

## REPOSITORY OF DROUGHT EVENT IMPACTS ACROSS THE DANUBE CATCHMENT COUNTRIES BETWEEN 1981 AND 2016 USING PUBLICLY AVAILABLE SOURCES

Jiří Jakubínský<sup>1</sup>, Monika Bláhová<sup>1</sup>, Lenka Bartošová<sup>1</sup>, Klára Steinerová<sup>1</sup>,  
Jan Balek<sup>1</sup>, Petra Dížková<sup>1</sup>, Daniela Semerádová<sup>1</sup>, Daniel Alexandru<sup>2</sup>,  
Galia Bardarska<sup>3</sup>, Sabina Bokal<sup>4</sup>, Goran Borojević<sup>5</sup>, Andreea Bucur<sup>6</sup>, Ksenija  
Cindrić Kalin<sup>7</sup>, Anda Claudia Barbu<sup>2</sup>, Barbara Debre<sup>8</sup>, Milica Đorđević<sup>5</sup>,  
Ines Đurić<sup>5</sup>, Bianca Florina Mircea<sup>2</sup>, Sandra Gatarić<sup>5</sup>, Gregor Gregorič<sup>9</sup>, Stefan  
Hasenauer<sup>8</sup>, Mirjana Ivanov<sup>10</sup>, Andrea Kircsi<sup>11</sup>, Livia Labudová<sup>12</sup>, Maroš  
Turňa<sup>12</sup>, Ivana Marinović<sup>7</sup>, Mihajlo Marković<sup>5</sup>, Elena Mateescu<sup>2</sup>, Gal Oblišar<sup>9</sup>,  
Andreea Popescu<sup>2</sup>, Zorica Srđević<sup>13</sup>, Tatjana Savić-Šljivić<sup>14</sup>, Dejan Supić<sup>5</sup>,  
Andreja Sušnik<sup>9</sup>, Natasa Pazin<sup>10</sup>, Miras Drljević<sup>10</sup>, Tonka Kuc<sup>10</sup>, Luka Mitrović<sup>10</sup>,  
Slavica Micev<sup>10</sup>, Wolfgang Wagner<sup>1,6</sup>, Josef Eitzinger<sup>15</sup>, Vojko Daneu<sup>1,15</sup>,  
Veit Blauhut<sup>16</sup>, Kerstin Stahl<sup>16</sup>, Miroslav Trnka<sup>1</sup>

<sup>1</sup>Global Change Research Institute CAS, Bělidla 986/4a, 602 00 Brno, Czech Republic

<sup>2</sup>National Meteorological Administration of Romania, Sos. București-Ploiești nr.97, Sector 1, 013686 Bucharest, Romania

<sup>3</sup>Association „Global Water Partnership-Bulgaria“, 14 Hristo Belchev Str., Sofia 1000, Bulgaria

<sup>4</sup>GWP CEE Regional Secretariat, Slovak Hydrometeorological Institute, Jeseniova 17, 833 15 Bratislava, Slovakia

<sup>5</sup>University of Banja Luka, Faculty of Agriculture, Institute for the Agroecology and Soil Sciences, Bulevar Vojvode Petra Bojovica 1A, Banja Luka, 78000, Bosnia and Herzegovina

<sup>6</sup>Department of Geodesy and Geoinformation, Technische Universität Wien, Gußhausstrasse 27-29 /E120-01-1 (CB0322), 1040 Vienna, Austria

<sup>7</sup>Croatian Meteorological and Hydrological Service, Grič 3, 10000 Zagreb, Croatia

<sup>8</sup>EODC Earth Observation Data Centre for Water Resources Monitoring GmbH, Franz-Grill-Strasse 9, 1030 Vienna, Austria

<sup>9</sup>Slovenian Environment Agency, Vojkova 1b, SI-1000 Ljubljana, Slovenia

<sup>10</sup>Institute of Hydrometeorology and Seismology of Montenegro, IV proleterske 19. 81000 Podgorica, Montenegro

<sup>11</sup>Hungarian Meteorological Service, H-1024 Budapest, Kitaibel Pál u. 1., Budapest, Hungary

<sup>12</sup>Slovak Hydrometeorological Institute, Jeseniova 17, 833 15 Bratislava, Slovakia

<sup>13</sup>University of Novi Sad, Faculty of Agriculture, Trg D. Obradovica 8, 21000 Novi Sad, Republic of Serbia

<sup>14</sup>Republic Hydrometeorological Service of Serbia, Kneza Višeslava 66, 110 00 Belgrade, Republic of Serbia

<sup>15</sup>Institute of Meteorology, University of Natural Resources and Life Sciences BOKU, Gregor Mendel Strasse 33, 1180 Wien, Austria

<sup>16</sup>Faculty of Environment and Natural Resources, University of Freiburg, Fahrenbergplatz, D-79098 Freiburg, Germany

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### Abstract

Drought directly and indirectly affects human society in a number of ways. In many regions of the world climate change will exasperate the effects of droughts, affect national economies more intensely. The main aim of this article was to catalogue and analyze the drought impacts in the 11 Central and South Eastern European states located in the Danube river basin. The identification of dry episodes was based on information from publicly available sources, namely, newspaper and journal articles that reported drought impacts. Information on drought impact occurrences was classified into one of five defined categories in which the drought impact report was most clearly manifested (i.e., agriculture, forestry, soil systems, wildfires and hydrology). In terms of the spatial distribution of drought impacts, individual recorded events were analyzed at the level of EU NUTS regions (or their equivalent in non-EU countries). The analysis highlights country-specific vulnerability to drought. Furthermore, gradual increases in drought events and the number of reported impacts were identified, which was particularly evident in the agricultural sector.

Keywords: drought impact, Danube basin, agriculture, climate change, water stress

### INTRODUCTION

Drought has been described as a natural phenomenon resulting mainly from deficiencies in precipitation compared to the expected or normal amount (Wilhite *et al.*, 2007). Compared to other natural disasters, droughts have the largest spatial extent and longest duration (Sheffield *et al.*, 2012). Drought tends to develop slowly and has the potential to persist over several years, reaching from regional (e.g., Zink *et al.*, 2016) to continental coverage (Svoboda *et al.*, 2002; Samaniego *et al.*, 2013). Recent drought episodes in Russia in 2010 (Trenberth and Fasullo, 2012), the USA in 2011–2012 (Hoerling *et al.*, 2014), China in 2013 and Brazil in 2014 were, for each particular year, among the 10 natural disasters with the highest recorded damage worldwide (Munich Re, 2015). A series of recent droughts sparked widespread research activity, leading to the deployment of high-resolution drought monitoring schemes in the Czech Republic (post-2012 drought), Germany, Austria and Slovakia (post-2015 drought). This is

understandable as the economic damage caused by droughts is comparable to that of floods. Yet, in some countries (e.g. Croatia) drought causes the highest economic losses among all natural hazards (Cindrić *et al.*, 2015). Generally, floods and droughts are the two most disastrous natural events that affect the Danube region.

