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DEVELOPMENT OF DROUGHT RESPONSE PLAN
- WATER AVAILABILITY

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PREFACE

Drought is a major factor of uncertainty that continues to hunt Indian agriculture and economy. The year 1987 reminds us as one of the worst drought spell in the recent times affecting two-third geographical coverage of the country and casting the national exchequer 1500 crores of rupees alone in drought relief measures; real cost in terms of damage to agriculture, live-stock population, drinking water supply and socio-economic imbalances are many times more. The primary objective of the drought management plan is to prevent dislocation of the economic activities and to minimize the impact of hardship due to water shortage in the drought affected areas.

Successful drought management depends on the blending of several ingredients aimed at ensuring effective amelioration of real distress with the optimum utilization of resources and setting up of an effective system for assessment and response activities during drought. A well designed drought management plan will be the key to expedite the decision making process and to reduce the response time required by the government to react to developing situation.

An attempt has been made in this study to develop a comprehensive drought management plan, by designing assessment and response activities separately. Development of such drought response plan by the states which are facing frequent drought scarcity situation may provide added incentives to governmental machinery for timely and systematic dealing with drought. It is hoped that this new approach will lead us towards a better future

where droughts may visit us - but will not cause us of a suffering. This study has been carried out by Shri R P Pandey, Scientist B of Drought Studies Division under the guidance of Dr G C Mishra, Scientist F.

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ABSTRACT

The occurrence of drought in past have affected many aspects of social and economic life of the country, especially activities such as agriculture, municipal water supply, forestry, industry, commerce, wild life preservation and fishery. Shortages of water and possibility of a subsequent drought arise because of significant changes in the availability conditions of water for supply and to meet the demand.

The recent widespread drought has resulted in severe adverse effects on food and agriculture production in many parts of the world leading to low market prices, a depressed economy, and population displacement. The response to drought should aim at making available timely and accurate data and information to enable government authorities to take remedial decisions. These data and information should include not only climatological information, but also information of the hydrological , special and economic impacts. A systematic description of important problem areas and the potential solution is necessary for effective and frugal government response in order to avoid over or under reactions. There is also a need to integrate the response of various private , public and governmental bodies, and maintain proper channels of communication and responsibility as the drought identifies.

The drought response system is developed with the view that it would avoid past problems, reflect needs that are pertinent to the current and expected conditions and ensure effective management of drought response in the long run. The system does not only incorporate the lessons learned and capability to take definitive action, but it would also be flexible enough to adjust

quickly to newer unexpected impacts. In order to deal with the complexities of emergency drought conditions, an assessment system has been kept separate from response system. The assessment system is composed of representatives of concerned agencies comprising a number of task forces. This system depends on the variety of data and information from a broad range of sources. The assessment system would work for drought monitoring, drought identification and impacts assessment. The response system would be responsible for any action to be taken to solve the particular drought problem. This includes decisions to make media announcements, funding and co-ordination of effort and resources, etc.

The criteria/indices of drought identification and plan activation is discussed in brief. Development of drought response plan could provide an idea of organizational structure to coordinate assessment and response activities of central and state government. Also the limited resources available to the government to mitigate the effects of drought could be allocated in an optimal manner.

1.0 INTRODUCTION

Drought has been the root cause of many famine in many parts of the world and more so in India. Among all the natural disasters, droughts affect large number of people in the world. From much of the ancient times to present times the drought has been a frequent hazard. A number of approaches have been adopted in various countries depending upon the availability of resources for drawing up strategies for combating drought. Efforts are on to develop drought forecasts so that the advance actions for meeting the situation can be taken. Many studies and research activities on drought have focused their attention on agriculture, forestry, environment, industry, water supply, geographical and natural factors for understanding and controlling drought problems. The efforts are lacking in the direction of organised response, evaluation and planning activities that provide timely and reliable assessments, such as a drought early warning system, and procedures for a coordinated and efficient response such as drought declaration etc.

The recent widespread droughts in indian subcontinent has resulted in severe adverse effects on food and agriculture production in many pats of the country leading to a depressed economy and population displacement. As a consequence in recent years, in view of frequent occurrence of drought and considerable damage as a result, attention has been paid for more careful planning for future droughts. Planning of droughts at state and federal levels is at considerable advanced stage in countries like Australia, Canada and USA., Planning for droughts is done either just before likelihood of its occurrence or during drought period. Such kind of planning often results in implementation of hastily

prepared strategies which ultimately had ineffective, poorly coordinated and untimely response. Therefore, if the planning were initiated between periods of drought, the opportunity would exist to develop an organized response that might address issues and specific problem areas more effectively.

In order to improve assessment and response capability of governmental authorities for organised coordination and implementation of drought mitigation measures in a timely manner,and to provide added incentives for decision makers for better dealing with severe water and food shortages caused by drought. Based on WMO model response plan and drought policies of US and Australia, an attempt has been made to develop an effective outline of a comprehensive drought response plan for the country.

OBJECTIVES:

The major objectives of the drought response plan are:

1. To provide timely and systematic data of drought causing variables.
2. To evolve criteria for drought identification and to establish effective drought indices.
3. To advise governmental authorities for timely and organised response to drought mitigation measures.
4. To design an integrated organizational structure to serve as an effective channel between the government and the public during drought.
5. To improve the methods of assessment of drought impacts.

2.0 RELEVANCE AND SCOPE

Drought alone is not sole reason for the occurrence of famine. The late implementation of mitigation measures, inefficient management of available water resources, shortsighted and improper planning, and poor coordinated response could have even greater negative impacts. Therefore, the development of reliable and effective drought plan to improve significantly the drought assessment and response capability of governmental authorities has become a crucial issue, if we are to guarantee timely and adequate response during drought.

Not enough relevant informations on past droughts of the country has been systematically arranged and compiled to permit drought characteristics for generalization of drought control strategies. Such an effort would assist to policy makers and institutions in developing efficient and organised approach to mitigate drought impacts.

The identification and quantification of drought phenomenon are still complex. There are no universally accepted definitions and indices determining drought and its characteristics . Establishment of well designed drought management plan will provide a comprehensive evaluation of the existing drought indices and would contribute for future drought studies, and will greatly provide better dealing with drought conditions.

3.0 HISTORICAL DROUGHTS IN INDIA

In the history of Hydrology the period prior to 1400 A.D. is considered as a period of speculation (chow-1964) due to lack of systematic records. But many vedic hymns, invoking rains and praying gods to keep people free from "Akal" and "Durbhiksha" refer to famines Hydrological phenomena indicated in ancient literature are described here. In Vedic literatures (12th Skandh of Mahabharat and Sidhant Shiromani), atmosphere is divided into 7 layers. The lower most, called Bhuvayu extends 12 Yojan (150 km) high and generates weather.

