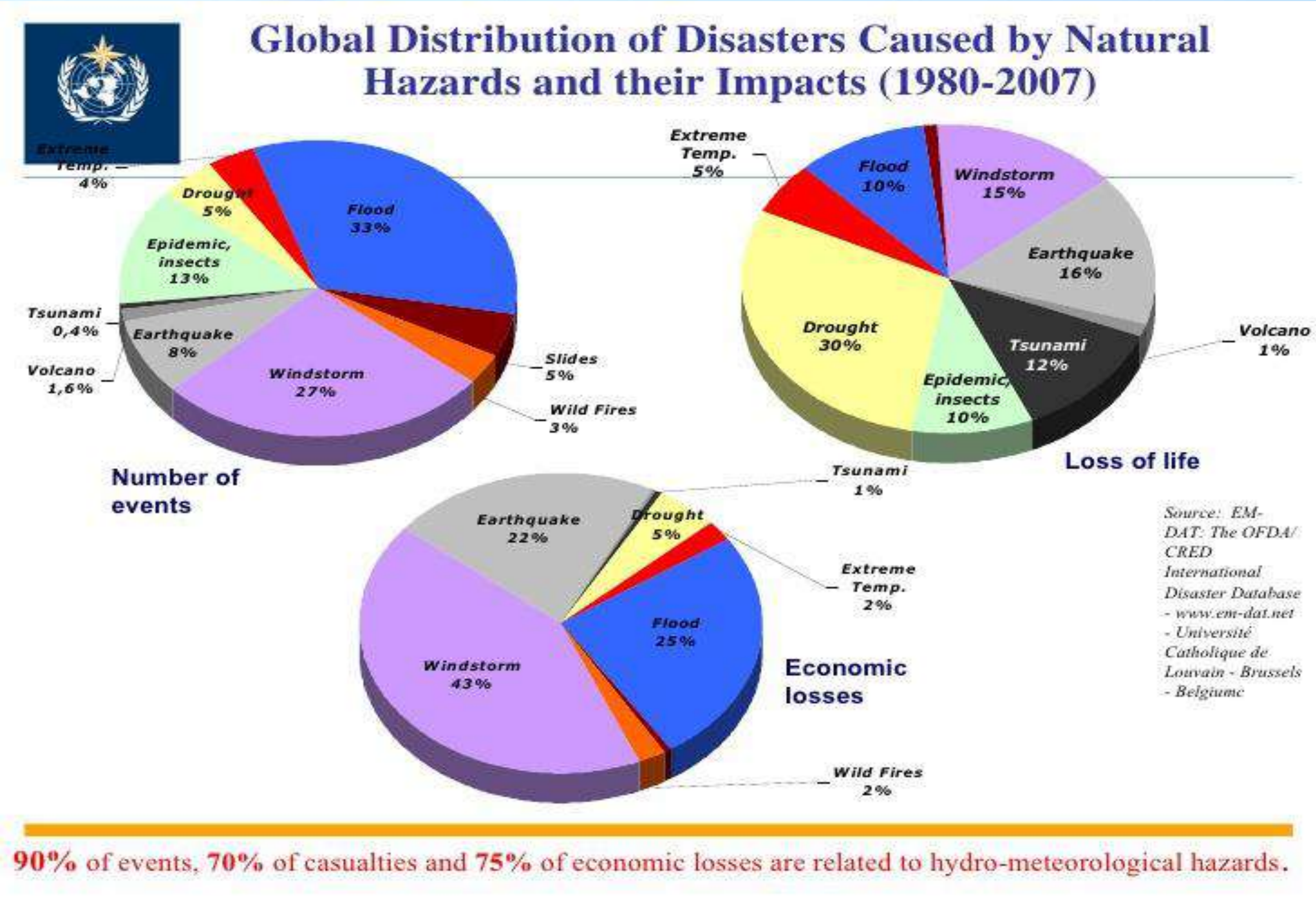
भारत मौसम विज्ञान विभाग

INDIA METEOROLOGICAL DEPARTMENT

Major Natural Hazards

Global Distribution of Natural Hazards



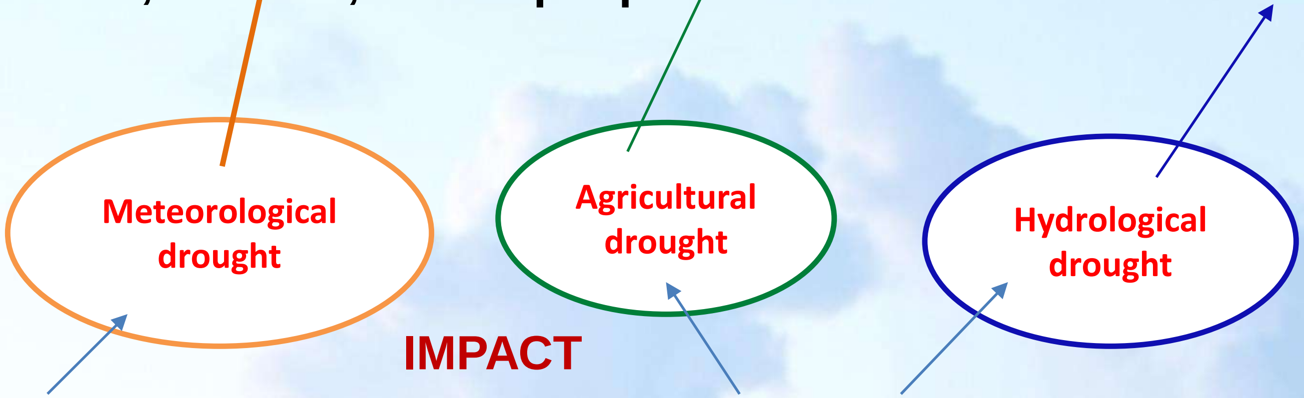
State-wise details of Districts declared by States drought affected

SN	State	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	ANDHRA PRADESH	0	13	13	13	13	13	4	0	0	13	0	13	6	3	6	10	7	4
2	ASSAM	0	0	0	0	0	0	20	0	0	27	0	0	0	0	0	0	0	0
3	BIHAR	0	37	0	0	19	0	0	0	0	26	38	0	0	33	0	0	0	0
4	CHHATTISGARH	12	0	14	0	14	0	0	0	0	0	0	0	0	0	0	25	0	20
5	GUJARAT	22	0	14	0	0	0	0	0	0	0	0	0	16	0	0	6	0	0
6	HARYANA	0	0	19	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0
7	HIMACHAL PRADESH	12	0	12	0	0	12	0	0	0	12	0	0	0	0	0	0	0	0
8	JAMMU AND KASHMIR	6	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0
9	JHARKHAND	0	0	22	15	20	22	0	0	0	24	24	0	0	0	0	22	0	0
10	KARNATAKA	0	25	24	25	21	0	23	0	21	20	0	24	26	22	9	24	0	0
11	KERALA	0	0	11	14	0	0	0	0	0	14	0	0	14	0	0	0	14	0
12	MADHYA PRADESH	30	6	33	0	26	0	10	38	0	37	0	0	0	0	0	43	0	18
13	MAHARASHTRA	26	16	32	11	25	0	0	0	0	28	0	15	17	0	26	28	0	0
14	MANIPUR	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0
15	NAGALAND	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0
16	ODISHA	28	0	30	0	0	0	0	0	0	17	16	0	0	0	0	25	0	0
17	PUDUCHERRY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
18	PUNJAB	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	RAJASTHAN	31	18	32	3	25	22	22	0	12	26	0	0	12	29	0	23	13	13
20	TAMIL NADU	0	0	28	29	0	0	0	0	0	0	0	0	31	0	0	0	0	0
21	TELANGANA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0
22	UTTAR PRADESH	0	0	68	0	60	0	0	9	0	56	0	0	0	0	43	49	0	0
23	UTTARAKHAND	1	0	13	8	0	11	0	9	11	0	0	0	0	0	0	8	0	0
24	WEST BENGAL	0	0	3	0	0	0	6	0	0	0	11	0	0	0	0	0	0	0
	Total	168	115	383	118	223	80	85	56	44	338	89	52	122	87	105	270	36	55

Drought

What is Drought?

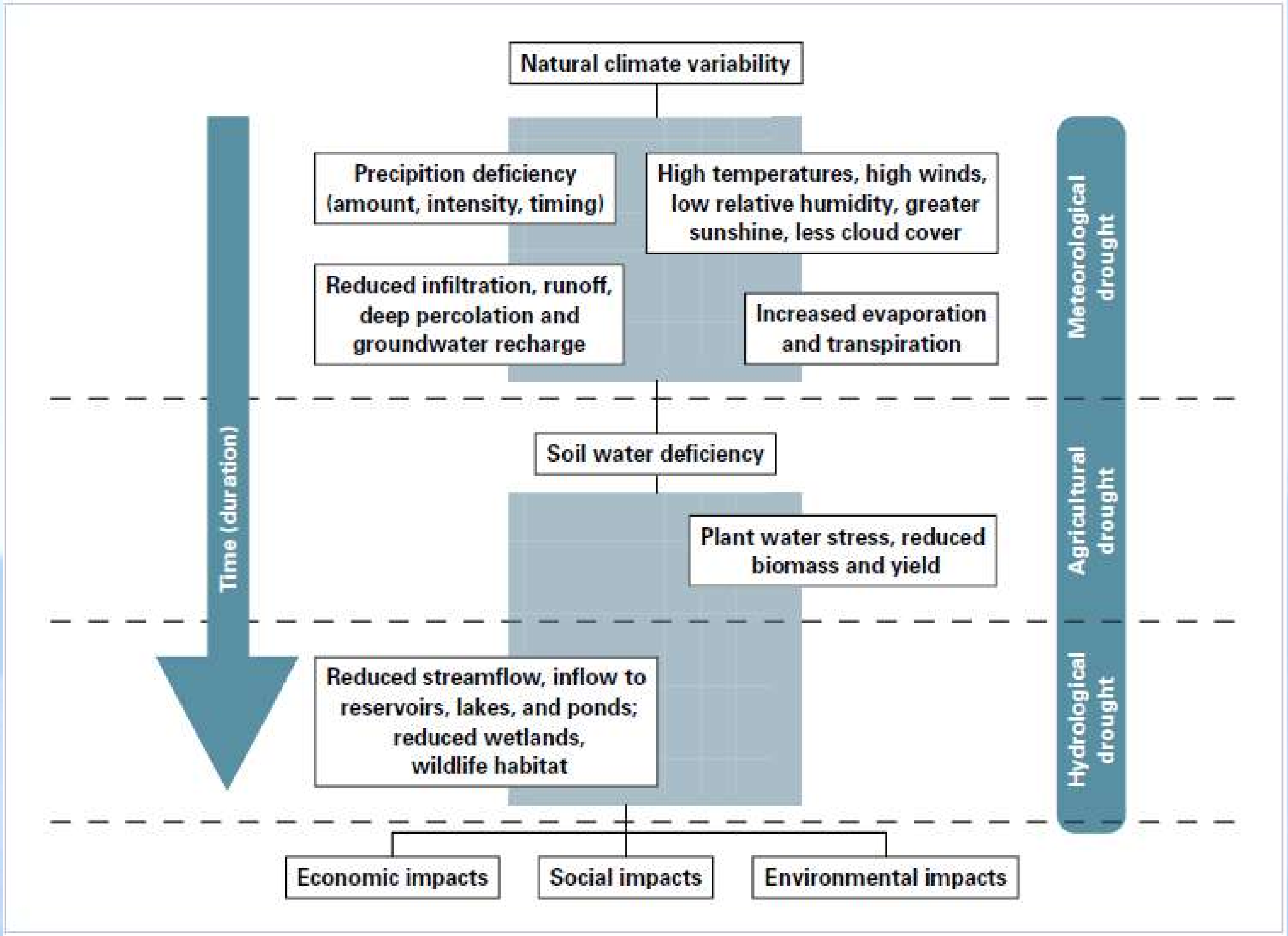
Drought is a deficiency in precipitation over an extended period, usually a month or season or more, resulting in extensive damage to crops, loss of yield, resulting in a water shortage causing adverse impacts on vegetation, animals, and/or people.



CAUSE **IMPACT**

It is a normal, recurrent feature of climate that occurs in virtually all climate zones, from very wet to very dry.

Type of Drought and time response



1 to 2-months

1 to 4 months

4 to 12 months or more

Socio economic drought

Drought monitoring by IMD

- During 1965 and 1966, major parts of India were under prolonged and severe drought conditions due to deficient monsoon rainfall.

- On the recommendations of the Planning commission, India Meteorological Department (IMD) has started Drought Research and monitoring at Pune in 1967.

- IMD monitors drought by using four well established drought indices. One of which is purely meteorological drought, the second one is agricultural drought and the third and fourth ones started few years back covers meteorological, agricultural as well as hydrological droughts.

Indices used for monitoring drought at IMD

1. Percent of Normal

- The percent of normal precipitation is one of the simplest measurements of rainfall departure/deficiency for a location.

- Analyses using the percent of normal are very effective when used for a single region or a single season. Percent of normal is also easily misunderstood and gives different indications of conditions, depending on the location and season.

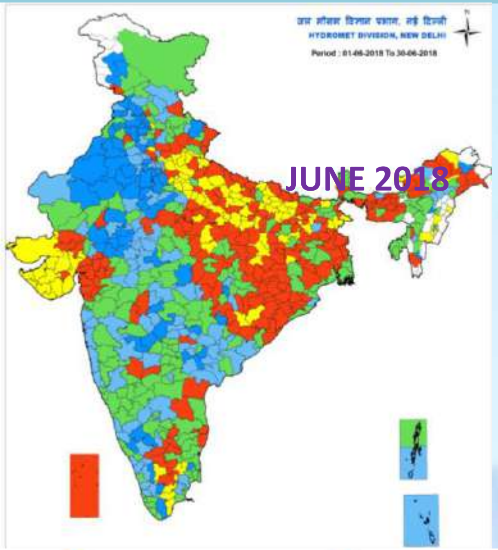
- It is calculated by dividing actual precipitation by normal precipitation i.e. long period average and multiplying by 100%.

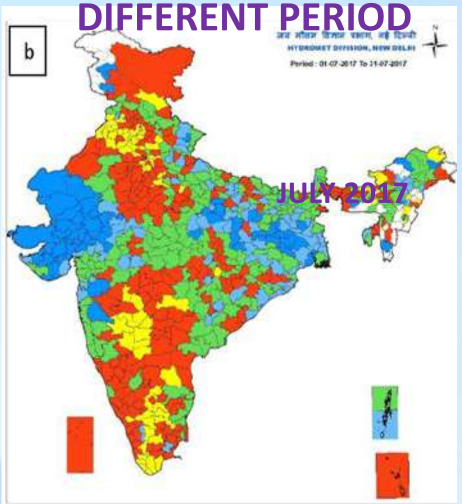
- This can be calculated for a variety of time scales. Usually these time scales range from a day, week or month to a group of months representing a particular season, to an annual or water year. Normal precipitation for a specific location is considered to be 100%.

Rainfall Monitoring/Forecast : percent of normal

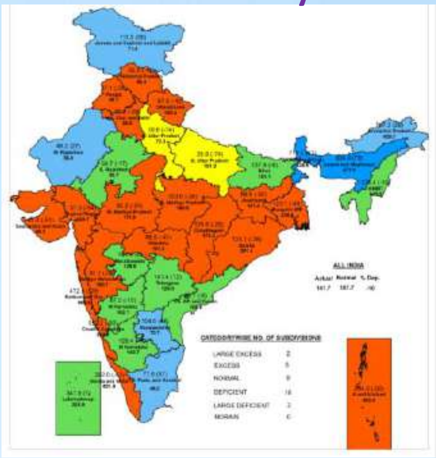
The percent of normal (or % Departure from normal) precipitation is one of the simplest measurements of rainfall departure/ deficiency for a location to know the dry/wet condition for a specific period of time.

DIFFERENT PERIOD

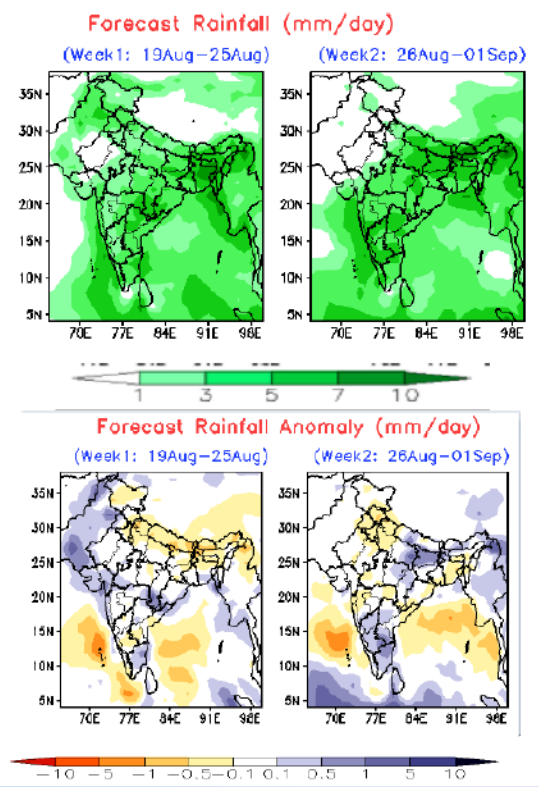




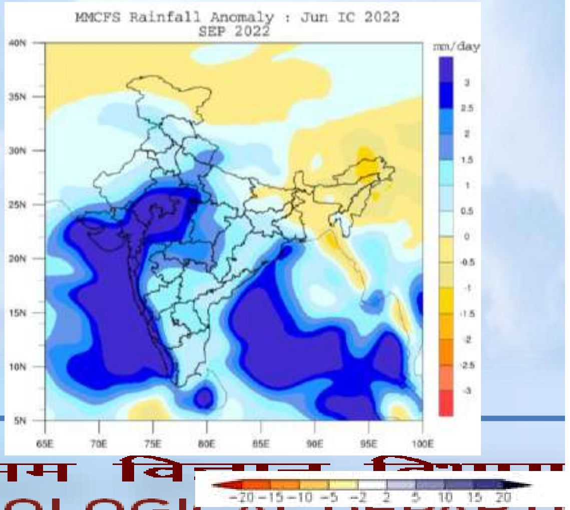
1st JUNE -29th July 2022



LEGEND: L. EXCESS (+60% OR MORE) EXCESS (+20% TO +59%) NORMAL (+19% TO -19%) DEFICIENT (-20% TO -59%) L. DEFICIENT (-60% TO -99%) NO RAIN (-100%) NO DATA



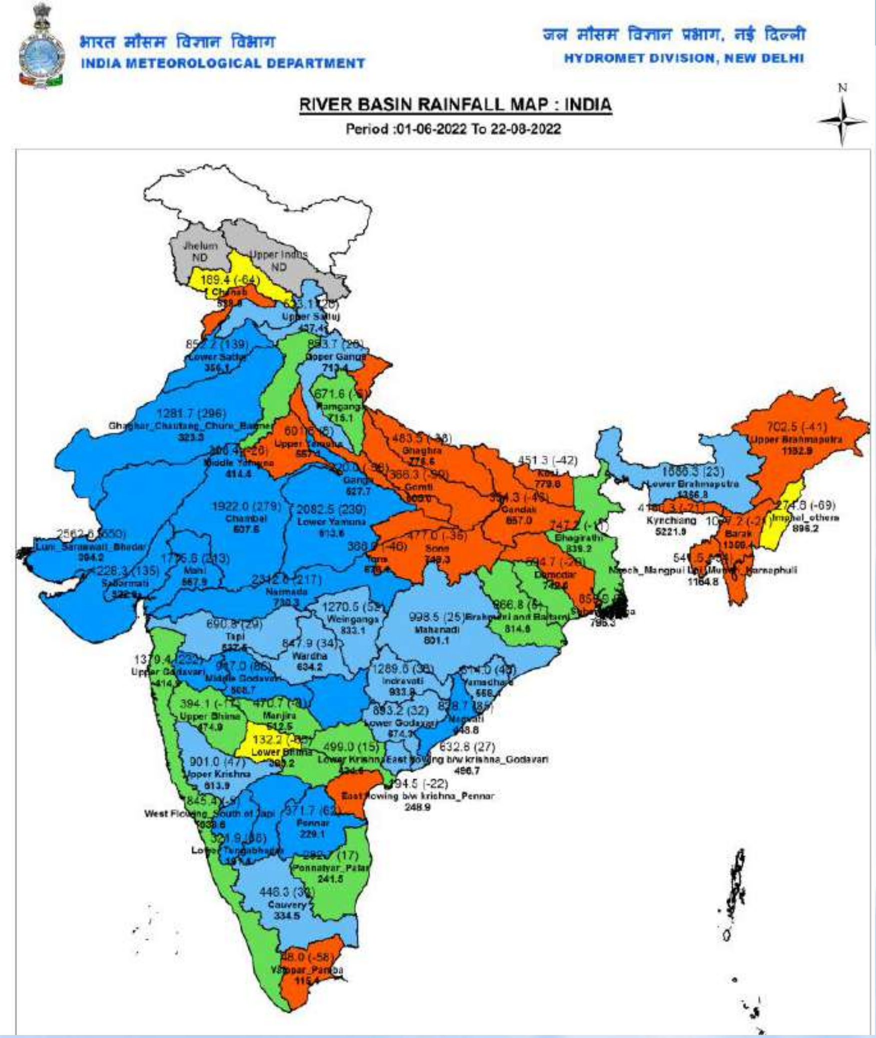
Rainfall Anomaly (mm/day)

