Monitoring Agricultural Drought: An Indian perspective

Jayanta Sarkar

India Meteorological Department

Pune-411005

India

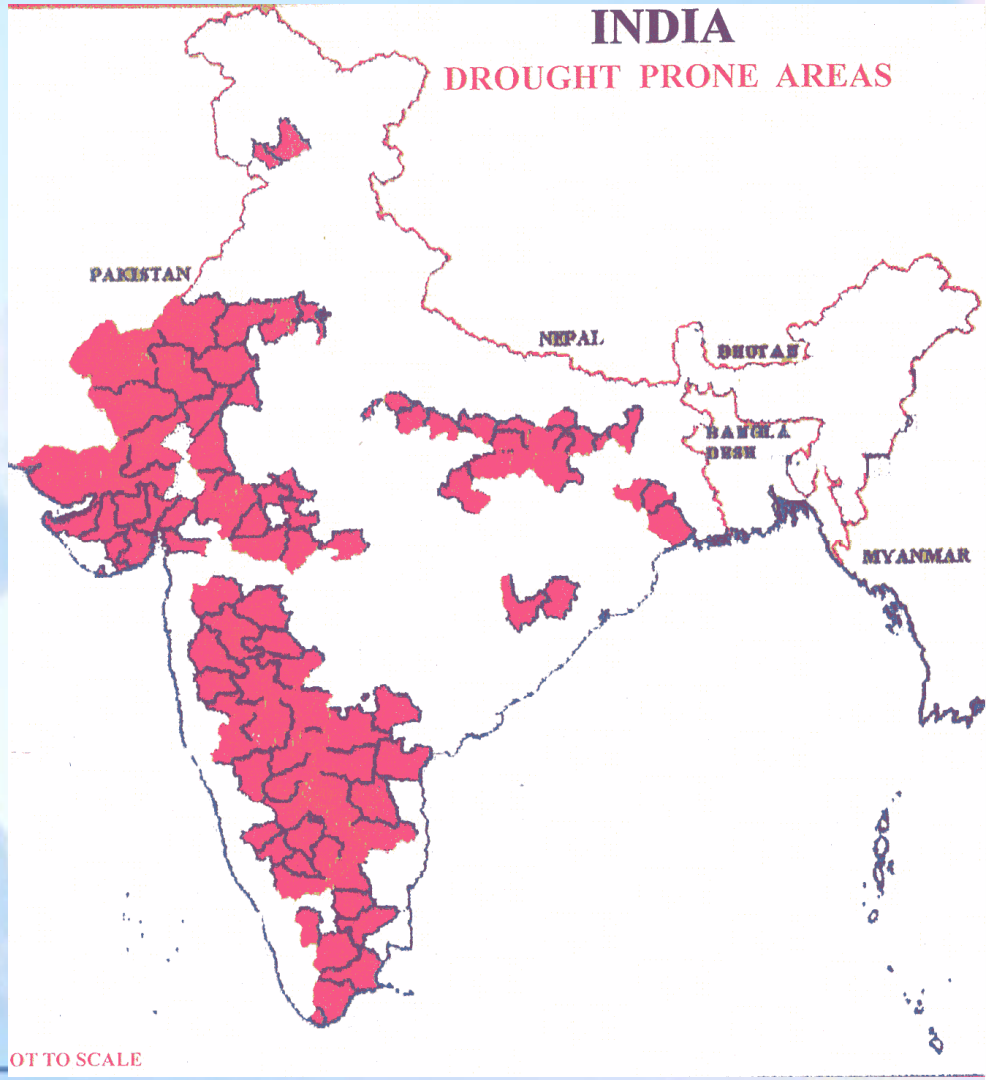
India – a land with a unique climatic regime

- Two monsoon seasons (southwest & northeast monsoons)
- Two cyclone seasons (pre & post monsoon cyclone seasons)
- Hot weather season characterized by severe thunderstorms, heat waves
- Cold weather season characterized by violent snow storms in the Himalayan regions and cold waves

  – 8% of the total area is prone to cyclones
  – 40 million hectares prone to floods
  – 68% of the area is susceptible to drought
  – 60% of the landmass prone to earthquakes of various intensities

Drought prone areas

STATE	NO OF DROUGHT PRONE DISTRICTS	% AREA OF THE STATE CONSIDERED DROUGHT PRONE
GUJARAT	19	79
MAHARASHTRA	13	40
RAJASTHAN	13	63
MADHYA PRADESH	11	25
HARYANA	04	33
UTTAR PRADESH	05	20
BIHAR	07	22
ORISSA	02	14
WEST BENGAL	03	31
ANDRA PRADESH	08	43
KARNATAKA	10	55
TAMILNADU	08	45

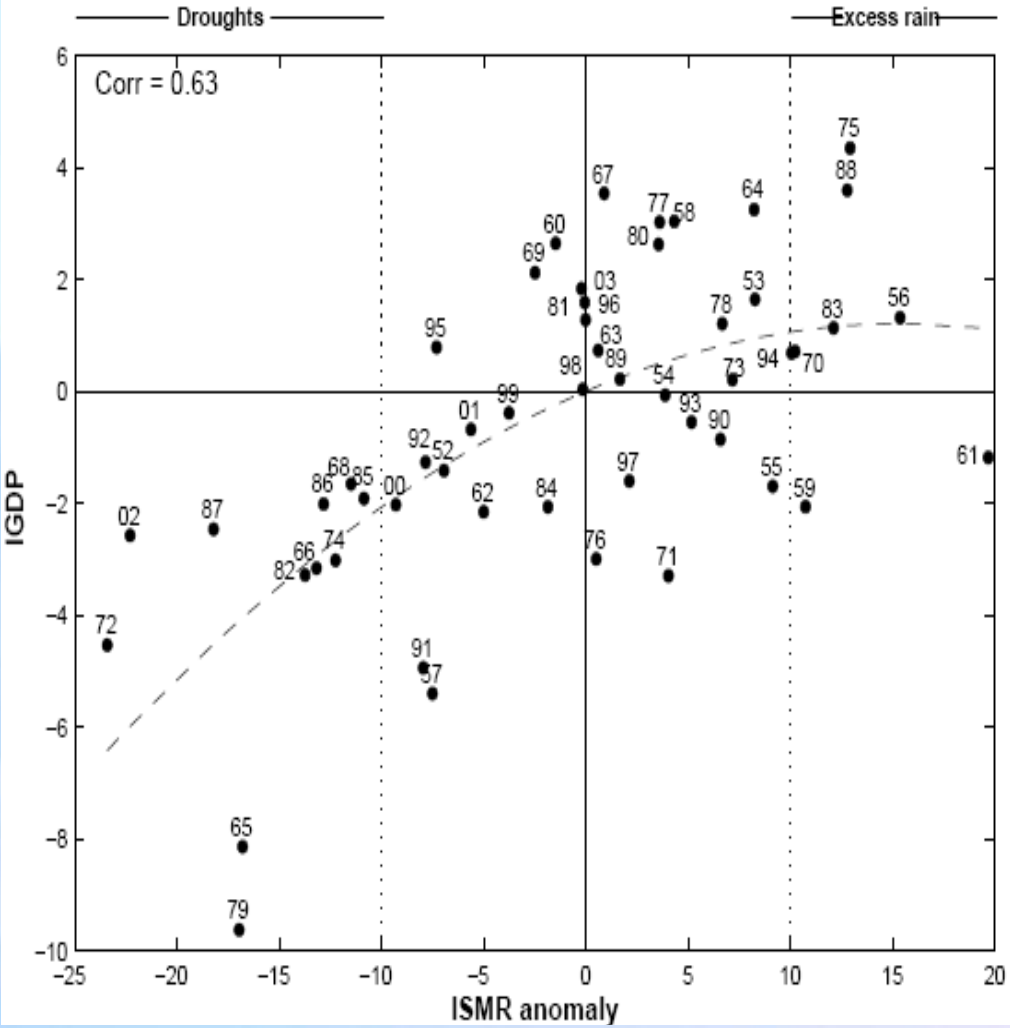


GDP and Indian Monsoon Rainfall

Impact of a severe drought on GDP remains 2 to 5% throughout, despite the substantial decrease in the contribution of agriculture to GDP over the five decades.

Gadgil and Gadgil (2006) Economic and Political Weekly, Vol XLI no 47 Nov 25-Dec1, p 4887-4895.

Two-thirds of the workforce is in agriculture



DROUGHT RESEARCH UNIT

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, Drought Research Unit started functioning at Pune in 1967 in the office of the Additional Director General of Meteorology (Research)

Drought Research Unit started conducting studies on different aspects of Drought. The **salient activities of this Unit are as under:-**

- **Defining meteorological Drought and it's intensity.**
- **Delineation and identification of - Drought Prone areas of the country**
- **Study of past droughts and**
- **Monitoring Agricultural drought conditions during Southwest and Northeast monsoons and**
- **Issuing Crop Yield Forecasts for kharif rice and wheat crops based on statistical models**

DROUGHT RESEARCH UNIT (CONTD.)

- **DRU of India Meteorological Department (IMD) defines Meteorological Drought based on rainfall deficiency (SW monsoon, June-September) on sub-divisionwise basis.**
- **The meteorological Droughts are classified into**

(a) moderate and (b) severe based on rainfall deficiency, i.e. 26 to 50% and more than 50% respectively.

DROUGHT MONITORING BY IMD

- **DRU has been deleneating sub-divisionwise drought since 1875.**

  In our country, a year is considered to be a DROUGHT YEAR in case the area affected by moderate and severe drought, either individually or together, is 20-40% of the total area of the country and seasonal rainfall deficiency during south-west monsoon season for the country as a whole is at least 10% or more.

