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L E T T E R S

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LONG TERM ASSESSMENT OF SOUTHWEST MONSOON DROUGHT EVENTS AT TALUKA LEVELS IN GULBARGA DISTRICT OF KARNATAKA

1. Drought is considered to be a strictly meteorological phenomenon. It is also a complex phenomenon whose severity depends on the precipitation amount, its time and space distribution, evapo-transpiration and on hydrological factors. For most parts of the world, drought remains as a threat that may occur with little or no warning. In spite of technological advancement made by India, the drought still continues to be a major factor of uncertainty. Sometimes it takes the form of national calamity creating serious crisis in drinking water, food production and power generation. By the experience of the past century the Indian arid and semi-arid zones experience drought situations once in alternate three years Mohan and Mahesh, (2004). Prolonged droughts are experienced about five times in a century, leading to severe scarcity of food fodder, fuel, fruits, flowers and fiber. Ramdas and Mallik (1948) have defined 'drought week' as a week receiving rainfall equal to or less than half of the average rainfall of the week. Banerji and Bhhabra (1963) analyzed the drought conditions during the south-west monsoon season using the definitions on the basis of rainfall deficits from normal as; between 11 to 25 per cent-slight drought; between 26 to 50 per cent-moderate drought; and if it is greater then 50 per cent-severe drought. Sharma *et al*. (1987) analyzed monthly and yearly drought for agricultural planning. Above definitions were used to study the drought situation at different corner of the country, *e.g*., Dabral, (1996); Kumar and Kumar, (1989); Ray *et al.* (1987); Ranade and Gupta, (1992). Erratic and scanty rainfall, excessive depth to ground water, absence of perennial rivers, and porous nature of soils are interrelated. The major causes contributing to drought are increased pressure of both human and livestock population during the previous century which had imposed tremendous pressure on natural resources particularly in the arid and semi arid regions.

Gulbarga is one among the drought affected districts, in Karnataka. It has a long history of droughts and on an average the district is suffering by drought once in three years. However, in present times, this situation has further aggravated due to continuous failure of monsoon for the last few years. Hence, a detailed study of the drought conditions in the district is required. The district is situated in rain shadow area. The rainfall in the district mainly depends on depressions in the Bay of Bengal near Andhra Coast. The drought conditions in the districts are the result of sharp climatic variations in rainfall distribution and occurrence of breaks. There is a great variability in monsoon rain from year to year or in time and space in any one year. The district is situated in rain shadow area. South-West monsoon season in the district is consisting of the two currents which originate in the south Bay of Bengal and the Arabian Sea during the hot weather season [Jay Rami Reddy (2004)]. It is in this South-West monsoon season that a major portion of the country receives more than 75 per cent of the rainfall. However, South-West monsoon season period is not the period of continuous rainfall. There may be breaks of about a week, month or more with no rainfall activity. So far in the Gulbarga district, details studies using Remote Sensing & Geographical Information system have not been carried out to analyze the drought severity, intensity and duration considering the South West monsoon period.

2. *Study area* - Gulbarga district has been situated towards North-Eastern part of the State of Karnataka extended on latitude 16° 12′ and 17° 46′ north and longitude 76° 04′ and 72° 42′ east. The height from the mean sea level of the district is about 693 m. The district is divided into two agro climatic zones, namely North-Eastern transition zone, comprising Aland and Chincholi taluka and North-Eastern dry zone comprising remaining eight talukas, namely Afzalpur, Chithapur, Gulbarga, Jewargi, Sedam, Shahapur, Shorapur and Yadgir. Gulbarga district is the second biggest district of the state.

The district lies on Deccan plateau composed of basaltic, literate, sedimentary and other rock formations. The district is having four major soil types, *viz*., deep and medium block soils are found in Sedam, Chithapur, Gulbarga, Afzalpur and Aland talukas. Red loamy and Sandy Loamy soils in Yadgir, part of Chincholi, Shahpur and Shorapur. The ground water in the district occurs under semi confined conditions in highly decomposed, weather and fractured zones of the formations. The ground water table in the district is steadily decreasing.

