Develop Drought Monitoring in Sri Lanka Using Standard Precipitation Index (SPI)

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ABSTRACT

Drought is one of the major hazards related to water in the world. Every year, many people die and economical losses occur over most of the countries in the world due to droughts. Sri Lanka usually every year faces droughts damaging the properties, causing death to human beings and agricultural failures. Droughts occur due to the irregular rainfall pattern i.e deficit of rainfall.

This Report addresses important considerations on simulating a suitable drought monitoring method to suit the Sri Lankan content. To detect drought conditions, Standard Precipitation Index (SPI) is the most commonly used tool in the world today. In this study, SPI was simulated with the cumulative rainfall and average rainfall in Hambantota area for 2001 to verify the use of SPI and to determine the suitable SPI time Scales.

The results showed that the 3-month SPI time scale is the most suitable to monitor onset of drought, but 6-month time scale is explained the severity and the length of drought period in Sri Lanka.

***KEYWORDS: Drought monitoring, SPI, Cumulative Average Rainfall, Cumulative Rainfall, SURFER 09 software*.**

1 Introduction

Droughts and floods are extreme climate events that percentage-wise are likely to change more rapidly than the mean climate (Trenberth et al. 2003). The damages and the economic losses due to the flood and droughts are very high and it will affect to very large number of people in each year (Wilhite 2000). Drought is the single most important climatological hazard, often aggravated by human actions. Drought may start at any time and reach varying levels of severity (Premalal 1998). The occurrence of dry spell or droughts is not normally expected to be a characteristic feature of the climate of tropical islands. Drought is described as a deficiency of precipitation over an extended period of time, which results in shortages of water. Drought is also a normal, recurrent feature of climate that occurs in most climatic zones. Generally, these droughts have a duration of 6 to 9 months (Lyon et al., 2009), but the typical length for humid tropics regions are 6 months (Sheffield and Wood, 2007). Drought is also related to the timing of precipitation. Other climatic factors such as high temperature, high wind, and low relative humidity are often associated with drought.

Often a region adopts itself to a certain level of water shortage based on the long-term climatic conditions experienced by it. Any negative departure from these levels creates conditions of drought, depending on the intensity and duration of this deficit. Thus drought conditions differ from region to region. Hence the definitions of Droughts are area specific. Hence in general, drought is defined as an extended period - a season, a year, or several years - of deficient rainfall relative to the statistical multi-year average for a region. However, dozens of more specific drought definitions are used (http://www.un-spider.org/risks-and-disasters/disaster-risk-management-guides).

Inter-Governmental Panel for Climate Change (IPCC, 2007) has projected that the occurrence of drought is increasing due to Global Warming. Therefore it is important to monitor the drought occurrence. However, the precise quantification of droughts and wet spells is difficult because there are many different definitions for these extreme events (e.g., meteorological, hydrological, and agricultural droughts; (see below), Wilhite 2000 and Keyantash and Dracup 2002) and the criteria for determining the start and end of a drought or wet spell also vary. Furthermore, historical records of direct measurements of the dryness and wetness of the ground, such as soil moisture content (Robock et al. 2000), are sparse. In order to monitor droughts and wet spells and to study their variability, numerous specialized indices have been devised using readily available data such as precipitation and temperature (Heim 2000; Keyantash and Dracup 2002).

Meteorological drought is brought about when there is a prolonged period with less than average precipitation. Meteorological drought usually precedes the other kinds of drought.
Agricultural droughts are droughts that affect crop production. This condition can also arise independently from any change in precipitation levels, soil condition and erosion triggered by poorly planned agricultural attempts causes a shortfall in water available to the crops. However, in a traditional drought, it is caused by an extended period of below average precipitation.
Hydrological drought is brought about when the water reserves available in sources such as lakes and reservoirs falls below the statistical average. Like an agricultural drought, this can be triggered by more than just a loss of rainfall.
Socioeconomic drought associate the supply and demand of some economic goods.Its occurrence depends on the processes of supply and demand. Socioeconomic drought occurs when the demand for an economic good exceeds the supply as a result of a weather-related shortfall in water supply. The drought may result in significantly reduced hydroelectric power production

Prolonged periods of dry weather are not uncommon in the hydrological history of Sri Lanka, although the occurrence of dry spells or droughts are not normally expected to be a characteristics feature of the climate of tropical island (Premalal, 1998). In Sri Lanka drought occurs due to the delay of monsoon onset or the temporal variability of the rainfall.

