State of bare soil surface as a spring drought indicator

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Abstract: To evaluate soil moisture conditions in spring crops sowing term, data of bare soil surface state were used. Analysis included 32 stations throughout the Czech Republic. Number of days with dry soil surface in each year was compared with the average number of those days in the period 1961–2010 for a given station. The limits of the individual categories were then determined for the period 1961–2010. The individual values of the number of days with dry condition of soil in the early spring period were compared with acquired 10th, 25th, 75th and 90th percentile average (1961–2010). More days with dry soil are usually observed in April than in March. In both months there are 11 days with this condition of soil altogether on average. Dry early spring occurred mainly in 1961, 1968, 1974, 1981, 1990, 2002, 2003, 2007 and 2009. Wet spring occurred in years 1965, 1970, 1980, 2001 and 2006 at almost all stations. There is a significant correlation ($p < 0.01$) between number of days with dry condition of soil and elevation ($r = -0.51$, $n = 32$). Average number of days with dry condition of soil surface in March and April in the period 1961–2010 ranges from 5 to 21 days, which is similar to the median values. Trend analysis did not produce conclusive results, but linear trend of smoothing April data was significantly increased in most localities. The number of days with dry condition of soil in the past decades has no significant upward or downward trend. However four years (2002, 2003, 2007 and 2009) have been evaluated as dry and two years (2001 and 2006) were evaluated as wet. An amount of extreme spring weather increases.

Key words: drought, condition of soil, soil moisture, extremity

1. Introduction

Crop growth is limited by sufficient amount of the water for evapotranspiration. The soil surface moisture is an important link between land surface

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and atmosphere, because the soil moisture is a source of water for the atmosphere through processes of evapotranspiration (*Zhao et al., 2012*). Surface soil moisture influences the partitioning of the incoming energy into latent and sensible heat components *(Owe, 2008).* Through this impact on the heat fluxes, soil moisture has several impacts on climate processes. That is why soil moisture–climate interactions have received increasing interest in recent years (*Seneviratne et al., 2010*). Therefore, identification of drought risk associated with the present as well as with expected climatic conditions remains an important issue (*Trnka et al., 2004*). Although an increased occurrence of extreme precipitation totals was observed, local or regional drought occurred more often in recent decades. Causality of this is in increased evapotranspiration demand due to rising air temperature (*Takáč, 2013*).

The impact of drought, which will depress crop yields, depends not only on actual length, but also on intensity of meteorological drought and period of occurrence (*Brázdil et al., 2007*). Agronomical drought is defined as soil water shortage in consequence of previous or prevailing meteorological drought. Drought during vegetative growth stages of cereals affects crop germination and subsequent reduction of tillers (*Haberle and Mikysková, 2006*). The study of *Hlavinka et al. (2009)* that compared the sensitivity of plants to water stress during the growing period (1961–2000) showed that drought significantly reduced the yield of spring barley compared to the yield of winter wheat. *Trnka et al. (2007)* determined that the seasonal water balance (April–June) significantly influenced the spring barley production.

According to *Blinka (2005)* dry periods occured in the Czech Republic in the years 1953–1954, 1973–1974, 1982–1984 and extremely dry years were 1943, 1976. In 1947 and 1974 the drought affected the whole area. Droughts and dry periods predominate in the colder half of the year. In drought studies done in the Czech Republic, the Standardised Precipitation Index (SPI) and the Standardised Precipitation Evapotranspiration Index (SPEI) were usually analysed (*Potop et al., 2013*). The Palmer drought severity index (PDSI) was also used (*Trnka et al., 2004*). Their comparison and possibilities of their use for assessment of climate change potential impacts on future drought occurrence was presented by *Dubrovský et al. (2009).*

Outside the interest often remains easily accessible characteristic recorded at climatological stations. It is a condition of soil, thus consistency properties of the surface soil layer (*Slabá et al., 1972*).