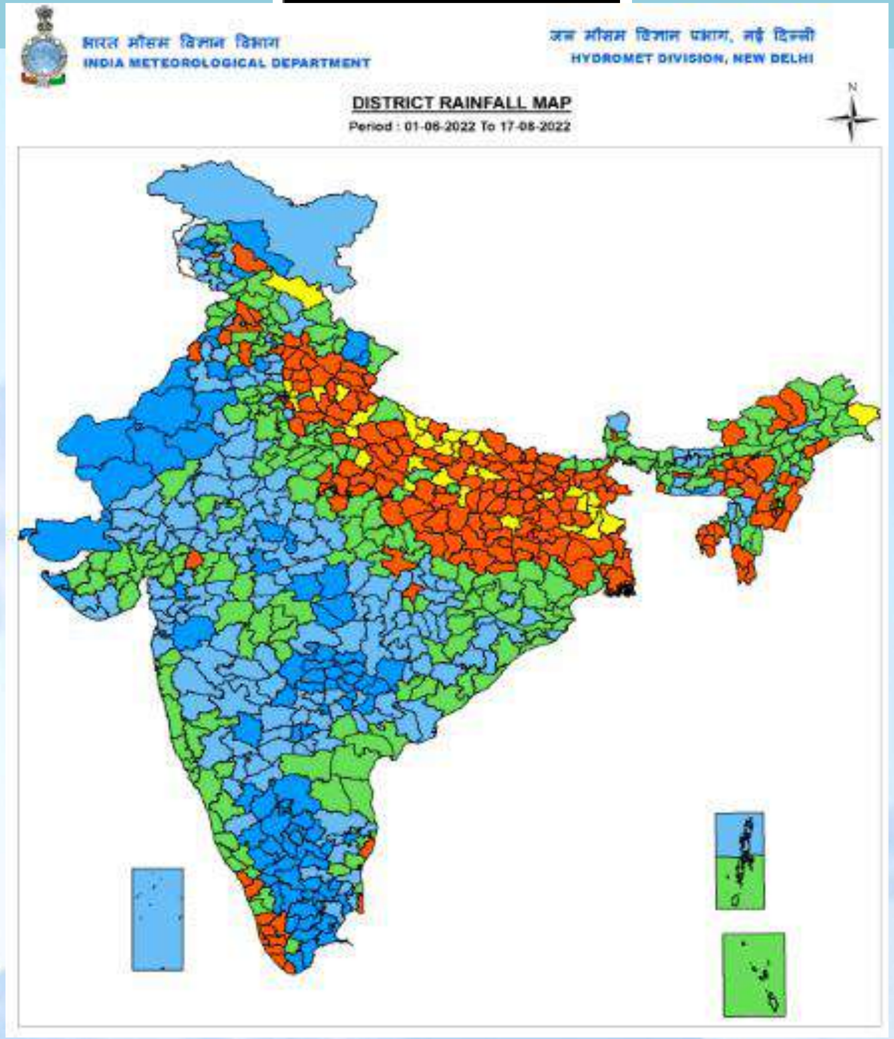


However percent of normal is very effective

1. When used for a single region or a single season.
2. When the distribution is normal/Gaussian

DISTRICT RAINFALL MAP





Legend

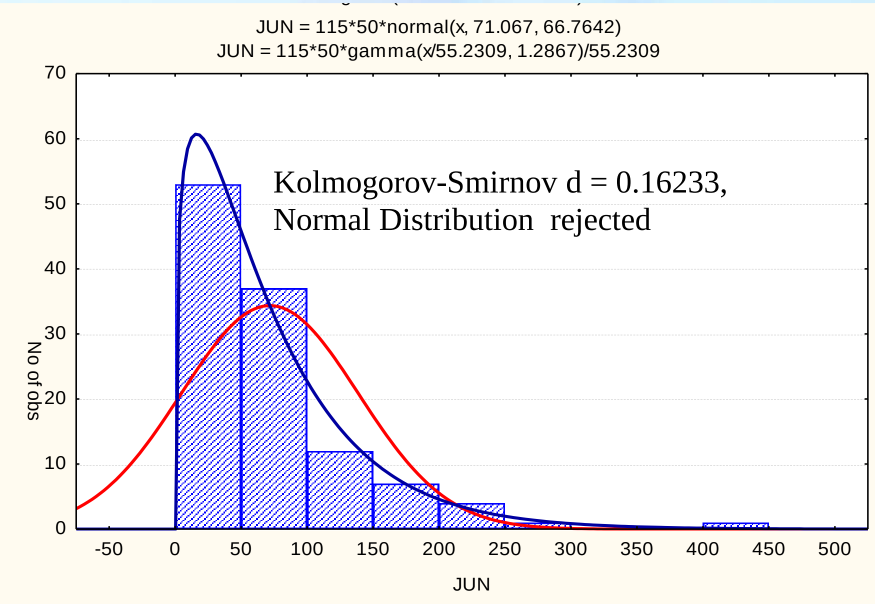
Large Excess [60% or more] | Excess [20% to 59%] | Normal [-19% to 19%] | Deficient [-59% to -20%] | Large Deficient [-99% to -60%] | No Rain [-100%] | NO DATA

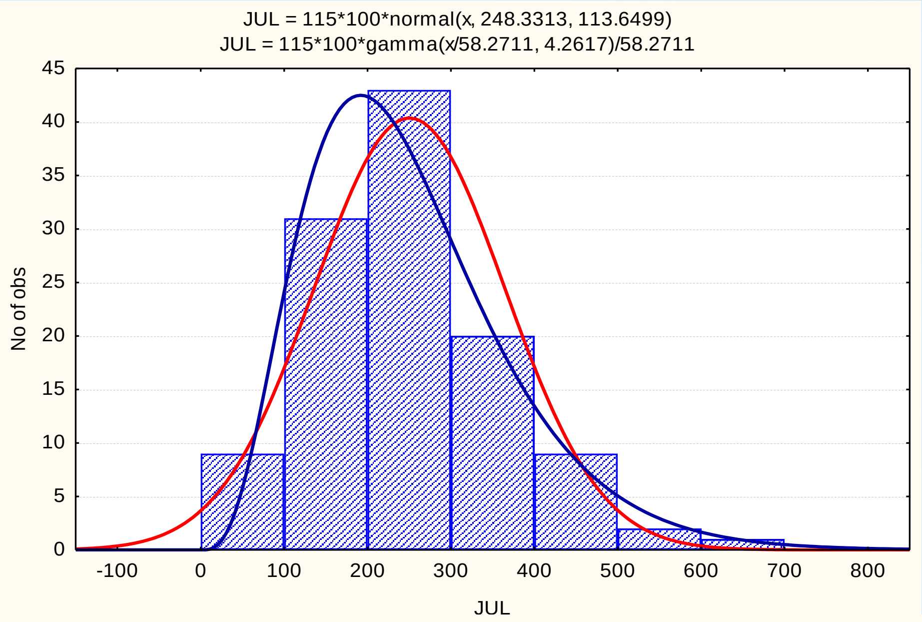
- One of the disadvantages of using the percent of normal precipitation is that the mean, or average precipitation is often not the same as the median precipitation, which is the value exceeded by 50% of the precipitation occurrences in a long-term climate record. The reason for this is that precipitation on monthly or seasonal scales does not have a normal distribution. Use of the percent of normal comparison implies a normal distribution where the mean and median are considered to be the same.

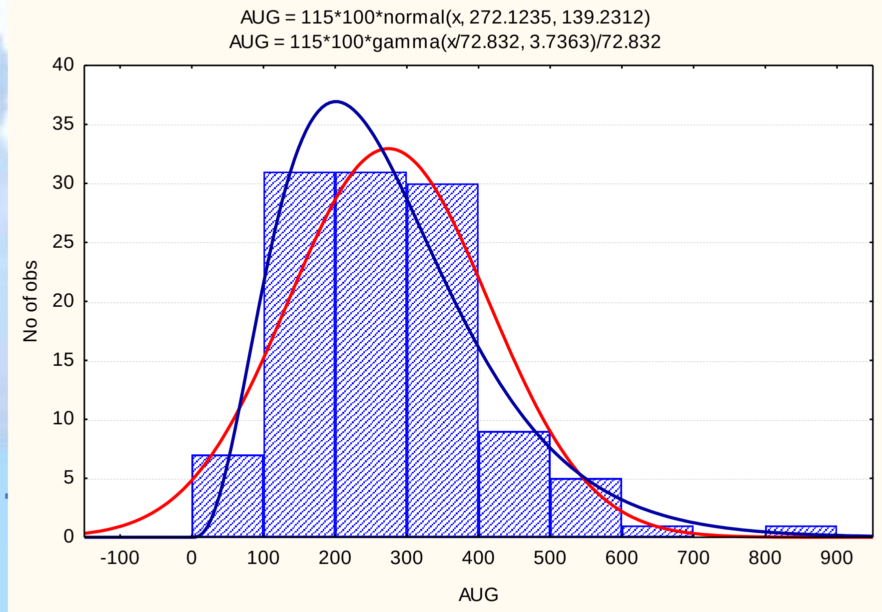
- An example of the confusion this could create can be illustrated by the long-term precipitation record in Chitradurga district, Karnataka, for the month of August. The median August precipitation is 48.7 mm, meaning that in half the years (between 1901-2015) less than 48.7 mm is recorded, and in half the years more than 48.7 mm is recorded. The mean is 68.1mm. So, a monthly August total of 48.7 mm would be only 72% of normal when compared to the mean, which is often considered to be quite dry (deficient).

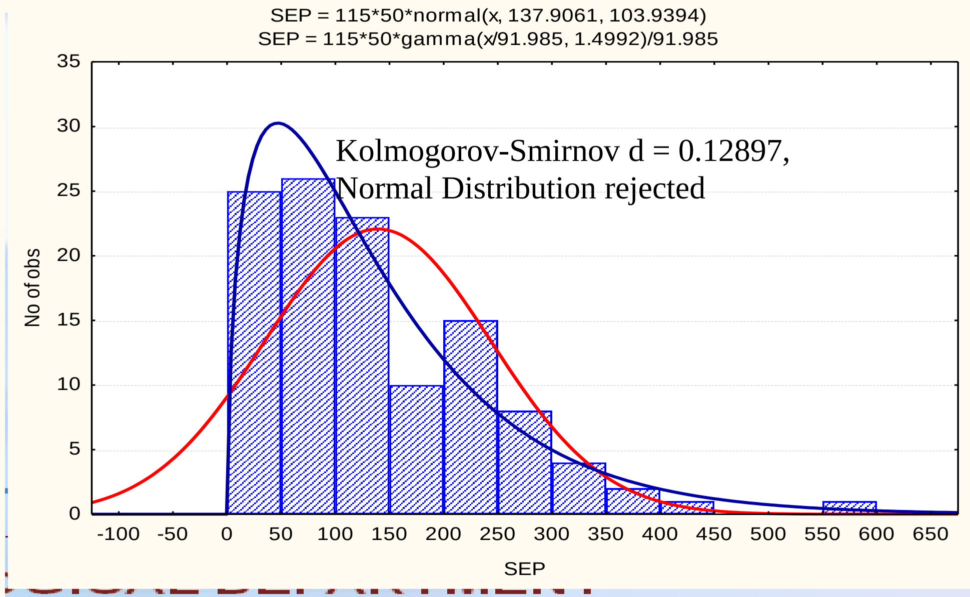
- The long-term precipitation record in Gwalior district, MP, for the month of June and September. The median June precipitation is 52.4 mm, meaning that in half the years (between 1901-2015) less than 52.4 mm is recorded, and in half the years more than 52.4 mm is recorded. The mean is 71.1mm. So, a monthly August total of 52.4 mm would be only 74% of normal when compared to the mean, which is often considered to be quite dry (deficient).

Gwalior monthly rainfall histogram and distribution fitting

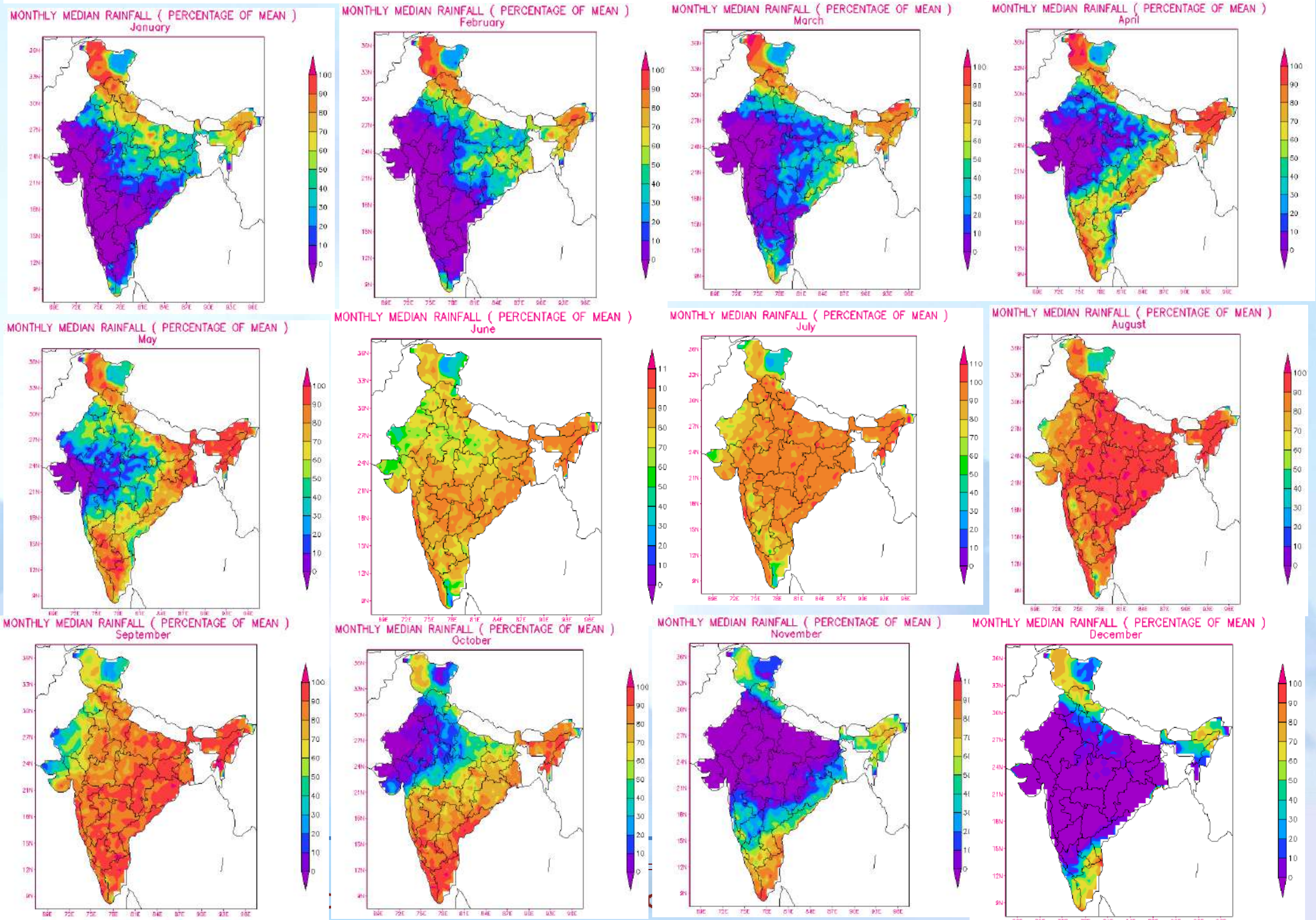








During non monsoon months rainfall distribution is far away from normal distribution and the median rainfall is much less than the mean in most of the places(in different spatial scales like point grid/station, districts, states/met subdivisions)



Drought Monitoring using Aridity Anomaly Index

- Thornthwaite's (1948) water balance technique is generally used to compute the aridity anomaly index at a location. This index is one of the tools to monitor agricultural drought. According to the methodology that is now widely used to represent crop moisture stress, an index known as aridity index (AI) is computed as given below:

$$AI = Water\ deficit / Water\ need$$
$$= (PE - ET)/PE$$

where ET is the actual evapotranspiration computed from the water balance technique and PE the potential evapotranspiration, which is supposed to represent the water need of the plant. For monitoring and mapping agricultural drought, a shorter time interval, say a week, is generally considered. The difference between the actual *AI* and its normal value for that week (i.e., $\overline{AI}$) furnishes an anomaly that is expressed as percentage:

$$\textbf{Aridity Anomaly Index} = (AI - \overline{AI})$$

Aridity Anomaly Index : Computation Procedure

- According to this procedure, rainfall is first utilized by the plants for evapotranspiration purpose. When the evapotranspirative demands of the plants are fully met (as given by PE) the excess amount of rainfall percolates and recharge the soil. This soil moisture recharge continues till the soil reaches its field capacity. Any excess amount of rainfall after the evapotranspirative demands are fully met and the soil is recharged completely is considered as water surplus and goes as surface or deep drainage runoff. When the rainfall is less than the evapotranspirative demands, the plant extracts moisture from the soil till the soil is desiccated of its moisture.
- For Calculation of ET we use the following equation:

  During the periods of deficient rainfall, soil loses moisture as per the empirical law (Thornthwaite):

$$S = fc \times \exp APME / fc$$

- Where S = moisture remaining in the soil as storage. APME is accumulated potential water loss (sum of negative (P-PE) values), fc is field capacity and P is precipitation.

- The Aridity Index is worked out on weekly/biweekly basis. It refers to the water stress suffered by a growing plant due to shortage of available moisture (both rainfall and soil moisture). An anomaly from a normal value would thus signify the water shortage from a long term climatic value.

- When the anomaly is worked out for a large network of stations for different weeks, plotted, and analyzed, it is possible to identify areas where the crop might be suffering from moisture stress of various degrees. The anomaly is used to categorize agricultural drought of various types, as below :

Anomaly of Aridity Index	Agricultural Drought Intensity
1 – 25	Mild
26 – 50	Moderate
> 50	Severe

- **Aridity Anomaly Map gives information about the moisture stress experienced by growing plant. This analysis would indicate qualitatively retardation in the plants growth and so poor yields. Indirectly, this may also be helpful for irrigation scheduling, the amount and the time at which the water is badly needed by the plant.**
- Using this technique, IMD is monitoring agricultural drought during both *kharif* and *rabi* seasons using a wide network of stations.

Data required for Calculations of Weekly/Biweekly Aridity Anomaly

1. District wise Rainfall For 718 Districts
2. District wise Maximum and minimum Temperature for 718 Districts
3. Field Capacity Data from Agrimet Division of IMD Pune for 718 Districts

For Computation of Weekly Aridity Outlook

1. Forecast Districtwise Rainfall For 718 Districts From GFS Model (NWP Delhi)
2. Forecast Maximum and Minimum Temperature for 718 Districts From GFS Model (NWP Delhi)

Drought vs. Aridity

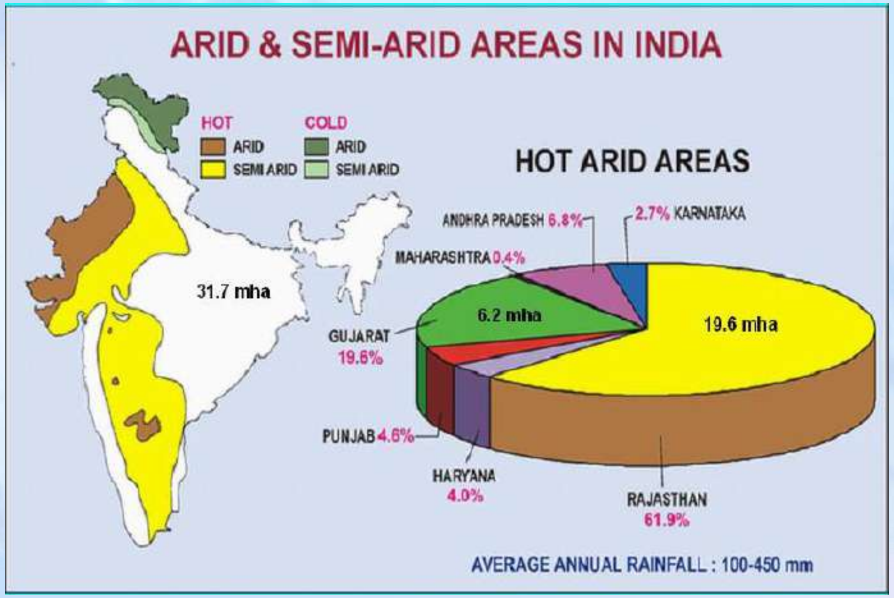
Aridity is defined, in meteorology and climatology, as "the degree to which a climate lacks effective, life-promoting moisture" (Glossary of Meteorology, American Meteorological Society).