Past studies shown that droughts are related to other global tele-connection such as El Nino Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), and North Atlantic Oscillation (NAO) etc. Several recent studies have characterized the influence of ENSO on rainfall over Sri Lanka (Rasmusson and Carpenter, 1983; Suppiah, 1996). Others have addressed the influence of Indian Ocean Sea Surface Temperatures (SSTs) and the Indian Ocean Dipole (IOD) Mode (Saji and Yamagata, 2003) on rainfall over Sri Lanka (Malmgren et al., 2007; Zubair et al., 2003).

Many indices have been defined to simulate drought. Some of them are Standard Precipitation Index (SPI), Palmer Drought Severity Index (PSDI) etc. In Sri Lanka drought occurs due to the lack of rainfall. Therefore Standard Precipitation Index (SPI) was used to evaluate and monitor droughts.

2. Drought in Sri Lanka and Method to Monitor

The history of the drought in Sri Lanka coming from king's era. According to the Mahawansa, drought has occurred even in 161-137 BC. During the last century the droughts of 1908 and 1911 were the most extensive droughts, affecting more than 20 districts in the "Yala" agricultural season while the most extensive drought during the "Maha" agricultural season occurred in 1938 and affected 20 districts (Amaradasa-2001).Most recent severe droughts was in 2001. It affected severely in the dry zone and intermediate zone, but Hambantota area experienced a prolonged and very severe drought in 2001 and 2002. The total affected families from the drought were more than 800000 in the year 2001 (http://www.desinventar.lk/).

Most of the people in the rural area use ground water for their domestic purposes; in addition their livelihood is highly depending on agriculture. Therefore the people in rural area are highly vulnerable for drought. Therefore developing drought monitoring system for Sri Lanka will help to reduce the vulnerability of the people to some extent by adapting their day to day activities to the drought conditions. But it is not an easy task. Therefore this study introduces a drought monitoring system using Standard Precipitation Index (SPI). In this study, SPI was simulated in Hambantota area for 2001 to verify the use of SPI for drought monitoring system. Results were verify further by simulation SPI indices for the drought at Hambantota in 1976. Finally analysis has conducted for several (26) rainfall measuring stations and mapped spatial to find distribution of drought in 2001.

3. Theory of Standard Precipitation Index (SPI)

The SPI was calculated based on precipitation only. The SPI calculation for any location is based on the long-term precipitation record for a desired period. Better probability distribution function is needed to fit the historical rainfall observation data (Guttman, 1999) for better results. Generally rainfall data does not fit for normal distribution, but the gamma distribution is flexible at representing a variety of precipitation distributions and thus commonly used to calculate SPI (Husak et al., 2007).

McKee et al. (1993) developed the Standardized Precipitation Index (SPI) to monitor the status of drought in Colorado. In brief, computing the SPI begins with building a frequency distribution from precipitation data at a location for a specified time period. A gamma probability density function is fitted to the precipitation data and the cumulative distribution of precipitation is determined. An equiprobability transformation is then made from the cumulative distribution to the standard normal distribution with a mean of zero and variance of one. This transformed probability is the SPI value, which varies between +2.0 and −2.0, with extremes outside this range occurring 5% of the time (Edwards and McKee, 1997).

SPI value	Condition
2.0 or more	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

Table 1: Drought categorization

2 Data and Methodology

SPI is the most widely used drought monitoring tool used in the world today. This study was conducted in order to demine the applicability of this index in Sri Lankan drought monitoring system. A basic approach was adopted to determine the best suit SPI time scales for Sri Lanka by simulating the most significant two drought seasons in Hambantota area in 1976 and 2001. Moderate drought condition was occurred in 1976 and the drought was severe in 2001.