2. Material and methods

To evaluate moisture conditions in early spring and at the beginning of the growing season, data on the condition of soil in March and April recorded at the stations of CHMI (Czech Hydrometeorological Institute) network to altitude of 500 m from period 1961–2010 were used. Observation of the soil is done on the station plots and its vicinity at all observation times (at 7 AM, at 2 PM, at 9 PM). Condition of the soil is registered using the defined code numbers (*Žídek and Lipina, 2003*). Dry soil surface code is number 0; wet surface is number 1; wet (soaked) surface is number 2 up to the soil surface covered with loose snow with number 9. Interest was then focused on the number of days when soil conditions "0", i.e. the dry soil surface was recorded at least in one observation term. Given that this characteristic is affected to a certain degree of subjectivity, the correlation between the number of days with the "0" state of soil in March and April each year for the selected stations has been tested. For most stations statistically significant ($p < 0.05$) or statistically highly significant ($p < 0.01$) relationships were found, only 3 stations showed inconclusive addiction and were excluded from other reviews. More detailed analysis included 32 stations throughout the country (Fig. 1).

Notes to figures and tables: HOLE – Holešov, TUR – Tuřany, KUCH – Kuchařovice, VMEZ – Velké Meziříčí, STRA – Strakonice, VRAZ – Vráž, CBUD – České Budějovice, TAB – Tábor, TREB – Třeboň, DOMA – Domažlice, NEPO – Nepomuk, KRAL – Kralovice, CHEB – Cheb, FREN – Frenštát pod Radhoštěm, LUC – Lučina, MOSN – Mošnov, OPAV – Opava, VITK – Vítkov, OLOM – Olomouc, PRER – Přerov, VALM – Valašské Meziříčí, VSET – Vsetín, PKAR – Praha-Karlov, PKBE – Praha-Kbely, PRUZ – Praha-Ruzyně, BRAN – Brandýs nad Labem, SEMC – Semčice, HAVL – Havlíčkův Brod, ONDR – Ondřejov, DOKS – Doksany, JAPO – Jablonné v Podještědí, LIBC – Liberec.

An average number of days with dry soil surface (the condition "0") in March–April 1961–2010 was determined. That forms the basis of evaluation. Number of days with dry soil surface in each year was compared with

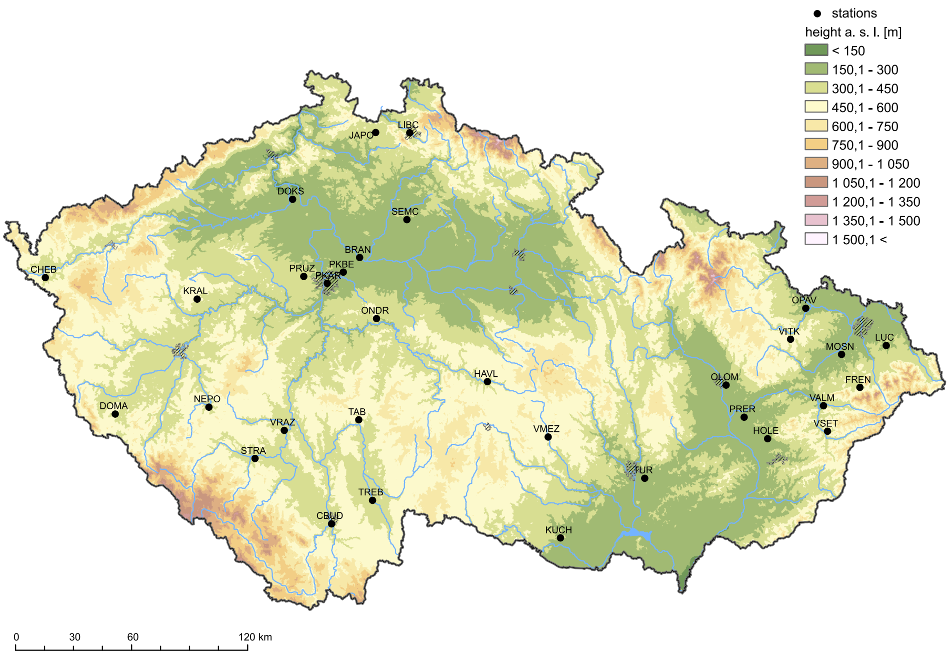


Fig. 1. Location of the climatological stations used in the evaluation.

the average number of those days in the period 1961–2010 for a given station. The limits of the individual categories were then determined for the period 1961–2010. Qualitative assessment was chosen, meaning that categories were created into which the values were assigned. As the numbers of days take only non-negative values the percentile values seemed to be the best way to establish the different categories of the theoretical distribution of climatological characteristics.