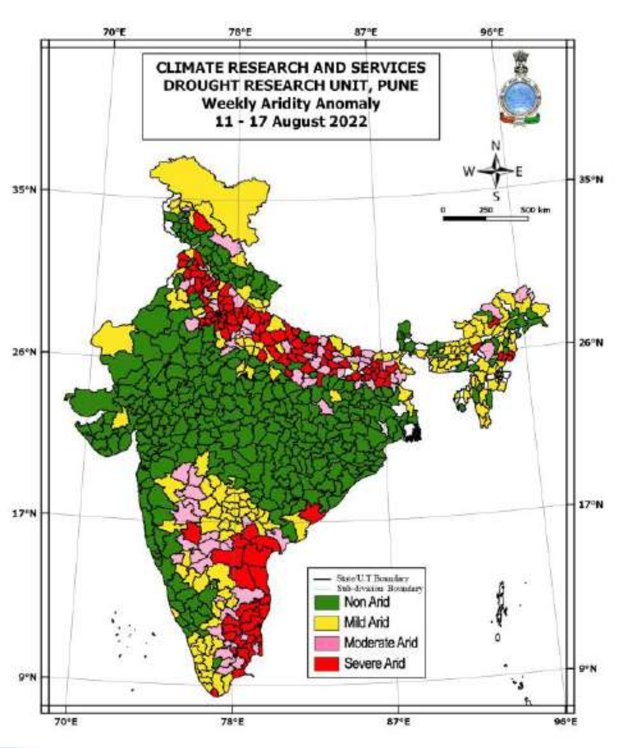
Drought is "a period of abnormally dry weather sufficiently long enough to cause a serious hydrological imbalance".

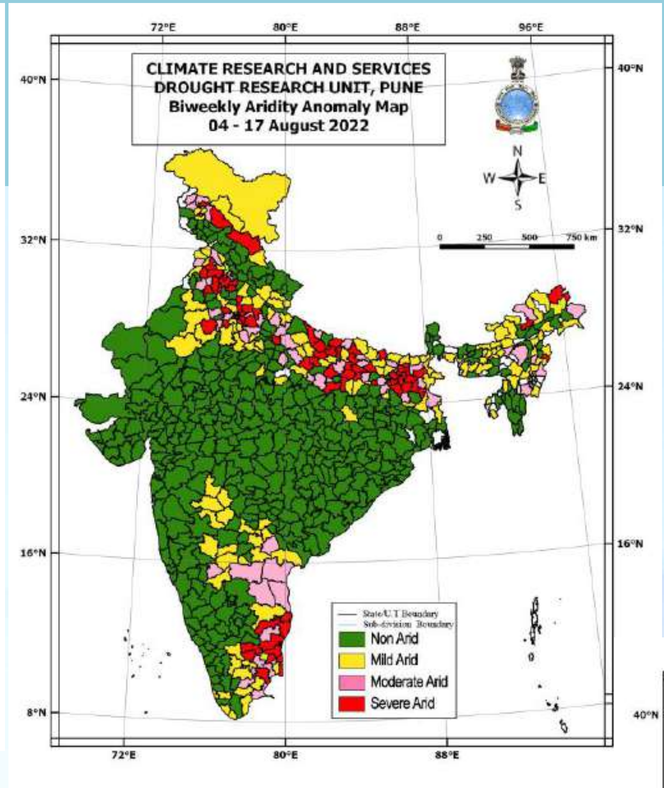
Aridity is measured by comparing long-term average water supply (precipitation) to long-term average water demand (evapotranspiration). If demand is greater than supply, on average, then the climate is arid.

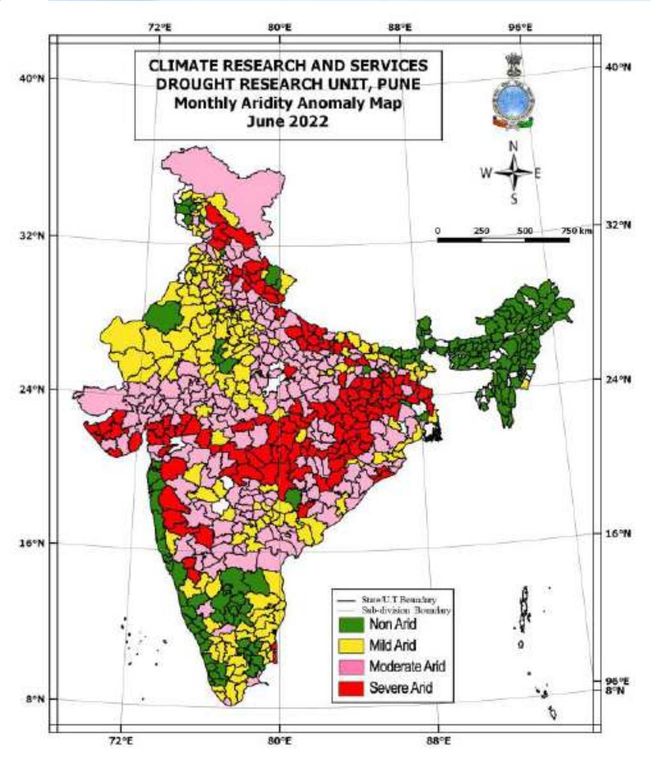
Drought refers to the moisture balance that happens on a month-to-month (or more frequent) basis. If the water supply is less than water demand for a given month, then that month is abnormally dry; if there is a serious hydrological impact, then a drought is occurring that month.

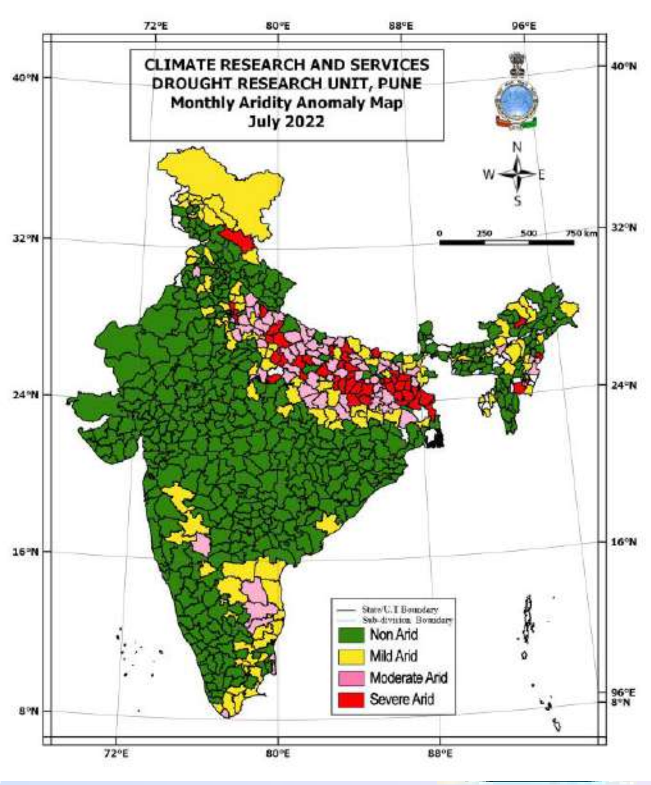
Aridity is permanent, while drought is temporary. Aridity Anomaly Index measures the Departure of aridity condition of a region from its climatic normal aridity (moisture availability). More departure means more water stress and thus can be measure as drought indicator



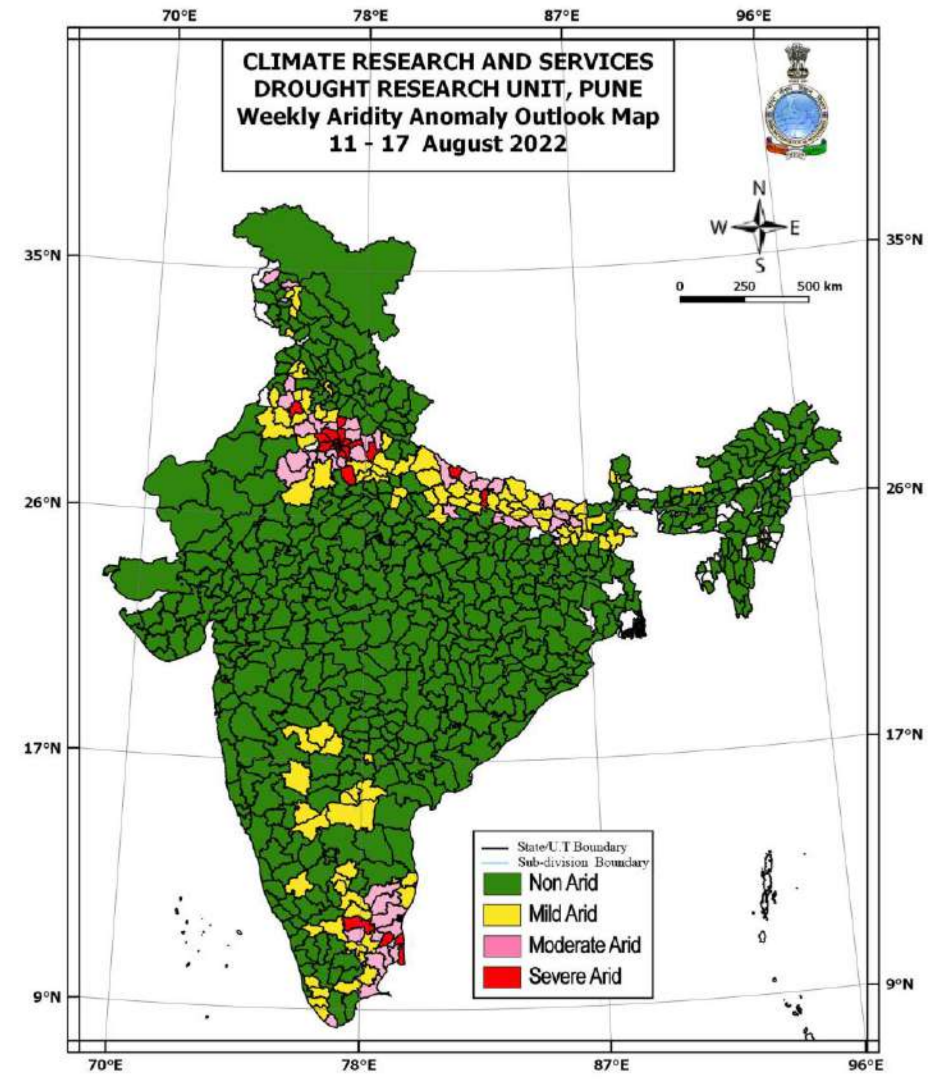

CLIMATE RESEARCH AND SERVICES
DROUGHT RESEARCH UNIT, PUNE
Weekly Aridity Anomaly
11 - 17 August 2022
Non Arid
Mild Arid
Moderate Arid
Severe Arid

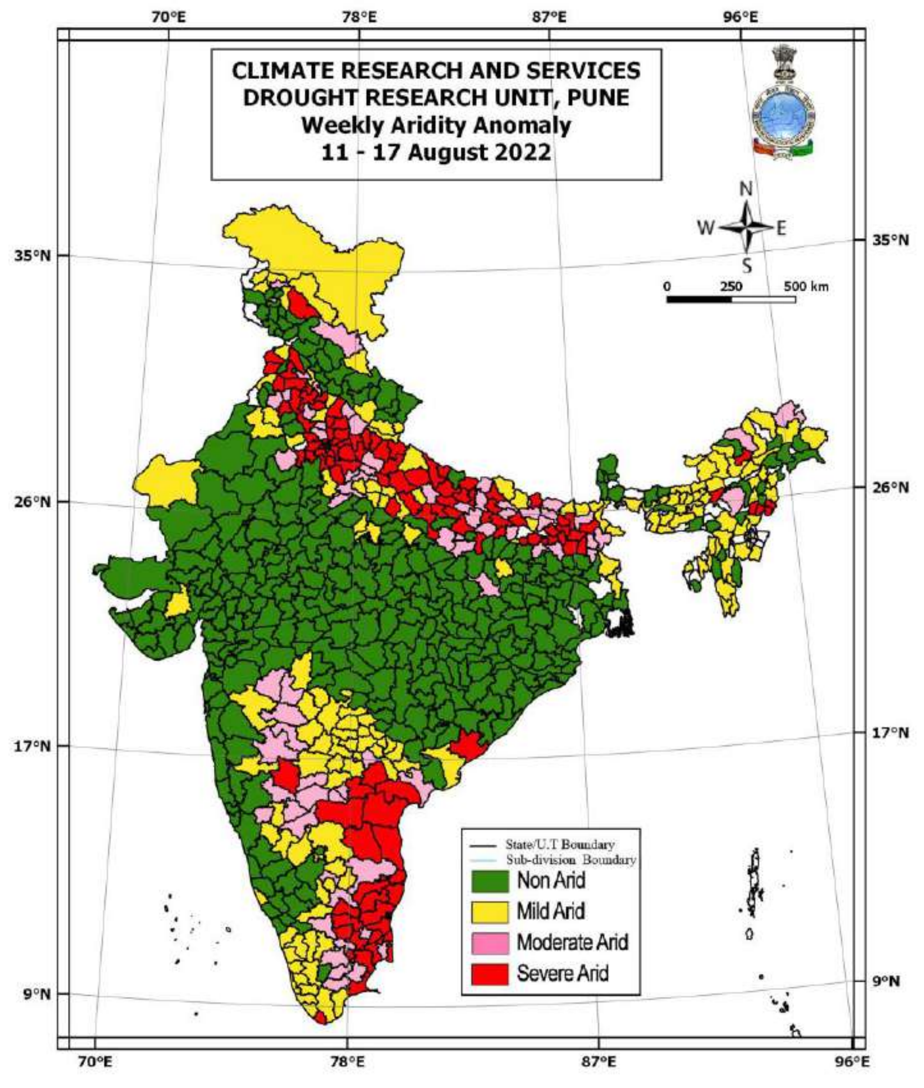

CLIMATE RESEARCH AND SERVICES
DROUGHT RESEARCH UNIT, PUNE
Biweekly Aridity Anomaly Map
04 - 17 August 2022
Non Arid
Mild Arid
Moderate Arid
Severe Arid


CLIMATE RESEARCH AND SERVICES
DROUGHT RESEARCH UNIT, PUNE
Monthly Aridity Anomaly Map
June 2022
Non Arid
Mild Arid
Moderate Arid
Severe Arid

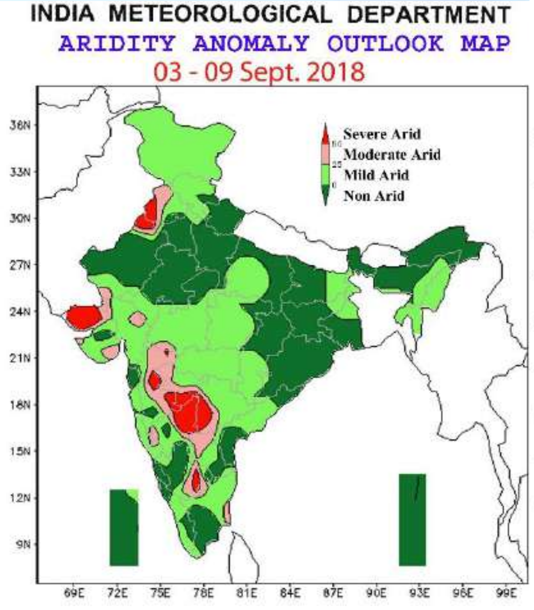

CLIMATE RESEARCH AND SERVICES
DROUGHT RESEARCH UNIT, PUNE
Monthly Aridity Anomaly Map
July 2022
Non Arid
Mild Arid
Moderate Arid
Severe Arid

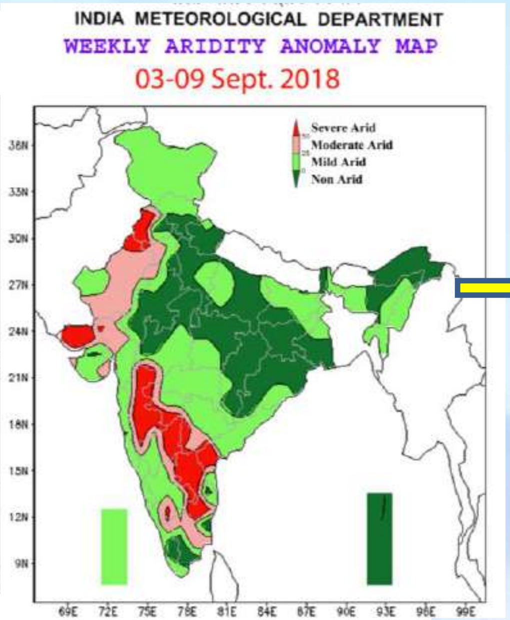
Weekly Aridity Anomaly Outlook





Weekly Drought Outlook maps: Using cumulative rainfall forecast of IMD Global Forecasting system (GFS) model for the coming week, AAI is being calculated for the coming week and AAI outlook map is being generated every week





Following contingency table gives the performance of the Drought outlook for the week (03 to 09 Sep 2018) for 185 stations.

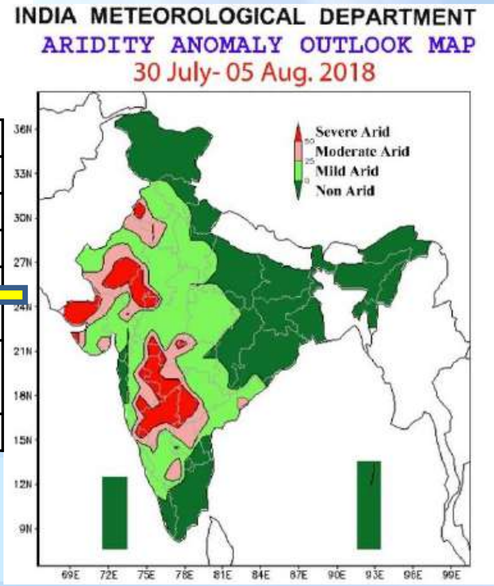
O U T L O O K		ACTUAL			
		Non Arid	Mild Arid	Moderate Arid	Severe Arid
	Non Arid	69	25	5	5
	Mild Arid	9	40	5	3
	Moderate Arid	0	1	5	4
	Severe Arid	0	0	1	13

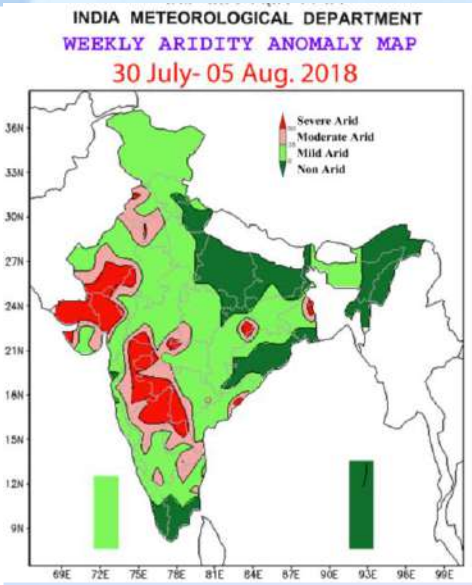
1) Percentage of correct forecast = 69%
2) Percentage of forecast within ± 1 category out = 93%

Following contingency table gives the performance of the Drought outlook for the week (30 July to 05 Aug 2018) for 182 stations.