According to Vishnu Puran, there are four sources of atmospheric moisture namely, sea, river, earth and living bodies. In later part of Yajurved, monsoon season is described as 'Salil vat' . In Arthshastra (Kautilya) and Vrihat Sanhita (Varah Mihir) the normal rainfall distribution over the country has been described. It is stated that desert areas receive 16 dronas of rain and humid parts get double of it. the temporal variation of seasonal rainfall is considered even, if 1/3rd of it falls towards the end of rainy season and 2/3rd in the middle. The Arthshastra and vrihat Sanhita, both describe the technique of rainfall measurement in detail.Rainfall was measured as weight of the water collected in specified vessel (Kumbh). the units were Pala, Arhak and Drona.

There are evidences of terrible famine which lasted for continuous twelve years (310 to 298 B.C.) in the empire of Chandra Gupta Maurya. In another severe drought in Kashmir (1917-18) the river Jhelum completely dried up. Rigveda gives a number of 'Parajanya Sukta' to induce rain through 'Vrishti yagya'. There is mention of irrigation schemes during Harappa and Mohanjodaro civilization based on the present day scientific

concept of storage, linkage, drainage and transportation.

Thus droughts have been an age old problem and people have suffered heavily in the rural area of Indian sub-continent in the past. Atleast one to two major famine occurred in every fifty years in pre-British period. During the period of 1765 to 1858 the country experienced 12 major famines and 4 severe scarcities Between 1860 to 1908 famine or scarcity prevailed in one part of the country or the other. Some important famines in India which needs to be mentioned were: famine in North Western Provinces., Punjab, Rajputana and Kutch (1860-61), famine in Orissa, Bengal, Bihar and Madras (1865-66); famine in Rajputana, North Western Provinces., Central Provinces and Bombay (1866-70), famine of Bengal and Bihar (1873-78); famine North Bihar, Tributary states of Orissa and Bengal (1888-89) famine in Bundelkhand, Bihar, Bengal, Bombay, Madras, North Western provinces and Oudh (Agra and Oudh) 1896-97; famine Central, Western and Southern India (1899-1900). Many worst drought years of 20th century, which have affected various parts of western, central, southern and eastern India were as follows:. (1901, 1905, 1907, 1918, 1920, 1941, 1943 Bengal famine), 1951, 1965, 1966(Bihar famine), 1969, 1972, 1974, 1976, 1979, 1982, 1987, and 1991).The droughts in past 200 years are listed in table 3.1.

Table - 3.1 The droughts in Past 200 years :

Quarter of the century	Frequency of droughts	Years
1801-25	6	1801,04,06,12,19,25
1826-50	3	1832,33,37
1851-75	6	1853,60,62,66,68,73
1876-1900	5	1877,83,91,97,99
1901-25	7	1901,04,05,07,11,18,20
1926-50	2	1939,41
1951-75	6	1951.65,66,71,72,74
1976-91	4	1979,82,87,91

(Source : Upadhyay 1989)

The historical records of droughts and famines as mentioned above indicate that more or less, they had been occurring over specific geographical territories. Thus, it reveals that certain areas such as Bihar, Rajasthan, Bengal, Gujarat, Maharashtra, Andhra Pradesh, Madhya Pradesh and North Western Provinces are more drought prone than the other parts of the country.

4.0 REVIEW OF DROUGHT PLANS

4.1 General: Whenever the droughts have occurred in the past, there have been few plans of action for drought relief and management. A brief review of few drought plans has been presented below

In Unites State and Australia the governments have played a key role in attempts to mitigate the impacts of drought. Government actions have usually taken the form of loans and grants to individual citizens, businessmen, and municipalities experiencing the hardship of drought. Donald (1986) reviewed and evaluated the recent drought policy in United States and Australia, the recommendations were offered on way to improve US approach. An operational drought plan was also suggested through which the recommendations could be implemented.

Donald et al.(1985) reported that several states of US have recognized the value of drought emergency planning and have developed plans to assists them in responding more effectively to prolonged periods of water shortage. These states have created an organizational structure to coordinate the assessment and response activities of state and federal agencies. Each state's drought response plan is unique since each stage's water supply and management problem and their consequent impacts are unique. They reviewed the drought response plans developed by Colorado, South Dakota and New York in detail and yielded a number of recommendations for the other states which are affected by frequent and sever water shortages also develop drought emergency plans.

4.2 Gujarat Plan:

In view of dealing with the drought conditions in Gujarat, the attempts have been made during recent past droughts to streamline the drought management practices. The drought plan of Gujarat state has been effective and relatively good coordinated but it is realised that the response actions were too late and too inadequate(Koshi,1987). In Gujarat the expertise gained by administration in the management of drought proves that by careful planning, the drought can be predicted timely, and its impact can be successfully controlled. This drought plan comprises a drought monitoring system to detect onset of drought conditions),preparation of master plan and its implementation and vigilance squads.

The drought monitoring system is responsible for current monitoring of various parameters which would indicate the development of conditions signaling the onset of scarcity condition.The major parameter which are considered for drought warning are rainfall, reservoir levels, crop prospects, and ground water levels. The reports of district collectors play a great role for declaration of scarcity. During scarcity, conditions the district collector submit a full report to Govt on the following:

1. The nature of the principal crops grown normally whether cash of food crops and their relative extent
2. The estimated anna valuations of crops in the area with the actual anna valuations during the two preceding years.
3. The nature and conditions of the population
4. The extent of grain and fodder supply, with their normal and prevailing prices

5. The state of trade and the progress of exports and imports of food grains and fodder.

6. The trend of current agricultural and non-agricultural usages as compared with normal times.

7. The opportunities of employment available on agricultural operations and works started by Government, local bodies and big employers.

8. Mortality statistics.

9. Unusual movement of labours in search of employment.

10. The state of crime with special reference to petty gain theft

11. Any other facts which indicate signs of distress such as malnutrition among children.

The collector's report supported by statistical data and is therefore a very important element of the advanced drought warning for the state Government (Koshy, 1987).

All the above information is compiled and analysed at the office of the directorate of Relief which is the key permanent nodal agency. It provides these information to government to take formal decision on the declaration of drought conditions. During the monsoon or even before, the Directorate of relief is warned that the current monsoon is likely to be weak and an assessment of expected impact of the current situation on water availability, agriculture and the economic conditions of the people is made available to government for assessing a total picture of the developing drought situation in the state.

Once the drought situation is declared, the district wise master plan for affected regions are prepared. The master plan consists the planning for drought relief operations using the village as its basic unit. The district master plan aims at tackling the drought conditions in three ways.

i. Generation of employment

ii. Provision of drinking water

iii. Preservation of cattle wealth.