Drought affects all socioeconomic and ecological systems (Stahl *et al.*, 2016), with particular impacts on anthropogenic sectors, such as agriculture, forestry, water resource management, energy generation, and health. More detailed information on the categorization of drought effects is provided by Tallaksen and Lanen (2004). In general, drought impacts can be separated into direct and indirect impacts (Wilhite *et al.*, 2007). Direct impacts include reduced crop yield and forest productivity, increased forest fires, reduced water levels, and increased mortality rates for livestock. The direct and indirect effects of drought may force a societal response (e.g., Brázdil *et al.*, 2016) aimed to foster resilience to the hazard. Indirect drought impacts are volatile food prices, which are potentially

exacerbated by market effects in the agricultural sector. As a result, it is difficult to estimate the total costs and losses at the regional and national levels. Indirect losses of droughts often exceed those of direct ones (Wilhite *et al.*, 2007) but are more difficult to link to a particular event. Such events lead to responses in terms of legislative changes (e.g., after the 1947 drought in Central Europe, according to Brázdil *et al.*, 2016) or to development of drought monitoring systems, such as the establishment of the U.S. Drought Monitor after major drought events in the late 1990s (Svoboda *et al.*, 2002). The link between drought intensity and legislative measures was also discussed by Blauhut *et al.* (2015a).

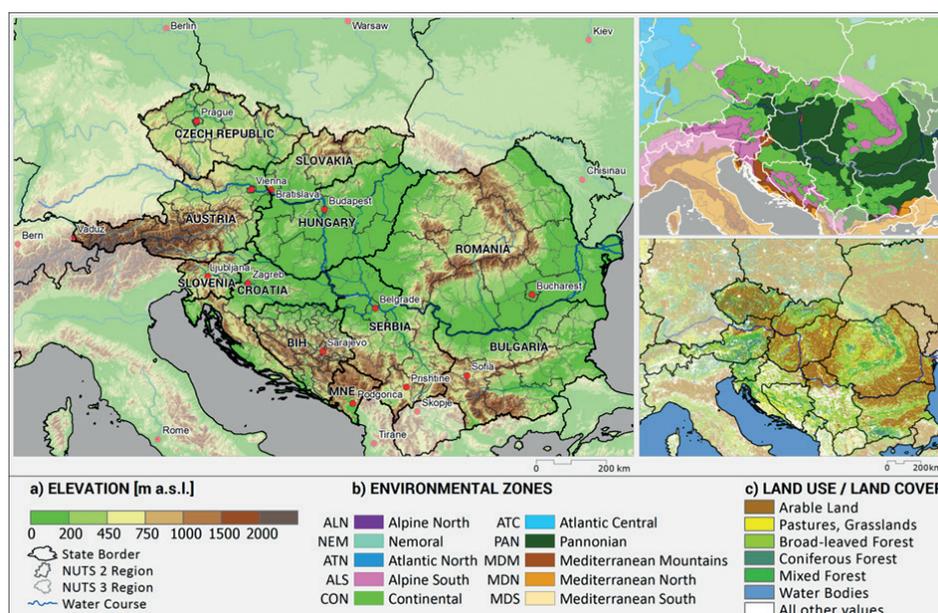
The main objective of the article is to identify areas within the Danube basin that were most affected by drought between 1981 and 2016 according to information obtained from the selected national periodicals in each country. In order to develop a detailed database of drought effects, the national newspapers in each country were screened for drought impact information. Accordingly, the identified drought impacts were classified into a particular category as stated above – i.e., agriculture, forestry, soil system, wildfires and hydrology. The importance of the article can also be seen as a means of informing the professional public about the existing database of drought impacts in the Danube region, which did not previously exist and is one of the main reasons why the risk of drought has not yet been fully assessed at the pan-European level. Data on the drought impacts in this region are to some extent also provided by the European Drought Centre within the European Drought Impact Report Inventory – EDII (EDC 2018), but the data analyzed in this article are more detailed as they were obtained from national newspapers, written in the respective language of each state.

The article is based on data obtained from available, pre-selected, national periodicals, and although the numbers of articles referring to the effects of drought certainly correspond to the magnitude of the actually observed drought impacts and their intensity, it should be emphasized there are also other factors that can make mutual comparisons difficult. In particular it is a different human perception of the significance of identical problems in different countries, which is directly reflected in the number of published articles on the matter. However, given the extent of the territory studied and the length of the analyzed period, it can be stated that there is probably no more detailed and accurate data source that would be available at the same quality in all selected countries.

## MATERIALS AND METHODS

### Area of interest

The analysis focuses on eleven neighboring countries in Central and Southeast Europe, which cover the majority of the Danube River basin (Fig. 1). Most of the studied area is located in the Continental and Pannonian environmental zone in Central and Southeast Europe, while the higher mountain areas are part of the Alpine southern zone; in the Dalmatian area, the Mediterranean mountains zone is located according to the classification of environmental zones (see the additional map in Fig. 1). The area of interest is characterized by a large variety of natural conditions and anthropogenic usage. According to the Köppen climate classification, the majority of the area of interest is under a wet continental climate (the cooler subtype Dfb), which passes into the warmer Dfa variant (with summer temperatures above 30 °C) in the Pannonian lowlands and subpolar climate (Dfc) in the mountainous areas (especially the Alps and the Carpathians). According to the European Environmental Agency (EEA, 2019), an average annual air temperature increase of approximately 0.10–0.35 °C per decade was observed within the analyzed area based on measurements between 1960 and 2017 (European Climate Assessment and Dataset). The most significant change was recorded in the northwest part of the study area. In terms of the number of warm days (defined as being above the 90th percentile of the daily maximum temperature across Europe between 1960 and 2017), the most significant increase was observed in the southern part of the territory, in Croatia and Bosnia and Herzegovina, where the increase was up to 8–9 warm days per decade. For most of the study area, the typical annual rainfall sums were approximately 600–700 mm, and higher values could only be observed in mountainous areas. In terms of changes in precipitation sums (1960–2015 according to the Royal Netherlands Meteorological Institute), the area of interest is divided into two parts: Romania and Bulgaria had a slight increase in annual precipitation of an average of 10 mm per decade, while the other countries showed a decreasing trend of approximately 10 mm per decade. A significant decrease was recorded in cases of summer precipitations, where the decline was up to 20 mm per decade in some areas (EEA, 2019). Further selected characteristics that directly and indirectly affect climatic conditions or describe the given countries are shown in Tab. I.