O U T L O O K		ACTUAL			
		NON Arid	Mild Arid	Moderate Arid	Severe Arid
	Non Arid	70	28	6	3
	Mild Arid	3	28	4	3
	Moderate Arid	2	2	10	3
	Severe Arid	0	0	2	16

Percentage of correct forecast = 69%
Percentage of forecast within ± 1 category out = 92%





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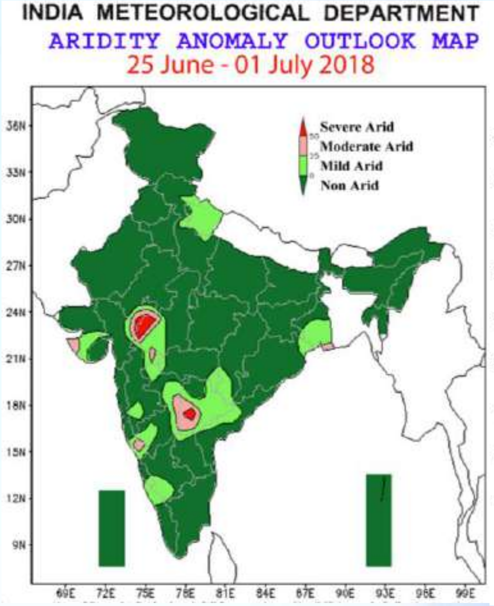
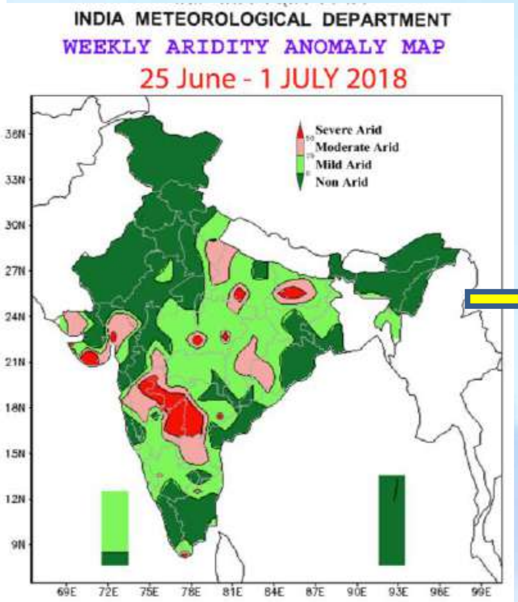




Following contingency table gives the performance of the Drought outlook for the week (25 June to 01 July 2018) for 183 stations.

O	ACTUAL				
U		Non Arid	Mild Arid	Moderate Arid	Severe Arid
T	Non Arid	104	36	14	13
L	Mild Arid	4	0	1	2
O	Moderate Arid	1	0	1	5
O	Severe Arid	1	0	0	1
K					

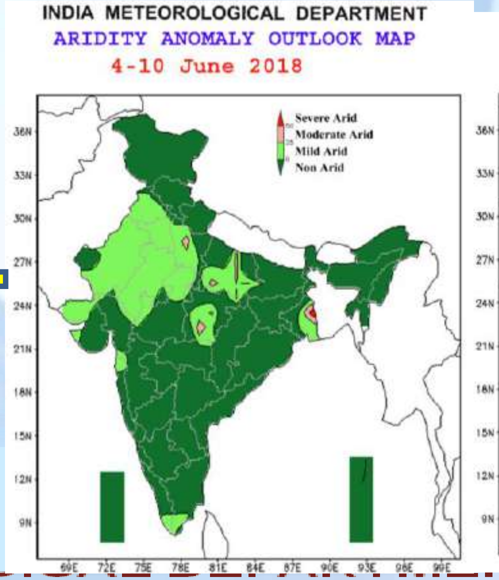
1) Percentage of correct forecast = 58%
2) Percentage of forecast within ± 1 category out = 83%

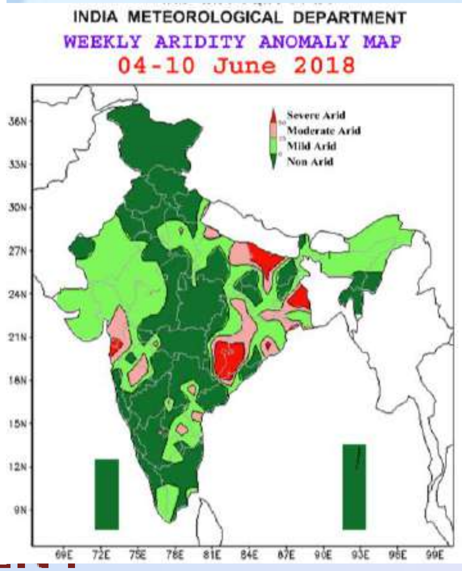
Following contingency table gives the performance of the Drought outlook for the week (04 to 10 June 2018) for 182 stations.

O	ACTUAL				
U		NON Arid	Mild Arid	Moderate Arid	Severe Arid
T	Non Arid	89	26	15	10
L	Mild Arid	15	22	2	0
O	Moderate Arid	2	1	1	0
O	Severe Arid	1	0	0	1
K					

Percentage of correct forecast = 63%

Percentage of forecast within ± 1 category out = 81%





Contingency table of the performance of Drought outlook for Southwest Monsoon Season 2017

O	ACTUAL				
U		Non Arid	Mild Arid	Moderate Arid	Severe Arid
T	Non Arid	1887	564	155	146
L	Mild Arid	151	326	64	31
O	Moderate Arid	38	34	115	29
O	Severe Arid	23	14	17	65
K					

1. Percentage of correct forecast = 65%

2. Percentage of forecast within ± 1 category out = 89%

Standardized Precipitation Index (SPI) in Drought Monitoring

- The Standardized Precipitation Index (SPI) is a tool which was developed primarily for defining and monitoring drought (McKee et al 1993). It allows an analyst to determine the rarity of a drought at a given time scale (temporal resolution) of interest for any region with historic data. It can also be used to determine periods of anomalously wet events.

- In 2009, the participants at the Inter-Regional Workshop on Indices and Early Warning Systems for Drought held at the University of Nebraska-Lincoln issued "The Lincoln Declaration on Drought Indices" (Hayes *et al.*, 2011). There were fifty-four experts from all regions agreed on the use of a universal meteorological drought index for more effective drought monitoring and climate risk and gave recommendation to WMO

- The World Meteorological Organization (WMO) recommends, that all national meteorological and hydrological services should use the SPI for monitoring of dry spells (Press report December 2009, WMO No. 872).

- The World Meteorological Organization (WMO) releases "Standardized Precipitation Index User Guide", WMO-No. 1090 in 2012 giving details and some key points: about using SPI. It is desirable one should go through this before applying SPI.

Interpretation:

- For each time step, precipitation of the preceding t months is accumulated, where t is referred to as the time scale. The time series is first fitted with a model distribution to the data (for precipitation series, the Gamma distribution is typically used) Subsequently it is transformed to values of the standard normal distribution for each calendar month separately.

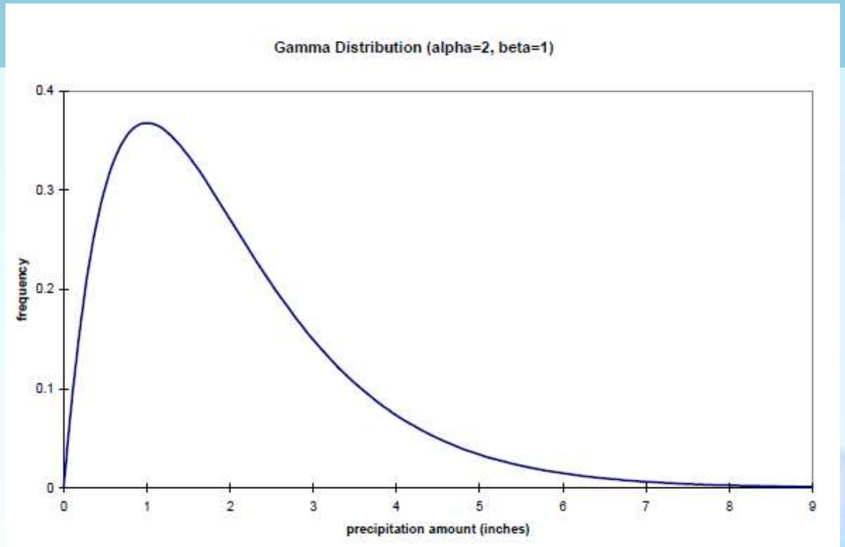
- The resulting time series has no seasonality and takes values of the standard normal distribution, where negative values indicate below average water availability. Positive values indicate greater than median rainfall; negative values indicate less than median rainfall.

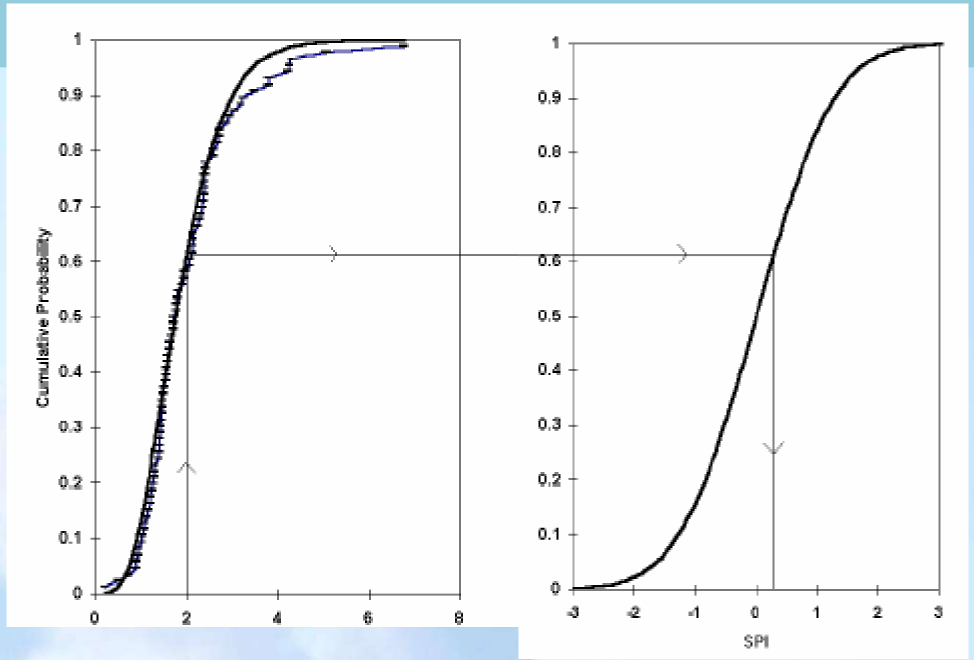
- The interpretation of SPI is strictly probabilistic. As SPI has units of the standard normal distribution, its values can be directly related to probability of occurrence. The standardization implies also that SPI is independent of the mean conditions, it do not differs in magnitude between different regions and is thus suitable to analyse the synchronicity of drought events. This enables an easy and direct comparison between locations with different climate. The possibility to compute SPI for different time scales (t) allows for an adaptation of the index to slowly or fast evolving environmental or societal systems.

- The understanding that a deficit of precipitation has different impacts on groundwater, reservoir storage, soil moisture, snowpack and stream flow led scientists McKee, Doesken and Kleist to develop the Standardized Precipitation Index (SPI) in 1993.

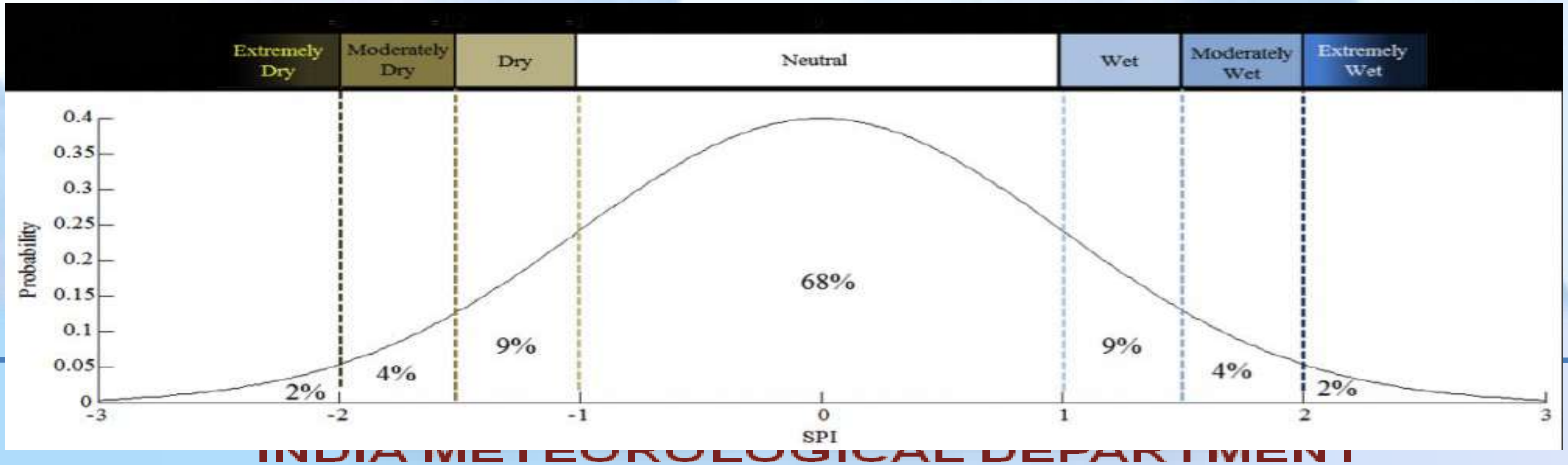
- Positive SPI values indicate greater than median precipitation and negative values indicate less than median precipitation. Because the SPI is normalized, wetter and drier climates can be represented in the same way; thus, wet periods can also be monitored using the SPI.
- A drought event occurs any time when the SPI is continuously negative and reaches an intensity of -1.0 or less. The event ends when the SPI becomes positive. Each drought event, therefore, has a duration defined by its beginning and end, and an intensity for each month that the event continues. The positive sum of the SPI for all the months within a drought event can be termed the drought's "magnitude".

Category number	Categories	SPI range
8	Extremely wet	2.00 or more
7	Severely wet	1.50 to 1.99
6	Moderately wet	1.00 to 1.49
5	Mildly wet	0 to 0.99
4	Mildly dry	0 to -0.99
3	Moderately dry	-1.00 to -1.49
2	Severely dry	-1.50 to -1.99
1	Extremely dry	-2.00 or less





Example of equiprobability transformation from fitted gamma distribution to the standard normal distribution.



Merits

- Minimal data requirements (only monthly precipitation data)
- Simple and quick
- Can be calculated for varying time scales
- Can provide early warning of drought
- Can help assess drought severity
- Can answer such questions as; when, how long, and how severe a drought is.
- Work on standardization and is thus independent from geographical position. Can be used for different locations for drought monitoring

Demerits

- SPI uses only rainfall parameter and so it could not identify the pattern of increase in the duration and magnitude of droughts resultant from higher temperatures.
- short time periods (daily, weekly or even less than one month) regions with low precipitations can give misleading SPI values

Some key points:

• Because the SPI is normalized, wetter and drier climates can be represented in the same way; thus, wet periods can also be monitored using the SPI.

• The SPI was designed to quantify the precipitation deficit for multiple timescales.

• These timescales reflect the impact of drought on the availability of the different water resources, which was the initial intent of the SPI's creators.

• Soil moisture conditions respond to precipitation anomalies on a relatively short timescale. Groundwater, stream flow and reservoir storage reflect the longer-term precipitation anomalies. So, for example, one may want to look at a 1- or 2-month SPI for meteorological drought, anywhere from 1-month to 6-month SPI for agricultural drought, and something like 6-month up to 24-month SPI or more for hydrological drought analyses and applications.

Drought Monitoring by IMD using SPI

- IMD has started monitoring drought situations in district scale using SPI since January, 2013 in monthly scale as a part of climate monitoring.
- To meet the demand from Agricultural Division of IMD for its National level Weekly agricultural Advisory, we have started producing SPI district map in every week based on cumulative recent 4 weeks since June 2013.
- Standardized Precipitation Index (SPI) for the cumulative four weeks period is being generated operationally in every week (Thursday/Friday) to identify the districts experiencing moisture stress situation for preparation of appropriate agromet advisories. During the SW monsoon season in every week SPI condition map is generated for the cumulative period since 1st June.
- We have also started generating Standardized Precipitation Index weekly forecast since the 1st week of Southwest monsoon 2014 using IMD GFS/MME weekly district rainfall forecast as input.
- From this SPI outlook map is also generated every week for the coming 2 to 4 weeks using IITM IMD ERF system rainfall forecast.

Dry/wet conditions at the end of South West Monsoon (June –September) 2020

Analysis with Standardized Precipitation Index

Climate Application and User Interfaces

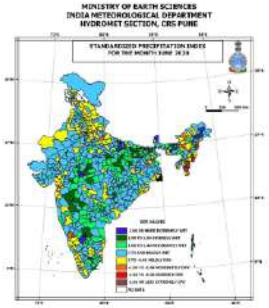
Office of Climate Research and Services

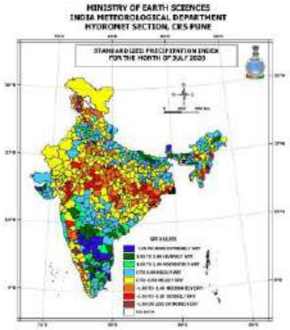
India Meteorological Department, Pune

Ministry of Earth Sciences

Standardized Precipitation Index (SPI), is an important and well accepted index for drought monitoring and is based only on precipitation. This index is negative for drought, and positive for wet conditions.As the dry or wet conditions become more severe, the index becomes more negative or positive.Ministry of Agriculture in its recent drought manual identified SPI as one of the mandatory indicators for declaration of any region of the country as drought affected.The SPI maps are being generated every week as well as every month to identify the regions with prevailing or beginning/ending of the extremely/severely/moderately dry/wet conditions. The detail statistics of the SPI computed for the period since beginning of southwest monsoon will help to the various state government agencies for initiating drought management.

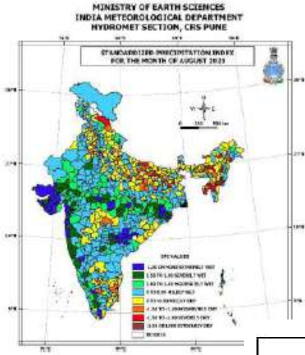
In the beginning of monsoon for the month of June, few districts of Nagaland, Manipur, Mizoram, Tripura; one or two districts of Arunachal Pradesh, Assam & Meghalaya, Jharkhand, West Uttar Pradesh, Haryana, Delhi & Chandigarh, Jammu & Kashmir, Gujarat Region, South Interior Karnataka and Kerala were under moderate to extremely severe dry conditions. Only 2.73% of the country areas were under moderate to extremely dry conditions. Except parts of North East, North India, and few districts from other regions all the country was under mildly wet to extremely wet conditions (almost 71% of country area)

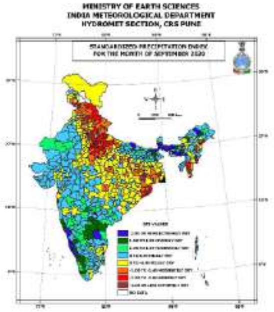




During July Extremely / severely /moderately dry conditions prevailed over many districts Jammu & Kashmir, East Madhya Pradesh; few districts of Nagaland, Manipur, Mizoram, Tripura, Orissa, East Rajasthan, West Madhya Pradesh, Gujarat Region, Madhya Maharashtra, Chhattisgarh; one or two districts of Assam & Meghalaya, Gangetic West Bengal, Jharkhand, East Uttar Pradesh, West Uttar Pradesh, Uttarakhand, Haryana, Delhi & Chandigarh, Punjab, Himachal Pradesh, Vidarbha, North Interior Karnataka, South Interior Karnataka and Kerala. Around 19% of the country areas were under moderate to extremely severe dry conditions.

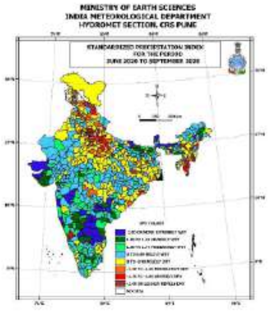
Extremely / severely /moderately dry conditions prevailed over few districts of Assam & Meghalaya, Nagaland, Manipur, Mizoram, Tripura, East Uttar Pradesh; one or two districts of Arunachal Pradesh, Sub Himalayan West Bengal & Sikkim, Jharkhand, Bihar, West Uttar Pradesh, Uttarakhand, Haryana, Delhi & Chandigarh, Punjab, Himachal Pradesh, Vidarbha, Tamil Nadu and South Interior Karnataka in the month of August 2020.Around 7% of the country areas were under moderate to extremely dry conditions during August.





