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Study of Precipitation Indices for Drought Intensity at New Delhi, India

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***Abstract**: Rainfall, the most popular climatic factor, plays vital role in crop production. In the present study, variation in rainfall for New Delhi was analysed on the basis of daily rainfall dataset of 31 years (1981-2011) in terms of indices namely, Precipitation Anomaly Index (PAI), Precipitation Departure Index (PDI), Dependable Precipitation Index (DPI), Standardized Precipitation Index (SPI) and Standard Index of Annual Precipitation (SIAP) which revealed very high rainfall variability and subsequent the drought intensity.*

***Keywords**: Precipitation; indices; PAI; PDI; DPI; SPI; SIAP.*

I. Introduction

Rainfall is the most important hydrological variable which is measured at almost all places in arid and semi-arid areas. The rainfall variability indices, used to identify droughts with rainfall as a single input perform comparatively well in comparison to more complicated indices in depicting periods and density of droughts. Decision making for developing projects in arid and semi-arid areas encounters constraints related to limited and unreliable rainfall and high variability in rainfall pattern, therefore, it is necessary to understand variability in amount of rainfall received to develop effective management strategies and critical importance of rainfall is noted in recent drought years.

II. Materials and Methods

In this study, daily rainfall dataset of 31 years (1981-2011) for New Delhi was utilized in accordance with WMO recommendation that for agro-meteorological purposes, 30 year dataset would be quite adequate. For this, rainfall was analysed in terms of Precipitation Anomaly Index (PAI), Precipitation Departure Index (PDI), Dependable Precipitation Index (DPI), Standardized Precipitation Index (SPI), and Standard Index of Annual Precipitation (SIAP), described hereunder as:

Precipitation Anomaly Index (PAI), an index used to explain annual rainfall inconsistency [1] has proved itself to be a very effective in comparison to other complex indices [2]. The PAI is used to describe annual rainfall variability and is calculated for both positive and negative anomalies as:

$$\text{PAI} = \pm 3 \times \frac{(YP - AP)}{(A_{10} - AP)}$$

where YP = actual rainfall for individual years; AP = average rainfall; and A_{10} = 10 extreme rainfall values (highest and lowest) observed during the study period.

Precipitation Departure Index (PDI) is the measure of annual variability and long-term trends can be achieved by plotting rainfall departure from arithmetic mean for the period of record. Dependable Precipitation Index (DPI) can be measured by using equation:

$$\text{DPI} = 0.8 \times \sqrt[n]{P_1 \times P_2 \times P_3 \times \ldots\ldots\ldots \times P_n}$$

where P = years' rainfall; n = number of annual rainfall observations; and 0.8 = constant coefficient.

The obtained rainfall intensity can be classified in terms of normal rainfall (NR), dry-year threshold (D) and wet-year threshold (W) as NR = DPI ≤ P ≤ GM, D = P < DPI and W = P > GM where GM is geometric mean of rainfall values observed during the study period.

Standardized Precipitation Index (SPI) is a simple, powerful and flexible rainfall index based on probability of rainfall for any timescale [3]. In order to calculate this index, rainfall data series is fitted to gamma distribution function (pdf) given as:

$$f(x) = \frac{x^{(a-1)} e^{(-x/b)}}{b^a \Gamma(a)} \quad [\text{for } x > 0]$$

where x > 0 = rainfall; a > 0 and b > 0 are shape and scale parameters; and r (a) is gamma function. The aim of fitting distribution to data is to estimate parameters "a" and "b". By integrating pdf w.r.t. "x" and inserting estimated values of "a" and "b", the gamma cumulative distribution function (cdf) is computed at each value of "x" which is then transformed into standard normal distribution to yield SPI values. According to [4], SPI is less complex than Palmer drought severity index and many other available indices. The drought intensities resulting from SPI were classified [3] for drought events as:

Classification	SPI value
Extremely wet	2.00 and more
Very wet	1.50 to 1.99
Moderately wet	1.00 to 1.49
Near normal	-0.99 to 0.99
Moderately dry	-1.00 to -1.49
Severely dry	-1.50 to -1.99
Extremely dry	-2.00 and less

A drought event occurs any time when SPI value is continuously negative and reaches intensity of -1.00 or less and it ends when it becomes positive [3]. The SPI values can be calculated from 1 to 72 months and statistically, 1-12 months is best practical range of application [5].

The values of Standard Index of Annual Precipitation (SIAP) can be computed by using equation:

$$\text{SIAP} = \left(P_i - \overline{P}\right) / \ PSD$$

where P_i = annual rainfall in i^{th} year; $\overline{P}$ = average rainfall; and *PSD* = standard deviation observed for rainfall during study period. The trend of drought and wet years can be ascertained [6] on following basis:

Classification	SIAP value
Extremely wet	0.84 or more
Wet	0.52 to 0.84
Normal	-0.52 to 0.52
Drought	-0.52 to -0.84
Extreme drought	-0.84 or less

III. Results and Discussion

The analysis conducted for PAI revealed that it ranged in between (+) 4.83 in 2003 and (-) 4.52 in 1987 (Fig. 1), which shows that rainfall varied a lot around average value. The variation (upward and downward movement) observed in PDI (Fig. 2) shows above and below average rainfall from which it is clear that study area has experienced very strong rainfall departure from average rainfall. The results obtained from rainfall analysis pertaining to SIAP (Fig. 3) shows that 14 extremely drought, 4 drought, 19 normal, 4 wet, and 10 extremely wet years were observed at New Delhi.