SPI was calculated for 1 month, 3 months cumulative and 6 months cumulative time scales to find out the suitable period for Sri Lankan climatology. Analysis of 1 month cumulative time scale shows even short term rainfall deficiency (Figure 1), but the analysis does not indicate any severe drought event throughout the year. One month deficiency of rainfall is generally common and it does not indicate continuation of drought. According to the figure 1, the SPI value is nearly -1.5 in May 2001 and it indicated moderate drought condition. Value of SPI, are negative

Even after May, but the values are nearly -1.5 (moderate). Continuous negative values of SPI indicated the negative rainfall anomaly and hence possibility of drought conditions, but it does not show any severe conditions. Many medias and studies indicated the severe drought conditions in 2001 at Hambantota area. Even though the SPI values are negative after May 2001, it does not indicate any severe conditions. So it is clear that one month analysis of SPI does not suitable to measure severity of drought conditions. Analysis of cumulative rainfall for few months may be a better approach to overcome this problem.

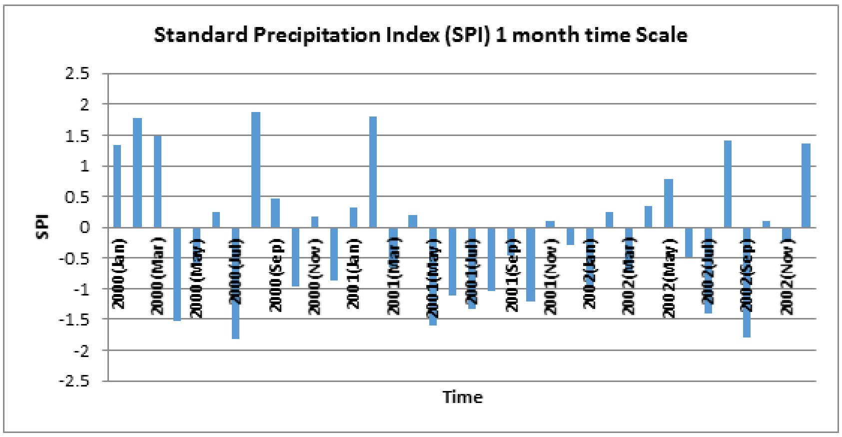

Figure 1: SPI for Hambantota (1 month time scale)

To clarify the situation, analysis extended to find out the three months cumulative SPI values. Figure 2 shows the calculation of SPI for three (3) months period and it indicates July 2001 as a severe drought month because SPI indicated nearly -2.0. The condition continued only one month until August. Cumulative rainfall analysis for three months indicated onset of drought in July 2001 and after it shows the severity for only one month. Therefore it is clear that both one month and 3 month cumulative analysis give some indication about drought in 2001, but it does not show severity and continuation.

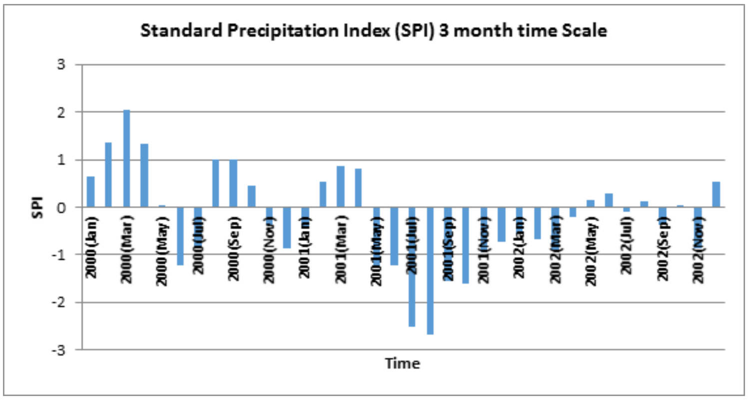

Figure 2: SPI for Hambantota (3 month time scale)

Many media reported about the drought condition even after October 2001, and it clearly explained the continuation of drought until 2002. One and three months analysis are better to find onset, but it does not give any indication for extending drought conditions; therefore analysis was extended to find 6 months cumulative SPI indices. Analysis of 6 months period time scale to identify the drought during 2001 is shown in the figure 3.

