Comparison of Standardized Precipitation and Selyaninov Hydrothermal Drought Indices

Laima Taparauskienė, Veronika Lukševičiūtė, Antanas Maziliauskas
Aleksandras Stulginskis University, Lithuania

Abstract

A lot of recent works have been done for development of drought indices as well as to review theirs application and comparison of their advantages and drawbacks. The Standardized Precipitation Index was proposed to characterize meteorological droughts from 2009 by World Meteorological Organization. Selyaninov's hydrothermal coefficient is used to evaluate the agro-climatological conditions in some European countries and it is confirmed to be a drought index in Lithuania. The purpose of investigation was to compare the Standardized Precipitation Index (SPI) as the reference drought index accepted by the World Meteorological Organization and the Selyaninov's hydrothermal coefficient (HTC) as the main drought index used in Lithuania. Assessment of vegetation period during 2003-2012 (May – September) according HTC indicated 70 % as wet periods (2004 - 2007, 2010- 2012) and 30 % as enough humid (2003, 2008, 2009), there were no dry periods indicated. Assessment according SPI indicated 90 % near normal of all periods (2003-2009 and 2011-2012), moderately wet was period of 2010. Evaluation of one month time scale periods according HTC and SPI1 differed in 39 of the 50 cases (78 %). Excessively wet and optimally wet according HTC were 52 % and 24 % accordingly. According SPI1 very wet and moderately wet were identified 8 and 16 % of total months accordingly. There was no month evaluated as extremely wet. According HTC as weak dry were identified 52 % of all months, according SPI1 72 proc. were identified as near normal. It was found out the very strong correlation (r=0,855) between HTC and SPI1, thought the rating of values according HTC and SPI1 differed. HTC < 0.7 equals to SPI1 < -1.4 and HTC < 0.5 equals to 1.8. The biggest differences determined during humid and wet periods.

Indroduction

Drought is among the most complex climatic phenomena affecting society and the environment (Wilhite, 1993). In general, drought can be categorized into meteorological or climatological, agricultural, hydrological, and socio-economic drought based on its time scale and impacts (Heim, 2002). This complexity is related to the difficulty of quantifying drought severity since the drought is identified by its effects or impacts on different types of systems, and there is not a physical variable we can measure to quantify droughts (Vicente-Serrano et al., 2012). Drought can be monitored effectively using drought indices such as the Palmer Drought Severity Index (PDSI; Palmer, 1965), the Standardized Precipitation Index (SPI; McKee et al., 1993, 1995) calculated with in-situ meteorological data from weather stations or others. A drought index value is typically a single number and is more useful than raw data for decision –making (Altman, 2012). A lot of recent works have been done for development of drought indices as well as to review theirs application and comparison of their advantages and drawbacks (Sivakumar et al, 2011). Drought indices have evolved from simplistic approaches based on some measure of rainfall deficiency, to more complex problem-specific models (Heim, 2002), anyway still no one definition covers all possible forms of drought and no one index can possibly capture all the various definitions (Svoboda et.al., 2004). It is a difficult to assess droughts due to variations in temporal and spatial extends of the complex events and their severity, there is no universal drought indicator and previous studies identified significant discrepancies between the drought indices (Altman, 2012).

Currently to monitor drought conditions drought indices are used in real time manner that is easily understood by end users (Svoboda et al., 2002; Shukla et al., 2011). The Standardized Precipitation Index (SPI) was proposed by McKee et al. (1993) and it has been increasingly used during the last decades because of its solid theoretical development, robustness and versatility in drought analyses (Redmond, 2002). The SPI uses only precipitation data, and can be obtained for flexible time scales by aggregating precipitation amount using a temporally moving window. Through a standardization process, SPI values may be comparable over space and time. Several studies have also demonstrated variation in the response of agricultural drought (Vicente-Serrano et al., 2006; Quiring and Ganesh, 2010). Practitioners prefer to get hands on indices that are simple to apply and as specific as possible to their crops (Niemeyer, 2008). Here, specific drought indices are required in order to define indicators, thresholds, and triggers for practical management of water resources in case of drought. These indices have to describe best the local and regional conditions of the hydrological cycle, and have to comply with the already available data that are measured routinely (Niemeyer 2008).

For many years in Lithuania, the humidity of vegetation period has been described using Selyaninov's hydrothermal coefficient (HTC). According to Farago's classification, it belongs to drought indices of water balance group "supply/demand" (Farago et al., 1989) as it uses daily values of precipitation and air temperature for the calculation of the period. According research done in Lithuania HTC, does not demonstrate the actual role of meteorological conditions in plant growth (Daugeliene and Zekoniene, 2009), it would be expedient either to modify the methodology for calculation or to search for more appropriate calculation methods. HTC does not consider soil moisture, thus period of medium humidity is often evaluated as dry if there was a wet period before it or contrary (Taparauskiene, 2009). Despite the limitations of Selyaninov's hydrothermal coefficient, it is still used for the evaluation of the humidity of period in the Lithuanian climatic conditions and it is confirmed to be a drought index by the Lithuanian Government's decision.

