Research Article

Estimation of extreme weather conditions flood and drought forecast for Jammu

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Abstract

Introduction: Various indices are in use to define and estimate weather conditions of a region. Each of the indices has its pros and cons. Among all indices Standardized Precipitation Index is most commonly used.SPI, being the most appropriate of the existing indices for the estimation of drought; present paper studies the time series of SPI at 1-month, 3-month, 12-month, 48-month scale.
Keywords: Drought, Flood, SPI, Wet day, Dry Day.

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INTRODUCTION

Drought is being considered by many researchers as a complex weather phenomenon and least understood of all natural hazards, affecting more people than any other hazard. It is not possible to avoid drought or drought like conditions but the impact of drought can be minimized by managing the drought through advance preparedness. The success of management depends on how well the drought is defined and how well the drought characteristics are quantified .There are numerous definitions of hydrological, agricultural, ecological and economic drought. In this paper we have studied the quantified definition and characterization of drought. Many indices have been developed for drought characterization and classification, some of the widely used drought indices are the PDSI (Palmer, 1965), the Deciles (Kininmonth *et al.,* 2000), the SPI (McKee *et al.,* 1993), and the RDI (Tsakiris and Vangelis 2005).In this paper, we have studied the meteorological drought of Jammu on the basis of statistical tool SPI (Standard Precipitation Index). Rao and Padmanabhan (1984) investigated the stochastic nature of yearly and monthly Palmer drought index (PDI) and to characterize those using valid stochastic models to forecast and to simulate PDI series. Kim and Valdes (2003) used PDSI as drought parameter to forecast drought in the Conchos River Basin in Mexico. Durdu (2010) used ARIMA models to predict drought. The present study is envisaged to develop reliable and promising linear stochastic model of SPI for multiple time scale to forecast drought for Jammu region of J and K state. Linear stochastic model known as autoregressive integrated moving average (ARIMA) and is taken into consideration to predict drought for Jammu region using SPI as drought index. The Standardized Precipitation Index (SPI) is an index which was developed for defining and monitoring the phenomenon of drought and is widely used for defining and monitoring the metrological droughts and to

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know the behaviour of precipitation of a climatic zone or region. It is a popular index used globally because of its unique relation to probability, and normally distributed so it can used not only to monitor droughts but also wet as well as dry periods (Tsakris *et. al.* 2007). It provides a sound basis to researcher to determine and analyze the rarity of a drought at a given time scale (temporal resolution) for any rainfall station with some past data. Most of the researchers focussed on investigation variability of seasonal drought events. Patel *et al* 2007 concluded that SPI at a 3 month time scale was found effective in capturing seasonal drought patterns over space and time. But in this paper we have used along with 3 month time scale other time scales too for comparative results.

MATERIALS AND METHODS

Daily rainfall data recorded at the meteorological observatory of Sher-E-Kashmir University of Agricultural Sciences and Technology, Jammu was used for assessing various drought indices for Jammu region. Daily rainfall data of the period 1987-2013 is used for this study and distribution of monthly rainfall is shown in Fig. 1.

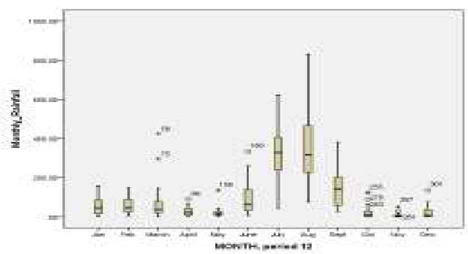
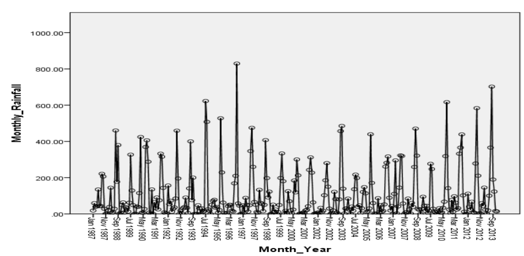


Figure 1: Distribution of monthly rainfall for Jammu City



THE STANDARDIZED PRECIPITATION INDEX (SPI)

Mathematically speaking, the SPI is based on the cumulative probability of a given rainfall event occurring at a meteorological station. Based on the past rainfall data, one can compute the probability of occurrence of rainfall being less than or equal to a certain specified amount. If a particular rainfall event (Dry) gives a low probability on the cumulative probability function, then this is indicative of a likely drought event. Alternatively, a rainfall event which gives a high probability on the cumulative probability function is an anomalously wet event. While soil moisture respond to precipitation anomalies on a relative short scale; groundwater, stream flow, and reservoir storage reflect longer- term precipitation anomalies. McKee *et al.* (1993) developed the SPI to quantify the precipitation deficit for multiple time scales, reflecting the impact of precipitation deficiency on the availability of various water sources. The SPI provides a simple and ready approach for drought analysis of a meteorological station or city. Computation of the SPI involves fitting a gamma probability density function to a given time series of precipitation, whose probability density function by the expression:

