Use of SPI and Rainfall Deciles for Drought Assessment

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Abstract— Drought assessment is very important to manage water resources in lean period. It plays vital role in managing water demands especially in agriculture sector. Present approach for assessment of drought is accomplished by use of Standardized Precipitation Index (SPI) and Rainfall deciles, which are fully based on monthly rainfall data. Presently Drin C (Drought indices calculator) is used for determining SPI and Rainfall deciles. SPI has been proposed to monitor dryness and wetness on multiple time scales (McKee, 1993). Standardized Precipitation Index (SPI) and Rainfall deciles are used to assess the drought in Khedbrahma region of Gujarat. Monthly rainfall data for the years 1968 to 2010 is considered. SPI 3, SPI 4, SPI 5 and SPI 6 values are determined and analysis is carried out for the slope of the trendline for drought condition. Rainfall deciles are used to check the severity of drought. In present approach SPI 3, SPI 4, SPI 5 and SPI 6 values are determined for 4 decades, i.e. 1970 to 1979, 1980 to 1989, 1990 to 1999 and 2000 to 2009. The trendline for each decade are analysed and the Severity of drought are assessed for each decade.

Key words: Drin C, Drought assessment, Rainfall deciles, Standardized Precipitation Index, Trend analysis

I. INTRODUCTION

Drought is a normal feature of any climate. It is a temporary, recurring natural disaster, which originates from the lack of precipitation and brings significant economic loss. It is not possible to avoid droughts. But drought preparedness can be developed and drought impacts can be managed. Drought definitions vary from region to region and may depend upon the dominating perception. It should be generally defined to some long term average condition such as precipitation, balance between precipitation and evapotranspiration etc.

Presently, There are various indicators of drought, and tracking these indicators provides us with a crucial means of monitoring drought. Drought indices assimilate thousands of bits of data on rainfall, snowpack, streamflow, and other water supply indicators into a comprehensible big picture.

A drought index value is typically a single number, far more useful than raw data for decision making. Palmer (1965) developed a meteorological drought index widely known as PALMER Drought Severity Index (PDSI).The PDSI uses a simple monthly water budget model, with inputs of rainfall, temperature and available catchment soil moisture content.

McKee et al. (1993) developed the Standardized Precipitation Index (SPI) as an alternative to the PDSI for Colorado, U.S.A. The SPI was designed to quantify the rainfall deficit as a drought monitoring tool, and has been used to monitor drought conditions across Colorado since 1994.

SPI VALUE	INTERPRETATION
2.00 or more	Extremely wet
1.50 to 1.99	Very wet
1.00 to 1.49	Moderately wet
0 to 0.99	Mildly wet
0 to -0.99	Mild drought
0.99 to -0.99	Near normal
-1.00 to -1.49	Moderate drought
-1.50 to -1.99	Severe drought
-2.00 or less	Extreme drought

Table 1: Drought classification based on SPI (McKee et al. (1993))

Percent of Normal (PN) is one of the simplest drought monitoring tools which is commonly used by the TV weathercasters and general audiences. It is expressed as the actual rainfall in percentage compared to the normal rainfall.

Deciles were developed by Gibbs and Maher (1967) in Australia. In Deciles, the long-term monthly rainfall record is first ranked from highest to lowest to construct a cumulative frequency distribution. The distribution is then divided into ten parts, which are called "deciles". The first "decile" is the rainfall amount not exceeded by the lowest 10% of the rainfall occurrences. The second "decile" is the rainfall amount between the lowest 10 and 20% of occurrences. The definitions of these deciles continue until the rainfall amount identified by the tenth "decile" which is the largest "decile" within the long-term record.

Deciles 1-2 (lowest 20%)	Much below normal
Deciles 3-4 (next lowest 20%)	Below normal
Deciles 5-6 (middle 20%)	Near normal
Deciles 7-8 (next highest 20%)	Above normal
Deciles 9-10 (highest 20%)	Much above normal

Table 2: Classification based on Deciles

Solanki and Parekh (2014) stated useful index for drought monitoring based only on monthly precipitation data is the Standardized Precipitation Index (SPI). It has been proposed to monitor dryness and wetness on multiple time scales. The present situation examines the SPI drought index in application for the Vallabh Vidyanagar Station and it is evaluated accordingly by historical precipitation data (1969-2006) for meteorological station. From the result, the worst drought years of 1974, 1986 and 1987 in the Vallabh Vidyanagar station indicate severe dryness and hence, the irrigation requirement can be evaluated on the rainfall deficits & its severity for the given years.

