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in

López-Francos A. (comp.), López-Francos A. (collab.).
Economics of drought and drought preparedness in a climate change context

Zaragoza : CIHEAM / FAO / ICARDA / GDAR / CEIGRAM / MARM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 95

2010
pages 85-89

Comparing the Effective Drought Index and the Standardized Precipitation Index

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Abstract. In this study, the performances of the Effective Drought Index (EDI) and 1-, 3-, 6-, 9-, 12- and 24-month Standardized Precipitation Indices (SPIs) were compared for drought monitoring data accumulated over 200-year period from 1807 to 2006 for Seoul, Korea. The results confirmed that the EDI was more efficient than the SPIs in assessing both short and long-term droughts.

Keywords. Effective Drought Index – Standardized Precipitation Index.

Comparaison de l'indice effectif de sécheresse et de l'indice standardisé des précipitations

Résumé. *Dans cette étude, les performances de l'Indice Effectif de Sécheresse (EDI) et des Indices Standardisés des Précipitations (SPIs) sur 1, 3, 6, 9, 12 et 24 mois ont été comparés concernant les données de surveillance de la sécheresse accumulées sur une période de 200 ans de 1807 à 2006 pour Séoul, Corée. Les résultats confirment que EDI était plus efficient que les SPIs pour évaluer aussi bien les sécheresses à court qu'à long terme.*

Mots-clés. *Indice Effectif de Sécheresse – Indice Standardisé des Précipitations.*

I – Introduction

Various drought indices have been developed to quantify drought status. The SPI is the most commonly used index. However, the SPI has limitations. First, it is calculated based on monthly precipitation, as are many other drought indices. Even if a drought occurs, an index value is not available until the last day of the month or the subsequent month, when statistical analyses of precipitation for the particular month are completed. In addition, droughts can be relieved by a single day of heavy rainfall; however, this situation continues to be considered a drought until statistics on precipitation for the month are available. Second, the SPI utilizes a simple average of precipitation for each concerned period. The SPI cannot take into consideration the fact that substantial water resources generated by rainfall that occurred many months ago may have already been lost due to outflow and evaporation. Similar issues exist for all of the other drought indices. Finally, the SPI provides drought severity over various timeframes, including 1-, 3-, 6-, 9-, 12-, 24- and 48-month periods. The element of subjectivity comes into play when determining whether a drought is occurring because the person responsible has to choose from among the time periods available. To overcome these limitations, Byun and Wilhite (1999) developed the Effective Drought Index (EDI), which is an intensive measure that considers daily water accumulation with a weighting function for time passage. This study systematically proved the theoretical advantages of EDI by the analysis on various time scale droughts.

II – Materials and methods

1. Precipitation data

Daily precipitation data have been recorded for Seoul, Korea since 1778, thereby providing one of the longest records in the world; thus, these data are particularly useful for application and assessment of drought indices. Precipitation was measured from 1777 to 1907 using a Chukwookee (a traditional rain gauge of Korea) and restored by Jhun and Moon (1997). For this study, precipitation data accumulated over 200 years from 1807 to 2006 were used.

2. The Effective Drought Index (EDI)

The following equations were used for the EDI calculations.

$$EP_i = \sum_{n=1}^{i}\left[\left(\sum_{m=1}^{n} P_m\right)\Big/ n\right] \qquad (1)$$

$$DEP = EP - MEP \qquad (2)$$

$$EDI = DEP / SD(DEP) \qquad (3)$$

In equation (1), EP_i represent the valid accumulations of precipitation and P_m represents the precipitation level for a day, "m" days prior to a specific date. "i" in equation (1) begins from 365. Therefore, EP becomes the valid accumulation of precipitation for 365 days from a particular date. DEP in equation (2) represents the deviation of EP from MEP (30-year average EP for the calendar date). When DEP is negative for two consecutive days, "i" becomes 366 (=365 + 2 – 1) and the calculation begins once again. Therefore, the drying effect on the soil from a drought that occurred several years ago is reflected in the EDI. For detailed explanations, please refer to Byun and Wilhite (1999). The "drought range" of the EDI indicates extreme drought at $EDI \leq -2$, severe drought at $-2.0 < EDI \leq -1.5$, and moderate drought at $-1.5 < EDI \leq -1.0$. Near normal conditions are indicated by $-1.0 < EDI \leq 1.0$.

3. The Standardized Precipitation Index (SPI)

The SPI is calculated as follows: build a frequency distribution from the historical precipitation data (at least 30 years of data) at a location for a specified period (1, 3, 6, 9, 12, 24 or 48 months). Then, a theoretical probability density function (e.g., gamma distribution) is fitted to the empirical distribution of precipitation frequency for the selected time scale. An equiprobability transformation is then applied from the fitted distribution to the standard normal distribution (e.g., Edwards and McKee, 1997). Because the SPI is standardized in the same manner as the EDI, the range of droughts is the same as for the EDI. A 1-month SPI is abbreviated as SPI1; a 3-month SPI, as SPI3.

