Evaluating the Standard Precipitation Index and the Soil Moisture Index on Drought Monitoring in Southwest Oklahoma

J. Carter, L. Galvin, J. Pollnow, E. Wyatt
Soil Physics, Department of Plant and Soil Sciences, Oklahoma State University

Abstract. Drought prediction and monitoring is becoming an increasingly important tool in the management of water resources such as reservoirs and soil moisture. Timely and accurate drought information can be crucial to producers and government agencies faced with tough decisions related to water. During this project we compared two drought monitoring indices. The Soil Moisture Index (SMI) is a relatively-recently developed scale based on wilting point and field capacity (Hunt et al., 2009). The Standardized Precipitation Index (SPI) is an index that uses long-term precipitation records to predict the probability of the existence or absence of drought. (Mozny et al., 2012) The Standard Precipitation Index recorded more drought months, 77 months, compared to SMI, which recorded 56 drought months in southwest Oklahoma, during the period from 2001 to 2011. SPI appears to be more volatile and prone to record drought more often than SMI. Although SPI is the more accepted drought monitoring index, SMI shows to be more reliable at recording actual drought because it is based on soil moisture. More research is needed to prove that the SMI index is more reliable than the SPI index.

1. Introduction

Drought monitoring is becoming a more useful service as we have faced one of the worst droughts in recent history. Drought prediction and monitoring can provide useful information to many entities dealing with water resources: government agencies for drought aid, municipalities for water conservation, agricultural producers for crop yield estimates, etc. Two drought indices were examined in this experiment. The Soil Moisture Index (SMI) is a relatively-recently developed scale based on wilting point and field capacity. (Hunt et al. 2009) The Standardized Precipitation Index (SPI), is a prediction for the probability of drought based on prior long-term precipitation records. (Mozny et al. 2012). The two indices have different methods of input for calculating drought, so there could be important information to consider if there is correlation found between the two sets of data. The objective of this study is to determine the number of drought months recorded by the SMI and SPI indices and evaluate the differences between the two methods.

2. Methods

The data for each index were selected from separate databases. SPI values were drawn from data on the National Climate Data Center website and placed in a table so that month to month averages for the years from 2001 to 2011 could be compared to those of SMI. For SMI, we obtained soil moisture data from the Oklahoma Mesonet website (www.mesonet.org). Six experimental sites were chosen in the southwestern division of Oklahoma: Apache, Hinton, Hollis, Medicine Park, Tipton, and Waurika. The sites were chosen by evaluating the total number of available soil moisture days for each location. These six sites proved the most accurate (low water tables and non-irrigated sites) and had the least amount of missing data. From each site, the Mesonet data included ΔT_{ref} soil moisture readings for depths at 5 cm and 25 cm, daily rainfall accumulation, and soil textural class. Average soil hydraulic parameters used in these calculations were taken from ROSETTA. (Schaap et al, 2001)

This data was then used to determine the soil matric potential:

$$\psi_m = -c\ e^{\alpha \Delta T_{ref}}$$

The value from the matric potential was then used to calculate soil volumetric water content (θ) for depths 5 cm and 25 cm. The Van Genuchten (Illston et al, 2008) equation was used to calculate soil volumetric water content:

$$\theta = \theta r + \frac{(\theta s - \theta r)}{[1+(-\alpha\, \psi_m)^n]^m}$$

Permanent wilting point and field capacity were calculated using the Hunt et al. 2009 method, which places the 95th percentile as the field capacity of the soil and the 5th percentile as the permanent wilting point. Adjusting permanent wilting point and field capacity values to this methodology reduced the variability in the data since the hydraulic parameters used in the Van Genuchten equation are only estimates of the real values. The soil volumetric content value was then used to calculate the fractional available water (FAW) content for the depths of 5 cm and 25 cm:

$$\text{FAW} = (\theta - \theta_{wp})/(\theta_{fc} - \theta_{wp})$$

The values from the depths of 5 cm and 25 cm were then averaged for an average daily FAW (Hunt et al. 2009). The average daily FAW was then used to calculate the SMI (Hunt et al. 2009) for each day:

$$SMI = -5 + 10\ (FAW)$$

The daily SMI values were compiled into monthly averages and compared to the monthly SPI values to evaluate the total difference in drought months and any correlation that may arise between the two drought monitoring indices.

3. Results and Discussion

The Standard Precipitation Index recorded more drought months, 77 months, compared to the Soil Moisture Index, which recorded 56 drought months. Figure 1 shows the number of drought months per year for each index. In all years except 2004, SPI shows more drought months per year than the SMI.