Mishra and Nagarajan (2012) worked on the run analysis and Standardized Precipitation Index (SPI) were used to investigate drought behaviours in Tel watershed,

which is about 2,756 square kilometres and lies in Kalahandi district of Odisha, India.

JABER AL MEDEIJ collect wide range of monthly total precipitation data from January 1967, to December 2009 of Kuwait which is used for the assessment.The computation of the SPI series is performed for intermediate and long time scales of 3,6,12 and 24 months.

Sharma, Dadhwal, Jeganathan, Tolpekint classified SPI value from -3 to -1.5 as drought and SPI value from -1.5 to +3 as no drought category. To validate the findings from SPI, Govt. based drought assessment reports were used and correlation coefficient of 0.89 was achieved, which indicates strong positive correlation.

II. MATERIAL AND METHODS

Khedbrahma is a town and a taluka in Sabarkantha, Gujarat. There is a sangam (meeting point) of three small rivers here, namely Hirnakshi, Bhimakshi and Kosambi. After the confluence of these three rivers, the river is named Harnav which merges with Sabarmati river. It divides the town in a northern and a southern part. Harnav river was formerly known as Hiranyaksh or Harnai river. Population of Khedbrahma is approximately 25000. Coordinates of Khedbrahma region is 24°1'42 "N 73°2'29"E.

DrinC (Drought Indices Calculator) is a software package which was developed for providing a simple, though adaptable interface for the calculation of drought indices.

DrinC was developed at the Centre for the Assessment of Natural Hazards and Proactive Planning and the Laboratory of Reclamation Works and Water Resources Management of the National Technical University of Athens.

DrinC can be used for the calculation the Reconnaissance Drought Index (RDI), the Streamflow Drought Index (SDI), the Standardised Precipitation Index (SPI) and the Precipitation Deciles (PD). Moreover, the software includes a module for the estimation of potential evapotranspiration (PET) through temperature based methods, useful for the calculation of RDI.

The software may be used in a variety of applications, such as drought monitoring, assessment of the spatial distribution of drought, investigation of climatic and drought scenarios, etc. The applications of DrinC in several locations, especially in arid and semi-arid regions, show that it is gaining ground as a useful research and operational tool for drought

III. RESULTS AND ANALYSIS

A. SPI 3

1) SPI 3- (Jun-Aug)

Range of SPI values and Condition	Affected years
Near Normal (0.99 to -0.99)	1968, 1969, 1971, 1974, 1975, 1976, 1977, 1979, 1980, 1981, 1984, 1986, 1990, 1992, 1997, 1999, 2000, 2001, 2002, 2003, 2004, 2006, 2007, 2009

Table 3: SPI 3 CHARTS

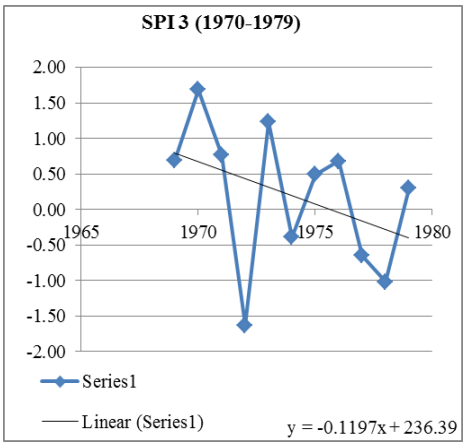

Fig. 2: SPI 3 for decade (1970-1979)

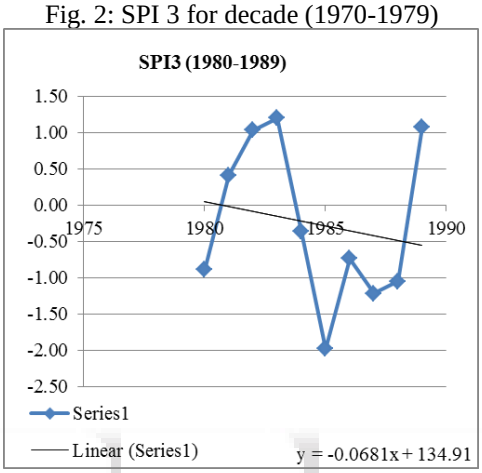

Fig. 3: SPI 3 for decade (1980-1989)