The individual values of the number of days with dry condition of soil in the early spring period were compared with acquired 10th, 25th, 75th, and 90th percentile average (1961–2010). Evaluation method assumes that the data have a gamma distribution.

The following categories were established:

The percentile value	**Category**
< 10	Strongly subnormal number of days
> 25	Subnormal number of days
$\leq 25;\ 75 \geq$	Average number of days
> 75	Above average number of days
> 90	Strongly above normal number of days

To find a trend, the data series were smoothed by a 4253H filter (*Velleman, 1980*) in STATISTICA 7.0 software. The trend was evaluated in case of two lowest stations (Doksany 158 m a.s.l. and Brandýs 179 m a.s.l.) and two highest (Vítkov 497 m a.s.l. and Ondřejov 485 m a.s.l.). March and April data from 1961 to 2010 were evaluated separately.

3. Results and discussion

In March fewer days with dry soil are usually observed than in April. Number of such days in March is on average 4-fold lower than in April. A similar difference was determined by *Tekušová et al. (2011)* at the station Hurbanovo in Slovakia.

On average, in March two days with the condition of soil 0 occurred; in April 9 days occurred. During the period almost at all stations there were years when dry condition of soil was not observed even in March or in April. This was particularly in years 1970 (13 stations) and 2006 (12 stations). Station with the highest number of years without the condition "0" in March and April was Velké Meziříčí (13 years) and Jablonné v Podještědí (12 years). There is a highly significant correlation ($p < 0.01$) between number of days with dry condition of soil and elevation ($r = -0.51$, $n = 32$).

Trend analysis of number of days with dry soil surface in March did not show clear progress. Linear trend of April data was significantly increased ($p < 0.01$) at Vítkov station ($r^2 = 0.648$), Brandýs ($r^2 = 0.751$) and Ondřejov ($r^2 = 0.211$). Linear trend in Doksany station was significantly ($p < 0.05$) decreasing ($r^2 = 0.104$).

Average number of days with dry condition of soil surface in March and April in the period 1961–2010 ranges from 5 to 21 days (Table 1), which is similar to the median values. The highest median of such days was determined in Doksany (21 days), Olomouc and Kuchařovice (20 days).

Table 1. Average number of days with dry condition of soil in March and April (1961–2010)

Station	HOLE	TUR	KUCH	VMEZ	STRA	VRAZ	CBUD	TAB
Average	8.3	12.2	20.4	6.9	8.1	8.2	11.6	9.7
Station	TREB	DOMA	NEPO	KRAL	CHEB	FREN	LUC	MOSN
Average	7.1	14.6	5.6	12.3	7.3	17.1	6.3	7.8
Station	OPAV	VITK	OLOM	PRER	VALM	VSET	PKAR	PKBE
Average	10.7	7.9	20.5	15.5	9.4	4.7	15.8	13.9
Station	PRUZ	BRAN	SEMC	HAVL	ONDR	DOKS	JAPO	LIBC
Average	14.7	18.1	17.6	8.0	12.9	21.1	7.1	4.7

Figures 2 and 3 present the range of values of number of days with dry condition of soil in early spring for the period 1961–2010. Highest value of median was determined at station Doksany (21 days) and the lowest at stations Liberec, Vsetín and Nepomuk (3 days).