- **When the spatial coverage of drought is more than 40% it will be called as ALL INDIA SEVERE DROUGHT YEAR.**

(Ref.: IMD Technical Circular No. 2/2007)

- **The droughts over a period of 135 years (1875-2009) have been identified and classified so far.**

- **The drought prone areas, have been identified and probabilities of severe drought occurrences are also computed sub-divisionwise over the country.**

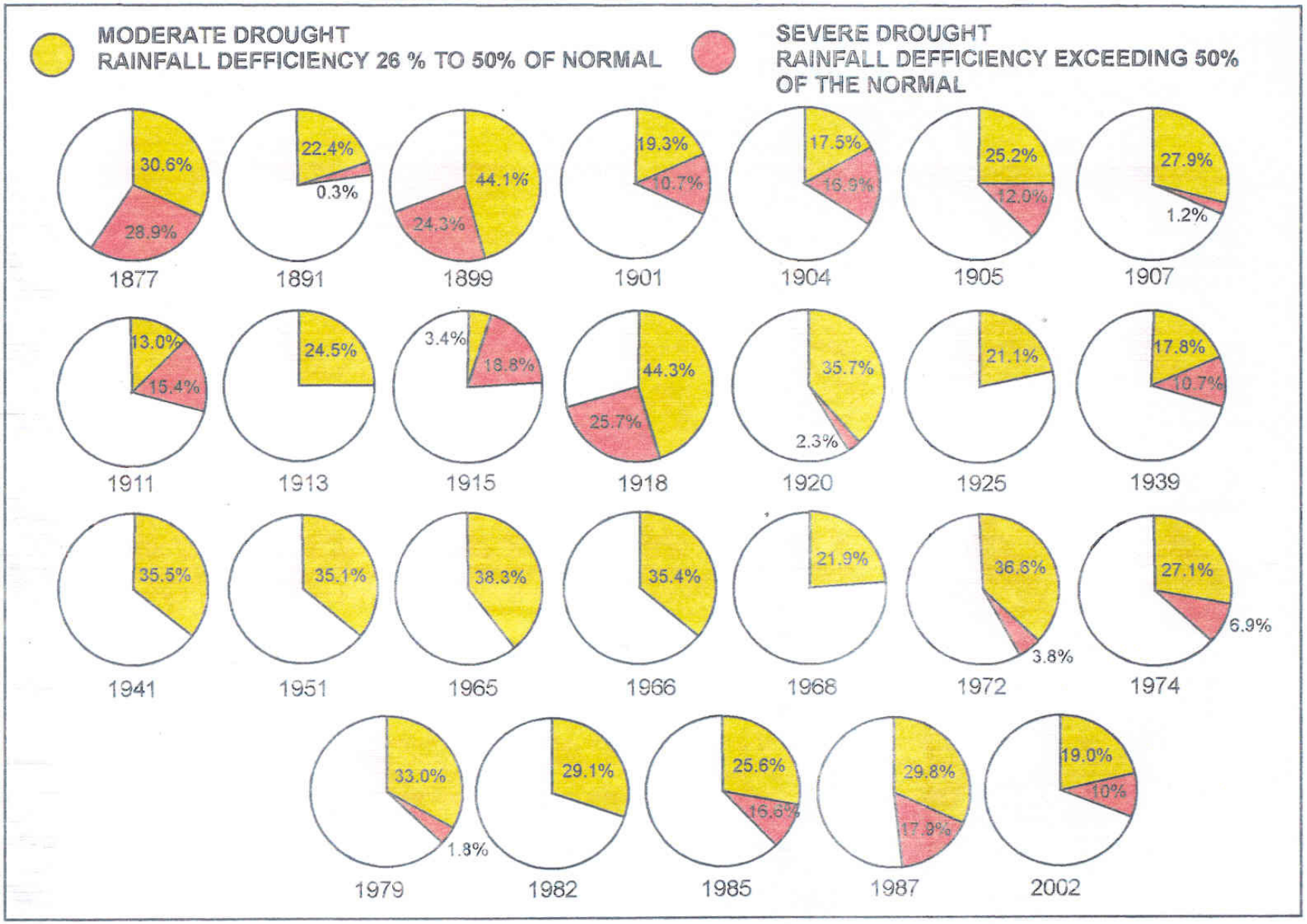
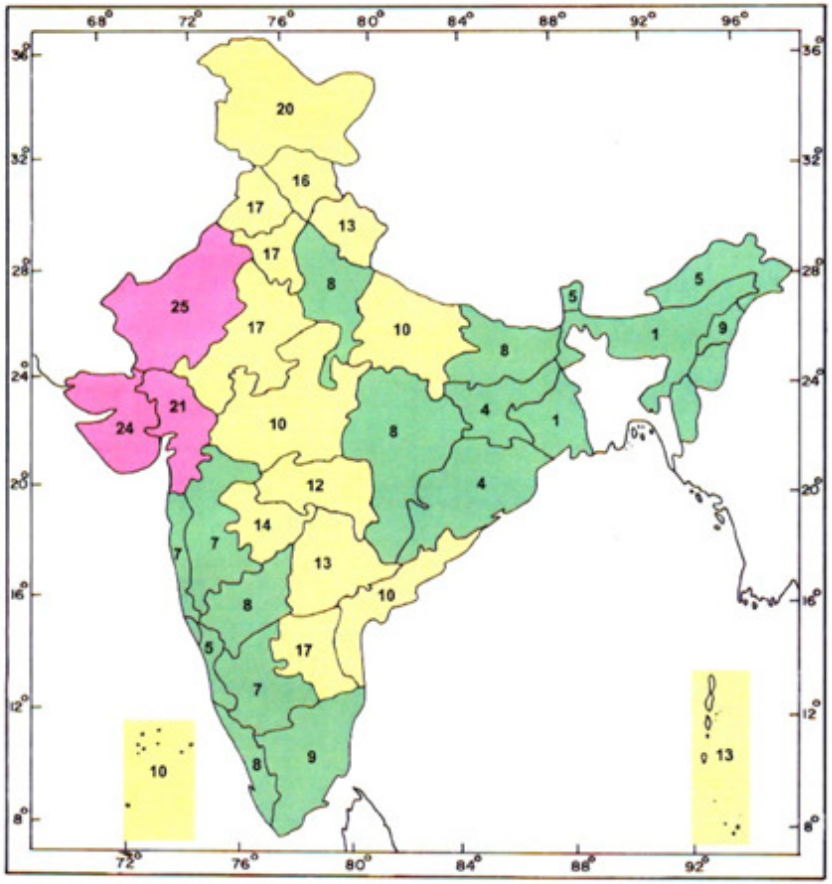


Fig. 3 : Drought years in India with percentage of the area affected since 1875 based on June - September rainfall

Sub-divisionwise frequencies of moderate & severe Drought during 1875-2008 and Drought probabilities

Sl.No.	Name of Sub-division	Moderate	Severe	Total	Drought
					Prob. Total(%)
1	Andaman & Nicobar Islands	17	0	17	13
2	Arunachal Pradsh	7	1	8	6
3	Assam & Meghalaya	4	0	4	1
4	Nagaland, Manipur, Mizoram &	12	0	12	9
5	Sub-Himalayan West Bengal	7	0	7	5
6	Gangetic West Bengal	2	0	2	1
7	Orissa	5	0	5	4
8	Bihar	11	0	11	8
9	Jharkhand	6	0	6	4
10	East Uttar Pradesh	12	1	13	10
11	West Uttar Pradesh	12	1	13	10
12	Uttarakhand	15	2	17	13
13	Haryana, Delhi & Chandigarh	20	4	24	18
14	Punjab	19	4	23	17
15	Himachal Pradesh	19	3	22	16
16	Jammu & Kashmir	20	6	26	20
17	West Rajasthan	21	12	33	25
18	East Rajasthan	17	5	22	17
19	West Madhya Pradesh	13	0	13	10
20	East Madhya Pradesh (including Chattisgarh)	11	0	11	8
21	Gujarat Region	16	11	27	21
22	Saurashtra & Kutch	16	15	31	24
23	Konkan & Goa	9	0	9	7
24	Madhya Maharashtra	7	2	9	7
25	Marathwada	17	1	18	14
26	Vidarbha	15	1	16	12
27	Coastal Andhra Pradesh	13	0	13	10
28	Telangana	17	0	17	13
29	Rayalaseema	20	2	22	17
30	Tamil Nadu & Pondicherry	12	0	12	9
31	Coastal Karnataka	5	0	5	5
32	North Interior Karnataka	10	0	10	8
33	South Interior Karnataka	9	0	9	7
34	Kerala	10	0	10	8
35	Lakshdweep	10	3	13	10

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



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

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

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

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

AGRICULTURAL DROUGHT

It occurs when available *soil moisture* is inadequate for healthy crop growth and cause extreme stress and wilting.

AGRICULTURAL DROUGHT CATEGORIES

- **Early season drought**
- **Mid season drought**
- **Late season drought**
- **Permanent drought**
- **Apparent drought**

❖MONITORING AGRICULTURAL DROUGHT

Aridity anomaly index

AI = (PE- AE)/PE* 100

(210 stations)

where, AI = weekly/fortnightly aridity index

AE = Actual evapo-transpiration (thornthwaite,PE, ACTUAL RF, FC)

PE = Potential evapo-transpiration (penman,TM, SOL RAD.,R.H., WIND SPEED)

For the sake of computing anomaly, long term weekly/fortnightly values of aridity index are computed. The difference between **actual AI** in any week/fortnight of the crop season and the **normal AI** expressed as a percentage called aridity anomaly which represents water stress condition. Based on the **AI** the **incidence**, **spread**, **intensification** and **cessation** of different drought intensities on weekly/fortnightly basis is monitored. Following criteria are used in defining various agricultural drought intensities :

Weekly/fortnightly Anomaly of AI	***Associated Drought Intensity***
1 - 25	Mild
26 - 50	Moderate
>50	Severe

THORNTHWAITE'S WATER BALANCE TECHNIQUE

- WATER BALANCE REFERS TO THE BALANCE BETN. WATER INCOME(PPTN.) AND LOSS OF WATER BY EVAPOTRANSPIRATION CAUSING CHANGE IN SOIL MOISTURE AND RUNOFF.
- IT'S A CLI. WATER BALANCE OBTAINED BY COMPARING MARCH OF PPTN. WITH EVAPOTRANSPIRATION (ET), YIELDING A NO. OF MOISTURE PARAMETERS WS, WD, SOIL MOISTURE CHANGE AND RO.

- BASIC EQUN.

  P= ET+CHANGE IN 'S' +RO

THORNTHWAITE'S WATER BALANCE TECHNIQUE

- AN IMP. FEATURE OF WATER BALANCE CONCEPT:TO RECOGNISE THAT SOIL PLAYS AN IMP. ROLE IN THE EXCHANGE OF MOISTURE BETN. THE EARTH'S SURFACE AND THE ATM.
- SOIL ACTS AS A MEDIUM FOR STORING WATER (UPTO A LIMIT) DURING EXCESSIVE RF AND RELEASING THE SAME (IN A RESTRICTED MANNER) AT OTHER TIMES FOR EVAP. AND TRANSPIRATION.
- FOR WATER BALANCE COMPUTATION 3 PARAMETERS REQD.: ET (WATER NEED), P (WATER SUPPLY), AWC (AV. WATER CAPACITY,FC)

THORNTHWAITE'S WATER BALANCE TECHNIQUE

- DURING THE PERIODS OF EXCESSIVE 'RF' THE BALANCE OF WATER, AFTER MEETING CROP DEMAND RECHARGES THE SOIL TILL 'FC' IS ATTAINED. ANY FURTHER ADDITION MEANS 'RO'.
- 'AWC' OF A PLACE DEPENDS ON THE TYPE OF SOIL AND THE ROOT ZONE DEPTH OF THE CROP.
- DURING DEFICIENT 'RF' 'SM' IS USED FOR 'ET' PURPOSES. AS SOIL DRIES , ET RATE DECREASES. ACC. TO THORNTHWAITE, THE RELEASE OF MOSTURE FROM SOIL FOLLOWS THE FOLLOWING EQUN.:

  S=FC.exp –APME/FC

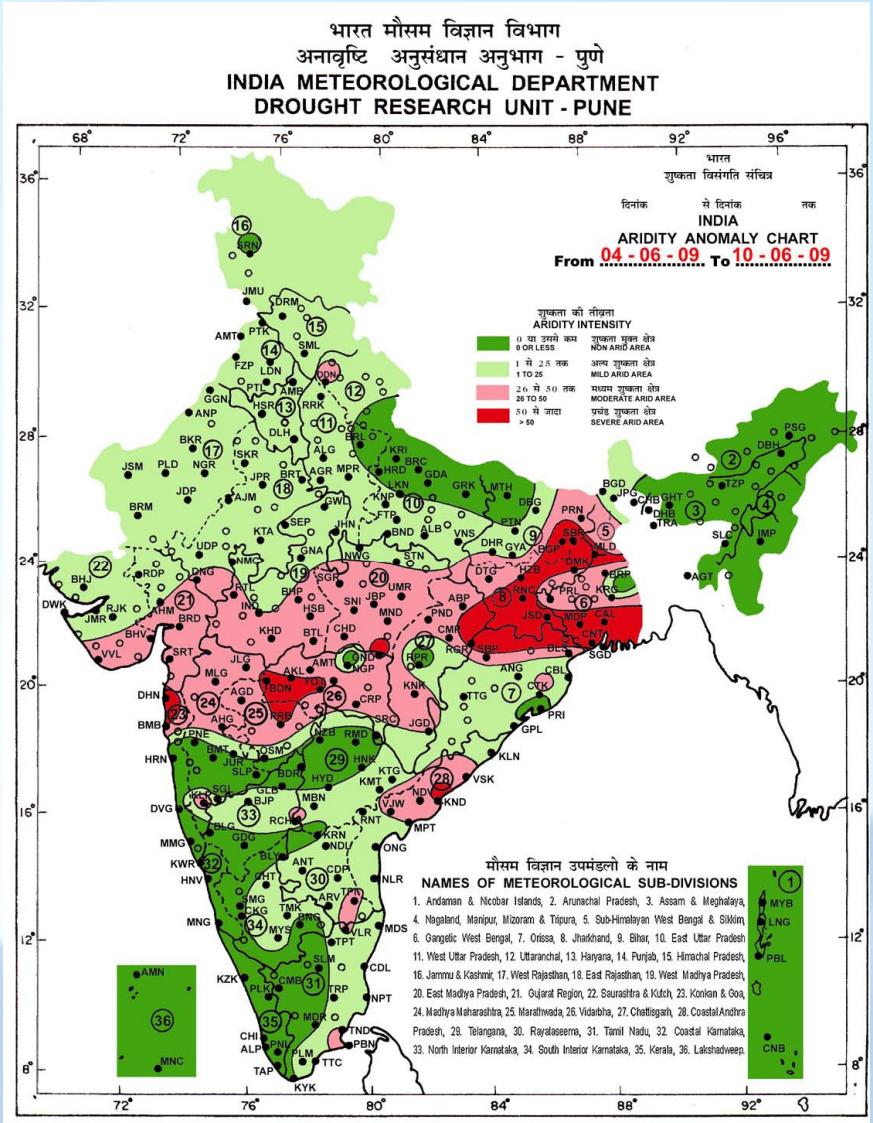
  S= Moisture remaining in the soil as storage

	J	F	M	A	M	J	JY	A	S	O	N	D
PE	75.1	94.5	153.1	180.7	224.4	129.4	116.4	110.4	107.0	112.0	88.2	69.7
P	13.2	21.8	29.6	49.8	134.6	263.2	320.1	318.1	252.7	134.2	29.2	3.6
P-PE	-61.9	-72.7	-123.5	-130.9	-89.8	133.8	203.7	207.7	145.7	22.2	-59.0	-66.1
Acc. –VE(P-PE)	-187.0	-259.7	-383.2	-514.1	-603.9						-59.0	-125.1
S	78.5	54.5	29.4	15.2	9.7	143.5	200.0	200.0	200.0	200.0	148.9	106.9
S*	-28.4	-24.0	-25.1	-14.2	-5.5	133.8	56.5	0.0	0.0	0.0	-51.1	-42.0
AE	41.6	45.8	54.7	64.0	140.1	129.4	116.4	110.4	107.0	112.0	80.3	45.6
WD	33.5	48.7	98.4	116.7	84.3	0.0	0.0	0.0	0.0	0.0	7.9	24.1
WS	0.0	0.0	0.0	0.0	0.0	0.0	147.2	207.7	145.7	22.2	0.0	0.0
RO	10.3	5.1	2.5	1.2	0.6	0.3	73.7	140.7	143.2	82.7	41.3	20.6

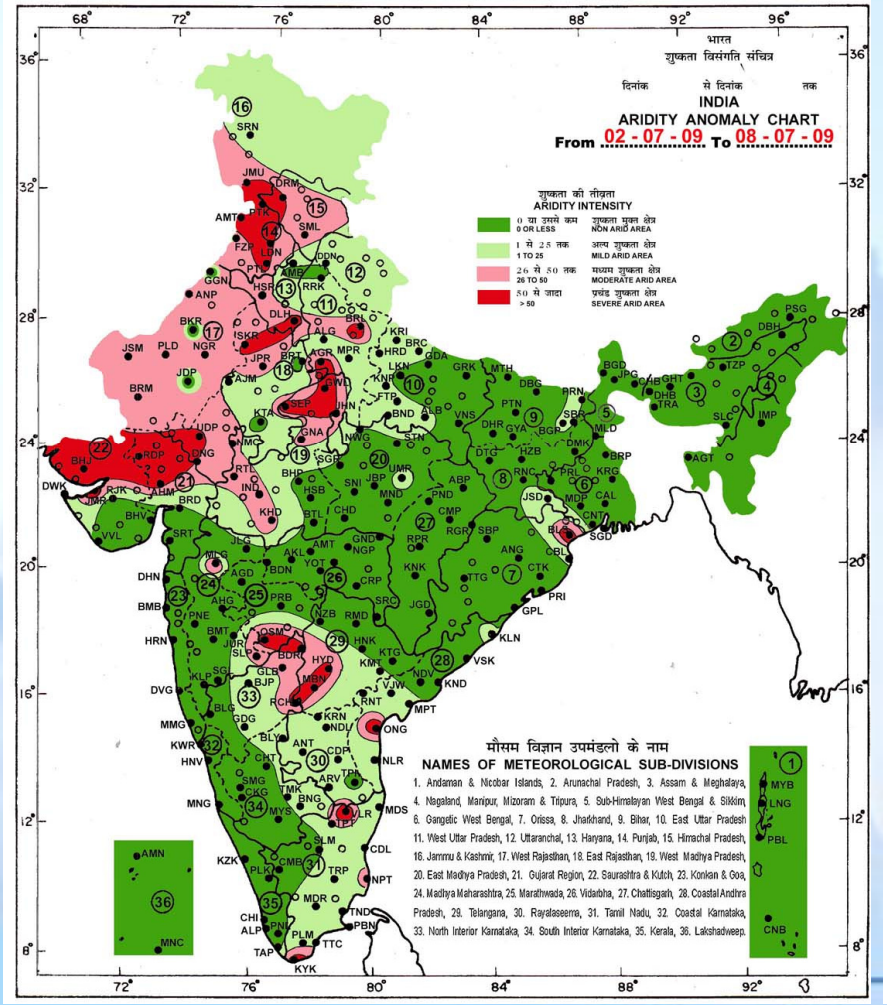
LEGENDS

- Acc. P-PE = ACCUMULATED POTENTIAL WATER LOSS (SUM OF –VE VALUES OF (P-PE))
- S= STORAGE
- S*= CHANGE IN STORAGE
- WD= PE-AE
- WS= P-PE
- RO= (‘WS’ of that month+’RO’ of the prev. month)/2