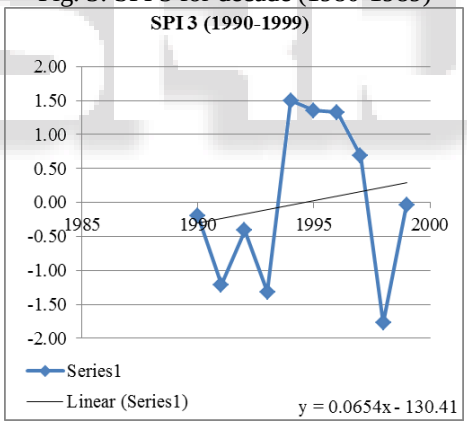

Fig. 4: SPI 3 for decade (1990-1999)

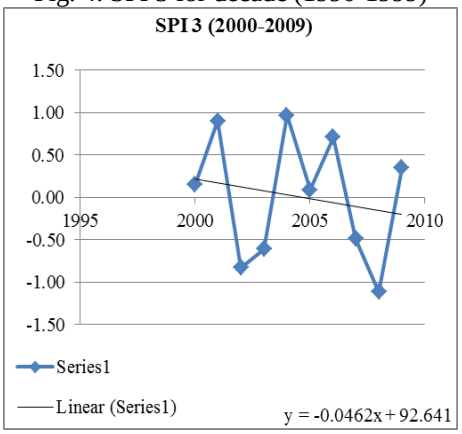

Fig. 5: SPI 3 for decade (2000-2009)

From above graphs it's clear that in 1990-1999 trend is opposite than all other decades.

And last decade of 2000-2009 reveals that it's slope is greater than all other decades.

B. SPI 4

1) SPI 4- (Jun-Sept)

Range of SPI values and Condition	Affected years
Severely Dry	1987, 1988, 1993, 1998
Moderately Dry	1977, 1978, 1980,1985, 2002, 2003
Near Normal	1968, 1969, 1971, 1972, 1973, 1974, 1975, 1979, 1981, 1982, 1983, 1986, 1989, 1990, 1991, 1992, 1994, 1995,1997, 1999, 2000, 2001, 2004, 2005, 2007, 2008, 2009

Table 4:

2) SPI 4 CHARTS

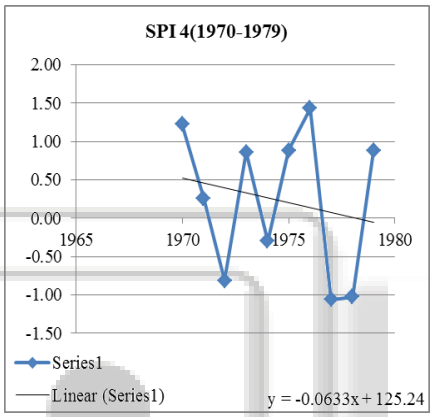

Fig. 6: SPI 4 for decade (1970-1979)

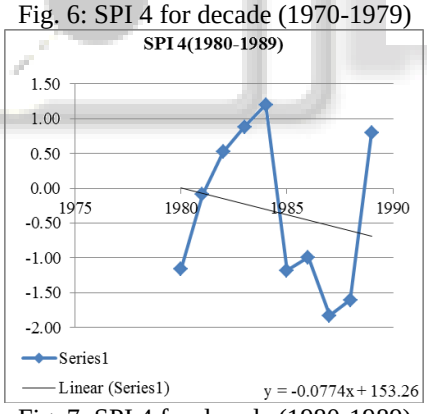

Fig. 7: SPI 4 for decade (1980-1989)