Similarly, analysis pertaining to DPI revealed that 8 dry years, 17 wet years and 6 normal years were observed during 31 years of study period at New Delhi.

The values of SPI on 1, 3, 6, 9, 12 and 24 month timescales for New Delhi (**Table 1**) indicate that during study period, 8, 4, 4, 3, 4 and 0 months were classified as extremely wet, whereas, 43, 40, 35, 46, 47 and 53 months were observed as moderately wet on 1, 3, 6, 9, 12 and 24 month timescale respectively.

Figure 1: Variation in PAI values

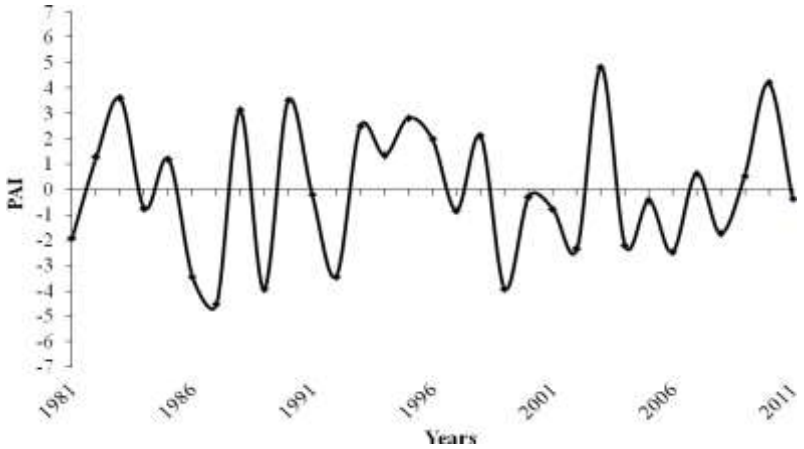

Figure 2: Variation in PDI values

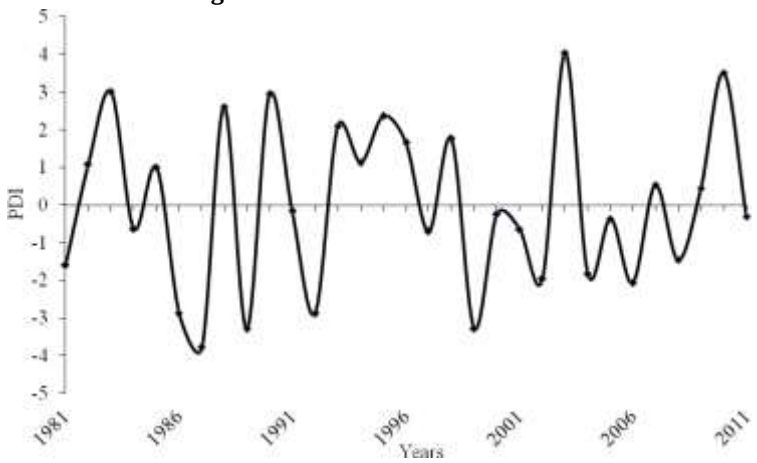

Figure 3: Variation in SIAP values

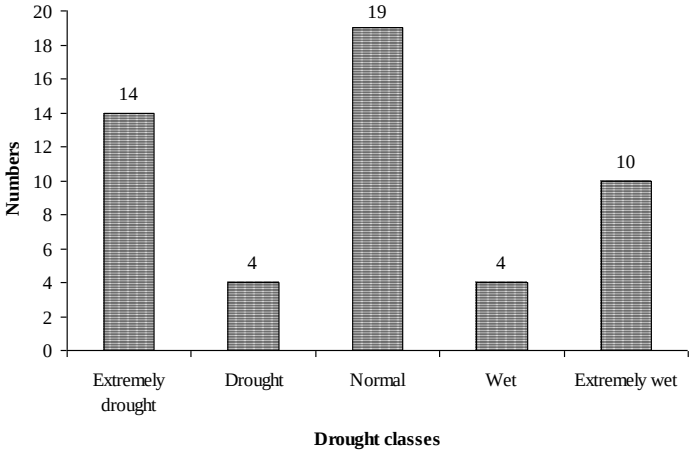

Table 1: SPI values observed at New Delhi

Classification	Total number of months in Timescale (months)					
	1	3	6	9	12	24
Extremely wet	8	4	4	3	4	0
Very wet	16	16	16	18	12	12
Moderately wet	43	40	35	46	47	53
Near normal	269	248	244	230	230	242
Moderately dry	24	36	36	37	39	23
Severely dry	8	17	23	20	17	6
Extremely dry	4	11	14	17	23	36

IV. Conclusions

Successful agricultural planning can be obtained only with scientific information about variation of climatic factors. Rainfall being the only climatic parameter which is normally recorded its variability for agricultural planning should be given much attention. With increasing change in rainfall occurrence during crop growing period, the sowing date, especially in arid and semi-arid zones, should be decided keeping in view the prevailing rainfall trend.

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