# DROUGHT MONITORING IN SLOVAKIA

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***Drought monitoring in Slovakia is based on operationally taken evaluation of drought events. The growth of drought intensity is monitored not only in pastcasting regime just after it was detected in the particular region, but also in forecasting regime. Number of methods was applied in order to evaluate the drought events in the past but none of them was converted to operational. Due to the climate change impacts the extreme events including drought events in Central Europe grow both in frequency and intensity.***

***This article brings the methodical attempt to evaluate to evaluate recent events in 2011 and 2012 as well as the frequency of drought events in 1961-2012 and to suggest a simple system for drought monitoring with a follow up in the close future.***

***Four indices /SPI, PDSI, Tomlain climatic watering index and Koncek watering index/ were calculated for 31 stations for 2011 and 2012 and SPI, rPDSI and rZ indices for 1961-2010. The evaluation showed the growing number of drought events from the north regions of Slovakia towards south east and south west regions with maximum in Podunajska lowland, whiles the distribution of drought intensity in the particular years /2011 and 2012/ was rather scattered.***

***Based upon the above mentioned evaluation an operative system of four indices calculated once a week at selected stations in Podunajska and Vychodoslovenska lowlands is in run since March 2015. The results are freely available at http://www.shmu.sk.***

***Further monitoring based on the daily gridded meteorological data is planned in cooperation with the Czech Republic and Austria when applying the INTERDROUGHT system also for the territory of Slovakia.***

***Keywords: drought monitoring, SPI, SPEI, Palmer Z-index, CMI, Slovakia***

## INTRODUCTION

Drought is generally characterized by lack of water in soil, in water basins, in biosphere or in atmosphere. According to this we distinguish hydrological, agricultural and meteorological drought and eventually also socio-economic drought. Basic cause of drought is lack of precipitation within a certain time period. Sum of precipitation during the vegetation cycle together with water supply in soil in the beginning of the growing season is decisive for the crops. Water requirements differ from crop to crop. Lack of precipitation is frequently not the only reason causing the drought. The existence and the deepening of drought is influenced by atmospheric parameters impacting on evapotranspiration like air humidity, sunshine, wind speed but also on area slope and soil water characteristics (hydrolimits). Field capacity, available water capacity and wilting point belong to the basic hydrolimits. Underground water also influences the water quantity available in soil and can lower the intensity of drought.

Number of indices are used to evaluate drought. Each of them has a number of advantages and disadvantages. That is why the way of using more indices brings a complex approach in evaluation of drought intensity.

There was no continuous operative drought monitoring in Slovakia in the previous years. Drought was evaluated mostly in scientific papers which evaluated drought from climatological point of view. Recent publication of that kind was Climatic Atlas of Slovakia. Three indices (SPI, PDSI and Z-index) were calculated and presented over the whole territory of Slovakia for the period 1961-2010.

Slovakia represents a broken ground with relatively high difference in elevation in short distance. Top hills in Slovakia exceed 2600 m and the lowest areas are positioned below 100 m. The horizontal distance between the highest (2655 m) and lowest (94 m) elevated points in Slovakia is about 150 km. Geographical distribution of the mountains, their positions to the prevailing directions of air mass circulation bringing the precipitation strongly impact on the precipitation distribution over the country. Prevailing north-west to west air circulation together with the windward-side and lee-side effects create big differences in space distribution of precipitation in Slovakia. The mountains in the north part of Slovakia receive more than 1500 mm of precipitation while the areas in the south-west of country receive just around 500 mm per annum. Similarly, dry scattered areas of relatively small size are in the north-west of Zahorska nizina as well as in some higher positioned basins with precipitation totals less than 550 mm. Less precipitation in these positions hasn`t that big impact on potential drought like in the lowlands in south-west and south-east of the country. Drought indices calculated in Climate Atlas of Slovakia defined the most vulnerable areas in Slovakia – north part of Zahorska nizina positioned in the west, Podunajska nizina in the south-west and Vychodoslovenska nizina in the south-east of Slovakia. That is why we concentrated on the Podunajska nizina and Vychodoslovenska nizina when creating new system of drought monitoring in Slovakia. These regions represent the most fertile areas in Slovakia with the most intensive agricultural production. The combination of low precipitation totals and high temperatures creates mainly during the vegetation season higher risk of drought which stresses the need of continual operative drought monitoring.