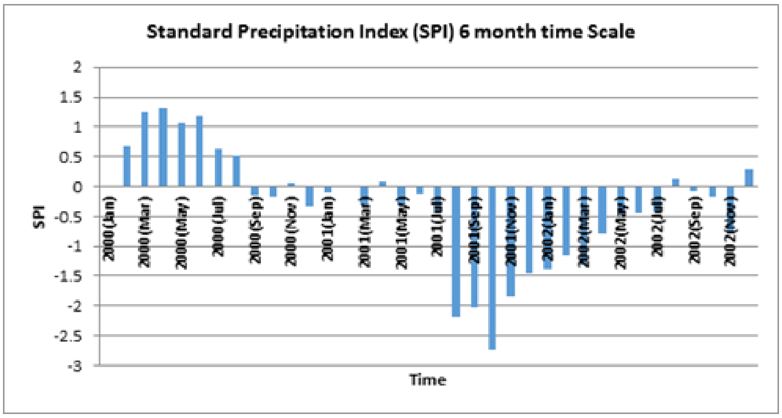

Figure 3: SPI for Hambantota (6 month time scale)

Analysis of SPI for 6 months time scale clearly indicated the severe drought conditions and it continued up to July2002 even though some rain spells occur within that period.

Therefore 3 months time scale has been considered as a best time scale to monitor onset of drought, but time scale should be longer to identifythe strength and the length of drought spell. As analysis of six (6) months time scale explained the length of drought, it is the better scale to identify the length and also the strength.

Drought condition at Hambantota in 1976 also severe but not as 2001. To clarify the method, analysis was adopted to identify the drought in 1976. The SPI simulation for Hambantota area in 1976 is shown in the

Figure 4 to 6 for the time scale 1, 3 and 6 respectively. As explained above, clear indication for drought given by the analysis of SPI for continuous 3 and 6 months.

