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Drought Assessment Using Standardized Precipitation Index

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Abstract: ***Drought assessment and monitoring is very essential in identifying climate and water supply trends and thus to detect the probability of occurrence and the anticipated severity of drought. Drought occurs when precipitation is lower than normal. When this phenomenon extends over longer period of time, precipitation is inadequate to demand of human activities. This paper includes developing a methodology to assess drought severity and monitoring of the study area. Drought originates from a deficiency of precipitation over a given period of time: short time scales (months) characterize meteorological drought, while longer time scales (years) hydrological drought. A 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. SPI Index is a useful tool to assess the severity of drought for the study area.***

Keywords: Drought Assessment, Precipitation, Severity, SPI Index, Trend Analysis

1. Introduction

Drought is an extended period when a region receives below average precipitation. Drought has many effects on human activities, human lives and various elements of the environment. Conventionally, decrease of precipitation is considered as the origin of drought. This leads to a reduction of storage of water and fluxes involved in the hydrological cycle depending on the choice of the hydrological or agricultural. Drought is an unexpected reduction in precipitation over period of time in an area which is not necessarily arid. Characterizing periods of deficit and drought has been an important aspect of planning and management of water resources systems for many decades. Drought is one of the most harmful natural disasters that affected the human population.

Low precipitation levels can lead to severe hydrologic deficits. These deficits may impact on low crop yields for agriculture, un replenished ground water resources, depletion in lakes/reservoirs, and shortage of drinking water and, reduced fodder availability etc, which can negatively impact on local populations. Consequently, the ability to forecast and predict the characteristics of droughts, especially their frequency, monitoring and severity are important. Drought assessment and monitoring is necessary for water resource management as well as for the agricultural industry.

Unlike other natural disasters like flood, earthquakes droughts have a slow evolution time. The effect of droughts required considerable amount of time to come in to effect with respect to their initiation and when they are perceived by ecosystems and hydrological systems.

An effective tool is used to monitor current drought conditions is a drought index. Several drought indices have been developed around the world in the past based on rainfall as the single variable, including the widely used Deciles, Standardized Precipitation Index (SPI), and Effective Drought Index (EDI). There is also the well-known Palmer Drought Severity Index (PDSI), which considers temperature along with rainfall. In this study, the SPI drought index has been chosen to assess the drought condition due to its simplicity, its ability to represent drought on multiple time scales, and because it is based on probability. Temperature, wind and relative humidity are also important factors. Types of Droughts are meteorological, agricultural and hydrological drought. One of the major challenges of agricultural systems is how to reduce the impacts of droughts. Drought impact on agricultural systems, economically as well as environmentally. From an environmental perspective, droughts can deprive crops and soils of essential precipitation as well as increase the salt content in soils and irrigation systems.

To overcome the impacts of drought an effectively and timely monitoring system is required. Effective monitoring of droughts can aid in developing an early warning system. An objective evaluation of the drought condition in a particular area is the first step for planning water resources in order to prevent and reduce the impacts of future occurrences of drought.

2. Standardized Precipitation Index

SPI is a probability index, considered only precipitation for any given time scales, which was developed for monitoring and assessing drought for any rainfall station with historic data. The SPI was developed by McKee et al (1993). It was designed to quantify the precipitation deficit for multiple time scales.

In order to calculate the SPI, a probability density function that adequately describes the precipitation data must be determined. The gamma distribution function was selected to fit the precipitation data from each station. The SPI is a *z*-score and represents an event departure from the mean, expressed in standard deviation units. The SPI is a normalized index in time and space. SPI values can be categorized according to classes. The departure from the mean is a probability indication of the severity of the wetness or drought that can be used for risk assessment. The time series of the SPI can be used for drought monitoring by setting application-specific thresholds of the SPI for defining drought beginning and ending times. Accumulated values of the SPI can be used to analyze drought severity. The SPI is usually calculated for monthly periods. The meteorological station(s) to be analyzed should be chosen to be representative of the area being assessed for drought risk. The quality of the monthly data should be checked for reliability and suitability prior to its use for an SPI analysis. Long records are desirable because SPI is a statistical approach and long records provide more reliable statistics.

Over the years, many drought indices were developed and used by meteorologists and climatologists around the world. Those ranged from simple indices such as percentage of normal precipitation and precipitation percentiles to more complicated indices such as the Palmer Drought Severity Index. However, an index needed to be simple, easy to calculate and statistically relevant and meaningful. Moreover, the understanding that a deficit of precipitation has different impacts on groundwater, reservoir storage, soil moisture and stream flow American scientists McKee, Doesken and Kleist developed the Standardized Precipitation Index (SPI) in 1993. It is just as effective in analysing wet periods/cycles as it is in analysing dry periods/cycles. At least 20-30 years of monthly value is needed and with 50-60 years (or more) being optimal and preferred outputs (Guttman, 1994).

