Drought disaster challenges and mitigation in India: strategic appraisal

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Drought is the most widespread hydro-meteorological syndrome of 'prolonged period of water scarcity affecting natural resources, environment and, thereby, the people'. Environmental changes, viz. climate change, land-use changes and natural resource degradation have aggravated drought occurrences and vulnerability, thus disrupting the normal socio-economic settings. All the regions of India suffer with drought incidences of varying periodicity, with 13 states repeatedly declared as drought-prone. Complexities of drought symptoms and impacts have sought for an understanding of an ecosystem approach for drought management, rather than as a hardcore meteorological discipline. Regions of Rajasthan, Bundelkhand, Karnataka and Orissa are typical examples of drought-related deprivation and resultant conflicts, whereas drought in states like Chhattisgarh, Punjab, Haryana, etc. are the result of improper agriculture practices and poor water management. In this article, the strategies of drought monitoring, data management, impacts and mitigation approach are critically assessed in the Indian perspective. Integration of drought management with the framework on natural resources and climate-change adaptation at different levels have also been discussed.

Keywords: Assessment, drought management, mitigation, relief.

DROUGHT is a complex, slow-onset phenomenon of ecological challenge that affects people more than any other natural hazards by causing serious economic, social and environmental losses in both developing and developed countries. The period of unusual dryness (i.e. drought) is a normal feature of the climate and weather system in semi-arid and arid regions of the tropics, which covers more than one-third of the land surface and is vulnerable to drought and desertification[1]. A drought is an extended period where water availability falls below the statistical requirements for a region. Drought is not a purely physical phenomenon, but instead is an interplay between natural water availability and human demands for water supply[2]. There is no universally accepted definition of drought. It is generally considered to be occurring when the principal monsoons, i.e. southwest monsoon and northeast monsoon, fail or are deficient or scanty. Monsoon failure causing crop failure, drying up ecosystems and shortage of drinking water results in undue hardship to the rural and urban communities[3]. Although droughts are still largely unpredictable; they are a recurring feature of the climate. Drought varies with regard to the time of occurrence, duration, intensity and extent of the area affected from year to year[4]. Land abuse during periods of good rains and its continuation during periods of deficient rainfall is the combination that contributes to desertification[5].

Dry regions in India include about 94 mha and about 300 million people (one-third of India's population) live in these areas; more than 50% of the region is affected by drought once every four years[6]. Different countries and states have developed codes, manuals, procedures, processes and policies for monitoring and management of drought with varying understanding. Over the years, India has developed a fairly elaborate governance system of institutionalized drought monitoring, declaration and mitigation at different levels[7]. India's response to the need for enhanced drought management has contributed to overall development. For example, the drought of 1965–1967 encouraged the 'green revolution', after the 1972 drought employment generation programmes were developed for the rural poor; the 1987–1988 drought relief effort focused on preserving the quality of life[6].

Drought: causes and effects

Drought is defined in many ways, like, 'a period of dry weather'[1]; 'a condition of abnormal dry weather resulting

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in a serious hydrological imbalance, with consequences such as losses of standing crop and shortage of water needed by people and livestock'[8]; 'a temporary reduction in water or moisture availability significantly below the normal or expected level for a specified period', and 'a creeping situation of scarcity without recharging of resources'[9]. The variables[10] to be used are, for example, rainfall, run-off aquifer level; duration considered – annual, seasonal, instantaneous minimum; truncation level – percentage, quartile, standardized anomaly, and area of region – single site, river basin, country zone, etc. Common causes for drought in India are summarized in Figure 1. Drought has been categorized under different classification systems based on the characteristics of occurrence (Table 1). Drought is responsible for many direct and indirect economic, social and environmental consequences throughout the world. Certain impacts are unavoidable but can be reduced significantly through planned interventions, whereas few other impacts can be mitigated by way of drought resistance.

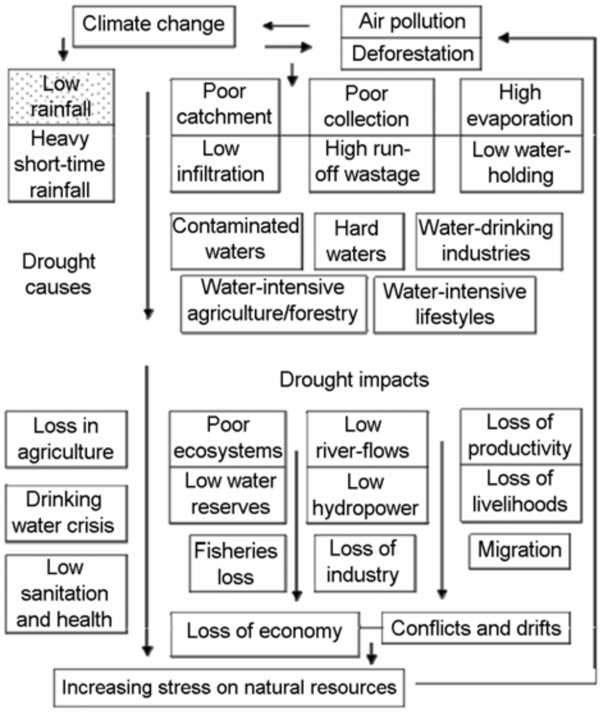

Figure 1. Common causes and impact of droughts.