Various drought strategies in the master plan are implemented through existing Govt. departments. To meet the drought situation various relief committees are set up at Taluk and district level consisting of both officials and non-officials. At government level a senior officer of the rank of Secretary is designated as Commissioner of Relief to supervise and coordinate the relief administration. A cabinet subcommittee under the chairmanship of Revenue Minister of State is set up to review the relief operation.

The Government of Gujarat also constituted vigilance squads at district and taluk level . The purpose of the squads are to undertake surprise random checks at the work site where actual measurement would be made and payment checked and to initiate corrective actions for proper utilization of financial resources.

Thus the drought plan of Gujarat state is a plan for crisis management.The planning consist short term strategies which are implement to save the life but it has less provision to minimize the impact of drought an agriculture and water scarcity.

4.3 Maharashtra plan :

A copy of drought assessment and management system in Maharashtra was received from under Secretary Irrigation Department, Government of Maharashtra . Based on the copy supplied a brief note of Maharashtra Drought Plan is given below:

The declaration of drought in Maharashtra state is based on 'Nazar Paisewari'which is an eye estimate of crop conditions and on the report submitted by District Collector. The collector's

report includes the similar informations as discussed in the Gujarat plan.

The informations provided by district collectors is compiled at the office of the Secretary (Relief and Rehabilitation) in Revenue Department and conveyed to the decision makers at top Govt. level for declaration of scarcity conditions.

The scarcity relief measures generally adapted by the Govt. to provide timely succour to the affected population are as follows:

1. Priority is fixed for utilization of water stored in irrigation reservoirs.
2. Protection of standing Kharif crops.
3. Power supply to irrigation pumps on priority basis.
4. Suspension of recovery of Government dues.
5. Credit facilities to farmers through cooperative institutions.
6. Ban on transportation of fodder out of the affected district.
7. Augmentation of fodder supply through import
8. Distribution of fodder togai to needy agriculturists.
9. Fodder growing programme is undertaken on the lands of taluk seed multiplication centres & Agril.Univs.
10. Opening of cattle camps
11. Opening of relief works under employment guarantee scheme
12. Alternative measures for drinking water supply
13. Supply of agricultural inputs such as seed fertilizer to the drought affected farmers
14. Distribution of cash doles to infirm, blind, old etc, who cannot take up employment on relief works.
15. Public Health measures; District health centres andother

offices of the Public Health Department are responsible for implementation of Public Health measures like establishment of camps for medical facilities at relief work sites.

To ensure coordination and for smooth implementation of various drought relief measures executed by various departments, a departmental coordination committee is set up under the chairman ship of Chief Secretary of the Government and with other Secretaries and Heads of concerned department as members. This committee takes all the expeditious decisions on several matters concerned with the administration of relief and the provision of succour to the distressed population.

The inter-departmental coordination and monitoring of relief works is done by Secretary (Relief and Rehabilitation) of Revenue Department.

5.0 DEVELOPMENT OF DROUGHT PLAN

The consequence of several consecutive years of drought in different parts of the country has drawn our attention to develop drought plan at national and state level. Though the occurrence of drought cannot be prevented but being well prepared for its likely occurrence will tend to lesson its impacts on various fact of life. Various states like Gujarat, Maharashtra , Andhra Pradesh, Madhya Pradesh etc. have been implemented their own programme for drought management. This has indicated a growing belief among policy makers that the systematic planning can reduce significantly the potential impacts of water shortage induced by drought.

The local aspects of drought also influences the emphasis of the plan for example at one region there is a need to place more importance on agriculture, municipal water supply and wildlife preservation, and at second region emphasis are needed for municipal and industrial water supply and tourism and some other regions may need emphasis on agriculture only.

To provide an effective and systematic means to deal with complexities of drought problems which may occur over the short or long term, an assessment system should be established separate from response system. The assessmentsare produced continuously throughout the drought periods, but responses are made only when the needs and impacts are identified and assessed. The sectoral task forces would be set up to develop methodologies for drought assessment. The task forces would provide the monitored information to apex body to declare the existence of drought and its impacts. After the declaration of existence of drought the response system will be responsible for final drought assessment report as well as for drawing up of appropriate drought

