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Study of Drought in two Districts of Punjab

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Abstract : Punjab has a large canal network providing irrigation to its fertile plains. Food grain production is large in the state. Over the years, the irrigated area has expanded with increase in groundwater utilization. Due to semi arid climate, replenishable groundwater resource is limited in the state. Global and regional phenomena e.g. ENSO, EQUINO further influence the weather and reduce the rainfall in certain years. Several years face drought of varying intensity. Suitable planning is required to combat the droughts. Drought characterization is important for water resources planning in drought mitigation. Several drought indices are used to characterize drought. SPI (Standardized Precipitation Index) is based on precipitation data alone and uses data of various scales e.g. monthly, quarterly, half yearly etc. Based on the index value, drought is classified as moderate or severe. Further criteria are defined to compute start and end of drought events, their magnitudes etc. In this study, drought events were identified and their magnitudes were computed for two districts, namely Bathinda and Patiala in Punjab.

INTRODUCTION

Drought is a phenomena indicating the reduced availability of water to human, animal and plants over extended period of time. This reduction in availability in water is characterized considering rainfall, surface and groundwater storage and soil moisture etc. Drought indices based on rainfall alone are easy to calculate and thus are more prevalent. IMD uses percent deviation from normal as a drought index for its meteorological sub divisions. SPI (Standardized Precipitation Index) was developed by McKee and others in 1993 as a drought index. The index uses probability distribution function for rainfall. The indices are described below.

Percent deviation

IMD defines a normal rainfall as an average rainfall computed from time series of rainfall of a given scale. For a given year and time scale, a percent deviation from the normal rainfall is used to characterize drought. For a given period a rainfall deficiency between 26 and 50 per cent from mean results in moderate drought. A deficiency of more than 50% results in severe drought.

SPI : SPI was devised by McKee and others (1993) (vide Hayes 2006). Rainfall time series have negatively skewed distribution with smaller rainfall magnitudes occurring with larger frequencies. A two parameter Gamma probability distribution function provides better fit for the data. To classify severity of dryness, values of the standard normal variate are used. These values are -3, -2.5, -2, -1.5, -1, -0.5 and 0 (Table 1.0). SPI values are determined first finding cumulative probability for a given rainfall value.

Drought event, its duration and magnitude

Drought often persists over time. This period could be few weeks to several years. For identifying drought event of a given scale, drought index values of a similar or less scale are required. For example drought event of monthly

Table 1. Classification of SPI

SPI Values	Drought/ Wetness condition
- 0.99 to 0.99	Near normal
- 1.0 to – 1.49	Moderately dry
- 1.5 to – 1.99	Severely dry
- 2.0 and less	Extremely dry

scale can be identified using drought index of scale monthly or weekly time scale. A drought event is defined as an event when the SPI is smaller than -1.0 at any time during the event. The event starts when SPI becomes negative and ends when SPI becomes further positive. The duration is defined as period between start and end of the event. The magnitude is a positive sum of the SPI values during the event. Intensity is obtained by dividing the magnitude with duration.

STUDY AREA

Bathinda

Bathinda District is situated in the Southern part of Punjab State. It is lies between 29°33′ & 30°36′ North latitude and 74°38′ and 75°46′ East longitude. The district covers an area of 3367 sq. km and has a population of 11.8 lakh (Census 2001). It is the nearest to the Thar Desert of Rajasthan and also far away from the Major rivers lines that run through the state. The district has a very hot in summer and frequently scorching heat is in full swing. Dust storms are a regular feature in summer season. The monsoon is scanty and meager. The average rainfall is 410 mm. The soil in the district is mostly sandy. Being sandy Plain region is dotted with scattered sand dunes which have a tendency to shift towards eastern side. But with the development of latest Technology and machinery the topography is under vast change with respect to various aspects connected with green revolution.

Patiala

Patiala district lies in south-eastern part of the state between 29°49′ and 30°47′ north latitude, 75°58′ and 76°54′ east longitude. The geographical area is 3625 Sq. km and population is 18.4 lakh. The district forms a part of the Indo-Gangetic plain and consists of three types of region, namely Upland Plain, Foothill Plain, Floodplain of the Ghaggar River. The river Ghaghar is the most important water channel of the district. It is essentially a seasonal stream, remaining dry during most part of the year. The district also has three important canals, namely Bhakra Main Line canal, Nawana Branch, and Ghaghar Link. The irrigation canals have helped to transform the parched fields into fertile, double-crop lands. The Climate here is typical of Punjab plain i.e. very hot in summer and very cold in winter. The annual average rainfall is 688mm. On an average there are 61 rainy days. The month of May is the hottest with the mean monthly maximum temperature of 43.1°Celsius. January is the coldest month with mean monthly minimum temperature of 2.1°Celsius.