Impact of drought: Indian scenario

The disaster risks associated with drought is a recurrent feature in India. There are evidences of continuous famine for 12 years during 310–298 BC during the region of Chandra Gupta Maurya. During a severe drought in 1917–1918, the River Jhelum dried up completely in Kashmir[1]. On an average, 28% of the geographical area of India is vulnerable to drought[7]. Meteorologically, ± 19% deviation of rainfall from the long-term mean is considered 'normal' in India. Deficiency in the range 20–59% represents 'moderate' drought, and more than 60% is 'severe' drought[7]. Aberrations in the total volume and pattern of rainfall from the SW monsoon are primarily responsible for droughts in India. Studies have revealed that El Niño phase of the Southern Oscillation (ENSO) too has impacted droughts in India. The country has experienced 22 large-scale droughts; five of them were severe[2].

The drought-prone areas are confined mainly to the peninsular and western parts of the country, and there are only few pockets in the central, eastern, northern and southern parts. These regions suffer drought mostly due to the cumulative effects of changing precipitation pattern, excessive water utilization and ecologically unsuitable agriculture practices[1]. It has been reported that 26 mha (795 mha of geographical area) is subjected to different degrees of water stress and drought conditions, which includes 38.7 mha of arid areas and of 7 mha of cold deserts[11]. About 107 mha of the country spread over administrative districts in several states is affected by drought[1] (Table 2). However, most drought response strategies in India accounted on net sown area or crop yield. Emphasis on ecosystems, particularly forests and wetlands, and urban drought is lacking.

Over the past 200 years India has faced a number of droughts (Table 3). Some of these were very severe, posed a threat to the food security and caused human mortality all over the country. Drought occurrence, people affected and impacts in India during 1900–2002 are shown in Table 4.

Drought assessment: tools and techniques

Drought risk is due to a region's exposure to this natural hazard in the context of its vulnerability to extended periods of water shortage[12]. To reduce the serious consequences of drought, a drought-prone nation or region must understand the temporal and spatial variation of the hazard and establish comprehensive and integrated drought early warning systems (EWS) that incorporate climate, soil and water supply factors such as precipitation, temperature, soil moisture, snow pack, reservoir and lake levels, groundwater levels and stream flow. Analysis of drought assessment after instrumental measurements is required, in addition to indices that are used as threshold in drought declaration.

Drought assessment parameters

Rainfall, temperature, evaporation, vegetation health, soil moisture, stream flow, etc. are some of the critical parameters that are used in drought risk analysis[13]. Continuous measurement and analysis of these parameters are

Table 1. Drought classification systems

Drought class	Conditions of drought and effects
Classification by British Rainfall Organization (BRO, 1936)	
Absolute drought	When there are at least 15 consecutive days with less than 0.01 inch of rainfall per day.
Partial drought	When there are at least 29 days having mean rainfall of 0.01 inch or less.
Dry spell	When 15 consecutive days receive less than 0.04 inch of rain per day.
Thornthwaite (1947) classification[1,14]	
Permanent	Characteristics of the desert climate, possibility of vegetation and agriculture only by irrigation.
Seasonal	Planting dates and crop duration should be synchronized with rainy season and residual moisture storage.
Contingent	Irregular occurrence and there is no regular season of occurrence.
Invisible	Occurs even when there is frequent rainfall and occurs in humid region.
Classification based on physical aspects[10,38–40]	
Agricultural	When soil moisture is inadequate to support healthy growth of crops, resulting in very low yield.
Hydrological	Associated with shortfalls in surface or subsurface water supply (stream flow, reservoir and lake levels, and groundwater) on a watershed or river basin-scale.
Meteorological	Related to the deficiency of rainfall compared to the average mean annual rainfall of an area.
Indian National Commission on Agriculture (1978)	
Meteorological	Normal precipitation below 25%.
Hydrological	Prolonged meteorological drought and drying of reservoirs, lakes, streams and rivers, cessation of spring flows and fall in groundwater levels.
Agricultural	Depletion of soil moisture during the growing season. A dry situation with 20% probability and rainfall deficiency of more than 25% in drought-prone states of India.

Table 2. Administrative districts frequently affected by drought

State	District
Andhra Pradesh	Anantapur, Chittoor, Cuddapah, Hyderabad, Kurnool, Mehaboobnagar, Nalgonda and Prakasam
Bihar	Munger, Nawadah, Palamau, Rphtas, Bhojpur, Aurangabad and Gaya
Gujarat	Ahmedabad, Amrely, Banaskanta, Bhavanagar, Bharuch, Jamnagar, Kheda, Kutch, Meshana, Panchmahal, Rajkot and Surendranagar
Haryana	Bhiwani, Gurgao, Mahendragarh and Rohtak
Jammu and Kashmir	Doda and Udhampur
Karnataka	Bangalore, Belgaum, Bellary, Bijapur, Chitradurga, Chickmangalur, Dharwad, Gulbarga, Hassan, Kolar, Mandya, Mysore, Raichur and Tumkur
Madhya Pradesh	Betul, Datia, Dewas, Dhar, Jhabuva, Khandak, Khargaon, Shahdol, Shahjapur, Sidhi and Ujjain
Maharashtra	Ahmednagar, Aurangabad, Beed, Nanded, Nashik, Osmanabad, Pune, Parbhani, Sangli, Satara and Sholapur
Odisha	Phulbani, Kalakhandi, Bolangir and Kendrapada
Rajasthan	Ajmeer, Banaswada, Barmer, Churu, Dungarpur, Jaisalmeer, Jalore, Jhunjhunu, Jodhpur, Nagaur, Pali and Udaipur
Tamil Nadu	Coimbatore, Dharmapuri, Madurai, Ramanathapuram, Salem, Tiruchirapalli, Tirunelveli and Kanyakumari
Uttar Pradesh	Allahabad, Banda, Hamirpur, Jalaun, Jhansi, Mirzapur and Varanasi
West Bengal	Bankura, Midnapur and Purulia

done by different agencies, and used in the assessment of climatic change and spatial distribution of drought conditions on a global, regional, drainage basin and local level event preparedness (Table 5). A nodal agency coordinates the information and analyses it prior to declaration of drought warnings.