1: Area of interest – its environmental zones and land-use/land cover categories

I: Selected characteristics influencing climate conditions in the countries of interest (data source: EEA 2019, World Bank Group 2019, CLIDATA database [IHMS, Montenegro])

Country	Average altitude [m a.s.l.]	Forest cover [%]	Average annual temperature* [°C]	Average annual precipitation* [mm]	Population density [inhab./km <sup>2</sup> ]
Austria	910	47.2	6.35	1111	106
Bosnia and Herz.	500	53.0	9.85	1030	69
Bulgaria	472	32.7	10.55	608	64
Croatia	331	44.3	10.90	1098	73
Czech Republic	433	34.2	7.55	677	135
Hungary	143	23.6	9.75	589	105
Montenegro	1086	60.0	10.55	1736	45
Romania	414	29.1	8.85	637	82
Serbia	473	31.1	10.55	686	90
Slovakia	458	40.8	6.80	824	111
Slovenia	492	60.2	8.95	1160	102

\* Based on measurements realized between 1960 and 2017.

### Drought impact information – temporal and spatial resolution

Drought impact information was obtained through the extensive review of articles published in selected national periodicals (in printed and, more recently, electronic versions) for the period 1981 to 2016. Where available, this qualitative information was supplemented by data provided by national statistical offices of each country. The data source specifications for all countries involved in this study are listed below.

Most of the data in Slovenia were obtained from archive issues of an agricultural newspaper “Kmečki glas” and national newspaper “Slovenske novice” from the library of Agricultural Institute of Slovenia. Information was also obtained from the digital archive of the journal “Ujma,” decadal agricultural bulletins prepared by the Slovenian Environment Agency (ARSO) and internal report of the DMCSEE Project – Historical overview of drought impact records in Slovenia.

The Hungarian historical data collection of drought impacts is based on the Archive of the Hungarian News Agency (MTI), the largest

online news repository of Hungary, from January 1, 1988, until present (<http://www.mti.hu>). The archive provides news from a wide range of sources (from national to world news and from official press release to original text service) and gives an important base to daily works of Hungarian media companies (newspapers, magazines, special thematic journals, radio and TV broadcast). We used “drought, water scarcity, low water level, fire, yield losses” keywords to prepare a short-list from 3,173,715 news items between 1988 and 2016. Geographical (Europe, Central Europe, Hungary) and thematic constrict (natural disasters, weather event) were applied to find the most relevant news.

Data about drought impacts in Slovakia were extracted from three main sources – a national newspaper (“Pravda”) and two thematic journals (“Roľnícke noviny” and “Vodohospodársky spravodajca”). The “Roľnícke noviny” focuses on agriculture and agricultural techniques. In the past, the journal was issued on a daily basis, but it has been published weekly since 1994. The journal “Vodohospodársky spravodajca” is published bimonthly and is focused on information in the field of water management.

In Croatia, drought impact data for the period 2000–2016 were extracted mainly from DHMZ Meteorological and Hydrological Bulletin in which daily online newspaper articles related to extreme weather impacts in Croatia are collected; and also from two thematic journals “Hrvatska vodoprivreda” and “Vatrogasni vjesnik” that are concerned with hydrological events and forest fires, respectively. However, drought impact data for an earlier period, 1981–1999, were collected from the national daily newspaper (“Večernji list”) that regularly published 2 or 3 issues per day; those data are manually searched in the National and University Library. Mainly the summer months, when drought impacts are most evident, were considered.

The historical data collection regarding the drought impact in Romania from 2000–2016 period was elaborated using references from scientific journals (e.g., International Journal of Biometeorology), Romanian national newspapers ([adevarul.ro](http://adevarul.ro), [zf.ro](http://zf.ro), [financiarul.ro](http://financiarul.ro), [realitatea.net](http://realitatea.net), [digi24.ro](http://digi24.ro)), Romanian regional newspapers (e.g., [ziuadevest.ro](http://ziuadevest.ro), [ziarulceahlaul.ro](http://ziarulceahlaul.ro), [newsbv.ro](http://newsbv.ro), [aradon.ro](http://aradon.ro)) and Romanian agriculture specialized magazines (e.g., [agroinfo.ro](http://agroinfo.ro), [agointel.ro](http://agointel.ro), [agropress.ro](http://agropress.ro), [lumeasatului.ro](http://lumeasatului.ro), [revista-ferma.ro](http://revista-ferma.ro), [agromonitor.ro](http://agromonitor.ro), [agrimedia.ro](http://agrimedia.ro), [agroromania.manager.ro](http://agroromania.manager.ro)). The data were

validated and correlated with the soil moisture reserve available in the National Meteorological Administration Agrometeorological database, giving more detailed information of the drought phenomena, such as the beginning/ending date of the drought episode, region and detailed description.

The drought impacts over the 1981–2017 period in Austria were collected from two newspapers, “Der Standard” (2000–2017) and “Die Presse” (1981–1999). The archive of the newspaper Der Standard is available online, while the archive of the Die Presse newspaper is available only on microfilm and was consulted at the library. In order to identify reports of drought impacts, a few key words were used: “Dürre” (drought), “Trockenheit” (dryness), “Trocken” (dry, aridity), and “Dürreschäden” (drought damages). Most of the drought impacts found in these publications were reported over EU NUTS2 regions (a total of 9 regions in Austria).

Most of the drought impact data in Bosnia and Herzegovina were taken from daily newspapers (“Glas Srpske”), databases of the Statistical Office of the Republic of Serbia, and selected records of the Institute of Agroecology and Soil Science, Faculty of Agriculture, University of Banja Luka, Republic of Serbia (BIH).

In Montenegro, two different data sources were used: a) archives of the daily newspaper “Vijesti” (also online data available at the website for period 2000–2016) and b) data provided by the Statistical Office of Montenegro (MONSTAT).

In the Czech Republic, several newspaper sources were used for data processing on drought effects, especially the daily newspaper “Mladá fronta DNES,” where information was collected for the period 2000–2016. As another suitable data source, the thematic journal “Zemědělec” was chosen for necessary information, which was again used for data from the same period. Individual issues of newspapers and thematic journals were analyzed by manual, detailed browsing in the library or using a web database if their electronic versions were available. However, the disadvantage of the electronic database is the fact that the data are available only from the year 2000. All older volumes of newspapers and journals were therefore manually searched in the libraries or archives.