Extremely / severely /moderately dry Conditions prevailed over most districts of West Uttar Pradesh, Uttarakhand, Himachal Pradesh; many districts of Haryana, Delhi & Chandigarh; few districts of Nagaland, Manipur, Mizoram, Tripura, Gangetic West Bengal, Orissa, Jharkhand, East Uttar Pradesh, Punjab, Jammu & Kashmir; One or Two districts of Arunachal Pradesh, Assam & Meghalaya, Bihar, East Rajasthan, West Madhya Pradesh, East Madhya Pradesh, Vidarbha and Chhattisgarh. Around 14.98% of the country areas were under moderate to extremely dry conditions during September 2020.

During the south west monsoon season (June- September) extremely / severely /moderately dry Conditions prevailed over many districts of West Uttar Pradesh; few districts of Nagaland, Manipur, Mizoram, Tripura, Himachal Pradesh, Jammu & Kashmir; one or two districts of Arunachal Pradesh, Assam & Meghalaya, Sub Himalayan West Bengal & Sikkim, Gangetic West Bengal, Orissa, Jharkhand, East Uttar Pradesh, Uttarakhand, Haryana, Delhi & Chandigarh, Punjab, East Rajasthan, West Madhya Pradesh, Vidarbha, Chhattisgarh, Coastal Andhra Pradesh and South Interior Karnataka for the cumulative period June to September 2020. Around 9.14% of the country areas were under moderate to extremely



Percentage area and number of districts under each category of SPI for the months of June, July, August and September and for the cumulative period June to September 2020

SPI Categories	June		July		August		September		June-September	
	%Area	No. of districts	%Area	No. of districts	%Area	No. of districts	%Area	No. of districts	%Area	No. of districts
Extremely wet (2.00 or more)	1.66%	15	4.17%	20	6.47%	35	2.81%	22	7.95%	38
Severely wet (1.50 to 1.99)	6.65%	47	5.75%	36	8.40%	51	4.86%	32	7.14%	47
Moderately wet (1.00 to 1.49)	14.15%	105	6.75%	49	13.16%	73	9.56%	46	11.56%	71
Mildly wet (0 to 0.99)	47.62%	299	23.99%	175	39.39%	234	37.52%	228	33.61%	212
Mildly dry (0 to -0.99)	27.19%	176	40.86%	270	25.76%	208	30.28%	210	30.59%	215
Moderately dry (-1.00 to -1.49)	1.60%	18	12.01%	71	4.73%	44	8.89%	78	4.99%	44
Severely dry (-1.50 to -1.99)	0.28%	2	5.34%	38	1.65%	17	4.85%	42	2.59%	27
Extremely dry (-2.00 or less)	0.85%	6	1.11%	10	0.45%	7	1.24%	11	1.56%	14

Drought Condition Assessment based on Drought indices generated at India Meteorological Department

Period – September 2021 and June- September 2021

Climate Application & User Interfaces,
Office of Climate Research and Services,
India Meteorological Department
Ministry of Earth Sciences
Shivajinagar, Pune 411005

Summary

- The Drought Indicator assessment has been done for 28 states and 8 union territories (696 districts) for the month of September 2021 and the period June to September 2021 using the drought monitoring indices viz, Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index (SPEI) and Aridity Anomaly Index (AAI).
- 161 districts are in deficient/ large deficient category for the period June to September 2021 whereas 195 districts are in deficient/ large deficient category for the month of September 2021 based on rainfall percentage departure from normal.
- For the month of September 2021, 69 districts are in moderately/ severely/ extremely dry condition or moderately/ severely Arid condition in any two of three drought indices (SPI, SPEI, AAI) and 15 districts are in aforementioned dry condition in all the three drought indices.
- For the period June to September 2021, 48 districts are in moderately/ severely/ extremely dry condition or moderately/ severely Arid condition in any two of three drought indices (SPI, SPEI, AAI) and 14 districts are in aforementioned dry condition in all the three drought indices.
- Maximum number of districts in dry/ arid condition as per the three drought indices are in Uttar Pradesh state for the period June to September 2021.

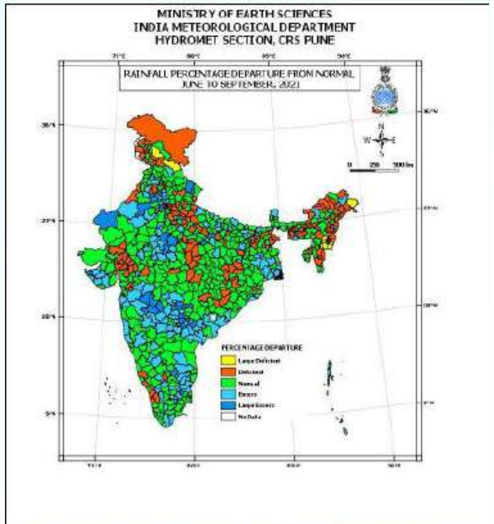


Figure 2: Rainfall Percentage departure from Normal for the period June to September 2021

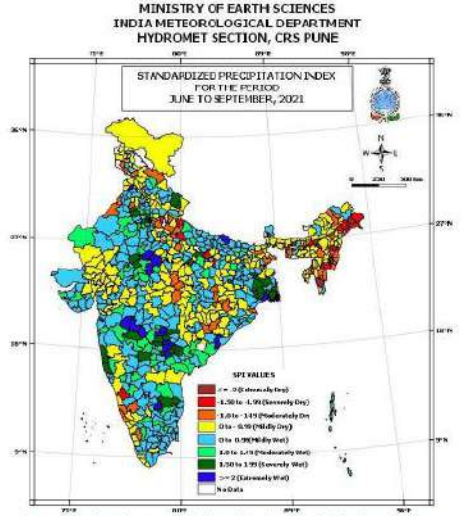


Figure 6: Map based on Standardized Precipitation Index (SPI) for the period June to September 2021

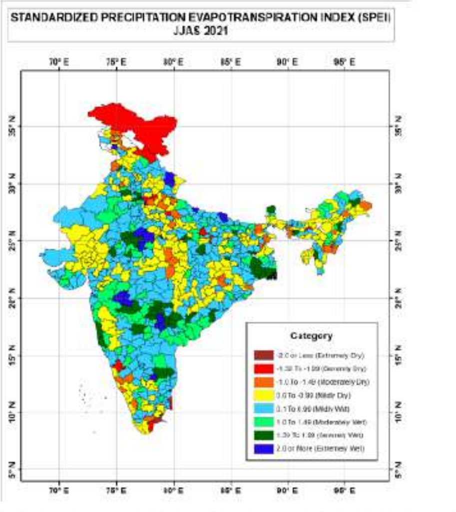


Figure 8: Map based on Standardized Precipitation Evapotranspiration Index (SPEI) for June to August 2021

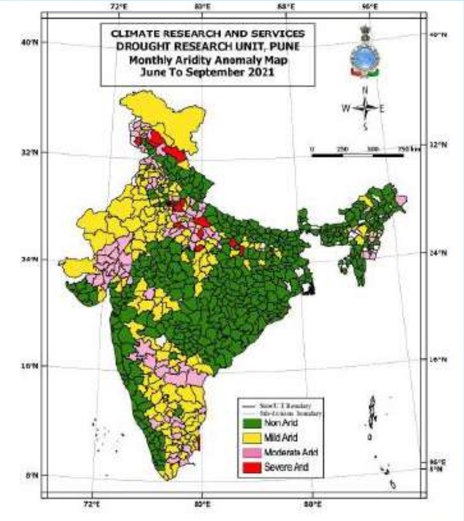


Figure 4: Map based on Aridity Anomaly Index for the period June to September 2021

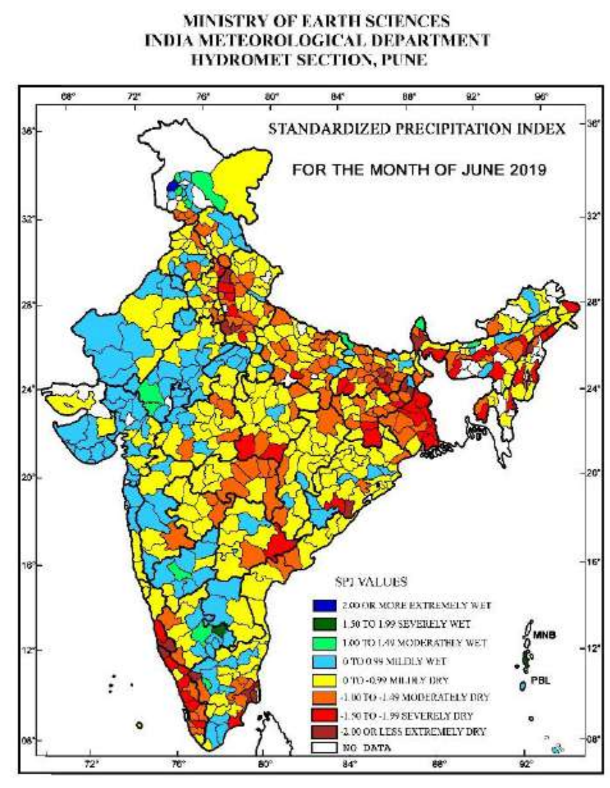
State	Districts in Moderately/ Severely/ Extremely dry / Moderately/ Severely Arid condition in all three drought indices (AAI, SPEI and SPI)
Arunachal Pradesh	Anjaw
Himachal Pradesh	Lahul And Spiti
Jammu And Kashmir	Shopian
Punjab	Mansa
Uttar Pradesh	Budaun, Bulandshahr, Chandauli, Farrukhabad, Hardoi, Jaunpur, J.Phule Nagar, Kanpur Dehat, Pilibhit, Rampur

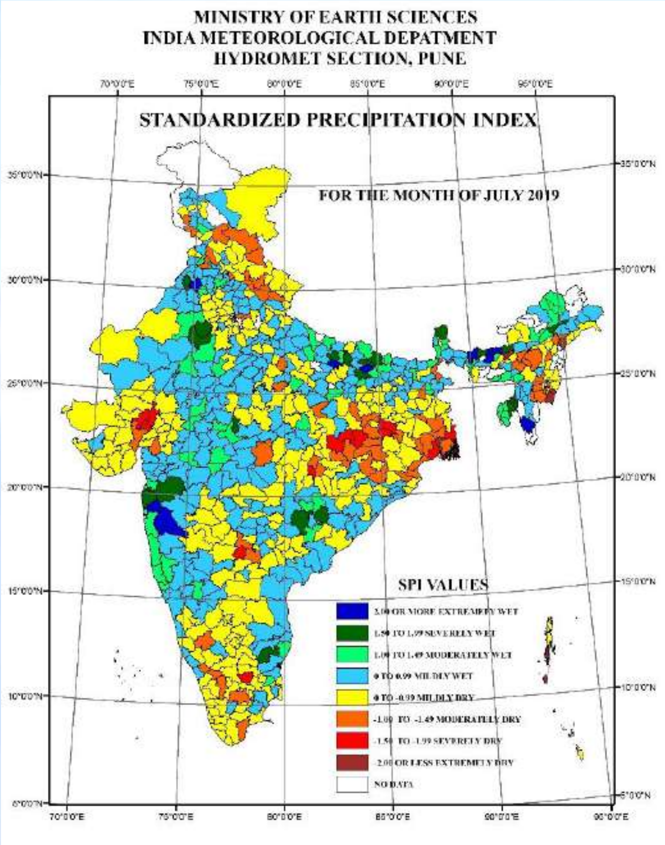
Table 10: List of districts in all three of the Drought indices viz SPI, SPEI and AAI for June to September 2021

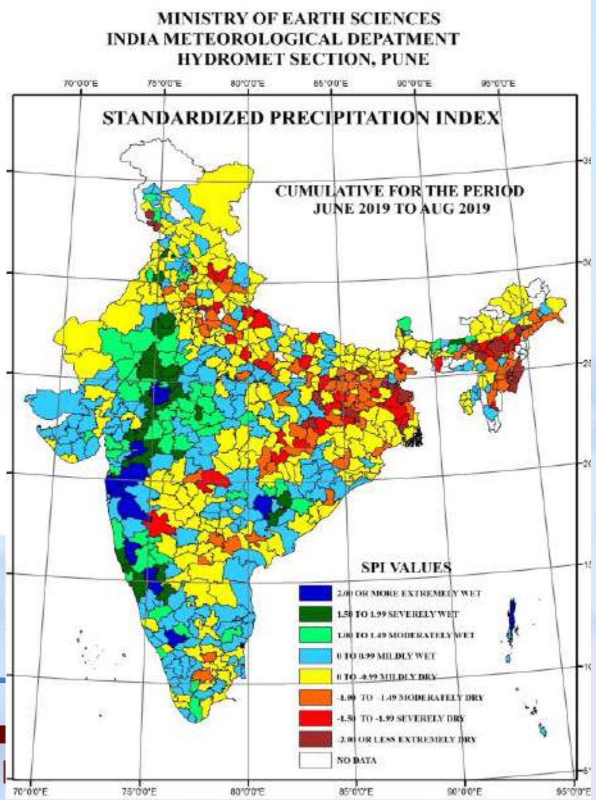
State	Districts in Moderately/ Severely/ Extremely dry / Moderately/ Severely Arid condition in any two of Indices (AAI, SPEI and SPI)
Arunachal Pradesh	Anjaw
Assam	Kamrup, Nagaon, Dhubri, Dibrugarh, Kamrup Metropolitan
Bihar	Purnea
Himachal Pradesh	Lahul And Spiti
Jammu And Kashmir	Anantnag, Doda, Jammu, Shopian, Bandipore, Rajouri
Karnataka	Hassan, Kanara South, Shimoga
Kerala	Kannur, Palakkad
Madhya Pradesh	Damoh, Jabalpur, Seoni
Manipur	Bishnupur, Chandel, Churachandpur, Senapati
Nagaland	Phek
Punjab	Amritsar, Mansa
Tamil Nadu	Chennai, Nagapattinam, Ramanathapuram, Virudhunagar
Union Territory	Puducherry
Uttar Pradesh	Budaun, Badaun, Bulandshahr, Chandauli, Farrukhabad, Gautambudhnagar, Ghaziabad, Hardoi, Jaunpur, J.Phule Nagar, Kanpur Dehat, Pilibhit, Rampur, Shahjahanpur

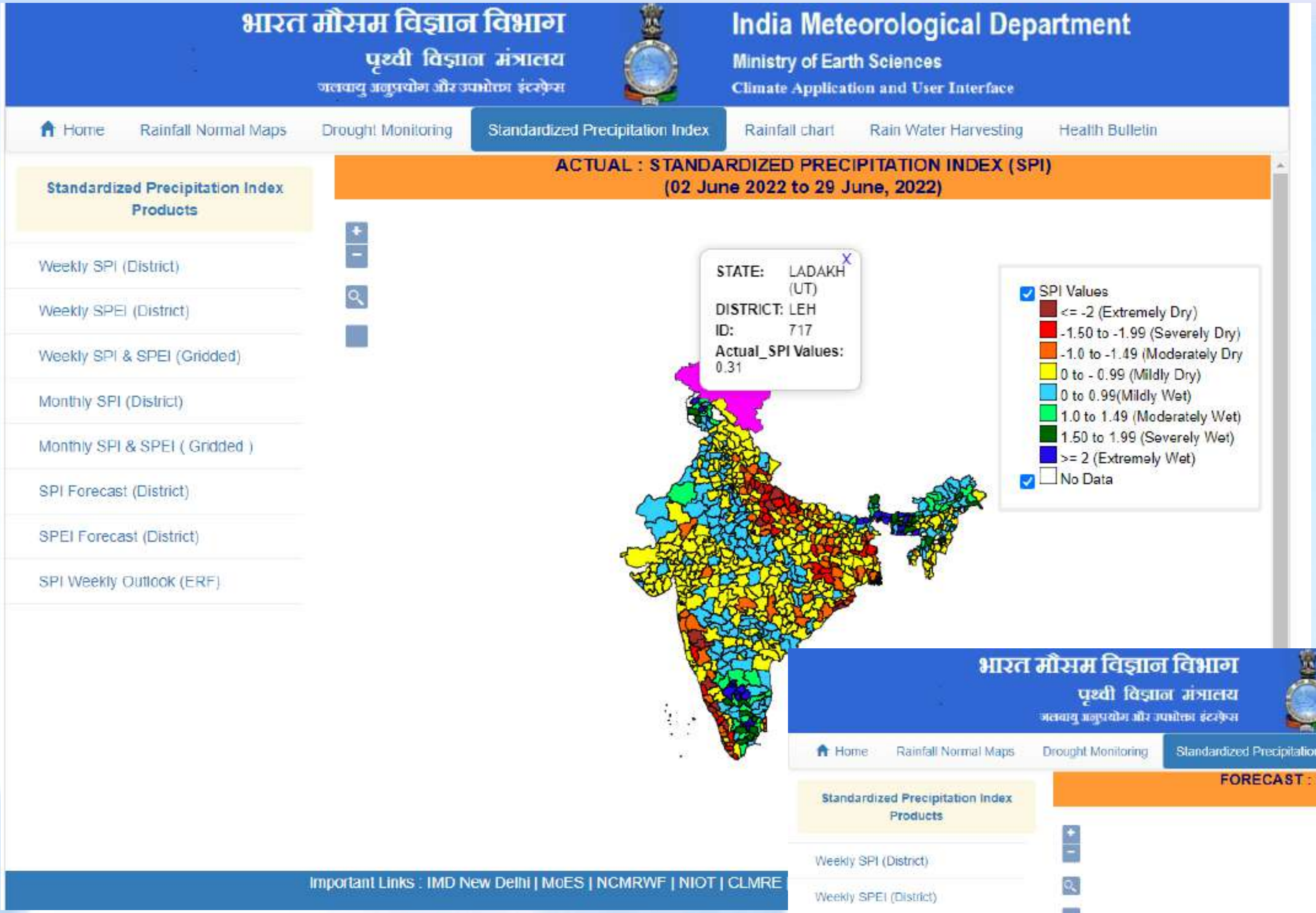
Table 9: List of districts in any two of the three Drought indices viz SPI, SPEI and AAI for June to September 2021

Monthly, seasonal, annual and cumulative 2-3-4 months SPI for Climate Monitoring (used in Climate Diagnostic Bulletin of India)





