Drought

Drought definition

It is a climatic anomaly characterized by deficient supply of moisture. The drought can be defined in terms of moisture deficiency, which is a balance between the water availability and water demand.

Drought means different to different persons, fields and places depending upon the specific purpose. A meteorologist considers it to be an area affected by deficient rain water over a period of time. For an hydrologists, it is below average water level in reservoirs, lakes, river flow etc. either on surface or under ground. It is a poor crop yield for a farmer due to inadequate soil moisture to the crops. An economist looks it as water shortage which will adversely affects the established economy of the country. Thus it differs from discipline to discipline.

The most important among these is Meteorological Drought. The low rainfall that unevenly distributed in time and space added with high temperature, stronger winds has a profound impact in almost all fields. Among different types of droughts, Agricultural Drought is more complicated one embracing many fields associated with crops like soil physics, plant physiology, agronomy, pre and post harvest management etc. It will be crop, season and place oriented.

Drought is defined in two aspects, namely, conceptual or operational. It has to be based on deficiency of available water over sufficiently longer area for longer periods of time unlike aridity or short period localised dry spells. The definition can help to work out various statistics, drought intensities, duration and spatial extension, identification of drought prone areas etc. They are grouped under Atmospheric, Meteorological, Agricultural, Socio-economy etc. One has to remember that there is no universal definition covering all the fields. However one cannot avoid the simple and most important parmeter, namely rainfall or its index, reflected in all of them. Meteorological Drought is mainly based on deficient rainfall and its duration over an area. It is sometimes clubbed with other meteorological parameters also. The time scale may be a month, a season or an year. The spatial scale varies from a district to whole country.

In India, meteorological drought is mainly based on rainfall deficiency of season or an year. India Meteorological Department, for operational purposes, adopted the following definition i.e. if a meteorological subdivision (part of India) receives total southwest monsoon seasonal rainfall less than 75% of the normal value, it is considered to be affected by drought. Further, it is classified as moderate and severe if the rainfall deficiency is in between 26 to 50% and more than 50% of the normal, respectively. A year is considered to be a drought year, in case the area affected by one of the above, either individually or collectively is more than 20% of the total area of the country. Some other definitions based on theoretical considerations are also available.

Drought is a temporary aberration, unlike aridity or even seasonal aridity (in terms of a well defined dry season), which is a permanent feature of climate. Drought in contrast is a recurrent, yet sporadic feature of climate, known to occur under all climatic regimes and is usually characterized by variability in terms of its spatial expanse, intensity and duration. Conditions of drought appear primarily, though not solely, on account of substantial rainfall deviation from the normal and / or the skewed nature of the spatial / temporal distribution to a degree that inflicts an adverse impact on crops over an agricultural season or successive seasons. What is universally accepted is that drought stems from a deficiency or erratic distribution in rainfall but the spread and intensity of the calamity is contingent on several factors, including the status of surface and ground water resources, agro-climatic features, cropping choices and patterns, socio-economic vulnerabilities of the local population etc. It is difficult to provide a precise and universally accepted definition of drought due to its complex nature and varying characteristics that manifest across different agro-climatic regions of the world in a myriad different ways.

Classification of drought:

According to Thornthwaite (1947) there are four types of droughts,
(a) Permanent (b) Seasonal (c) Contingent and (d) Invisible drought

(a) Permanent drought:

It is found in the desert areas where, in no season the precipitation equals to the water need. Plants therefore are adapted to dry conditions. Agriculture is impossible without irrigation facilities in this region.

(b) Seasonal drought:

This drought can be expected in each year. These droughts are resulted from large seasonal air circulation changes. Agriculture is possible during the rainy season or with the use of irrigation in the dry season. Regions of seasonal drought have well defined rainy and dry seasons.

(c) Contingent drought:

This drought results from the irregular and variable rainfall. They occur in any season and are usually more severe during greatest water need periods. This drought is unpredictable.

(d) Invisible drought:

This can occur at any time, even during period with rainfall, when the daily rainfall fails to meet the daily water need of plants. As a result, there is a slow drying of the soil and plants fail to grow at their optimum rate.

National Commission of Agriculture (NCA) (1976) there are three types of droughts

(1) Meteorological drought:
It is a situation where there is significant decrease from normal precipitation over an area. The meteorological drought over an area for a year has been defined by 'India Meteorological Department (IMD)' defines drought as a situation when the seasonal rainfall over the area or place is less than 75 per cent of its long term average or the normal.

(2) Hydrological drought:
Meteorological drought if prolonged, results in hydrological drought with marked depletion of surface water and subsequent drying up of reservoirs, lakes, streams and river and fall in ground water level.

(3) Agricultural drought:
It occurs when soil moisture and rainfall are inadequate during the growing season to support a healthy crop growth till maturity, causing extreme crop stress and wilt.

There are seven kinds of agricultural drought:

1. **Permanent drought**: This type of drought is common in arid regions. Under such condition rainfall is not sufficient to grow crop in any seasons during year.
2. **Early season drought**: It is due to delayed monsoon which alters optimum time of sowing, growing season of crop, incidence of insect and pest deceases crop productivity
3. **Mid-Season drought:** It is caused by the breaks in the monsoon during crop growing seasons. Drought during vegetative phase results in stunted growth low leaf area development and reduced plant populations.
4. **Late-Season drought:** It is caused due to early withdrawal of rainy season It has impact at reproductive stage leading to force maturity.
5. **Apparent drought:** It is caused due to mismatching of the cropping pattern with rainfall distribution and moisture availability.
6. **Contingent drought:** It is caused due to irregularity of rain fall in any season.
7. **Invisible drought:** This type of drought occurs in humid region when daily rain water is not enough to meet daily water requirement of the crop.

History:

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. The frequency of drought has varied over the decades. From 1899 to 1920, there were seven drought years. The incidence of drought came down between 1941 and 1965 when the country witnessed just three drought years. However, during the 21 years, between 1965 and 1987, there were 10 drought years which was attributed to the El Nino Southern Oscillation (ENSO).

Among the many drought events since Independence, the one in 1987 was one of the worst, with an overall rainfall deficiency of 19% which affected 59–60% of the normal cropped area and a population of 285 million. This was repeated in 2002 when the overall rainfall deficiency for the country as a whole was 19%. Over 300 million people spread over 18 States were affected by drought along with around 150 million cattle. Food grains production registered an unprecedented steep fall of 29 million tonnes. In 2009, the overall rainfall deficiency for the country as a whole was 22%, which resulted in decrease of food grain production by 16 million tonnes. During 2014-15 and 2015-16 large parts of the country were affected by drought causing widespread hardships to the affected population since the calamity encompassed major agricultural States in the country.

Droughts during the colonial period, tended to degenerate into severe famines causing massive human losses. According to one estimate, in the latter half of the 19th century, there were approximately 25 major famines across India, which killed 30-40 million people. The first Bengal famine of 1770 is estimated to have wiped out nearly one third of the population. The famines continued until Independence in 1947, with the Bengal famine of 1943–44 which affected 3-4 million people, being among the most devastating. The situation improved remarkably in post-independent India. Investment in irrigation works, promotion and availability of quality inputs, focus on research & extension led to increased agricultural productivity and greater resilience among the farming communities. This development did not only render the country self-sufficient in food production but to a considerable extent, famine proof. Though population quadrupled since Independence, the country did not witness a famine in the past 69 years and in fact, India has become a major exporter of agricultural produce in the world.

Records of the Drought /Famines of GUJARAT since last 616 years !(Earliest since 1396).

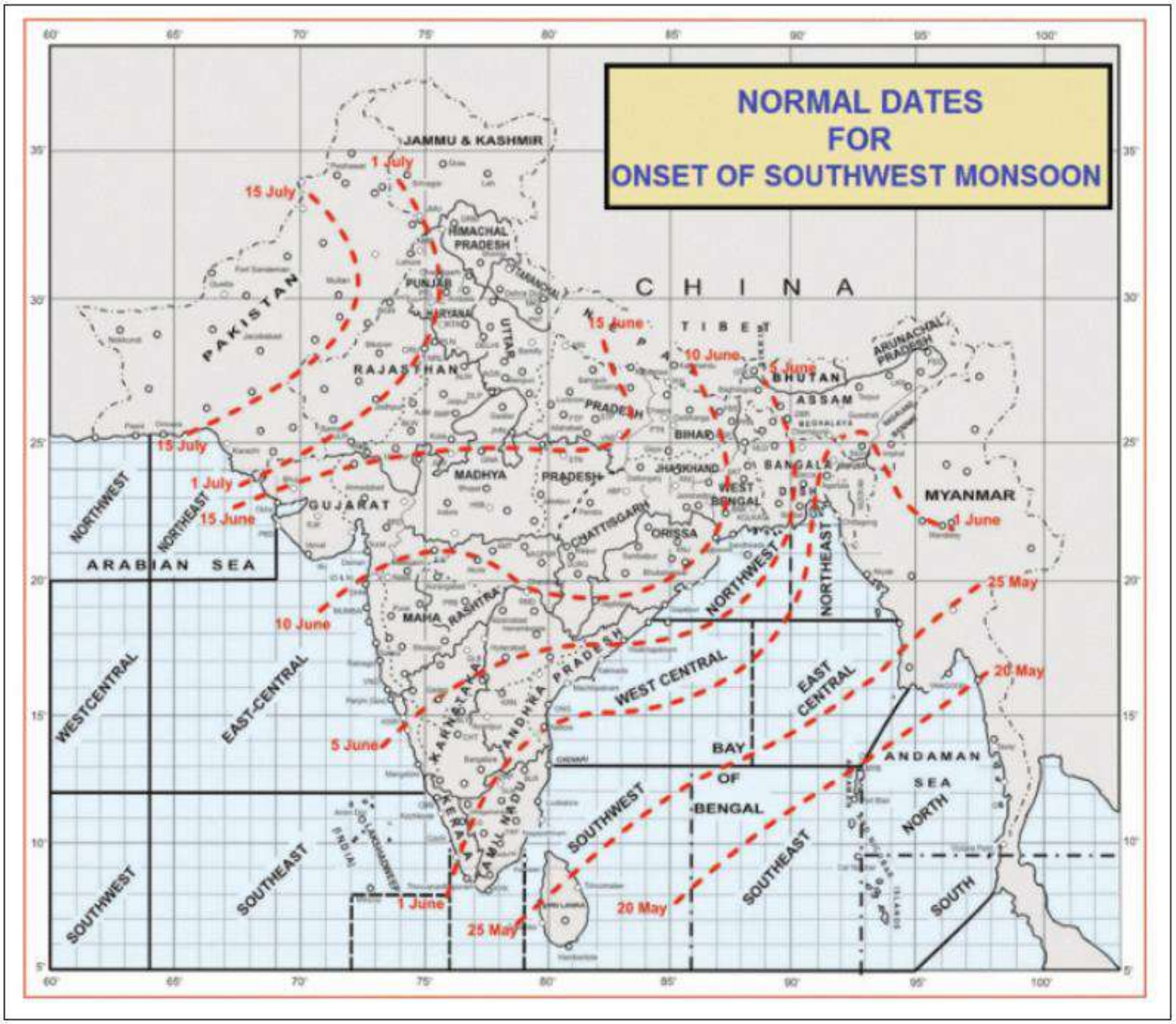
1396 AD	West India &Gujarat		South of Narmada depopulated
1482	Surat		
1559	Saurashtra	Jagadusha During Moguls	
1577	KUTCH		
1631-32	Whole of the Gujarat	Satyasyo lasted till 1640AD	Satyasyo = VS1687 -56 = 1631 AD
1647	Saurashtra		
1681-97	Throughout Gujarat	Reoccurring droughts	Severe famine in the Gujarat
1708 -1800		During the Mogul Periods	
1757-58	KUTCH	Famines of Kutch	Many famines during the periods
1774-75	KUTCH	Famines of Kutch	Many famines during the periods
1782- 83	KUTCH	Famines of Kutch	Many famines during the periods
1784	KUTCH	Famines of Kutch	Many famines during the periods
1791-92	Whole of the Gujarat	SADTALO means VS 1847	SADTALO=VS 1847-56= AD 1791
1801-03	KUTCH & SURAT	TILOTRA=3 famines	3 FAMINES in KUTCH - TILOTRO
1812-13	KUTCH	AGNOTRO VS 1869	AGNOTRO VS 1869-56= AD 1813
1815	Whole of the Gujarat		
1824-25	1833-34, 24-35, 39-40	KUTCH Saurashtra	
1845-46	1856, 1861, 1864, 1876	Many Parts of the Gujarat	
1800-1947		During the British Periods	
1897-98	Gujarat Famine		
1899-1900	KUTCH & Gujarat	CHAPANO lasted 1901-02	CHAPANO=VS1956-56=AD1900
1911, 21, 26	Gujarat Saurashtra		
1935, 1938	Gujarat		
1939-40	Gujarat, Saurashtra		
1940-41	KUTCH & Gujarat	CHANANO=VS1996	CHANANO=VS1996-56=AD1940
1946-47	KUTCH&Panchmahal		
1947-1960		POST INDEPENDENCE	
1947-48	Parts Of Gujarat	(PACHHOTARO)	Due to LATE RAINS
1948-49	Kheda, SabarKantha		
1951-53	Parts of the Gujarat	Saurashtra	
1957-58	KUTCH & Gujarat		
1960Latest		POST INDEPENDENCE	
1960, 65, 68	Most Parts of Gujarat		
1971, 73, 74	And 1979-80	Parts of the Gujarat	
1885, 87,88	Most Parts of Gujarat		