Due to the absence of a continuous time series of one journal or newspaper title, several different data sources were used in Bulgaria. These were mainly data from Knight *et al.* (2004), Koleva and Alexandrov (2006), Branzova (2015), Popova *et al.*

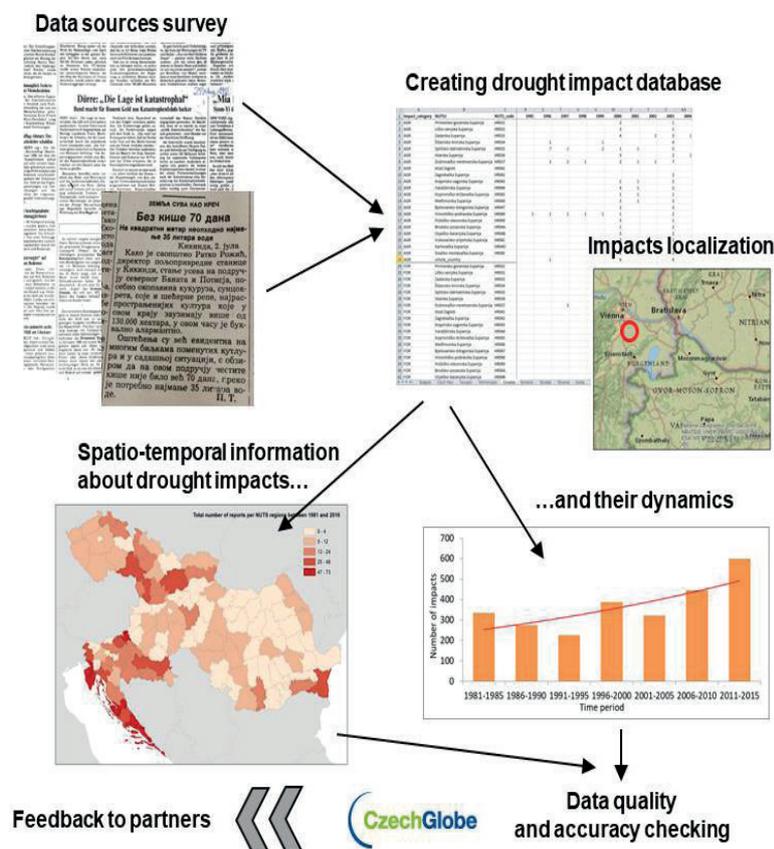
(2015), as well as information from the EC projects on climate and forests, National Statistical Institute of Bulgaria, and agricultural reports, published by Ministry of Agriculture and Food (MAFF 2017).

All the drought impacts that occurred in Serbia were analyzed on the basis of the data obtained from the national newspaper “Politika.”

### Drought impact database

Using the national data described above, a comprehensive drought impact database was created for the period 1981 and 2016. The individual drought impact reports were classified into one of five predefined categories, depending on the sector in which the impacts of the drought episode were the most apparent: agriculture, forestry, soil system, wildfires and hydrology. Very often, articles describing the drought episode that occurred in several sectors suddenly appeared (e.g., in agriculture and soil system or water resources management at the same time), in which case, the impact was classified on the basis of the most significant impact to likely result from the contexts mentioned in the article. It follows that every drought impact report found in the newspaper

was considered an indicator of the occurrence of one separate drought. If the terms of the impacts overlapped (and it was a drought in the identical region), this was considered as one drought event. From the point of view of the spatial distribution of the phenomena analyzed, the impacts were localized to the level of the EU NUTS 3 regions (Nomenclature of Units for Territorial Statistics) within the Member States of the European Union whenever possible. In other (non-EU member) countries, national division with the area of each region roughly equivalent to the size of NUTS regions at the third level was used. Even with regard to the geographical distribution of drought effects, information on impacts affecting more than one NUTS 3 region (often the entire country) was often found. In such cases, the impacts of drought were counted separately for each region that was demonstrably affected by the event – on the basis of information in analyzed newspapers and journals. However, for some countries, with regard to spatial resolution of the data, it was not possible to distinguish the effects of droughts on the NUTS 3 region level. For this reason, the information was processed only for the whole state territory. The procedure by which the drought impact data



2: Scheme of drought impact data processing

were processed and the database created is shown in the scheme in Fig. 2.

## RESULTS

With almost 800 references to drought impacts, the largest number of reported drought impacts stemmed from Croatia, where the majority of impacts occurred in the coastal regions of the Adriatic Sea. The second highest number of drought events (over 400 impacts) was recorded in Slovakia, especially in the lowland southern regions adjacent to Hungary. The drought-prone area extends from southern Slovakia to the neighboring

Czech Republic, where the effects of drought have been found, especially in southern Moravia. The third most affected region was Slovenia, where 260 impacts were recorded, concentrating mainly on the Pomurska region adjacent to Austria and Hungary. A further region with frequently reported drought impacts was the Dobrudja region around the Romanian city of Constanța at the Black Sea coast. The exact number of impacts in each country is given in Tab. II.

Since the comparison of resulting values is difficult due to the very different duration of periods in individual countries (from 17 to 36 years), relative values were assessed – i.e. The average number of

II: Summary of the period analyzed, number of impacts in selected sectors (AGR – agriculture, FOR – forestry, SOI – soil system, WFR – wildfires, HYD – hydrology) and three years with the highest number of drought impacts in all countries of interest

Country	Period analyzed	Number of impacts					Years with the highest number of impacts*
		AGR	FOR	SOI	WFR	HYD	
Austria	1981–2016	71	22	0	19	31	2003, 1992, 1983
Bosnia and Herz.	1983–2016	47	0	0	11	12	2000, 2003, 1988
Bulgaria	1981–2016	20	28	1	0	33	1992, 2001, 2010
Croatia	1981–2016	393	15	27	46	303	2007, 2012, 2003
Czech Republic	2000–2016	36	6	4	35	79	2015, 2007, 2013
Hungary	1988–2016	42	3	4	31	30	1993, 2003, 2012
Montenegro	1982–2016	160	1	1	117	89	2000, 1988, 1983
Romania	2000–2016	161	11	12	0	0	2015, 2016, 2012
Serbia	2000–2016	31	1	0	5	3	2000, 2007, 2012
Slovakia	1981–2016	401	2	12	6	14	1983, 1982, 2012
Slovenia	1981–2016	226	5	27	2	0	2003, 1993, 1988

\* Sort by number of drought impacts descending from the largest value (from left to right).

III: Average number of drought impacts per year in selected sectors (AGR – agriculture, FOR – forestry, SOI – soil system, WFR – wildfires, HYD – hydrology) in all countries of interest