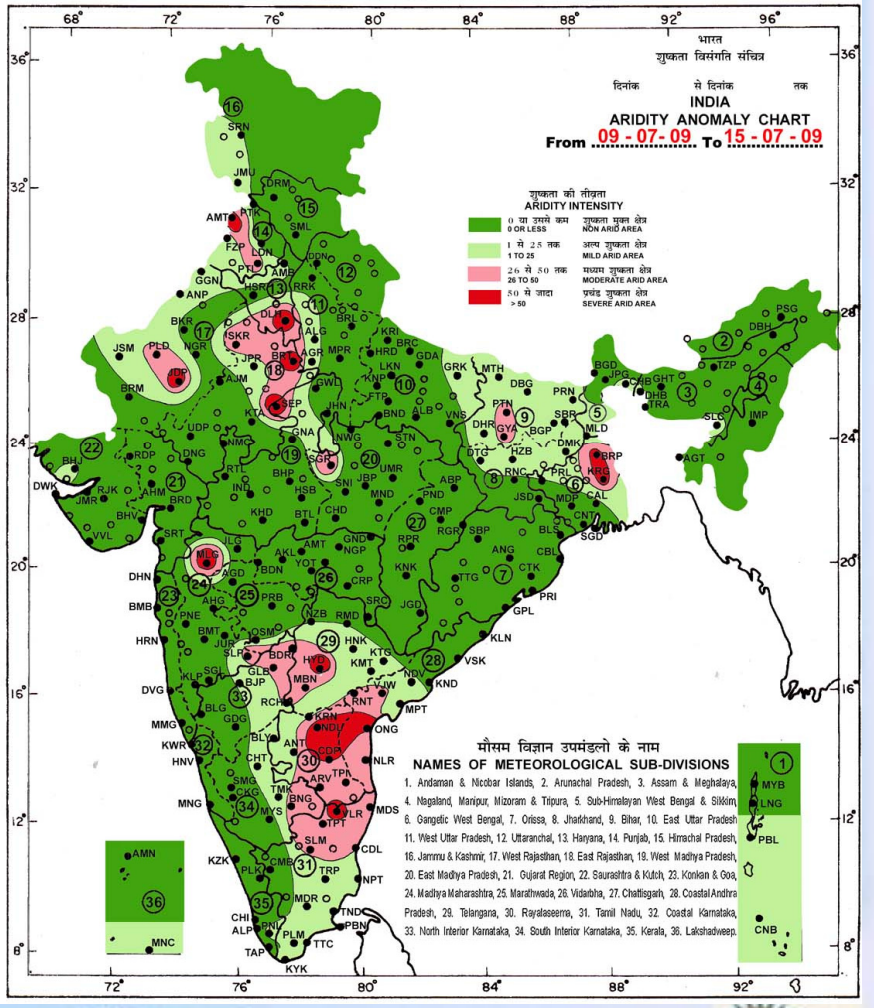
DROUGHT MONITORING Monsoon 2009



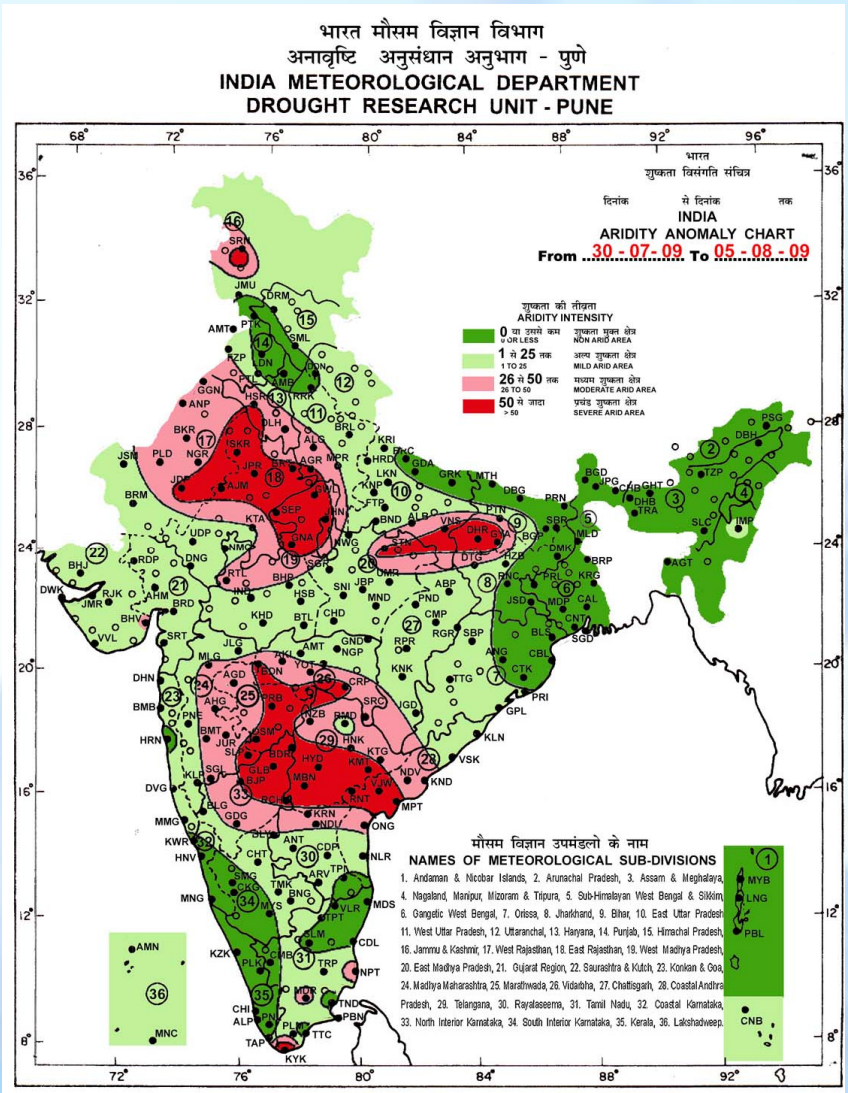
भारत मौसम विज्ञान विभाग
अनावृष्टि अनुसंधान अनुभाग - पुणे
INDIA METEOROLOGICAL DEPARTMENT
DROUGHT RESEARCH UNIT - PUNE



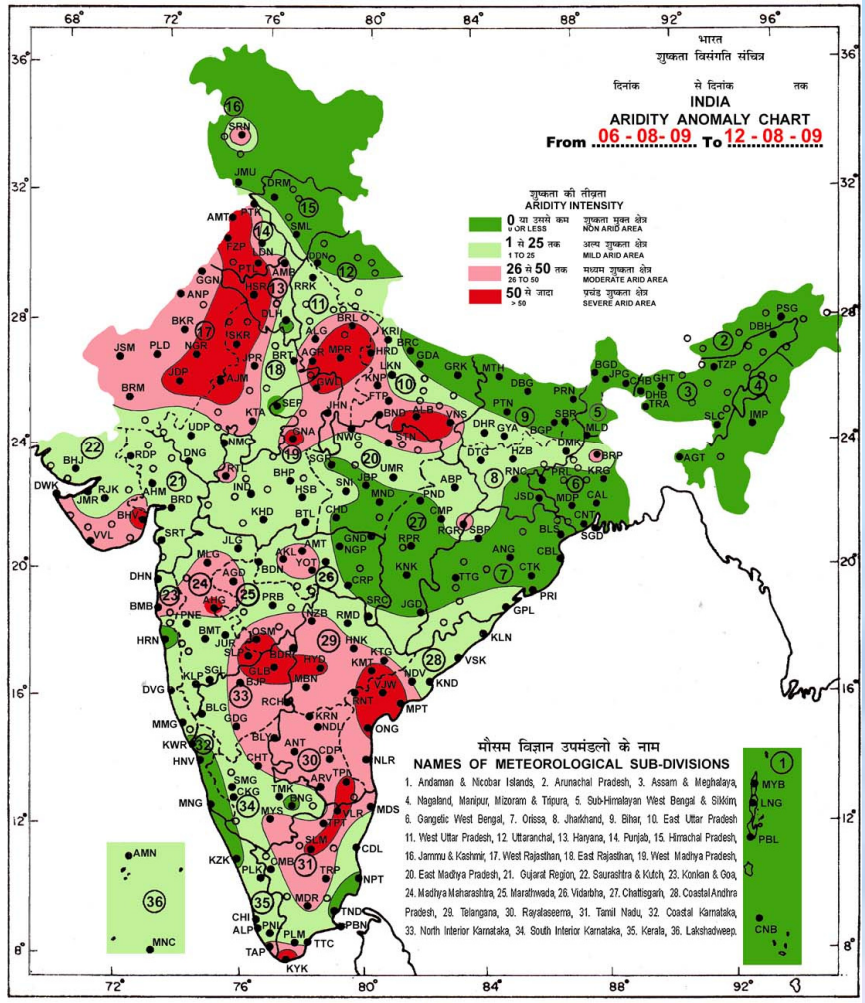
भारत मौसम विज्ञान विभाग
अनावृष्टि अनुसंधान अनुभाग - पुणे
INDIA METEOROLOGICAL DEPARTMENT
DROUGHT RESEARCH UNIT - PUNE



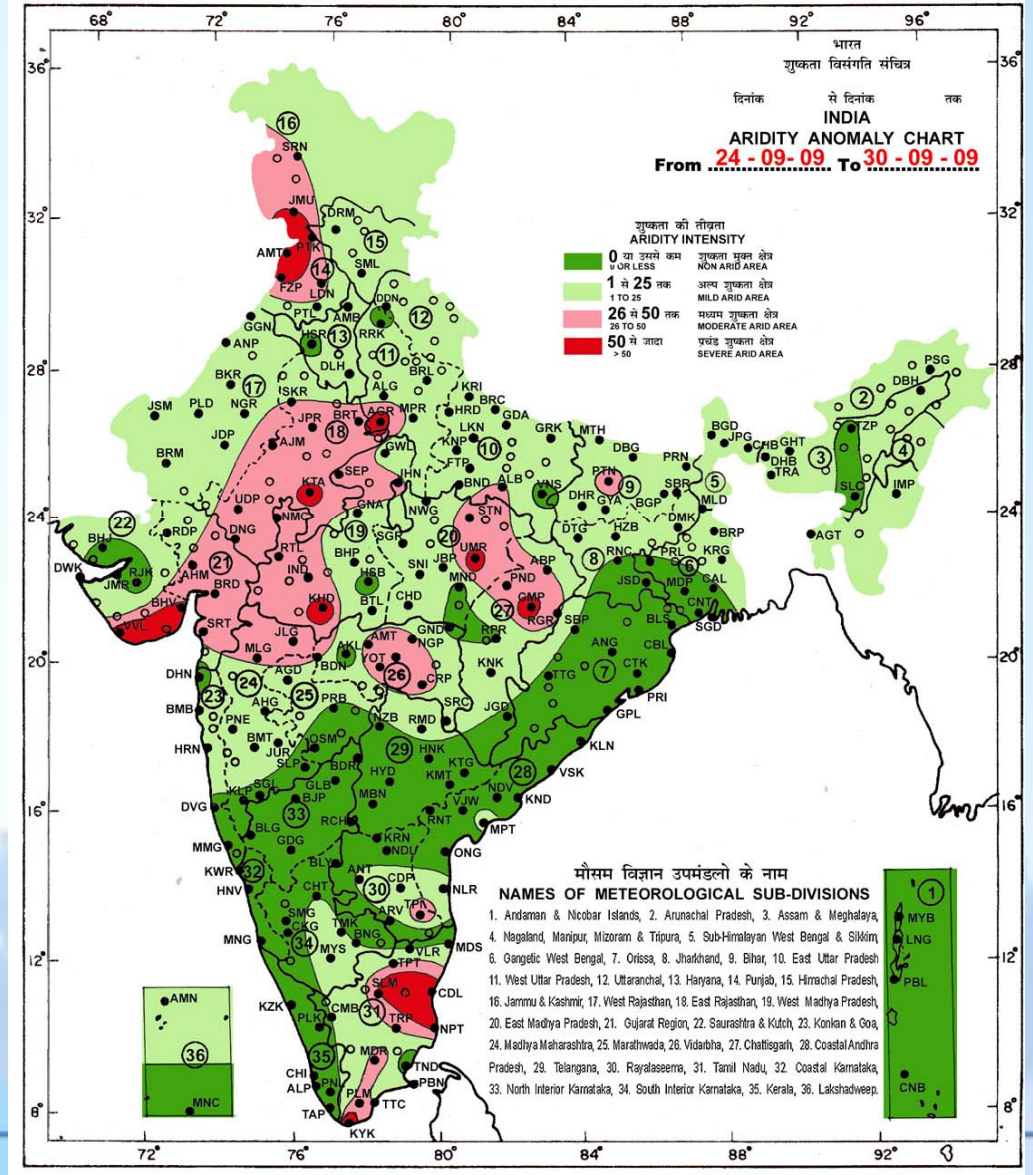
भारत मौसम विज्ञान विभाग
अनावृष्टि अनुसंधान अनुभाग - पुणे
INDIA METEOROLOGICAL DEPARTMENT
DROUGHT RESEARCH UNIT - PUNE



भारत मौसम विज्ञान विभाग
अनावृष्टि अनुसंधान अनुभाग - पुणे
INDIA METEOROLOGICAL DEPARTMENT
DROUGHT RESEARCH UNIT - PUNE



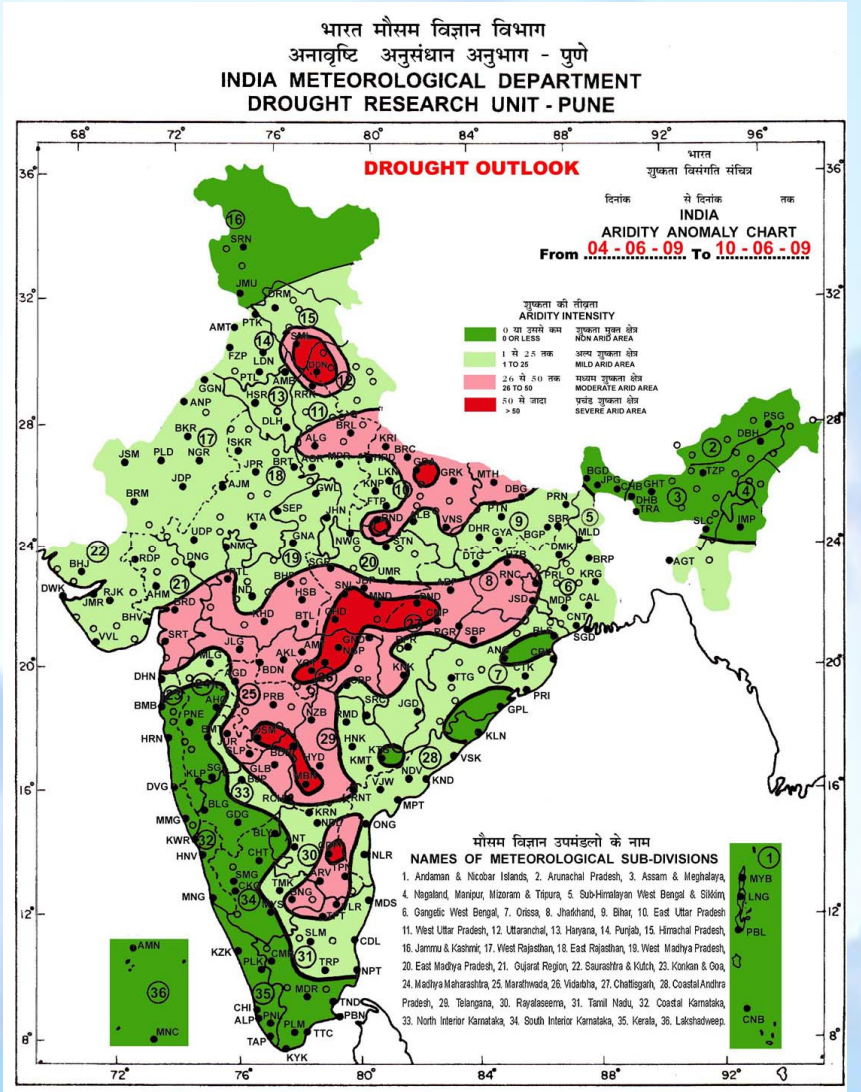
भारत मौसम विज्ञान विभाग
अनावृष्टि अनुसंधान अनुभाग - पुणे
INDIA METEOROLOGICAL DEPARTMENT
DROUGHT RESEARCH UNIT - PUNE