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

where $\alpha > 0$ is a shape parameter, $\beta > 0$ is a scale parameter, and $x > 0$ is the amount of precipitation. $\Gamma(\alpha)$ is the gamma function defined as:

$$\Gamma(\alpha) = \int_0^{\infty} y^{\alpha-1} e^{-y} dy \qquad (2)$$

For fitting the distribution to the available data we require the estimation of distribution parameters α and β . Using the approximation results of Thom (1985), the estimated value of these statistical parameters of gamma distribution are:

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right), \beta = \frac{\bar{x}}{\alpha},$$

here A=ln($\bar{x}$) - $\frac{\sum \ln(x)}{n}$ (3)

where n is the number of observations. Integrating the probability density function with respect to x yields the following expressions G(x) for the cumulative probability density function:

$$G(x)=\frac{1}{\Gamma\alpha}\int_0^x t^{\alpha-1}\, e^{-1} dt \quad (4)$$

Since the gamma distribution is undefined for x = 0 but meteorological data have several zero values in the recorded sample set. So, in order to account for zero value probability, the cumulative probability function for gamma distribution is modified as:

$$H(x) = q + (1-q)G(x) \quad (5)$$

where q is the probability of zero precipitation. To get the SPI values, the cumulative probability distribution is transformed into the standard normal distribution. Following the following approximate conversion provided by Abramowitz and Stegun (1965), it results:

$$Z = SPI = \begin{cases} -\left(t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2d_3t^3}\right), \text{for } 0 < H(x) < 0.5 \\ +\left(t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right), \text{for } 0.5 < H(x) < 1.0 \end{cases} \quad (7)$$

where $t = \sqrt{\ln\left(\frac{1}{(H(x))^2}\right)}$

and constants are c_0=2.515517; c_1=00802853; c_2=0.010328d_1=1.432788; d_2=0.189269; d_3=0.001308.

Once standardized, the strength of the SPI, as given in the Table 1 (Lloyd-Hughes and Saunders,(2002)) can be visualized. Positive SPI values indicate greater than medium precipitation, and negative values indicate lower than medium precipitation. Since the SPI is normalized, wetter and drier climates can be represented in the same way, and the wet periods can also be monitored using the SPI.

Table 1: Drought classification by SPI values and corresponding event probability

SPI Value Range	Category
SPI>=+2.0	Extremely wet
1.50<=SPI<=1.99	Severely wet
1.00<=SPI<=1.49	Moderately wet
0.00<=SPI<=0.99	Mildly wet
-0.99<=SPI<=0	Mild-drought
-1.49<=SPI<=-1.00	Moderate -drought
-1.99<=SPI<=-1.5	Severe –drought
SPI<=-2.00	Extreme –drought

Table 2: Frequency of % occurrence of extremely wet at different SPI

Month	SPI 1	SPI 3	SPI 12	SPI 48
Jan	2.63	2.91	2.91	0.13
Feb	2.51	2.42	2.55	0
Mar	2.75	2.06	3.03	5.96
Apr	2.35	2.76	3.01	0
May	3.11	2.18	1.45	1.65
Jun	2.96	2.26	3.13	0
Jul	2.87	2.30	0.73	2.53
Aug	2.75	1.70	1.58	2.41
Sep	2.35	2.63	2.51	0.26
Oct	10.75	2.06	3.03	2.53
Nov	18.77	2.63	3.01	5.12
Dec	2.25	2.53	2.76	1.38

Table 3: Frequency of % occurrence of severely wet at different SPI

Month	SPI 1	SPI 3	SPI 12	SPI 48
Jan	3.70	3.64	2.67	3.42
Feb	4.37	4.30	5.65	0.85
Mar	2.75	4.85	1.33	5.96
Apr	11.73	3.01	6.77	5.38
May	3.11	5.70	3.15	4.31