3. Study Area and Data Collection

The entire Gujarat is divided into the various agro-climatic zones. Vallabh Vidyanagar is located in the Anand district and lies in middle Gujarat agro-climatic zone III of Gujarat state.

3.1 Geography: Vallabh Vidyanagar Station

Vallabh Vidyanagar is located at 22°32’ N latitude, 72°54’ E longitude at an altitude of 34 m above mean sea level. It is bounded on the north by the Kheda district and south by the Gulf of Khambhat, on the west by Ahmedabad district and, on the east by Vadodara district.

3.2 Climate

The climate of Vallabh Vidyanagar station is semi-arid with fairly dry and hot summer. Winter is fairly cold and sets in, in the month of November and continues till the middle of February. Summer is hot and dry which commences from mid of February and ends by the month of June. May is the hottest month with mean maximum temperature around 40.08 ^{0}C. The average rainfall is 853 mm.

3.3 Soil

The soil is representative of the soils of the region, popularly known as ‘Goradu’ soil. It is alluvial in origin. The texture of the soil is sandy loam and black. The soil is deep enough to respond well to manuring and variety of crops of the tropical and sub-tropical regions. The soil is low in organic carbon and nitrogen, medium in available phosphorus and available sulphur. Status of potassium is found medium, while micronutrient status is found sufficient.

4. Methodology

This section describes how the SPI has been calculated for the Vallabh Vidyanagar Station. Set up an input file containing precipitation data from the selected study area, all input files must follow 3-column format: Year, Month, and Monthly Precipitation Value. In this study, the SPI_SL_6 program developed by the National Drought Mitigation Centre, University of Nebraska-Lincoln has been used to compute time series of drought indices (SPI) for the selected station and for each month of the year at different time scales.

Different SPI timescales to be computed 1-month, 3-month, 6-month, 9-month, 12-month, 24-months and 36- months SPIs. Positive and negative SPI values indicate wet and dry conditions respectively. A drought event starts when SPI value reaches -1.0 and ends when SPI becomes positive again.

5. Result and Analysis

In this paper, the drought assessment has been carried out for monitoring the drought severity in the Vallabh Vidyanagar Station.

Table 1 shows sample SPI calculation for the year of 1986 for Vallabh Vidyanagar Station, which gives the drought severity of the particular month for the assessment of drought. In reference with the above sample calculation, the most severe case happened in the month of Oct with lowest rainfall value. As the rainfall increases, less is the severity of drought.

Table 1: Sample SPI calculation for the year 1986 for Vallabh Vidyanagar Station

Year	*1986*				
Month	*June*	*July*	*Aug*	*Sept*	*Oct*
Rainfall(mm)	167	44.2	109	1	0
SPI-This Month	0.41	-2.29	-0.72	-1.44	-0.07
SPI(3)- 3 Month	0.31	-1.19	-1.55	-2.39	-1.25
SPI(6)- 6 Month	0.29	-1.20	-1.61	-1.71	-1.79
SPI(12)-12 Month	-0.30	-0.98	-1.38	-1.09	-1.79
SPI(24)-24 Month	-0.99	-1.43	-1.93	-1.92	-1.91
SPI(36)-36 Month	-0.83	-1.35	-1.80	-2.02	-2.03
Combined SPI=SPI(12)*0.6+ SPI(24)*0.3+ SPI(36)*0.1	-0.56	-1.15	-1.59	-1.43	-1.85

Table 2: Drought severity for the years of 1969 – 2006 for Vallabh Vidyanagar Station

Station	*Drought Years*	*Drought Severity*	*Average Rainfall*
Vallabh Vidyanagar	1985 2000 2001 2002	Moderate Dry	More than 100 mm
	1974 1986 1987	Severe Dry	Less than 100 mm

Table 2 shows the drought severity years for Vallabh Vidyanagar station. According to SPI values and average rainfall, drought can be classified in two categories shown in Table 2. If the average rainfall value is more than 100 mm and SPI calculated is in between -1 to -1.49, then those years can said to be moderate dry. In the years of 1985, 2000, 2001 and 2002, the average rainfall is more than 100 mm, so it can be categorized as moderate dry. In the years of 1974, 1986 and 1987, the average rainfall value is less than 100 mm and SPI calculated is in between -1.5 to -1.99, then those years can said to be severe dry. Drought severity class has been carried out in reference of below Table 3 which was developed by McKee et al in 1993.

Table 3: Drought classification based on SPI (McKee et al 1993)

SPI values	*Class*
>2	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-0.99 to 0.99	near normal
-1 to –1.49	moderately dry
-1.5 to-1.99	severely dry
< -2	extremely dry

Fig 1 & 2 shows the SPI calculated for 5 month rainfall totals for the monsoon season of India (June-July-Aug-Sept-Oct) from 1972 to 2006 for Vallabh Vidyanagar station. It shows the drought severity for that particular year.