DATA

The monthly precipitation time series for period 1901 to 2002 was downloaded from India Water Portal (www.indiawaterportal.org). The data is based on Climate Research Unit (CRU) TS2.1 dataset, of the Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia in Norwich, UK. An interpolated data set is available at 0.5° latitude-longitude grid from global monthly rainfall. The dataset was processed in GIS software GRASS (Geographic Resources Analytical Support System) on an Ubuntu Linux operating system. GRASS GIS modules along with Linux scripting were used to extract data for Indian subcontinent. The gridded data was averaged for districts. For data gap of 25% of the district area or less, an approximation was done. For data gap larger than 25%, data was left blank. It is recommended that local data should be used where ever available. The data could be useful for regional studies (http://indiawaterportal.org/node/7160).

METHODOLOGY

A two parameter Gamma distribution (Equation 1-4) is fit to the monthly rainfall time series. Using the distribution, the cumulative probabilities (being equaled or remaining less) for all rainfall values are computed. Inverse cumulative normal distribution is used to obtain

SPI time series. The SPI time series is filtered for monsoon months of June to September. Most of the rainfall occurs during these months in Punjab. From this series, the drought events are identified. The SPI values were summed for each drought event to find its magnitude. Duration is obtained by counting the number of months in the drought event. The rainfall and median rainfall are also summed for the drought events. The absolute deviation and percent absolute deviation of the total rainfall from the total median rainfall is computed. The events are ordered in terms of drought magnitudes. Cumulative probability and its inverse for Gamma and Standard Normal distributions may be computed in spreadsheet Excel using functions, namely Gammadist, Gammainv, Normsdist and Normsinv.

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \quad \ldots(1)$$

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1+\frac{4A}{3}}\right) \quad \ldots(2)$$

$$\beta = \frac{\bar{x}}{\alpha} \quad \ldots(3)$$

$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n} \quad \ldots(4)$$

Where, n = number of precipitation observations, $\bar{x}$ is mean precipitation

The computer program to compute SPI can be downloaded from site http://drought.unl.edu/monitor/spi/program/spi_program.htm. The program is already compiled and all libraries are included (it was compiled in C++ for PC) to generate executable file (file with extension exe). At least 30 consecutive years without missing monthly data, and more than 60 years is recommended for the SPI calculation. To execute the program it can be run at the DOS prompt.

The precipitation values are entered in one hundredths (i.e. multiply precipitation values by 100) integer values in input to the SPI program. Zero precipitation is changed to one- hundredth (smallest denomination). Missing data values are expressed as zero. A computer program in C++ was written to convert the monthly rainfall data to the data format required by the SPI program. Rainfall for SPI, median (SPI= zero) and mean rainfall were also computed in MS Excel. Rainfall deficit from median were computed for each month.

Seasonal drought (monsoon)

Months, SPI values, rainfall, median (by repeating median values in each month) column were populated in MS Excel sheet. Rainfall deficit from median was computed. 'AutoFilter' was used to filter the monsoon months for computations. The drought events were identified based on SPI values. The magnitude and duration were entered at end of each drought event. The durations of the drought events were counted. Magnitudes were computed by summing SPI values for the drought durations. The sheet was again filtered for 'non blank' values in drought duration. The values of the sheet were copied to another sheet for further ordering as per magnitude and rainfall deficits. For finding drought probability, only most severe drought event was considered in each year. The Weibull distribution was used for finding the probability of occurrence of a drought event of given magnitude or deficit rainfall.

RESULTS

Rainfall for SPI values

Bathinda district

In Bathinda district, the high rainfall occurs in July and August months. Rainfall in June and September is nearly one third of that in July and August. Some rainfall also occurs in January to May. October to December receives nearly no rainfall. Deficit from median varies from 25 to 90% of median rainfall in July and August for values of SPI -0.5 to -3.0. For Other months, higher percent deficit occurs at same SPI value. Similar values occur for percent deficit from mean rainfall values. Rainfall

deficit from median varies from 25 to 85 mm and from mean varies from 35 to 90 mm for July and August. Rainfall for different SPI is given in Fig. 1.0.

Patiala district

The district receives higher rainfall compared to the Bathinda district. Seasonal rainfall pattern is similar to that of Bathinda district. Deficit from median varies from 20 to 80% of median rainfall in July and August for values of SPI -.5 to 3.0. For Other months, higher percent deficit occurs at same SPI value. Similar values occur for percent deficit from mean rainfall values. Rainfall deficit from median varies from 30 to 120 mm and from mean varies from 40 to 130 mm for July and August. Rainfall for different SPI is given in Fig. 1.

Drought magnitude

Bathinda district

Drought of magnitude 1.5 or higher has 35% chance of occurrence (Fig. 1). Drought of magnitude two or higher has 24% chance of occurrence. Drought of magnitude 2.5 or higher has 12% chance of occurrence. These droughts may be classified as mild, moderate and severe respectively. Drought years and deficit rainfall during droughts are given in Table 2 and 4 respectively.

Patiala district

Drought of magnitude 1.5 or higher has 40% chance of occurrence (Fig. 2). Drought of magnitude two or higher has 26% chance of occurrence. Drought of magnitude 2.5 or higher has 17% chance of occurrence. These droughts may be classified as mild, moderate and severe respectively. Drought years and deficit rainfall during droughts are given in Table 3 and 4 respectively.