The Gulbarga district having the total area around 16, 240.0 sq km and accounts 8.45 per cent of the Karnataka state area. The forest area is only 68,000 hectare (Director, 2005). There are 1378 villages in the

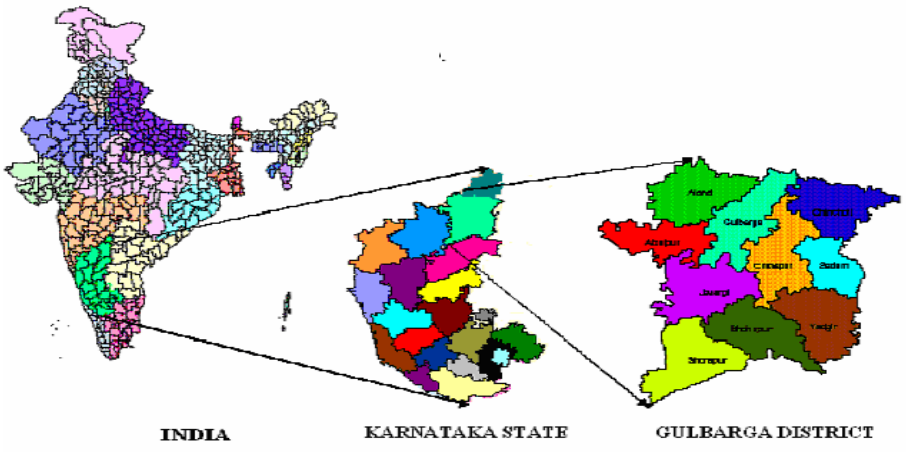

Fig. 1. Location map of Gulbarga district, Karnataka

district and the population of district is 31, 30,922 as per recent census. The district shares the boundaries with Bidar and Usmanabad of Maharastra state (MS) at North, Medak and Mehaboobnagar of Andhra Pradesh (AP) and Raichur at South and Bijapur, Sholapur, (MS) at West. The State Highway No.19 passes through the central part of the district. The South Central Railway line passes through the district linking with Hyderabad, Delhi, Bangalore, Chennai and Mumbai cities Refer Fig. 1. The district has been divided into 10 talukas for the purpose of administration. It comprises of 3 revenue sub-divisions and 7 police sub-divisions. Apart from, one Corporation (Gulbarga city), there are 12 Municipalities, 18 towns, 337 Gram Panchayats, 1360 inhabited villages, 77 Un-inhabited villages and 413 Thanas.

The climate of the Gulbarga district is sub-tropical, semi-arid type with moderate to severe summer, moderate winter and having low erratic rainfall. The average annual rainfall is 800 mm and it is bimodal in nature by spreading over 6 months from June to November. The South-West monsoon season contributes about 80 per cent of the annual rainfall. September is the rainiest month and the district gets little rain during the later part of the summer and post monsoon months, mostly as thunder showers. The temperature starts rising after the month of February and reaches its maximum in the month of May with a mean daily maximum of 43 °C and mean minimum of 22 °C (A Report, on Statistics of the Gulbarga district, 2006). In 48 years of study the highest annual rainfall of 1214 mm was recorded in the year 1975. The year 1972 received the lowest rainfall of 366 mm.

The total cultivated area in Gulbarga district is 12.55 lakh hectares, out of which Kharif area is 6.66 lakh hectares and Rabi area is 5.89 lakh hectares. The district normally has three cropping seasons namely (Contingency plan for Drought Relief Work, 2003) Kharif, Rabi and summer. The principal crops grown in the district are tur, bajra, ground nut, sunflower and Rabi jawar. Red gram is the single monocrop, occupying the highest area in the state and in the country. The district has a total of 2,41,482 small and marginal farmers. The district is economically backward with 80 per cent of the population depending on the agriculture. Most of the families reside in villages. The Gulbarga district has a long history of continuous droughts. The district also has very poor human development index. The total no. of agricultural labours is 4, 44,440. There appears to be no end to problems associated with pending irrigation projects in this drought-prone district. Even after spending Rs. 722.30 crore so far, not a single acre of land had been provided for irrigation under the one major and two medium irrigation projects taken up in Gulbarga district (Sivanandan 2010). The original cost of these three projects put together was just Rs. 21.45 crore when they were given approval by the Government 37 years ago. Another Rs. 150.75 crore was required to complete the Bennethora Major Irrigation Project, the Amarja Medium Irrigation Project and the Lower Mullamari Irrigation Project. Now, their revised cost as per latest estimates is Rs. 868 crore. A sum of Rs. 722.30 crore has already been spent on these projects. At present, out of total cultivated area only 18 per cent is under irrigation. The balanced cultivated area totally depends on rainfall only. With the completion of ongoing irrigation projects like Bennethora, Gandorinala and Amarja, the area under irrigation will be increased to 35 per cent of cultivable area only.