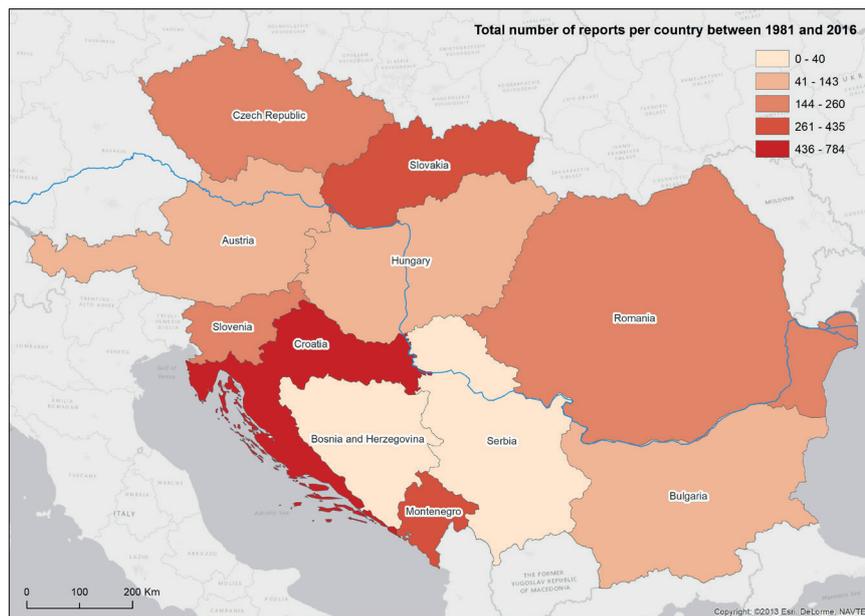
Country	Average number of impacts per year				
	AGR	FOR	SOI	WFR	HYD
Austria	1.97	0.61	0.00	0.53	0.86
Bosnia and Herz.	1.38	0.00	0.00	0.32	0.35
Bulgaria	0.56	0.78	0.03	0.00	0.92
Croatia	10.92	0.42	0.75	1.28	8.42
Czech Republic	2.12	0.35	0.24	2.06	4.65
Hungary	1.45	0.10	0.14	1.07	1.03
Montenegro	4.57	0.03	0.03	3.34	2.54
Romania	9.47	0.65	0.71	0.00	0.00
Serbia	1.82	0.06	0.00	0.29	0.18
Slovakia	11.14	0.06	0.33	0.17	0.39
Slovenia	6.28	0.14	0.75	0.06	0.00

drought impacts per year. This characteristic was also analyzed by country and within the five sectors most affected by drought (agriculture, forestry, soil system, wildfires and hydrology) – Tab. III shows the resulting values. Although the average number of articles about drought impacts has its peaks in individual countries in the same sectors as in the case of absolute values, in other cases the order of countries is already changing. More significant changes can be observed especially in sectors with higher numbers of individual drought cases, assuming that the country has only a shorter time

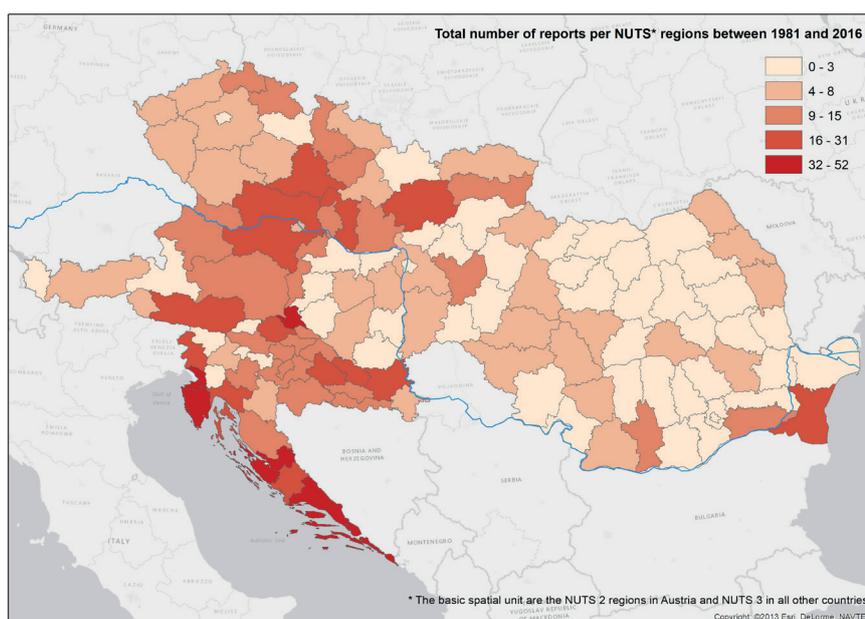
series of source data. This is evident, for example, in the case of the Czech Republic and data relating to articles mentioning wildfires or water resources issues.

In general, three most frequently impacted hot spots were identified for the Danube basin:

- 1) the Adriatic region along the Adriatic coast;
- 2) the Pannonian plain along the middle part of the Danube river and its tributaries (Morava and Váh river), passing north-eastern to the highlands of central Slovakia;



3: Total number of reports per country between 1981 and 2016

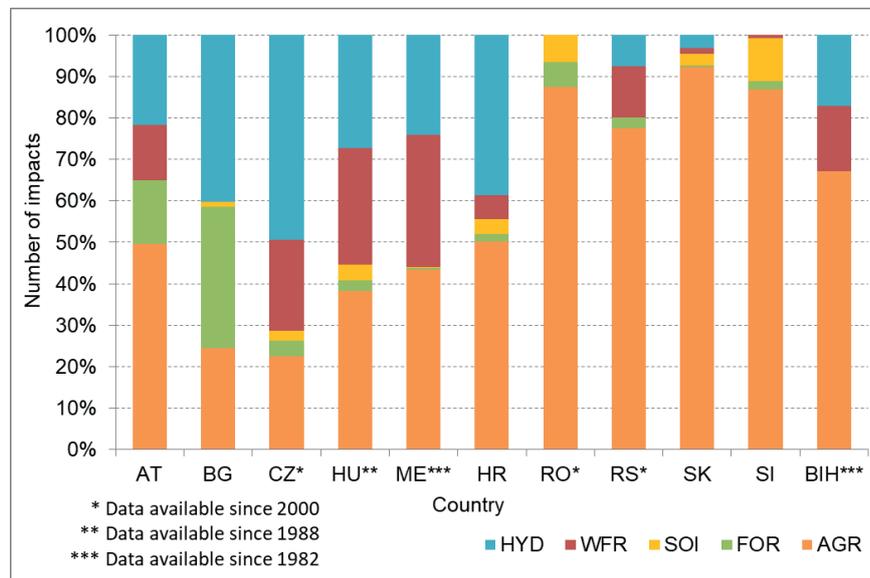


4: Total number of reports per NUTS 3 regions between 1981 and 2016

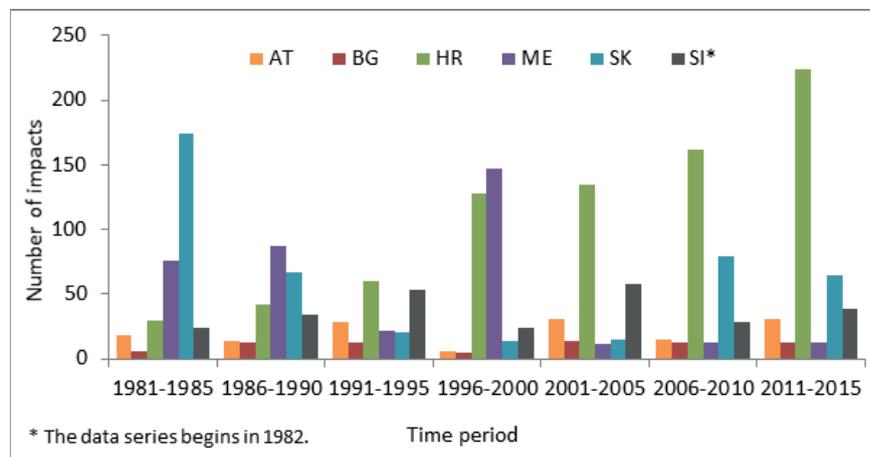
3) the coastal regions of Eastern Romania and Bulgaria.