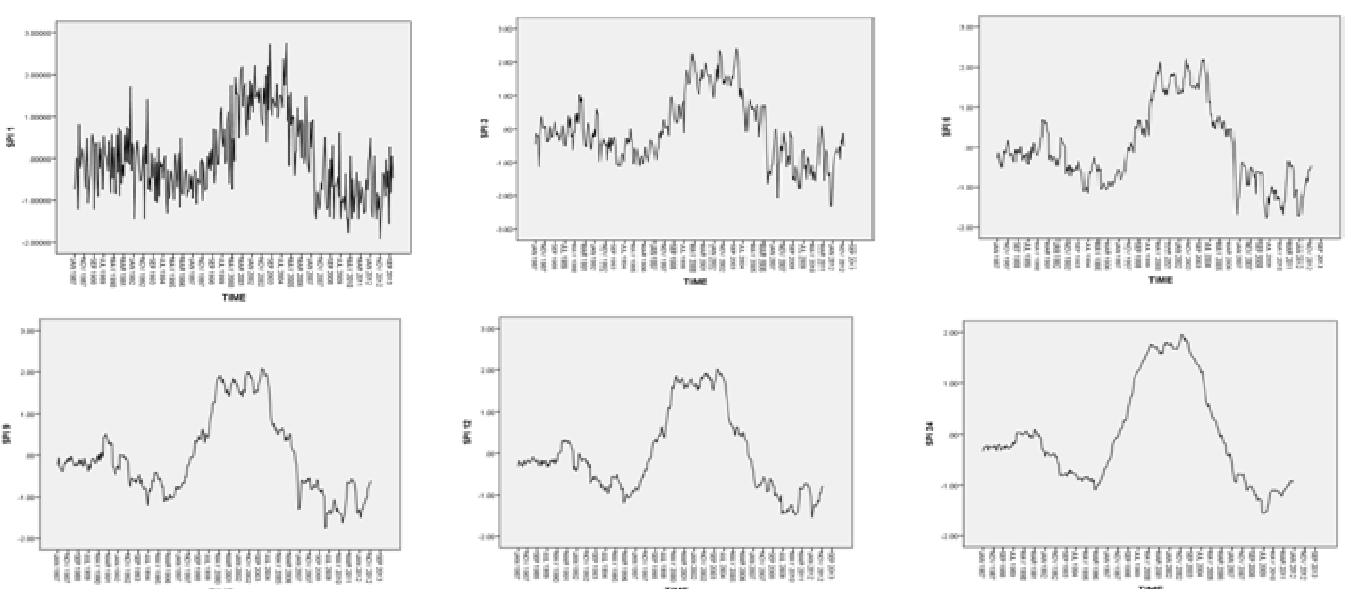
Jun	3.33	4.01	3.51	11.55
Jul	4.42	4.24	4.85	4.31
Aug	4.06	4.00	5.21	8.24
Sep	4.07	3.51	5.64	1.84
Oct	26.76	4.48	4.48	6.97
Nov	73.33	27.32	7.27	1.84
Dec	35.22	3.36	3.48	4.01

Table 4: Frequency of % occurrence of severe drought at different SPI

Month	SPI 1	SPI 3	SPI 12	SPI 48
Jan	0.00	0.00	0.00	7.48
Feb	0.00	0.00	0.00	2.11
Mar	0.00	0.00	0.00	2.03
Apr	0.00	0.00	0.00	3.15
May	0.00	0.00	0.00	3.42
Jun	0.00	0.00	0.00	5.12
Jul	0.00	0.00	6.06	1.90
Aug	0.00	0.00	5.33	2.59
Sep	0.00	0.00	1.00	6.04
Oct	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	5.39

Table 5: Frequency of % occurrence of Extreme drought at different SPI

Month	SPI 1	SPI 3	SPI 12	SPI 48
Jan	0.00	0.00	0.00	1.52
Feb	0.00	0.00	0.00	6.64
Mar	0.00	0.00	0.00	1.65
Apr	0.00	0.00	0.00	5.12
May	0.00	0.00	0.00	1.65
Jun	0.00	0.00	0.00	1.57
Jul	0.00	0.00	1.94	4.31
Aug	0.00	0.00	2.18	2.41
Sep	0.00	0.00	0.00	2.89
Oct	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00



RESULTS AND DISCUSSION

SPI at different time scales of 1-month,3-months,6-months ,9 months,12-months and 24 –months were computed for short and long term extreme weather conditions particularly drought. The SPI sequence plot is shown in Fig. From SPI at 3 month time period it can be concluded that Jammu experienced moderate and severe drought (SPI<-1) during the year 2005 and 2012 in the months of Sept and Jan respectively. From the graph it can be seen that it touched low in 2012 during the entire period data under study. The frequency analysis of occurrence of annual minimum SPI at higher time scale of 6-months and above showed that Jammu experienced moderate and severe drought for winter months of the years. A minimum SPI value for 6-months and 9-months occurred at Jan 2009 while for, 12-months and 24 months occurred at Jan-2012 and July 2009 respectively.

CONCLUSION

In this paper, we studied the extreme weather phenomenon for the Jammu region on basis of SPI values for different series. Temporal characteristics of the extreme weather phenomenon imply that region experienced occasional severe drought or drought like conditions (i.e. SPI <-1) for almost all months of the year. Thus, linear stochastic model can me employed for prediction of extreme weather event indicator SPI for multiple time scale to foresee the occurrence of drought which will help policy makers and planners to initiate the plans to mitigate the impact of extreme weather event.

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