3. *Data used* - In this study the Survey of India (SOI) Topo sheets of 56C/3, 56C/4,56C/6, 56C/7, 56C/8, 56C/10, 56C/11, 56C/12, 56C/14, 56C/1656D/5, 56D/6,

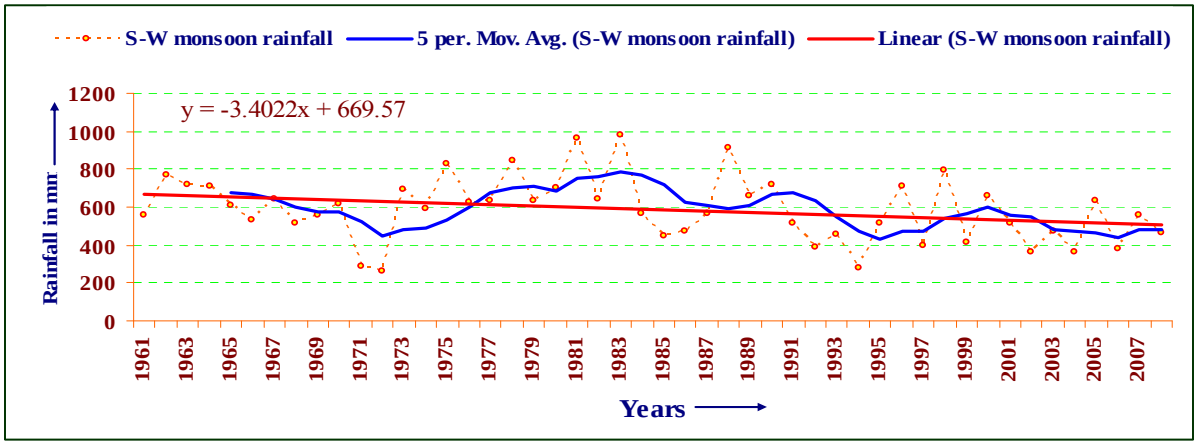

Fig. 2. Five years moving average trend in total SW monsoon rainfall of Gulbarga district

56D/7, 56D/9, 56D/10, 56D/11, 56D/13, 56D/14, 56D/15, 56G/2, 56G/4, 56G/6, 56G/7, 56G/8, 56G/10, 56G/11, 56H/1, 56H/2, 56H/3, 56H/5, 56H/6, 56H/7 in 1:50,000 scale, which covers the Gulbarga district were used. The average monthly rainfall data in all the ten talukas of the district collected from 1961 to 2008 (48 years) for all available rain gauge stations in the district from Drought Monitoring Cell Bangalore, were used for the analysis.

4. *Methodology* - All the topo sheets of Gulbarga district (37 numbers) of 1:50,000 scales which are purchased from Survey of India Department which covers the Gulbarga district are coloured scanned with high resolution DPI. All individual topo sheets are rectified with respect to latitude and longitude using ERADAS IMAGINE 8.5 Software. After rectifying the entire topo sheets unwanted portion is removed using sub set command in ERADAS IMAGINE 8.5 Software. All 37 topo sheets are mosaiced and then re-projected the mosaiced SOI topo sheets image. Again the projected mosaiced SOI topo sheets image is opened in ERADAS IMAGINE 8.5 Software viewer and then digitized the entire base feature using permanent control points like district boundaries, taluka boundaries, main roads, settlement area etc.

The raw IRS-1D (LISS-III) remote sensing and PAN satellite data of row 60 to 61 and path 98 to 99 of December 2000 which are collected from Karnataka Remote Sensing Application Centre Bangalore is processed. First the IRS-1D (LISS-III) image is rectified with respect to already rectified projected mosaiced SOI topo sheets and PAN satellite data is also rectified with rectified projected mosaiced SOI topo sheets. After rectifying both IRS-1D (LISS-III) and PAN data, using Special Enhancement Resolution Merge Menu, the IRS-1D (LISS-III) and PAN data are merged together**.** Covering the entire area of the Gulbarga district, choosing twenty five (25) training sites which are equally distributed in the study area, are selected by the field work, the signature editing of the image was carried out for already collected training sites. Adopting the same procedure the same signature editing was done for the entire area to prepare the drought maps.

