Drought Management in Different Climatic Region in India

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Abstract- **The drought frequency, severity and the tendency of persistence vary across the climatic regions. Above characteristics depends on mean annual precipitation, evapotranspiration and length of wet season. In India, drought is linked to the amount and distribution of monsoon season (June-Sept) rainfall. The major causes of droughts are late onset of monsoon, less than normal amount of rainfall, long dry spells during rainy season and early withdrawal of monsoon. The arid and semi-arid regions in India face more frequent droughts with an average return period of 3 and 4 years, respectively. It is 5-6, 7-8 and 8-15 years, respectively, in dry-sub-humid, sub-humid and humid regions. The magnitude of severity and socio-economic impacts are much higher in arid and semi-arid regions compared to other climatic regions. The occurrence of persistent drought events for 2 or 3- consecutive years are more in arid regions followed semi-arid and dry sub-humid regions. The persistent drought events in sub-humid and humid regions are rare.**

The Ministry of Agriculture monitors drought condition in India. Declaration of drought and implement relief and mitigation measures is done by Sates while the central government only aids and supports. Current drought management system in India is very much steered towards relief and crisis management rather than proactive mitigation. This paper presents analysis of drought characteristic in different climatic regions using 113 years (1901-2013) rainfall for 425 stations and the details of drought management system in India. A model drought management plan for different climatic regions has been proposed.

Keywords: Ground water level, monsoon, seasonal variation, rainfall, Bhiwani

I. INTRODUCTION

Droughts have always been a major concern of the society. Despite fascinating achievements of science and technology in 20th century, drought events continue to hit human heritage and undermine development by breaking continuity. Devastating droughts can be viewed as enemies of sustainable development (Kundzewicz and Kaczmarek 2000). Droughts in India cause great damage to agricultural crops, horticulture, and regional economy. Droughts are regional in nature and their characteristics at a given place depend on the regional climatic parameter (Dracup et al., 1980a Ponce et al. 2000; Pandey and Ramasastri 2001, 2002). The most common climatic factors which govern frequency, severity and the chances of persistence of drought over an area/region are precipitation, temperature and humidity, and hence the evapotranspiration. The other important feature of climate that influence regional drought characteristics is the distribution of rainfall over the year and hence, the length of wet season. Since the long-term records of precipitation, potential evapotranspiration, and length of wet period are usually available in mid-latitudinal regions, defining climatic areas on the basis of these climatic factors may be particularly useful for drought characterization, in mid-latitudinal regions, where impacts of droughts on society are more compelling.

It is widely believed that the hydrological cycle is getting accelerated due to global climate change (IPCC 2007). Any change in temperature affects the moisture holding in atmospheric, precipitation, changes in the rate of evaporation and circulation pattern of the atmosphere which may lead to intensification of hydrological cycle. Intensification of processes of hydrologic cycle is responsible for occurrence of floods and droughts (Ponce et al. 2000). Regions with higher variability of rainfall and runoff are more vulnerable to droughts (Kundzewicz and Kaczmarek 2000).

The human settlements and the economic activities on the earth are largely concentrated in mid-latitudinal regions and therefore, the impacts of floods and droughts are more apparent in these regions (Karl 1983; Ponce 1995a). Droughts are recurring natural phenomena; therefore, they cannot be prevented. However, coping with droughts is possible through proper prediction and planning. To reduce the impact of drought hardship, it is necessary to develop capabilities to predict regional drought characteristics, i.e., its frequency (How often will it recur?), its severity (How severe will it be?), and its persistence (How long will it last?) Once these characteristics are known for a given climatic region, they can be used as a management tool for proactive drought mitigation (Ponce et al. 2000).

The primary purpose of this paper is to present the relationship of climatic parameters with drought frequency, severity and persistence drought characteristics in different climatic regions in India. It is hoped that the paper may enhance understanding about regional drought characteristics and may lead to develop better skills to cope with adverse impacts of droughts on the society.

II. DELINEATION OF CLIMATIC REGIONS IN INDIA

Classifications of the earth's climate have been proposed by several researchers from time to time. The initiatives for climatic classification of the earth were launched by the biologists in the mid-nineteenth century. The Wladimir Köppen of University of Graz, Austria, first presented his classification in 1900 with primary division of the earth's surface into five great zones, namely, 'dry', 'tropical rainy', 'temperate rainy', 'cold snowy forest', and 'polar climate (Köppen 1931; Köppen and Geiger, 1939). Subsequently, the Thornthwaite (1948) proposed a climatic classification based on balance between incoming and outgoing heat and moisture at the earth's surface. Thornthwaite used potential evapotranspiration (PE) and precipitation (P) as key climatic constituent to define climatic regions. Using a simple concept of water balance, the potential evapotranspiration was compared with the precipitation and the periods of moisture deficiency (D) and excess (S) were obtained to express relative moistness or aridity of a climate. The climatic classifications given by Köppen (1931); Köppen and Geiger (1939) and the Thornthwaite (1948) did not specify the central tendency of the climate. Since, droughts are usually defined by relative deficiency of moisture (precipitation, streamflow, water storages etc.) with reference to their central tendency (mean or median or predefined threshold). Therefore, to characterize droughts in mid-laitudinal regions a climatic classification proposed by Pandey and Ramasastri (2002, 2001), which essentially defines the middle of climatic spectrum given in Table 1, has been used to delineate the climatic regions in India (Figure 1).