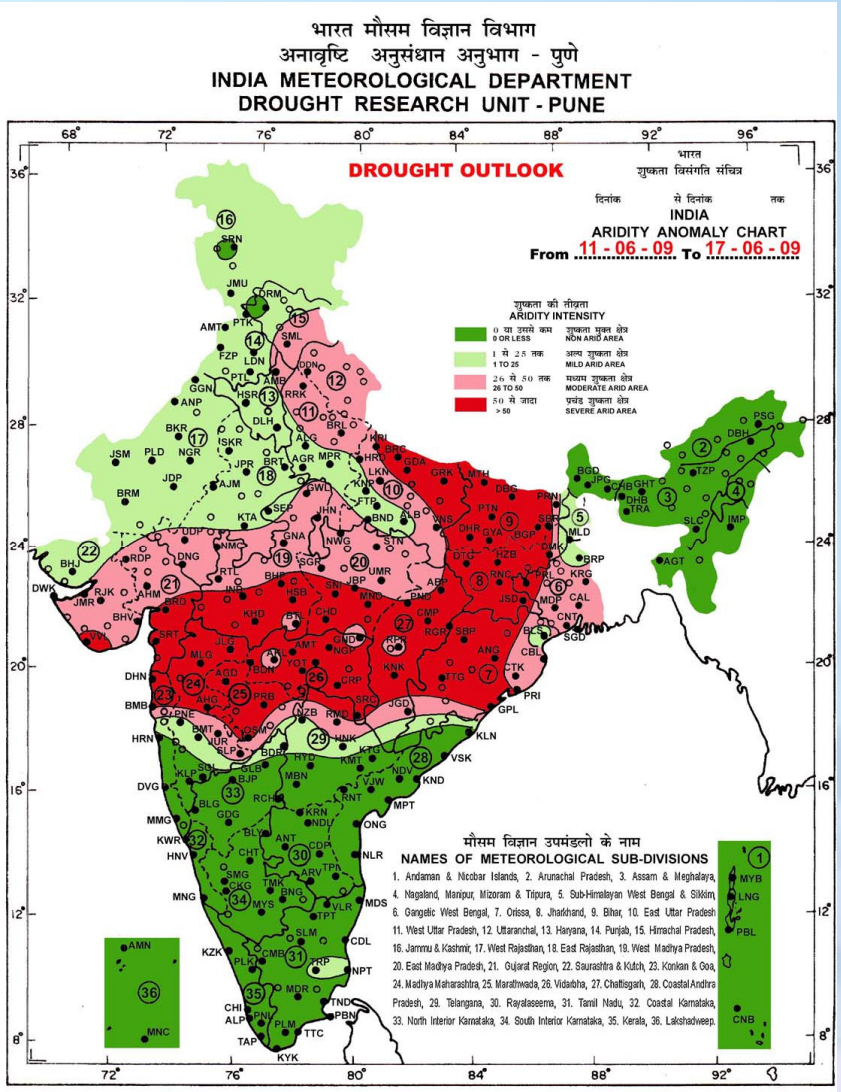
Operational Drought Outlook

- Using operational medium range forecast of monsoon rainfall, alongwith the prevailing aridity anomaly condition, IMD generated weekly drought outlook during Monsoon 2009 on experimental basis.

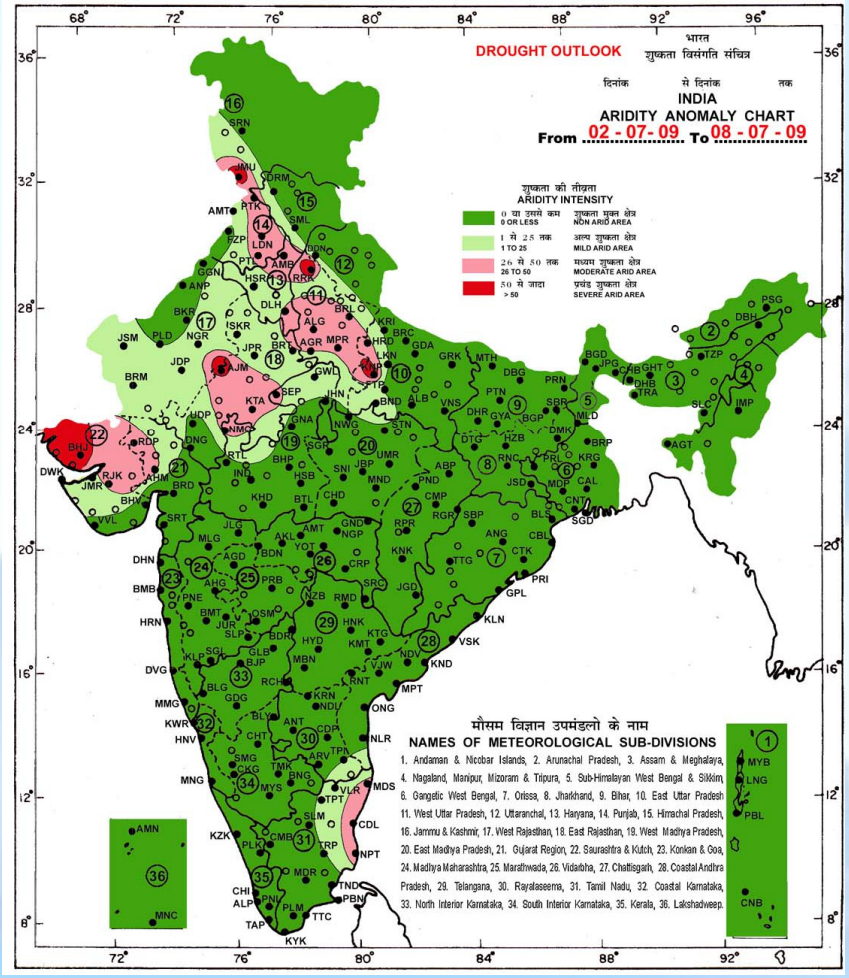
भारत मौसम विज्ञान विभाग
अनावृष्टि अनुसंधान अनुभाग - पुणे
INDIA METEOROLOGICAL DEPARTMENT
DROUGHT RESEARCH UNIT - PUNE



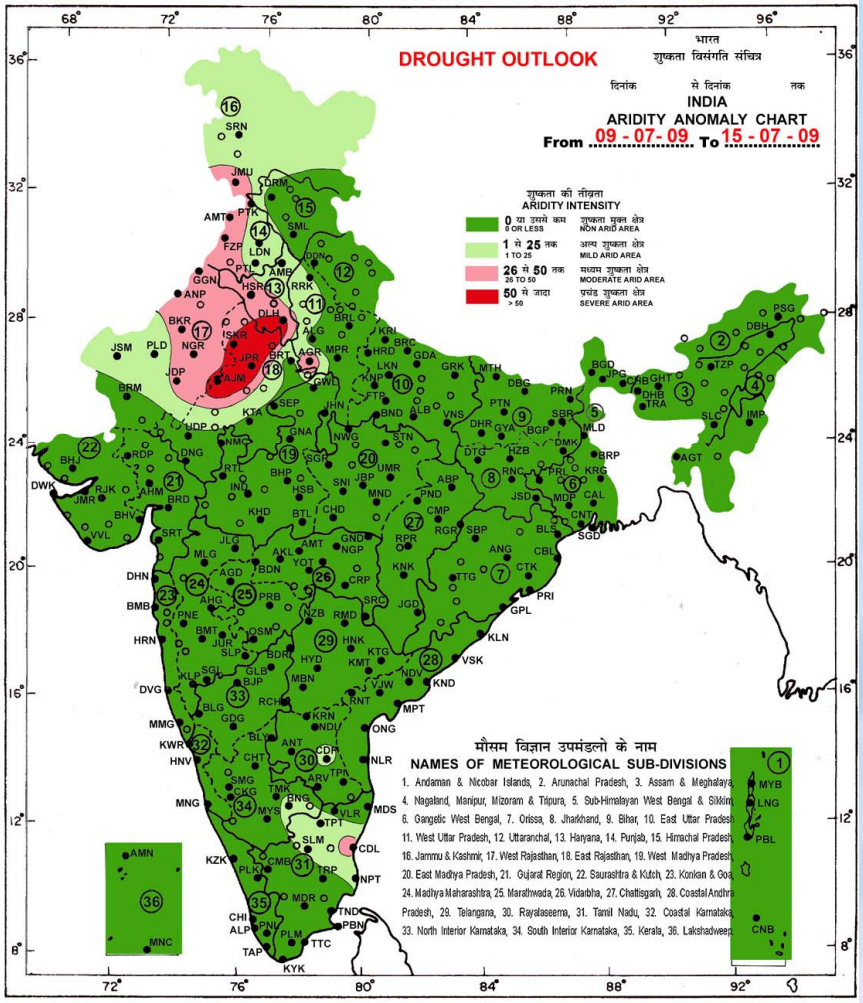
भारत मौसम विज्ञान विभाग
अनावृष्टि अनुसंधान अनुभाग - पुणे
INDIA METEOROLOGICAL DEPARTMENT
DROUGHT RESEARCH UNIT - PUNE