Seasonal characteristics of Drought

The occurrence of drought is contingent on a number of factors such as cropping choices and agronomic practices, soil types, drainage and ground water profiles, to name a few. However, rainfall deficiency and spatial and temporal distribution, duration and dry spells are acknowledged as the most important triggers for drought.

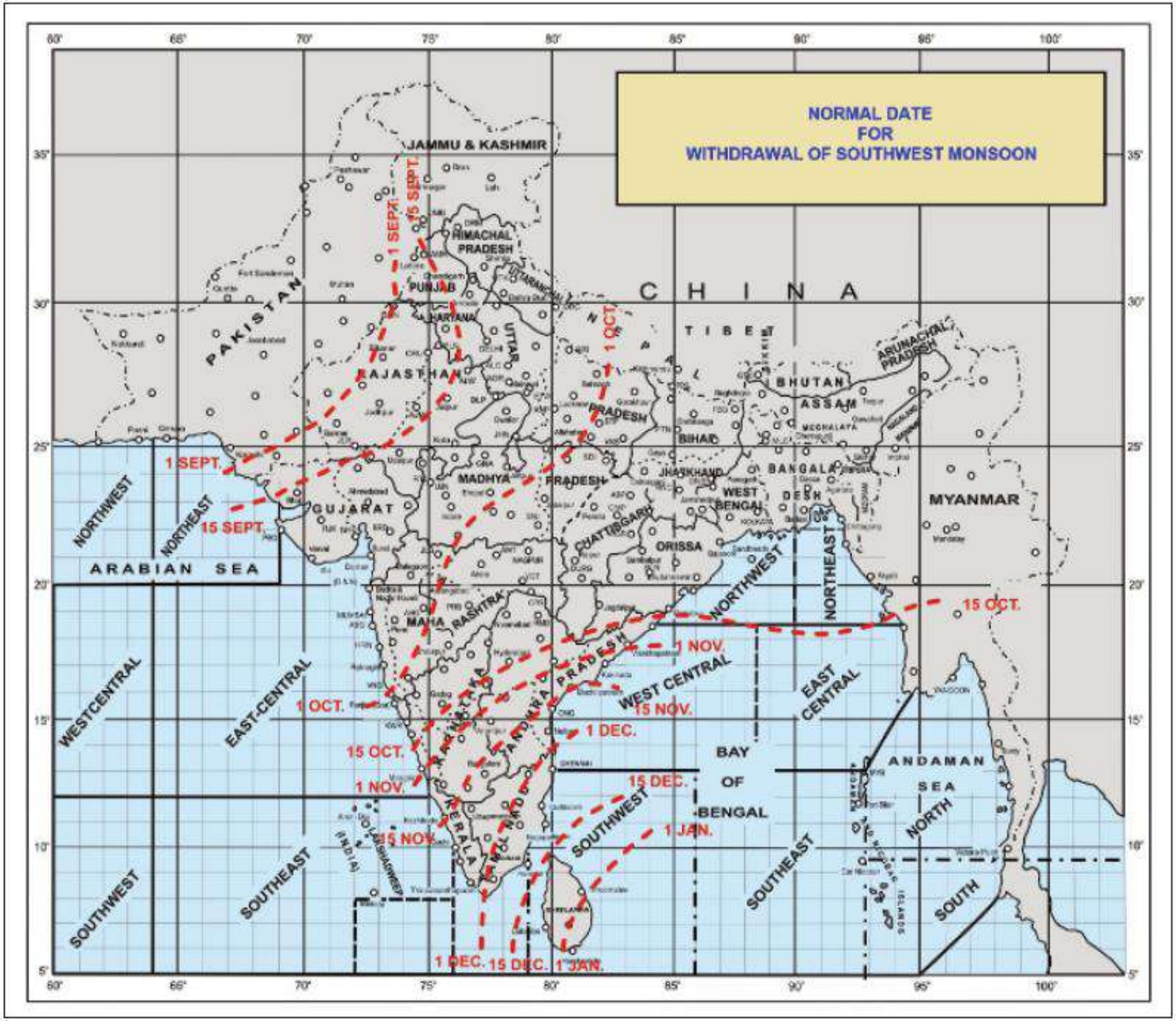
India receives most of its rainfall (73%) from the South-West or "summer" Monsoon i.e., (the rainfall received between June and September). The summer monsoon sets in during the first week of June in the south-west corner of India and gradually proceeds towards the north-west region covering the entire country by the second week of July. The withdrawal of the Monsoon commences in the first week of September from the west and north and recedes from most parts of the country by the month-end. Even when the overall rainfall in the country was normal, large variations were noticed across regions, within States, and sometimes, even within districts. IMD set up 36 meteorological sub-divisions straddling over the territories of a dozen districts on an average, in each of the subdivisions. Rainfall is categorized as excess, normal, deficient or scanty and the possibility of drought arises in the event of deficient or scanty rainfall. onset (Map 1.1) and withdrawal (Map 1.2)

Map 1.1: *Normal Dates for Onset of Southwest Monsoon*



Source: India Meteorological Department

Map 1.2: *Normal Dates for withdrawal of Southwest Monsoon*



Source: India Meteorological Department

Seasonal characteristics of Drought (Conti…)

The duration of the rainy season in the north-west region of the country is less than a month on account of the late arrival and early cessation of monsoon activities. Conversely, Kerala and north-eastern parts of India receive more than 4 months of rainfall due to the wide window afforded by the early arrival and late withdrawal of the monsoons. Coastal areas of peninsular India and Tamil Nadu, in particular, receive bulk of its annual rainfall from October to December, from the receding monsoon and periodic cyclonic disturbances in the Bay of Bengal, but primarily on account of the North-East monsoons. The broad seasonal distribution of rainfall in India is presented in Table 1.1.

Table 1.1: *Seasonal Distribution of Rainfall in India*

Season	Period	Percentage of Distribution
Pre-monsoon	March-May	10.4
South-west monsoon	June-September	73.4
Post-monsoon (Northeast Monsoon)	October-December	13.3
Winter rains	January-February	2.9

Source: India Meteorological Department, Government of India.

The spatial and temporal extent of rainfall deficiencies in the South West Monsoon season recorded across meteorological subdivisions in the country during the drought years. It would appear that the geographical spread of the drought over meteorological subdivisions was the maximum in 1987 and 2002 among the drought events in the recent past (Table1.2). The drought in 2015 too had a very wide coverage, and the impact substantially magnified, by the pervasiveness of the ill effects of a major drought during the immediately preceding year.

Table 1.2: *Meteorological Sub-Division wise Distribution of Deficient Rainfall during Major Drought Events (Number of meteorological sub-divisions = 36)*

Drought year	Mid-July	Mid-August	Mid-September
1966	19	14	16
1972	13	21	21
1979	17	15	15
1987	25	25	21
2002	25	25	21
2009	15	19	16
2014	16	14	13
2015	23	23	14

Source: India Meteorological Department

Month-wise all India rainfall distribution shows (Table 1.3) a comparison of the extent of departure of rainfall from the normal during the recent major droughts in 1972, 1979, 1987, 2002, 2014, 2015. Rainfall variation in 2009 appears to be higher compared to other drought years at an all India level. The South West Monsoon Season in 2009 opened in June with an ominous rainfall deficiency of 47%, which was further aggravated by continuing shortfalls in the remaining months. Earlier, during the drought years of 1972, 1979 and 1987 too, a similar pattern was noticed when each of the four months between June and September recorded deficient rainfall at an all India level.

In 2014, the first three months of the South West Monsoon were characterized by deficient rainfall to an extent that the late season rally in September was not sufficient to revive agriculture in most parts of the country. In contrast, the 2015 season started with normal rainfall, prompting farmers to undertake large scale agricultural operations, before the situation turned progressively adverse into a serious drought in the remaining 3 months, causing serious damage to agriculture and losses to the farmers.

Table 1.3: *Month-wise All India Rainfall Distribution (Percentage departure for the country as a whole in recent major drought years)*

Year	June	July	August	September	June-Sept
1972	-27	-31	-14	-24	-24
1979	-15	-16	-19	-28	-19
1987	-22	-29	-4	-25	-19
2002	+4	-51	-4	-10	-19
2009	-47	-4	-27	-20	-22
2014	-42	-10	-10	+8	-12
2015	+16	-16	-22	-24	-14

Source: India Meteorological Department

Poor rainfall in successive years tend to compound the adverse effect of drought by reducing scope for the recharge of surface and ground water resources, replenishment of soil moisture and recovery of financial capacity of agriculturists to make investments in agricultural operations. Table 1.4 shows the extent of departure of rainfall in the *Kharif* season during successive drought years.

