IDENTIFICATION OF EXTREME DRY AND WET CONDITIONS BASED ON DIFFERENT DROUGHT INDICES

Patrik NAGY[1], Martina ZELEŇÁKOVÁ[1], Maria Manuela PORTELA[2]

1. TUKE, Faculty of civil engineering, Department of Environmental Engineering, Vysokoškolská 4, Košice 042 00, Slovakia,patrik.nagy@tuke.sk,martin.zelenakova@tuke.sk

2. Instituto Superior Tecnico/Universidade de Lisboa (IST/UL), CERIS, maria.manuela.portela@tecnico.ulisboa.pt

ABSTRACT

The paper compares the ability of the following drought indexes applied to 1-month time scale to recognize the very and extremely dry and wet periods: the Standardized precipitation index (SPI), the Standardized evapotranspiration index (SPEI), the Streamflow drought index (SDI) and the Reconnaissance drought index (RDI). The period adopted in the analysis was from 1960 to 2015 and the records concerned the monitoring station of Poprad/Svit, located in the northeastern Slovakia. The results showed that the indices have the capability of identifying extreme conditions however not always occurring at the same time.

Keywords: drought index; precipitation; evapotranspiration; streamflow; climate; dry season

1. INTRODUCTION

Drought as a natural phenomenon is an extreme phenomenon whose consequences threaten not only nature and landscape, but also society. The primary cause of a drought is the lack of precipitation that originates reduced surface runoff in the river catchments. Drought can negatively affect agriculture and industry, drinking water supply and electricity production systems. Assessing the occurrences of droughts and of the wet seasons and monitoring their consequences is important in terms of prevention and adaptation measures to the natural phenomenon. In the scope briefly mentioned, the paper refers to a comparison of the performance of the Standardized precipitation index (SPI), the Standardized evapotranspiration index (SPEI), the Streamflow drought index (SDI) and the Reconnaissance drought index (RDI regarding the recognition of dry and wet periods based on the monthly records at a river gauge station located in northeastern Slovakia. The SPI, SPEI, RDI and SDI indexes have equivalent design however differing in the input parameters (Svoboda, Fuchs, 2016). The data required by the study was provided by the Slovak Hydrometeorological Institute, Košice Regional Center. It should be mentioned that, despite the moderate climate of the watershed adopted as case study, droughts in the same are also expected to become more frequent.

Droughts are difficult to define based on hydrometeorological variables and socio-economic factors, due to the different characteristics of the water availability and demands in different regions of the world. Yevjevich (1967) stated that very different views on the definition of drought are one of the main obstacles in assessing drought. However, a distinction must be made between conceptual and operational definitions. The conceptual definition of drought is determined in relative terms (e.g., drought is a long dry period). The operational definition of drought attempts to identify the onset, severity and end of drought. The general definition of drought can be used to analyze drought frequency, severity and duration during a given period (Mishra, Singh, 2009). Droughts are classified into different categories according the type of water reservoir affected at the watershed level: meteorological, hydrological, agricultural and socio-economic. Many drought indices have been developed to assess drought, each with its strengths and weaknesses.

2. MATERIAL AND METHODS

Drought indices provide nothing but numerical representations (standardized values) of the drought intensity, based on climatological and hydrometeorological data. Negative values stand for dry periods and positive values for wet periods. Table 1 specifies the values for the different intensity categories. In this paper the SPI, SPEI, RDI and SDI indices at the 1-month time scale were applied and compared as for their ability to recognize the dry and wet periods.

The standardized precipitation index SPI, developed by McKee et al. (1993), uses precipitation records. SPI should be calculated based on a minimum length of the precipitation time series of 20 years or, ideally, of 30 years. Regarding this index or the remaining ones, the time step of the input data can vary from 1 month to 48 months. In the study, only the time scale of 1 month was considered, as previously mentioned, because it already provides information about the changes in the soil moisture and in the streamflows due to the scarcity or to the excess of rainfall. In addition to precipitation, the standardized evapotranspiration index, SPEI, uses air temperature to calculate evapotranspiration (Vicente-Serrano et al. 2010). The Streamflow drought index, SDI, considers as input data streamflows and a formulation similar of the one of the SPI. Reconnaissance drought index, RDI contains a simplified equilibrium equation that includes precipitation and potential evapotranspiration. It has three outputs: initial value, normalized value and standardized value. The standardized value of RDI is similar in nature to SPI and can be directly compared to it. However, RDI is more representative than SPI because it considers full water balance instead of rainfall alone. Input parameters are monthly temperature and precipitation (Svoboda, Fuchs, 2016).