Ponce et al. (2000) concluded that the land area with 800 mm of mean annual rainfall (P_g) may have reasonable scope to practically manage and cope with water scarcity and drought condition and hence it was considered that a region receiving about 800 mm mean annual rainfall falls in the middle of the climatic spectrum. Thus, a value of P_g= 800 mm was preferred as a landmark value in the new climatic classification given by Pandey and Ramasastri (2002). Accordingly, the middle of the climatic spectrum was defined as $P_a/P_g = 1$, where, P_a refers to mean annual rainfall at a given place. Thus, regions with $P_a/P_g < 1$ have less than average moisture. On the other hand, regions with $P_a/P_g > 1$ have more than average moisture. Thus, the climatic spectrum was divided into eight regions as shown in Figure 1. Also, this classification was found in close agreement with other existing classifications given by Bull (1991), Dutt (1986), Stern et al. (1999) and Ponce *et al.(*2000). This classification has been utilized in the study for describing the drought characteristics in different climatic regions of India.

Table 1. New climatic regions based on Pa/Pg and E_p/P_a ratio (Pandey and Ramasastri (2002)

Sl. No.	**Climatic regions**	**P_a/P_g ratio**	**E_p/P_a ratio**	**Length of Wet Season *(in Months approx.)***
1	Superarid	$P_a/P_g < 1/8$	$E_p/P_a \geq 30$	< one month
2	Hyperarid	$1/8 \leq P_a/P_g < 1/4$	$30 > E_p/P_a \geq 12$	Nearly one
3	Arid	$1/4 \leq P_a/P_g < 1/2$	$12 > E_p/P_a \geq 5$	Nearly two
4	Semiarid	$1/2 \leq P_a/P_g < 1$	$5 > E_p/P_a \geq 2$	Nearly three
5	Subhumid	$1 \leq P_a/P_g < 2$	$2 > E_p/P_a \geq 3/4$	Nearly four
6	Humid	$2 \leq P_a/P_g < 4$	$3/4 > E_p/P_a \geq 3/8$	Nearly six
7	Hyperhumid	$4 \leq P_a/P_g < 8$	$3/8 > E_p/P_a \geq 3/16$	Nearly eight
8	Superhumid	P_a/P_g $P_a/P_g \geq 8$	$E_p/P_a < 3/16$	> 10 months

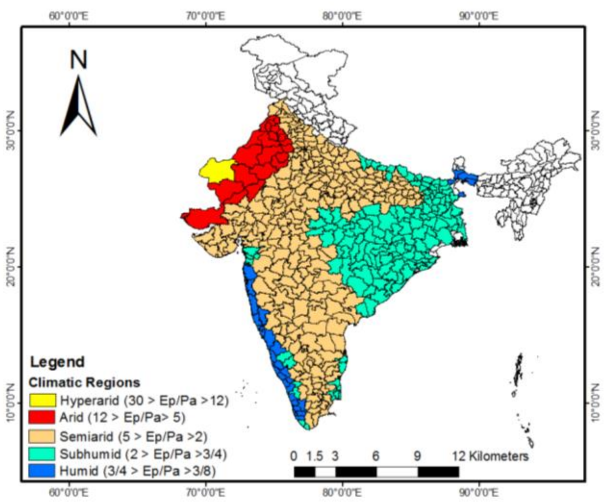

Figure 1: Map showing climatic regions in India

III. THE METHODOLOGY AND DATA USED0020IN THE STUDY

Precipitation records are used as the principal indicator in most of the studies for analyzing drought characteristics (Wilhite, 2000; Ponce *et al.*, 2000, Pandey & Ramasastri 2001 & 2002; Mishra and Singh, 2010; Dogan et al., 2012; Pandey et al., 2014; Moorhead et al, 2015). Thus, the most popular perception of drought is as a "meteorological phenomenon," characterized by deficiency of rainfall compared to the expected amount over a given period of time. A meteorological drought exists when annual or seasonal rainfall is below 75% of the long-term mean (Glantz 1994), while others might consider it to occur at or below 60 or 50% of normal. In this study a definition suggested by the India Meteorological Department (IMD) has been used, i.e. "for a given time period (seasonal/yearly), if a meteorological station/division receives total rainfall less than 75 percent of its normal, it is considered as a drought" (National Commission on Agriculture 1976).

In the present study, the annual rainfall series for 425 raingauge stations in India for the period 113 years for each of the station was analysed using percentage annual rainfall departure from normal (PARD) to identify the drought years and the drought events. All the 425 stations are the district headquarters in the different states except hilly states of north-eastern region, Jammu and Kashmir and Himanchal Pradesh. Using the definition given by IMD, a meteorological drought year is marked as PARD ≤ -25%. Plots of percentage annual rainfall departure from mean were prepared for identification of drought years and the drought events. The sample plots of PARD for Bhopal station in Madhya Pradesh is shown in Figure 2. The average drought return period (T) has been obtained as numbers of years of rainfall records analyzed divided by the number of meteorological drought years. The years for which rainfall records were missing at a given station, were not included in the analysis while estimating total number of years of records analyzed for a given station.