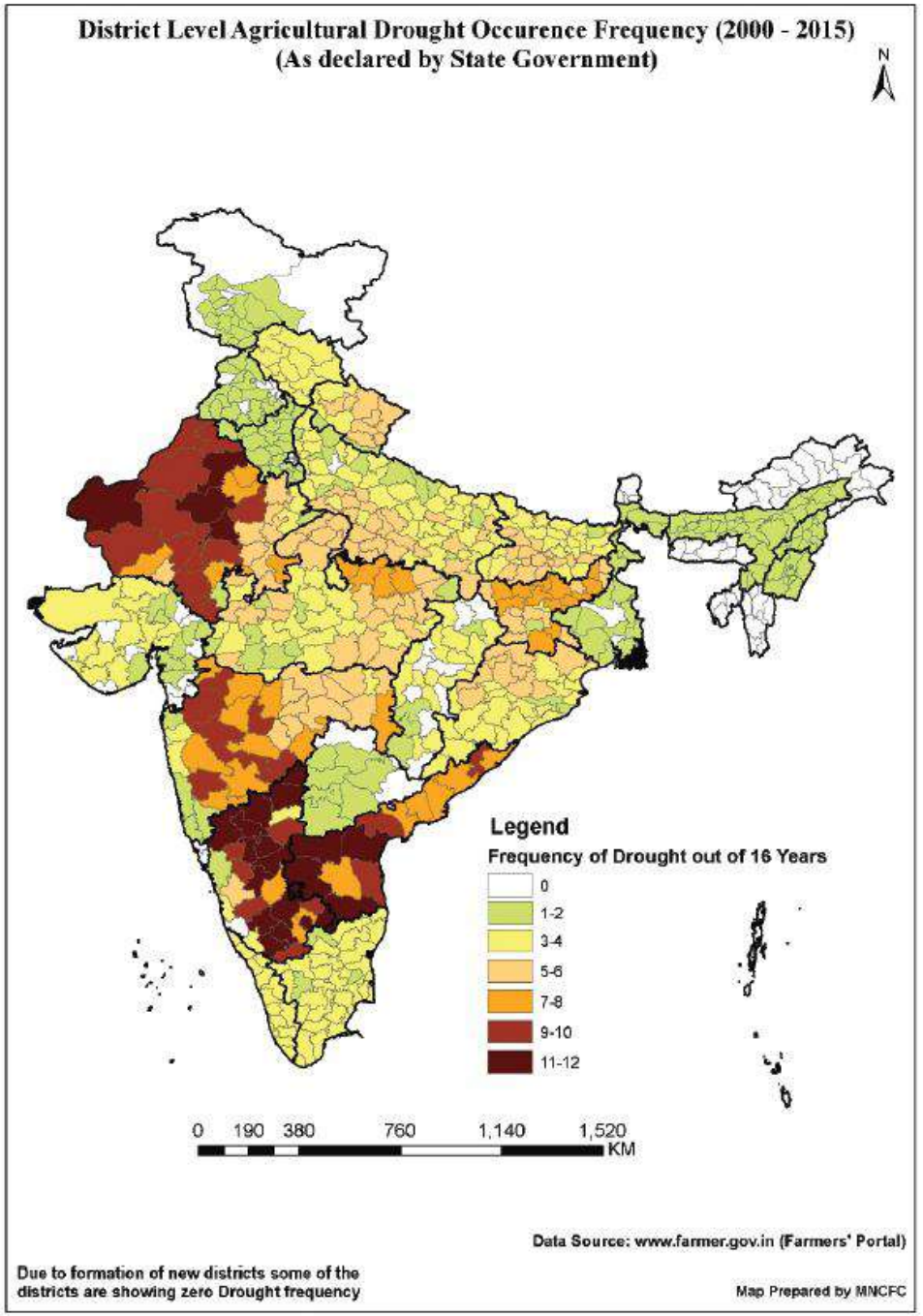
Table 1.4: Percentage Departure of Rainfall from Normal for Country as a Whole (SW Monsoon) during successive Drought years.

Year	Percentage Departure from Normal
1965	-18
1966	-16
1985	-7
1986	-13
1987	-19
1999	-4
2000	-5
2001	-8
2002	-19
2014	-12
2015	-14

It is evident from Table 1.4 that at the macro-level, the serious droughts in 1966, 1987, 2002and 2015 were a culmination of the build up of adverse rainfall events of the preceding years. It is worth noting that in several instances, the low rainfall spells have continued over several years e.g. 1985-87 and 1999-2002 periods.

The map 1.5 provides a pictographic representation of the frequency of drought occurrences in districts between 2000-2015. The frequencies are derived from the number of occasions when droughts were declared in such districts by State Governments during the 15-year period. It is hoped that the map will help provide guidance to policy makers in identifying areas that are most susceptible to drought for the establishment of monitoring and early warning systems. In addition, the map will help focus attention of the Central and State Governments to particularly vulnerable areas in order to plan and prioritize mitigation measures through urgent execution of District Irrigation Plans, Crop Contingency Plans, Drinking water and MGNREGS related activities etc. It would appear that certain parts of Karnataka, Andhra Pradesh, Maharashtra, Rajasthan have been particularly susceptible to drought episodes.

Map 1.5: Frequency of Occurrence of Drought (2000-2015)



Geographical Spread of Drought

It has been shown that about 68% of cropped area in India is vulnerable to drought, of which 33% receives less than 750 mm of mean annual rainfall and is classified as "chronically drought-prone" while 35% which receive mean annual rainfall of 750-1125 mm is classified as "drought-prone". The drought-prone areas of the country are confined primarily to the arid, semi-arid, and sub-humid regions of peninsular and western India (Table 1.5).

Table 1.5: *Cropped Area Falling Under Various Ranges of Rainfall in India*

No.	Mean Annual Rainfall Ranges	Classification	%
1	Less than 750 mm	Low rainfall	33%
2	750 mm to 1125 mm	Medium rainfall	35%
3	1126 mm to 2000 mm	High rainfall	24%
4	Above 2000 mm	Very high rainfall	8%

Source: Drought 2002, A Report, Ministry of Agriculture, Government of India

Table 1.6 below indicates that while the droughts in 1965-67 and 1979-80 impacted comparatively high rainfall regions, whereas the droughts during 1972, 1987, and 2002 affected mostly semi-arid and sub-humid regions. In recent years, central, north-west and peninsular India appear to have suffered frequent drought occurrences. These are traditionally low rainfall zones and the frequent failure of monsoons seems to have aggravated the intensity of droughts in these regions.

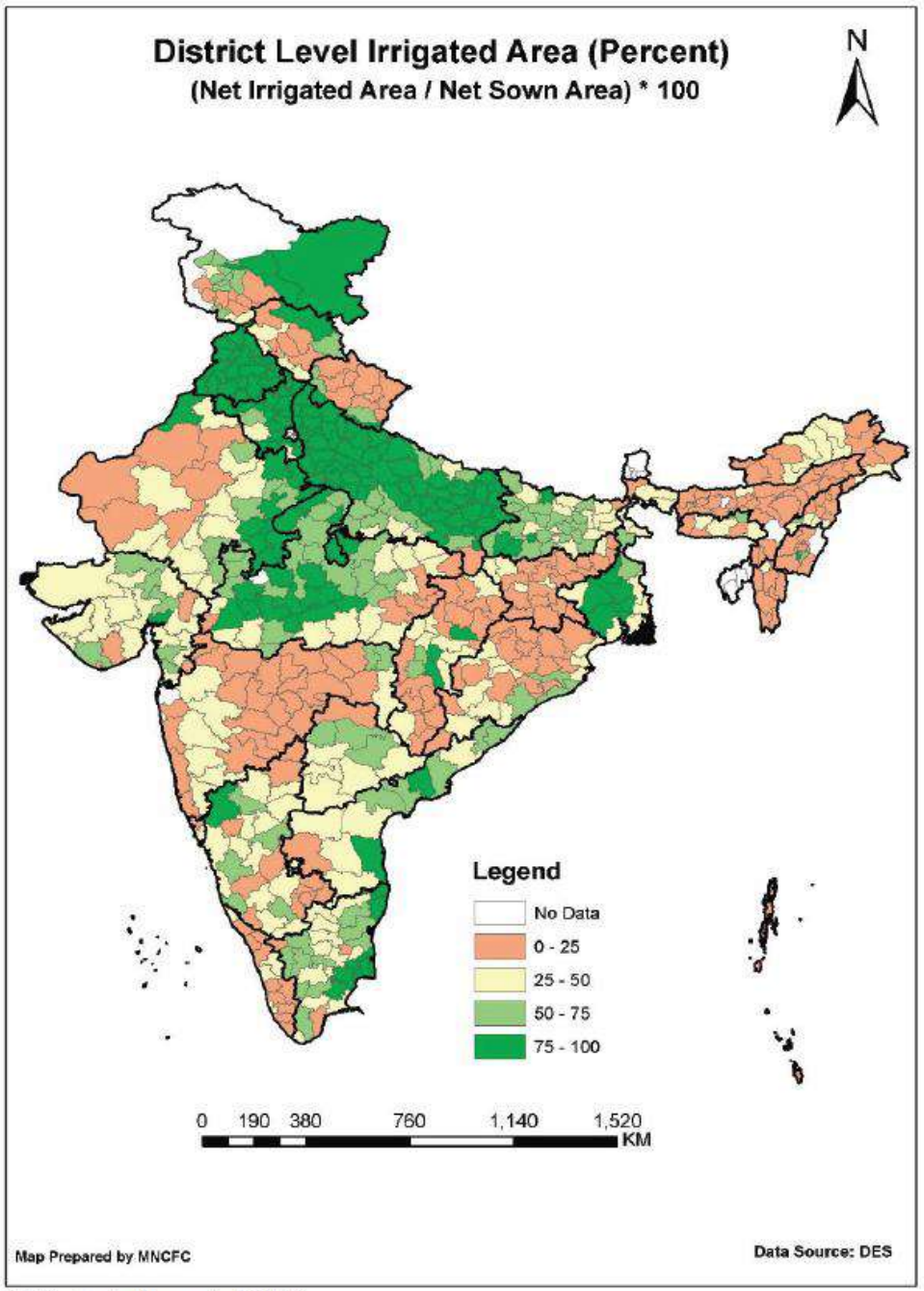
Table 1. 6: *Region-wise Percentage of Departure of Rainfall from Long-term Average during SW Monsoon in Major Drought Years*

Region	1918	1965	1972	1979	1987	2002	2009	2014	2015
All India	-24.9	-18.2	-23.9	-19	-19.4	-19.2	-21.8	-11.9	-14.3
North-west	-46.9	-35.4	-31.3	-41.7	-43.9	-26.1	-35.5	-21.5	-17
Central	19.3	1.7	-18.7	-6.9	26.2	-6.7	-24.1	-10.1	-8.4
East	-31.1	-23	-24.5	-17.9	-29.4	-16.9	-20.1	-9.6	-16.3
Peninsular	-38.7	-8	-19.6	-4.9	-18.9	-32.5	-5.6	-7	-15.4

Source: India Meteorological Department

Irrigation systems are well developed in some parts of the country as depicted in Map 1.6. It has been noticed that regions bestowed with assured irrigation have tended to escape the adverse impact of poor monsoon rainfall to a large extent, as is often the case with many districts of Haryana and Punjab.