Drought indices

Drought may be recognized most unmistakably through its economic consequences. However, it requires a scientific approach on the quantitative index of water shortage. A drought index value is a single number used for decision making. There are several indices that measure on how much precipitation for a given period of time has deviated from historically established norms[1].

Meteorological indices: This type of drought considers the degree of dryness, duration of the dry period, and specific atmospheric conditions that result in deficiencies for its description. Following are some of the suitable indices.

Table 3. Reported drought events in India over the past 200 years[26]

Period	Drought years	Period	Drought years
1801–1825	1801, 1804, 1806, 1812, 1819, 1825	1901–1925	1901, 1904, 1905, 1907, 1911, 1918, 1920
1826–1850	1832, 1833, 1837	1926–1950	1939, 1941
1851–1875	1853, 1860, 1862, 1866, 1868, 1873	1951–1975	1951, 1965, 1966, 1971, 1972, 1974
1876–1900	1877, 1883, 1891, 1897, 1899	1975–2000	1977, 1978, 1979, 1982, 1983, 1985, 1987, 1988, 1992

Table 4. Occurrence and effects of droughts in India during 1900–2002

Date	Location (state, region or district)	Effects
July 2002	Uttar Pradesh, Madhya Pradesh, Rajasthan, Punjab, Haryana, Delhi, Karnataka, Kerala, Nagaland, Orissa, Chhattisgarh, Himachal Pradesh, Gujarat, Maharashtra, Andhra Pradesh and Tamil Nadu	300,000,000 affected; damage – US$ 910,721,000
May 2001	New Delhi, Rajasthan, Gujarat, Orissa	20 deaths
November 2000	Mahasamund, Raipur, Kawardha, Rajnandgaon and Durg districts in Chhattisgarh region	
April 2000	Gujarat, Rajasthan, Madhya Pradesh, Orissa, Andhra Pradesh and Maharashtra	90,000,000 affected; damage – US$ 588,000,000
March 1996	Rajasthan	
March 1993	Bihar, Orissa, Andhra Pradesh, Maharashtra, Gujarat, Madhya Pradesh, Uttar Pradesh and Karnataka	1,175,000 affected
July 1987	Orissa	110 deaths
1987	Gujarat, Rajasthan, Orissa, Madhya Pradesh, Andhra Pradesh, Maharashtra and four Union Territories	300 deaths, 300,000,000 affected
11 April 1983	Kerala, Tamil Nadu and Rajasthan	100,000,000 affected
1973	Central India	100,000,000 affected
1972	Central India	100,000,000 affected; damage – US$ 50,000,000
August 1964	Mysore	166,000,000 affected
1964	Rajasthan, center	500,000 affected
1942	Kolkatta, Bengal region	1,500,000 deaths
1900	West Bengal	1,250,000 deaths

(i) Normalized deviation,

$$ND = (P_{tot} - P)/P,$$

where P_{tot} is the total annual precipitation (in mm) for a particular year and P the average annual rainfall for the area. The precipitation normally does not exceed double the mean precipitation in drought-prone areas. Hence the deviation ranges between +1 and –1. The negative index always indicates the deficiency in rainfall.

(ii) Dryness index,

$$I_d = 56 \times \log_{10} (120 \times T)/P,$$

where T is the annual average temperature (in °C) and P the annual average precipitation (in mm). The index becomes positive for dry climatic region and negative for mist climates. It is classified as arid extreme if >72, arid moderate 50–71 and arid mild < 50.

(iii) De Martonne's index,

$$I_A = P/(T - 10).$$

If the index is < 5, it is considered as true desert; 5–10 as arid zone and 20–30 as semi-arid zone.

(iv) Pluvothermic quotient,

$$PQ = (100 \times P/(T_M + \mathrm{T_m})/(T_M - T_m)),$$

where P is the precipitation (in mm), T_M is the average maximum temperature in the hottest month and T_m the average minimum temperature in coldest month. If PQ is < 40 it is desert, 60–100 semi arid and > 300 it is humid zone.

(v) Aridity anomaly index (AI)[14] describes the expression of water deficiency by the plants.

$$AI = (PE - AE/PE) \times 100,$$

where PE is water need of the plants, AE the actual evapotranspiration and $PE - AE$ denotes the deficit. In Penman's modified equation, PE is computed from water balance procedures, which consider the water-holding capacity of the soil. AI signifies the water shortage from a long-term climatic value. The difference between the actual AI for the week and normal aridity intensity is estimated and grouped into mild arid (0–25), moderate (26–50) and severe (> 50) by the India Meteorological Department (IMD).