As presented in Fig. 5, many countries were dominated by agricultural impacts and impacts affecting the water management sector according to the data sources used. In the Czech Republic, impacts on the water management sector are predominant, and the number of impacts on agriculture and wildfires is gradually increasing – both are related to the escalating effects of drought in the region after 2000. A different situation prevails in neighboring Slovakia, where the majority of impacts are reported for agriculture. The other sectors are only affected to a minimal extent. The main reason is that the impacts are concentrated in lowland areas in the southern part of the country, which are

dominated by agricultural production. A similar distribution of impacts across the sectors is also evident in Romania, Serbia and Slovenia, where impacts on agriculture dominate. For Hungary and Montenegro, there are many impacts in the wildfire category, which are not common elsewhere (judging by the number of articles reporting this type of impact). Austria is characterized by a fairly even distribution of the different categories of drought impacts. Although the number of impacts in agriculture predominate (especially in the Lower Austria region), the impacts in water management and forestry are more significant. Forestry is most affected in Bulgaria. There is also a specific data distribution in Croatia, which has the most impacts on agriculture. However, the second most heavily represented areas are



5: Number of reports per sector in each country between 1981 and 2016 (AGR – agriculture, FOR – forestry, SOI – soil system, WFR – wildfires, HYD – hydrology)



6: Number of impacts in selected countries aggregated over 5 years

impacts on the water management sector – this is due to often problems with water supply during drought events, particularly at the Adriatic islands.

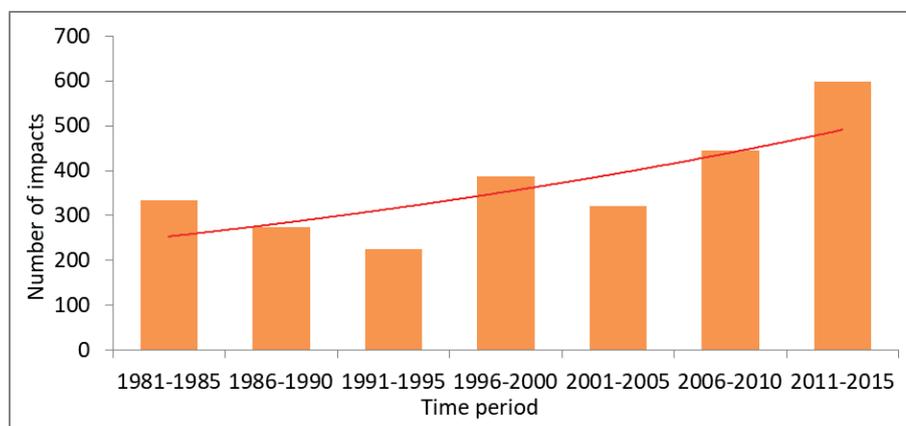
When classifying the effects of drought in the 5-year periods since 1981, the dataset shows that the least impact in the entire Danube catchment region was recorded between 1991 and 1995 and in the previous episode in the second half of the 1980s. On the other hand, the last period, between 2011 and 2015, is characterized by the greatest number of drought impacts. An important finding from Fig. 6 is the fact that the number of impacts has developed relatively differently in each country. A rather interesting comparison is illustrated in Fig. 7, showing the development of drought effects in selected countries of the area of interest. It is apparent that, while Bulgaria, Slovenia and Austria only experienced stagnation in the number of impacts over the period under review, Croatia had a substantial and rapid increase in impact. The explanation comes from different ways of collecting the impact data – manually from one newspaper in the past (1981–1999) and electronically from all newspapers and two thematic journals. Furthermore, in 1990–s during a war in Croatia, there is a reduced information on drought, especially in the eastern part of Croatia, the region where agriculture was the most developed. For example, in 2000 there are 81 drought impact data whereas during whole past period (1981–1999) there are 171 data collected.

Opposite (and therefore positive) development was recorded only for Slovakia, which is characterized by a declining trend. However, it should be noted that the number of impacts was significantly uneven, and there were large differences between the episodes. There is also a correlation between the number of impacts and

their time distribution in Austria and Slovenia, which can verify the quality of the input data to a certain extent due to the proximity of both countries.

## DISCUSSION

As stated by Blauhut *et al.* (2015a), in contrast to flood risk, the drought risk in Europe has not yet been thoroughly assessed, which is mainly due to the difficulty in obtaining information concerning the effects of drought and the resulting damage. The identification of individual drought events and their spatial extent and duration are subject to a certain degree of uncertainty due to the different quality and character of the data sources. Particularly problematic is the comparison of records of drought effects from a common newspaper article in the national press, intended for the general public, and an article in a specialized journal, which may be thematically focused on hydrometeorological extremes. Thematically specialized articles often report less significant episodes of drought, with only a local character of impact. In contrast, routine newspaper articles usually only inform about significant impacts directly influencing human society (e.g., through low annual crops, lack of drinking or service water, forest or meadow fires). Another problem is the mutual differentiation of the individual impacts, where they occur in close proximity (e.g., one impact is manifested in several different sectors), or their correct classification into a particular NUTS region, if a larger area is affected. Although the applied method of collecting information on drought impacts is subject to some degree of subjectivity and uncertainty in the quality of the data, it is likely to be the most



7: Number of impacts aggregated over 5 years (based on data from selected countries, i.e. Austria, Bulgaria, Croatia, Montenegro, Slovakia and Slovenia)

effective way to reliably map the intensity of past droughts.

Among the results obtained and the conclusions of other published studies, there are some coherencies that, to some extent, confirm the correctness of the data obtained – for example, concerning the greatest number of drought effects that were recorded in the agricultural sector. For instance, similar conclusions were reached by Blauhut *et al.* (2015b) or Olesen *et al.* (2011). The quality of the data obtained varies from country to country and also throughout time, as the analyzed regions have undergone considerably different levels of development. From the point of view of the data quality and its reporting ability, the early 1990s in the Balkan countries are particularly problematic. Low numbers of drought impacts within this era are most likely influenced by a series of wars that took place in the area of former Yugoslavia; therefore, the resulting number of impacts likely does not match the real situation.