Map 1.6: *District Level Irrigation Percentage Map (Data Source: DES, DAC&FW)*



DES-Directorate of Economics & Statistics

Causes of Drought

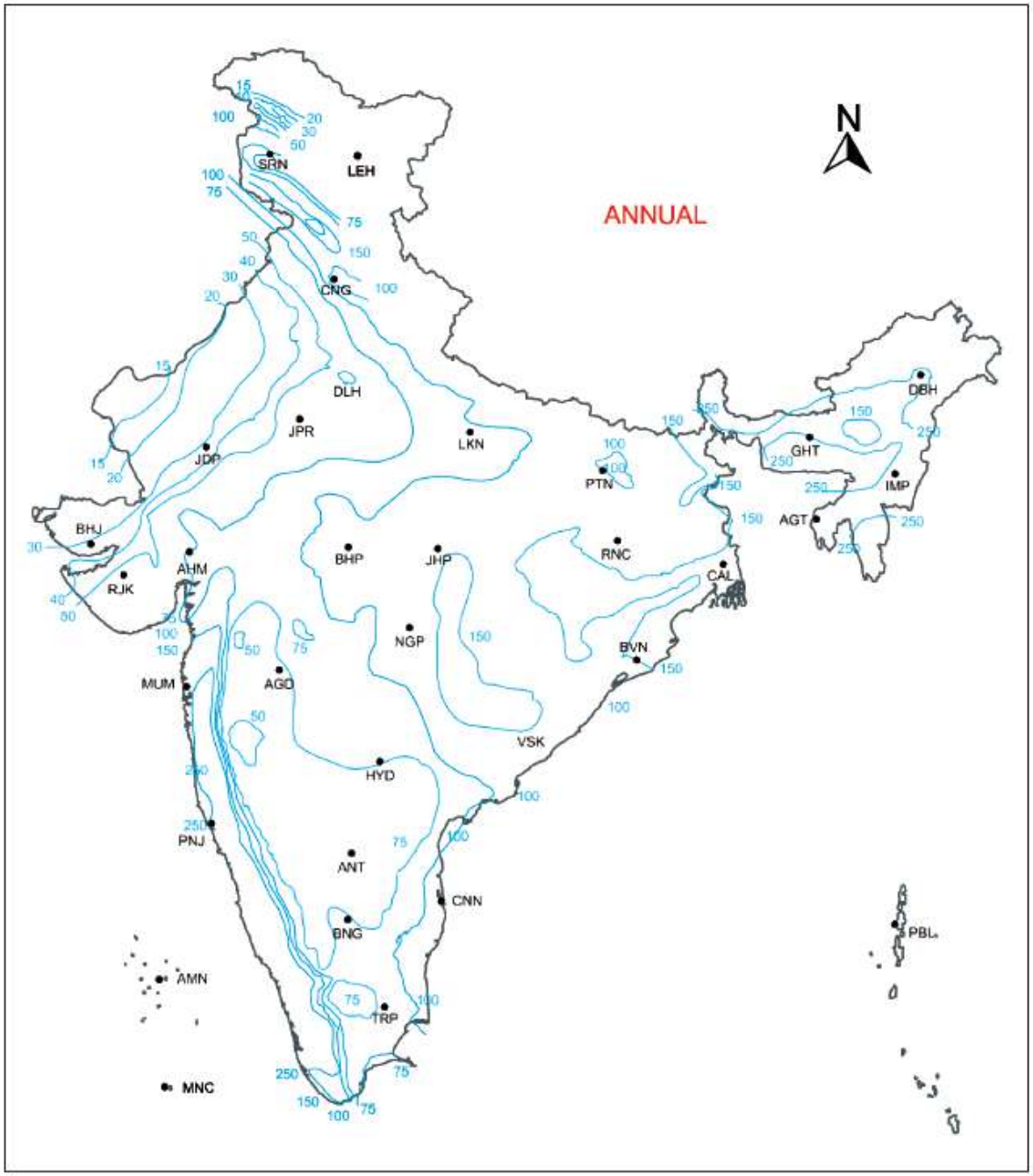
The occurrence of persistent drought is primarily linked to displacements or variations in strength on time scales of a month to several years in the normally observed large-scale features of the atmospheric general circulation. These circulation variations affect the development of the local rain-producing disturbances. The causes of such circulation variations are not well understood but links with sea-surface temperature and snow cover have been established. For example, El-Nino and Southern Oscillation (ENSO) events are associated with major displacements of normal rain-producing areas. The Australian drought in 1982 is believed to have been a direct result of ENSO in 1982-83. Similarly, some correlation has been found between the 1991-92 drought in southern Africa and the ENSO event in 1991. Likewise, correlations have been found between Sahel droughts and such large-scale factors as anomalous sea-surface temperature in the Atlantic and the weakening of the West African monsoon. However, such knowledge does not yet constitute an adequate basis for reliable drought prediction.

A number of regional interactions between the atmosphere and the underlying surface are thought to play a part in maintaining droughts. Such feedback (the desert feeds on itself) could result from a large increase in surface albedo, and its effect on the radiation balance, that occurs in drought conditions, and from diminished water storage, and hence reduced evaporation over continental areas. WMO and its Members will continue research into the above circulation variations and the interactions between the atmosphere and the land. An improved knowledge will help prediction of the weather and climate in drought-prone areas.

Causes of Recurring Drought in India

A deficiency in rainfall causes depletion of soil moisture, fall in surface and ground water levels which in turn is likely to have a deleterious effect on agricultural operations, due to insufficient availability of water for the crops, especially during the critical stages of plant growth. The correlation between quantum of rainfall and the trigger for drought in India vary across agro-climatic zones. In the semi-arid regions, even a well distributed 400 mm rainfall during a crop season could be adequate for the sustenance of crops, while in high rainfall regions like Assam, an annual rainfall of 1,000 mm could still create a potential for drought like development. Though deficient rainfall is considered to be the primary instigating factor for drought, yet the occurrence, spread and intensity is determined by several factors including susceptibilities introduced by climate change, hydrological and soil profiles, availability of soil moisture, choice of crops and agricultural practices, availability of fodder, socio-economic vulnerabilities etc. The recurrence of drought in India is owed largely to the unique physical and climatic susceptibilities of the country, which include: yy Considerable annual / seasonal/regional variations in spite of a high average annual rainfall of around 1,150 mm. The mean annual rainfall across the country is shown in Map. 1.4;

Map 1.4: Normal Annual Rainfall (cm) Map of India

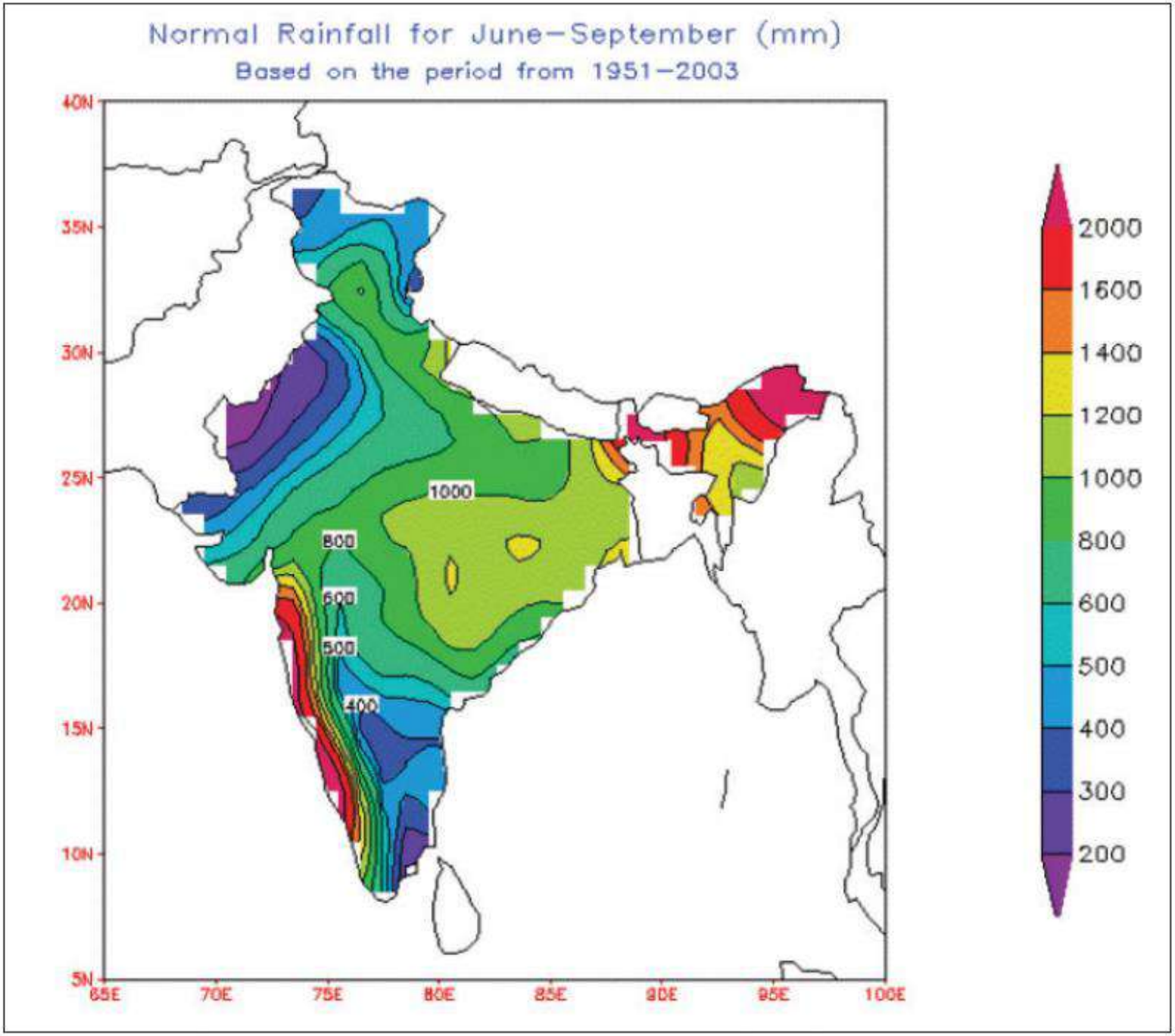


Source: India Meteorological Department

Causes of Recurring Drought in India (Conti…)

A relatively short window of less than 100 days during the South-West Monsoon season (June to September) when about 73% of the total annual rainfall of the country is received. The normal rainfall in various parts of the country is shown in Map 1.3.

Uneven distribution of rainfall over different parts of the country in that some parts bear an inordinately high risk of shortfalls, while others tend to receive excessive rainfall. Even though India receives abundant rain on an average, for the country as a whole, much of the excess water, which otherwise could have contributed towards enhancing natural resilience towards drought, gets lost as run-offs. The variability in rainfall exceeds 30% in large areas of the country when compared to Long Period Average (LPA) and exceeds 50% in parts of drought-prone Saurashtra, Kutch and Rajasthan;



Source: India Meteorological Department

Causes of Recurring Drought in India (Conti…)

Low average annual rainfall of 750 mm over 33% of the cropped area in the country heightens the susceptibility to drought;

Over-exploitation of ground water and sub-optimum conservation and storage capacity of surface water leading to inadequate water availability for irrigation, particularly in the years of rainfall deficiency.

Steady decline in per capita water availability for humans and animals even in non-drought years;

Out migration of cattle and other animals from drought hit areas heightens the pressure on resources in surrounding regions.

Limited irrigation coverage (net irrigated area in the country is less than 50%) exacerbates the impact of drought on account of complete dependence of agriculture in such areas on rainfall (Map 1.6)

Five Categories of Indices

- Rainfall
- Crop sowing
- Vegetation Condition
- Water availability
- Other collateral parameters

Three steps

- Trigger 1: Cause indicator
- Trigger 2: Impact Indicators
- Verification: Ground Truth

State Governments are expected to develop monitoring systems at the smallest possible administrative unit levels.

Parameters for Drought

Levels	Category	Parameters
Trigger 1 (Cause)	Rainfall Based	1. RF Deviation or SPI 2. Dry Spell
Trigger 2 (Impact)	1. Remote Sensing 2. Crop Situation 3. Soil Moisture 4. Hydrological	1. NDVI & NDWI Deviation or VCI 2. Area under sowing (<50% by Jul/Aug) 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

PARAMETERS Gujarat state

- Rainfall deviation

Deviation from Normal Rainfall (%)	Category
+ 19 to -19	Normal
-20 to -59	Deficient
-60 to -99	Large Deficient
-100	No Rain

- Dry spell
  - 4 weeks of low/no rainfall
  - 3 weeks of low/no rainfall in case of light soil
  - 2 weeks of low/no rainfall in arid areas with sandy soil

Impact of Drought

The impact of drought on agriculture, land use and degradation and water-resource management is especially visible in semi-arid and sub-humid areas.

In many semi-arid and sub-humid areas the occurrence of drought has been a phenomenon observed periodically for hundreds or thousands of years. Basically, the local plant, animal and human life has adapted itself to the occurrence of drought. In a "balanced" system, the exploitation of micro-climatic opportunities maintains or even enhances their existence. There is a certain "elasticity" to accommodate a temporary change in one of the components in the supply/demand balance, be it a seasonal or annual drought or a sudden temporary increase in precipitation. Ecosystems are not able to cope, without major modifications in their characteristics and appearance, with permanent changes in these components, such as those caused by climatic changes as opposed to climatic variability or by a permanent increase in the animal or human population, initially sustained by outside forces. If such permanent changes occur, the function of an interaction between each component of an ecosystem need to be reassessed.