Table 5. Drought assessment parameters, measurement and data use

Parameter	Measuring instrument	Use of data in drought declaration
Rainfall	Recording and non-recording rain gauges	Indian Meteorological Department declares an area as drought or moderate drought region, which receives annual rainfall less than 75% or 20–25% of normal.
Temperature (maximum and minimum)	Thermometers	Information is used in the estimation of evaporation from the surface water storage reservoirs, except to indicate the sweat factor or chillness of a place.
Evaporation and evapo-transpiration	Pan evaporimeters and percolation gauges and lysimeter	Data are used in water loss estimation from the reservoirs and plants, and demand and supply analysis.
Soil moisture	Estimation from change in the weight of native soil and after removal of water through oven-heating. Using soil moisture sensors, e.g. SMR-1. Passive microwave radiometric techniques.	Information is used by the irrigation Department/ water authorities in water release scheduling.
Reservoir water level and river flow	Calculation of volume in reservoir by daily water-level measurement. River gauge stations to monitor river flow between two stations	During the low-rainfall year threshold level and volume of the previous drought events are taken into consideration prior to stoppage/cut in the water release or supply from the reservoir. Flow level at a station is compared with the previous records, in deciding the imminent drought situations over the adjoining areas.
Crop area and yield	Healthy vegetation assessment carried out on ground level as well as through remote sensing method.	The shrinkage in the area of vegetation cover, vegetation vigour status, phonological condition, etc. are considered as indirect evidence of drought situation.

(vi) The Bhalme and Mooley index is also known as accumulated negative moisture index (NMI). NMI values are classified between normal and extreme drought by Palmer's drought intensity classification.

$$\text{NMI}(M) = 100(P_{\text{m tot}} - P_{\text{m mean}})/e,$$

where $P_{\text{m mean}}$ is the monthly mean over N years of observation, $P_{\text{m tot}}$ the total monthly rainfall, M the month under considerations and e the standard deviation. NMI demarcates the boundary conditions between monthly moisture conditions.

(vii) Percentage of normal precipitation is one of the simplest methods and best suited for the needs of general audiences through TV, in experiencing variation. It is estimated by dividing the actual precipitation by normal precipitation (30 years mean) and expressing it as percentage.

(viii) Standardize precipitation index (SPI) quantifies the precipitation deficit for multiple timescales. It helps in issuing warnings of drought and helps in the assessment of drought severity. The calculation is done on the long-term basis. This long-term period is fitted to a probability curve and then transformed into a normal distribution so that the mean desired period is zero. A drought event occurs when the SPI is continuously negative and reaches an intensity where SPI is –1.0 and it terminates when it becomes positive. Further, SPI could be calculated for all the months/weeks within the drought event.

(ix) Palmer drought severity index (PDSI) is a soil moisture algorithm. It is based on a supply and demand model of soil moisture. Supply is comparatively straightforward to calculate, but demand is more complicated as it depends on many factors like temperature, amount of moisture in the soil, evapotranspiration and recharge rate (a potential drought). The index has proved most effective in determining long-term drought of several months and is not as good with forecasts over a matter of weeks. It uses '0' as normal, and drought is shown in terms of (–) numbers; for example, –2 is moderate drought, –3 is severe drought and –4 is extreme drought.

Hydrological indices: Droughts are those periods of time when natural or managed water systems fail to provide enough water to meet the established human and environmental uses, due to natural shortfalls in precipitation or stream flow. The persistence of hydrological drought for 20 or more years is due to several land surface feedback combinations[15].

(i) Water budget method is used for drought assessment.
(ii) Surface water supply index is calculated for a river basin, stream flow, precipitation and reservoir storage. It represents water supply conditions unique to each basin or water management requirements of each basin.

(iii) Reclamation drought index is calculated at the river basin-level. It is a tool for defining drought severity and duration, in addition to prediction of onset and end of drought periods. It allows states to seek assistance for mitigation measures.

Agriculture index: Crop moisture index uses a meteorological approach to monitor week-to-week crop conditions and evaluate moisture conditions across major crop-producing regions.

Data analysis

Drought monitoring and assessment is done through analyses of variables such as rainfall, stream flow and soil moisture data on a variety of timescales[16].

There are several methods that are applicable in this process. Frequency or probability-based methods analyse the low flows or low flow volume during a specific period[17]. Regression-based methods bring out the relationship between the drought parameters such as geomorphic and/or climatic factors, crop-yield factors, etc. with severe drought events[18]. In the theory of runs-based methods; the probabilistic structure of duration (run length) and severity (run sum) of a drought are analysed using the notion runs. Drought parameters such as longest duration and largest severity are analysed[19], based on the time series of random or Markovian variables. Discrete autoregressive and moving average processes model the variability of wet and dry years[20]. Group theory-based methods show the duration and lengths, as groups and cluster of groups. Datasets are analysed to develop drought prediction and forecasting techniques utilizing the concept of pattern recognition[18] and neural networks[21].

The PDSI-based methods, the time series of PDSI are synthesized to identify and characterize the severity of droughts. Since PDSI series display a Markovian structure, such indices and their derivatives have been the focus for forecasting of agriculture droughts[22]. Moisture adequacy index (MAI)-based methods: It is a measure of the degree of soil-moisture availability for plant growth. The Food and Agriculture Organization (FAO) of the United Nations has developed an algorithm to generate MAI time series for characterization of agricultural droughts and their severity[18].

Remote sensing and geoinformatics application

The process of resource exploitation and land-use patterns, migration and environmental degradation are responsible for the changing patterns of drought. Accurate, efficient and reliable information on drought hazard with spatial and temporal coordinates and attributes is necessary to communicate the potential risk to the specific vulnerable parts of the society.

Early warning and alert messages based on scientific monitoring techniques and methods would minimize the severity of the tragedy. The advancements made in the orbital satellite technology could aid in mapping the disaster area, prediction/forecasting of impending disaster, and disaster relief management[1]. A number of satellites are available for weather forecasting, earth surface observations, monitoring and assessment. Table 6 enlists the features of the meteorological and communication satellites for drought observation purposes.