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पृथ्वी विज्ञान मंत्रालय
जलवायु अनुप्रयोग और उपभोक्ता इंटरफ़ेस
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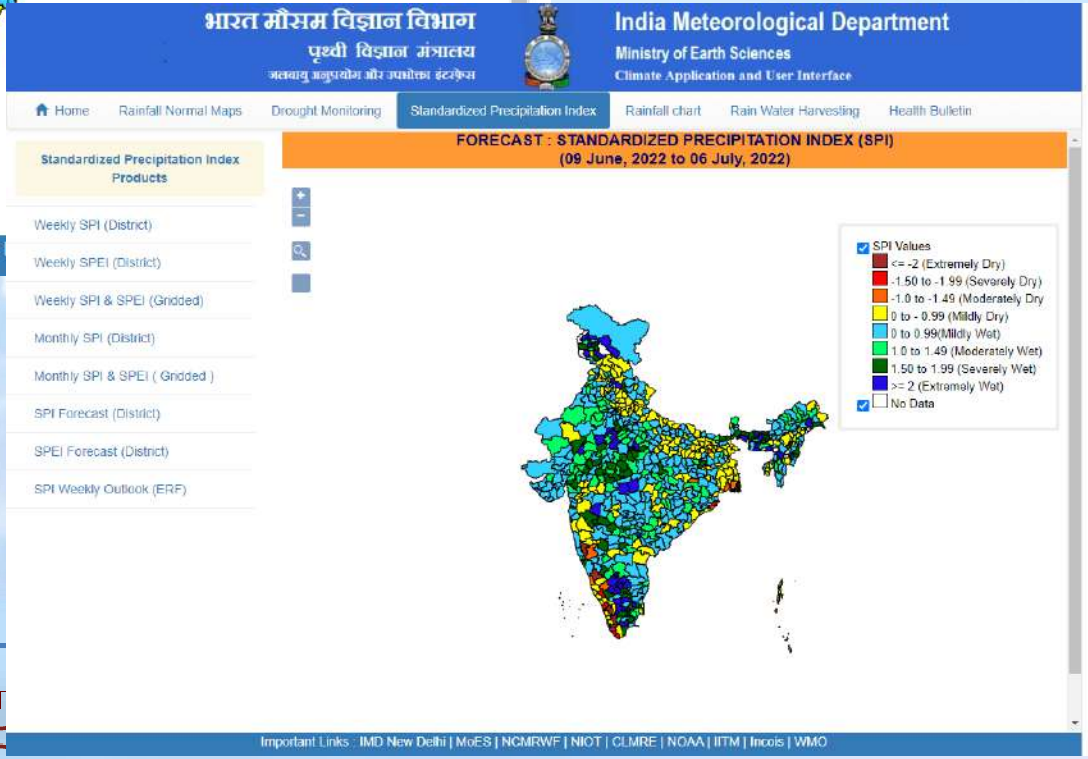
Drought Monitoring
Standardized Precipitation Index
Rainfall chart
Rain Water Harvesting
Health Bulletin
Standardized Precipitation Index Products
Weekly SPI (District)
Weekly SPEI (District)
Weekly SPI & SPEI (Gridded)
Monthly SPI (District)
Monthly SPI & SPEI (Gridded)
SPI Forecast (District)
SPEI Forecast (District)
SPI Weekly Outlook (ERF)
ACTUAL : STANDARDIZED PRECIPITATION INDEX (SPI)
(02 June 2022 to 29 June, 2022)
STATE: LADAKH (UT)
DISTRICT: LEH
ID: 717
Actual_SPI Values: 0.31
SPI Values
<= -2 (Extremely Dry)
-1.50 to -1.99 (Severely Dry)
-1.0 to -1.49 (Moderately Dry
0 to - 0.99 (Mildly Dry)
0 to 0.99(Mildly Wet)
1.0 to 1.49 (Moderately Wet)
1.50 to 1.99 (Severely Wet)
>= 2 (Extremely Wet)
No Data
Important Links : IMD New Delhi | MoES | NCMRWF | NIOT | CLMRE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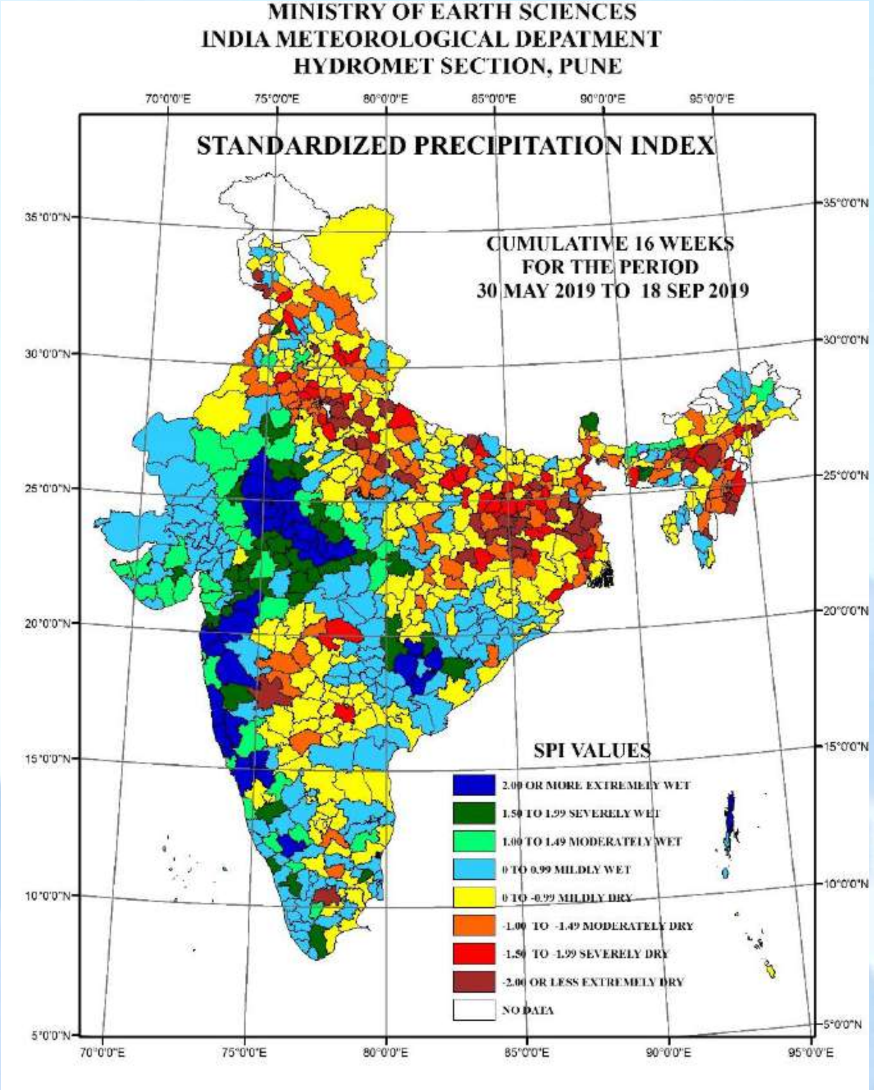
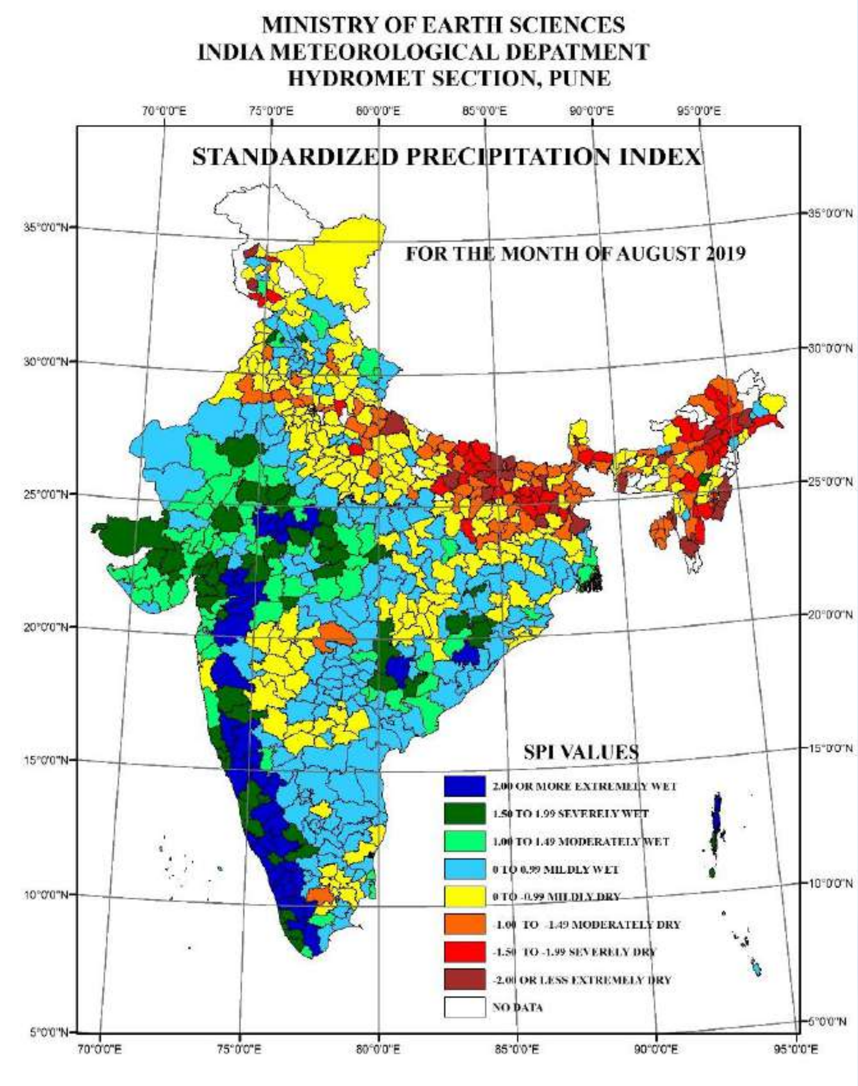
Monthly SPI (District)
Monthly SPI & SPEI (Gridded)
SPI Forecast (District)
SPEI Forecast (District)
SPI Weekly Outlook (ERF)
FORECAST : STANDARDIZED PRECIPITATION INDEX (SPI)
(09 June, 2022 to 06 July, 2022)
SPI Values
<= -2 (Extremely Dry)
-1.50 to -1.99 (Severely Dry)
-1.0 to -1.49 (Moderately Dry
0 to - 0.99 (Mildly Dry)
0 to 0.99(Mildly Wet)
1.0 to 1.49 (Moderately Wet)
1.50 to 1.99 (Severely Wet)
>= 2 (Extremely Wet)
No Data
Important Links : IMD New Delhi | MoES | NCMRWF | NIOT | CLMRE | NOAA | IITM | Incois | WMO



WEEKLY

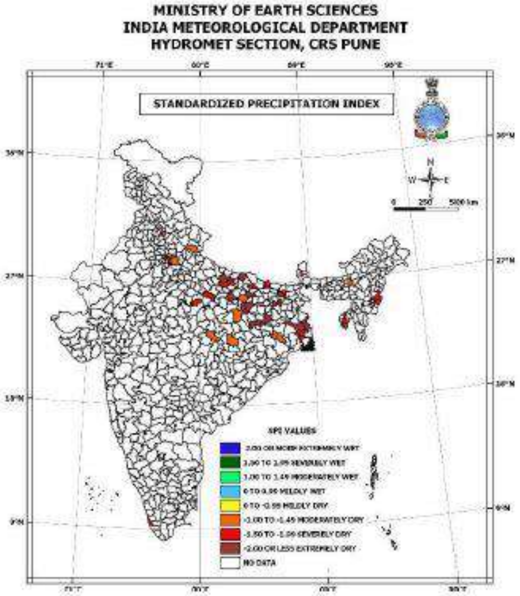


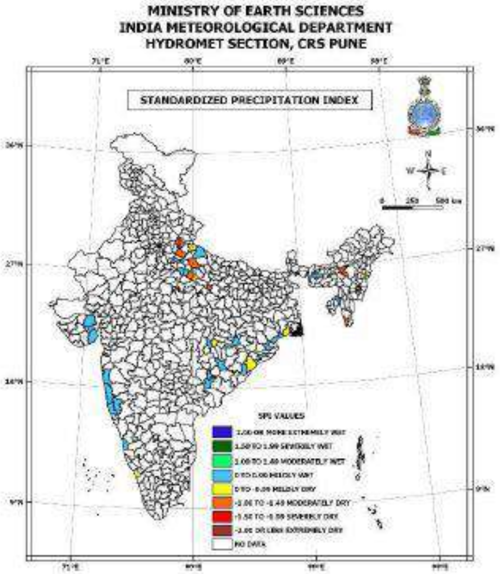
MONTHLY

CHANGE IN DRY CONDITION DURING THE WEEK ENDING ON 10th AUGUST 2022

CHANGE IN DRY CONDITION DURING THE WEEK ENDING ON 10th AUGUST 2022

Districts with Dry Condition Intensified Since Last Week	Districts with Dry Condition Improved Since Last Week



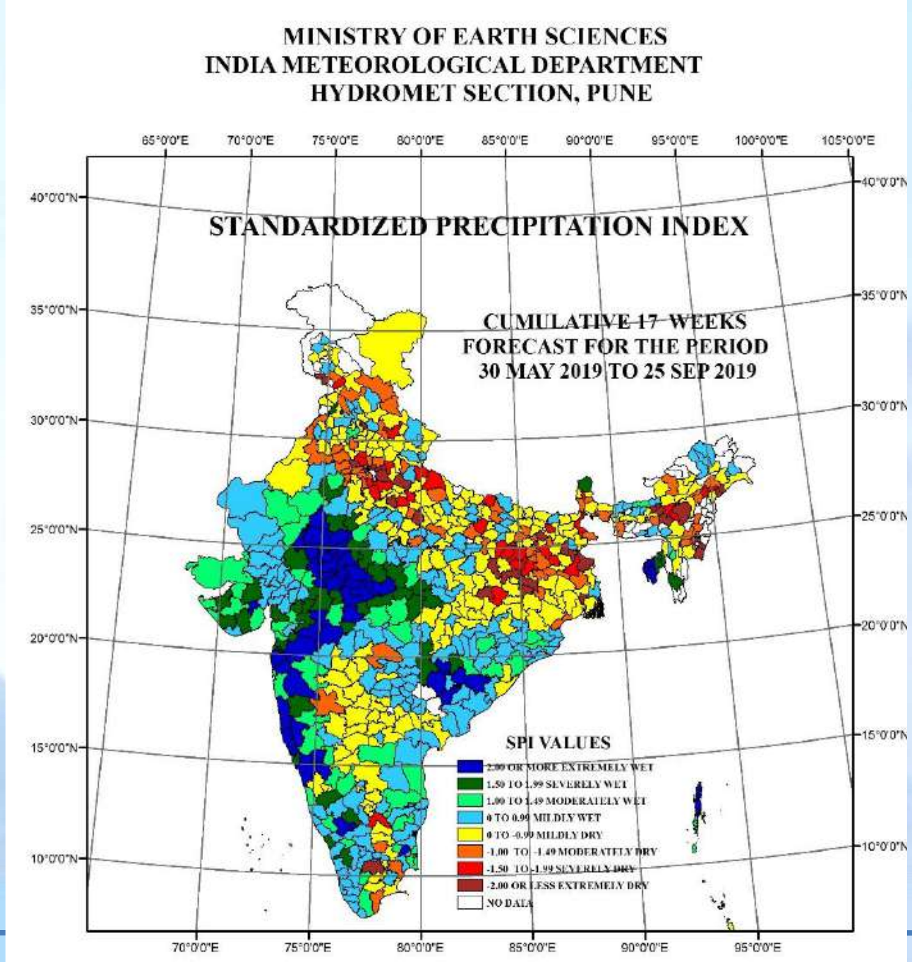


- MODERATELY DRY WHICH WAS EARLIER MILDLY DRY OR WET.
- SEVERELY DRY WHICH WAS EARLIER MODERATELY DRY/MILDLY DRY OR WET
- EXTREMELY DRY WHICH WAS EARLIER MODERATELY/SEVERELY/MILDLY DRY OR WET

- MILDLY DRY WHICH WAS EARLIER MODERATELY/SEVERELY/EXTREMELY DRY.
- MODERATELY DRY WHICH WAS EARLIER SEVERELY/EXTREMELY DRY
- SEVERELY DRY WHICH WAS EARLIER EXTREMELY DRY
- MILDLY WET OR OTHER CATEGORIES OF WET WHICH WAS EARLIER MILDLY/ MODERATELY/SEVERELY/EXTREMELY DRY

	EXTREMELY WET	SEVERELY WET	MODERATELY WET	MILDLY WET	MILDLY DRY	MODERATELY DRY	SEVERELY DRY	EXTREMELY DRY
PERCENTAGE AREA IN SPI CATEGORY FOR WEEK ENDING 10th AUGUST 2022 (CURRENT WEEK)	8.53	9.20	12.58	31.75	22.06	7.37	4.35	4.11
PERCENTAGE AREA IN SPI CATEGORY FOR WEEK ENDING 3rd AUGUST 2022 (LAST WEEK)	6.37	10.77	11.41	32.01	24.11	6.92	5.79	2.57

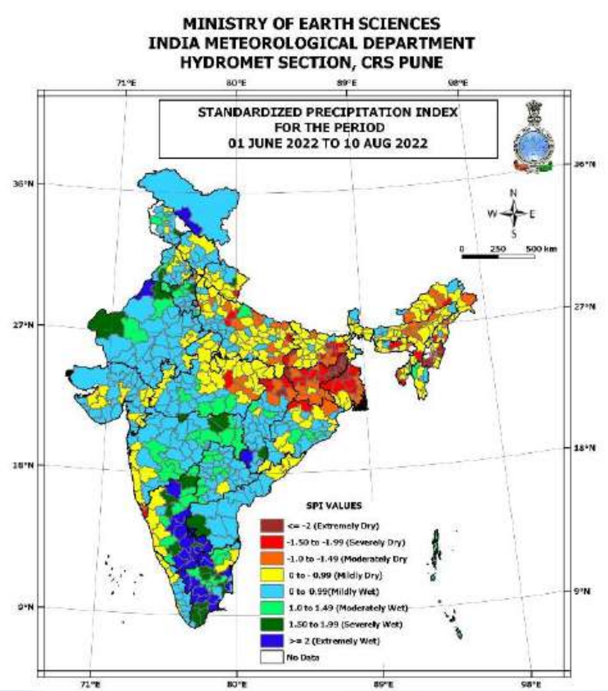
1. SPI Outlook map for one week advance using IMD GFS weekly district rainfall forecast



Generating SPI Outlook maps for One week to Four weeks

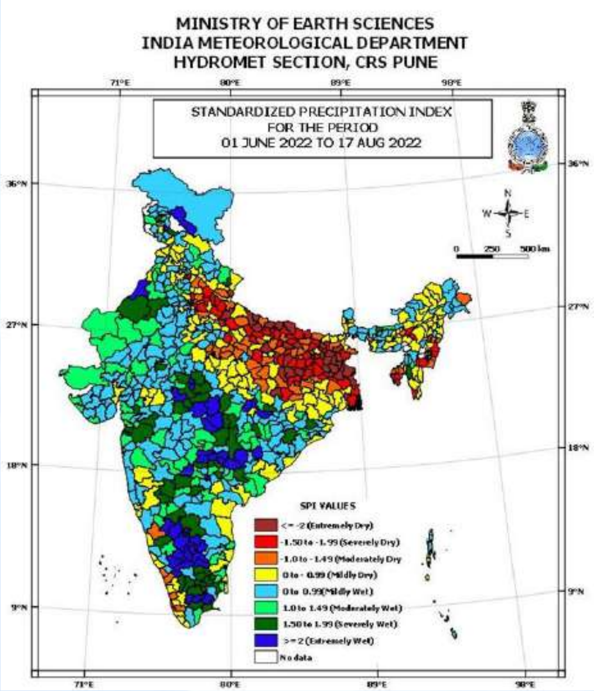
1. SPI Outlook map for one week advance using IMD GFS weekly district rainfall forecast

Till Last Week



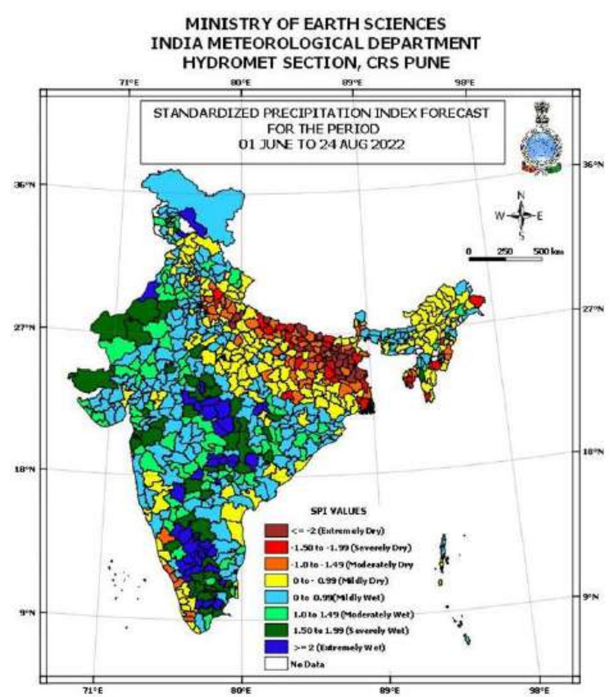
SPI for the period 1st June to 10th August 2022