Until the characteristics of the general circulation and the causes of drought have been accurately assessed, one cannot say that human interference as such causes drought. It can, however, certainly change the impact of drought from a reversible and tolerable one to an irreversible and intolerable one.

Drought produces wide-ranging impacts that span across many sectors of the economy. The reverberations are felt by the society and economy much beyond the areas actually experiencing the onslaughts of physical drought because agricultural production and water resources are integral to our ability to produce goods and services.

Drought affects the overall economy of the country at macro and micro economic levels, both directly and indirectly**. Direct impacts are usually visible in** falling agricultural production and heightened food insecurity among poor and vulnerable sections; depleted water levels; higher livestock and wildlife mortality; cattle and animal migration; damage to ecosystem from indiscriminate exploitation; increased fire hazards etc. Indirect impacts of drought can be gauged from the reduction in incomes for farmers and agribusinesses, increased prices for food and fodder, reduction in purchasing capacity and slump in consumption, default on agricultural loans, distress sale of agricultural land & livestock, rural unrest, shrinkage in avenues for agricultural employment etc. These deleterious impulses have huge negative multiplier effects in the economy and society. The impacts of drought are generally categorized as economic, environmental, and social.

Economic impacts:

refer to production losses in agriculture and related sectors, especially animal husbandry, dairy, poultry, horticulture and fisheries. It affects livelihoods and quality of life for the majority of farmers, share croppers, farm laborers, artisans, small rural businesses and rural population in general that is dependent on agriculture. All industries dependent upon the primary sector for raw materials suffer on account of reduced supplies and hardening prices. Drought thus causes a dampening impact on the economy by squeezing profit margins, drying up income and revenue streams and constricting employment avenues through disruption caused to supply chain managements, slowing down flow of credit and tax collections, depressing industrial and consumer demand, increased dependence on imports, and lowering of overall market sentiments.

Environmental impacts:

Can be gauged from low water levels in ground water and surface reservoirs, lakes and ponds, reduced flows in springs, streams and rivers, loss of forest cover, migration of wildlife and sharpening man-animal conflicts and general stress on biodiversity. Reduced stream flow and loss of wetlands may affect levels of salinity. Increased groundwater depletion rates, and reduced recharge may damage aquifers and adversely affect the quality of water (e.g., salt concentration, acidity, dissolved oxygen, turbidity) which in turn may lead to a permanent loss of biological productivity of soils.

Social impacts:

are manifest in widespread disruption in rural society on account of outmigration of the population from drought affected areas, rise in school dropout rates, greater immoderation and indebtedness, alienation of land and livestock assets, malnutrition, starvation and loss of social status among the most vulnerable sections. The situation of scarcity in some cases may exacerbate social tensions and lead to erosion of social capital.

National Guideline on Drought Management and Overview of Drought Manual

Drought is a complex phenomenon characterized by slow onset. Careful monitoring of the symptoms of drought and early warning are key to effective management of the calamity. It is essential that along with a drought monitoring system, medium and long term area specific plans be prepared for drought proofing of susceptible areas. In addition, contingency and Crisis Management Plans need to be formulated with care to deal with drought in the short term. Such well conceived plans, when executed promptly, can go a long way in mitigating distress and disruption to the rural economy and society. The objectives behind an effective monitoring and early warning system are to:

provide accurate and timely information on rainfall, crop sown area, data on soil moisture(wherever possible), stream flow, groundwater, lake and reservoir storage at the relevant spatial scale at the State / district / sub-district levels.

detect drought conditions as early as possible in order to implement District Agriculture Contingency Plans and the Crisis Management Plan.

The development of such a system and its success depends on the coordinated efforts on the part of all affected parties viz. Government of India, State Governments, Scientific Institutions and farmers.

The Central and State Governments should set up institutional mechanisms for drought monitoring and early warning at the National and State levels.

The existing capacities of these institutions need to be enhanced and strengthened for the purposes of data collection, analysis, and derive meaningful and actionable conclusions.

1. Central Drought Relief Commissioner (CDRC):

Additional Secretary in the Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW) serves as the CDRC and is assisted by the Disaster Management (DM) Division in the Department.

A Drought Management Cell in the DM Division is created to help collate information for diverse sources, monitor drought conditions, issue advisories, coordinate with other Ministries of the Central Government, State Governments and relevant agencies to mitigate/combat the effect of drought.

2. Crop Weather Watch Group

The Crop Weather Watch Group (CWWG), in the DAC&FW, can act as an Inter-Ministerial mechanism, which should meet at least once a week during June to September period to monitor drought situation in the country.

State Drought Monitoring Centres :

The State Governments to consider setting up of Drought Monitoring Centres (DMCs) staffed by a multi-disciplinary team of meteorologists, hydrologists and agriculture scientists to provide critical inputs to the State Executive Committee / State Disaster Management Departments / Other Institutional Structures established by the States. The DMCs will collect, collate and analyse information on drought parameters from National and State level agencies e.g., the IMD, NRSC/ SRSCs, MNCFC, CWC, CGWB, State agricultural department etc.

Scientific & Support Organizations:

1. India Meteorological Department (IMD)
2. Mahalanobis National Crop Forecast Centre(MNCFC)
3. Central Research Institute for Dryland Agriculture (CRIDA)
4. Ministry of Water Resources, River Development and Ganga Rejuvenation (MoWR, RD & GR)
5. Indian Space Research Organisation (ISRO)
6. State Remote Sensing Application Centres (SRSACs)

Key Variables for Monitoring Drought

State Governments monitor drought by obtaining information from various sources on key variables of drought which include
rainfall, reservoir / lake water levels, surface water / groundwater, soil moisture and sowing / crop conditions etc.

- Meteorological Data – Rainfall and other parameters like Temperature, Wind speed and Relative Humidity
- 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

Sowing and Crop Conditions

An important indicator of drought is the total area sown. The State Government agriculture departments provide information on sowing on a weekly basis. A delayed sowing indicates rainfall deficiency and is a portent for the onset of drought. Reports on crop conditions also provide an indication of the severity of the drought situation e.g. wilting of crops signifies soil moisture stress. The agriculture contingency plans and other mitigation measures are activated on the basis of reports on different crops sown during the monsoon.

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

Levels of Early Warning

The early warning system should include the following:

1. Receipt of forecasts, early warning signals, and advisories from scientific institutions;
2. Monitor key drought indices at the National / State / District / Sub-district levels using composite index of various drought indicators;
3. Efficient dissemination of early warning so as to activate contingency measures.

Capacity Development for Drought Monitoring

The States are advised to undertake capacity building activities from time to time for all the stakeholders engaged in drought monitoring, response and mitigation with the support of relevant National and State Institutes.

Drought Monitoring Checklist

(For Ministry of Agriculture and Farmers Welfare, Government of India and Relief Commissioner, State Governments)

Meteorological Data:

Agencies: India Meteorological Department, National Centre for Medium Range Weather Forecasting, State Governments

Indices to be Monitored: Daily, weekly, and monthly rainfall, snow fall / fog

Hydrological Data:

Agencies: Central Water Commission, Central Ground Water Board, State Governments (irrigation departments, groundwater agencies, water resources departments/ projects)

Indices to be Monitored: Water storage in reservoirs / ponds / lakes, river flow, groundwater level, yield and draft from aquifers, water loss through evaporation, leakage, seepage.

Agricultural Data:

Agencies: National Crop Forecast Centre, Directorate of Economics & Statistics, Indian Council of Agricultural Research, Agricultural Census Data, State Government agriculture departments, agricultural universities

Indices to be Monitored: Soil moisture, area under sowing and type of crop, crop water requirement, status of growth, crop yield, alternative cropping possibilities, land holdings.

Data from Space:

Agencies: National Remote Sensing Centre, Indian Space Research Organisation.

Indices to be Monitored: Vegetation monitoring, rainfall, surface wetness and temperature.

Socio-economic Data:

Agencies: NITI Aayog, Department of Food & Public Distribution, Department of Consumer Affairs, Department of Rural Development. Ministry of Women and Child Development ,Department of Animal Husbandry, Dairying & Fisheries, Revenue Department of State etc.

Indices to be Monitored: Availability and prices of foodgrains, availability of fodder, migration of population.

Analysis of Data from Ground and Remote Sensing Sources

Prediction/ Forecasting / Declaration of Drought.

Drought declaration

Five categories of indices are recommended for developing a monitoring matrix for drought. The five categories of indices are Rainfall, Vegetation, Water, Crop and others. Rainfall is considered to be the most important indicator and therefore related meteorological data should be mandatorily considered in making any assessment of drought.

Rainfall Deviation: The rainfall deviation (RFdev) which is expressed in percentage terms is calculated as below:

$$RFdev = \{(RFi - RFn)/RFn\}*100$$

Where RFi is current rainfall for a comparable period (in mm) and RFn is the normal rainfall (at least 30 years average) for the same period (in mm). The IMD classification of rainfall deviation.

Table : Categories of Rainfall Deviations (IMD)

Deviation from Normal Rainfall (%)	Category
+ 19 to -19	Normal
-20 to -59	Deficient
-60 to -99	Large Deficient
-100	No Rain

Dry Spell:
A dry spell is a short period, usually 4 weeks (upto 3 weeks in case of light soils), of low rainfall or no rainfall. Thus, consecutive 3-4 weeks after the due date for the onset of monsoon with rainfall less than 50% of the normal in each of the weeks is defined as a Dry spell.

Standardized Precipitation Index (SPI):
expresses the actual rainfall as a standardized departure with respect to rainfall probability distribution function. Long term data require at least 30 or more will give more reliable results.

SPI Value	Category
<- 2	Extremely Dry
-1.99 to -1.5	Severely Dry
-1.49 to -1.0	Moderately Dry
-0.99 to 0	Mildly Dry
0 to 0.99	Mildly wet
1.0 to 1.49	Moderately wet
1.5 to 1.99	Severely wet
>2.0	Extremely Wet

June and July is deficient by 50% or more it should be declared as drought. October and November is deficient by 50% or more then drought. For entire duration June to September
Rainfall is less than 75 % or SPI less than -1.0 it should be drought declared.

Remote Sensing based Vegetation Indices:

NDVI = (NIR – Red) / (NIR + Red),

NIR and Red are the reflectance in visible and near infrared

Normalized Difference Wetness Index (NDWI)

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

where, NIR and SWIR are the reflected radiation in Near-Infrared and Shortwave Infrared channels.
Higher values of NDWI signify more surface wetness.

Water, clouds and snow have higher reflectance in the visible region and consequently NDVI assumes negative values for these features. Bare soil and rocks exhibit similar reflectance in both visible and near IR regions and the index values are near zero. The NDVI values for vegetation generally range from 0.2 to 0.6, the higher index values being associated with greater green leaf area and biomass.

Satellite based crop condition anomalies which point towards agricultural drought can be generated by computing Vegetation Condition Index (VCI) or NDVI/NDWI deviations from the normal years. Normal NDVI/NDWI is generated by averaging the NDVI/NDWI of at least 3 recent normal years.

$$NDVIdev = \{(NDVIi - NDVIn)/NDVIn\}*100$$

$$NDWIdev = \{(NDWIi - NDWIn)/NDWIn\}*100$$

Where subscript 'n' refers to normal value and 'i' to current period.

The value so obtained for a given NDVI or NDWI ranges from–1 to +1. A negative number or a number close to zero is indicative of poor vegetation and a number close to >0.6—1.0 signifies healthy vegetation in the case of NDVI and absence of water stress in the case of NDWI.

NDVI/NDWI deviation of -20 to -30% represents moderate drought conditions and that of <-30%represents severe conditions.