For the drought analysis the criteria given by India Meteorological Department (IMD 1971) and National Commission on Agriculture (NCA 1976), classified the droughts on the basis of annual rainfall deficiency.

From field survey and overall examination of the drought conditions in semi-arid climatic regions of Gulbarga districts, on the basis of percentage departure given by (IMD, 1971) and (NCA, 1976). The district drought severity changes with cumulative effect of modification of physical environment, growth in population leading to water demand, variation in climate, damage to the hydrological cycle by way of landscape and land use modification, rapid industrial growth, contamination of existing water resources. It is found that percentage departure slightly requires modification to describe realistically the drought in this selected region. The five yearly moving average annual rainfall of the district were worked out to ascertain the trend line. From the analysis it was also observed that the decreasing trend in rainfall was noticed. Hence, the percentage departure criteria was modified to suit the tropical weather conditions of Gulbarga districts. The modifications introduced were in respect of the assumptions and

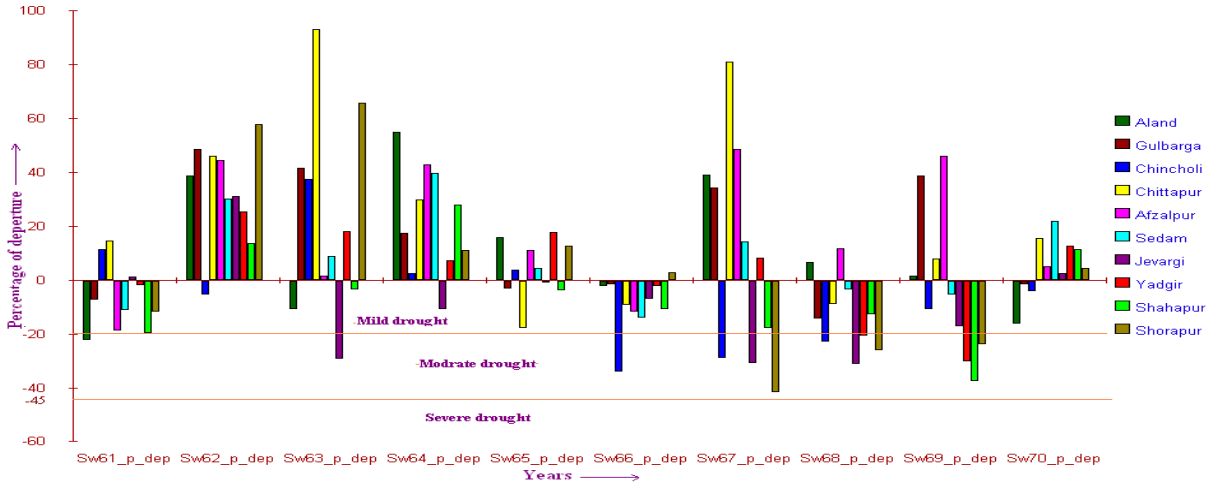

Fig. 3. Percentage of departure and drought conditions for southwest monsoon rainfall (1961-1970)

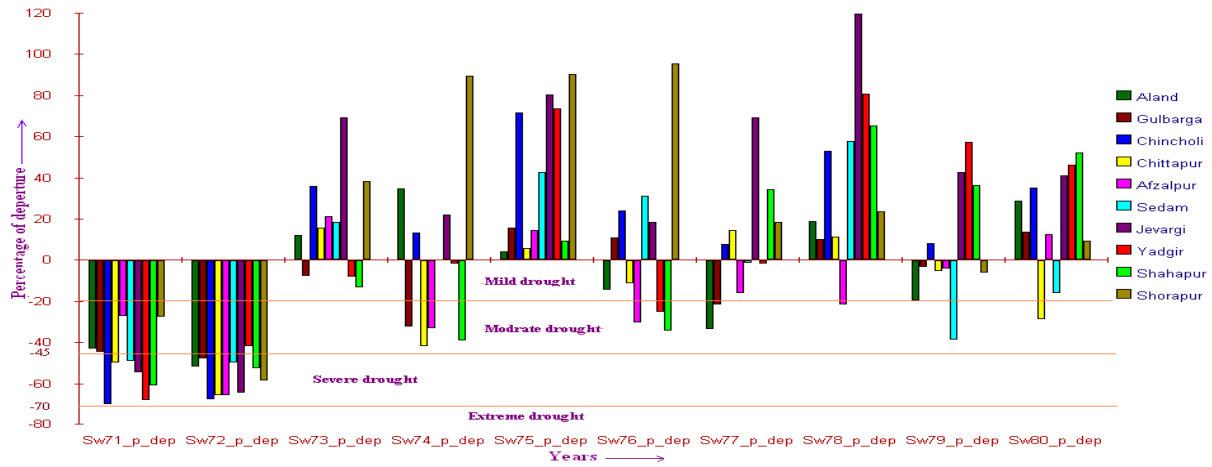

Fig. 4. Percentage of departure and drought conditions for southwest monsoon rainfall (1971-1980)