The National Meteorological and Hydrological Services (NMHSs) around the world are encouraged by World Meteorological Organization to use the Standardized Precipitation Index (SPI) to characterize meteorological droughts from 2009. Thus it is important to understand the accordance of SPI with other used indices. Drought indices under Lithuanian climatic conditions were compared by few researches. Valiukas (2011) found that during summer periods in Vilnius SPI identified less than half of droughts identified by HTC.

The purpose of investigation was to compare the Standardized Precipitation Index (SPI) as the reference drought index accepted by the World Meteorological Organization and the Selyaninov's hydrothermal coefficient (HTC) as the main drought index used in Lithuania by evaluation of theirs accordance.

Methods

We have used the two most widely drought indices regionally. On the one hand, the HTC drought indices that are currently implemented in Lithuanian drought monitoring system, and the Standardized Precipitation Index (SPI), accepted by the World Meteorological Organization as the reference drought index for more effective drought monitoring and climate risk management (Hayes et al., 2011).

Drought indices were calculated using the monthly precipitation and mean temperature dataset during May – September registered at the Meteorological station in Kaunas, the geographical position corresponds to 54°88' NL and 23°09' EL. Evaluation of indices accordance was done for period of 2003-2012.

The Selyaninov's hydrothermal coefficient (*HTC*) was calculated according (Dirse et all., 1984):

$$HTC = \frac{H}{0.1 \cdot \sum T_{10}} \tag{1}$$

where H – precipitation amount of estimated period mm;

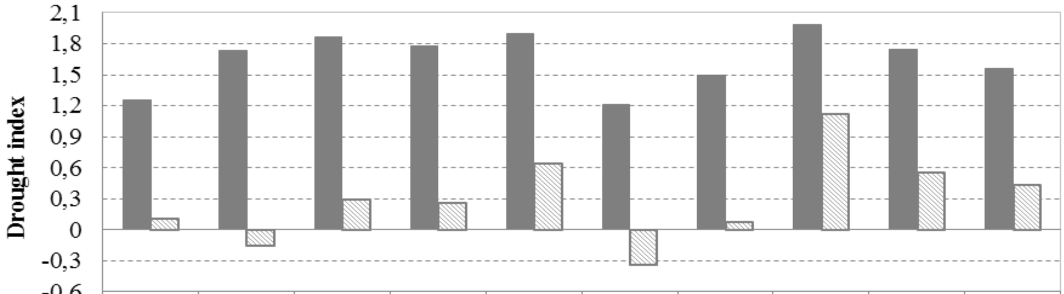
T_{10} – the sum of average air temperature (>10 ^{o}C) at the same period, ^{o}C.

The value of HTC < 0,3 – means very dry; 0,4-0,5 – dry; 0,6-0,7 – middle dry; 0,8-1,0 – not enough humid; 1,0-1,5 – enough humid, > 1,5 - wet (Dirse et all., 1984).

The SPI calculation is based on the long-term precipitation record for a particular location and long-term period. For investigation used period of 2003-2012. *SPI* is calculated using special software (National.., 2013). Usually, the different hydrological, ecological and agricultural systems respond to different drought time scales due to the varied strategies of natural vegetation and crops to cope with water deficit (Chaves et al., 2003) or the different lithologic, land cover and/or water management regimes in the case of streamflow data (López-Moreno et al., 2012). The seasonal time scales of 3- month and 6-month are most appropriate if the major interest of study is agricultural drought (Rouault & Richard, 2003). As the highest correlation between SPI3 and summer HTC and between one-month HTC and SPI1 have been reported in Lithuania (Valiukas, 2011). Therefore, the SPI were calculated at different time scales from 1 up to 48 months (data are not presented) and in this study the priority was given to SPI1. Assessment was done summarizing fifty months data.

Results

The values of HTC and SPI counted for total vegetation period in 2003-2012 shown in figure 1. As it can be seen HTC changes from 1.21 in 2008 to 1.98 in 2010 and SPI – from -0.34 in 2008 to 1.12 in 2010. Assessment according HTC indicated 70 % as wet periods (2004 - 2007, 2010- 2012) and 30 % as enough humid (2003, 2008, 2009), there were no dry periods indicated. Assessment according SPI and HTC differed as according SPI were indicated 90 % near normal of all periods (2003-2009 and 2011-2012), moderately wet was period of 2010.