Crop Situation Related Indices

Drought: Total sown area under kharif crops was less than 33.3% of the total normal sown area by the end of July/August.

Severe drought: 50% or less
In *rabi* crop less than 50% area

Soil Moisture Based Indices:

Percent Available Soil Moisture (PASM)

$$PASM = [(SMw - PWP) / (FC - PWP)] * 100$$

Where SMw is the weekly calculated volumetric soil moisture (vol/vol) for the current week,

FC is the field capacity of soil (vol/vol) and PWP is the permanent wilting point of the soil (vol/vol).

PASM (%)	Agricultural Drought Class
76 – 100	No drought
51-75	Mild drought
26-50	Moderate drought
0-25	Severe drought

Moisture Adequacy Index (MAI):

Moisture Adequacy Index (MAI) is also based on a calculation of weekly soil water balance

MAI = [AET/PET] * 100
Where, AET = Actual Evapo-transpiration
PET = Potential/Reference Evapo-transpiration

MAI (%)	Agricultural Drought Class
76 – 100	No drought
51-75	Mild drought
26-50	Moderate drought
0-25	Severe drought

Limitations of MAI

a. These are important indices for rainfed areas and estimated by considering rainfall, available moisture in soil, AET & PET.

b. The computation of MAI generally does not take into account irrigation because of the non availability of irrigation data related to roster schedules and quantum of release. Therefore, the application of MAI to irrigated areas is recommended where appropriate data on irrigation is available.

c. The calculation of soil moisture from models due to the non-availability of information on soil profiles may lead to the estimation of soil moisture of the surface soil alone.

Hydrological Indices:

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-a-vis long term averages.

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

Groundwater Drought Index (GWDI):

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

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

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.

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

Stream-Flow Drought Index (SFDI):

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

1) The ratio of deficit flow volume to corresponding volume at the truncation levels; and
2) 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,

Vd = deficit flow volume,

VTL = corresponding flow volume expected at TL flow

de = duration of independent drought event, and

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

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

Ground-truth for Verification

- In the event that trigger 2 is set off, States will conduct sample survey for ground truthing 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’.
- Ground Truthing (GT) needs to be conducted in each of the 10% of the drought affected villages, selected on a random basis
- In each of the selected villages, representative locations (about 5 sites for each of the major crops), may be inspected for data collection.
- Estimation f crop damage/loss of 33% or more based on GT will qualify for drought declaration.

- GT collection is objective based on technology and only for declaration.

- GT should not be confused with traditional system of ridawari/paisewari/annewari etc.

Other Factors

The State Governments may further monitor socio-economic indicators (the following factors) in making a holistic evaluation of drought.

- Extent of fodder availability and its prevailing prices compared to normal prices and information on cattle camps;
- Scarcity of drinking water supply (human and livestock;
- Demand for employment on public works, and unusual outmigration of labour in search of employment
- Current agricultural and non-agricultural wages compared with normal times.
- Supply of food grains, and price situation of essential commodities.

Need for Scientific Approach

- Traditional practice such as the annewari/ paisewari/ girdawari systems of eye observation
- Crop cutting experiments for crop yield loss is time -consuming
- Need for a uniform approach for all states
- Tremendous progress in technology available to assess the crop situation
- Availability of data from various sources
- Drought being a complex (multi-faceted) phenomenon, there is a need to integrate various parameters fro drought declaration
- Intensity of drought needs to be assessed.

Five Categories of Indices

- Rainfall
- Crop sowing
- Vegetation Condition
- Water availability
- Other collateral parameters

Three steps

- Trigger 1: Cause indicator
- Trigger 2: Impact Indicators
- Verification: Ground Truth

State Governments are expected to develop monitoring systems at the smallest possible administrative unit levels.

Parameters for Drought

Levels	Category	Parameters
Trigger 1 (Cause)	Rainfall Based	1. RF Deviation or SPI 2. Dry Spell
Trigger 2 (Impact)	1. Remote Sensing 2. Crop Situation 3. Soil Moisture 4. Hydrological	1. NDVI & NDWI Deviation or VCI 2. Area under sowing (<50% by Jul/Aug) 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

PARAMETERS Gujarat state

- Rainfall deviation

Deviation from Normal Rainfall (%)	Category
+ 19 to -19	Normal
-20 to -59	Deficient
-60 to -99	Large Deficient
-100	No Rain

- Dry spell
  - 4 weeks of low/no rainfall
  - 3 weeks of low/no rainfall in case of light soil
  - 2 weeks of low/no rainfall in arid areas with sandy soil

- Crop acreage
  < 85% of normal area sown by end of July/August,
  'Severe' if area under crops fall to 75% of normal
  --------In case of Rabi, end of October/November

- VCI of NDVI and NDWI

NDVI dev (%)	VCI (%)	Category
>-20	60-100	Normal
-20 to -30	40-60	Moderate
<-30	0-40	Severe

- MAI

MAI (%)	Drought class
76-100	No drought
51-75	Moderate drought
0-50	Severe drought

- GWDI

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

DECISION

First Drought Trigger based on Rainfall parameters will be set off then

- **Severe drought**

At least 2 of selected 3 impact indicators are in 'severe' and one in 'moderate' class

- **Moderate drought**

At least 2 of selected 3 impact indicators are in 'moderate' class

- **Normal**

All other cases

The state can reduce drought category by one rank if irrigation percentage of the region is more than 75% where drought declared. In such situation when intensity reduced 'Moderate' to 'Normal', the state required to conduct field verification.

If trigger 2 set off with severe or moderate, state will conduct sample survey. GT will be final for judging 'severe' or 'moderate' based on crop loss. In case of 80% of GT reveals crop loss of >50 %, state have option to upgrade the intensity of drought from 'moderate' to 'severe'.

Declaration

- Kharif Drought Notification: by 30th October
- Rabi Drought Notification: by 31st March

In case of delayed sowing/transplanting, states can ask for extension request upto 3 weeks, with documentary evidence.

Early Season Drought Declaration

- Deficit rainfall in June and July with prolonged dry spells leading to significant reduction in crop sown area can trigger the declaration of early drought.

- Indicators for early season drought

  Rainfall deficiency based on rainfall deviation or SPI and the dry spell - Mandatory

  Reduction in crop sown area or failed sowing, MAI, Ground water or Reservoir water index are important.

  NDVI is less effective when the canopy coverage is low. In such situation NDWI, a surface wetness indicator is preferred to NDVI.

Annexure\3

Government of Gujarat
Revenue Department
Sachivalaya, Gandhinagar
SCY-102018-791-S.1
Date: /10/2018
30 OCT 2018

Drought Declaration Certificates

Declaration of Drought

Having taken into account the conditions as arising from rainfall deficiency, decline in the availability of ground and surface water, poor crop conditions, and parameters related to remote sensing & socio-economic parameters etc. ascertained the distress situation that is likely to develop in the area affected by these conditions through sample field verification , and , on the basis of reports available from the collectors of concerned districts, the state Government has decided to declare drought of a severe/Moderate nature in the following tehsils etc.in the state:

Sr.No.	Name of the District	Name of the Taluka	Category of Drought
1	2	3	4
1	Ahmedabad	Mandal	Moderate
2	Ahmedabad	Viramgam	Moderate
3	Ahmedabad	Detroj	Moderate
4	Banaskatha	Wav	Moderate
5	Banaskatha	Suigam	Severe
6	Banaskatha	Kankrej	Moderate
7	Banaskatha	Tharad	Moderate
8	Banaskatha	Bhabhar	Moderate
9	Banaskatha	Deesa	Moderate
10	Bhavnagar	Gariadhar	Moderate
11	Devbhumi Dwarka	Dwarka	Moderate
12	Jamnagar	Dhrol	Moderate
13	Jamnagar	Jodia	Moderate
14	Kutch	Lakhpat	Severe
15	Kutch	Rapar	Moderate
16	Kutch	Abdasa	Severe
17	Kutch	Nakhatrana	Moderate
18	Kutch	Bhuj	Moderate
19	Kutch	Bhachau	Moderate
20	Kutch	Mandvi(K)	Moderate
21	Kutch	Mundra	Moderate
22	Kutch	Anjar	Moderate
23	Kutch	Gandhidham	Moderate
24	Mahesana	Jotana	Moderate
25	Mahesana	Visnagar	Moderate
26	Mahesana	Kheralu	Moderate
27	Mahesana	Unjha	Moderate
28	Morbi	Halvad	Moderate
29	Morbi	Malia Miana	Severe
30	Morbi	Wankaner	Moderate
31	Patan	Chanasma	Moderate
32	Patan	Santalpur	Moderate
33	Patan	Patan	Moderate
34	Patan	Sami	Moderate
35	Patan	Shankheshwar	Severe
36	Patan	Harij	Moderate

37	Patan	Radhanpur	Moderate
38	Patan	Sarswati	Moderate
39	Rajkot	Paddhari	Moderate
40	Rajkot	Vichhiya	Moderate
41	Surendranagar	Lakhtar	Moderate
42	Surendranagar	Dhrangadhra	Moderate
43	Surendranagar	Muli	Moderate
44	Surendranagar	Dasada	Moderate
45	Surendranagar	Sayla	Moderate
46	Banaskatha	Deodar	Moderate
47	Banaskatha	Dhanera	Moderate
48	Banaskatha	Lakhani	Moderate
49	Devbhumi Dwarka	Kalyanpur	Moderate
50	Surendranagar	Limbdi	Moderate
51	Surendranagar	Thangadh	Moderate

The Declaration of drought would come into effect on 1st December 2018 and would continue to be in effect for six months from this date unless revoked earlier by an order of the state Government.

The State Government hereby authorizes the Collectors/Deputy Commissioners of the concerned districts to undertake relief measures in the notified area.

By the order and in the name of Honourable Governor of Gujarat.

(Pankaj Kumar)
Additional Chief Secretary,
Revenue Department,
State of Gujarat.

Contingency Planning: Preparedness and Real-Time Implementation

Preparedness:

Careful advance preparation is critical to an effective response and containment of drought. The ambit of preparedness should extend to the following:

- Establishment of a functional DMC at the State Headquarters.
- Preparation of Agriculture Contingency Plans for districts and sub-district levels, especially in vulnerable districts.
- Identification of drought prone areas, preferably at the sub district level
- Monitoring of seasonal forecasts of IMD and other national / international agencies.
- Prepositioning of inputs like drought resilient variety seeds at strategic locations.
- Activate agricultural extension to encourage shift to crops and varieties .
- Repair and maintenance of water bodies / tanks / wells etc. to help critical irrigation during dry spells.
- Creation of drought contingency cells at districts to monitor dry spells.
- Develop protocols for various departments to initiate contingency measures with clear allocation of responsibilities.
- Following management practices are recommended for adoption by the farming communities in susceptible areas

Agricultural practices to be taken under drought conditions:

1. Drought resistance cultivars of plants / seeds should be preferred for sowing.
2. The use of keeping fallow land as a management technique.
3. Erosion of drought affected soils and adoption of water harvesting technology.
4. Pasture land management or grasses may be grown in drought prone area.
5. Effect of drought on the lives of various insects and pests and on diseases is brought about by reducing moisture content of their natural environment.
6. In general drought is adverse to agriculture, but it brings a measure of compensation in greatly reducing economic loss from some pests and diseases. Powdery mildew often flourishes in dry weather and aphids and birds, which migrate early from drying, grass to alternative sites such as crops and orchard trees, causing greater damage.
7. Some agricultural practices can influence meteorological condition in the plant /soil environment and these may be used to advantage under drought conditions e.g. wind barriers can reduce evapo-transpiration in their lee ward side, thus reducing the demand on the store of soil moisture.
8. Elimination of weed and conserve soil moisture for crop use in later stage.