weighting factor. The modified drought index was observed to produce better and realistic results. For the modifications on the basis of assumptions the following factors are considered accordingly and Weightage are given for different factors for the analysis of drought.

Gulbarga district comes under arid to semiarid climatic region. Hence the generalized criterion mentioned by IMD for the classification of drought on the basis of percentage departure required slight modification.

(*i*) Computations of the intensity of the drought, the difference in the Percentages of departure for mild and moderate drought the range is 25 but for the severe drought the percentage of departure range is 50 to 100. This shows imbalance in defining the severity of drought.

(*ii*) Drought typically results from a synergistic interaction between original local and remote influences. But in the criteria given by IMD the local and remote influences are not taken into account.

The factors which will govern the severity of different category of drought are Rainfall, Increased Evapo-transpiration, Cultivation, Crop Pattern, Ecological imbalance, Temperature, Reduced cloud cover, Water vapour deficit, Ground water deficit, Reduced Forest, Low

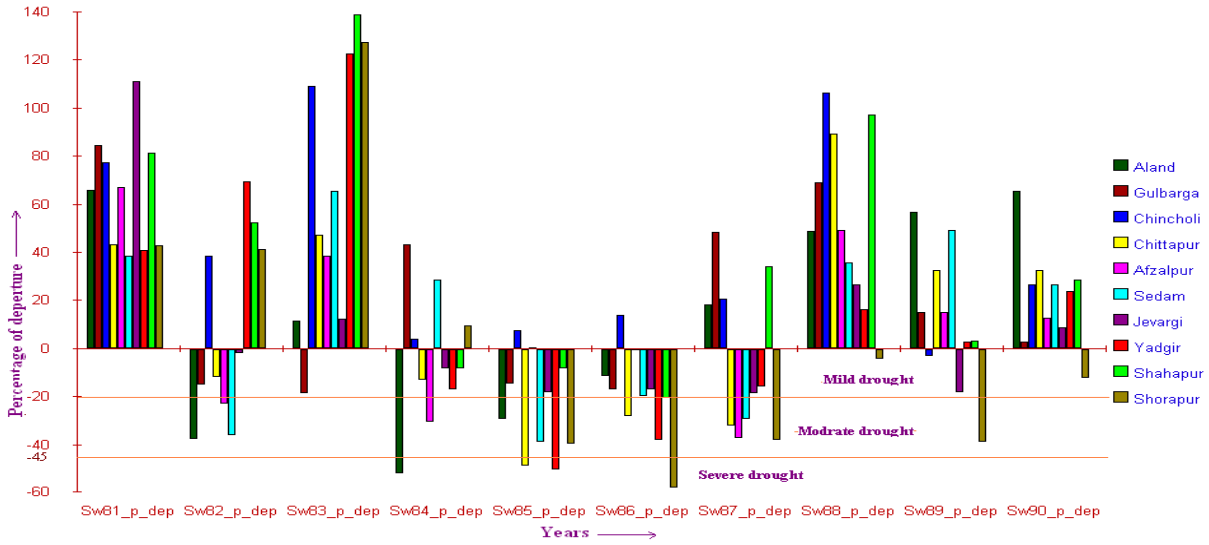

Fig. 5. Percentage of departure and drought conditions for southwest monsoon rainfall (1981-1990)

