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Haim Kutiel*, Jelena Luković[1]**

* *University of Haifa, Department for Geography and Environmental Studies, Laboratory of Climatology, Israel*
** *University of Belgrade, Faculty of Geography, Serbia*

VARIOUS ASPECTS OF DRYNESS IN SERBIA

Abstract: In this manuscript we analyze daily rainfall observational records from 22 weather stations located in different regions over Serbia in the period 1949–2007. We examine the characteristics of dryness by using the Dry Days Since Last Rain – DDSLR approach. In order to quantify the DDSLR we use three metrics for each weather station: *severity*, *consistency* and *uncertainty*. Results show that these three metrics vary independently of each other as well as that there is a weak relationship between them. Weather stations in the northern parts of Serbia, with moderate annual amount of rainfall less than 650 mm, present higher dryness conditions whereas the lowest values were obtained for central parts in Serbia. Limited number of studies examined drying tendencies in Serbia and neighboring countries so far. We consider Serbia as an area of particular interest because of its position in a frontier between Mediterranean conditions on the southwest and the continental inland.

Key words: dryness, DSLR, Serbia

[1] jelena.lukovic@gef.bg.ac.rs (corresponding author)

Introduction

Dryness can cause many negative consequences on the environment, economy and societies in different regions around the world. Prolonged dry periods may affect water supply, may cause large damages to the agriculture and the environment, enhance and intensify forest fires and land degradation.

Precipitation deficit during the rainy season, including prolonged droughts (Seager et al., 2014), is nothing new to Mediterranean region referred to as climate change hotspot. Mediterranean region is devoted to agriculture, consuming 60–80% of water supply (Hoerling et al., 2012). Increased drought frequency is a serious threat to the regions' food security. Therefore, the study of precipitation patterns (Zhang et al., 2000; Osborn et al., 2000; New et al., 2001) is a key to predicting changes in agriculture, water resources and ecosystems alike.

In Serbia, recent studies that analysed the rainfall regime were mainly focused on trend analysis, relationship to global circulation patterns and the analysis of climate extremes (Tošic, 2004; Unkaševic et al., 2004; Tošic & Unkaševic, 2005; Unkaševic & Tošic, 2011; Bajat et al., 2012; Lukovic et al., 2013; Tošic & Unkaševic, 2013; Hrnjak et al., 2014).

To date, there is a limited number of studies examining droughts in Serbia and neighboring countries despite the fact that recent drought events has led to decline in crop yields and rise in prices[2]. Serbia is an area of specific interest due to its position between Mediterranean conditions on the southwest and the continental inland. Three main types of climates are characterizing Serbia: continental, moderate continental and modified Mediterranean climates. A typical continental climate characterizes the northern parts of the country (Unkašević & Radinović, 2000), while the south and southwestern regions of the country are subjected to Mediterranean influences.

In this manuscript we aim to quantify, analyze and map dry events in Serbia over the last recent decades. The structure of the paper is as follows: "Data sets and methods" section contains a brief description of observational precipitation records and methodology applied. "Results" section provides details about DDSLR, while "Conclusions" section concludes the paper.

Data and methodology

Daily rainfall observational data from 15 weather stations across Serbia for a period of 59 years (56 in some stations) from 1949 to 2007 were analyzed. Fig. 1 displays their location and their average annual rainfall. The study area comprises countries of Serbia which cover an area of 88,361 km^2 or approximately 18% of the Balkan Peninsula.

All data are compiled from weather stations. They are quality controlled in terms of correction of misprints and relocation of the stations (WMO, 2002). There were no missing data. Tošić (2005) tested homogeneity for the precipitation series in Serbia using the Alexandersson test (1986) and found that some stations were not homogenous. As a result, the time series with inhomogeneities were excluded from further analysis.