Till This Week



SPI for the period 1st June to 17th August 2022

Till Next Week



SPI for the period 1st June to 24th August 2022

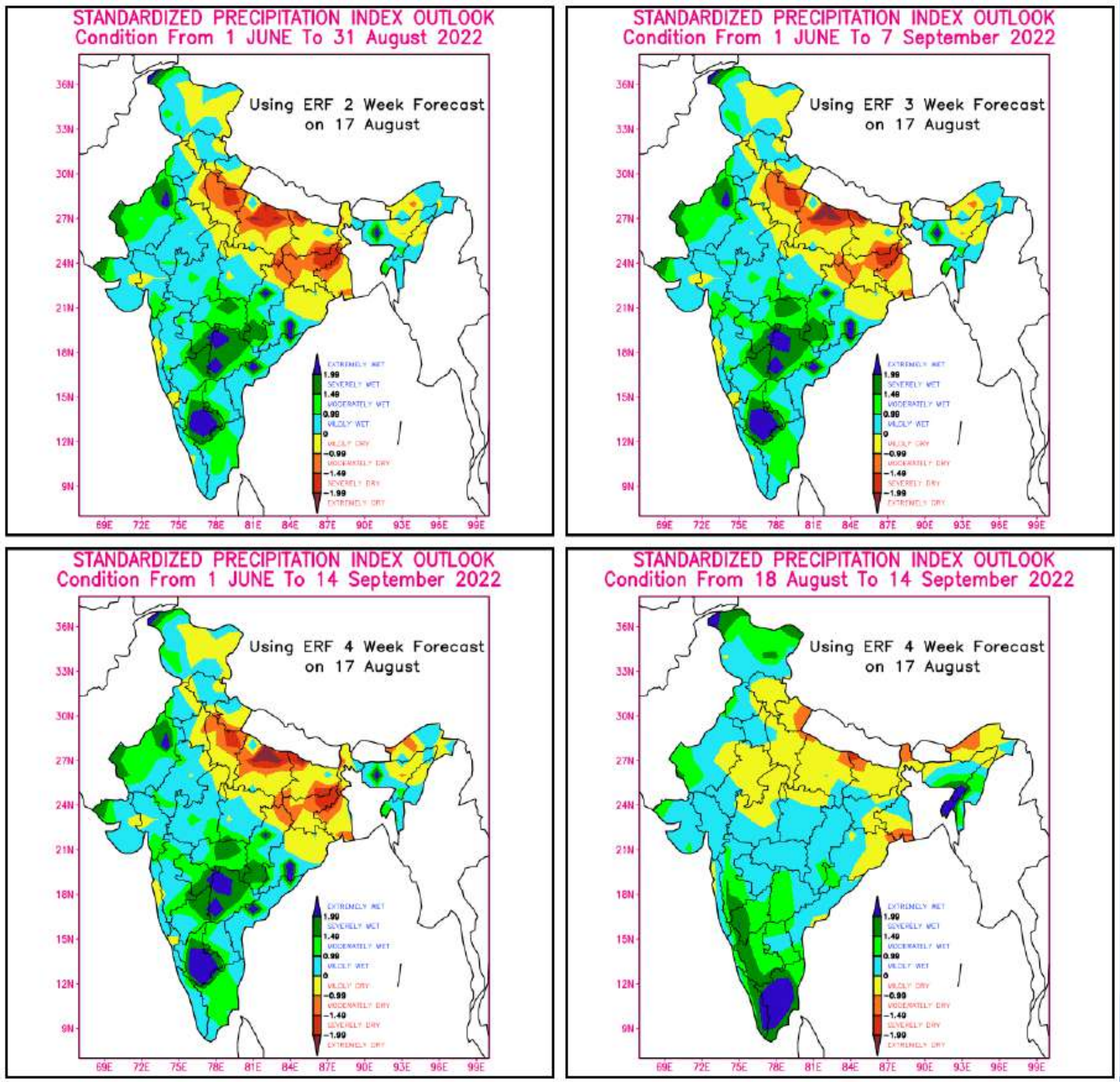
Performances of one week SPI outlook during SW Monsoon 2018

WEEK 2018		Correct F/C	In ±1 cat	In ± 2 cat	In ± 3 cat	In ± 4 cat	In ± 5 cat	In ± 6 cat	In + 7 cat
26	Freq	213	229	81	42	8	0	0	0
26	%	**37.2**	**40.0**	**14.1**	**7.3**	**1.4**	**0.0**	**0.0**	**0.0**
27	Freq	223	237	74	31	3	2	1	0
27	%	**39.1**	**41.5**	**13.0**	**5.4**	**0.5**	**0.4**	**0.2**	**0.0**
28	Freq	233	210	82	38	5	2	0	0
28	%	40.9	36.8	14.4	6.7	0.9	0.4	0.0	0.0
29	Freq	273	195	73	25	4	1	0	0
29	%	47.8	34.2	12.8	4.4	0.7	0.2	0.0	0.0
30	Freq	304	190	50	23	3	0	0	1
30	%	53.2	33.3	8.8	4.0	0.5	0.0	0.0	0.2
31	Freq	352	182	27	7	2	0	1	0
31	%	61.6	31.9	4.7	1.2	0.4	0.0	0.2	0.0
32	Freq	396	155	17	2	1	0	0	0
32	%	**69.4**	**27.1**	**3.0**	**0.4**	**0.2**	**0.0**	**0.0**	**0.0**
33	Freq	339	200	23	6	0	0	0	0
33	%	59.7	35.2	4.0	1.1	0.0	0.0	0.0	0.0
34	Freq	334	211	21	2	1	0	0	0
34	%	58.7	37.1	3.7	0.4	0.2	0.0	0.0	0.0
35	Freq	372	172	16	7	1	1	0	0
35	%	**65.4**	**30.2**	**2.8**	**1.2**	**0.2**	**0.2**	**0.0**	**0.0**
36	Freq	428	126	13	2	0	1	0	0
36	%	**75.1**	**22.1**	**2.3**	**0.4**	**0.0**	**0.2**	**0.0**	**0.0**

In most of the weeks the forecast was correct within one category out was more than 90%

Generating SPI Outlook maps for One week to Four weeks

2. SPI Outlook map for two to four weeks in advance using Extended Range Forecast System



Standardised Precipitation-Evapotranspiration Index (SPEI)

Relatively New index proposed by Vicente et al, 2010

Ref: Vicente-Serrano, S.M., S. Begueria and J.I. Lopez-Moreno, 2010: A multi-scalar drought index sensitive to global warming: the Standardized Precipitation Evapotranspiration Index. *Journal of Climate,* 23: 1696–1718. DOI: 10.1175/2009JCLI2909.1.

A new drought index: the Standardised Precipitation-Evapotranspiration Index (SPEI)

- The SPEI fulfils the requirements of a drought index since its multi-scalar character enables it to be used by different scientific disciplines to detect, monitor and analyze droughts.

- Like SPI, the SPEI can measure drought severity according to its intensity and duration, and can identify the onset and end of drought episodes.

- However, a crucial advantage of the SPEI over other widely used drought indices is that it considers the effect of PET on drought severity and its multi-scalar characteristics enable identification of different drought types and impacts in the context of above normal heating.

Computation of the SPEI

- The SPEI is really simple to calculate, and is based on the original SPI calculation procedure.
- The SPI is calculated using monthly (or weekly) precipitation as the input data. The SPEI uses the monthly (or weekly) difference between precipitation and PET. This represents a simple climatic water balance which is calculated at different time scales to obtain the SPEI.
- A number of equations exist to model PET based on available data (e.g. the Thornthwaite equation, the Penman-Monteith equation, the Hargreaves equation, etc), and the SPEI is not linked to any particular one.

- With a value for PET, the difference between the precipitation (P) and PET for the month i is calculated:

$$D_i = P_i - PET_i$$

which provides a simple measure of the water surplus or deficit for the analyzed month.

- The calculated D_i values are aggregated at different time scales, following the same procedure as for the SPI and SPEI is calculated using the same procedure as in SPI. However for SPEI we have used Log logistic distribution instead of Gama distribution

Standardized Precipitation Evapotranspiration Index (SPEI)

- **The Standardized Precipitation Evapotranspiration Index (SPEI)**

  - SPEI can measure drought severity according to its intensity and duration, and can identify the onset and end of drought episodes. However, a crucial advantage of the SPEI over other widely used drought indices is that it considers the effect of PET on drought severity and its multi-scalar characteristics enable identification of different drought types and impacts in the context of above normal heating.

  - The SPEI uses the monthly (or weekly) difference between precipitation and PET. This represents a simple climatic water balance which is calculated at different time scales to obtain the SPEI. With a value for PET, the difference between the precipitation (P) and PET for the month i is calculated:

$$\mathbf{D_i = P_i - PET_i}$$

which provides a simple measure of the water surplus or deficit for the analysed month.

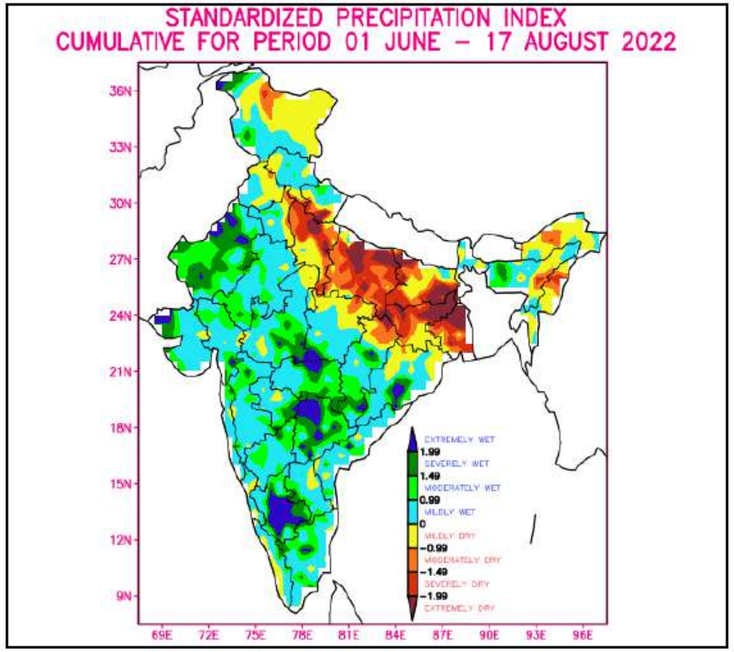
  - The calculated $\mathbf{D_i}$ values are aggregated at different time scales.

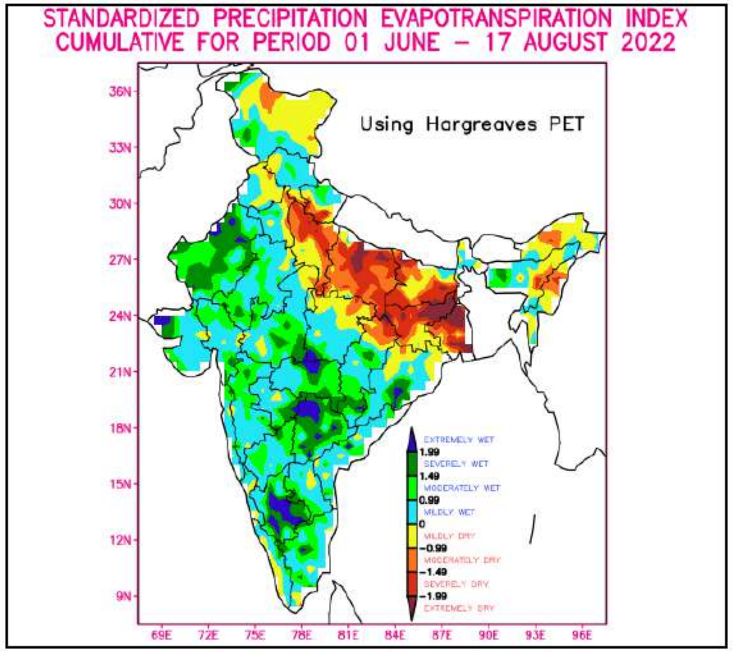
- **Hargreaves-Samani PET Method**

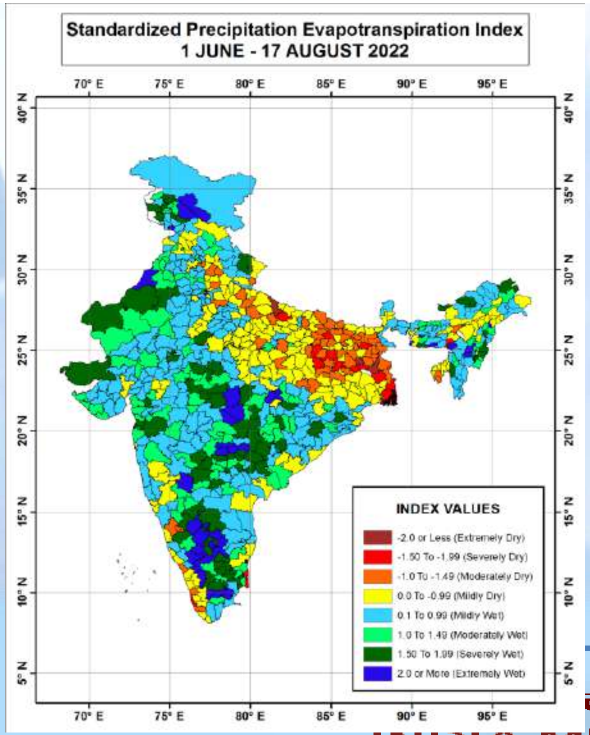
$$ET_o = 0.0023(T_m + 17.8)\left(\sqrt{T_{\max} - T_{\min}}\right)R_a$$

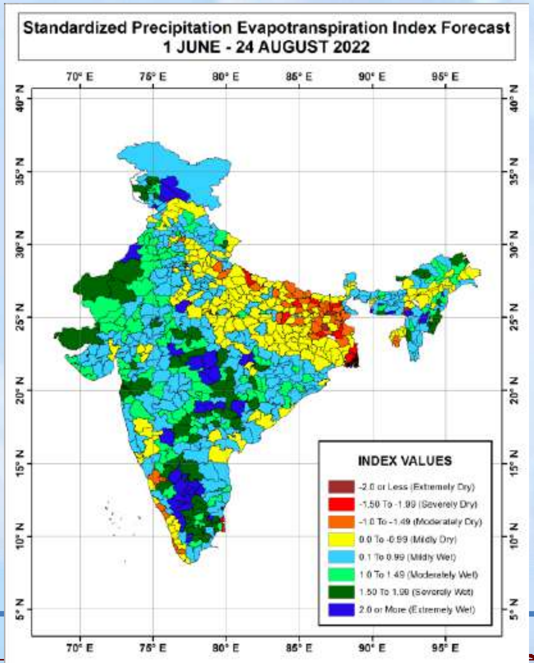
Where, Tm is daily mean air temperature [°C], Tmax is daily maximum air temperature [°C], Tmin is daily minimum air temperature [°C], and Ra is extra-terrestrial radiation [MJ m-2 day-1].

Ra can be calculated using Equation references from "Duffie, J.A. and W.A. Beckman, Solar Engineering of Thermal Processes, Wiley, New York, as summarized in Maidment, Handbook of Hydrology, 1993".









INDIA METEOROLOGICAL DEPARTMENT

Immediate

No. 9/1/2014-DM-1 (Pt.)
Government of India
Ministry of Agriculture and Farmers Welfare
Department of Agriculture, Cooperation & Farmers Welfare
(Drought Management Division)

Krishi Bhawan, New Delhi
Dated the 28th December, 2016

To
The Chief Secretary
Government of
(Andhra Pradesh/Arunachal Pradesh/Assam/Bihar/Chhattisgarh/Goa/Gujarat/Haryana/ Himachal Pradesh/Jammu & Kashmir/Jharkhand/Karnataka/Kerala/Madhya Pradesh/ Maharashtra/Manipur/Meghalaya/Mizoram/Nagaland/Odisha/Punjab/Rajasthan/Sikkim/ Tamil Nadu/Telangana/Tripura/Uttarakhand/Uttar Pradesh/West Bengal)_

Subject: Revision of Manual for Drought Management – forwarding copy of Manual for Drought Management, 2016.

Sir/Madam,

I am directed to forward a copy of the Manual for Drought Management 2016, for information and necessary action.

Yours faithfully,
(Vijay Rajmohan)
Director (DM)
Tel.: 23386681
Email: vijay.rajmohan@nic.in

Encl: As above.

Copy, with a copy of the enclosure, forwarded to Secretary (Disaster Management)/ Secretary (Revenue) / Relief Commissioner, of all State Governments, for information and necessary action.

MANUAL FOR
DROUGHT
MANAGEMENT

DECEMBER 2016

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

3.3 PROCESS FOR THE DETERMINATION OF DROUGHT

3.3.1 Steps in the Determination of Drought

Following steps are suggested for the determination of drought:

Step 1: Mandatory Indicators viz. RF deviation or SPI or Dry Spell will be considered as per matrix at Table 3.9 to assess if the first drought trigger is set off.

Table 3.9: *Matrix for rainfall deviations and dry spells (Trigger-1)*

Rf Dev/SPI	Dry spell	Drought trigger
Deficit or scanty rf/SPI<-1	Yes	Yes
Deficit or scanty rf/SPI<-1	No	Yes if rainfall is scanty or SP<-1.5, else No
Normal rf/SPI>-1	Yes	Yes
Normal rf/SPI>-1	No	No

Step 2: In the event that the first drought trigger is set off in Step 1, the Impact Indicators will be examined as per the matrix at Table 3.10.

Table 3.10: *Matrix for impact indicators (Trigger-2)*

Mandatory Indicators		Impact Indicators				Category of drought
Rainfall Indices		Agricul-ture	Remote Sensing	Soil Moisture	Hydrology	
Rainfall Deviation (RFdev) or SPI	Dry Spell	Crop Area Sown	VCI or NDVI Deviations	PASM / MAI	SFI / RSI / SGWI	

The States may consider any three of the four types of the Impact Indicators (one from each) for assessment of drought, the intensity of the calamity and make a judgement.

Step 3: In the event that trigger 2 is set off, States will conduct sample survey for ground truthing as described at 3.2.6 above and in order to make a final determination of drought. The finding of field verification exercise will be the final basis for judging the intensity of drought as 'severe' or 'moderate'.

However, sparse availability of long term Block/Taluk/Mandal level quality data in many States is a limitation in computation of SPI. The States are advised to refer to URL of IMD viz. imdpune.gov.in for SPI data and related information.

Crop Weather Watch Group

Table 2.2: Details of CWWG Monitoring and Information Management

Parameters	National-level	State-level	District-level	Field agencies
A. Meteorological				
Delay in the onset of monsoon	D	D	D	D
Rainfall	D	D	D	D
Dry spell during sowing Period	D	D	D	D
Dry spells during critical crop-growth periods	D	D	D	D
B. Hydrological				
Water availability in reservoirs	W	W	W	D
Water availability in tanks	F	F	F	D
Stream flow	F	F	F	D
Groundwater Level	S	S	S	S
C. Agricultural				
Delay in sowing	W	W	W	W
Sown area	W	W	W	W
Crop vigour	F	F	F	W
Soil moisture deficit	F	F	F	F
Change in cropping pattern	W	W	W	W
Supply and demand of agricultural inputs	W	W	W	W

D= Daily; W= Weekly; F= Fortnightly; M= Monthly; S= Seasonal (pre- and post-rains)

Key Variables for Monitoring Drought

- Meteorological Data – Rainfall and other parameters like Temperature, Wind speed and Relative Humidity (subject to availability)
- Weather forecast - Short, medium, extended range
- Soil Moisture (subject to availability)
- Sown Area / Crop Health / Stress
- Satellite based Vegetation Index
- Stream Flow – Discharge
- Groundwater Levels
- Reservoir and Lake Storage / Level
- Impacts – distress sale and migration of cattle, human migration, fodder availability, drinking water, animal health, employment opportunities in agriculture sector

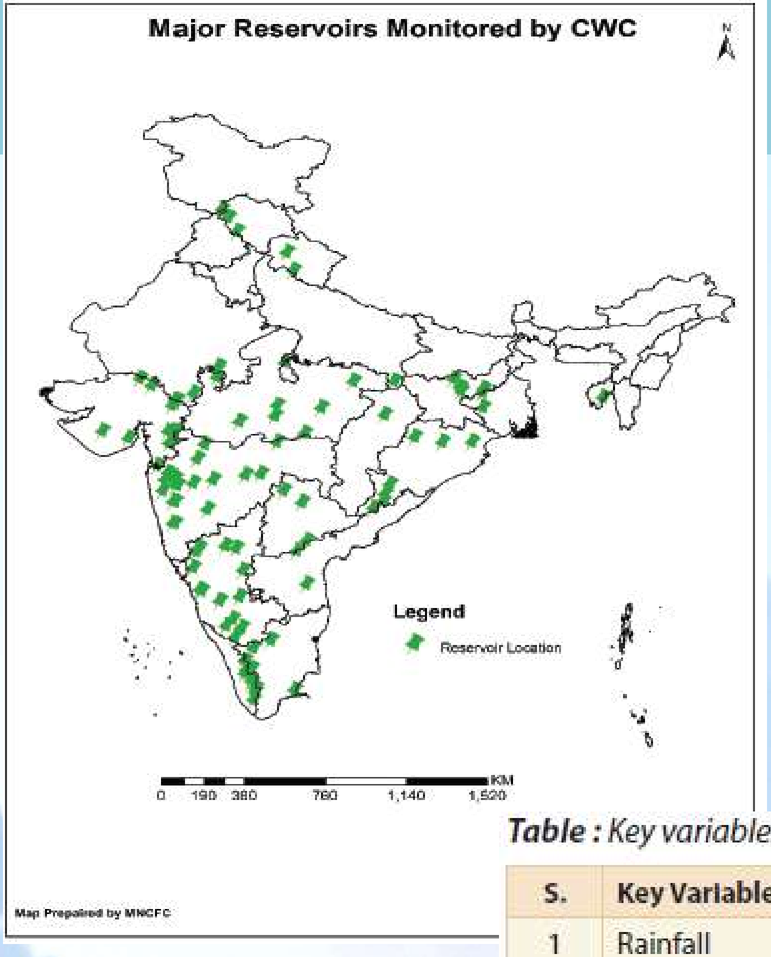


Table : Key variables, indicators and sources of data for drought

S.	Key Variable	Indicator / Index(ices)	Sources of Data
1	Rainfall	Rainfall Deviation / SPI Dry Spell	IMD, State Govt.
2	Crop Sown Area	Deviation from normal	State Govt. (Department of Agriculture)
3	Satellite based crop condition	NDVI, NDWI deviation from normal VCI form of NDVI/NDWI	MNCFC, NRSC, ISRO and State Remote Sensing Centres
4	Stream Flow	SFDI	CWC / India-WRIS
5	Groundwater Levels	GWDI	CGWB
6	Reservoir Level		CWC, Irrigation Department, Water Resources Department

3.2.4 Hydrological Indices

Depletion in stream-flow, reduction in reservoir storages / water spread area and the rate of ground water table depletion can serve as useful indicators of drought. These indices are subject to availability of relevant data from Central Water Commission (CWC), the Central Ground Water Board and State agencies, etc.