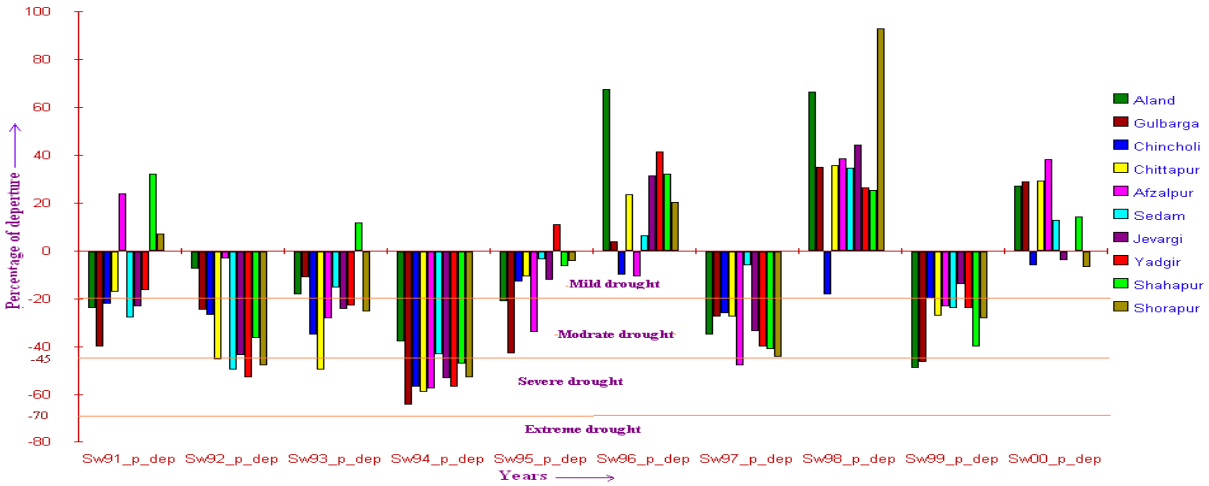

Fig. 6. Percentage of departure and drought conditions for southwest monsoon rainfall (1991-2000)

soil water recharge, Low moisture holding capacity, Reduced green ground cover, Irrigation, River network, Monsoon mechanism, Low pressure, El Nino Southern Oscillation, Available water resources, Economic activity of the region.

Considering the above factors directly and indirectly affecting the intensity of drought in the study area the impact of drought severity increases. While observing the moving average annual rainfall trend line of the district, the results showed that the southwest monsoon rainfall decrease @ 3.40 mm per year (Fig. 2). The trend however be attributed to variation in above mentioned factors, decreasing forest cover and all other hydro meteorological variation in the study area.

Hence, the increase in negative percent of departure of each above mentioned factors are assumed to be 0.25% and the total per cent of departure is increased to -5.00 for the prediction of drought in the study area. Also from the above description the condition given by IMD and

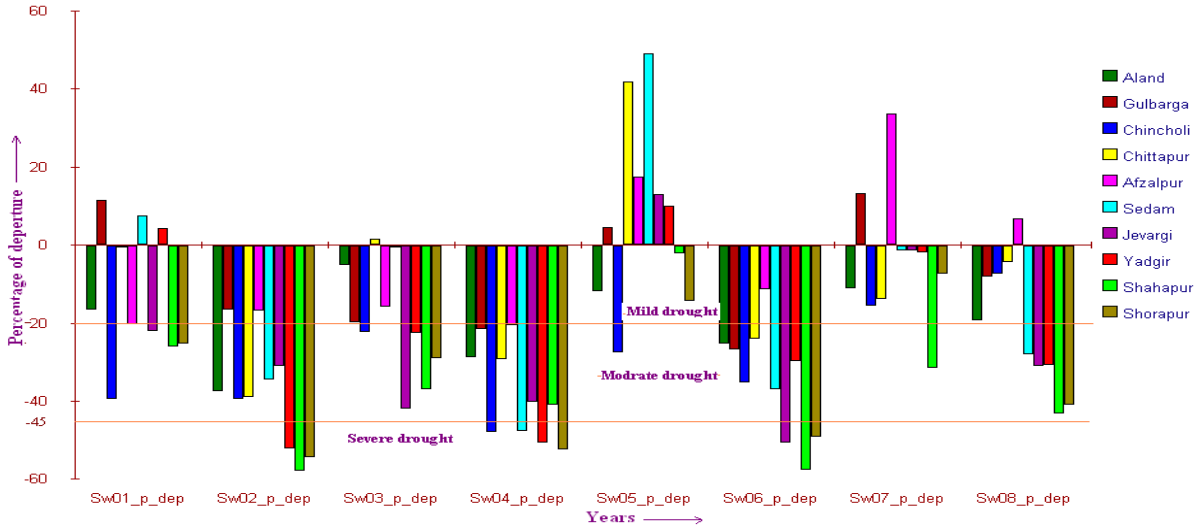

Fig. 7. Percentage of departure and drought conditions for southwest monsoon rainfall (2001-2008)

NCA is modified as given below and drought severity analysis is carried out for the annual rainfall for the district.