The annual potential evapotranspiration rates, 45 years of daily meteorological data (1965–2010) from 425 stations were used. Potential evapotranspiration (PET) was estimated using the Penman-montieth Method (Allen et al. 1998) and the estimates were compared with the data published by the India Meteorological Department (IMD) (Rao et al. 1971) to assess trustworthiness of the computed PET values.

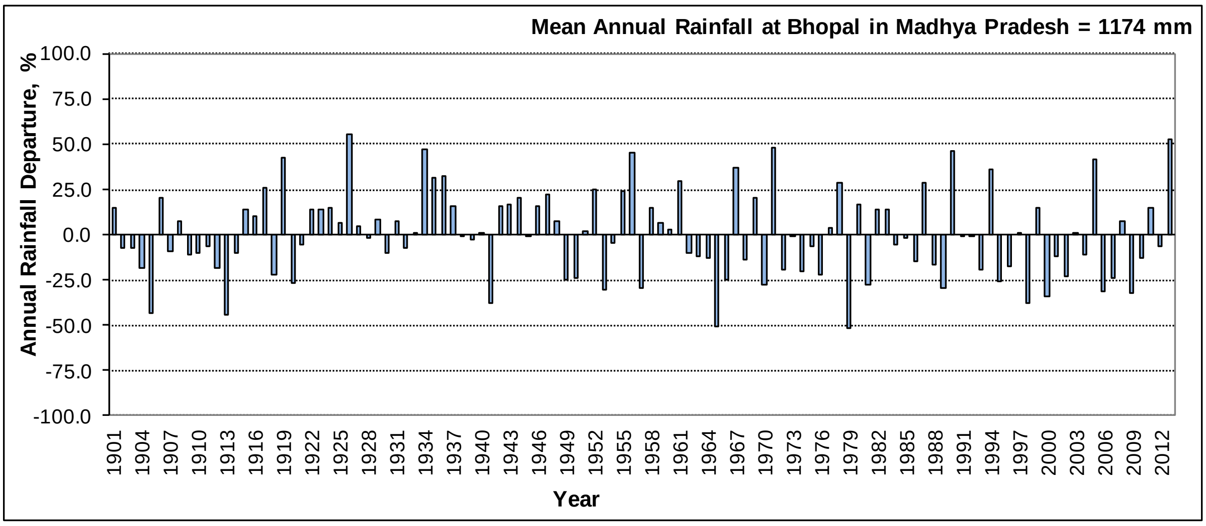

Fig. 2: Plot of percentage annual rainfall departure from mean for Bhopal, Madhya Pradesh

Scrutiny of long-term rainfall records from 425 stations in India indicated that the mean annual rainfall (P_a) ranges from 171 mm at Jaisalmer in Rajasthan to 4075 mm at Udupi in Karnataka and the potential evapotranspiration varies from 1340 mm in Kottayam, Kerala to 2664 mm at Jaisalmer (in Rajasthan). Here, the mid-climatic regions of India are taken as arid, semiarid, subhumid and humid climatic regions.

IV. REGIONAL DROUGHT CHARACTERISTICS AND CLIMATIC PARAMETERS

The drought characteristics refer to the frequency, severity and the duration (or persistence) of events over a given region. Drought frequency (*F*) pertains to the number of years that it would take a drought of a certain severity to recur; for instance, once in 10 years. The reciprocal of the frequency is the return period (T=1/F) or recurrence interval. In common usage, however, frequency and return period are often used interchangeably, for instance, a frequency of 10 years. Since dry periods are generally followed by corresponding wet periods, it follows that the recurrence interval of drought is always greater than the drought duration. The climatic factors used in this study are to mean annual precipitation and mean annual potential evapotranspiration. Since the time unit is a year, the minimum duration of a meteorological drought event is one year in this case and the minimum drought return period may be two years. Percentage annual rainfall departures from normal were estimated from long-term annual rainfall series for each of the given stations to identify the drought years and the drought events. The average drought return period for each station was thus computed from the number of years of rainfall records at a given station divided by number of meteorological drought years (i.e. the number of years for which annual rainfall was less than 75% of its mean value).