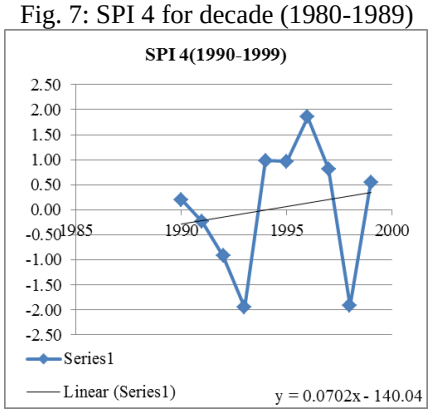

Fig. 8: SPI 4 for decade (1990-1999)

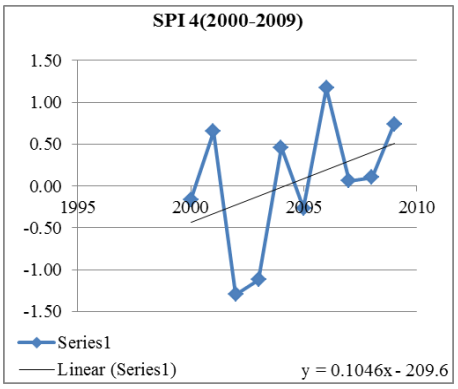

Fig. 9: SPI 4 for decade (2000-2009)

From above graphs it's clear that in 1990-1999 and 2000-2009 trend is opposite than all other decades. It shows positive slope.

And last decade of 1980-1989 reveals that it's slope is greater than all other decades in negative value.

C. SPI 5

1) SPI 5- (Jun-Oct)

Range of SPI values and Condition	Affected years
Severely Dry	1988
Moderately Dry	1980, 1986, 1992,2002, 2003
Extremely Dry	1987, 1993
Near Normal	1968, 1969, 1970,1971, 1972, 1974,1977, 1978, ,1981, 1982, 1983, 1985, 1989, 1990, 1991, 1994, 1997, 1999, 2000, 2001, 2004, 2005, 2006, 2007, 2008

Table 5:

2) SPI 5 CHARTS

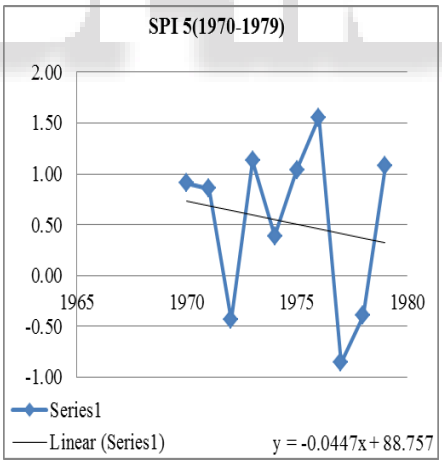

Fig. 10: SPI 5 for decade (1970-1979)

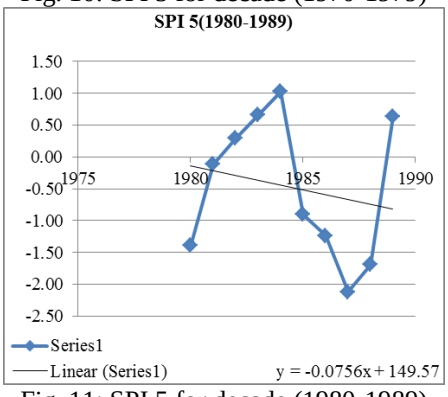

Fig. 11: SPI 5 for decade (1980-1989)

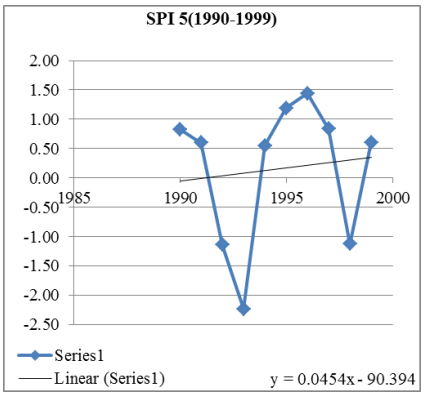

Fig. 12: SPI 5 for decade (1990-1999)

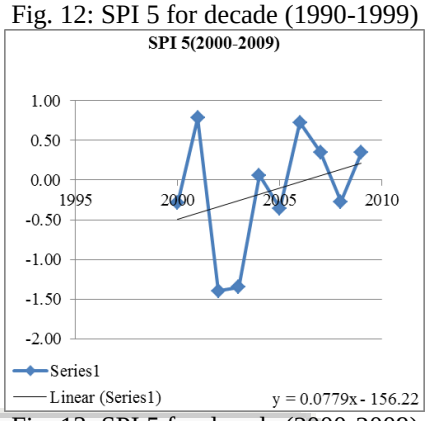

Fig. 13: SPI 5 for decade (2000-2009)

From above graphs it's clear that in 1990-1999 and 2000-2009 trend is opposite than all other decades. It shows positive slope.

