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L E T T E R S

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DROUGHT ANALYSIS OF SINDH USING STANDARDIZED PRECIPITATION INDEX (SPI)

1. Drought is a normal, recurrent feature of climate. It occurs almost everywhere, although its features vary from region to region. Defining drought is therefore difficult; it depends on differences in regions needs and disciplinary perspectives (Wilhite and Glantz, 1985). In the most general sense, drought originates from a deficiency of precipitation over an extended period of time, resulting in a water shortage for some activity, group, or environmental sector (Jain *et al*., 2009). Whatever the definition, it is clear that drought cannot be viewed solely as a physical phenomenon. During drought, many people migrate to areas outside the drought affected area. One of the most severe noticeable effects of drought is famine.

Due to the multidisciplinary importance of droughts, several drought indices can be found in the literature, like, Palmer (1965 & 1968); Gibbs and Maher (1967); Bhalme and Mooley (1980); Rao and Rama (1981) etc.

2. Drought is a perennial and recurring feature in southern parts of Pakistan as most parts of Sindh and Baluchistan provinces often experience very low rainfall. In these areas, droughts lead to large scale migration in search of alternative livelihoods, loss of human life due to stress, starvation or unhygienic conditions and increased social conflict. As the rainfall did not occur during 2002-2003, there was a drought in Thar which resulted in the loss of all livelihood means among 80% of the house holds; similarly, more than 50% of them have migrated to canal irrigated areas out of Thar in search of food and fodder. Sindh is one of the most affected provinces in Pakistan due to drought and in last few decades, major portion of Sindh suffered from severe drought, where rainfall sometimes remained even much below average. Thus, Sindh is chosen as the study area, as some of the areas in this province are dependant on rain-fed agriculture and others are dependant on River Indus over the centuries. The selected areas *viz*., Karachi, Hyderabad, Badin, Rohri, Mohenjodaro, Jacobabad, Nawabshah, Padidan and Chhor experience a general deficiency of rainfall. During last few years, the yearly rain has decreased to more than 50% of the annual average in the drought affected areas (Faisal and Sadiq 2009). Revised monthly data for the period 1961-2004 set have been used, provided by the Computerized Data Processing Centre (CDPC) of Pakistan, to get the opportunity to investigate the occurrence of drought over the Sindh province of Pakistan. Processing Centre (CDPC) of Pakistan, to get the opportunity to investigate the occurrence of drought over the Sindh province of Pakistan.