Relationship of E_p/P_a Ratio and Drought Return Period

The ratio of mean annual precipitation (P_a) and mean annual potential evapotranspiration (E_p) has been used as climatic parameters. Regressions have been applied to develop the relationships of the E_p/P_a ratio with the average return period of drought. The inferences for drought frequency (F) have been drawn in relation to the E_p/P_a ratio. The results have been compared with the documented experiences in other parts of the earth. Since the ratio of mean annual potential evapotranspiration to mean annual precipitation (E_p/P_a) may never be zero, both power and exponential regression models were applied to relate the E_p/P_a ratio with the average drought frequency (i.e. in terms of return period). The power type regression (Figure 3) showed better correlation ($R^2 = 0.72$) compared to other. It is evident from Figure 3 that the frequency of meteorological droughts has a significant relationship with the Ep/Pa ratio and it reveals that the average return period decreases with increase in the E_p/P_a ratio. Average drought frequency (expressed in terms of return period) varies from 2 to 3 years in arid regions (with $12 > E_p/P_a \geq 5$), 4 to 5 years in semiarid regions (with $5 > E_p/P_a \geq 2$), 6 to 10 years in subhumid regions (with $2 > E_p/P_a \geq 3/4$) and 10 years or more in humid regions. From the relationship presented in Figure 3, it can be stated that the arid regions where the mean annual potential evapotranspiration is more than five times the amount of mean annual precipitation experience most frequent drought, i.e. once in every 2 to 3 years. In the semiarid regions, the mean annual potential evapotranspiration is two to five times the total amount of mean annual rainfall, the drought occurs once in every four or five years on an average. Further, in semiarid areas, where the total annual rainfall is of the order of about half of the local mean annual potential evapotranspiration (i.e. $E_p/P_a \approx 2$), droughts occur once in every 5 years (Figure 3). In areas with E_p/P_a ratios between 2.0–3.0 and 3.0–5.0, droughts recur every 4–5 and 3–4 years, respectively. Also, this may be clearly seen in Figure 6.4 that the drought frequency decreases exponentially with the increase of wetness. The spatial distribution of drought return period and its contour plots in mid-climatic regions of India are shown in Figure 4 and 5 respectively. In sub-humid areas ($0.75 \leq E_p/P_a < 2$), the average drought frequency is once in 5 years to once in 10 years (Figure 3). In areas where mean annual rainfall is nearly equal to mean annual potential evapotranspiration (i.e. $E_p/P_a \approx 1$), the drought return period is more than 10 years. Further, if the area belongs to the further wet side of the climatic spectrum, (i.e. $0.5 \leq E_p/P_a < 1$), the drought frequency vary in the order of once in 11 years to once in 16 years.

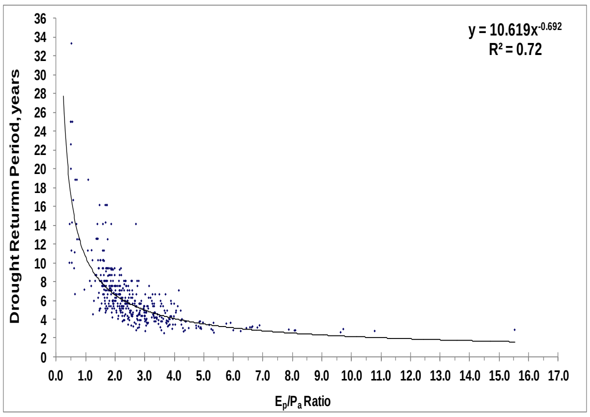

Figure 3: Relationship of drought return period with E_p/P_a Ratio in mid-climatic regions of India

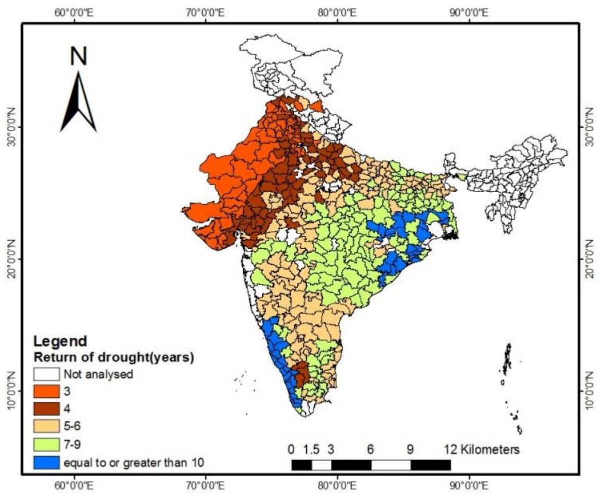

Figure 4: Spatial distribution of drought return period in mid-climatic regions of India

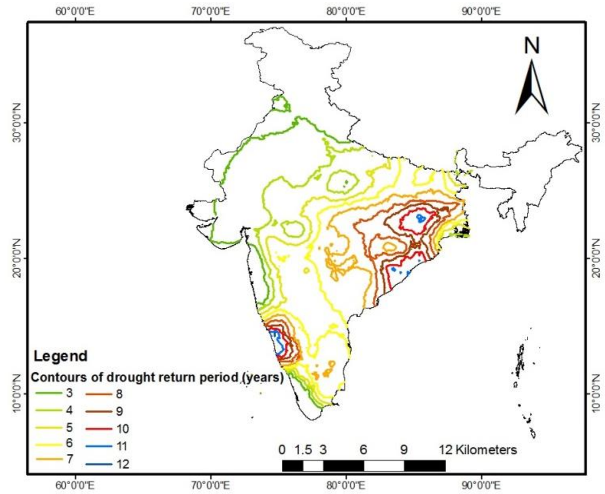

Figure 5: Contour plots of drought return period in mid-climatic regions of India

Also, it can also be seen from analysis (Figure 3) that a few stations in sub-humid regions, namely, Midnapur and Bankura in West Bengal, Phulbani in Orissa and Belgaum in Karnataka State, whose mean annual rainfall nearly equals the local mean annual potential evapotranspiration, experienced less frequent droughts. The average frequency of drought at these stations was once in every 16, 15, 14 and 15 years, respectively. This typically indicated the possibility of some influence of other physical/regional/morphological factors particularly the proximity of station from mountains, h_s and from the sea, d_s). It may also be one of the possible reasons restricting the value of correlation coefficient of above relationships to moderately significant level (i.e., $R^2 = 0.72$).