III – Results

A scatter diagram of monthly minimum EDI values *vs* SPI values <–1 (Fig. 1) was prepared to assess how accurately the two indices measured drought. The scatter diagram of SPI1 and EDI is very scattered, and the R^2 value is close to 0. For 86.3% of the SPI values <–1, the EDI had negative values. For 48% of these SPI values, the EDI had values <–1. Thus, there was no clear correlation between the two indices; however, the results confirm that to some extent, the EDI detected short-term droughts detected using the SPI1. The relationship between the two indices improved for SPI3. For 92.2% of the SPI3 values <–1, the EDI had negative values. For 68.3% of these SPI3 values, the EDI had values <–1. On the other hand, the EDI had positive values for 29 out of the 372 months in which SPI3 <–1. These months ranged from November to April, which correspond to the hydrologic dry season in Seoul. These instances represent a relatively low amount of precipitation was short during the dry season following a summer rainy season with a high level of precipitation. Thus, the EDI value, in which precipitation accumulated for more than 1 year is considered, did not represent a drought; however, the SPI3 value, in where precipitation accumulated over three months is considered, represented a severe drought. Hayes *et al.* (1999) noted that SPI1 and SPI3 indicated a severe drought even if only a low amount of precipitation was short in dry seasons, since SPI1 and SPI3 are nearly the same concepts as percentage anomaly. The SPIs on long time scales show similar behaviour to the EDI as can be identified visually. The EDI had a negative value in all of the drought months identified by SPI9 and SPI12, and about 96% of the EDI values represented droughts. In particular, SPI12 had a high R^2 value of 0.52 and was the closest to the EDI, because both of these indices essentially consider 1-year precipitation. The difference between the EDI and SPI12 values was the greatest in April 1903 (EDI: –3.29, SPI12: –1.11). This drought event was characterized by an accumulated rainfall shortage of more than 3 years. Because the EDI considers a continued dry period, it can take into account an accumulated rainfall shortage over 3 years. However, the SPI12 considers rainfall shortage for only 1 year, and thus, the large observed difference in index values occurred. For 99.7% of all drought months identified by SPI24, the EDI had a negative value. For 82.9% of them, the EDI identified droughts. There were 166 months for which SPI9, SPI12, and SPI24 simultaneously had values <–1. In these cases, the monthly minimum EDI was <–1 as well. On the other hand, there were 24 months for which SPI1, SPI3, and SPI6 had values <–1, while SPI9, SPI12, and SPI24 had values >–1, indicating short-term drought. In 21 (19) of these cases, the monthly minimum EDI was <0 (–1). Each of the 3 cases for which the EDI had values >0 occurred in February and April, in the latter part of the dry season. In these cases, precipitation in the previous summer rainy season (June to September) was higher than normal by >30%.

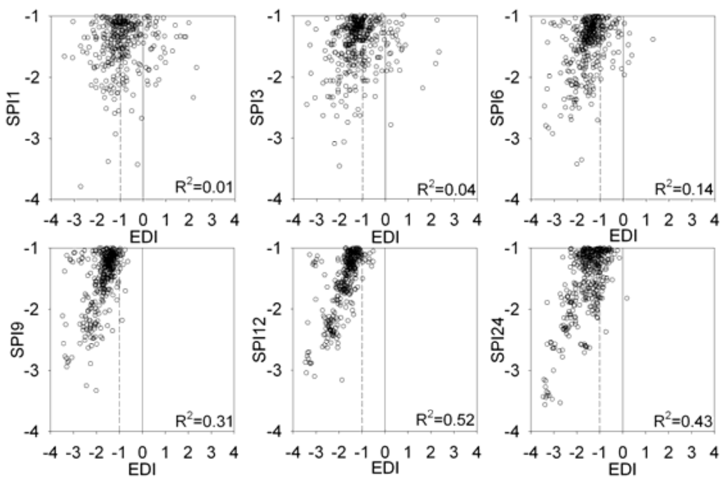

Fig. 1. Scatter diagram of SPI less than –1 and monthly minimum EDI from 1807 to 2006.

1. Long-term drought

For 1406 days from 6 July 1899 to 15 May 1903, negative EDI values continued (Fig. 2). This was the longest drought among all the events measured by the EDI within the 200-year study period. As low precipitation continued from 1899 to 1902, accounting for 54, 34, 28 and 54% of normal annual precipitation, respectively, the drought gradually worsened. As the drought period lengthened, the short-term SPIs underestimated the severity of the drought. While the drought continued, SPI1 and SPI3 indicated several times that the drought was relieved. In January 1903, when the drought had continued for about 3 years, SPI1 and SPI3 showed that the drought had been relieved. SPI6, SPI9, and SPI12 identified it as a moderate drought (about –1). Only EDI and SPI24 showed that it was an extreme drought (less than –2.5). This example illustrates that the short-term SPIs cannot detect the progress of long-term droughts.