TABLE 1

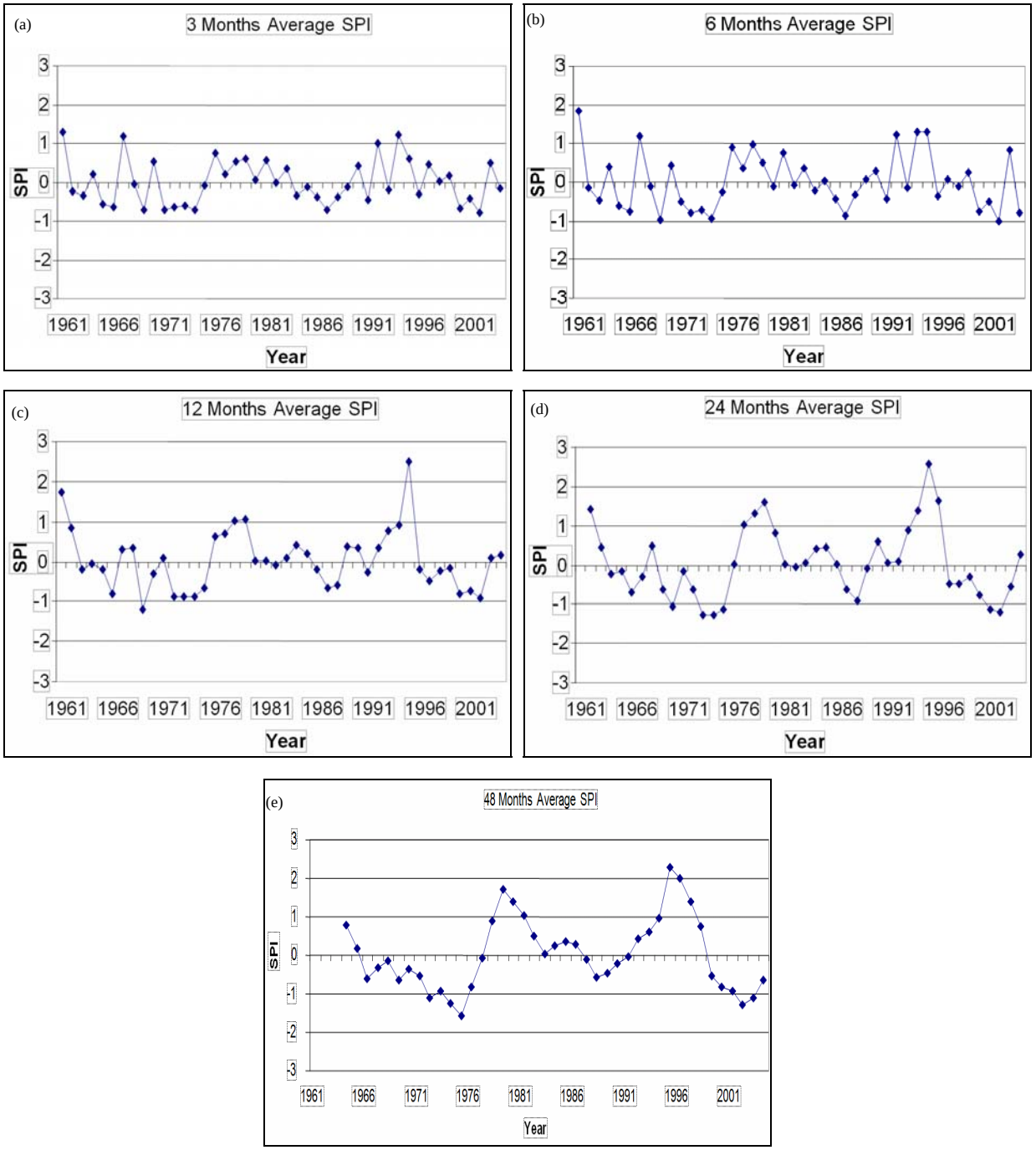
Drought intensity *versus* SPI

SPI	Intensity	Percentage of time w.r.t. SPI
-0.00 to 0.99	Mild	34.1%
-1.00 to -1.49	Moderate	9.2%
-1.50 to -1.99	Severe	4.4%
-2 .00 or less	Extreme	2.3%

Legend - SPI : Standardized Precipitation Index

3. Standardized Precipitation Index (SPI) is a probability index for monitoring drought. This drought index is developed to detect drought and wet periods for different time scales in various regions of the world. The definition of drought proposed by McKee *et al.* (1993) employing the Standardized Precipitation Index (SPI) is used to measure drought for time scales ranging from 3, 6, 12, 24 and 48 months. The gamma distribution has been found to fit climatologically precipitation time series well. Therefore, computation of the SPI involves fitting a gamma probability density function to a given time series of monthly precipitation totals for a station. The resulting parameters are then used to find the probability of a particular precipitation event over a given time scale. This probability is then converted to the standard normal random variable *Z*, which is the SPI index value. Conceptually, the SPI for a given time scale is the difference of precipitation from the mean divided by the standard deviation. McKee *et al*. (1993) define drought intensity using the following categories in Table 1.