A comparison of the above inferences with drought data and experiences elsewhere indicates that the results are rationally comparable. For instance, in Brazil, in Sarido, which belongs to an arid region with $E_p/P_a \approx 5.8$, and in semiarid Caatinga and Saritao, where the E_p/P_a ratio varies from 2.2 to 4.8, the droughts recur approximately once in every 3 year and once in every 5 years, respectively (Ponce, 1995a) . However, in sub-humid Agreste and Mata, where the *Ep/Pa* ratio varies between 1.3 and 2.0 and between 0.7 and 1.1, respectively, the droughts recur every 8 years and every 12 years on an average (Magalhaes & Magee 1994; Ponce 1995a). For sub-humid climatic regions in the upper midwest United States with mean annual precipitation of about 1500 mm (NOAA 1980), the average return period of drought is reported as approximately 10 years (Klugman, 1978). French (1987) analysed long-term series of annual rainfall for Georgetown in South Australia, where the mean annual rainfall is 475 mm. The records from 1874 to 1985 show 20 drought events, i.e. an average frequency of once in 5.5 years. Swearingen (1994) reported that Morocco, which belongs to the semiarid climatic region (*Pa* = 400–500 mm), experienced approximately 25 years of drought during the period from 1901 to 1994, i.e. an average drought frequency of once in 3.5 years. Thus, the relationships proposed broadly follow the drought frequency behavior in similar climatic regions in other parts of the world. It is hoped that these relations may be useful for further critical analysis of drought in different climatic regions.

Relationship of Severity of Droughts and the E_p/P_a Ratio

For given drought years, the magnitudes of annual deficits were computed in the respective years using equation 1 as follows:

$$S = \frac{p_{id} - p_a}{p_a} \qquad \text{(Eq.1)}$$

The precipitation P_{id} in a drought year is always less than P_a at a given place (i.e. $P_{id} < P_a$), and therefore, equation 1 estimates the negative values of drought severity (S). Depending on the magnitude of deficits, Dash (2006) proposed a new classification for severirt as Mild (S_{ml}) = -0.25 ≥ S > -0.35; Moderate (S_m) = -0.35 ≥S> to -0.45, Severe (S_s) = -0.45 ≥S> -0.60, and Extreme (S_e) S≤-0.60. This classification of severity has been utilized for further analysis of drought intensity in this study. For the purpose of simplicity in presentation, S_{ml} and S_m were combined into a single class, and percent probabilities of occurrence of three major categories (i.e. S_{ml}-S_m, S_s, and S_e) were computed. Relationships between the E_p/P_a ratio and probabilities of occurrence of mild-&-moderate, severe and extreme severity droughts is shown in Figure 6. The power type regression showed better correlation (R^2 = 0.57) than the logarithmic or exponential type regression. Figure 6 shows that the probability of occurrence of severe and extreme drought events increases progressively from the sub-humid to arid regions; it however, decreases in the case of mild-moderate severity drought. For example, an area with the E_p/P_a ratio equal to 1.5 has percent probabilities of occurrence of mild-moderate, severe and extreme intensity droughts as 80%, 18% and 2%, respectively, and for the area with the Ep/Pa ratio as 4.0 these values are 64%, 28% and 7%, respectively. In case of a place in arid region where the Ep/Pa ratio is 7.0 the values are 55%, 35% and 10%, respectively.

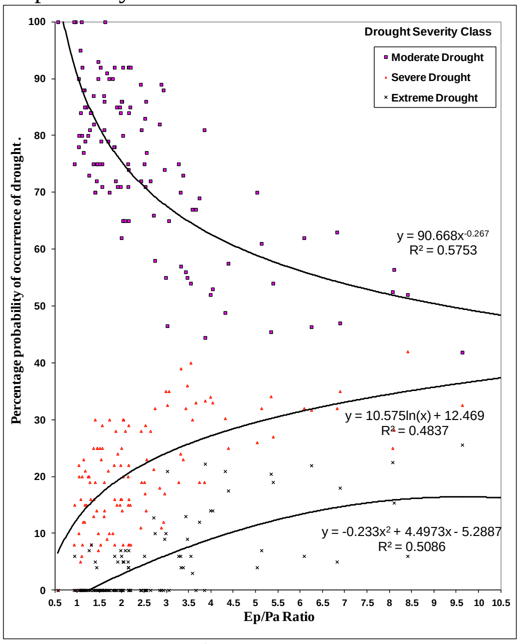

Figure 6 : Relationship of E_p/P_a ratio with percent probability of occurrence of drought events of different severity

Thus, the areas located in arid and semiarid climatic regions are likely to suffer relatively more frequent severe and extreme meteorological droughts than the areas in sub-humid climatic region. The probability of occurrence of severe droughts is below 18% in the regions with the Ep/Pa ratio less than 1.5. The relationships, shown in Figure 6, indicate that the extreme drought events are almost none in the regions with the Ep/Pa ratio less than 1.25. This categorically substantiates that the regions which receive mean annual precipitation in the order of more than 80% of their local mean annual potential evapotranpiration (i.e., E_p/P_a < 1.25) are nearly free from the risk of occurrence of extreme drought events. Further, it is also clear from Figure 6 that the regions where amount of mean annual rainfall is more than local mean annual potential evapotranpiration (i.e. E_p/P_a < 1) the prevalence of severe drought events is rare or negligible. Thus, the arid and semiarid climatic regions are more vulnerable to severe and extreme drought events than those of sub-humid climatic regions in India.