2. Short-term drought

As shown in Fig. 2, the drought that occurred from April 1899 to May 1899, which was the initial stage of an extreme long-term drought, was detected by the EDI and short-term SPIs, but was not detected by the long-term SPIs (12- and 24-month). Another example of a short-term drought is shown in Fig. 3. This intensive, short-term drought occurred due to an extreme shortage of rainfall in spring and early summer. The total precipitation in March-June 1965 was 63 mm, comprising only 17% of the average rainfall for that period (367 mm). SPI12, which is the most similar to the EDI, was not able to detect this short-term drought, nor was SPI24. In May 1965, SPI9 was >0, indicating wetness; however, in June, the SPI9 value abruptly dropped to <–2, indicating an extreme drought. Such an abrupt decrease in an index value can hinder early warning of a drought. The reason for this phenomenon was that the 378.9 mm precipitation received in September 1964, 265% of precipitation in normal years, was considered in the SPI9 in May 1965 but was not considered in June 1965. This example clearly illustrates the disadvantage of a calculation method in which the same weight is applied to recent and past precipitation. In contrast, the EDI value accurately reflects the fact that a drought gradually becomes more severe as a precipitation shortage continues. On 4 July, right before heavy rainfalls relieved the drought in early July 1965, the EDI recorded its minimum value of –2.0. The EDI is able to detect a short-term drought that cannot be detected by SPI12 because it uses the intensive measure method in which precipitation is summed on a daily basis, applying a higher weight to recent precipitation and a lower weight to past precipitation.

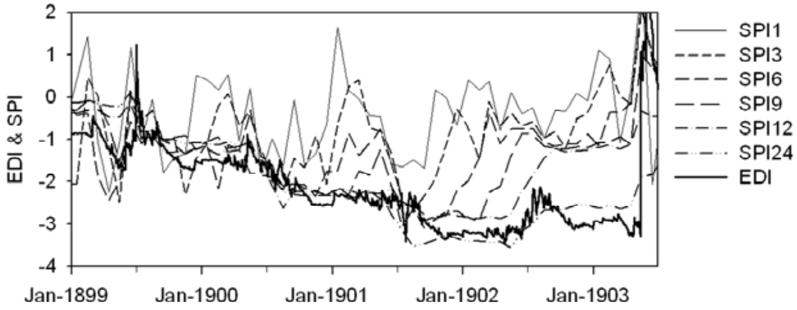

Fig. 2. Time-series of EDI and 1-, 3-, 6-, 9-, 12-, 24-month SPIs from 1 January 1899 to 30 June 1903.

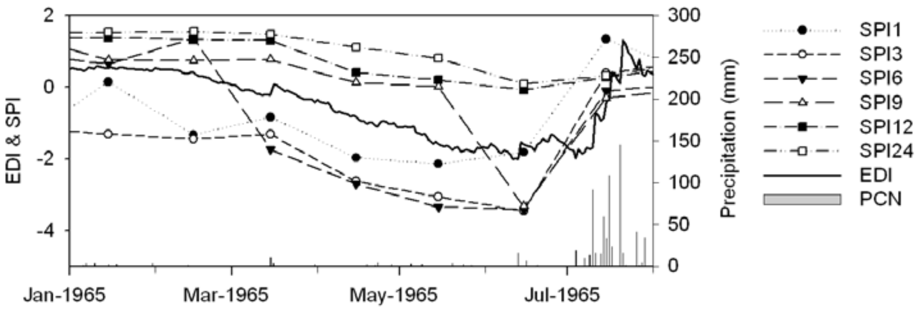

Fig. 3. Time-series of EDI, 1-, 3-, 6-, 9-, 12-, 24-month SPIs, and precipitation from 1 January to 31 July 1965.

IV – Conclusions

The results of this study confirmed that the EDI has the following advantages over the 1-, 3-, 6-, 9-, 12- and 24-month SPIs when diagnosing droughts: (i) the EDI detects long-term droughts that cannot be detected by the short-term SPIs; (ii) the EDI detects extreme long-term droughts that are detected only by the 24-month SPI; (iii) the EDI detects short-term droughts that cannot be detected by the long-term SPIs; (iv) the short-term SPIs do not detect a short-term rainfall that does not occur in units of a calendar month; however, the EDI does; (v) the various SPIs produce many different values for the same period, while the EDI calculates a single value; (vi) because the SPI gives long-past precipitation and recent precipitation the same weight, the index value may drop abruptly in a single time-step, depending on whether a high amount of rainfall in a specific past month is included in the period of interest or not. However, the EDI is able to represent the gradual development of droughts; and (vii) there are many cases where short-term SPIs overestimate a relatively small rainfall shortage in the period of interest as a severe drought even if excessive rainfall occurs right before the period of interest. This misreading of drought severity does not occur in the EDI. The EDI can thus measure both long-term droughts and short-term droughts, and the EDI is superior to SPI in that quantities of accumulated water resources are calculated rationally. Real-time monitoring system based on the EDI has been operating in Korea (http://atmos.pknu.ac.kr/~intra/).

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