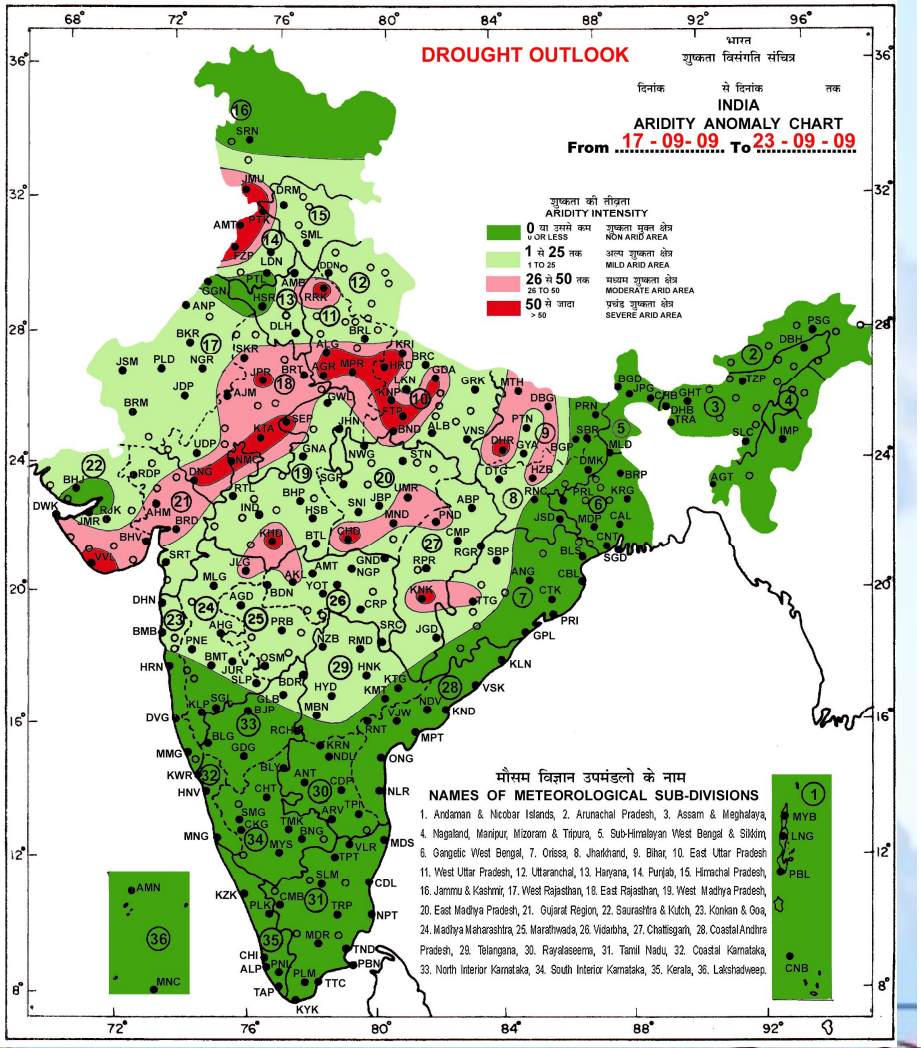
भारत मौसम विज्ञान विभाग
अनावृष्टि अनुसंधान अनुभाग - पुणे
INDIA METEOROLOGICAL DEPARTMENT
DROUGHT RESEARCH UNIT - PUNE



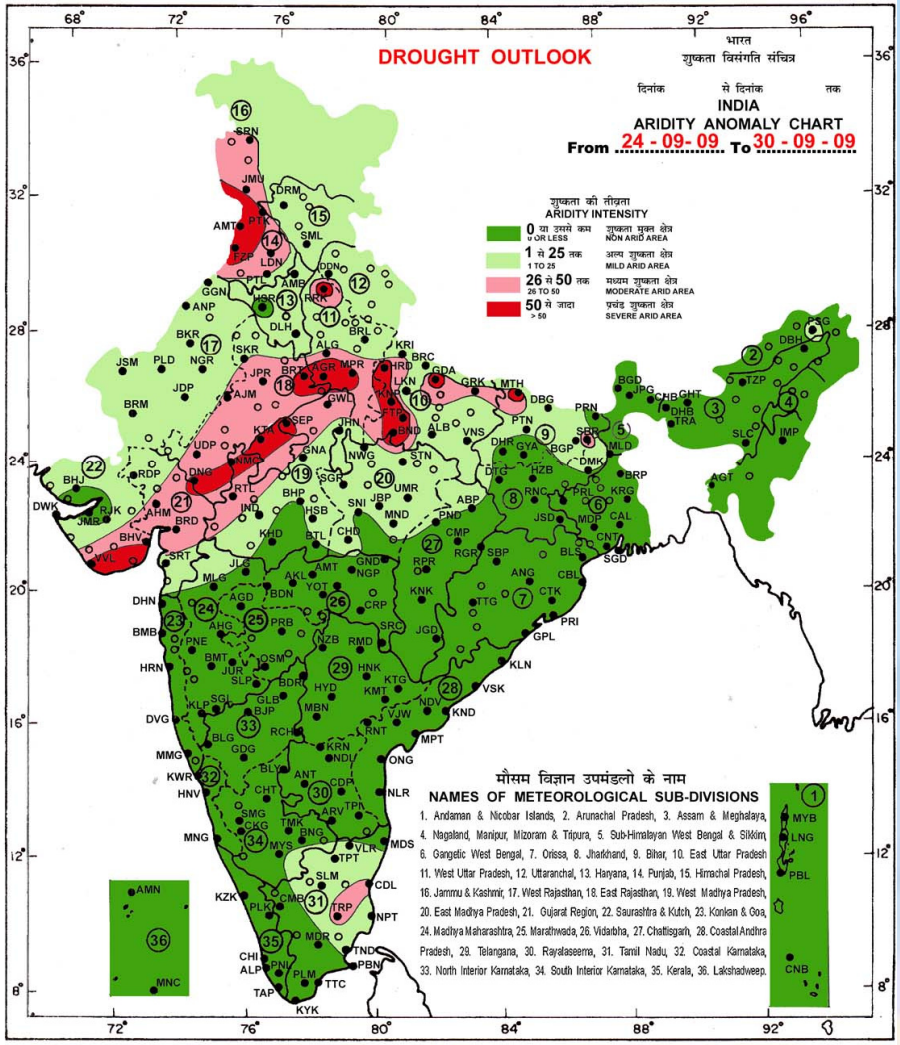
भारत मौसम विज्ञान विभाग
अनावृष्टि अनुसंधान अनुभाग - पुणे
INDIA METEOROLOGICAL DEPARTMENT
DROUGHT RESEARCH UNIT - PUNE



भारत मौसम विज्ञान विभाग
अनावृष्टि अनुसंधान अनुभाग - पुणे
INDIA METEOROLOGICAL DEPARTMENT
DROUGHT RESEARCH UNIT - PUNE

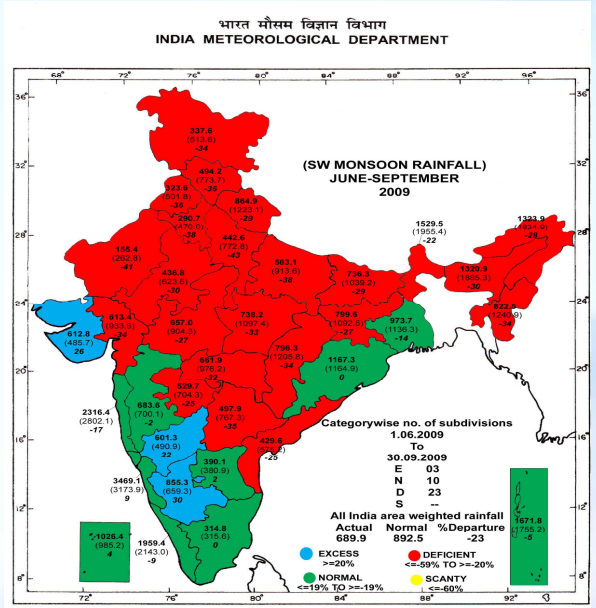


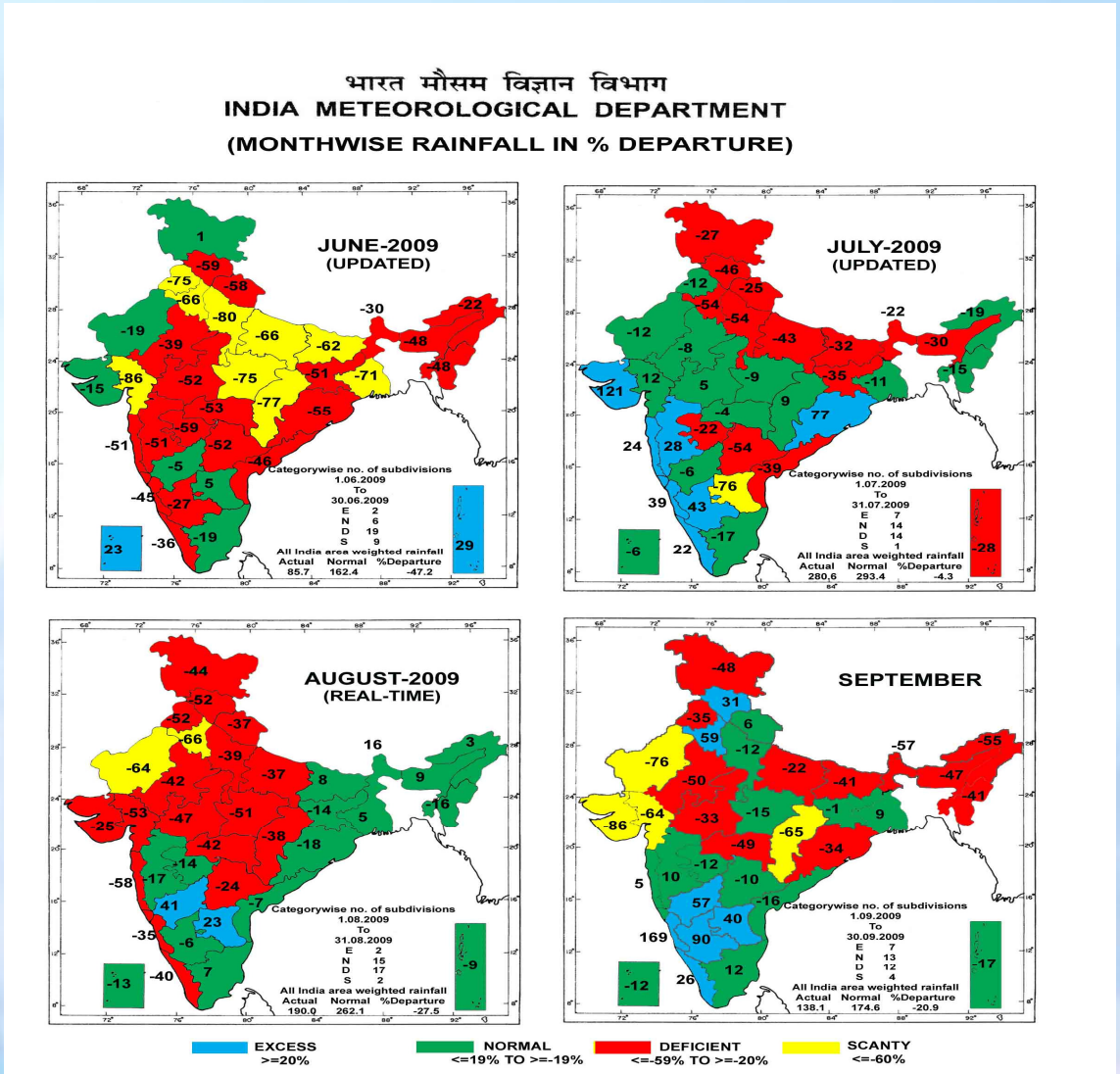
भारत मौसम विज्ञान विभाग
अनावृष्टि अनुसंधान अनुभाग - पुणे
INDIA METEOROLOGICAL DEPARTMENT
DROUGHT RESEARCH UNIT - PUNE



भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

The Real Picture (MONSOON 2009): Monthly and Seasonal Rainfall Distribution





Verification of Operational Forecast: Monsoon 2009

Region	Period	Issued on	Forecast	Actual
All India	June to September	17 April, 2009	96% ± 5% of LPA	77% of LPA
		24 June, 2009	93%± 4% of LPA	
All India	July	24 June, 2009	93%± 9% of LPA	96% of LPA
All India	August	24 June, 2009	101% ± 9%of LPA	73% of LPA
Northwest India	June to September	24 June, 2009	81% ± 8%of LPA	64% of LPA
Northeast India			92% ± 8%of LPA	73% of LPA
Central India			99% ± 8%of LPA	80% of LPA
South Peninsula			93% ± 8%of LPA	96% of LPA

Actual monsoon onset over Kerala: 23rd May, Forecast: 26th May ± 4 days.