And last decade of 1980-1989 reveals that it's slope is greater than all other decades in negative value.

D. SPI 6

1) SPI 6 (Jun-Nov.)

Range of SPI values and Condition	Affected years
Severely Dry	1988
Moderately Dry	1980, 1986, 1992, 1998, 2002, 2003
Extremely Dry	1987, 1993
Near Normal	1968, 1969, 1971,1972, 1974,1977,1978, 1981, 1982,1983, 1985,1989,1990, 1991,1994,1997, 1999, 2000,2001, 2004, 2005,2006, 2007, 2008

Table 6:

2) SPI 6 CHARTS

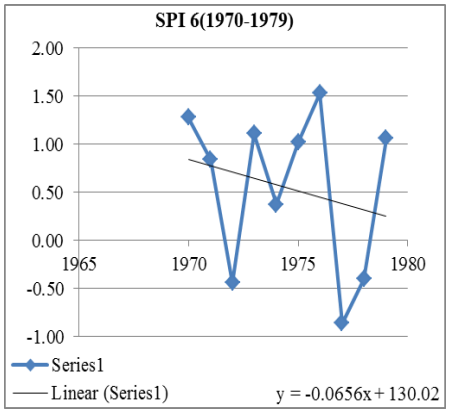

Fig. 14: SPI 6 for decade (1970-1979)

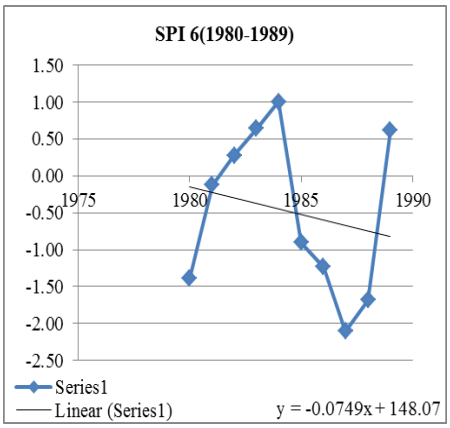

Fig. 15: SPI 6 for decade (1980-1989)

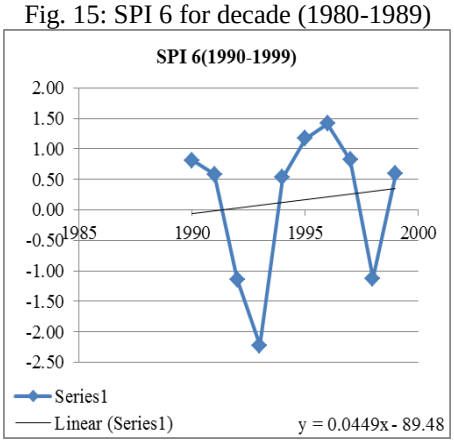

Fig. 16: SPI 6 for decade (1990-1999)

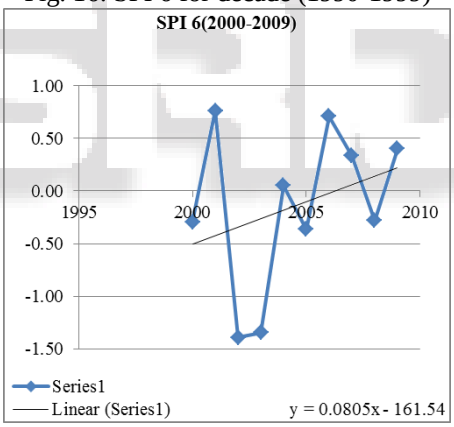

Fig. 17: SPI 6 for decade (2000-2009)

From above graphs it's clear that in 1990-1999 and 2000-2009 trend is opposite than all other decades. It shows positive slope.