% of departure from normal rainfall	*Intensity of Meteorological drought*	*Code*
0.0 or above	No drought	M_0
00.0 to -20.0	Mild drought	M_1
-20.01 To -45.0	Moderate droughts	M_2
-45.01 to -70.0	Severe drought	M_3
-70.01 or above	Extreme drought	M_4

The major uncertainty in the southwest monsoon period is the beginning of the rain may be delayed considerably on the whole, there may be prolonged break or breaks lasting over the greater part of July and August, The rain may end considerably earlier than usual and the rain may persist more than usual.

5. *Results and discussion* - The increasing trend of rainfall is observed from 1962 to 1965. The rainfall in all talukas approximately showed the negative deviation starting from 1967 and it reaches minimum value up to 220 mm in 1972 onwards. Increasing trend of rainfall is observed from 1973 it continued up to 1984. Again rainfall trend decreases from 1985 to 1987. The rainfall increases slightly from 1988 to 1990. Again decreasing trend starts 1991 onwards it continues up to 1995. From 1996 the yearly fluctuation from positive to negative trend in the rainfall is observed up to 2008. The study of 5 years moving average curve shows that the decreasing trend of rainfall was observed from 1966 up to 1976. From the year 1977 the increasing trend of rainfall pattern was noticed which was up to 1993. Again from 1994 the decreasing trend was noticed up to 1998. Again the rainfall slightly increases in 1999 and decline started from the year 2002 which continues up to 2008.

For the study period of 1961 to 2008 the analysis, indicate that on two (02) occasions majority of the district area has experienced severe drought. The occurrence of drought appears to be a random phenomenon. From the drought study also it was observed that always moderate drought is immediately followed by mild drought and vice-versa. The Mild drought situations were observed minimum in Shorapur (08 times) (Figs. 3 to 7) and maximum in Gulbarga (15 times) of the district. Moderate drought occurred in those regions where the rainfall was moderate. Minimum in Gulbarga (09 times) taluka and was maximum in Shorapur (13 times). Severe drought occurred in those regions where the rainfall was very scanty (Table 1 and Fig. 8). The Severe drought was minimum in Afzalpur Gulbarga Aland taluka (03 times) and maximum in Shorapur (07 times) taluka. No extreme drought events are observed in this occasion. The

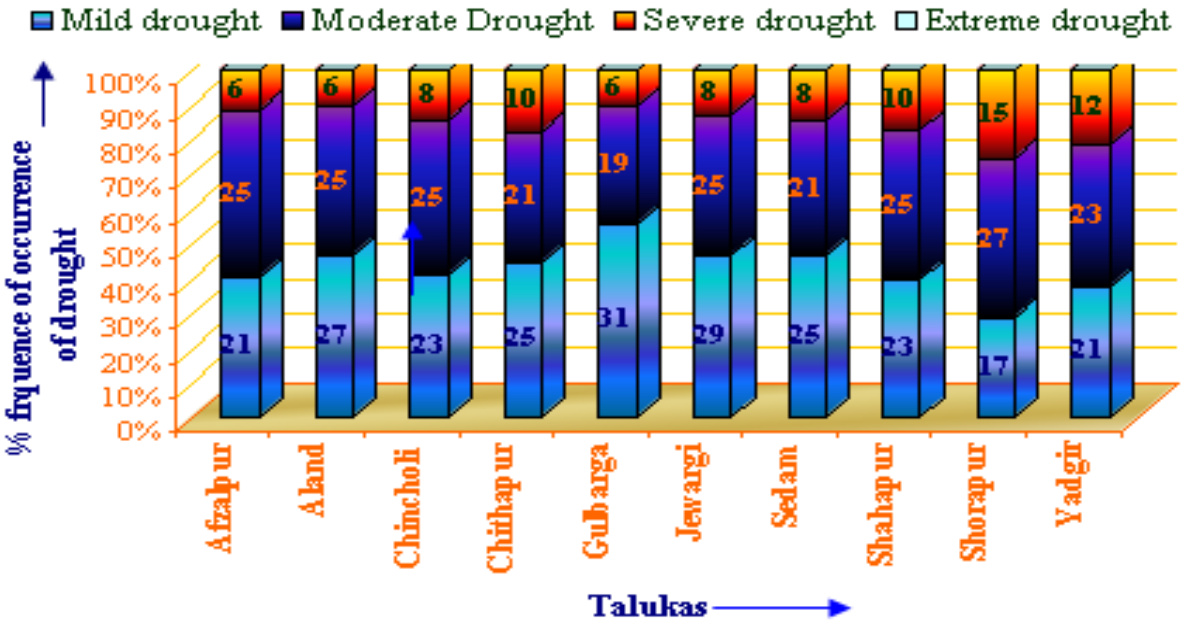

Fig. 8. Taluka wise percentage of different drought occurrence for southwest monsoon period in Gulbarga district