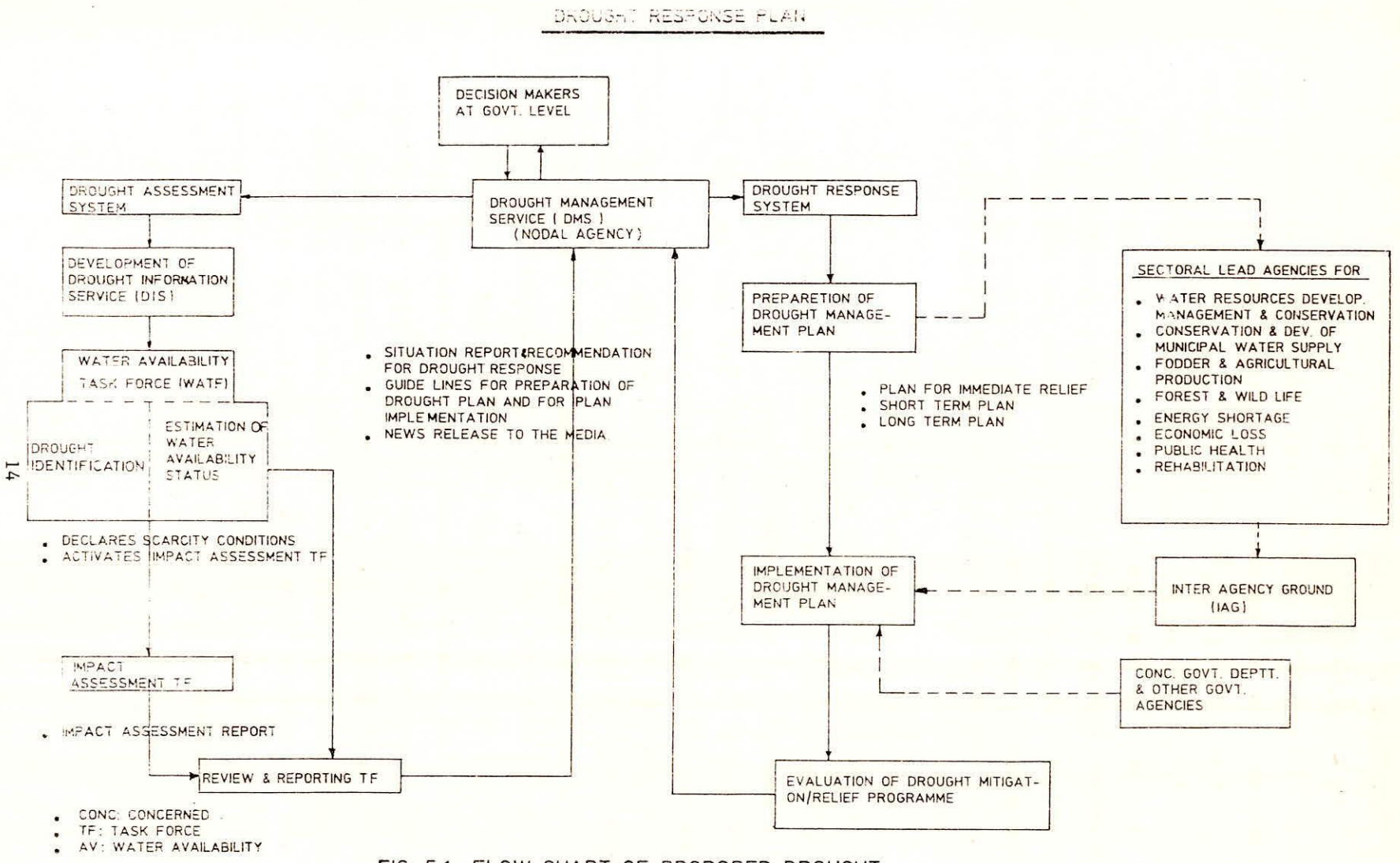

FIG. 5.1 FLOW CHART OF PROPOSED DROUGHT RESPONSE PLAN

response plan. A comprehensive outline of the developed drought response plan has been shown in flow chart (figure 5.1). The following sections describe the components of drought plan.

5.1 Assesssment System

The assessment system is responsible for gathering and evaluating data about the nature of drought conditions and their impacts on various sections. This system depends on variety of data and informations collected from various state departments/organisations and regional offices of central government operating in the state. The organizational structure for the assessment system is composed of representative organizations form task forces to develop and process information on water availability and drought impacts. Thus the assessment system would work for drought monitoring, drought identification, estimation of water availability status and impact assessment.

The water availability task force (WATF) is supposed to analyze the water situation and bring out a regular document monthly and advise to declare drought or not and also activates impact assessment task force (IATF) to asses extent of drought damage on various sectors. Review and reporting Task Force will prepare the recommendations based on the reports/informations received from WATF and IATF . Various organisation induced in different sectoral Task Forces under assessment system are given in Appendix I.

5.1.1 Drought Monitoring

In order to facilitate constant drought monitoring an integrated Drought Information Service (IDIS) would be established for gathering data/information from different concerned agencies for example, the rainfall data are generally recorded by meteorological organisation while the data on streamflow, ground

water levels, reservoir levels etc. by other organizations. On the other hand the data concerning cropped area, crop yield and land use statistics by revenue /agriculture department etc. The IDIC regularly monitors the drought related information. The tasks of IDIS are listed below:

1. Collection, processing and storage of meteorological, hydrological and allied data and disseminate the same to users, planners and researchers for drought management.
2. Monitoring of drought affects on agriculture, water supply, fodder, forest, hydroelectric energy production etc.
3. Monitoring of water quality conditions.
4. Monitoring of health and other problems.
5. Identify gaps in the data and their measurements, and suggest remedial efforts to concerned agencies.
6. Provide data/information to water availability task force regularly for drought identification and estimation of water availability in the region.

The data to be monitored and theirfrequency are listed in table :5.1.

Table 5.1 Data to be monitored for drought studies

S.No.	variable	frequency of observation	time of observation
1.	Rainfall	Daily/hourly	08.30
2.	Snow	Daily	08.30
3.	Pan evaporation	Daily	08.30
4.	Evapotranspiration	Daily	14.00
5.	Soil moisture	weekly	07.00
6.	Other routine meteorological data	daily	14.00
7.	Steam/river flow	daily (thrice a day)	08.00,13.00 and 18.00
8.	Reservoir (inflow, outflow levels)	daily	8.30

9.	Ground water table	weekly	-
10.	River water quality	1/2 monthly	-
11.	Ground Water Quality	pre and post monsoon	-
12.	Water use		
	municipal water use	daily	
	agricultural water use	seasonal	-
	source wise irrigated areas	seasonal	-
	source wise water domestic users	seasonal	-
	Water demand for domestic & cattle uses	monthly	-
	Industrial water uses	monthly	-
13	Land use		
	crop cropping pattern	seasonal	-
	area under each crop	seasonal	-
	area under dry and rainfed agriculture	seasonal	-
14.	Catchment details hydrological structure		
	of gauging sites	yearly	-
	Soils and land use	yearly	-
	Wells and tubewells	yearly	-
	Irrigation tanks	yearly	-
	Percolation tanks/ ponds	yearly	-
	Area affected by flood/drought	yearly	-
15.	General features (socio-economic details)		
	populations		
	human and animal	5 yearly	-
	occupation	5 yearly	-
	Land holdings	5 yearly	-
16.	Other related data	5 yearly	-

5.1.2 Drought Identification

The water availability task force (TF) receives relevant data/information from IDIS monthly and utilizes for analysis and interpretation of scarcity conditions. One cell of Water Availability TF works for drought identification and the other cell works for estimation of water availability conditions. Various existing threshold drought indices may be used for determination and identification of meteorological, hydrological or agricultural drought. Some of these indices have been discussed in section 5.1.4. The natural resources and environmental indicators for drought identification are:

Meteorological:

- Incidence of rainfall, amount, spatial and temporal distributions variation with respect to normal
- Ambient air temperature, relative humidity
- Solar radiation, surface isolation, potential evapotranspiration

Hydrological

- Hydrological extremes of low flows
- Depletion in surface water bodies
- Decline in soil moisture
- Lowering of ground water table
- Increase in irrigation water demand
- Decline in storage, required to meet prescribed draft on demand.

Agriculture:

- Decrease in crop acreage
- Reduction in crop yield
- Impact on crop vigor/crop stress

Ecological

- Decrease in area and vigor of vegetation
- Erosion and extinction of valuable soil cover complex.

The estimation of water availability status would be prepared by the second cell of water availability task force. It will be responsible for providing the following informations.

- Estimates of current water availability on reservoirs, lakes, groundwater storage, rivers, tanks, etc.
- Capability of natural water resources to deal with the situation
- possibilities of immediate water resources developments.
- Possibilities of future water resources developments.

etc.

The informations regarding drought identification and water availability would be regularly compiled and according to situation the water availability task force would declare the existence of drought conditions and activate to impact assessment task force.

5.1.3 Drought Impact Assessment

In order to enable to take up appropriate drought mitigation measures at right time and at right place and to clearly understand the extent of damages and other negative impacts caused by drought, the assessment of specific drought impacts on various sectors are necessary. As the drought is identified and declared the sectoral impact task forces assess the impacts of drought on various relevant sectors. The impact task force provides the impact assessment information to review and

reporting task force on the following

- Drought impact on ground water storage, reservoir storage, river/stream flow, tanks & lakes storage etc.
- Drought impact on agriculture (crop growth, soil moisture, crop yield etc)
- Drought impact on forest and wild life
- Drought impact on drinking water supply
- Drought impact on commercial and industrial water supply
- Drought impact on socio-economic conditions.