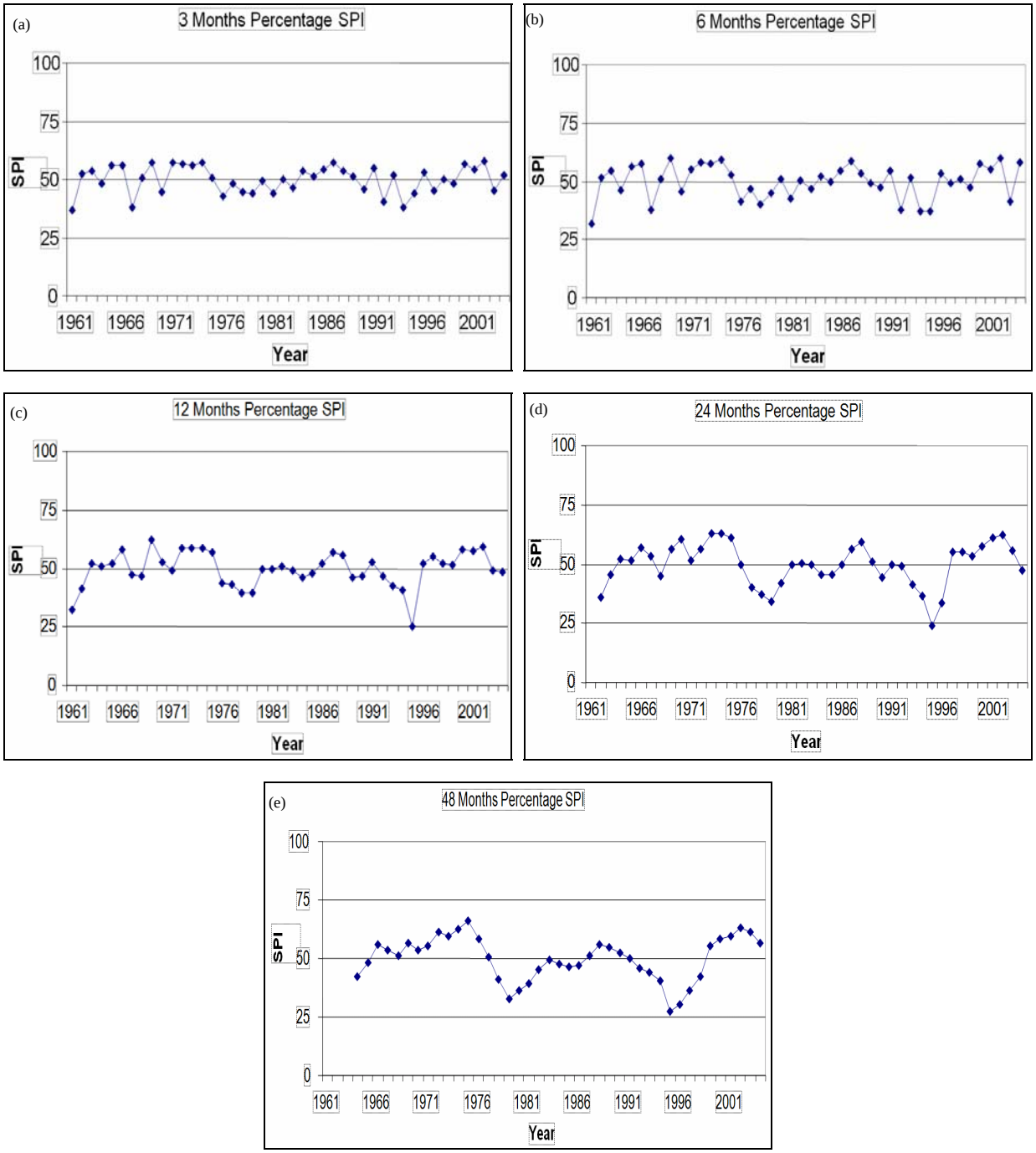
They developed the SPI in 1993 and originally calculated the SPI for 3, 6, 12, 24, and 48 month time scales. Additionally, it defines an event a drought when the SPI becomes -1.0 or less. The beginning of this drought is then defined as when the SPI first went negative. The end of the drought does not occur until the SPI goes back to positive. SPI is in mild drought 34% of the time, in moderate drought 9.2% of the time, in severe drought 4.4% of the time and in extreme drought 2.3% of the time.



Figs. 1(a-e). The average SPI of Sindh, Pakistan for (a) 3 months, (b) 6 months, (c) 12 months, 24 months and (e) 48 months

Because the SPI is standardized, these percentages are expected from a normal distribution of the SPI. The 2.3% of SPI values within the "extreme drought" category is a percentage that is typically expected for an "extreme" event. In contrast, the Palmer (1965) Index reaches its "extreme" category more than 10% of the time across portions of the central Great Plains. This standardization allows the SPI to determine the rarity of a current drought, as well as the probability of the precipitation necessary to end the current drought.