Table 1. Drought intensity categories.

Drought intensity	Value of index
Extremely wet	> 2.0
Very wet	1.5 to 1.99
Moderately wet	1 to 1.49
Near normal	-0.99 to 0.99
Moderately dry	-1 to -1.49
Severely dry	-1.5 to – 1.99
Extremely dry	< -2

3. ASSESSMENT OF THE EXTREME PERIODS BASED ON POPRAD/SVIT CLIMATOLOGICAL AND RIVER GAGE STATION

The Poprad/Svit is a climatological and river gage station located in the northeastern Slovakia. The watershed area is 1262.41 km^2. Based on the monthly records at the station, from October 1960 to September 2015, made available by the Slovak Hydrometeorological Institute, Košice, the different indices were computed at the time scale of 1 month and applied to the recognition of the very or extremely dry periods and of the very or extremely wet periods. For the different months of the hydrological year, Table 2 identifies the years that experienced the former conditions and Table 3 the years that experienced the latter ones.

For the dry or very dry conditions, which, in general, are those under concern, Table 4 allows to compare the performance of the different indices regarding the identification of the months under extreme conditions along the study period.

4. CONCLUSIONS

The results achieved prove that the different drought indices have different ability to identify the extreme – either dry or wet – periods, which makes the choice about the index to use even more difficult. In what concerns the difference among results given by the SDI, on one hand, and the other indices, on the other hand, this is reasonable because the streamflows used in the SDI represent the integrated response of the Poprad/Svit watershed while the others indices only utilize point data at its outlet. Extremely and very dry periods were identified at the Poprad/Svit stations: based on the SDI index, 1981/1982 and 1997/ 1998; on the SPI index, 1963/1964 and 1981/1982; on the RDI and SPEI indices, 1963/1964, 1981/1982, 1985/1986 and 2011/2012. Despite the difference among the dates of the periods identified as being under extreme conditions, the results show that those conditions are recurrent and that occurred through the analysed period.