5.1.4 Definition and indices of drought for plan activation

The researchers, hydrologist and others have suggested various threshold indices to define drought situations. Some selected indices have been discussed in brief in this section. These may be useful for activation of proposed drought plan.

A commonly used simplest index has been to compare the depth of rainfall for a given period i.e. pentad, week, fortnight, month, season or year with long term mean or standard period, normal value of the given duration. Dry period can thus be designated when the ratio is less than unity. Drought severity would depend on the amount of current rainfall falling short by some percentage of normal corresponding to that place for that period. Ramdas (1950) defined drought as a week with actual rainfall to half of normal rainfall or less. Appendix III(a,b,c,) enumerate various definitions and the associated concept developed in a chronological order by various investigators.

Palmer Drought Index :

Palmer (1965) developed Drought Severity Index (PDSI) to describe prevailing drought conditions. PDSI is the primary tool currently used by various countries like USA, Australia ,

Canada etc. to identify the drought conditions and to activate their drought management actions. The recommendations were also made by WMO to activate such drought response plan on the basis of water availability index i.e. Palmer drought Index. The Palmer's water availability index is given in the table 5.2.

Table : 5.2 Palmer's water Availability Index.

Index	Character of weather
4.00 or more	extremely wet
3.00 to 3.99	severely wet
2.00 to 2.99	moderately wet
1.00 to 1.99	near normal
0.50 to 0.99	
0.49 to - 0.49	
-0.50 to - 0.99	
-1.00 to - 1.99	
-2.00 to - 2.99	moderate drought
-3.00 to - 3.99	sever drought
-4.00 or less	extreme drought

(Based on Palmer (1965) - Meteorological Drought. U.S.WB Research paper 45, Washington.)

A drought emergency may be declared when the Palmer Index reaches -2.00. The detailed computational procedure developed by palmer can be found in George et al. (1973), WMO (1975), and Sikka (1984).

It is well established that meteorological drought do not necessarily coincide with agricultural drought. It means an

agricultural drought may exist even through meteorological drought may not and vice versa. The agricultural drought indices have been mainly based on rainfall deficiency (both amount and distribution) and occurrence of dry spells, evapotranspiration, soil moisture deficit, and water. balance. Effect of these factors on crop yield is generally considered as a measure of drought.

Different limits of rainfall deficiency have been proposed by various workers and organization to study their impact on agricultural drought. It has been defined as an occasion when weekly rainfall in four consecutive weeks is half of the normal or less (normal weekly rainfall being 5 mm or more) in the period from middle of may to middle of october of six such consecutive weeks during the rest of the year (NCA, 1976, Malik et.al 1962-63).

The crop moisture index (CMI) is suggested by palmer (1968) to better reflect agricultural drought conditions for crop growing season in USA. it considers agricultural drought as an evapotranspiration deficit. It is applicable only for measuring short term (up to about 4 weeks), week to week status of dryness or wetness of growing crops. In India Bishion (1984) at Hissar developed new crop moisture Index to explain the crop conditions under dry land agriculture. The agriculture drought has been classified as under based on the crop moisture index values during growing season of crop:

Table : 5.3 Classification of Agricultural drought based on CMI.

CMI	Category of Agricultural drought
0.00 - 0.33	Extremely dry
0.34 - 0.75	Dry
0.76 - 1.00	Semi dry
1.01 - 2.0	Normal
2.01 - 3.0	Moist
3.01 - 4.00	Wet
more than 4.01	Extremely wet

The valve of CMI less than one is indicative of moisture stress during the crop growing season.

George et al(1973) while studying drought in India using PDSI indicated that in humid and moist sub humid areas. Palmer drought severity index may also represent hydrological drought. Based on surface water deficit Dezman (1982) developed surface water supply index (SWSI) to define hydrological drought conditions. The SWSI number is a general indication of basin wise surface water supply conditions which integrate historical data with current data of reservoir storage, stream flow and precipitation into a single index number. It generates monthly numerical values that express the current and future availability of water supplies to meet a multitude of competitive demands with an objectives that water supply conditions can be assessed to compare drought severity.

The drought assessment and response plan of Colorado and USA is implemented when SWSI and PDSI values exceeds specified thresholds.

A composite reservoir datum, snowpack datum, precipitation datum is found by summing monthly station data. Frequency analysis is carried out for each component of discharge

to find non exceedance probability (PN). As each component is reduced to one scale, comparisons among them becomes simple. Non exceedance probability analysis takes into account dispersion tendency also. SWSI can be found by using following weighting equation:

$$SWSI = \frac{[\ (axPN_{sf\ or\ sp}) + (bxPN_{pcp}) + (\ cxPN_{rs}) - 50]}{12} \quad \ldots\ldots(i)$$

where a,b, c - weights for each component, a+b+c =1

sf or sp, pcp, rs - streamflow or snowpack precipitation and reservoir components.

For each basin winter & summer a, b and c values are unique.

Now drought can be classified on the basis of SWSI values as shown in table 5.4.

Table 5.4 : Drought classification based on SWSI

SWI	Designation
+4	Abundant supply
+2	Near normal
-1	Drought water availability
-2	Task force activated
-3	Sever drought
-4	Extreme drought

The SWSI value less than -1 is indicative of situations to activate drought management actions.

5.1.5 Drought Assessment Task Forces

The following task forces will be required to be created:

1. Water availability Task Force:

This task force is required to collect and evaluate

following water availability data to make assessments and (i.e. changes in comparison to historical normals) on:

- Precipitation
- Stream/river flows
- Reservoir/tank levels
- Ground water levels
- Soil Moisture conditions
- Evapotranspiration
- Temperature
- Select or develop specific formats for reporting the above information
- Determine requirements and format for dissemination of special reports
- Analyse above data to give estimates of water availability/shortages on river basin wise to provide this information to impact task forces.
- Select a suitable index out of several available to classify the water availability condition . The index should be suitable to region
- Inform state headquarters about the beginning of drought and identification of water scarcity areas based on the selected index.
- Identify resource information and data gaps.

2. Impact Assessment Task Forces:

There may be number of task forces to study the impacts of drought on various aspects. In general, the tasks of all these are to:

- Identify existing drought related problems
- Anticipate the situations arising in case of continuing drought

- Assess impacts of drought on natural resources ,severity, societal, impacts, economy etc.
- Reports finding to a) Review and Reporting TF, b) response or relief agencies and c) Economic task force etc.