Drought indices offer only simplified view on global situation. They usually consider long time regime of the main meteorological characteristics like the daily mean temperature, precipitation, radiation or sunshine duration, wind speed and air humidity. Evapotranspiration is derived by using various formulas from these characteristics. The real conditions could be different. Water balance shows complicated regime and requires the results of long time systematic experimental measurements which are usually not available.

## MATERIALS AND METHODS

Drought monitoring is done by the SHMU by using four drought indices; Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index (SPEI), Palmer Z-Index and Crop Moisture Index (CMI). The indices are used worldwide and they belong to the basic drought indices being used for drought warning and in some applications also for drought forecasting.

## SPI and SPEI

SPI a SPEI are used in origin way to evaluate precipitation monthly deficit. SPI is based on the cumulative probability of a given rainfall event of pre-defined time period occurring in a locality. The most frequently used time periods are 1-, 2-, 3-, 6-, 9-, 12- and 24 months. As the gamma distribution has been found best to fit the precipitation distribution it is used to find the density of probability distribution. Each SPI value is related to a value of cumulative probability in the particular time period. The disadvantage of the SPI is that the drought is assessed based on the sum of precipitation only and further parameters like the moisture, radiation and soil conditions are neglected. SPEI on the other hand accounts also potential evapotranspiration. Various methods can be used to calculate potential evapotranspiration; we apply Penman-Monteith method. Water balance is calculated as a difference of the monthly sums between precipitation P and potential evapotranspiration ($P$ - $E_0$). The final values of SPEI are calculated in the similar way like SPI values. Gamma function is recalculated all the time when the data of next months are added and the values of the previous months are changed. This is possible to change by setting the reference period. The reference period of 1961-2010 was chosen for the monitoring we apply. The indices represent the deficit towards the long term sums only for the chosen locality. SPI or SPEI values in Table 1 characterize the particular period:

Tab. 1 Drought categories according to SPI and SPEI

| SPI/SPEI | Characteristic |
|---|---|
| 2,0 and more | extremely wet |
| 1,5 to 1,99 | very wet |
| 1,0 to 1,49 | moderately wet |
| -0,99 to 0,99 | close to normal |
| -1,0 to -1,49 | moderately dry |
| -1,5 to -1,99 | very dry |
| -2,0 and less | extremely dry |

## Palmer Z-index and CMI

The calculation of these indices represents a complex attitude and involves the calculation of run-off, inflow, potential evapotranspiration and percolation. Thornthwait method is used to calculate the potential evaporation.

Input data used to calculate Palmer indices are mean air temperature, precipitation sum, latitude and efficient water capacity which is defined for the soil profile of 1m upper layer and is specific for each locality. Z-index can be calculated for one month or one week period; CMI is calculated for one week only.

Z-index represents relative difference from long time series. Each station has its own long time series calculated for each week of the year which is calculated out of the precipitation and evapotranspiration calculated for the respective station. The value of Z-index determines the rate of drought intensity according to the long time series. Both precipitation sums and evapotranspiration of the last week and the soil water content in the end of the last but one week are considered when calculating Z-index of the recent week.

Palmer CMI index uses, similarly like SPEI, soil water balance being based on the difference between the precipitation and evapotranspiration while run-off and water inflow calculated for the recent week as well as the soil water content in the end of the last but one week enter also the calculation. Final deficit or surplus of the soil water is transformed to a simple non-dimensional number which represents the intensity of the drought in a particular locality. CMI values are comparable among the stations because the calculation of CMI is not based and has no relation to the long term time series related to the particular station. Table 2 and Table 3 show the drought categories according to the Z-index and CMI.