Must –Do –Practices (MDPs): Initial Preparedness

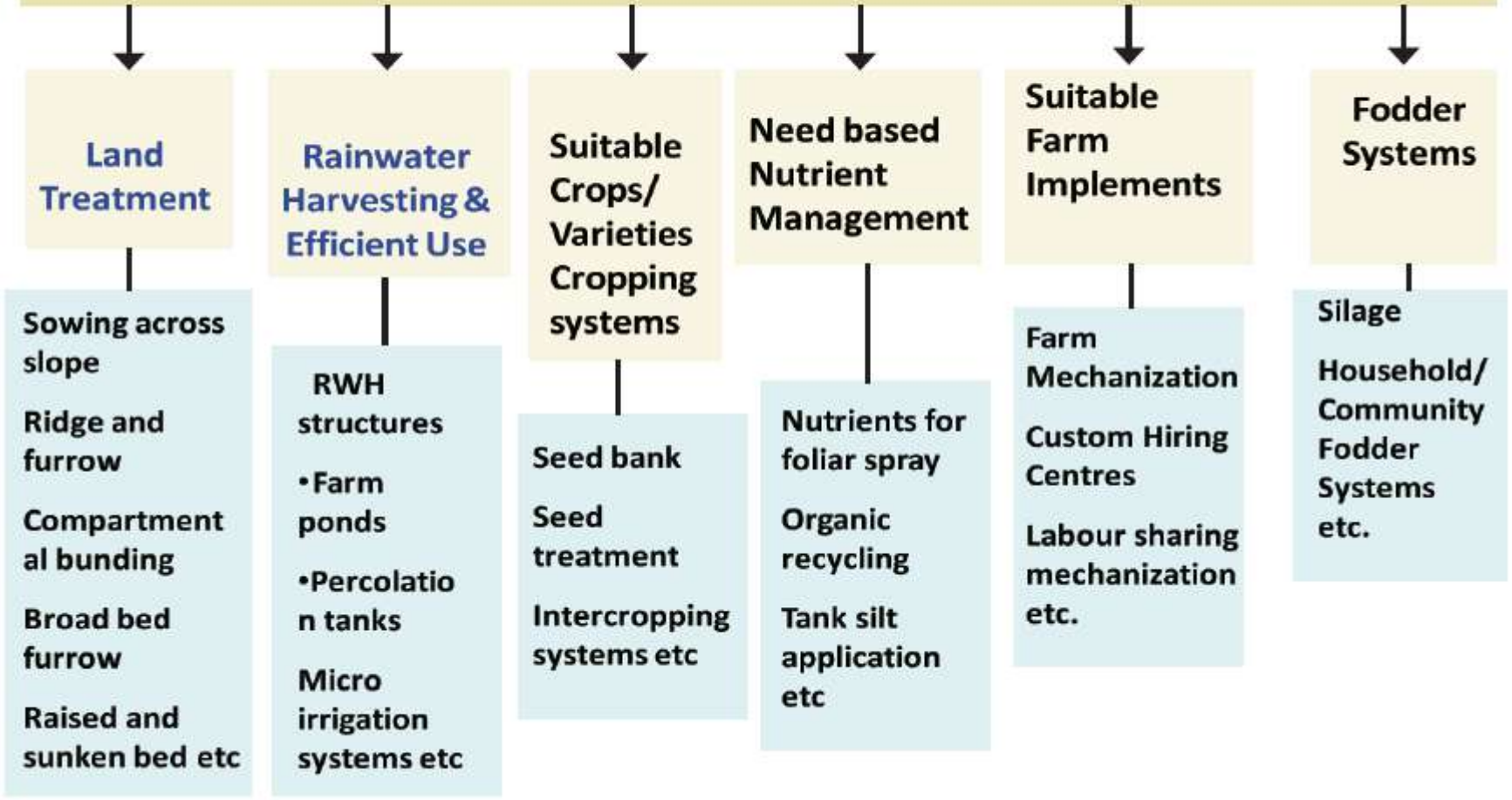
In common drought prone regions of India, initial preparedness is a sin qua non for effective and real time implementation of contingency plan. Various components of "Must Do Practices" are as follows (Fig. 4.1):

1. Land Treatment
   - Sowing across slope
   - Ridge and furrow system
   - Compartmental bunding
   - Broad bed furrow system
   - Raised / Raised Bed and sunken system, etc.

2. Rainwater harvesting and Efficient Use
   - Rainwater harvesting structures
   - Farm ponds
   - Percolation tanks
   - Micro Irrigation systems, etc

3. Suitable Crops / Varieties Cropping system
   - Seed bank
   - Seed treatment
   - Intercropping systems, etc
   - Agro-forestry
4. Need based Nutrient Management
   - Rainwater availability
   - Nutrient for foliar spray
   - Organic recycling
   - Tank silt application, etc.
5. Farm Mechanization
   - Suitable implements
   - Labour sharing mechanization
   - Custom hiring centres
6. Fodder Systems
   - Silage
   - Household / Community
   - Fodder systems, etc.

Must – Do – Practices (MDPs) : Initial Preparedness



Real-Time Implementation of Contingency Plans

Delayed onset of monsoon

In rainfed areas, as a general rule early sowing of crops with the onset of monsoon is the best-bet practice that gives higher realizable yield. Major crops affected due to monsoon delays are those crops that have a narrow sowing window and therefore cannot be taken up if the delay is beyond this cut-off date. Crops with wider sowing windows can still be taken up till the cut-off date without major yield loss and only the change warranted could be the choice of short duration cultivars. Beyond the sowing window, choice of alternate crops or cultivars depends on the farming situation, soil, rainfall and cropping pattern in the location and extent of delay in the onset of monsoon.

Early season drought

Early season drought may at times result in seedling mortality needing re-sowing or may result in poor crop stand and seedling growth. Further, the duration of water availability for crop growth gets reduced due to the delayed start, and the crops suffer from an acute shortage of water during reproductive stage due to early withdrawal of monsoon. The effect of early season drought is less on the crop, because during this period sowing is carried out. Various operations carried out are primary tillage, sowing, fertilizer application and intercultural operations. Other agronomic measures include resowing within a week to 10 days with subsequent rains for better plant stand when germination is less than 30%, thinning in small-seeded crops, interculture to break soil crust and remove weeds and create soil mulch for conserving soil moisture, avoiding top dressing of fertilizers till favourable soil moisture, opening conservation furrows at 10 to 15 m intervals, ridge and furrow across the slope for effective moisture conservation as well as in rainwater in wide spaced crops (>30 cm), pot watering may be taken up along with gap filling when the crop stand is less than 75% in crops like cotton, foliar spray of 2% urea during prolonged dry spells wherever ground/ surface water is available.

Mid-season drought

Stunted growth takes place if mid-season drought occurs at vegetative phase. If it occurs at flowering or early reproductive stage, it will have an adverse effect on the ultimate crop yield. *In-situ* soil-moisture conservation is a vital component of dryland crop management practices. During mid season drought plant protection, top-dressing of fertilizer, intercultural and supplemental irrigation are the usual practices. In case of long dry spells, crop based production system (location) related specific contingency plans are needed. Other agronomic measures include repeated interculture to remove weeds and create soil mulch to conserve soil moisture, thinning, avoiding top-dressing of fertilizers until receipt of rains, opening conservation furrows for moisture conservation, foliar spray of 2% KNO_3 or 2% urea solution or 1% water soluble fertilizers like 19-19-19, 20-20-20, 21-21-21 to supplement nutrition during dry spells, open alternate furrows, surface mulching with crop residues, providing supplemental irrigation (10 cm depth), if available.

Terminal drought

If there is a terminal drought, crop-management strategies like plant protection, soil and water conservation, interculture, supplemental irrigation and harvesting are to be adopted. Terminal droughts are more critical as the grain yield is strongly related to water availability during the reproductive stage. Further, these conditions are often associated with an increase in ambient temperatures leading to forced maturity. The agronomic measure include providing life- saving or supplemental irrigation, if available, from harvested pond water or other sources, harvesting crop at physiological maturity with some realizable yield or harvest for fodder and prepare for winter (*rabi*) sowing in double- cropped areas. Ratoon maize or pearl millet or adopt relay crops as chickpea, safflower, *rabi* sorghum and sunflower with minimum tillage after soybean in medium to deep black soils in Maharashtra or take up contingency crops (horsegram/cowpea) or dual-purpose forage crops on receipt of showers under receding soil moisture conditions.