[2] https://www.rs.undp.org/content/serbia/en/home/blog/2019/the-climate-changes-and-so-must-we---climate-change-as-a-definin.html

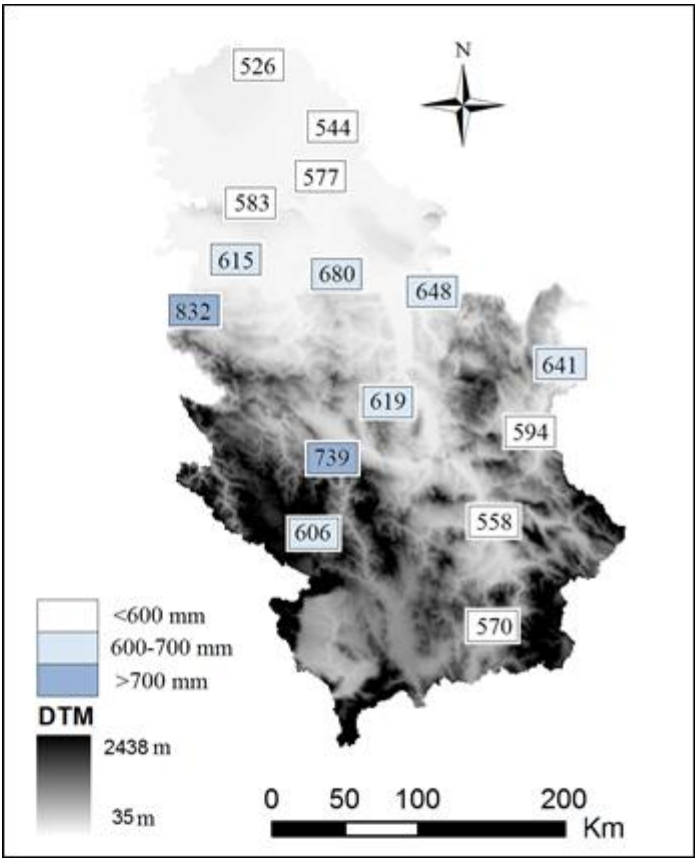

Fig. 1. Location map and the average annual rainfall in 1949-2007 (mm)

Dryness was analyzed using the Dry Days Since Last Rain (DDSLR hereafter) approach. This methodology, first suggested and developed by Kutiel (1985), has many advantages upon the traditional use of dry-spells (Aviad et al., 2009) and has been recently reemerged and applied for the analysis of dryness for the entire Mediterranean basin (Reiser & Kutiel, 2010), Spain (Lana et al., 2012; Ruiz et al., 2012) and Lisbon (Kutiel & Trigo, 2014).

According to the DDSLR methodology, each rainy day is attributed a "0" value, the first dry day is attributed a "1" value, the next consecutive dry day, a "2" value and so on, until the next rainy day which is attributed again a "0" value. Values are accumulated from one year to the consecutive one. Once all days in the analyzed period were attributed with a specific value that describes the distance/timing in days since the last rainy day, all values in each day are sorted in an ascending order, thus enabling to present values in a probabilistic way.

Three different aspects of the dryness are examined; its *severity*, its *consistency* and its *temporal uncertainty* (Fig. 2). The following charts on these panels show the sorted dry days since last rainfall - DDSLR.