Important Impact Assessment Task Forces and their specific tasks areas are described below:

i) Municipal Water Supply TF:

- Identification and assessment of available municipal water supply sources like reservoirs/tanks, direct streamflow and ground water
- Capacity of available municipal water supply sources to meet out drinking water supply, cattle needs during drought
- Capacity of available municipal water sources to meet demand of other such uses like industrial, fire fighting etc.

ii) Fodder and Livestock TF:

- Identification of water points for live stock
- Assessment of feed and fodder availability to support the cattle population
- Assessment of drought impact on fodder production and live stock migration and losses.
- Identify possible sources of feed and fodder from nearby areas
- Make suitable recommendations to public and concerned authorities regarding possible remedial measures.
- Make projections of drought impact in cattle migration in worst hit situation indicating possible place of migration

iii) Agricultural Task Force:

- Collecting damage assessment data to analyze the impact of drought on agriculture
- Identify sources of assistance and response action
- Emphasize agricultural damage i.e. agricultural production losses and soil erosion.

iv) Energy loss Task Force:

- Assessment of potential reduction in hydro-electrical energy production
- Additional sources of energy to meet the energy crisis.

v) Economic and social Task Force :

- Assessment of aggregate economic loss from other impact task forces involving sectors like revenue, labour, employment, agriculture, commerce, finance, transport etc. etc.
- Develop procedures and criteria for assessment of economic and social impacts
- Utilize economic modelling as an appropriate tool
- Assess social problems like migration, thefts, unemployment, purchasing capacity etc in the event of severe drought
- Identify additional resources required from outside for mitigating drought impacts.

vi) Forest and Wild Life Task Force

- Collect relevant data and assess loss or damage of forest, forest products and wildlife region wise
- Identify the problem areas and make suitable remedial recommendations

vii) Commercial and Industrial Task Force:

- Assessments should emphasize loss of sales , tax, revenue, increase in unemployment, and decrease in

tourism.

- Assessments of impact in industrial productions due to short supply or high cost of raw material inputs and water supply
- Identify major commercial and industrial problem areas and remedial measures

viii) Health and Sanitation Task Force:

- Organise and initiate assessment action activities in evaluating impact of drought on health e,g. spread of epidemics and problems of malnutrition.
- Investigate sanitation problems arising due to water scarcity
- Identify the problems and suggest suitable ideas to remedy them

3) Review and Reporting Task Force":

This Task Force interacts with other Task Forces and takes decisions about the extent and problem of droughts and initiate various activities. The important responsibilities to be assigned to this task force are:

- Review progress of impact task forces, to include comprehensiveness, frequency and adequacy of impact task force reports and procedures.
- Compile their views and recommendations to develop assessments, projections and trends
- Make available timely reports to higher authorities, decision maker, key elements of the response or relief system, heads of various organizations and press media.
- Ensure inter task force and inter government coordination including central govt. agencies
- Select and appoint additional members as required.

This task force should have chairpersons of all the task forces including departmental drought coordinators.

5.2 Response System

The response system refer to remedial actions that are to be taken to solve the particular drought problem. The response actions include news release to the media, allocation of funds, coordination of efforts and other resources to the affected area . For response system to function effectively, it is necessary to specify specific impacts of drought in various sectors agriculture, water supply, energy, economy, tourism, transport etc. Drought response can consist of either long terms or short terms activities or both . A wide range of long and short term drought management and relief strategies may be formulated to tackle with the situation of economic and physical hardship because of drought. Short term drought measures may range from providing food clothing and fuel, crash ground water exploitation programs for domestic and live stock water supply and life saving irrigation, soil moisture conservation measures, transport of water from distances through tankers, emergency loan programmes, emergency employment programmes, contingency agricultural plan to help and others unmet current and projected hardships. The long term measures are intended to reduce the impact of future droughts and may include strategies like construction of reservoirs for irrigation and domestic water supply purposes, regulations of land use, afforestation, creation of permanent assets, grass land and waste land development, ground water recharges, measure to reduce water loss through seepage and evaporation and ground water exploitation policies etc.

As the impacts of drought are identified by concerned sectoral task force and reported to the review and reporting task

force and concerned department. On the recommendations of Review and Reporting Task Force and green signals of decision makers, the DMS activates the response systems for:

- Preparation of drought management plan
- Plan implementation
- Evaluation of drought management plan

The response system composed of various government departments. The DMS should be located as nodal agency and will have on line dialogue capabilities with sectoral sub task forces. The interagency coordination will be performed by nodal agency with participation from concerned government/departments. The DMS will be responsible for final drought assessment report as well as drawing up of drought response plan for implementation. The Review and Reporting Task Force will provide technical coordination and guidance to sectoral agencies/departments in preparation of drought plan.

The designed appropriate drought plan of each sector will be implemented through concerned government departments. The assistance or relief will be provide through existing/proposed programmes and according to regular departmental procedures.

The departments/agencies most involved with various drought problems should be assigned leadership function for drought assistance. For example local administration (district collector) may provide assistance when drought adversity affect municipal water supply, tourism, commerce, labour employment, department of water resources deals water shortage, Department of Agriculture looks after agricultural drought problems etc.

To achieve these tasks, all concerned departments of the state and region should

- Designate a departmental drought coordinator
- Provide personal and resources to task forces

The response system should be so structured that the concerned agencies are able to address drought related problems and existing management measures through their departmental drought coordinator to impact task forces /review and reporting task force. Further, various agencies are to act as sectoral lead agency for the given sector when designated, and take action within assigned sectors of responsibility. The system can consider and recommend water conservation and other drought management practices to lead agencies. Further the system can make public announcements, impart education and create awareness in the public to know how to live with drought giving tips of reactive drought management measures in the concerned sectors of their responsibilities.

The various concerned agencies can be considered to act as lead agencies. These lead agencies provide direction and integration of effort to all agencies concerned with drought response within assigned sector or responsibility, utilizing normal programmes and resources available. The possible constitution of lead agencies is given in Appendix II.

If the response agencies can no longer provide drought assistance or if drought conditions worsen, or emergency conditions are prevailing, an Inter agency coordinating group (IACG) can be activated by the proclamation of government. This group should consist of senior level officials ('Heads of departments) of involved state and central government departments. This group works with or through these departments. The main tasks of IACF are:

- To review impact statements of unmet needs in order to recognise and identify alternate choice for response
- To develop recommendations for

* Government actions including inter departmental or external support

* Legislative or legal actions e.g. request for additional funding

- To ensure inter agency coordination and determine when to disband itself etc.

The assistance and relief measures which are utilized during drought would be evaluated by some committee formed by the government. The evaluation of drought mitigation measures would be made in terms of their accordance with the objectives of drought policy. It includes physical financial and social evaluation of relief measures. Each measure would be evaluated in terms of its positive, negative or neutral effects. Evaluation of alternative drought measures will provide added incentives to the response system in the adoption of more suitable drought measures for future droughts.