5. ACKNOWLEDGMENT

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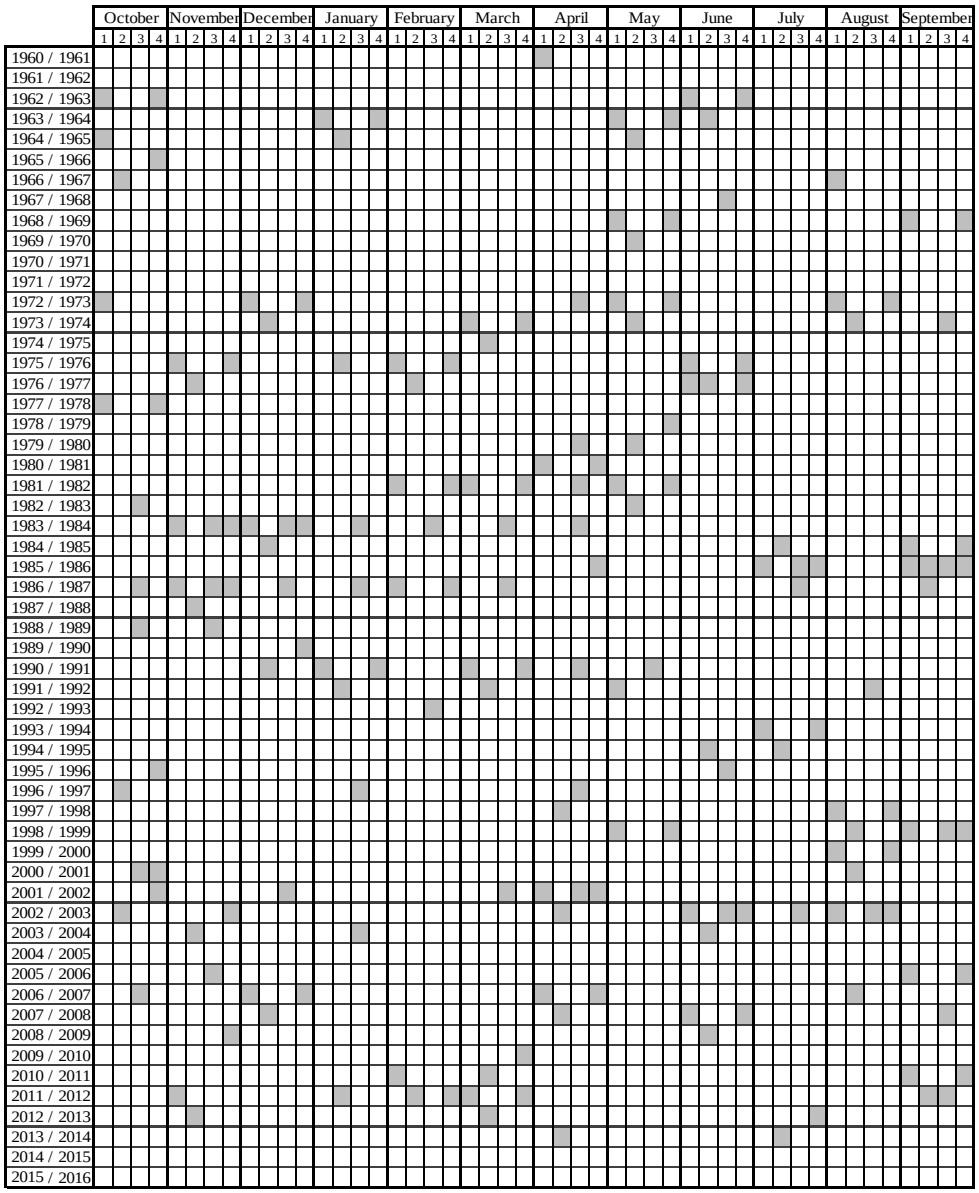
Table 2. Poprad/Svit climatological and river gage station. Period from Oct/1960 to Sep/2015. Occurrence of very or extremely dry conditions.

	Months of the hydrological year											
Drought index	October	November	December	January	February	March	April	May	June	July	August	September
Standardized precipitation index, SPI	1962/1963 1964/1965 1972/1973 1977/1978	1975/1976 1983/1984 1986/1987 2011/2012	1972/1973 1983/1984 2006/2007	1963/1964 1990/1991	1975/1976 1981/1982 1986/1987 2010/2011	1973/1974 1981/1982 1990/1991 2011/2012	1960/1961 1980/1981 2001/2002 2006/2007	1963/1964 1968/1969 1972/1973 1981/1982 1991/1992 1998/1999	1962/1963 1975/1976 1976/1977 2002/2003 2007/2008	1985/1986 1993/1994	1966/1967 1972/1973 1997/1998 1999/2000 2002/2003	1968/1969 1984/1985 1985/1986 1998/1999 2005/2006 2010/2011
Standardized evapotrans-piration index, SPEI	1966/1967 1996/1997 2002/2003	1976/1977 1987/1988 2003/2004 2012/2013	1973/1974 1984/1985 1990/1991 2007/2008	1964/1965 1975/1976 1991/1992 2011/2012	1976/1977 2011/2012	1974/1975 1991/1992 2010/2011 2012/2013	1997/1998 2002/2003 2007/2008 2012/2014	1964/1965 1969/1970 1973/1974 1979/80 1982/1983	1963/1964 1976/1977 1994/1995 2003/2004 2008/2009	1984/1985 1994/1995 2013/2014	1973/1974 1998/1999 2001/2002 2006/2007	1985/1986 1986/1987 2011/2012
Streamflow drought index, SDI	1982/1983 1986/1987 1988/1989 2000/2001 2006/2007	1983/1984 1986/1987 1988/1989 2005/2006	1983/1984 1986/1987 2001/2002	1983/1984 1986/1987 1996/1997 2003/2004	1983/1984 1992/1993	1983/1984 1986/1987 2001/2002	1972/1973 1979/1980 1981/1982 1983/1984 1990/1991 1996/1997 2001/2002	1990/1991	1967/1968 1995/1996 2002/2003	1985/1986 1986/1987 2002/2003	1991/1992 2002/2003	1973/1974 1985/1986 1998/1999 2007/2008 2011/2012
Reconnaissance drought index, RDI	1962/1963 1965/1966 1977/1978 1995/1996 2000/2001 2001/2002	1975/1976 1983/1984 1986/1987 2002/2003 2008/2009	1972/1973 1983/1984 1989/1990 2006/2007	1963/1964 1990/1991	1975/1976 1981/1982 1986/1987 2010/2011	1973/1974 1981/1982 1990/1991 2009/2010 2011/2012	1980/1981 1985/1986 2001/2002 2006/2007	1963/1964 1968/1969 1972/1973 1978/1979 1981/1982 1998/1999	1962/1963 1975/1976 1976/1977 2002/2003 2007/2008	1985/1986 1993/1994 2012/2012	1972/1973 1997/1998 1999/2000 2002/2003	1968/1969 1984/1985 1985/1986 1998/1999 2005/2006 2010/2011