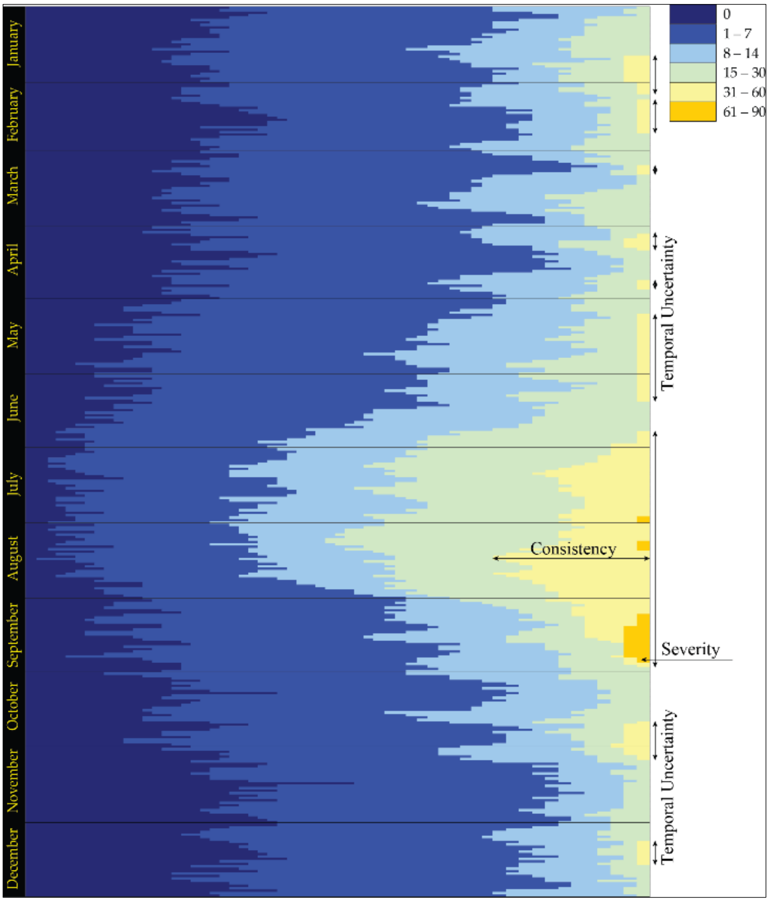

Fig. 2. The three metrics of the DDSLR

Each row represents a different day, starting on January 1, on the top line and ending at December 31, at the bottom line. The leftmost column represents the shortest elapsed period since last rain (usually 0, meaning a rainy day), while the rightmost column the longest elapsed period since last rain, to that day. The first band of color represents a rainy day, the next a period of 1-7 days after last rain, 8-14 days, 15-30, etc.

The *severity* of the dryness measures the longest length of the dry period. The longer this period is, the more severe the dryness is.

The *consistency* considers how frequently a dry period of a given length occurs. The higher this figure is, the more consistent the dryness is.

Finally, the *temporal uncertainty* considers the span of time when a dry period of certain duration can be expected. The longer is this period, the higher is the temporal uncertainty.

Results and discussion

Tab. 1 presents the various aspects (*severity*, *consistency* and *uncertainty*) of the dryness in the different stations. Stations are arranged in a descending order of severity of the dryness. These values represent the longest DDSLR in each station. Values given in the table range from 72 consecutive dry days in Novi Sad to 44 in Kraljevo. The most severe dryness is obtained for Novi Sad and Negotin, both located in the northern parts of Serbia with the average annual totals less than 650 mm (Fig. 1). On the other hand, the two stations that receive the lowest annual rainfall, Palić and Kikinda, in Northern Serbia, do not show the most severe dryness conditions.

Tab. 1. The various parameters of the dryness in the different stations

	Severity	*Consistency*		*Uncertainty*
	Longest DDSLR	% of years with DDSLR>30	Return period [years]	Range [days]
Novi Sad	72	10.2%	10	190
Negotin	68	8.9%	11	209
Zaječar	67	7.1%	14	157
Niš	67	5.1%	20	205
Vranje	67	5.1%	20	166
Zrenjanin	60	10.7%	9	153
Kikinda	60	8.9%	11	159
Novi Pazar	60	5.4%	19	153
Palić	55	5.1%	20	173
Veliko Gradište	53	6.8%	15	132
Kragujevac	53	5.1%	20	123
Sremska Mitrovica	51	5.1%	20	104
Loznica	51	3.6%	28	50
Belgrade	48	5.1%	20	117
Kraljevo	44	3.4%	30	61