Tab. 2 Drought categories according to Z-index

| Z-index (interval) | Characteristic |
|---|---|
| 4,00 and more | extremely wet |
| 3,00 to 3,99 | very wet |
| 2,00 to 2,99 | moderately wet |
| 1,00 to 1,99 | slightly wet |
| 0,50 to 0,99 | incipient wet spell |
| -0,49 to 0,49 | near normal |
| -0,50 to -0,99 | incipient dry spell |
| -1,00 to -1,99 | mild drought |
| -2,00 to -2,99 | moderate drought |
| -3,00 to -3,99 | severe drought |
| -4,00 and less | extreme drought |

Tab. 3 Drought categories according to CMI

| CMI | characteristic |
|---|---|
| 3,0 and more | excessively wet |
| 2,0 to 2,9 | wet |
| 1,0 to 1,9 | moderately wet |
| 0,1 to 0,9 | wet beginning |
| -0,9 to -0,1 | drought beginning |
| -1,9 to -1,0 | moderate drought |
| -2,9 to -2,0 | drought |
| -3,0 and less | excessive drought |

## Drought monitoring - description

Above mentioned four indices are calculated each Monday before the noon for eight localities with meteorological stations positioned in Podunajska nizina and Vychodoslovenska nizina. The list of stations can be found in Tables 4a and 4b.

Tab. 4a List of meteorological stations in Podunajska nizina

| Indic. | Station | latitude | longitude | altitude (m) |
|---|---|---|---|---|
| 11816 | Bratislava - Ivanka | 48°10´13´´ | 17°12´27´´ | 128 |
| 11819 | Jaslovské Bohunice | 48°29´09´´ | 17°39´52´´ | 176 |
| 11826 | Piešťany | 48°36´47´´ | 17°49´54´´ | 163 |
| 11855 | Nitra – V. Janíkovce | 48°16´50´´ | 18°08´08´´ | 132 |
| 11820 | Žihárec | 48°04´13´´ | 17°52´55´´ | 111 |
| 11858 | Hurbanovo | 47°52´21´´ | 18°11´35´´ | 115 |

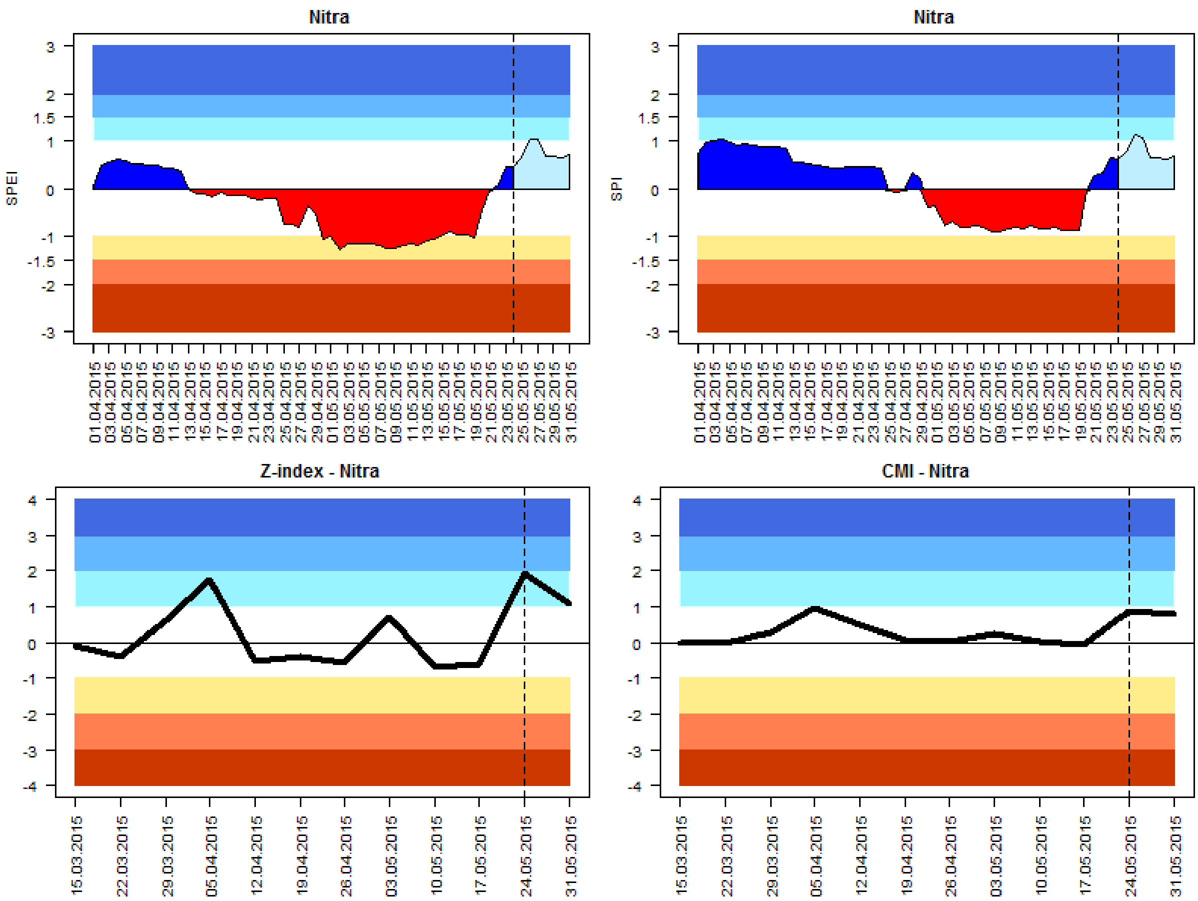
Tab. 4b List of meteorological stations in Vychodoslovenska nizina