And last decade of 1980-1989 reveals that it's slope is greater than all other decades in negative value.

IV. RAINFALL DECILES

Range of rainfall deciles and condition	**Affected years**
Much below Normal (Deciles 1-2)	1978, 1985, 1986, 1987, 1988, 1993, 1998, 2003, 2005
Below normal (Deciles 3-4)	1968, 1977, 1980, 1981, 2000, 2002, 2004, 2007

Table 7:

A. Rainfall Deciles Charts

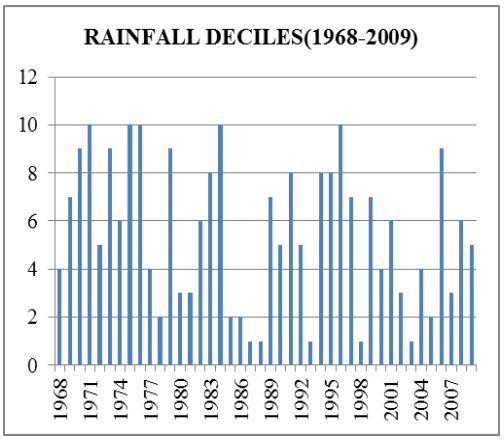

Fig. 18: Rainfall deciles from (1968-2009)

From above graph it can reveal that years 1978, 1985, 1986, 1987, 1988, 1993, 1998, 2003 and 2005 have severe drought condition in study area.

V. Conclusion

As per SPI-4, SPI-5, SPI-6 and rainfall deciles, 1988-1989 is extreme drought period.

- As per SPI-3, for decades 1970-1979, 1980-1989, 2000-2009, the nature of trend line decreases which shows that there is a need to initiate hydrological resources development.
- As per SPI-4, for decades 1970-1979, 1980-1989, the nature of trend line decreases which shows that there is a need to initiate hydrological resources development.
- As per SPI-5, for decades 1970-1979, 1980-1989, the nature of trend line decreases which shows that there is a need to initiate hydrological resources development.
- As per SPI-6, for decades 1970-1979, 1980-1989, the nature of trend line decreases which shows that there is a need to initiate hydrological resources development.
- As per deciles, the extreme drought decades were 1978, 1985, 1986, 1987, 1988, 1993, 1998, 2003and 2005.
- Amongst all SPI graphs, the slope of SPI-6 is steepest which shows that there is extreme need of hydrological resources development.
- All that we have worked out in this project can be used along with ANFIS (adaptive neuro fuzzy inference system) and ANN (artificial neural network) for future prediction.

References

[1] Gandhi F. R., Parekh F. P. (2015) " Assessment of drought using standardized precipitation index - A case study of Patan District", " VIER journal of Engineering Research ", April-2015

[2] Solanki J.K., Parekh F.P. (2014) "Drought Assessment and Forecasting: A case Study of Dharoi Sub Basin" in "International Journal of Scientific Engineering and Technlogy", Special issue(2014), Bhopal.

[3] S. Sangita Mishra+ and R. Nagarajan "Forecasting Drought in Tel River Basin using Feed-forward Recursive Neural Network" 2012 International Conference on Environmental, Biomedical and Biotechnology IPCBEE vol.41 (2012) © (2012) IACSIT Press, Singapore

[4] Evaluation, modification, and application of the Effective Drought Indexto 200-Year drought climatology of Seoul, KoreaDo-Woo Kim a, Hi-Ryong Byun a,*, Ki-Seon Choi b

[5] Review Papers, Drought modeling – A reviewAshok K. Mishra ⇑, Vijay P. SinghDepartment of Biological and Agricultural Engineering, Department of Civil and Environmental Engineering, Texas A&M University, 2117 College Station, TX 77843, USA

[6] Review, Automated Estimation and Analyses of Drought Indices in South Asia by v.u.smakhan d.a.hughes

[7] Assessment of drought hazard: a case study in Sehoul area , morocco

[8] Drought assessment by evaporation mapping in twente , the Netherlands by ugyen eden

[9] Agricultural drought assessment report mohalanobis national crop forecast centre, new delhi.