Relationship of E_p/P_a Ratio and Drought Duration

Duration of drought is one of the important characteristics, which forms a basis in the planning of strategies to cope with drought for a given region. Drought conditions may continue to prevail for one or more consecutive years. The tendency of drought conditions to prolong for more than one year is termed as drought persistence. For example, an event of drought with duration of two or more years is a persistent drought event. The experiences (reported in literature) show that the droughts have a tendency to last longer in those climatic regions which have greater inter-annual precipitation variability (WMO 1975; Karl 1983; Rasool 1984; Johnson and Kohne 1993).

In this study, an attempt has been made to relate drought persistence with climatic parameters in the arid, semiarid, and sub-humid climatic regions in India. The drought duration is seen to vary between 1 and 5 years in the different climatic regions. Identified drought events yielded the median duration of a persistent drought as 2 years, and maximum duration of persistent droughts has been 5 years. Relatively, a greater number of persistent drought events are observed in arid and semiarid climatic regions with the E_p/P_a ratio between 3.0 and 10.0. From the data-spread sheet, it was found that the drought events of 4- and 5-year durations are a few only. Therefore, plots of percent probability of occurrence of droughts for 2- and 3-years duration with the E_p/P_a ratio were prepared and presented in Figure 7. The depicted relationships could not lead to significant interpretation as the plots are quite scattered with low values of correlation coefficient. However, it can be expressed that the chances of occurrence of meteorological droughts of more than one year duration are relatively more in arid and semiarid regions.

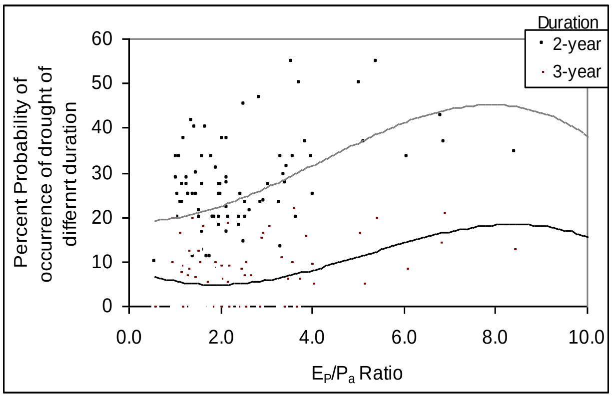

Figure 7: Relationship of E_p/P_a ratio with percent probability of occurrence of droughts of 2- and 3-years duration

V. ROUGHT MONITORING AND DECLARATION PROCEDURE IN INDIA

Monitoring of drought is the responsibility of both the state and central governments with frequent exchange of information. Ministry of Agriculture Govt. of India is the nodal agency for drought management in India. The Indian Meteorology Department (IMD) carries out the rainfall monitoring and forecasting and shares it with the Crop Weather Watch Group (CWWG) for the purpose of drought monitoring (Samra, 2004). Flow chart (Fig.8) given below shows current procedure of drought monitoring and declaration in India.