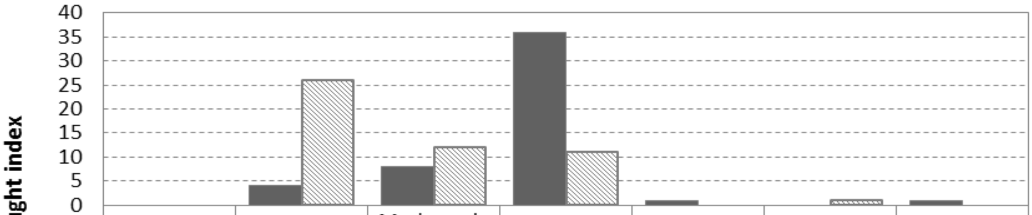
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
HTC	1,26	1,734	1,87	1,78	1,9	1,21	1,5	1,98	1,74	1,56
SPI	0,11	-0,15	0,292	0,256	0,642	-0,344	0,074	1,118	0,556	0,436

Figure 1. **Drought indeces of vegetation period during 2003-2012**

Note: According to HTC, < 0,3 – very dry; 0,4-0,5 – dry; 0,6-0,7 – middle dry; 0,8-1,0 – not enough humid; 1,0-1,5 – enough humid, > 1,5 – wet. According to SPI, ≤-2 – extremely dry, -1,5-(-1,99) – severely dry, -1-(-1,49) – moderately dry, -0,99-0,99 – near normal, 1,0-1,49 – moderately wet, 1,5-1,99 – very wet, ≥2,0 – extremely wet

In order to assess agricultural drought and plant water status it is needed to evaluate different time scales as the rainfall distribution differs a lot during separate month. Therefore, the next step was to calculate and assess HTC and SPI1 values for one month period. Evaluation of one month time scale periods difered in 39 of the 50 cases (78 %), what shown that identification of the same period drouth level is diferent according HTC and SPI1. The best coincidence was between dry periods: according HTC identified as dry 2 % of all month, according SPI1 – extremely dry 2 % and moderately dry – 2 %. Anyway it cannot be assumed as a rule as the period of investigation was more humid as dry in total and in order to prove this tendency should be investigated longer period with lack of precipitation.

The largest variance was during normal and wet periods. Excessively wet and optimally wet according HTC were 52 % and 24 % accordingly. According SPI1 very wet and moderately wet were identified 8 and 16 % of total months accordingly. There was no month evaluated as extremely wet. According HTC as weak dry were identified 52 % of all months, according SPI1 72 proc. were identified as near normal.



	Extremely wet *	Very wet * / Excessively wet	Moderately wet */ Optimally wet	Near norma*l / Weak dry	Moderately dry */ Medium dry	Severely dry* / Dry	Extremely dry* / Very dry
SPI*	0	4	8	36	1	0	1
HTC		26	12	11	0	1	0

Figure 2. **The distribution of Drought indices monthly values during 2003-2012**

The comparison of drought indices is complicated due to different methodological approaches. The first difference is between ratings of values. SPI is rated to seven levels, HTC – to six. Wet period's identification according SPI is more detailed, while the HTC – counts only excessively wet periods. The next SPI do not consider the beginning of active vegetation and if the actual vegetation starts in the middle of month SPI takes into account monthly precipitation values. Differently HTC is calculated from period when average air temperature is higher as 10 ^{o}C for three days and consider daily precipitation rate. During period of investigation the earliest beginning of active vegetation started at the end of March. This is at least 5-10 days earlier as annual average of many years. Earlier as normal, vegetation started in 2004-2005, 2009.

In order to evaluate the equivalence of HTC and SPI1 was made correlation analysis (fig.3). It was found out the very strong correlation (r=0,855) between HTC and SPI1. Similar results were reported by Valiukas (2011). He stated strong significant correlation between monthly values of SPI1 and HTC, as well as values of June – August of SPI with HTC for the same period. Anyway our results show the rating of values according HTC and SPI1 and identification of periods differs (fig. 3)