The numbers of identified drought impacts have been correlated with respect to their temporal development in the period studied (i.e., for 2000–2016 in all countries and for

the whole period between 1981 and 2016, only for selected countries for which all data are available). The results of these correlations are shown in Tabs. IV and V. In addition to a simple number of impacts, the changes in the number of impacts between two consecutive years were also correlated (Tabs. VI and VII). For the long time series (1981–2016), a moderate correlation (significant at  $p < 0.05$ ) between the number of drought impacts in Austria and Slovenia, Slovenia and Croatia and Slovenia and Bulgaria was identified. In the first two cases, the geographic proximity of both countries is therefore likely to play a crucial role, which affects the correlation of drought impacts. In the case of a shorter time series (2000–2016), a strong to very strong correlation is evident between the observed values, as with the longer time series, for Austria–Slovenia and Slovenia–Croatia. In addition, there is a strong positive correlation between the number of impacts in Hungary and Croatia and Serbia and Bosnia and Herzegovina, where the geographic proximity of these countries is likely to be the main factor – the identified drought impacts can therefore have the same causal factors. In

IV: Correlations of the number of drought impacts in selected countries between 1981 and 2016 (marked correlations are significant at  $p < 0.05$ )

	AT	SK	SI	HR	BG
AT	1.000				
SK	0.176	1.000			
SI	0.668	0.036	1.000		
HR	0.384	0.112	0.565	1.000	
BG	0.353	-0.093	0.482	0.379	1.000

V: Correlations of the number of drought impacts in all countries between 2000 and 2016 (marked correlations are significant at  $p < 0.05$ )

	AT	CZ	SK	HU	SI	HR	BiH	ME	RS	BG	RO
AT	1.000										
CZ	0.108	1.000									
SK	-0.038	0.046	1.000								
HU	0.610	-0.173	0.440	1.000							
SI	0.807	0.069	0.028	0.645	1.000						
HR	0.486	0.030	0.435	0.871	0.645	1.000					
BiH	0.485	-0.218	-0.017	0.556	0.670	0.607	1.000				
ME	0.046	-0.164	-0.092	0.204	0.163	0.327	0.779	1.000			
RS	0.196	-0.049	0.128	0.467	0.388	0.630	0.805	0.893	1.000		
BG	0.176	0.084	0.297	0.585	0.339	0.517	0.334	0.197	0.364	1.000	
RO	0.023	0.772	0.329	0.155	0.052	0.244	-0.110	-0.125	0.054	0.472	1.000

VI: Correlation of the changes in the number of drought impacts between two consecutive years for selected countries between 1981 and 2016 (marked correlations are significant at  $p < 0.05$ )

	AT	SK	SI	HR	BG
AT	1.000				
SK	0.311	1.000			
SI	0.645	0.313	1.000		
HR	0.399	0.320	0.673	1.000	
BG	0.452	0.169	0.472	0.372	1.000

VII: Correlation of the changes in drought impact numbers between two consecutive years for all countries between 2000 and 2016 (marked correlations are significant at  $p < 0.05$ )

	AT	CZ	SK	HU	SI	HR	BiH	ME	RS	BG	RO
AT	1.000										
CZ	0.522	1.000									
SK	-0.005	-0.053	1.000								
HU	0.572	0.102	0.545	1.000							
SI	0.793	0.419	0.230	0.643	1.000						
HR	0.526	0.282	0.465	0.895	0.714	1.000					
BiH	0.608	0.107	0.304	0.630	0.696	0.706	1.000				
ME	0.220	0.079	0.113	0.222	0.081	0.322	0.692	1.000			
RS	0.347	0.226	0.421	0.592	0.403	0.701	0.750	0.805	1.000		
BG	0.391	0.365	0.442	0.688	0.520	0.671	0.337	0.054	0.491	1.000	
RO	0.326	0.683	0.515	0.511	0.357	0.548	0.201	0.121	0.438	0.726	1.000

addition to the above-mentioned pairs, a relatively strong correlation was also recorded in the case of the Czech Republic and Romania, where geographic proximity is no longer possible. Based on the data in Tab. IV, a certain hotspot exists in terms of the number of drought impacts in the area including Austria, Hungary and Slovenia, which is also evident from the map in Fig. 4.

When correlating changes in the number of impacts in two consecutive years, similar results were achieved in both time periods (1981–2016 and 2000–2016), as in the above-mentioned simple correlations of drought impacts. In the case of a shorter time series, which includes a calculation for all countries, a stronger correlation was observed, especially when comparing Hungary and neighboring countries, as well as for the correlation between values for Romania and selected neighboring countries. In addition to confirming the existence of the first “drought impact hotspot” in the neighboring regions of Austria, Slovenia and Hungary (supplemented by Croatia), there was also a second, less extensive hotspot in Romania and Bulgaria (in the border region between the two countries). Increased

values of correlations were also observed between the temporal development of drought impacts in the central Balkan Peninsula, i.e., between Croatia and Bosnia and Herzegovina, Croatia and Serbia, and Montenegro with Serbia. Compared to the maps in Figs. 3 and 4, the correlation analysis showed that a relatively different situation in terms of drought impact numbers prevailed in Slovakia and in the Czech Republic, where, despite the rather high number of impacts identified, the temporal development was quite different compared with the southernmost regions of the area of interest. The situation in Central Europe corresponds (in terms of changes in the number of impacts over time) with developments recorded mainly in the Romanian-Bulgarian hotspot.

From the point of view of the spatial correlation of the found numbers of articles, in some cases the significant differences among the neighboring countries can be found there, even though they are almost similar in the landscape management. These include, for example, the case of Slovakia and Hungary and the number of reports about the effects of drought in the two countries in agricultural sector. While in Slovakia, there are

more than 11 drought impacts per year on average (according to Tab. III), in neighboring Hungary with very similar management practices, the average value is only 1.5 impacts per year. This is very likely due to the quality and character of the data sources used. In general, a number of identified differences between neighboring or geographically (and economically) very close countries are probably due to different press reader preferences in the countries. Unfortunately, these facts limit

the applicability of newspaper and journal articles to some extent as a source of information that is credible about the phenomena analyzed. On the other hand, it is necessary to add that there is currently no other suitable source of information for this issue (except in the form of meteorological, climatological or remote sensing data, which, however, do not directly indicate the nature and intensity of drought impacts on human society).

## CONCLUSION

In general, the trends observed in the development of the number of drought impacts in the hotspots (i.e. The central part of the Pannonian lowland around the Danube River, the Adriatic coast in Croatia and Slovenia, and the region on the border between Romania and Bulgaria near the Black Sea coast), are consistent with the conclusions of other authors' studies, based on different types of data. For example, Hanel *et al.* (2018) states that in some European regions (Austria and the Czech Republic are among the countries under this study), the years 2003 and 2015 were the most problematic in terms of drought, although there were significant droughts in these areas occurred earlier (e.g. in the multi-year drought series around 1950). Similar conclusions are also seen when looking at the development of key climate elements in the given period – i.e. The temperature anomalies, precipitation and water balance. According to Hänsel *et al.* (2019) the extremes in 2003 and 2015 are again visible in Central Europe, which correlates with the time series for selected countries (e.g. Austria) in Fig. 6. Spinoni *et al.* (2017 and 2019) points out that based on the analysis of precipitation amounts and potential evapo-transpiration, the central Europe (especially the Czech Republic, Slovakia and Austria) experienced more droughts in the middle of the last century than the values currently observed. In contrast, it is evident from these Spinoni's studies that in Southeastern Europe the climatological indicators mentioned have declined significantly after 1981. This illustrates why all of the hotspots found are located in the South East Europe region or in the southern edge of Central Europe.

