Original scientific paper
10.7251/AGSY1404279G

BIOCLIMATIC MOISTURE CONDITIONS IN THE LOWLANDS OF THE ŠUMADIJA-POMORAVLJE DISTRICT

Enike GREGORIC*, Gordana MATOVIC, Mirjana RUML, Vesna POCUCA, Nevenka DJUROVIC

University of Belgrade, Faculty of Agriculture, Belgrade, Serbia
*Corresponding author: enikag@agrif.bg.ac.rs

Abstract

The objective of this paper is to assess to what extent weather conditions that favor crop production have changed over the past five decades in the lowlands of the Šumadija-Pomoravlje District, an important agricultural area in Serbia. Meteorological data collected from the climatological stations at Ćuprija and Kragujevac were analyzed for the period 1961/62–2011/12. Bioclimatic conditions were determined using the Aridity Index (UNEP), the Moisture Availability Index (Hargreaves), the Reconnaissance Drought Index and the difference between precipitation and potential evapotranspiration. The results show that in the last two decades, compared to the previous three, the air temperature, number of annual tropical days, potential evapotranspiration and water deficit suffered by crops all increased. Severe drought events occurred more frequently during the past twenty years (every third or fourth year). Detected changes in bioclimatic conditions do not favor crop production, suggesting that a strategic approach to drought management is needed.

Key words: *drought, Aridity Index, Reconnaissance Drought Index, Moisture Availability Index, Serbia*

Introduction

The Šumadija-Pomoravlje District features a combination of mountainous and hilly areas and alluvial plains along rivers, the latter of which are very important from the point of view of agricultural production. These plains represent around 70% of the total agricultural area in this district. Cereal, fodder plant and vegetables are the most cultivated crops in this area. The remaining 30% of agricultural land is made up of meadows, pastures, orchards and vineyards. Agricultural production in this district, as in the rest of Serbia, occurs mainly in rainfed conditions. The use of irrigation is restricted to smaller, local areas, which means that agricultural production is directly dependent on climate conditions.

Climatic trends show regionally varying changes in temperature and rainfall in Europe and worldwide (IPCC, 2014). The heterogeneity of climatic trends is also present in Serbia, especially when precipitation is considered (Dedijer et al., 2007). A negative trend of annual precipitation is characteristic of eastern part of the Serbia and climaxing in the region of Negotin (Anđelković and Živković 2007), while a positive precipitation trend characterizes mountainous areas of southwestern Serbia (Ducić et al., 2009; Lukovic et al., 2013). The objective of this paper is to analyze long-term meteorological data and show to what extent weather conditions in Šumadija-Pomoravlje District have favored plant production in the past five decades and whether they are indicative of any trend change.

Material and method

Fifty-one-year monthly data (from 1961/62 to 2011/12) were obtained from the National Hydrometeorological Service of Serbia, from two weather stations, located at Kragujevac (Šumadija region) and Ćuprija (Pomoravlje region). The following parameters were assessed: mean annual air temperatures and mean air temperatures in the growing season (April-September); annual precipitation totals and precipitation totals in the growing season; and number of tropical days (Tmax>30^{o}C) during the growing season. The annual data discussed in this paper reflect the hydrologic year, which in Serbia and the extended region begins in October and lasts until September of the following year. Plants’ water demand is expressed via potential evapotranspiration, calculated applying the Thornthwaite method (Thornthwaite, 1948; Kafle and Bruins, 2009). Bioclimatic moisture conditions were determined by hydrologic year and by growing season. The following methods were used with regard to the hydrologic year: Aridity Index (UNEP, 1992), Moisture Availability Index – MAI (Hargreaves, 1992), and difference between potential evapotranspiration (ETo) and total rainfall (P). Bioclimatic conditions by growing season (April-September) were determined using the difference between potential evapotranspiration (ETo) and total rainfall (P), and the Reconnaissance Drought Index – RDI calculated, according to Tsakiris and Vangelis (2005). RDI was calculated as the ratio between total rainfall and potential evapotranspiration for the 6 month period (April-September).

Results and discussion

The main climate parameters for Ćuprija (123 m a.s.l) and Kragujevac (185 m a.s.l.) are shown in Table 1 and Fig. 1.