6.0 SUMMARY AND RECOMMENDATIONS

The purpose of this report is to approach towards the development of an effective drought plan suitable for providing timely and appropriate deal with drought hardship. The experience of drought management in past indicate that the state governments have responded to drought by crisis management rather than risk management and the drought relief efforts have been less effective and uneconomical. In order tc efficient deal with drought management the four critical needs are identified.

1. Reliable and timely information about drought, current status of water availability and alternate assistance measures readily available for implimentaions.

2. Improved impact assessment techniques, specially in agriculture sector, for use by government to identify period of abnormal risk and to trigger assistance measures

3. Administratively centralized drought declaration procedures that would be well publicized and consistently applied

4. Stand by assistance measures that encourage appropriate level of risk management would be equitable, consistent and predictable.

The drought plan has an assessment system and a response system. The assessment system depends on the variety of data/information from a broad range of sources. This assessment system is composed of representatives of concerned agencies comprising a number of task forces which works for drought monitoring, drought identification and impact assessment. The response system is responsible for any action to be taken to solve the particular drought problem. The assessment and response systems have been designed in such a way that the information on drought would be collected, analyzed and disseminated in a timely

and systematic way by regular monitoring of drought causing variables. The identification of scarcity condition and determination of start up and shut down of assessment and response activities would be reliable and effective. The provision of evaluation of response activities would provide added information for selection of alternate strategies of drought management. The recommendation made are as follows:

- It is required that all the drought affected states of the country should develop their own drought plan suitable to their regional priorities and needs. Each state plan should address both assessment land response capabilities of Government.

- The assessment procedures must be developed to provide objective, reliable and timely information on problems related to water supply and potential impacts. To accomplish this goal a data collection, analysis and dissemination system must be assembled well in advance of drought related water shortage.

- The responsibilities of local, state govt. and other agencies involved in various sectoral task forces must be well defined. Regulatory powers must be provided to appropriate agencies in order for resources to be allocated in a consistant, equitable and timely manner.

- Criteria must be established for determining start up and shut down of assessment activities and mitigation measures.

- Methods of assessing impacts of drought specially in agriculture and forest and wild life must be improved

- The assistance programmes must be available on the shelf for implementation in time of need

- Recipients of drought aid should benefit from knowing, in advance, what type of assistance will be and will not be provided

- Assistance to the farmers may be provided in the form of loans and the flexibility should be provided to the recipients to use the money in a way that best suit

their farming situations.

- The start up of the scarcity conditions and mitigation measures adopted should be published and announced through news media.

If the drought response plan as discussed in this report will be developed by the states that experience frequent and severe water shortage caused by drought, governmental ability to implement effective measures in a timely manner would be greatly improved.

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APPENDIX I

POSSIBLE CONSTITUTION OF ASSESSMENT TASK FORCES

Sl No. Task Force	Participating Agency at central and state govt.
1.Water Availability	Water Resources/Irrigation Dept.* Meteorology Department Soil & Water Conservation Dept Water Conservation cell Agricultural Department Ground Water Department Review Department Water Supply Dept. R&D organizations on hydrology and water resources Representative of Academic Instts.
2. Municipal Water Supply	Water Supply Department* Irrigation Dept Vet. Dept./Animal Husbandry Water Quality/Pollution Board Municipal Corporation/local affairs Roadways, Defence Services Ground Water Board
3.Fodder and Livestock	Dept. of Agriculture* Dept., of Animal Husbandry/Vet. Dept. of Forest Revenue Dept. Horticulture Dept. Bureau of economics and statistics Water Resources/Irrigation Dept.
4.Agricultural	Dept. of Agriculture* Dept. of Economics and Statistics Dept. of Irrigation/Water Resources Ground Water Board Revenue Dept. Dept. of Small Scale and Cottage Industries Meteorology Dept. Agricultural University

5. Energy Loss	Dept of Energy/Electricity Boards* Concerned Authorities of Multipurpose River Valley Projects Dept of Irrigation/Water Resources Dept of Non-Conventional Energy Resources Water and Power Res. Stations Rural Electrification
6. Economic and Social	Dept of Economics and Statistics* Dept of Planning and Budgeting Dept of Revenue Dept of Agriculture Dept of Labour and Unemployment Department of Social Welfare Dept of Industry Academic Institutions of Economics/ Sociology NABARD
7. Forest and Wild Life	Dept of Forest and Wild Life* Land use Planning Dept Remote Sensing Dept Soil Cons. Dept Dept of Environment NRSA Forest Research Institute
8. Commercial and Industrial	Dept of Industries * Dept of Sales Tax Dept of Revenue Dept of Labour and Unemployment Dept of Tourism Dept of Agriculture Chamber of Commerce
9. Health	Dept of Health/Medical Services* Water Supply Dept. Municipal Corporation Dept. of Family Welfare Dept. of Animal Husbandry and Vet Water Pollution Board Militancy Hospitals

10. Review and Reporting	Chairperson of WATF* Chairperson of Each Task forces Others as selected by Task Force Chairperson Irrigation/Water Resource Dept. R*D organization Meteorology Organization Agriculture Dept.

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* Department which should lead the task force

APPENDIX II

POSSIBLE SECTORAL LEAD RESPONSE AGENCIES

Sector of Drought response system	Lead Agency	Other concerned agencies
Water Resources Development, Management and Conservation	Irrigation/ Water Res.Dept.	Regional Office of CWC Ground Water Board Agricultural Dept. Forest Dept. Soil Conservation Dept Research Intuition & Academic Intuitions
Conservation & Development of Municipal Water Supply	Water Supply Department	Irrigation Dept. Ground Water Dept Animal Husbandry Municipal Corporation Department of Fire Services Defence Services Railways Water Quality/Pollution Board Voluntary Organizations& Individual Department of Horticulture Dept of Industries
Fodder Supply	Dept. of Agriculture	Dept of Forest Irrigation/Water Resources Revenue Dairy Development Boards Agricultural Universities Railways
Agricultural production	Dept. of Agriculture	Dept. of Irrigation- ICAR Institutes Agricultural Universities Ground Water Deptt. Revenue Board Small Scale & Cottage Industry

		Dept. of Fisheries
		Forest Deptt.
		Railways
Forest & Wild Life	Dept of Forest	Land Use Boards
		Agricultural Dept.
		Waste Land Development Boards
		Dept. of Environment
		Dept. of Irrigation
Economic Losses	Dept of Economics and Statistics	Dept of Revenue
		Dept of Agriculture
		Dept of Labour
		Dept of Social Welfare
		Dept of Industries
		Railways
		Dept of Irrigation

Appendix - III(a)