The SPI can be computed for different time scales, can provide early warning of drought and help assess drought severity and is less complex than the Palmer Index. For example, the drought in the period 1970s was well observed by the 3 month SPI. On the other hand, the



Figs. 2(a-e). The percentage SPI of Sindh, Pakistan for (a) 3 months, (b) 6 months, (c) 12 months, 24 months and (e) 48 months

24 month and 48 month SPI allows us to quantify long-term persistent droughts of the type that occurred over Sindh in the 1970s and 1990s. SPI is gaining increasing acceptance as a valuable tool for monitoring drought. It is currently being used in many monitoring centers of world.

4. The purpose of this study is to analyze the variability of drought from 1961-2004 in the province of Sindh, Pakistan in order to furnish drought mitigation planners and other users with information that will be helpful to review current drought in historical perspective. Fig. 1 shows the average SPI value for all stations in Sindh. The time series of the average 3 month SPI for all stations in Sindh shows that short term mild droughts are common throughout the period of record and the 6-month give a little indication of intense drought whereas 12 & 24

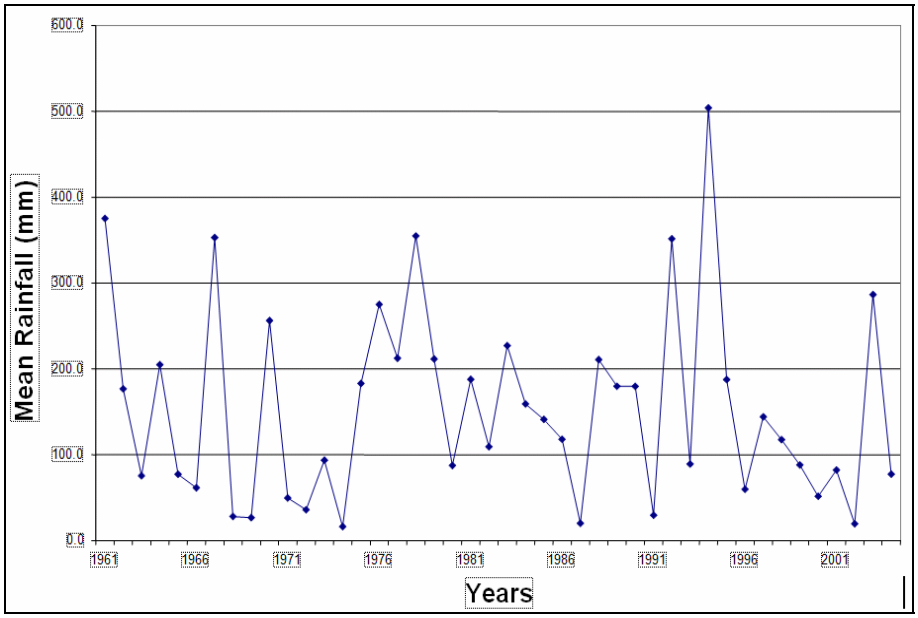


Fig. 3. Mean annual Precipitation over Sindh, Pakistan 1691-2004)