3.2.4.1 Reservoir Storage Index (RSI)

The availability of water in reservoirs can act as an effective foil against drought. The reservoir storage status derived from percentage of storage deficit vis-à-vis long term averages can provide an indication of drought (Table 3.6).

Table 3.6: *Category of deficit based on %age deficit in live storage volume of reservoir*

Percentage deficit in live storage volume of reservoir w.r.t. Average Storage of last 10 years	Category of deficit
Less than 20%	Normal deficit
20-30%	Mild deficit
30-40 %	Moderate deficit
40 – 60%	Severe deficit
>60%	Extreme deficit

3.2.4.3 Stream-Flow Drought Index (SFDI)

The amount of water flows in streams and rivers can provide valuable insights on hydrological drought. The flows in streams display high seasonal variability necessitating estimation of variable truncation levels for all twelve months in a year. The truncation level is an analytical interpretation of expected availability of water flow in a river (refer Table 3.8). The truncation level is defined as 75% dependable flow (discharge) at a given time and for a given site over a month long time period. Therefore, average monthly flow records are required to be used to derive flow duration curves for determination of monthly truncation level. Water flow in a river or stream below the truncation level is indicative of a drought like scenario.

The severity of drought event would be classified using a stream flow drought index (SFDI) defined as a function of :

i. the ratio of deficit flow volume to corresponding volume at the truncation levels; and

ii. the ratio of duration of deficit flow to the maximum expected duration of the independent stream flow drought event.

$$SFDI = \frac{V_d}{V_{TL}} x \frac{d_e}{d_m}$$

Where,

V_d = deficit flow volume,

V_{TL} = corresponding flow volume expected at TL flow

d_e = duration of independent drought event, and

d_m = maximum duration of an independent drought event (=365 days).

Table 3.8: *Classification of Drought based on Stream Flow Index*

Stream Flow Drought Index (SFDI)	Drought Severity class
< 0.01	Weak
0.01 to 0.05	Mild
0.05 to 0.2	Moderate
0.2 to 0.5	Severe

3.2.4.2 Groundwater Drought Index (GWDI)

The rate of depletion of groundwater table is useful for making an assessment of groundwater availability for agriculture and drinking water supply purposes.

The monthly groundwater (GW) table records are required for a minimum period of 10 years for computation of mean value of monthly ground water depletion rate. When rate of depletion of groundwater table in a given month/period is more than the corresponding mean value then it is an indication of water deficit. The computation procedure for Ground Water Drought Index (GWDI) is as follows:

$$GWDI_{ij} = \frac{MGWD_j - GWD_{ij}}{GWD_{iMax}}$$

Where,

GWDIij = Groundwater Drought Index for ith month and jth year.

MGWDj = Mean depth to groundwater table below surface (in meter)

GWDij = Depth to groundwater table in ith month and jth year (in meter).

GWDimax = Maximum depth to groundwater table in ith month in available data set for n number of years (in meter).

i = 1, 2, 3, 4, …………, 12.

j = 1, 2, 3, …………., n.

n = total numbers of years for which monthly groundwater records are used.

Table 3.7 : *GWDI and GW Deficit Class*

Groundwater Drought Index (GWDI)	Groundwater deficit class
> -0.15	Normal
-0.16 to -0.30	Mild
-0.31 to -0.45	Moderate
-0.46 to -0.60	Severe
< -0.60	Extreme

New Remote sensing based product started at IMD Pune

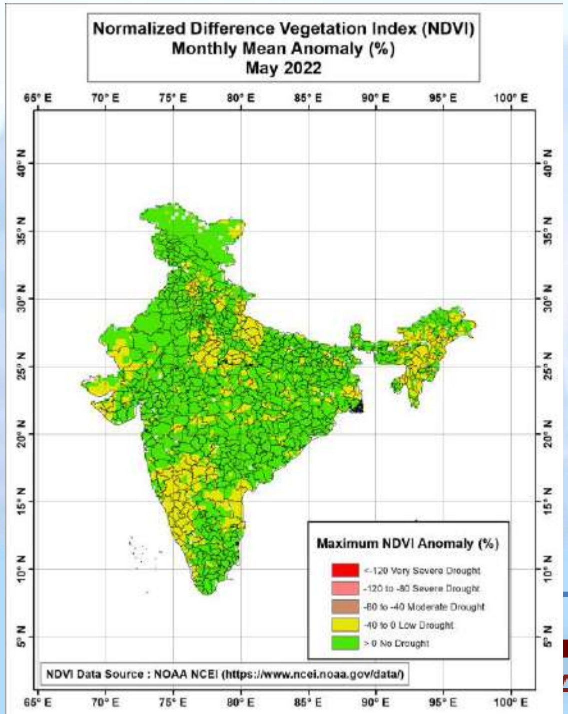
NDVI : "Normalized Difference Vegetation Index (NDVI) quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs)."

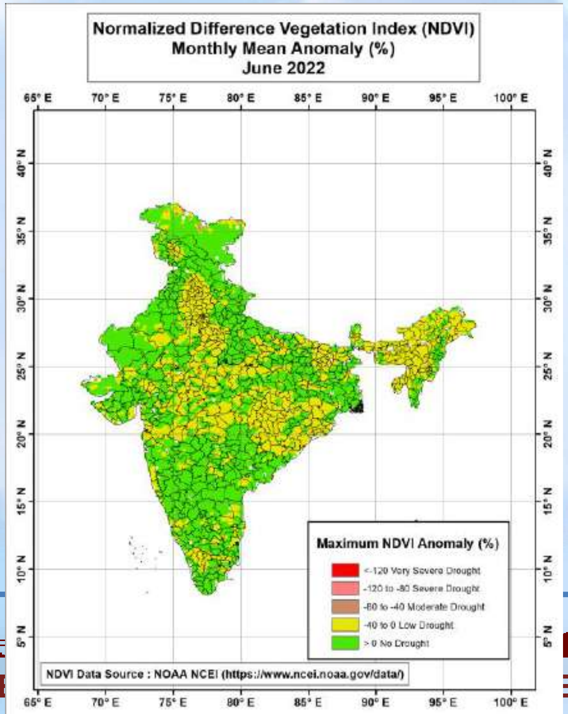
$$NDVI = (NIR-RED)/(NIR+RED)$$

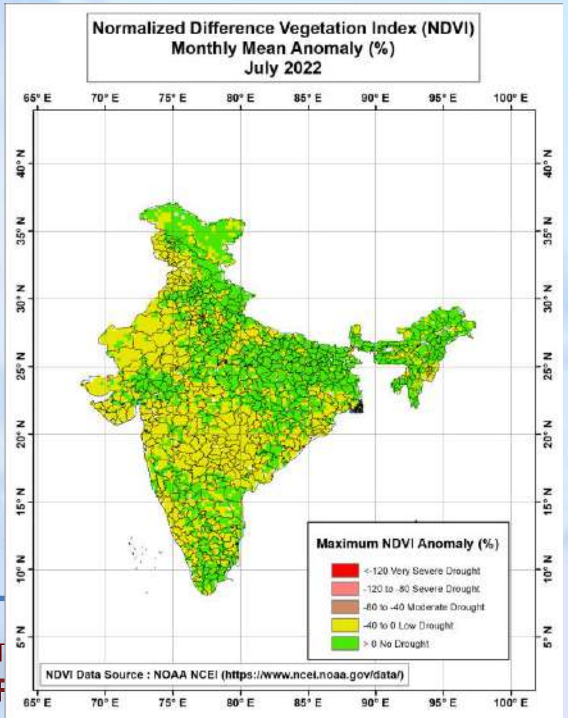
NDVI Anomaly is calculated using the following formula (Das S. et. al. 2013) and further converted into various drought categories. NDVI Anomaly = [(Average NDVI – Climatological Average NDVI)/(Climatological Average NDVI)]*100

Data Period :2014-2022

NDVI Anomaly (%)	Category
< -120	Very Severe Drought
-120 to -80	Severe Drought
-80 to -40	Moderate Drought
-40 to 0	Low Drought
> 0	No Drought







Climate Hazards and Vulnerability Atlas of India and its potential in Disaster Risk Reduction including Health Risk Reduction

Pulak Guhathakurta

Office of Climate Research and Services,

India Meteorological Department, Shivajinagar, Pune

Email: pguhathakurta@rediffmail.com

भारत मौसम विज्ञान विभाग

INDIA METEOROLOGICAL DEPARTMENT

Climate Hazards and Vulnerability Atlas of India

Available @: https://imdpune.gov.in/hazardatlas/index.html

Initiative at India Meteorological Department for mapping Climate Hazards and Vulnerability Atlas of India

- There were long demands to India Meteorological Department, Ministry of Earth Sciences from NDMA, and many other sectors for the Hazard and Vulnerability mapping and assessments of climate events that cause disasters.

- As an impact of climate changes it has been observed with the analysis of long period climate data of India in addition to the significant changes in mean climate patterns there are significant increases in the frequency of severe and extreme weather events.

- The work has been started in the beginning of the year 2020 at Climate Research and Services office, IMD Pune and finally released by the Honourable Minister of State for the Ministry of Science and Technology and Minister of state Ministry of Earth Sciences Dr. Jitendra Singh on 14th January, 2022 on the occasion of IMD 147th Foundation day.

Climate Hazards and Vulnerability Atlas of India

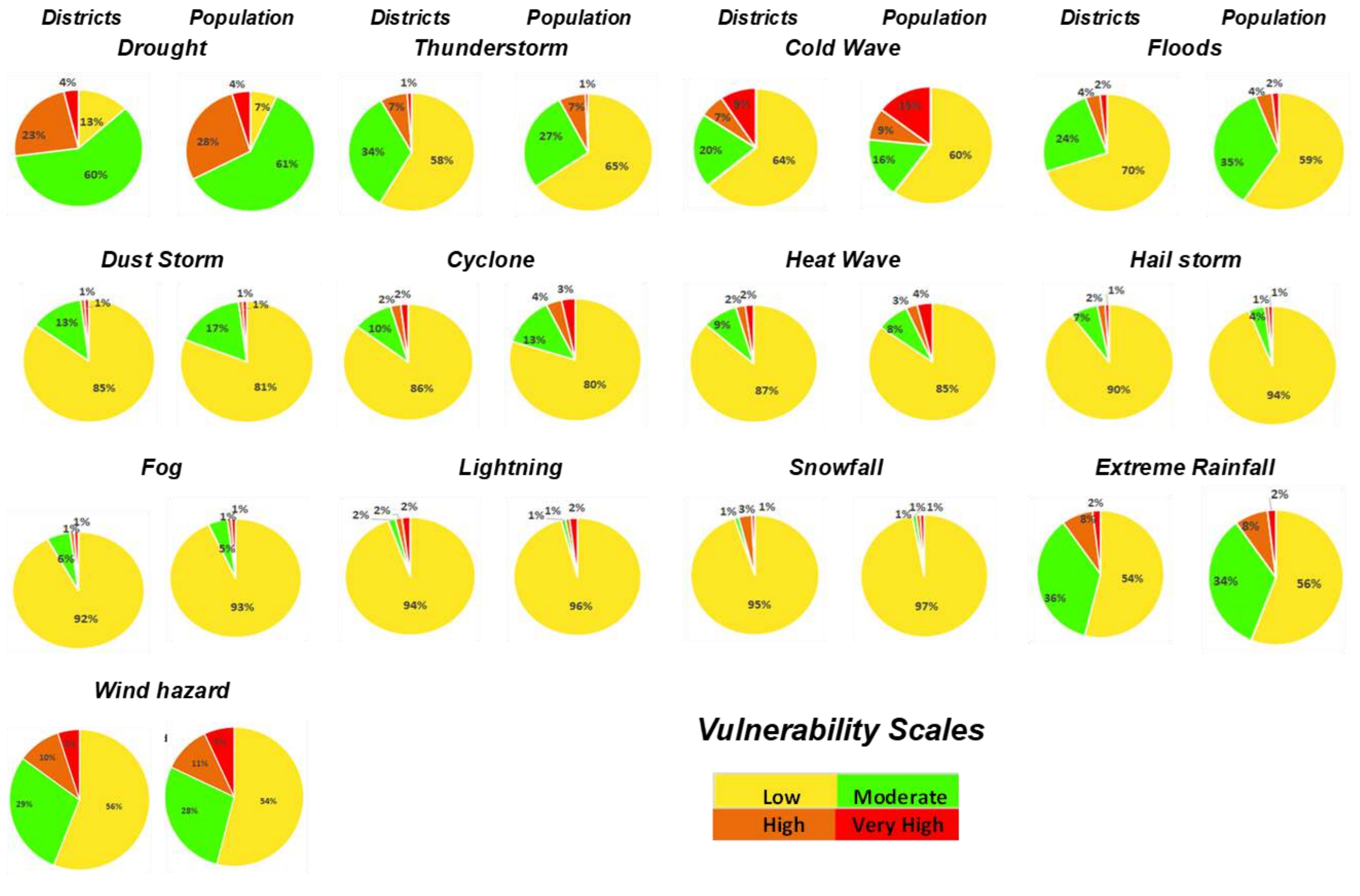
Available @: https://imdpune.gov.in/hazardatlas/index.htr

Climate Hazards and Vulnerability Atlas

- India Meteorological Department (IMD) monitors and provides impact-based early warning services for various meteorological disaster events at different temporal and spatial scales to support disaster risk reduction, mitigation and management.
- As a part of these services, IMD has prepared a Web GIS version of Climate Hazards and Vulnerability Atlas of India for the thirteen most hazardous meteorological events, viz. Cold wave, Heat Wave, Flood, Lightning, Snowfall, Dust Storm, Hail Storm, Thunderstorm, Fog, Strong winds, Extreme rainfall, Drought and Cyclone that cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption or environmental damage.
- The web Atlas is depicted using Geographic Information System (GIS) tools and is made available in IMD, Pune website (https://www.imdpune.gov.in/hazardatlas/index.html). The same is also available in IMD Delhi main website (https://mausam.imd.gov.in/)
- The Atlas provides districts maps on Hazard events and vulnerability for all the calendar months and at annual scale.
- The Hazard maps are prepared based on the climatological data, census data on population and housing density and using different statistical and mathematical methods.
- Climate vulnerability maps are prepared based on the disaster data from the annual publication of India Meteorological Department "Annual Disastrous Weather Reports" for the climate hazardous events that cause casualties in terms of death and other losses.
- Percentage of districts and population affected by disastrous weather events in different categories of vulnerability scales based on the Normalized vulnerability index for these thirteen climate hazards are given below using pie charts and brief description of thirteen hazardous events are also given

Climate Hazards and Vulnerability Atlas : Summary

Percentage of districts and population affected by disastrous weather events in different vulnerability scales



Climate Hazards and Vulnerability Atlas : HIGHLIGHTS

Hazard	% of High To very high vulnerable districts	% of High to very high vulnerable population	High to very high vulnerable state/UT in decreasing order of no. of districts
Drought	27	32	Madhya Pradesh(19), Uttar Pradesh(15), Gujarat(14), Karnataka(14), Maharashtra(12), Rajasthan(12), Bihar(11), Telangana(10), Delhi(9), Odisha(8), Jharkhand(7), Andhra Pradesh(6), Assam(6), Kerala(6), Tamil Nadu(6), Haryana(5), Tripura(5), Arunachal Pradesh(4), Himachal Pradesh(4), Punjab(4), West Bengal(4), Andaman & Nicobar Islands(2), Chhattisgarh(2), Jammu & Kashmir(2), Uttarakhand(2), Goa(1) and Manipur(1)
Thunderstorms	8	8	Assam(12), Jammu and Kashmir(12), Tripura(8), West Bengal(6), Manipur(6), Uttarakhand(4), Arunachal Pradesh(4), Kerala(2), Karnataka(1), Uttar Pradesh(1), Himachal Pradesh(1) and Nagaland(1)
Cold wave	16	24	Uttar Pradesh(75), Rajasthan(17), Bihar(14), Jharkhand(1) and Punjab(1)
Floods	6	6	Assam(23), Kerala(5), Karnataka(2), Maharashtra(2), Andhra Pradesh(1) and Telangana(1)
Dust storm	2	2	Uttar Pradesh(3), Assam(2), Delhi(1) and Uttarakhand(1)
Cyclones	4	7	Tamil Nadu(10), Andhra Pradesh(9), Odisha(6), Puducherry(3), West Bengal(3) and Andaman & Nicobar Islands(1)

भारत की जलवायु विपत्ति और भेद्यता एटलस
जलवायु अनुसंधान एवं सेवाएं
भारत मौसम विज्ञान विभाग, पुणे
पृथ्वी विज्ञान मंत्रालय

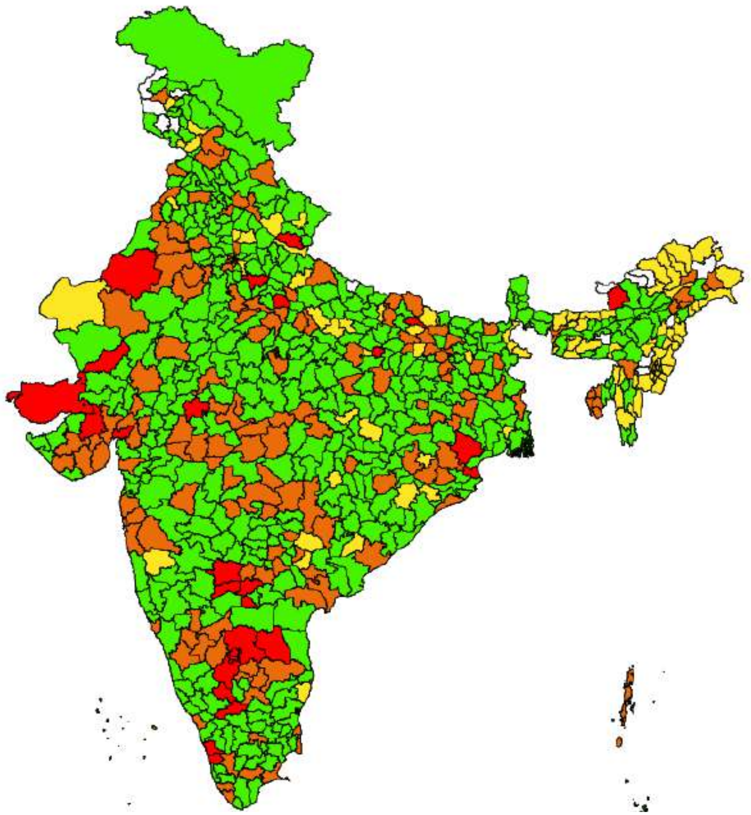
Climate Hazards and Vulnerability Atlas of India
Office of Climate Research and Services
India Meteorological Department, Pune
Ministry of Earth Sciences

Home | Climate Hazard | Climate Vulnerability

Wind Hazard | Extreme rainfall | Lightning | Dust Storm | HailStorm | Fog | Drought | Cyclone | Thunderstorm

- Moderately Drought
- Severely Drought
- Extremely Drought
- ALL Category of Drought

All Categories (Moderate, Severe and Extreme) Drought Normalized Vulnerability Index
(Based on Standardized Precipitation Index)



Normalized Vulnerability Index
Nil (0)
Low (> 0 and <= 0.25)
Moderate (> 0.25 and <= 0.50)
High (> 0.50 and <= 0.75)
Very High (> 0.75 and < = 1)
India District

Thanks