DROUGHT DEFINITIONS BASED ONLY ON ABSOLUTE VALUE OF RAINFALL AMOUNT AND DURATION OF DRY PERIOD

Sl. No.	Author	Year	Definition/Association Concepts	Region	Remarks
1.	-	1964	Period of 6 days with	Bali	
2.		1964	Period of 2 years without rain	Libya	
3.	Brounov	Early 20th century	Ten days with rainfall not exceeding 5mm	Russia	WMO (1975)
4.	Cole	1933	Fifteen days without rain	USA	-do-
5.	British Rainfall Organisation	1936	Absolute drought: at least 15 consecutive days none of which received as much as 0.25 mm Partial drought: at least 29 days during which mean rainfall does not exceed 0.25 mm per day. Dry spell: 15 consecutive days none of which has received as much as 1 mm.	UK	-do-
6.	Blumenstock	1942	Less than 2.5 mm in 48 hours	USA	-do-
7.	Conrad	1944	A period of 20 (or 30) consecutive days or more without 6.4 mm of precipitation in24 hours during season. (March to September inclusive).	USA	-do-

8. Fitzpatrick	1953	Period terminated by at least 6.4 mm during any 48 hours.	Australia	-do-
9 .Goodridge	1967	The accumulated average daily rainfall for the period in which no effective rainfall occurs; effective rainfall being the lower threshold value or daily rain which is significant in vaarious applications of this index.	(cited from Yevjevich, 1977) USA	-do-
10.IMD	1971	Drought is said to occur when the annual rainfall is less than 75% of the normal. Severe drought is said to occur when the deficiency of rainfall is above 50% of the normal.	India	

Appendix- III(b)

DROUGHT INDICES BASED ON RAINFALL CHARACTERISTICS AT A PLACE COMPARED WITH A LONG TERM AVERAGE AT THE PLACE

SL. NO.	Author	year	Definition / Concept	Region	Remarks
1.	Henry	1906	21 days or more when Rainfall is 30 % or less of average for the time and place. Extreme drought when rainfall fails to reach 10 % of normal for 21 days or more.	U.S.A.	WMO(1975)
2.	Hazen	1916	The coefficient of variation of the annual rain fall exceeds 0.35 The coefficient of variation of annual rainfall is between 0.15 to 0.25	Western U.S.A.	(cited from chow, 1964)
3.	Bates	1935	When annual precipication is 75 % of the normal or when monthly preciptation is 60 % of normal.	U.S.A.	WMO(1975)
4.	Hoyt	1936	Any amount of rainfall less than 85 % or normal	U.S.A.	-do-
5.	Baldwin-Wiseman	1941	Engineeris drought : Three or more consecutive months with deficit of 50 % from mean rainfall.	Australia	-do-
6.	Tennesse Authority	1944	No interval of 21 days received precipitation greater than one third of normal.	U.S.A.	-do-
7.	Ramdas	1950	When actual rainfall for a week is half of normal or less	India	

8. Foley	1957	Computed Residual mass curves of rainfall departures and developed a dimensionless drought severity Index by dividing the values obtained by average annual rainfall.	Australia -do-
9.Ramdas	1960	A year is considered is a drought year when the rainfall is less than normal by twice the standard deviation of the series .	

APPENDIX III(c)

Indices based on Rainfall and mean temperature

Author	Definition of drought or associated concepts	Region and comments
Lang(1915)	Precipitation factor=P/T P in mm, T in ^{o}C	Germany, Developed to aid climatic classification of soils
de Martonne (1926)	Index of aridity $I = \frac{P}{t+10}$ where P is monthly precipitation (mm) and it is mean monthly temperature (^{o}C). Monthly index of I is approximate indicator of aridity. Index modified to $I = \frac{n \times \bar{P}}{t+10}$ where n is number of days during a certain period from a few days to a year and $\bar{p}$ is daily mean precipitation in the period.	Used to define climatic limites of deserts, prairies and forests. Does not apply well in cool zones where t + 10 approaches zero. Used extensively by geographers and biologists to compute aridity.
Koloskov (1925)	Ratio of annual precipitation to accumulated mean daily temperature during vegetation period (divided by 100).	U.S.S.R. Ratio may be used as a comparative agroclimate index.
Selyaninov (1930)	Index given by $k = \frac{\sum p}{\sum t/10}$ where p is sum of rainfall 9 (mm) during those months when mean temperature is above $10^{o}C$ and t is the sum of the daily mean temperatures above $0^{o}C$ for the	U.S.S.R., Author suggested that a period be considered as a dry spell when $k < 1$ and as a drought when $k < 0.5$.

	same period.	
Koppen (1931)	Defines "dry" climate by: $p < 2t$ for regions of winter rain and $p < 2t + 14$ for regions of summer rain or no rainy season where p is annual precipitation in cm and t is mean temperature in °C "Desert climate defined by: $< t$ for winter rain ; $p < t + 14$ for summer rain; $p < t + 7$ for no rainy season.	Used extensively in classification of the dry climates of the world.
Imberger (1955)	$I = \frac{100p}{(M \times m)(M + m)}$ where M is the mean maximum temperature in the hottest month and m is the mean minimum temprature in the coldest month; p in mm and M and m in °C.	France.Based on de Martonne;s index, (M-m) is an index of continentality.
Knochenbauer(1937)	Daily maximum temperatures and humidity at time of afternoon observation used to define a dry spell.	Germany.
Condra (1944)	Period of strong wind; low precipitation, high temperature and usually low relative humidity.	U.S.A.,This anticipates the combination of low precipitation and high evapotranspiration.
Henin and Ternisien (1944)	Computed evapotranspiration and drainage from temperature and precipitation .	France. Procedure improved by Turc (1954) incorporating additional factors.
Popov (1948)	Index of aridity $P = \frac{\sum g}{2.4(t-t')r}$ where P is index of aridity ; $\sum g$ is annual amount of effective precipitation; t-t' is	

	annual mean wet bulb depression $^{\circ}C$; r is factor depending on day length; and g is that part of precipitation which is available for plants.	
Thronth-waite (1931)	Precipitation effectiveness as a function of mean temperature. $P/E = 1.65 \left(\frac{P}{T + 12.2}\right)^{(10/9)}$ in mm and $^{\circ}C$ where P/E is the precipitation evaporation ratio P is monthly precipitation in mm, and t is monthly mean temperature in $^{\circ}C$.	U.S.A. See also under "Climatic indices and estimates of evapotranspiration".
Gaussen (1954	When total monthly precipitation in mm is less than twice the mean temperature in $^{\circ}C$.	An approximation to rainfall less than evapotranspiration based on Koppen.
Budyko (1970)	Hydrothermal coefficient $K = \frac{r}{0.18\sum \ominus}$ where $0.18\sum \ominus$ gives the potential evapotranspiration in mm, $\sum \ominus$ being the annual sum of daily mean temperature higher than 10 $^{\circ}C$; r is annual precipitation in mm.	U.S.S.R.

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