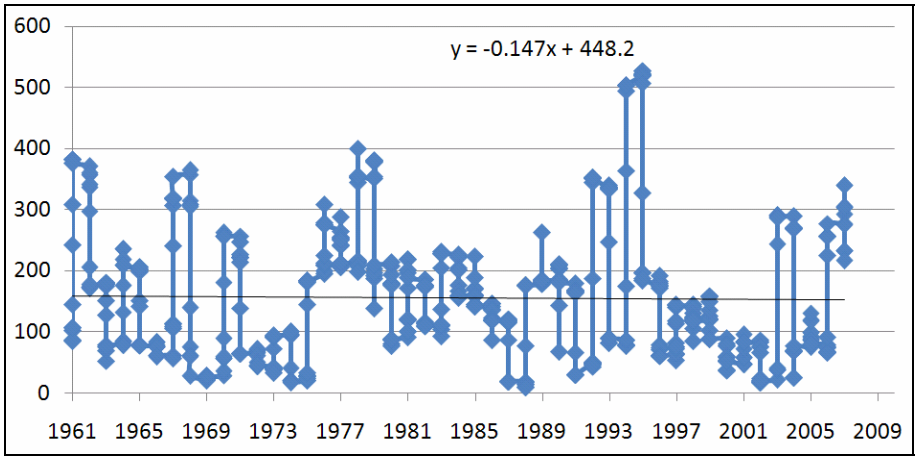


Fig. 4. Trend analyses for running 12-month mean precipitation for past 43 years and forecast for next 5 years

month SPI indicates sustained drought during the period from1960s and 1990s. However, the average 48-month SPI time series shows the long term sustained and intense droughts from 1968 to 1977 with its peak value (-1.6) in the year 1975 another intense period of drought is also observed from 1999 to 2004 with its peak value (-1.3).

Fig. 2 shows the per cent of Sindh stations in drought at different time scales. The percent of stations in long-term drought as defined by the 48-month time scale shows that the droughts of the 1970s & 1990s and in the early 2000s were the most widespread over Sindh. However, the percent of stations in drought as defined by the 3-month time scale shows that short-term intense droughts had widespread coverage outside of the 1970s and 1990s.

Figs. (3-4) show the running 12 month mean precipitation of all Sindh stations. The overall trend has been drier not only the last 43 years but also trend forecast for next 5 years, consistent with the results from the 48 month SPI time series from Figs. 2(a-e). For the last 25 years, the percent of stations in long-term drought is consistently less than 50 percent.

5. The forty-three years (1961 to 2004) monthly precipitation data of the climatic weather stations of Sindh

in Pakistan were used to calculate SPI for different time periods, *viz*., 3, 6, 9, 12, 24 and 48 months. Time series plots of SPIs indicated that the time scales less than 12-months had enormous fluctuations so that identifying drought and wet periods were not so clear. However, plots of 24-month SPI and 48-month SPI obviously could identify drought and wet periods of the region clearly. The duration, attenuation and intensity for any particular month during our recent records were time scale dependent. The results of this study also showed that long-term drought of early 1960s and late 1970s impacted Sindh's region. Based on these results we recommend the agriculturist and other stake holders to use SPIs of 12 month or less and water resources managers to apply 36-month SPI for Sindh region.

6. The data provided by Pakistan Meteorological Department is hereby acknowledged.

References

Bhalme, H. N. and Mooley, D. A., 1980, "Large scale droughts/floods and monsoon circulation", *Mon. Wea. Rev*., **108**, 1197-1211.

Faisal, N. and Sadiq, N., 2009, "Climatic Zonation of Pakistan through Precipitation-Effectiveness Index", Pakistan Meteorological Department, 6 -11.

Gibbs, W. J. and Maher, J. V., 1967, "Rainfall deciles as drought indicators", *Bur. Met. Bull.*, **48**, Commonwealth of Australia, Melbourne.

Jain, S. K., Keshri, R., Goswami, Sarkar and Chaudhry, A., 2009, "Identification of drought-vulnerable areas using NOAA AVHRR data", *Int. J. Rem. Sens*., **30**, 10, 2653-2668.

McKee, T. B., Doesken and Kleist, J., 1993, "The Relationship of Drought Frequency and Duration to Time Scales Preprints", 8th Conference on Applied Climatology, 17-22 January, Anaheim, California, 179-184.

Palmer, W. C., 1965, "Meteorological drought", Research Paper No. 45", US Weather Bureau: Washington, DC.

Palmer, W. C., 1968, "Keeping track of crop moisture conditions, nationwide: The new crop moisture index", *Weatherwise*, **21**, 156-161.

Rao, R., Sastri and Rama, K. Y. S., 1981. "An integrated scheme of drought classification as applicable to Indian arid region", *IDOJARAS*, **85**, 317-322.

Wilhite, D. A. and Glantz, M. H., 1985, "Understanding the drought phenomenon: The role of definitions", *Water Int*., **10**, 111-120.

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