The information from the NOAA, METEOSAT, INSAT and GMS, NOAA/AVHRR and IRS/WiFS, SPOT 4, DMSP/SSMI and IRS–P4/MSMR, TRMM, RESOURCESAT, MODIS and MERIS and LANDSAT, IRS and SPOT satellites are being used for prediction, vegetation-cover monitoring/early warning, drought information monitoring and drought management purposes[1].

GIS provides wider application of merging cartography, statistical analysis and database technology, for collation and interpretation, mapping and overlaying the attributes available as rater or vector data or non-spatial data on various aspects of drought risk and vulnerability. The benefit of using GIS over other conventional methods is mainly in handling large amounts of data in various scales and in bringing these on a map. GIS is significantly useful in combining spatial data from different sources together to identify and describe spatial associations present in the data and use the models for analysis and prediction. A number of methods are used to achieve this, viz. database query, overlay, proximity analysis, network analyses, digital terrain model, and statistical and tabular analyses.

Drought management and challenges

Unsustainable land and water management practices are the main culprits of drought intensification in both developing and developed nations[23,24]. In many situations, drought assistance or relief measures provided by governments and donor agencies exacerbate the societal vulnerability to drought and also move societies away from their traditional wisdom and pro-active risk management approach, making people more dependent on externalities.

The goal of risk management is to promote adoption of preventive or risk-reducing mechanisms and strategies that will mitigate the impacts of future drought events, and thereby reducing societal vulnerability. This paradigm shift in disaster management emphasizes preparedness, mitigation and improved EWS over emergency response and relief assistance[12]. Thus, the role of science and technology in sustainable drought management needs to be propagated and popularized. A drought management strategy consists of the following components.

Table 6. Weather and communication satellites[1]

Spectral band	Tiros-N	NOAA – 6, 8, 10	NOAA – 7, 9, d, H, I, J
(A) Meteorological satellite			
1	0.55–0.90	0.58–0.68	0.58–0.68
2	0.725–1.00	0.725–1.00	0.725–1.00
3	3.55–3.93	3.55–3.93	3.55–3.93
4	10.50–11.50	10.50–11.50	10.50–11.50
5	Nil	Nil	11.50–12.50
Altitude resolution	833–870 km		
Image swath width	Large area coverage – 1 km; Global area coverage – 4 km		
Repeat coverage	2253 km		
TIROS (USA) 1965	Daily worldwide		
MIBUS 1964–1978	Measurement and picture transmission		
NOAA	Night-time picture, TV coverage and 24 h weather		
Geo-stationary	Severe storm support, geo-stationary, atmospheric condition		
Operational environmental satellite	Rainfall, volcanic eruption, fire detection, oceanography		
(B) Communication satellite			
Satellite:	Functions:		
Starsys			
Worldstar	Global message/position services		
Teledesic-LEO			
Irridum	High-speed computer link		
INSAT 2E (Launch)			
2A 10-7-1992	Communication 12-transponders normal C		
2B 23-7-1993	5-transponders lower C		
2C 7-10-1995			
INSAT 1-1990			
3A 2000-2001			

Drought assessment

This can be done either by monitoring the drought-causing conditions or by predicting and forecasting the weather conditions.

Monitoring: Technical/scientific means of monitoring are necessary to provide early warning of droughts and to also provide an objective and transparent definition of droughts to be used in the allocation of resources[1]. But, at present the use of information available is partial and unsystematic. It requires strengthening of the institutional relationship between early warning and decision making.

Predictability: As drought is very much linked with the performance of the monsoon, it can be predicted by monitoring rainfall over the target region and taking into account previous rainfall history of the monsoon seasons.

Vulnerability analysis: Vulnerability expresses the degree of susceptibility to a hazard. Its analysis bridges the gap between impact assessment and policy formulation by directing attention to the underlying causes rather than post-disaster impacts[1,12]. Vulnerability to drought is dynamic and is influenced by a multitude of factors, including population growth and regional shifts in population, urbanization, technology, government policies, land-use and other natural resource management practices, desertification processes that reduce the productivity and the natural resource base, water use trends, and level of environmental awareness. Individually, these factors are important because they may increase or decrease vulnerability[25].

Early warning system

The objective of designing an EWS is to keep track of leading indicators (agro-climatic, market socio-economic indicators and late anthropometric indicators) to get ample lead-time to intervene at the drought onset phase itself. However, most interventions based on late indicators force the governments to adopt a crisis management approach to deal with drought-induced food insecurity stresses. There are many deficiencies in this approach, as it does not reduce vulnerability to drought in the long-run[26]. The effective warning systems should have meteorological/agricultural information, production estimates, price trends of food and feed, availability of drinking water and household vulnerability, so that a variety of indices related to production, exchange and consumption could be addressed[27].

Mitigation

Drought can be mitigated by two kinds of measures, either by adopting preventive measures or by developing a preparedness plan (Table 7). Preparedness refers to

Table 7. Preventive measures and preparedness plan for drought mitigation

Preventive measures	Preparedness plan
• Dams/reservoirs and wetlands to store water • Watershed management • Water rationing • Cattle management • Proper selection of crop for drought-affected areas • Levelling, soil-conservation techniques • Reducing deforestation and fire-wood cutting in the affected areas • Alternative land-use models for water sustainability • Checking of migration and providing alternate employment • Education and training to the people • Participatory community programmes	• Improvement in agriculture through modifying cropping patterns and introducing drought-resistant varieties of crops • Management of rangeland with improvement of grazing patterns, introduction of feed and protection of shrubs and trees. • Development of water resource system with improved irrigation, development of improved storage facilities, protection of surface water from evaporation and introduction of drop irrigation system • Animal husbandry activities can help in mitigation with use of improved and scientific methods

pre-disaster activities to increase the level of readiness, or improve operational and institutional capabilities for responding to a drought[28]. In order to delineate an implementable drought mitigation strategy, risk areas are identified on the basis of historical records to establish priority zones for comprehensive and integrated development programmes aimed at drought proofing and mitigation. Mitigation can be scientifically equated with 'resistance' as a combination of avoidance, tolerance and resilience.