| Indic. | Station | latitude | longitude | altitude (m) |
|---|---|---|---|---|
| 11978 | Milhostov | 48°39´47´´ | 21°43´19´´ | 102 |
| 11979 | Somotor | 48°25´17´´ | 21°49´06´´ | 97 |

Daily available operative data as well as uninterrupted long time series of needed parameters made the criteria for station selection. The course of calculated indices is presented in graphs independently for each station. Further to the activities monitoring the recent situation there is an effort put to forecast the course of respective indices for the next seven days. The outputs of numerical weather prediction model (NWP) of ECMWF is used for this purpose. The inputs for the calculation of the drought indices are represented by the averages of all ensembles taken from the last run of NWP model which happens on Monday 00 UTC. Following outputs of the NWP model are taken as the input parameters to calculate drought indices: maximal temperature, minimal temperature, daily mean temperature, daily precipitation, and daily mean of wind speed, relative humidity and cloudiness. The forecast is compared with the monitoring results in the beginning of the next week. Spot monitoring of drought is accurate for the particular locality only. Rising distance lowers the representativeness of the calculated indices. This fact becomes more visible during the summer time. Local heavy rains, usually connected with thunderstorms, bring big differences in precipitation even within a small region. This problem is further stressed in the drought forecast as the thunderstorm forecast is rather done in general statements than in concrete parameters. That is why the drought forecast brings rather the estimation of drought development in the coming week and not the exact forecast for the concrete locality.

## PRELIMINARY RESULTS

Figure 1 brings an example of graphic course of the drought indices at selected locality during a concrete weeks and this type of presentation is updated for each eight stations each week. The course of four indices are displayed independently for the last 60 days together with seven days forecast separated by the dashed line. Drought intensity, wetness intensity, resp., are characterized by the intensity categories distinguished by colors. The graphs visibly show the similar trend in their course during the start of vegetation cycle of 2015. Nevertheless, the influence of evaporative component at SPEI makes this index more dynamic in its ability to detect the starting drought as well as in its deepening. On the other hand the surplus of water shown by SPI is attenuated at SPEI. The third category of drought represents a serious threat to agricultural production. That is why we started to cooperate with the farmers and agricultural experts in order to verify the monitoring results and further to test the indices towards the drought impacts.




## CONCLUSION

There is a plan to increase rapidly the number of stations to further areas with agricultural production as well as to the forest areas in order to cover the major part of Slovakia by presented drought monitoring. 2015 is the first year of systematic drought monitoring in Slovakia. The system will be subjected to the analysis after finishing the vegetation season in autumn in order to evaluate the feasibility of selected drought indices as well as the possibility of spatial coverage of the area instead of spot calculation only.