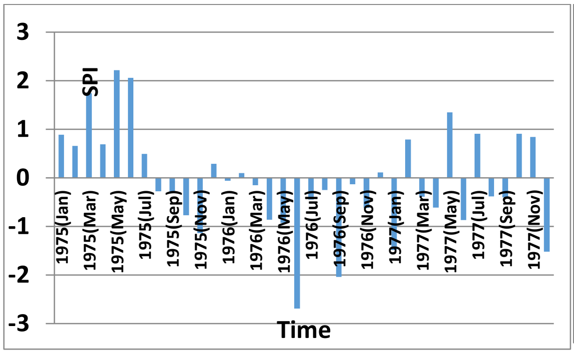

Figure 4: SPI for Hambantota (1976) 1 month time scale

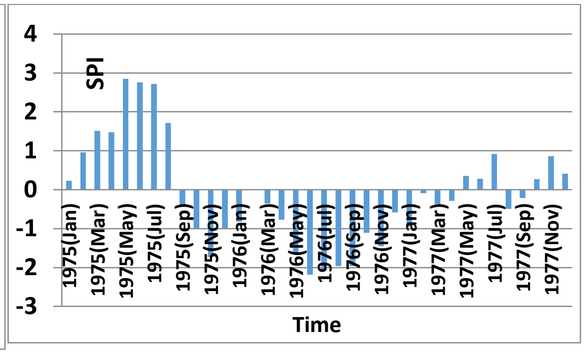

Figure 5: SPI for Hambantota (1976) 3 month time scale

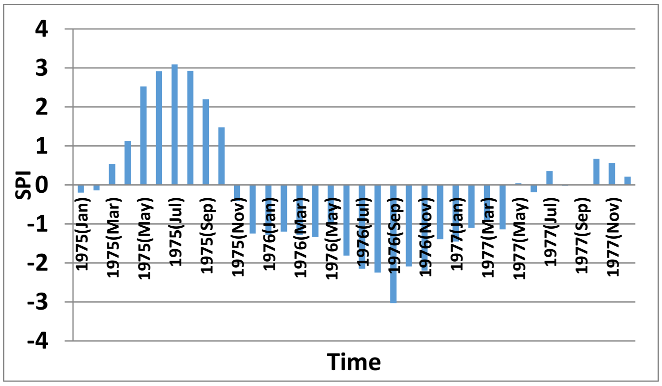

Figure 6: SPI for Hambantota (1976) 6 month time scale

To identify the spatial distribution of the drought in 2001, analysis were conducted for 26 rainfall measuring stations and mapped using SURFER 09 software for the time scales 3. Figure 7 indicated the onset of drought by analyzing 3 months timescale. It is clear that onset was started in May 2001 in the districts Hambantota and Kegalle.

Comparing all 3 months analysis indicate some possibility for onset of drought. Hence warning can be issued after analysis of 3 months cumulative SPI. By continuing the analysis for 3 months as well for 6 month, it is possible to issue the severity and the possibility of withdrawal of drought condition

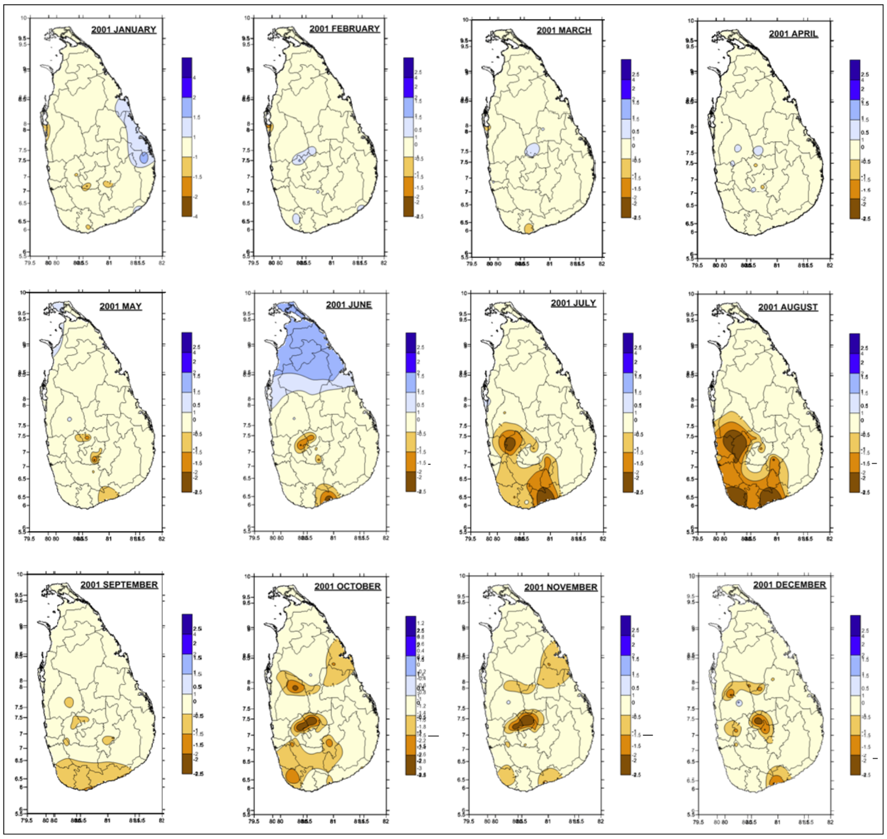

Figure 7: Spatial distribution of SPI for the year 2001 for 3 months time scales

3 Conclusion

This module seems to match with the monitoring drought condition in Sri Lanka, but the real feeling is different as what SPI shows, because the feeling of drought is different for different places. Soil condition, vegetative condition and the infrastructure areplaying tremendous role for drought condition. Not only that soil moisture recharging capacity also important for identify real drought condition.

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