There is only a weak correlation between *severity* and *consistency*. The *consistency* measures the percentage of years in which we may expect a dry period of a given length. It is also presented as return period [years] which is calculated as the inverse of the percentage. For example, Novi Sad and Negotin present both the highest *severity* and *consistency* values. In 10.2% of the years in Novi Sad and in 8.9% of the years in Negotin we may expect a dry period longer than 30 days. These values correspond to return periods of once every 10 years in Novi Sad and once every 11 years in Negotin. However, in Niš and Vranje for example, that share very similar *severity* degree like Negotin, a dry period longer than 30 days may occur only once every 20 years. On the other hand, in Zaječar, which has the same *severity* as Niš and Vranje and similar to the neighboring station of Negotin, a dry period longer than 30 days is expected once every 14 years (Tab. 1).

Only a weak correlation exists between the *uncertainty* and the other two metrics. In Negotin and Niš a dry period longer than 30 days may occur any time during a period of almost 7 months, in Novi Sad that period is longer than 6 months. On the other hand, in Kralievo this may happen during a limited period of only two months and in Loznica even during a shorter period (Tab. 1).

Conclusions

In this manuscript we analyzed dryness in Serbia using methodology developed by Kutiel (1985). Based on the results we show in the manuscript our conclusion is that the dryness is not a crucial climatic threat in Serbia. This is also evident from a recent publication in which this issue was addressed in the Vojvodina region, in Northern Serbia (Hrnjak et al., 2014). Being subjected to Mediterranean climate only in the southwestern parts with calculated Mediterranean index lower than 1, dryness threat is considerably reduced. On the other hand, seasonal distribution of rainfall in Serbia and slight tendency towards aridity during spring (Lukovic et al., 2014) might have implications on ecological, economic, agricultural and social processes. Agricultural land in Serbia occupies 70% (57,340 km^2) of the total area. Since irrigated areas cover only 3.7% of the total farmland (Ørum et al., 2010) Serbia is significantly dependent on rainfall. In this manuscript we show that the highest severity of dryness occur in the north and eastern parts of Serbia, which present the lowlands with most productive soil types (Babovic et al., 2009). Better understanding of dryness with its societal and economic implications is our key aim in the future research.

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Haim Kutiel[*], **Јелена Луковић**[**]

[*] *Универзитет у Хаифи, Департман за географију и животну средину, Лабораторија за Климатологију, Израел*
[**] *Универзитет у Београду, Географски факултет, Србија*

КАРАКТЕРИСТИКЕ СУШНОСТИ У СРБИЈИ

Резиме: Дуги периоди без кише могу изазвати негативне последице на животну средину, економију и друштво. Суше несумњиво утичу и на водне ресурсе, пољопривреду, интензитет шумских пожара и деградацију земљишта.

У овом раду анализиране су осмотрене дневне падавине у Србији у периоду између 1949. и 2007. године. Простор Србије је од посебног интереса с обзиром на његов географски положај између медитеранских и континенталних услова климе. У овом раду испитиване су карактеристике суше користећи приступ *Dry Days Since Last Rain* – DDSLR. За квантификацију DDSLR анализирана су три параметра на свакој станици: *severity, consistency* и *uncertainty*. Северни делови Србије, који имају релативно умерену количину падавина током године, показали су сушне тенденције. С друге стране, најниже вредности истраживаних параметара уочене се у централној Србији.

Имајући у виду резултате истраживања може се закључити да суша није значајна климатска претња за Србију. Другим речима, како је Србија изложена утицајима медитеранске климе у њеним југозападним деловима, са вредностима медитеранског индекса од 1, могућност од појаве суша значајно је умањена. Појава суше у Србији изражена је у северним и источним деловима земље, равницама са најпродуктивнијим типовима земљишта. Због тога је боље разумевање ове појаве у Србији и њених друштвених и економских последица кључно у будућим истраживањима.