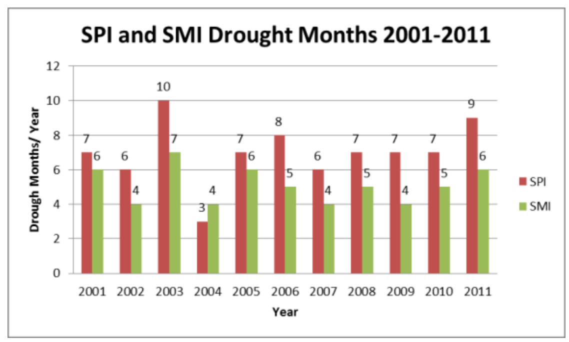

Figure 1: SPI and SMI Drought Months

Figure 2 shows that both indices tend to track each other over the experiment time period. The scatter plot of the same data retrieved a correlation coefficient of .6147, indicating a fairly strong positive correlation. SPI appears to be more volatile and tends to record drought more often than SMI. The higher drought incidences and volatility with SPI could be due to SPI possibly being calibrated for significantly wetter climates or areas that receive rainfall on a more regular basis.

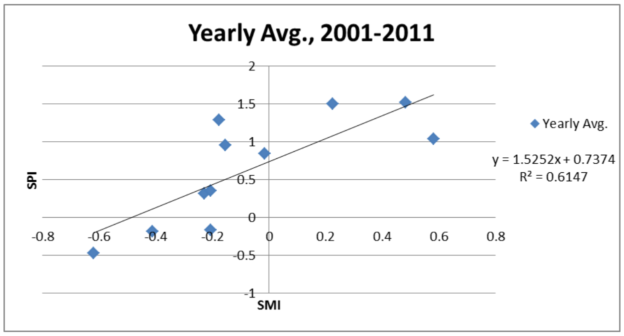

Figure 2: Correlation Between SMI and SPI indices

The data by year of each month indicate that SPI is the more volatile index, swinging between drought and non-drought conditions month-to-month in a given year.

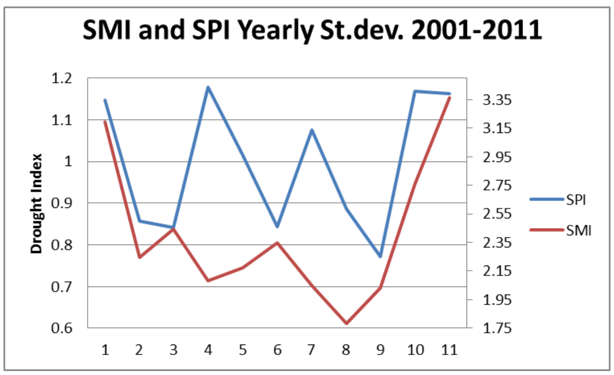

Figure 1: Standard Deviation of the SMI and SPI indices

SMI tends to remain in either drought or non-drought for longer – or more consecutive months – before entering the other side of the index. The index gradients for SMI tended to be less steep than SPI, perhaps owing to the soil's ability to retain moisture. The standard deviation values for SMI remain less on a relative scale than SPI, indicating that SPI likely experiences more dramatic swings in its values around a mean, even during years of less variability. Figure 3 also shows SMI as being more volatile in certain years such as 2001, 2010, and 2011, in which seasonal weather extremes may push the index from one end to the other.

4. Conclusion

Although SPI is the more accepted drought monitoring index, SMI seems to be more reliable at recording actual drought because it is based on soil moisture. The SMI is more ideal for agriculturalists, rangeland specialists, turfgrass producers, and any other person who depends on the soil for production or recreational use. The Standard Precipitation Index based on our assumptions is more useful for recording drought conditions that are associated with water resources such as lakes, ponds, streams, etc. This index would be a great tool for municipalities managing lake water supplies or river authorities managing watershed areas. More research is needed to prove that SMI is more reliable than SPI. Ideally, focus should be placed on daily drought monitoring when evaluating the two drought indices. Further research on SMI should include hydraulic parameters for each recording site to improve the accuracy of the index.

References

Hunt, E.D., K.G.Hubbard, D.A. Wilhite, T.J.Arkebauer, A.L. Dutcher. 2009. The development and evaluation of a soil moisture index. Int. J. Climatol. 29: 747-759

Illston, B.G., J.B. Basara, D.K. Fisher, R. Elliot, C.A. Fiebrich, K.C. Crawford, K. Humes, E. Hunt. 2008. Mesoscale monitoring of soil moisture across a Statewide network. Journal of Atmosph. and Oceanic Technology, 25, 167-182.

Mozny, M., M. Trnka, Z. Zalud, P. Hlavinka, J. Nekovar, V. Potop, M. Virag. 2012. Use of a Soil Moisture Network for Drought Monitoring in the Czech Republic. Theor. Appl. Climatol. 107:99-111.

Schaap, M.G., F.J. Leij, M.T. Van Genuchten. 2001. Rosetta: A computer program for estimating soil hydraulic parameters with hierarchical pedotransfer functions. Journal of Hydrology 251, 163-176.