Table 3. Poprad/Svit climatological and river gage station. Period from Oct/1960 to Sep/2015. Occurrence of very or extremely wet conditions.

	Months of the hydrological year											
Drought index	October	November	December	January	February	March	April	May	June	July	August	September
Standardized precipitation index, SPI	1964/1965 1974/1975 1980/1981	1962/1963 1979/1980 2010/2011	1976/1977 1982/1983 1993/1994 2005/2006	1975/1976 1978/1979 2006/2007 2012/2013	1968/1969 1969/1970 2004/2005	1999/2000 2006/2007 2008/2009	1971/1972 1988/1989 1993/1994	1995/1996 2009/2010 2013/2014	1964/1965 1972/1973 2009/2010	2000/2001	1995/1996	1983/1984
Standardized evapotrans-piration index, SPEI	1966/1967 1996/1997 2002/2003	1976/1977 1987/1988 2003/2004 2012/2013	1973/1974 1984/1985 1990/1991 2007/2008	1964/1965 1975/1976 1991/1992 2011/2012	1976/1977 2011/2012	1974/1975 1991/1992 2010/2011 2012/2013	1997/1998 2002/2003 2007/2008 2013/2014	1964/1965 1969/1970 1973/1974 1979/1980 1982/1983	1963/1964 1976/1977 1994/1995 2003/2004 2008/2009	1984/1985 1994/1995 2013/2014	1973/1974 1998/1999 2000/2001 2006/2007	1985/1986 1986/1987 2011/2012
Streamflow drought index, SDI	1964/1965 1974/1975 1980/1981	1962/1963 1979/1980 2010/2011	1976/1977 1982/1983 1993/1994 2005/2006	1975/1976 1978/1979 2006/2007 2012/2013	1968/1969 1969/1970 2004/2005	1999/2000 2006/2007 2008/2009	1971/1972 1988/1989 1993/1994	1995/1996 2009/2010 2013/2014	1964/1965 1972/1973 2009/2010	2000/2001	1995/1996	1983/1984
Reconnaissance drought index, RDI	1974/1975	1962/1963	2005/2006	1986/1987	1969/1970 2004/2005	1999/2000 2006/2007	1971/1972 1993/1994	2009/2010	1972/1973 1988/1989	2000/2001	1995/1996	

Table 4. Occurrence of very or extremely dry conditions Comparison among the results given by the different indices. Period from Oct/1960 to Sep/2015 (1, 2, 3 and for stands for SPI, SPEI, SDI and RDI, respectively)



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