Relief measures

State Governments in India have their relief manuals/codes with a prescribed role for each Department/officer in the State for managing natural disasters. These are reviewed and updated periodically based on the experience of managing the disasters and the need of the regions. The policy and the funding mechanism for provision of relief assistance to those affected by natural calamities are clearly laid down. These are reviewed by the Finance Commission appointed by the Government of India every five years. The Finance Commission makes a recommendation regarding the division of tax and non-tax revenues between the Central and the State Governments and also regarding the policy for provision of relief assistance and their share of expenditure thereon. A Calamity Relief Fund (CRF) has been set up in each State according to the recommendations of the Eleventh Finance Commission. The size of the CRF has been fixed by the Finance Commission after taking into account the expenditure on relief and rehabilitation over the past 10 years.

The Government of India contributes 75% of the corpus of the CRF in each State. Twenty-five per cent is contributed to by the State. Relief assistance to those affected by natural calamities is granted from the CRF. Overall norms for relief assistance are laid down by a national committee with representatives of States as members. Different States can have state-specific norms to be recommended by a state-level committee under the Chief Secretary. Where the calamity is of such proportion that the funds available in the CRF will not be sufficient for provision of relief, the State seeks assistance from the National Calamity Contingency Fund (NCCF) – created at the Central Government level. When such requests are received, the requirements are assessed by a team from the Central Government and thereafter the assessed requirements are cleared by a high-level committee chaired by the Union Home Minister. In brief, the institutional arrangements for response and relief are well established and have proved to be robust and effective.

Drought management framework in India

The Government of India has devised many short-, medium- and long-term strategies to mitigate and overcome adverse effects of drought, and has implemented relief and development programmes in cooperation with the concerned states. These measures include ensuring availability of food grains and fodder, judicious use of surface and groundwater, prevention of migration of cattle camps, appropriate selection of crops, cropping sequences and agronomic practices, promotion subsidiary income of the affected people, and employment generation in rural areas.

In the last 20 years, India has evolved many new strategies to cope with droughts by a change from a purely relief focus to the present drought management strategy. Monitoring and declaration are important components of disaster management and governance in India (Figure 2). Drought declaration is announced when the rainfall is –20% to –59% (early warning), –60% to 99% (drought) and –1005 of normal (severe drought) conditions[1].

Current drought management mechanism includes institutional mechanisms, employment generation and social welfare practices, assistance/support by Central and State Governments, and operation of EWS.

Institutional mechanism

The Drought Management Group, under the chairmanship of the Cabinet Secretary to coordinate the efforts to deal with drought in various states. The members are Secretaries of the Ministries of Agriculture, Rural Development, Food, Woman and Child Development, Railways and Drinking Water Supplies.

The National Disaster Management Cell, monitors the drought situation in different states and resource availability (under the Ministry of Agriculture, Government of India). The National Centre for the Calamity Management (NCCM) under the Ministry of Agriculture was established to monitor all types of calamities and make recommendations about the extent of assistance to be released to individual states from the NCCM. Presently, the National Calamity Contingency Fund from the Government (under the Ministry of Home Affairs) deals with calamities of severe nature. The National Agricultural Drought Assessment and Monitoring System, 1989 provides scientific information at district level for most of the states and sub-district levels in a few states. Drought-Prone Area Development Programme and Desert Development Programme use the plans prepared on the basis of the integrated estimation.

Research institutions like the International Crops Research Institute for Semi-arid Tropics; Central Arid Zone Research Institute; Indian Grassland and Fodder Research Institute; Central Soil Salinity Research Institute; Indian Council of Forestry Research and Training and those under the Indian Council of Agriculture Research provide information on various aspects of drought management. IMD and the National Centre for Medium Range Weather Forecasting offer meteorological information support for drought preparedness and early warning[4,28].

The National Institute of Disaster Management and its Indo-German Cooperative Programme, Environmental Knowledge for Disaster Risk Management (ekDRM) and Hydro-meteorological Disaster Division focusing on climate change, land use and natural resource linkage with disaster management help promote the coordinated network for capacity building on drought risk management in the country, including research and blended training courses on decision support system, geoinformatics application and drought impact analysis.

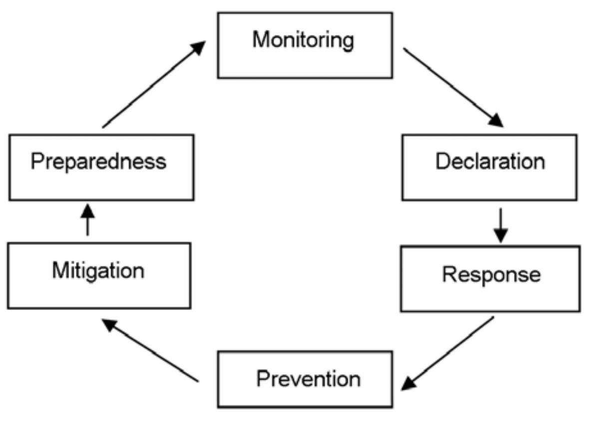

Figure 2. A schematic description of drought management cycle in India[28].