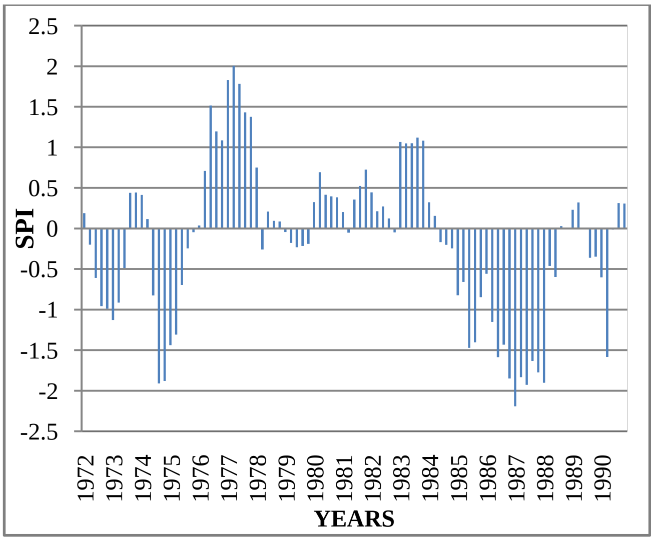

Figure 1: SPI calculated for Vallabh Vidyanagar station (1972-1990)

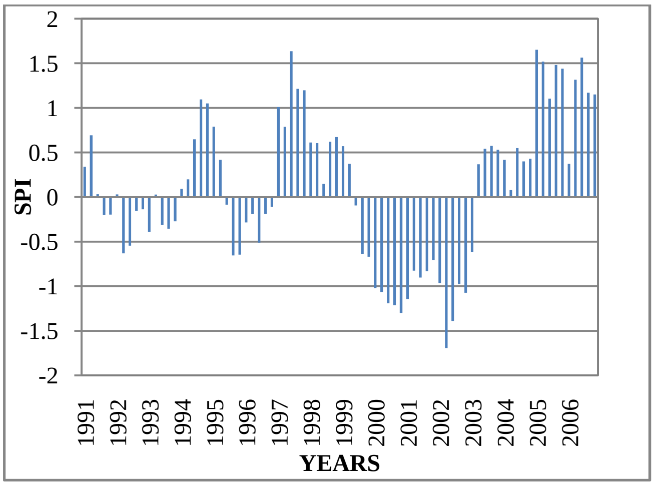

Figure 2: SPI calculated for Vallabh Vidyanagar station (1991-2006)

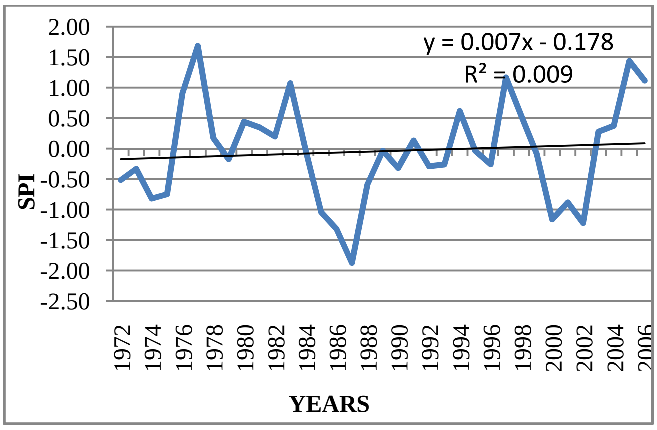

Figure 3: Trend analysis of SPI value

Figure 3 shows the trend analysis of SPI for V.V.Nagar station. The SPI value has been calculated from 1, 3, 6, 12, 24 and 36 months time scales. From graph it is observed that, SPI Index is following decreasing trend from the years 1972-1994. As the trend analysis SPI is in increasing order from the years 1995 to 2006.

6. Conclusion

- This study has tried to assess the drought severity of the Vallabh Vidyanagar Station for the year of 1969 to 2006. Although SPI permits comparisons over space and time better than any other index.
- At a given station, the drought intensity has been found to be more sensitive to the SPI in low rainfall station. The severity of drought may vary with the intensity of rainfall.
- To assess the drought situation, wide range of SPI index should be selected to represent dryness or wetness of the 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.
- From trend analysis of SPI it reveals that from 1972 to 1994 Vallabh Vidyanagar station was under drought condition but from 1995-2006 the area has not experienced the drought condition.

- SPI has gained importance in recent years as a potential drought indicator since it permits comparisons across time and space. SPI Index is a very useful tool to assess the severity of drought for the Vallabh Vidyanagar Station.

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