TABLE 1

Probability of occurrence of South-West monsoon period droughts (1961 to 2008)

S. No.	Talukas	Percentage frequency of occurrence of drought					Probability of occurrence of droughts
		Normal rainfall or No drought	Mild drought	Moderate drought	Severe drought	Extreme Drought	
		M_0	M_1	M_2	M_3	M_4	
		(%)	(%)	(%)	(%)	(%)	(%)
1.	Afzalpur	48	21	25	6	00	92.00
2.	Aland	42	27	25	6	00	71.00
3.	Chincholi	44	23	25	8	00	78.00
4.	Chithapur	44	25	21	10	00	78.00
5.	Gulbarga	44	31	19	6	00	78.00
6.	Jewargi	37	29	25	8	00	60.00
7.	Sedam	46	25	21	8	00	85.00
8.	Shahapur	42	23	25	10	00	71.00
9.	Shorapur	42	17	27	15	00	71.00
10.	Yadgir	44	21	23	12	00	78.00
Average percentage							76.00

probability of occurrence of drought was maximum (92.00 per cent) in Afzalpur taluka of the district. The average probability of occurrence of drought (76.00 per cent) was observed in the district. The different drought conditions with their magnitude of percentage of departure in various talukas of Gulbarga district for southwest monsoon for

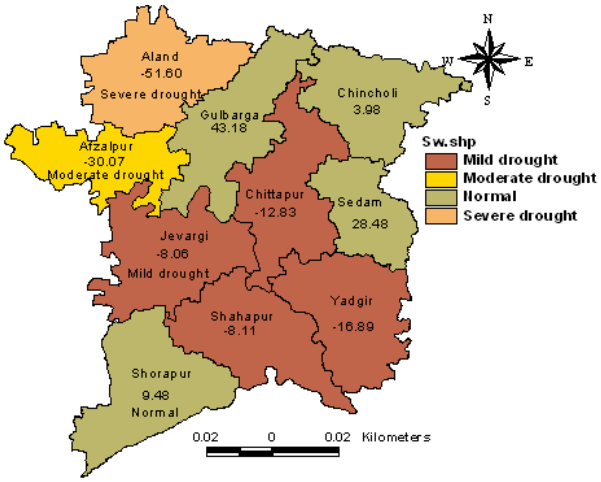

Fig. 9. Typical map of different drought conditions in southwest monsoon period of various talukas of Gulbarga district in the year 1984

the selected years 1971, 1972, 1994 and 2002 have been represented as typical maps in Fig. 9. The district experienced all types of drought conditions, *viz*., mild, moderate, severe droughts in one are other taluka of the district.

6. *Conclusions* - The occurrence of drought appears to be a random phenomenon, occurring at irregular intervals. There is no systematic time between two successive drought years in the district. From the analysis, it is observed that most of the talukas were affected by drought during the years 1971, 1972, 2003 out of these 1972, 2003 were the worst drought affected years. There is no systematic time lag between two successive drought years in the district. From the drought study it is observed that always moderate drought is immediately followed by mild drought *vice-versa*. During the period of (1961 to 2008) the analysis shows that there were two (02) occasions where majority of the district experienced severe drought conditions. The occurrence of drought in the district is quite high ranging from 50% to 65%. Most of the talukas were affected by drought about more than 50% during the period considered for analysis. This fact confirms that the entire district is a drought prone area. Continuous drought spells ranging from 2 to 5 years were observed in most of the talukas. Continuous drought of 8 years period from 1965 to 1972 is however observed in Yadgir taluk with occurrence of drought as high as 92%. In the study period of 48 years the district has experienced the mild drought 96 times, the moderate drought 139 times, the severe drought 161 times and extreme drought 156 times the probability of occurrence of droughts 76.14% in this period.

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