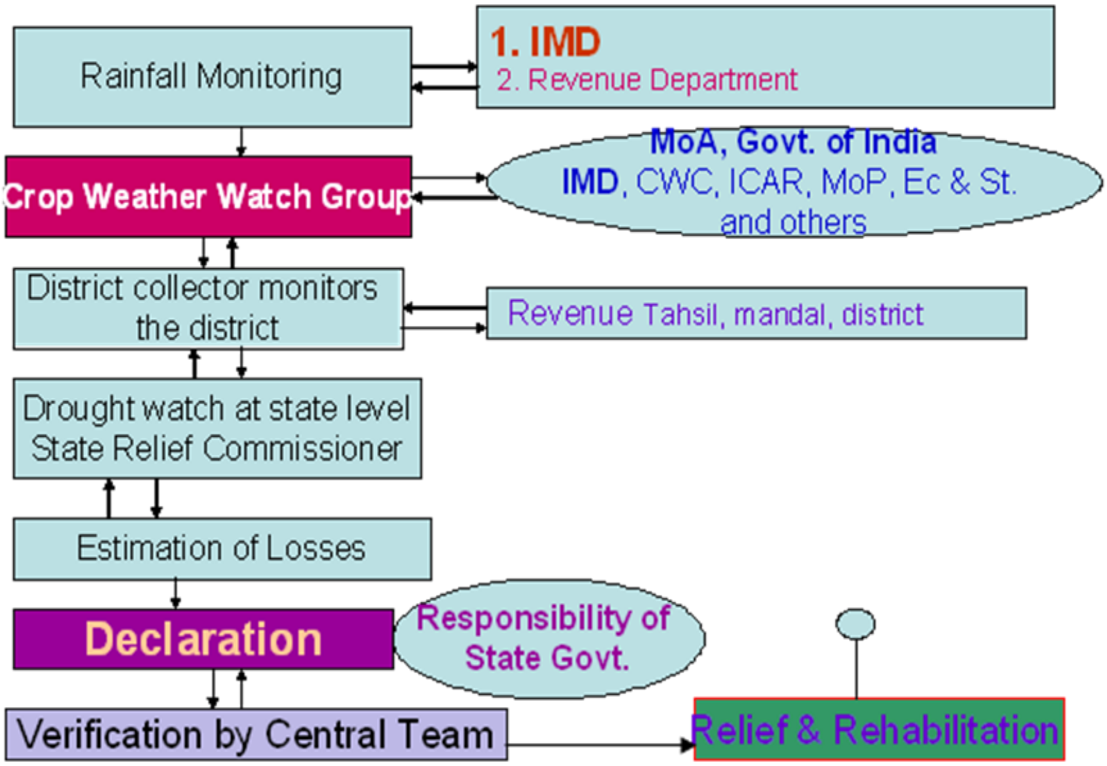

Fig. 8: Flow chart of current procedure of drought monitoring and declaration in India

Drought Monitoring

IMD prepares aridity maps on a weekly basis and has a continuing updating mechanism for sharpening and adjusting such forecasts. It also compiles weekly rainfall summaries giving figures of precipitation at the district level. IMD also determines the occurrence of meteorological droughts, i.e. rainfall deficit exceeding 19% of the mean, using data from 2,800 rain gauge stations distributed across the country. Weather data are also collected at tehsil and district level by revenue departments in all states.

In order to internalize information, data and early warnings of the IMD into tangible practical action, an institutional inter-ministerial mechanism of Crop Weather Watch Group (CWWG) within the Federal Ministry of Agriculture operates at federal Govt. level. The composition of CWWG its specific areas of responsibility are summarized in Table 2. Since 1979, this Group meets every Monday during the rainy season (June to September) and the frequency of their meetings is increasing during drought occurrence. For instance, in the year 2002 drought, annual rainfall deficit was within normal limits, but failure of rains in July in 18 out of 26 states was absolutely unique. The drought of 2002 was very different since crops could not be sown due to -51% rainfall deficiencies in July (Rathore 2002). This triggered the mechanisms of multi-sectoral or inter-ministerial CWWGs at the federal/state level with vigorous day-to-day consultation and monitoring. This group evaluates information and data furnished by the IMD and other scientific and technical bodies with a view to determine the likely impacts of meteorological events and other environmental parameters on agriculture. The deliberations of the Group and exchange of information with a similar kind of group at state level serve as the "triggering mechanism" to activate drought-response systems. The monitoring and information-management system of the CWWG group is summarized in Table 3.

Table.2: Composition and role of CWWG of the Ministry of Agriculture, Govt. of India.

Members of CWWG	Responsibilities
Additional Secretary, Ministry of Agriculture	Chairperson of the Group; promotes overall coordination
Economic & Statistical Adviser, MoA	Report behavior of agro-climatic and market indicators
India Meteorological Department	Rainfall forecast and progress of monsoonal conditions
Central Water Commission	Water-availability monitoring in major reservoirs
Plant Protection Division	Watch pests and diseases outbreak
Crop Specialists	Crop conditions and production
Agricultural input supply divisions	Supply and demand of agricultural inputs
Agricultural extension specialists	Report on field-level farm operations
Ministry of Power	Manage electrical power for groundwater extraction
Indian Council of Agricultural Research	Technical input and contingency planning
National Center for Medium Range Weather Forecast	Provide medium-term forecasts

Table 3: Monitoring and information management system of CWWG.

Parameters	National agencies	State agencies	District l agencies	Field agencies	Communication mode
A. Meteorological					
Delay in the onset of monsoon	W	W	D	D	Wireless/Fax/Telephone
Dry spell during sowing	W	W	D	D	Wireless/Fax/Telephone
Dry spells during critical crop growth period	W	W	D	D	Wireless/Fax/Telephone
B. Hydrological					
Water availability in reservoirs	W	W	D	D	Wireless/Fax/Telephone/ E-mail/written report
Water availability in tanks/lakes	F	F	F	W	Written report
Stream flow	F	F	F	W	Written report
Groundwater level	S	S	S	S	Written report
Soil moisture deficit	F	F	F	F	Written report
C. Agricultural					
Delay in sowing	W	W	W	W	Wireless/Fax/Telephone
Sown area	W	W	W	W	Wireless/Fax/Telephone/ E-mail
Crop vigor	F	F	F	W	Written report
Change in cropping pattern	W	W	W	W	Wireless/Fax/Telephone
Supply and demand of agricultural inputs	--	W	W	W	Wireless/Fax/Telephone/ NICNET

D = Daily, W = Weekly, F = Fortnightly, M = Monthly and S = Seasonal

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VI. DROUGHT DECLARATION

Drought declaration is the primary responsibility of the states while the central government only aids or facilitates and institutional processes. Forecasting of arrival dates of monsoons and rainfall deviations with respect to normal by IMD and monitoring at state level initiate the process of drought declaration. States also monitor rainfall at mandal or tehsil level and gather information from remote-sensing agencies. The Karnataka State has a Drought Monitoring Centre, which monitors rainfall, water-reservoir levels and other relevant parameters on a daily basis in the rainy season. Abnormal deviations beyond definite limits are generally highlighted by mass/electronic media, political processes get activated and humanitarian considerations become uppermost. Meteorologically, ±19% deviation of rainfall from the long-term mean is considered normal in India. Rainfall deficiency in the range of 20 to 59% represents a “moderate” drought. Negative deviation of more than 60% represents a “severe” drought.