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## REFERENCES

- BLAUHUT, V., GUDMUNDSSON, L. and STAHL, K. 2015a. Towards pan-European drought risk maps: quantifying the link between drought indices and reported drought impacts. *Environmental Research Letters*, 10: 014008.
- BLAUHUT, V., STAHL, K. and KOHN, I. 2015b. The dynamics of vulnerability to drought from an impact perspective. In: ANDREU, J. *et al.* [Eds.]. *Drought: Research and Science-Policy Interfacing*. London: CRC Press, pp. 349–354.
- BRANZOVA, P. 2015. Assess the economic impact of climate change on wheat, barley, maize and sunflower in Southeast Bulgaria. *Trakia Journal of Sciences*, 13 (supl. 1): 4–7.
- BRÁZDIL, R., DOBROVOLNÝ, P., TRNKA, M., BÜNTGEN, U., ŘEZNÍČKOVÁ, L. and KOTYZA, O. 2016. Documentary and instrumental-based drought indices for the Czech Lands back to AD 1501. *Climate research*, 70(2–3): 103–117.
- CINDRIĆ, K., TELIŠMAN PRTENJAK, M., HERCEG-BULIĆ, I., MIHAJLOVIĆ, D., PASARIĆ, Z. 2016. Analysis of the extraordinary 2011/2012 drought in Croatia. *Theoretical and Applied Climatology*, 123: 503–522.

- EDC © 2018. European Drought Impact Report Inventory. *European Drought Centre*. [Online]. Available at: <http://europeandroughtcentre.com/> [Accessed: 2018, January 18].
- EEA © 2019 European Environment Agency – Data and Maps [online]. Available at: <https://www.eea.europa.eu/data-and-maps> [Accessed: 2019, January 2].
- HANEL, M., RAKOVEC, O., MAKONIS, Y., MÁCA, P., SAMANIEGO, L., KYSELÝ, J. and KUMAR, R. 2018 Revisiting the recent European droughts from a long-term perspective. *Scientific Reports*, 8: 9499.
- HÄNSEL, S., USTRNUL, Z., LUPIKASZA, E. and SKALAK, P. 2019. Assessing seasonal drought variations and trends over Central Europe. *Advances in Water Resources*, 127: 53–75.
- HOERLING, M., EISCHEID, J., KUMAR, A., LEUNG, R., MARIOTTI, A., MO, K. and SEAGER, R. 2014. Causes and predictability of the 2012 Great Plains drought. *Bulletin of the American Meteorological Society*, 95(2): 269–282.
- KNIGHT, G., RAEV, I. and STANEVA, M. 2004. *Drought in Bulgaria. A Contemporary Analog for Climate Change*. Ashgate.
- KOLEVA, E. and ALEXANDROV, V. 2008. Drought in the Bulgarian low regions during 20<sup>th</sup> century. *Theoretical and Applied Climatology*, 92 (1–2): 113–120.
- MAFF. 2017. Agricultural reports. *Ministry of agriculture, food and forestry*. [Online]. Available at: <http://www.mzh.government.bg/bg/politiki-i-programi/otcheti-i-dokladi/agraren-doklad/> [Accessed: 2018, October 10]
- MUNICH RE. 2015. Geo Risks and Climate. *Change Munich RE*. [Online]. Available at: <https://www.munichre.com/en/homepage/index.html> [Accessed: 2018, July 6].
- OLESEN, J. E., TRNKA, M., KERSEBAUM, K. C., SKJELVÅG, A. O., SEGUIN, B., PELTONEN-SAINIO, P. and MICALE, F. 2011. Impacts and adaptation of European crop production systems to climate change. *European Journal of Agronomy*, 34(2): 96–112.
- POPOVA, Z., IVANOVA, M., PREREIRA, L., ALEXANDROV, V., KERCHEVA, M., DONEVA, K. and MARTINS, D. 2015. Drought and climate change in Bulgaria: Assessing maize crop risk and irrigation requirements in relation to soil and climate region. *Bulgarian Journal of Agricultural Science*, 21(1): 35–53.
- SAMANIEGO, L., KUMAR, R. and ZINK, M. 2013. Implications of parameter uncertainty on soil moisture drought analysis in Germany. *Journal of Hydrometeorology*, 14(1): 47–68.
- SHEFFIELD, J., WOOD, E. F., RODERICK, M. L. 2012. Little change in global drought over the past 60 years. *Nature*, 491: 435–440.
- SPINONI, J., NAUMANN, G. and VOGT, J. V. 2017. Pan-European seasonal trends and recent changes of drought frequency and severity. *Global and Planetary Change*, 148: 113–130.
- SPINONI, J., BARBOSA, P., DE JAGER, A., MCCORMICK, N., NAUMANN, G., VOGT, J.V., MAGNI, D., MASANTE, D. and MAZZESCHI, M. 2019. A new global database of meteorological drought events from 1951 to 2016. *Journal of Hydrology: Regional Studies*, 22: 100593.
- STAHL, K., KOHN, I., BLAUHUT, V., URQUIJO, J., DE STEFANO, L., ACÁCIO, V. and VAN LOON, A. F. 2016. Impacts of European drought events: insights from an international database of text-based reports. *Natural Hazards and Earth System Sciences*, 16(3): 801–819.
- SVOBODA, M., LECOMTE, D., HAYES, M., HEIM, R., GLEASON, K., ANGEL, J. and MISKUS, D. 2002. The drought monitor. *Bulletin of the American Meteorological Society*, 83(8): 1181–1190.
- TALLAKSEN, L. M. and VAN LANEN, H. A. (Eds.). 2004. *Hydrological drought: processes and estimation methods for streamflow and groundwater*. Developments in Water Science Vol. 48. Elsevier.
- TRENBERTH, K. E. and FASULLO, J. T. 2012. Climate extremes and climate change: The Russian heat wave and other climate extremes of 2010. *Journal of Geophysical Research: Atmospheres*, 117: D17.
- WILHITE, D. A., SVOBODA, M. D. and HAYES, M. J. 2007. Understanding the complex impacts of drought: A key to enhancing drought mitigation and preparedness. *Water Resources Management*, 21(5): 763–774.
- WORLD BANK GROUP. 2019. *Climate Change Knowledge Portal*. [Online]. Available at: <https://climateknowledgeportal.worldbank.org/> [Accessed: 2019, February 20].
- ZINK, M., SAMANIEGO, L., KUMAR, R., THOBER, S., MAI, J., SCHÄFER, D. and MARX, A. 2016. The German drought monitor. *Environmental Research Letters*, 11(7): 074002.

Contact information

Jiří Jakubínský: [jakubinsky.j@czechglobe.cz](mailto:jakubinsky.j@czechglobe.cz)