National Agricultural Drought Assessment and Monitoring System (NADAMS) : National Remote Sensing Centre (NRSC), India

- **Under NADAMS, agricultural conditions are monitored at district level using daily-observed coarse resolution (1.1km) NOAA AVHRR data for the entire country and at sub district level using better spatial resolution IRS AWiFS/ WiFS data.**
- **Indian Remote sensing Satellite (IRS) series (IRS 1C, IRS 1D and IRS P3) have WiFS (Wide Field Sensor) payload which collects data in red (0.62-0.68) and near infrared (0.77-0.86) spectral bands with spatial resolution of 188m and ground swath of 810km with a revisit period of 5 days.**
- **IRS P6 has Advanced WiFS sensor that provides spatial resolution of 56m for better monitoring of agriculture.**

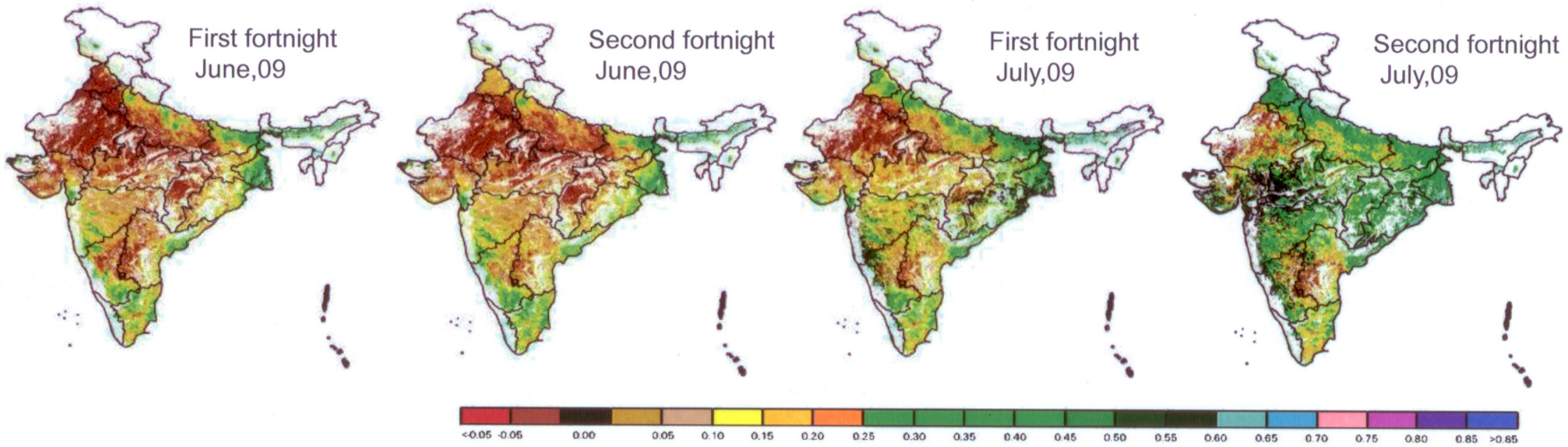
National Agricultural Drought Assessment and Monitoring System (NADAMS) : National Remote Sensing Centre (NRSC), India

- **Crop/vegetation reflects high energy in NIR band (due to its canopy geometry and health of the standing crops/vegetation) and absorbs high energy in the Red band (due to its biomass and photosynthesis).**
- **Using these contrast characteristics of vegetation in NIR and Red bands, which indicates both health and condition of crops/vegetation, NDVI is derived by the difference of these measurements and divided by their sum.**
- **To minimize the cloud ,monthly time composite vegetation index is prepared**

National Agricultural Drought Assessment and Monitoring System (NADAMS) : National Remote Sensing Centre (NRSC), India

- **The monthly vegetation index map for the state with district boundaries overlaid are given in specific colours for the vegetation index ranges.**
- **The various colours in the NDVI map yellow through green to violet indicate increasing green leaf area and biomass of different vegetation types.**
- **Cloud and water are represented in black and blue colours ,respectively**
- **Bare soil, fallow and other non-vegetation categories are represented in brown colour.**
- **The seasonal progress of caompared to that of normal and complementary ground data on rainfall crop sowing progress are utilized in assessing Agricultural Drought.**

Fig. Progression of surface wetness (NDWI) during Sowing period June – July 2009



AMSR-E Soil moisture – During Sowing period 2009

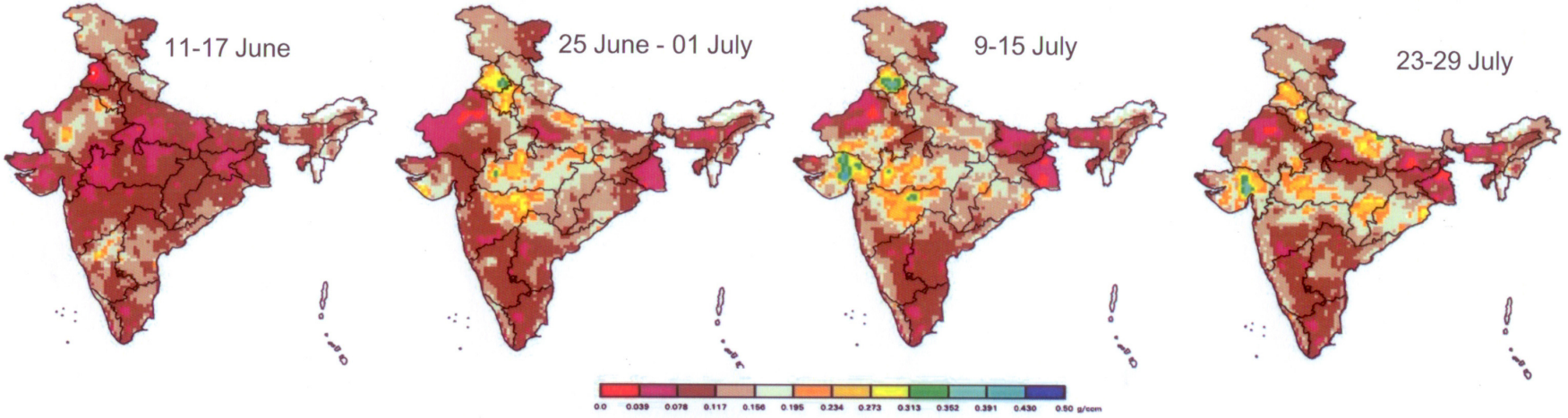
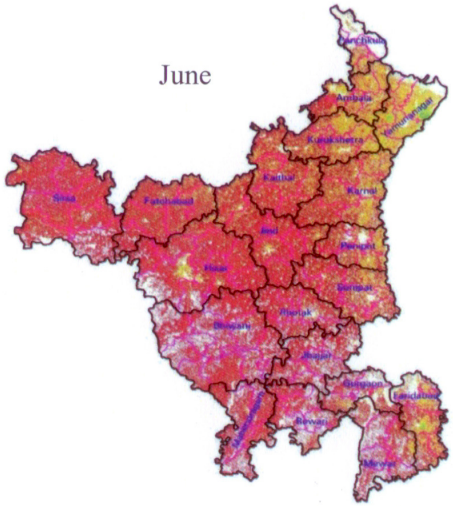
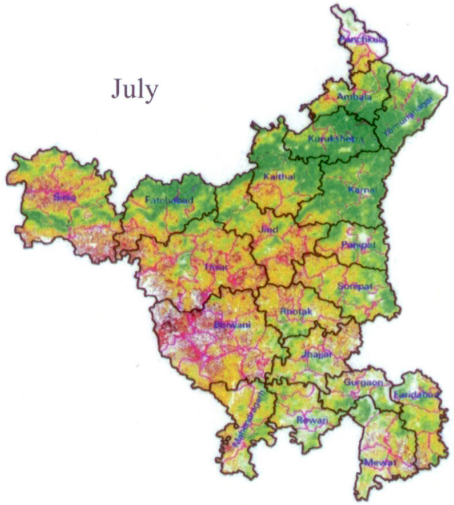
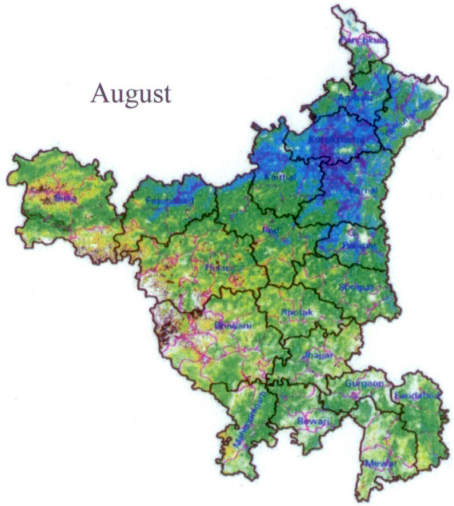
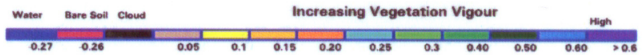


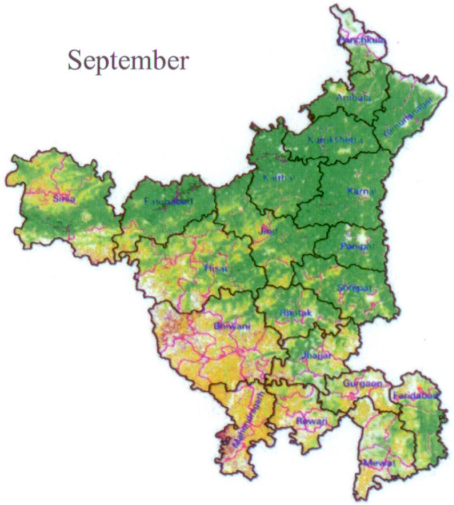
Fig. AWiFS NDVI over Agricultural area over Haryana state, kharif – 2009
(Showing improved agricultural situation since July)

