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A Case Study of the Deficit Spell Index for India’s Semiarid Delhi Region

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The Delhi region, the national capital region of India, is locked in by adjoining states like Uttar Pradesh and Haryana. Delhi has a characteristic continental type of climate, with extreme dryness, intensely hot summers, and dry cold winters. According to climatologists, this region is classified as semiarid tropical steppe. The monsoon rainfall is very erratic during June–September, which is the *kharif* crop-growing season. The monsoon breaks over the Delhi region between the first and second week of July and withdraws by the last week of September. The average annual rainfall is about 712.5 mm, of which 80% is contributed by the monsoon during *kharif* season.

With ever-increasing population in the Delhi region every year, there is a scarcity of drinking water, ground water levels are rapidly receding, usable land area is rapidly decreasing, and little agricultural activity is possible. Frequent droughts add to the misery. The frequency of droughts in the region is approximately 20–25%, with chronic drought experienced during 1918–19 and 1938–39.

Table 1 shows some recent drought years and good monsoon years that influenced the *kharif* crop yield. In the drought year of 1979, the paddy yield was only 10.9 q/ha. On the other hand, in 1990, a good monsoon year, the yield of paddy went up to 40.3 q/ha. Incidentally, rice is also a staple food along with wheat for Delhites; these crops are grown under both rainfed and irrigated conditions.

Year	Maize	Sorghum	Paddy
1979*	4.9	3.8	10.9
1987*	5.6	4.6	22.9
1988**	6.7	4.3	33.4
1989*	5.4	4.3	27.1
1990**	6.5	4.8	40.3

*** Drought year**
****Good monsoon year**

Table 1. Crop yield (q/ha) during good monsoon and drought years in the Delhi region.

It is the surplus and deficit rainfall over the crop-growing season, particularly in the *kharif* season, that needs study. A simple analysis of rainfall and potential evapotranspiration on a weekly basis gives us information like the Effective Precipitation Index (EPI) and deficit spells. From this, one can derive information about drought intensity and severity.

EPI is given as

$$\frac{\mathbf{P - PET}}{\mathbf{Pa}}$$

where **P** is the total precipitation for the week (in mm), **PET** is the total potential evapotranspiration for the week (in mm), and **Pa** is the total annual rainfall (in mm). To get rid of the negative sign when PET > P, the above equation can be rewritten as

$$\frac{\mathbf{EPI = P - PET}}{\mathbf{Pa}} \quad \mathbf{+ 1.0}$$

This leads to three situations:

EPI > 1.0 (surplus)
EPI = 1.0 (balance)
EPI < 1.0 (deficit)

The third situation is the most important in rainfed agriculture. The actual depth of water can be derived from the equation

$$\mathbf{P - PET = (EPI \bullet Pa) - Pa}$$

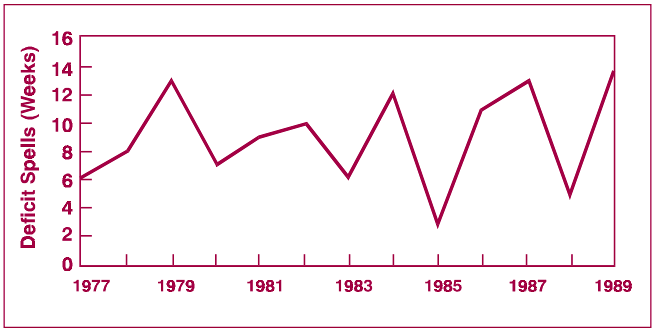

Figure 1. Deficit intensity (weeks), 1977–89.

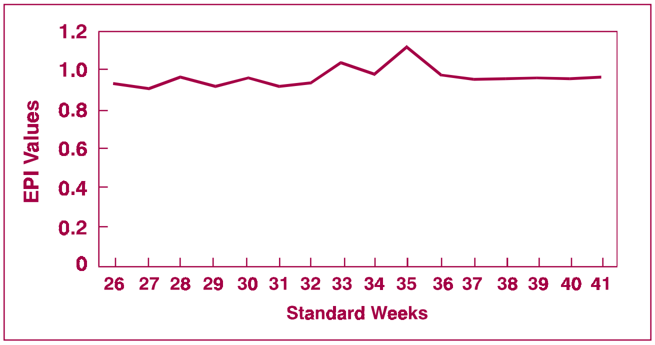

Figure 2. Effective Precipitation Index, 1987.

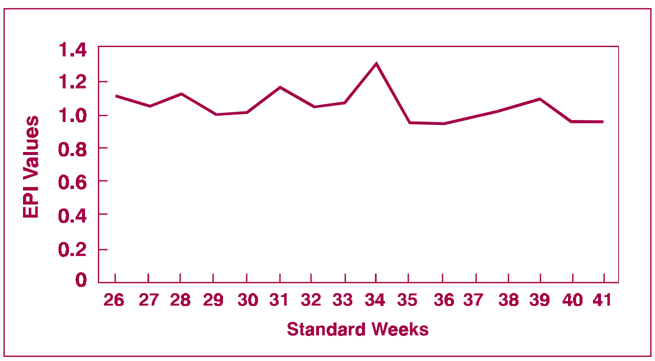

Figure 3. Effective Precipitation Index, 1988.