VII. DROUGHT IMPACT ASSESSMENT

States have set rules and guidelines of appraising agricultural losses for declaring drought for the whole or part of a district/state. The system of estimating agricultural losses varies from state to state. An example-the Annawari procedure of estimating losses used in Gujarat-is prescribed in Gujarat Relief Manual under the Gujarat Land Revenues Rules. The procedure allows losses to be assessed in terms of scores (1 to 12 scores). The assessment is carried out for each village by the Annawari Committee, which includes a Chairperson (a Circle Inspector or Deputy-Mamlatdar or Extension Officer or Gram Sewak) and Members (Talati, Sarpanch, Chairperson of Cooperative Society and a representative of the farmers). The committee estimates yield from three plots representing good, medium and poor crop conditions in a village, by actual harvesting (Samra, 2004). The Annawari score is calculated as follows:

Annawari score = (12 Observed yield)/ (Standard yield of the village)*

The score of less than 4 is considered to be the indication of a severe drought Moderate drought is indicated by the score between 4 and 6 points. The estimated Annawari is published by the Mamlatdar and invites objections, if any, from the villagers within 15 days. After the objection period is over the Mamlatdar submits the report to the Sub-divisional Magistrate, who sends the evaluation to the District Collector to finalize the decision.

In Maharashtra, a similar system is called the Patsewari system. It works on a scale of 1 to 100 scores, and if a village gets less than 50 scores, it is declared drought-affected. The State of Andhra Pradesh also supplements estimates of losses by remote sensing. In a predominantly rainfed state like Chattisgarh, rainfall deficit itself is the criterion for declaring drought without actual estimation of agricultural losses (Samra, 2004).

Once drought has been notified by the state, it is mandatory for the center to depute a team of experts to verify losses claimed by the state. The states also submit memoranda for financial assistance from the federal government, which are generally exaggerated and are invariably verified by the central teams later on. However, declaration by the states sets into motion several response mechanisms at various levels of management. Normally, such declaration is made by the states after assessing losses by crop-cutting experiments or satellite tracking. Multivariate crop production predicting models, based on climatic parameters, are also available in India and have been successfully validated.

The normal practice of the past was waived off and most of the states adopted the unusual approach of declaring drought on the basis of ‘eye-estimation’. If the states are unable to manage drought out of the already parked Central Relief Fund (CRF), they submit memorandum of additional assistance from NCCF, which is meant for ‘severe drought’ but recoverable from the states later on. Also, the states go on updating the list of drought-affected districts according to the progression of drought and areal coverage.

VIII. SUMMARY AND CONCLUSIONS

Drought has a major impact on socio-economy and human well-being. They affect the environment and the economy we depend on. Drought may, for example, cause losses in crop production, lead to lack of drinking water, hinder waterborne transport, reduce hydropower production, cause forest fires and may leads to poverty and regional conflicts. The impacts are serious and they cause loss of life and especially in developing countries aggravation of poverty and mass migration. Impacts are likely to increase with time as societies’ demands for water and environmental services increase.

The average drought frequency can be significantly described using dimensionless climatic parameters derived as the ratio of mean annual potential evapotranspiration to mean annual precipitation (E_p/P_a) and the ratio of mean annual deficit to mean annual precipitation ((E_p - P_a)/P_a). The frequency and severity of meteorological droughts have notable relationship with the E_p/P_a ratio. Average drought frequency (i.e. yr^{-1}) is seen to decrease gradually from dry to wet regions, from once in two to three years in the arid regions ($12 > E_p/P_a \geq 5$), three to five years in the semiarid regions ($5 > E_p/P_a \geq 2$) and five to nine years in the sub-humid regions ($2 > E_p/P_a \geq 3/4$). In semiarid to sub-humid regions with the Ep/Pa ratios between 3.5 and 0.5, the drought frequency decreases exponentially with increase in wetness. The relationship obtained between the average drought return period and the ratio of mean annual deficit to mean annual precipitation ($(E_p - P_a)/P_a$) also indicates the drought frequency to increase with increase in mean annual deficit.

The areas located in arid and semiarid climatic regions are susceptible to suffer from relatively more intense meteorological droughts than areas in the sub-humid climatic region. The occurrences of severe droughts are much rare in the regions with the E_p/P_a ratio less than 1.2. The extreme drought events are almost unnoticed in the regions with the E_p/P_a ratio less than 1.20. More frequent persistent drought events occur in arid and semi-arid climatic regions compared to other climatic regions. Presence of mountains and ocean in close vicinity influences the drought characteristics in the regions with $P_a \approx E_p$.

The Ministry of Agriculture monitors drought condition in India. Declaration of drought and implement relief and mitigation measures is done by Sates while the central government only aids and supports. Current drought management system in India is very much steered towards relief and crisis management rather than proactive mitigation. There is need to prepare region specific plan for drought management in India. The relations presented in this paper can be used as a sensible tool for prediction of regional drought characteristics and planning of appropriate drought management strategies for different climatic regions.

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