Employment generation and social welfare practices

Following are some schemes, which enhance employment and social security to people affected by drought, financially assisted by the Central Government[9]. Food for Work Programme, Employment Assurance Scheme (Rs 16.0 billion), Jawahar Gram Samridhi Yojana (Rs 16.5 billion), Pradhan Mantri Gram Sadak Yojana (Rs 5.0 billion). Antyodaya Anna Yojana, National Old Age Programme, Annapurna Scheme (Rs 3.0 billion), Integrated Child Development Scheme and Mid-day Meal – school children.

Assistance/support by Central and State Governments: Support by the government is through various departments or ministries in the relevant fields[1,29]:

1. Adequate availability of food grains at below poverty level rates, adequate advance stocks in feeder godowns and additional food grains of 40 kg/family/month under the PDS (Department of Food and Public Distribution).
2. Wages and employment programme with food for work (payment at work site) component in order to check migration.
3. Special health programmes for upkeep of health and nutritional levels of women, children, old and infirm people (Ministry of Health and Family Welfare).
4. Fodder and livestock management (Ministry of Animal Husbandry and Dairying).
5. Water and livestock movement by the Ministry of Railways for free of cost.
6. Prohibition of use of fossil water.
7. Roof water harvesting programmes (Rainfed Farming System, National Watershed Development Programme for Rainfed Areas).
8. Alteration in water rate structure to discourage use of groundwater for irrigation (Accelerated Rural Water Supply Programme).
9. Planning Commission approves plan allocation (assistance) for calamity prevention and preparedness, and
10. Tax exemption on donation/payment to relief activities (Department of Revenue).

Community participation: Community is the first responder, and thus community participation approach can play a key role in effectiveness of government efforts. In India, many committees and organizations have a participatory approach like:

- Gram Sabha/Panchayat recommend relief works.
- Districts and Block-level committees are involved in sanctioning and monitoring of relief works.
- NGOs play a significant role in training and motivation.

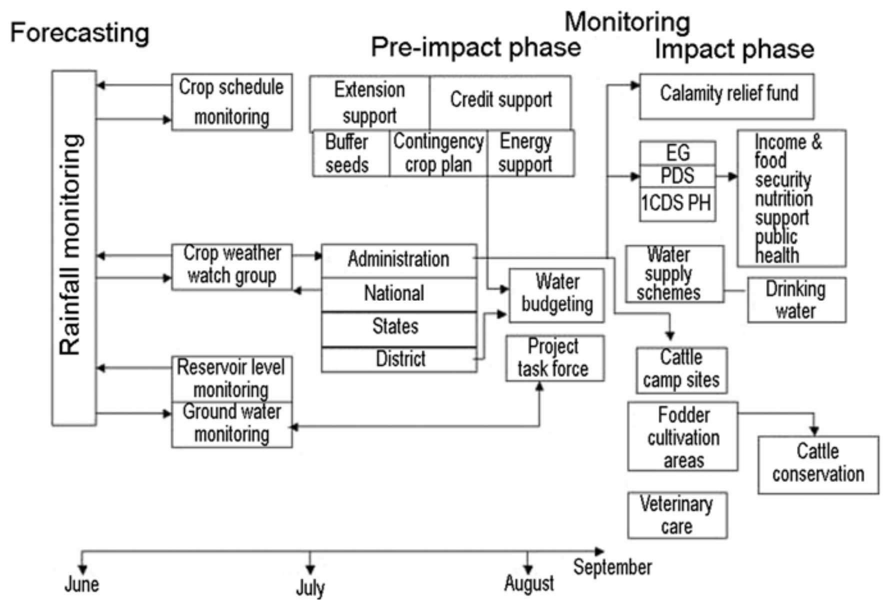

Figure 3. Drought early warning system[3,30].

Operation of EWS

There are two components of the National EWS: drought forecasting and drought monitoring. The drought forecasting function is carried out by the Inter-Ministerial National Crop Weather Watch Group (CWWG) which meets during the monsoon period from June to September. It monitors the impact of the monsoon on agricultural operations and also suggests corrective measures to minimize any possible adverse impact of aberrant monsoon conditions on crop production according to the standing contingency crop plan. In case the CWWG anticipates widespread adverse seasonal conditions, it sends out a report. This triggers the operationalization of an emergency contingency action plan for drought management, which envisages institutional arrangements and operating procedures for the drought monitoring system (Figure 3).

Rainwater harvesting

Key issues in policies, programmes and perspectives aimed at reducing drought or its adverse consequences for the poor need to emphasize on environmental conservation and management as a central strategy[30]. Drought proofing aims at permanent insurance against drought impacts through creation of water-harvesting structures like tanks or installation of tube wells; whereas drought escaping implies plantation of crops in such a manner that critical crop stages are able to escape the most probable period of drought. If any standing crop has been affected by drought, then management of the crop by thinning, mulching or any other practice will ensure survival of some crop[29,30]. The coping strategies could include abandoning a particular crop so as to concentrate resources on the next crop; shifting focus from crop to livestock, migration, borrowing, asset disposal, or other alternative livelihoods, etc.[31].