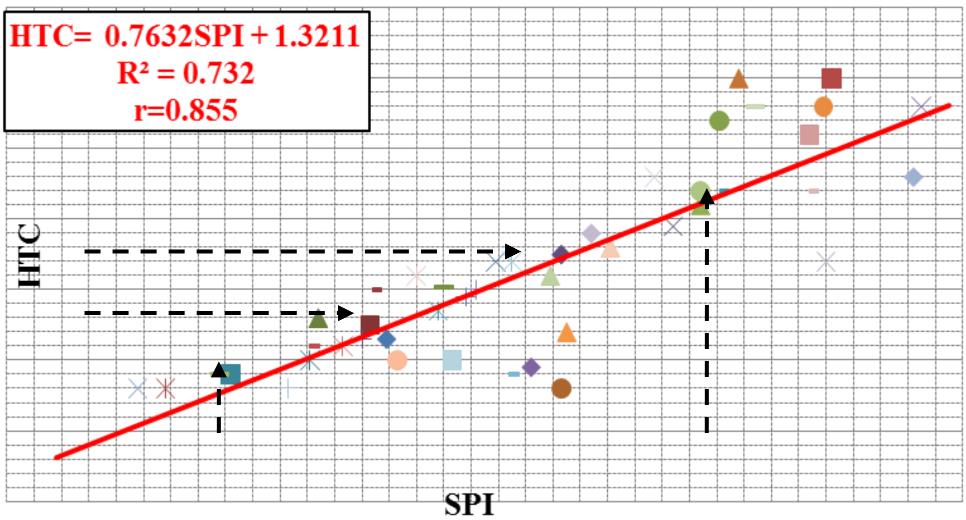


Figure 3. **The relationship between Selyaninov hydrothermal coefficient (HTC) and Standardized Precipitation index (SPI)**
Note: According to HTC, < 0,3 – very dry; 0,4-0,5 – dry; 0,6-0,7 – middle dry; 0,8-1,0 – not enough humid; **1,0-1,5 – enough humid,** > 1,5 – wet. According to SPI, ≤-2 – extremely dry, -1,5-(-1,99) – severely dry, -1-(-1,49) – moderately dry, **-0,99-0,99 – near normal**, 1,0-1,49 – moderately wet, 1,5-1,99 – very wet, ≥2,0 – extremely wet

The values officially confirmed in Lithuania as indicating drought HTC < 0.5 (dry) and HTC < 0.7 (middle dry), according Valiukas (2011) results equals to SPI1 <-1.5 and SPI < -2.0 accordingly. Our study shows that HTC < 0.7 equals to SPI1 < -1.4 and HTC < 0.5 equals to 1.8. As mentioned before the biggest differences determined during humid and wet periods. According to the dependence (fig.3) the SPI at near normal (0.2 – 0.99) are identified as wet according HTC (1 – 1.5). There were identifies 13 such cases. From the dependency it can be seen that periods according SPI1 identified as near normal, according HTC are identified as not enough humid or middle dry, eg if the period according HTC is identified not enough humid (0.8-1.0), according SPI1 – it is counted as near normal.

It is difficult to assess which index indicates drought better. It was stated that HTC tends to overestimate as dry or wet periods, i.e. moderate humid periods are evaluated as dry or wet (Taparauskiene, 2009). Similar results confirmed by drought review done in 1961-1995 (Buitkuviene, 1998).

For successful application of the standardized precipitation index in future necessary to assess the rating scale in compliance with Lithuanian Climatic conditions as well as to compare it with the actual data. As the SPI is recommended by WMO as reference drought index it is essential to integrate SPI with productive soil moisture content and to find the ways of SPI application to agricultural drought monitoring.

Conclusions

Assessment of vegetation period during 2003-2012 (May – September) according HTC indicated 70 % as wet periods and 30 % as enough humid, there were no dry periods indicated. Assessment according SPI indicated 90 % near normal of all periods, moderately wet – 10 %. Identification of humidity / drought according HTC and SPI1 for one month time scale periods differed in 39 of the 50 cases (78 %). Excessively wet and optimally wet according HTC were 52 % and 24 % accordingly. According SPI1 very wet and moderately wet were identified 8 and 16 % of total months accordingly. There was no month evaluated as extremely wet. According HTC as weak dry were identified 52 % of all months, according SPI1 72 proc. were identified as near normal.

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Laima TAPARAUSKIENĖ, Dr. assoc. prof., Institute of Water Resources Engineering, Aleksandras Stulginskis University. Research interest – crop water requirements, agricultural droughts, soil moisture dynamic, irrigation scheduling,. Adress: Universiteto 10, LT-53067 Kaunas-Akademija, Lithuania. Fax: +37037752392. Phone +37037752380. E-mail: laima.taparauskiene@asu.lt .

Veronika LUKŠEVIČIŪTĖ, Master student of technology science at the Institute of Water Resources Engineering, Aleksandras Stulginskis University. Research interest – agricultural droughts . Adress: Universiteto 10, LT-53067 Kaunas-Akademija, Lithuania.. Phone +37067773570. E-mail: veronikalukse@gmail.com.

Antanas MAZILIAUSKAS, Dr. prof., Institute of Water Resources Engineering, Aleksandras Stulginskis University. Research interest – environmental engineering and landscape management. Adress: Universiteto 10, LT-53067 Kaunas-Akademija, Lithuania. Fax: +37037752392. Phone +37037752300. E-mail: antanas.maziliauskas@asu.lt