The maximum number of days with dry condition of the soil was found

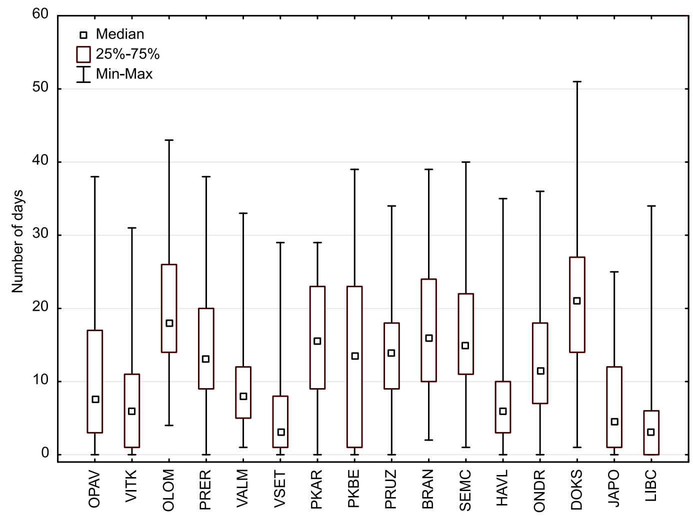


Fig. 2. Number of days with dry condition of soil surface in March and April 1961–2010.

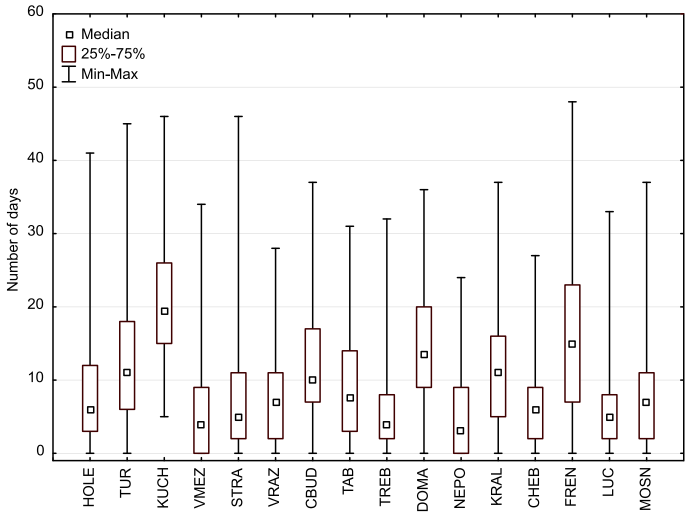
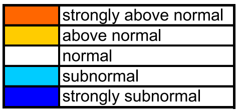


Fig. 3. Number of days with dry condition of soil in March and April 1961–2010.

at the station Doksany – 51 days in 1974 and in Frenštát p. Radhoštěm – 48 days in 1974. The year 1974 was very dry also at other stations as can be seen in Fig. 4, evaluating the conditions of soil in detailed for each station (it shows results of comparison of average number of days with dry soil surface for a given month in period 1961–2010 and number of such days in a single year of the period). At most stations (19 in total) in that year the condition of soil "0" was observed more than 31 days, i.e. more than half of the days in that period.

Dry early spring occurred in 1961, 1968, 1974, 1981, 1990, 2002, 2003, 2007 and 2009. Wet periods occurred in years 1965, 1970, 1980, 2001 and 2006 at almost all stations.

There are similarities with the study of *Takáč (2013)* where the highest average annual soil water content was calculated throughout Slovakia in period 1965–2010 and the lowest annual average was determined on the majority of localities in the year 1990. According to the SPEI values (*Potop et al., 2013*) the driest growing seasons years were (from most dry to least dry) 2003, 1992, 2000, 1983, 1982, 1976, 2009 and 1999. The wettest years during the growing season were 1965, 2010, 1977, 1996, 1966, 2001, 1972, Legend to the Figure 4:



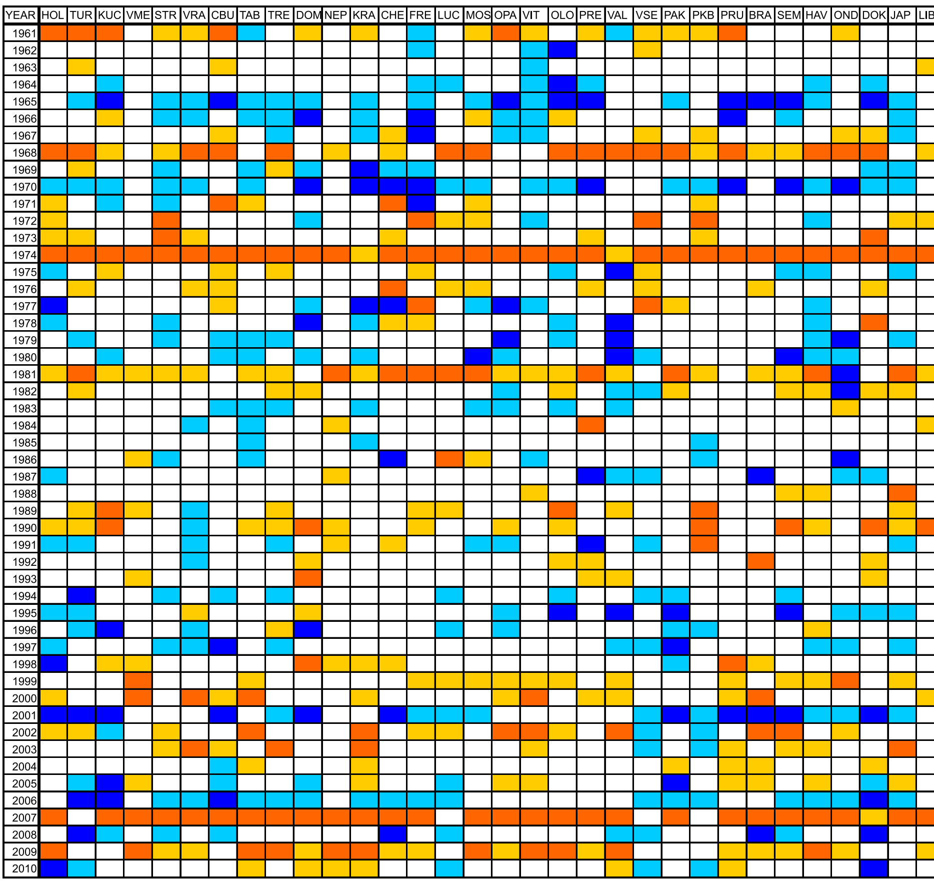


Fig. 4. Number of days with dry condition of soil compared with average (1961–2010).

1980 and 1995. The largest meteorological and agricultural drought during growing season was observed, chronologically, in: 1964, 1976, 1983, 1990, 1992, 1994, 1998, 2000, 2003 and 2007.

Blinka (2005) confirmed drought across the country in 1974. *Brázdil et* *al. (2009)* found that the wettest vegetation season in the Czech Republic in the second half of the 20th century in 1965 was associated with significant yield decrease for cereals and yield stagnation for forage crops and hay production.

According to most climate change scenarios, it is very likely that the frequency of drought spells and their severity will increase, at least during some years (*Trnka et al., 2007*). Even if greenhouse gases emissions are kept low and subsequent climatic changes are relatively minor a significant increase of areas experiencing high probability (more than 45 %) of aridic or xeric events is to be expected (*Trnka et al., 2004*). Up to 8% of the country area will face aridic or xeric events in at least six out of ten years by 2050 with a high probability of weak aridic and even typical aridic events. It should also be stressed that these areas belong to the prime agricultural regions of the country.

4. Conclusion

More days with dry soil are usually observed in April than in March. In both months there are 11 days with this condition of soil, on average. Dry early spring occurred mainly in 1961, 1968, 1974, 1981, 1990, 2002, 2003, 2007 and 2009. Wet spring occurred in years 1965, 1970, 1980, 2001 and 2006 at almost all stations. The occurrence of dry or wet early summer according to conditions of soil surface mostly corresponds with results of studies done on the basis of drought indices computation, remote sensing or *in situ* measurement methods. Despite this characteristic is influenced by a certain degree of subjectivity, it is a very useful tool when evaluation drought in the country and spring crop yield. Linear trend of smoothing April data was significantly increased in most localities. The number of days with dry condition of soil in the past decades has no significant upward or downward trend. However four years (2002, 2003, 2007 and 2009) have been evaluated as dry and two (2001 and 2006) as wet.

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