Water harvesting and conservation at basin, area, field or micro level can bring sustainability to the water sector and, consequently, increase water availability in drought years. In Rajasthan, and particularly in the low-rainfall western zone, there are several kinds of rainwater harvesting systems such as bawari, jhalara, talab, nadi, tanka, khadin, kund and harvesting of roof water. Among these, bawari and jhalara depend on groundwater, whereas talab, nadi, tanka, kund and khadin are based on harnessing surface run-off[32,33]. With the implementation of government schemes for domestic water supply in many areas, some of these systems were neglected. However, with increasing human population, shortfall in groundwater and recurring droughts, these rainwater harvesting systems are attracting growing attention. Modern technologies of rainwater harvesting and groundwater recharge such as anicut, percolation tank, subsurface barrier and pond with infiltration wells have recently been developed to rejuvenate the depleted freshwater aquifers[34].

Harvesting of roof water is an age-old practice to obtain safe drinking water, which is being revived and emphasized now. In ancient times, houses in western Rajasthan were constructed with stone and lime, and roof water was diverted to tankas[32]. Harvesting of roof water is being neglected because of pipe-borne water supplies even in rural areas, which is essentially based on groundwater withdrawal locally or in the vicinity[30]. Roof water harvesting is now becoming the order of the day in towns and in rural areas, due to the alarming rate of groundwater depletion. The estimated water yield from a 1500 m^2

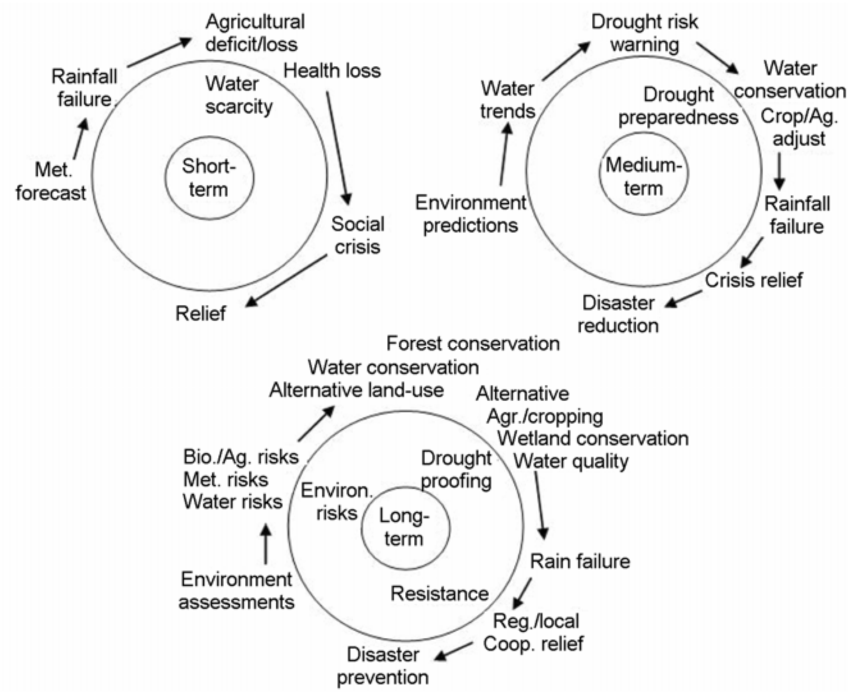

Figure 4. Drought risk management cycles[28].

roof top with an effective rainfall of 250 mm and a 0.8 run-off coefficient is 300 m^3, which is enough for a drinking water consumption of 30,000 person days at 10 l per capita per day[35].

Conclusion

The word 'drought' indicates scarcity of water for ecosystems, land and human use, resulting in failing crops, livestock, livelihoods and human health. Drought is a complex and least understood natural disaster, the impacts of which often depend upon the nature of socio-environmental background in the region, and affects more people than any other disaster. Within the framework of disaster management now, it is not viewed mainly as a meteorological or physical phenomenon but more often as a complex environmental or social challenge[28]. Unsuitability of water resources in terms of feasibility or water quality, water losses due to evaporation, over-exploitation and wastage, over use of water for non-agricultural and non-human purposes are some of the attributes aggravating agricultural drought and ecological crisis[36,37]. Most drought management strategies, manuals and guidelines still fail to recognize the scientific or strategic relevance of these aspects in causing or aggravating droughts.

Climate change and adaptation awareness have brought in the realization of the need to focus on natural resource and ecosystem approach for disaster management. The Ministry of Home Affairs, National Disaster Management Authority and Ministry of Agriculture, GOI have recently brought out a systematically developed *Drought Manual* and *Drought Disaster Management Guidelines*. Despite these being lengthy and comprehensive documents with excellent compilation of state-of-the-art literature critical gaps exist in recognizing the scientific understanding on systems approach. Figure 4 depicts important concerns of the drought management cycle in the short-, medium- and long-term context. The national disaster management guidelines according to the national policy prescribe a national action plan for drought mitigation as well.

The world is witnessing a second paradigm shift in disaster management, i.e. 'to ecosystem approach in climate-change adaptation and disaster risk management'. It is now important to work for alternatives to rainfall data-based drought prediction systems. Implications of global climate-change impacts coupled with local environmental modifications (land use, geomorphological changes, natural resource degradation) need to be assessed with the application of strategic environmental assessments. Suitable models of anticipatory environmental impact assessment can be developed further for long-term drought risk management. While drought management integration with programmes of forestry, watershed, public health, pollution control, wetland conservation, and biovillage concept are recognized now, linkages with the management of epidemics, forest fire and pest, environmental health, power generation, and socio-political conflict, including risk of terrorism and war-related disasters still need to be institutionalized[28]. It is also important to recognize the issues of 'urban drought' and 'water drinking industries' (Figure 1) while developing the drought management framework.

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