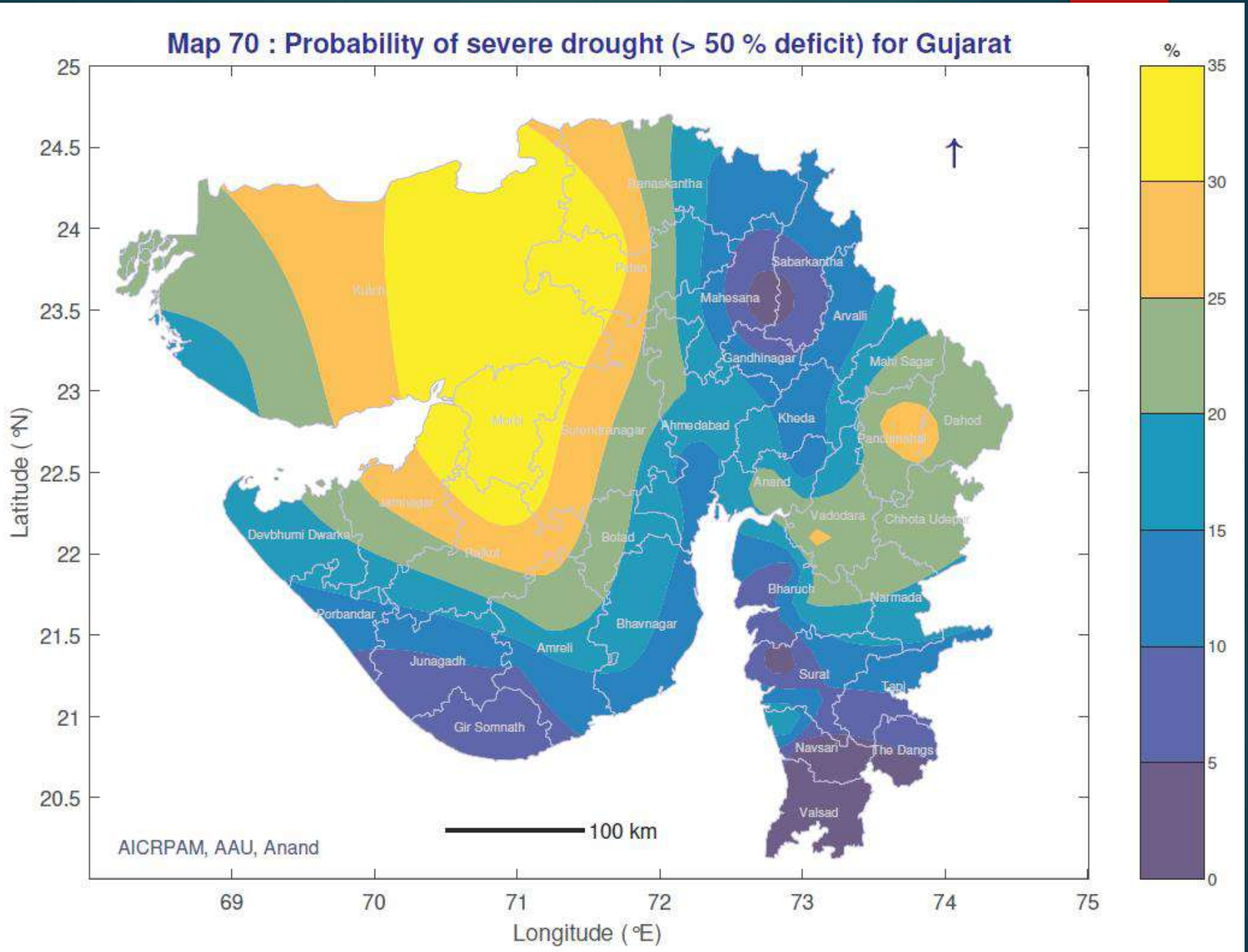
Drought Mitigation

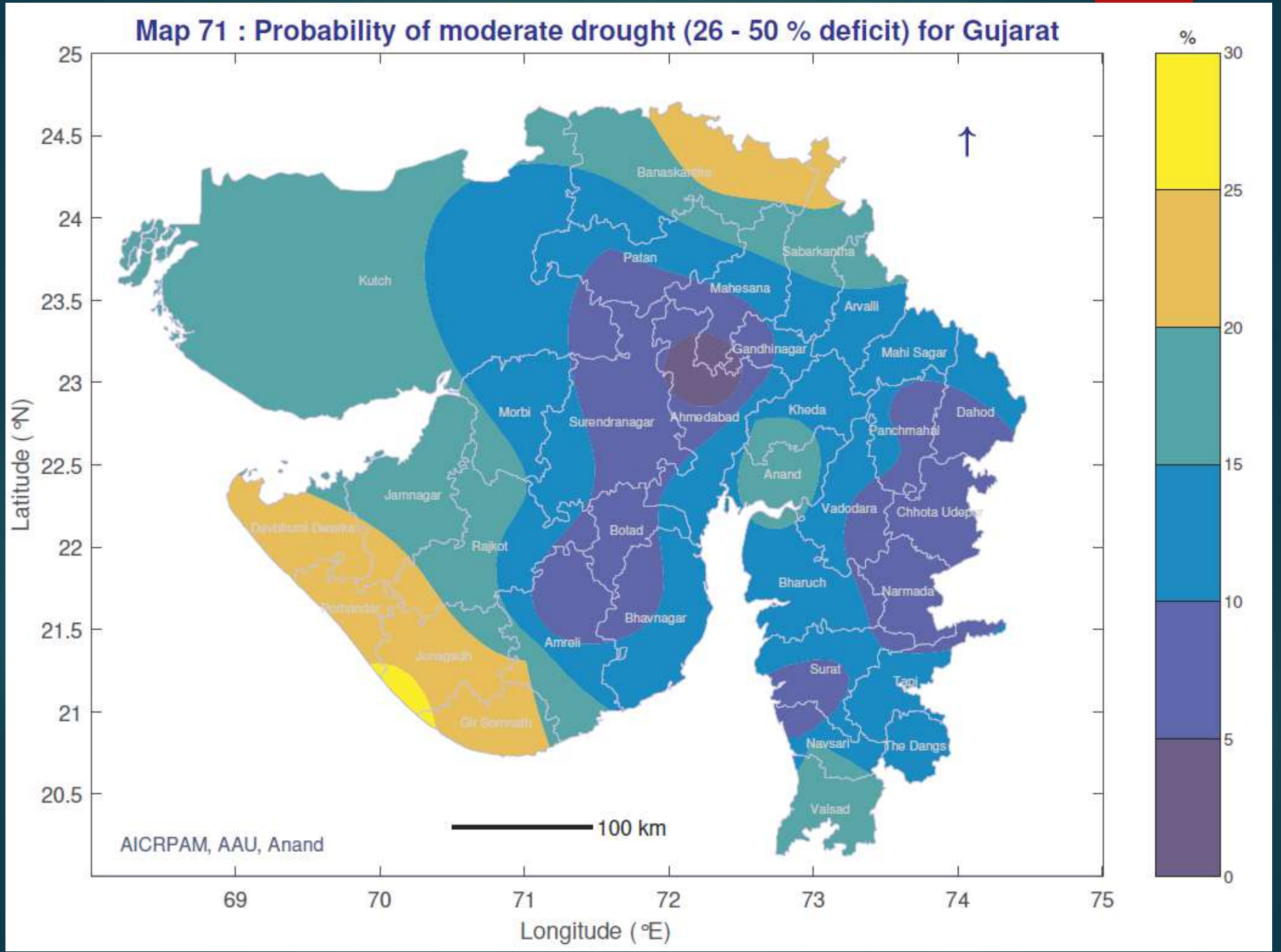
Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)
National Rainfed Area Programme
Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS)
Water Harvesting and Conservation
Artificial Recharge of Ground Water
Contour Bunding
Contour Bunding
Contour Cultivation
Bench Terracing
Graded Bunding
Gully plugging
Check Dams / Nalla Bunding Construction
Gabion Structure
Stream Bank Protection
Farm Ponds
Anicuts
Percolation Tanks (PT) / Spreading Basin
Sub-surface Barriers
Injection Wells

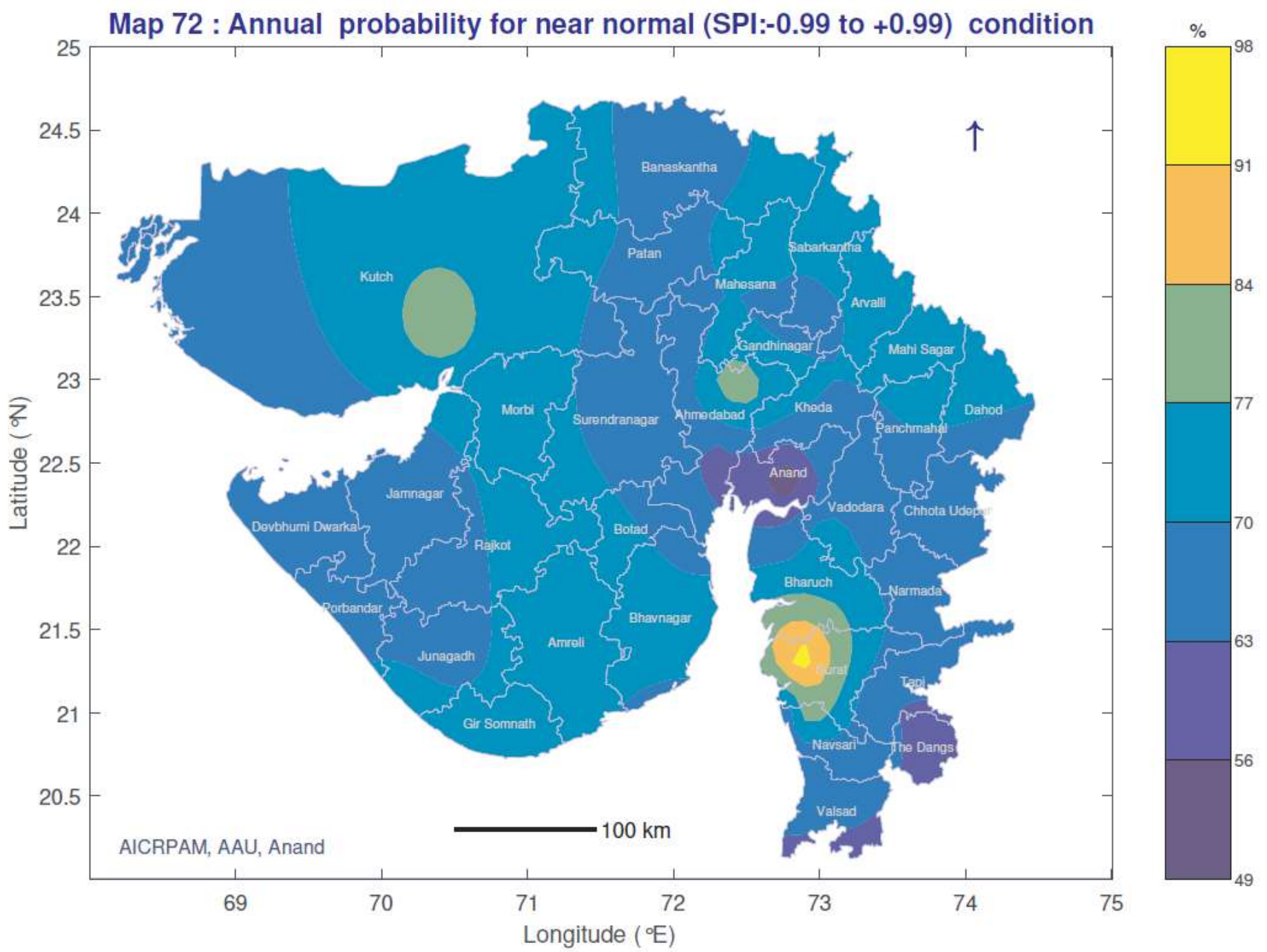
Traditional Water Harvesting and Conservation:
Dug Well Recharge
Village Pond / Tank
Tankas / Kunds / Kundis
Khadin
Vav / Vavdi / Baoli / Bavadi / Jhalara
Hill Slope Collection
Spring Water Harvesting
Rainwater Harvesting in Urban Areas
Rainwater harvesting can be harvested from the following surfaces:

- **Rooftops**
- **Paved and unpaved areas**
- **Water bodies**
- **Storm water drains**

Water Saving Technologies: Drip and Sprinkler Irrigation Systems
Improved Water Saving Farm Practices
Long-term Irrigation Management
Afforestation
Crop insurance
Community Participation in Drought Mitigation
Awareness and Capacity building


Map 70 : Probability of severe drought (> 50 % deficit) for Gujarat
%
35
30
25
20
15
10
5
0
Latitude (°N)
25
24.5
24
23.5
23
22.5
22
21.5
21
20.5
Longitude (°E)
69
70
71
72
73
74
75
Banaskantha
Patan
Kutch
Sabarkantha
Mahesana
Arvalli
Gandhinagar
Mahi Sagar
Morbi
Surendranagar
Ahmedabad
Kheda
Dahod
Panchmahal
Jamnagar
Anand
Vadodara
Chhota Udepur
Devbhumi Dwarka
Rajkot
Botad
Bharuch
Narmada
Porbandar
Bhavnagar
Amreli
Junagadh
Surat
Tapi
Gir Somnath
Navsari
The Dangs
Valsad
100 km
AICRPAM, AAU, Anand


Map 71 : Probability of moderate drought (26 - 50 % deficit) for Gujarat
%
30
25
20
15
10
5
0
Latitude (°N)
25
24.5
24
23.5
23
22.5
22
21.5
21
20.5
Longitude (°E)
69
70
71
72
73
74
75
Banaskantha
Sabarkantha
Patan
Kutch
Mahesana
Arvalli
Gandhinagar
Mahi Sagar
Morbi
Surendranagar
Ahmedabad
Kheda
Dahod
Panchmahal
Anand
Jamnagar
Vadodara
Chhota Udepur
Botad
Rajkot
Bharuch
Narmada
Bhavnagar
Amreli
Surat
Tapi
Navsari
The Dangs
Valsad
100 km
AICRPAM, AAU, Anand


Map 72 : Annual probability for near normal (SPI:-0.99 to +0.99) condition
%
98
91
84
77
70
63
56
49
Latitude (°N)
Longitude (°E)
25
24.5
24
23.5
23
22.5
22
21.5
21
20.5
69
70
71
72
73
74
75
Banaskantha
Patan
Sabarkantha
Mahesana
Arvalli
Kutch
Gandhinagar
Mahi Sagar
Morbi
Surendranagar
Ahmedabad
Kheda
Dahod
Panchmahal
Anand
Jamnagar
Vadodara
Chhota Udepur
Devbhumi Dwarka
Botad
Rajkot
Bharuch
Narmada
Porbandar
Bhavnagar
Amreli
Junagadh
Tapi
Gir Somnath
Navsari
The Dangs
Valsad
100 km
AICRPAM, AAU, Anand

Thank you