CONCLUSIONS

Rainfall is important for replenishment of groundwater resources. Rainfall is also useful for rainfed agriculture. Deficit during the cropping season may affect the crop yield and thus rainfall distribution is also important for getting good crop yield. Meteorological drought indices may play

Table 2 : Drought years in Bathinda district

Drought	Years									
Severe	1905	1947	1918	1938	1915	1987	1911	1937	1919	1952
		1974	1939	1907	1968	1982				
Moderate	1926	1901	1941	1904	1925	1930	1943	2002	1920	1954
Mild	1970	1931	1967	1965	1956	1950	1991	1903	1934	1962
		1912								

Table 3 : Drought years in Patiala district

Drought	Years									
Severe	1918	1907	1905	1987	1938	1947	1965	1911	1974	1952
		1935	1941	1939	2001	1903	1932	1920		
Moderate	1923	1937	2002	1926	1999	1915	1981	1930	1931	1991
Mild	1979	1982	1928	1954	1970	1925	1913	1993	1968	1934
		1959	1924	1929	1949					

Table 4 : Deficit rainfall during droughts in Bathinda and Patiala districts

Drought class	Deficit from median rainfall	Bathinda	Patiala
Mild	Max of Percent deficit	93%	86%
	Min of Percent deficit	17%	26%
	Average of Percent deficit	70%	64%
	Max of Deficit	67	104
	Min of Deficit	19	30
	Average of Deficit	37	62
Moderate	Max of Percent deficit	96%	90%
	Min of Percent deficit	25%	29%
	Average of Percent deficit	58%	57%
	Max of Deficit	99	129
	Min of Deficit	22	36
	Average of Deficit	68	92
Severe	Max of Percent deficit	99%	62%
	Min of Percent deficit	30%	24%
	Average of Percent deficit	73%	45%
	Max of Deficit	143	198
	Min of Deficit	23	96
	Average of Deficit	87	140

important role in water resources planning and management. Irrigation from groundwater may prove important to meet the water requirement of crop in drought years. Thus, information on drought may be incorporated in water resources planning.

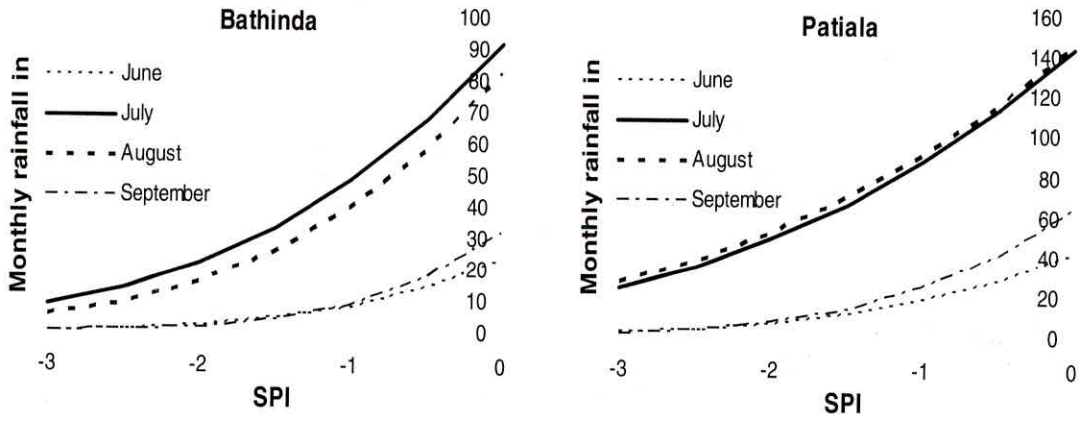

Fig. 1 : Rainfall for SPI values in Bathinda and Patiala districts

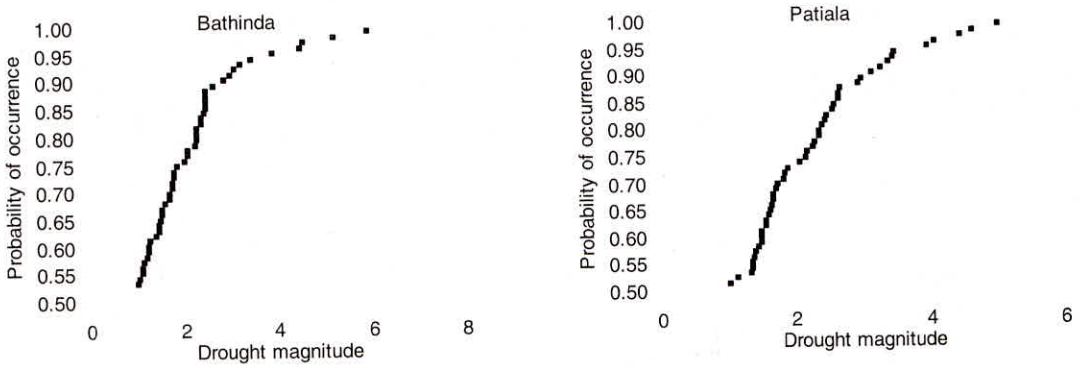

Fig. 2 : Probability of occurrence of droughts in Bathinda and Patiala districts

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