A case study of the EPI and deficit spells for the Delhi region has been made by analyzing the weekly values of precipitation and PET from the daily values for 1977–89 using the above conditions. Figure 1 shows the total deficit spell weeks in various years for the Delhi region. Drought years like 1989 have a maximum of 14 weeks of deficit spells, compared to a good monsoon year like 1985, which shows only a 3-week deficit spell.

As a case study for the region, the EPI was computed for a drought year (1987) and a good monsoon year (1988). Figures 2 and 3 depict the EPI for 1987 and 1988, respectively, on a weekly basis during *kharif* season. Figure 2 reveals that the EPI was below the threshold value of 1.0 during 13 weeks. But Figure 3 shows only 5 deficit weeks, reflecting good monsoon precipitation.

How these deficit spells are distributed or spread out in various phases is more important than the total amount of deficit spells in a particular season. This will help us to understand how the various phases of deficit spells influence the critical growth stages of *kharif* crops, particularly in a drought year. For example, if rainfed paddy suffers a deficit spell during critical growth stages like head development and flowering, its yield is affected. Similarly, sorghum and maize yield suffers during flowering and grain-filling stages because of deficit spells. Groundnut yield also is very much affected if deficit spells occur during its critical stages, like flowering and pod setting. Table 2 shows the distribution of these spells in different phases. The years 1984 and 1986 have three phases of deficit spells. On average, the first phase of a deficit spell lasts 4 weeks. But severe drought years like 1987 and 1989 contain 8 weeks of continuous dry spell in the first phase. Table 3 shows how much deficit the dry spell has created in various phases, during both bad and good monsoon years. This information is quite useful in agricultural activities like irrigation and water flow measurements. The drought years 1979 and 1987 have 13 deficit spell weeks in two phases with deficit amounts of 363.4 mm and 534.4 mm, respectively. In addition, most of

Year	Phase I (weeks)	Phase II (weeks)	Phase III (weeks)	Total
1977	2	4	-	6
1978	2	6	-	8
1979*	2	11	-	13
1980	2	5	-	7
1981	7	2	-	9
1982	3	7	-	10
1983	2	4	-	6
1984	3	4	5	12
1985	3	-	-	3
1986	4	5	2	11
1987*	7	6	-	13
1988	3	2	-	5
1989*	8	6	-	14

*** Drought year**

Table 2. Different phases of deficit rain spells (1977–89).

	Continuous deficit spells			Deficit amount (mm)			Period (Standard week)	
Year	Ph.1	Ph. II	Total	Ph. 1	Ph. II	Total	Ph. I	Ph. II
1979*	2	11	13	42.7	320.6	363.3	26-27	31-41
1987*	7	6	13	356.3	178.1	534.4	26-32	36-41
1989*	8	6	14	242.3	142.5	384.8	26-33	36-41
1985**	3	–	3	85.5	–	85.5	34-37	–
1988**	3	2	5	92.6	57.0	149.6	35-37	40-41

***Drought year**
****Good monsoon year**

Table 3. Deficit rain spells and amounts during good monsoon and drought years.

the deficit amount in these two years came in the first phase, between the 26th and 32nd standard weeks of the crop-growing period.

Table 4 shows the severity of the deficit spell in the form of an index called Index of Severity of Deficit Spell (ISDS). This is the ratio of the deficit gap of that week to the mean deficit gap computed with mean EPI values. Similarly, another index, the Index of Deficit Intensity (IDI), was computed by dividing ISDS by the number of deficit spells.

The 1989 drought in the Delhi region accounted for 87.5% of the total deficit spell, with an ISDS of 13.435. This is followed by the drought years of 1979 and 1987, in which 13-week deficit spells prevailed during the crop-growth period. The ISDSs for these years were 13.180 and 16.018, respectively. The IDI for 1987 was 1.232, compared to 1.011 for 1979. Although total deficit spells for both years were identical, their severity indices have different values, with 1987 values being greater.

These types of indices and analyses will serve as a guide to drought information for potential users of agriculture-related operations like water flow and reservoir management. In addition, EPI analysis has been applied to various aspects of catchment hydrology. These computed indices are amenable to probability analysis normally used in water resource programs.

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Year	Length of def. spells (weeks)	Percent of total	ISDS	IDI
1977	6	37.50	5.630	0.939
1978	8	50.00	6.540	0.817
1979*	13	81.25	13.180	1.011
1980	7	43.75	6.746	0.963
1981	9	56.25	9.817	1.090
1982*	10	62.50	10.610	1.061
1983	6	37.50	5.364	0.894
1984*	12	75.00	9.490	0.790
1985	3	18.75	2.819	0.939
1986*	11	68.75	13.341	1.212
1987*	13	81.25	16.018	1.232
1988	5	31.25	4.959	0.992
1989*	14	87.50	13.435	0.959

*** Drought year**

Table 4. Deficit spells and severity indices, 1979–89.