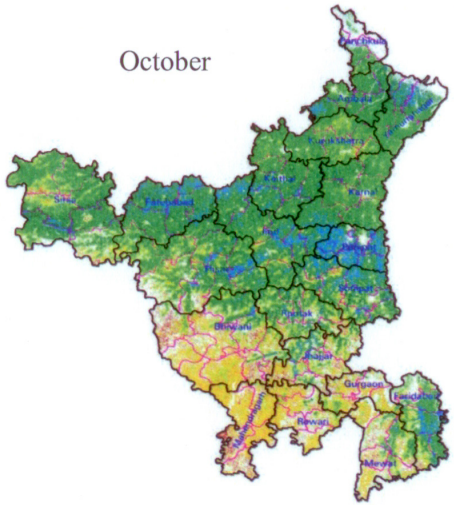








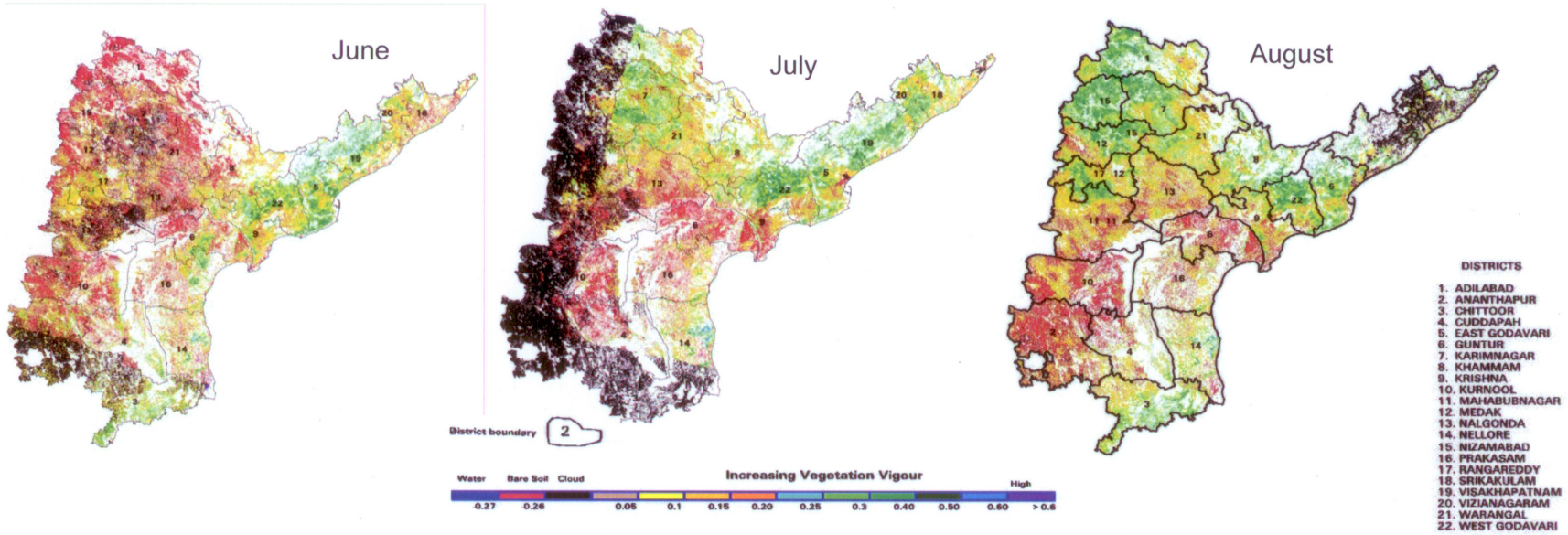


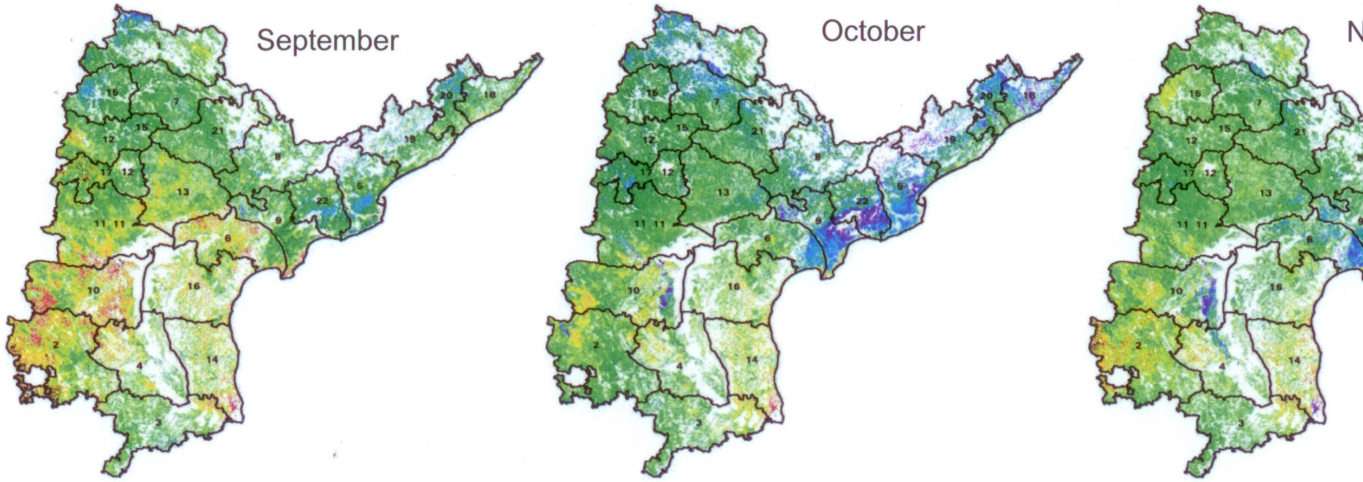


Agril. Drought assessment
Kharif 2009:

Mild: 2 dists/6 blocks
Rest Normal

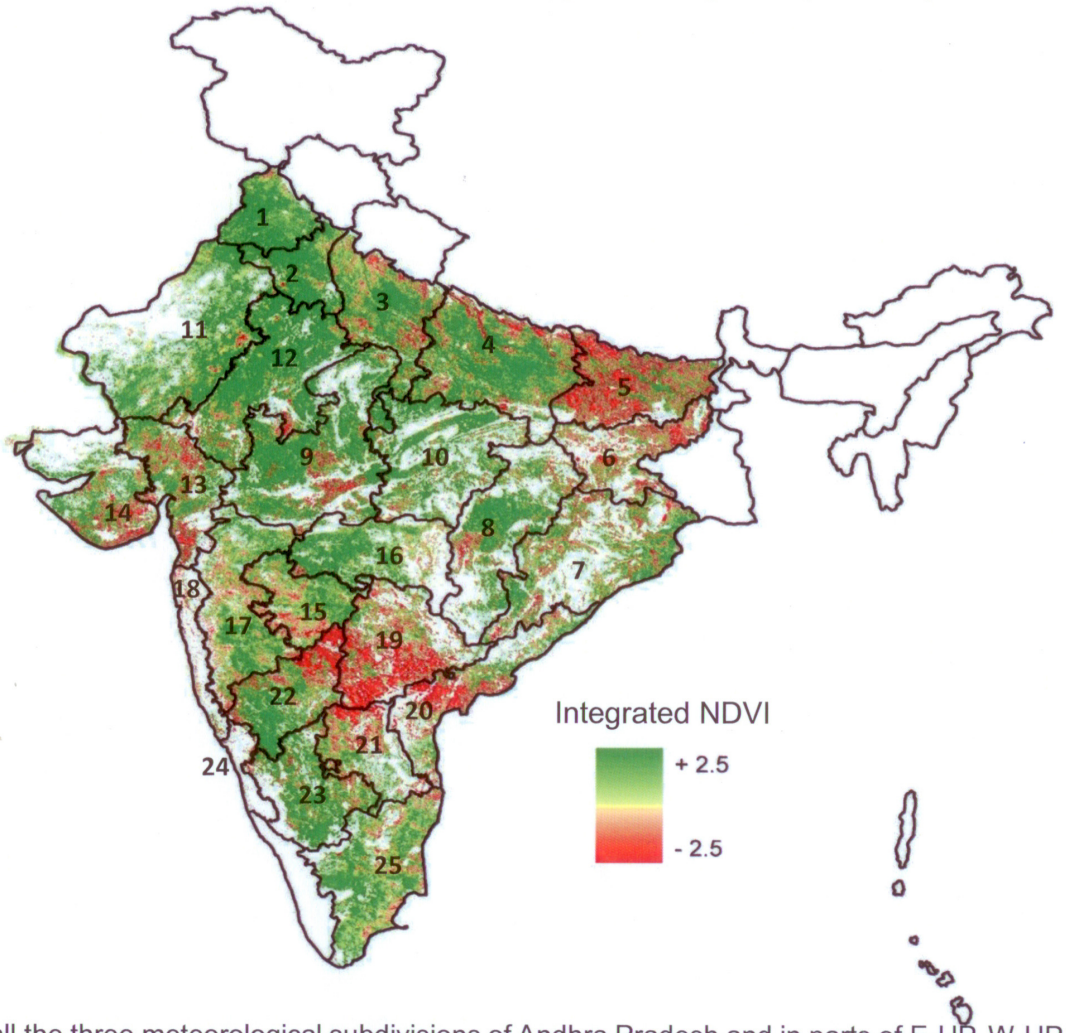
Fig. AWiFS NDVI over Agricultural area over Andhra Pradesh state, kharif – 2009
(showing persistant low NDVI and delayed agricultural season due to agril. drought)





Agril. Drought assessment
Kharif 2009:
Mod./Severe:16 dists/435 mandals
Mild: 5 dists/167 mandals
Rest Normal

Fig. Difference image (2009 – 2002) of integrated NDVI during crop growing period (sum of 4 fortnights of Aug to September).



Meteorological subdivisions

1. Punjab
2. Haryana Chandigarh Delhi
3. West UP
4. East UP
5. Bihar
6. Jharkhand
7. Orissa
8. Chhatishgarh
9. West MP
10. East MP
11. West Rajasthan
12. East Rajasthan
13. Gujrat region Daman DNH
14. Sourastra Kutch Diu
15. Marathwada
16. Vidharbha
17. Madhya Maharastra
18. Konkan & Goa
19. Telangana
20. Coastal AP
21. Rayalaseema
22. N I Karnataka
23. S I Karnataka
24. Coastal Karnataka
25. Tamilnadu & Pondicherry

In all the three meteorological subdivisions of Andhra Pradesh and in parts of E-UP, W-UP, Jharkhand, Gujarat, Saurashtra, Int. NDVI of 2009 is less than that of drought year 2002, indicating equally intensive agricultural drought situation in both the years. In North Interior Karnataka, the low values are partly due to cloud cover in 2009. In Bihar, since 2002 is normal, the low values Indicate that 2009 is less than normal.

Conclusions

- **Early warning of drought very important , but challenging.**
- **Monsoon forecasting– active/break spells, Long range forecast of monsoon rainfall (seasonal, monthly and all India scale, homogeneous region, sub-divisional scale) high priority.**
- For monitoring and assessing agril. Drought aridity anomaly index is used. Besides, remote sensing applications could also be very effective in assessing drought severity, their impacts on sectors like agriculture, and related policy decisions.
- **Generation of more reliable and area specific weather forecasts in medium and extended range help in drought management.**

THANK YOU