Tab. 1. Average air temperatures, precipitation (P), total potential evapotranspiration (ETo), number of tropical days and average soil moisture deficit/surplus (P-ETo) at Ćuprija and Kragujevac and average values for the Šumadija-Pomoravlje District

Period	Temperature (^{o}C)		Precipitation (P) (mm)		Potential evapotranspiration (ETo) (mm)		Tropi-cal days	P-ETo (mm)	
	Hydr. year	Grow. season (Apr-Sept)	Hydr. year	Grow. season (Apr-Sept)	Hydr. year	Grow. season (Apr-Sept)		Hydr. year	Grow. season (Apr-Sept)
	Ćuprija								
1961/62-1990/91	10.7	17.2	650	368	697	601	30	-46	-233
1991/92-2011/12	11.4	18.3	672	369	732	637	50	-60	-268
1961/62-2011/12	11.0	17.6	659	369	712	616	38	-53	-247
	Kragujevac								
1961/62-1990/91	11.0	17.3	633	373	704	601	26	-71	-228
1991/92-2011/12	11.9	18.6	627	363	747	644	44	-120	-281
1961/62-2011/12	11.3	17.7	630	369	721	619	33	-91	-250
	Average								
1961/62-1990/91	10.8	17.2	642	370	700	601	28	-58	-231
1991/92-2011/12	11.6	18.4	650	366	740	640	47	-90	-274
1961/62-2011/12	11.2	17.6	644	369	716	618	36	-72	-249

The average annual air temperature was 11.2^{o}C, while growing season temperature averaged 17.6^{o}C over the period 1961/62-2011/12. The warmest month was July, with an average temperature of 21.3^{o}C, and the coldest was January – 0.1^{o}C (Fig. 1). The average annual rainfall was 644 mm, of which 369 mm came during the growing season. The rainiest month was June (80 mm), and the driest were February (Kragujevac 39 mm) and March (Ćuprija 44 mm) (Fig. 1).

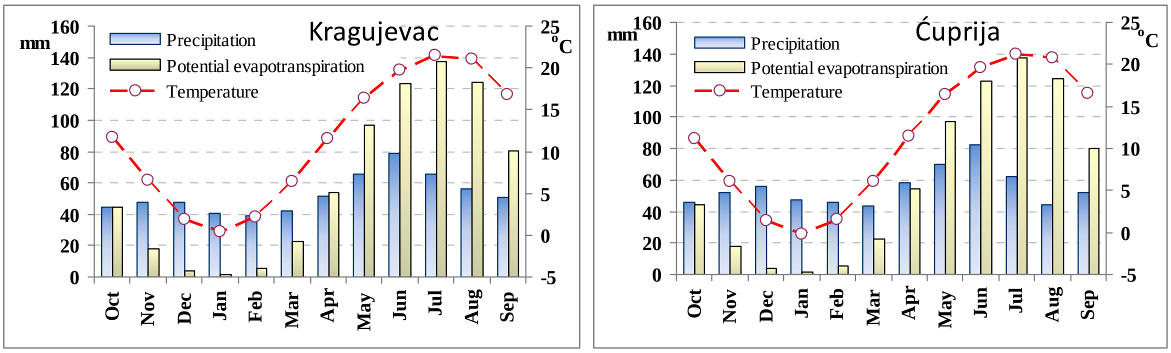

Fig. 1. Mean monthly (1961/62-2011/12) air temperatures, precipitation totals and potential evapotranspiration in the Šumadija-Pomoravlje District.

In the study area, the precipitation distribution during an average hydrologic year and the monthly plants’ water demand for the period 1961/62-2011/12 (Fig. 1) shows that abundant moisture was available in the winter months (November-February), when the plants were quiescent and their needs minimal. The lack of water was greatest in July and August (Fig. 1), when most crops undergo phenological stages sensitive to moisture deficit. A lack of precipitation during this period can cause a dramatic decrease in yields (Challinor et al., 2005; Jovanović and Stikić, 2012). A similar situation was noted in the Mačva-Kolubara District of Serbia (Matović et al., 2013b), where plants were found to be under considerable stress in July and August during 31 out of 51 growing seasons. According to the Moisture Availability Index (Hargreaves, 1992), these were classified as semi-arid and arid conditions. The potential evaporation (ETo) in the study area during the growing season was 618 mm on average (Tab. 1).

Like the Mačva-Kolubara District (Matović et al., 2013b), the study area registered an upward air temperature trend (Fig. 2). Upward air temperature trends have been registered across Europe (Jones and Moberg 2003), with regionally and seasonally different rates of warming (IPCC 2014). On average, long-term (1901-2005) data indicate that air temperatures in Europe are increasing more in winter than summer (Jones and Moberg, 2003). This also applies to the study area and Serbia’s main breadbasket — the Province of Vojvodina (Lalić et al., 2011). In the past two decades, compared to the previous three, temperatures during the growing season (April-September) increased by 1.2°C, while the annual average was 0.8°C (Tab. 1). The number of tropical days also increased significantly. In the study period there were 28 tropical days per annum on average, while from 1992 to 2012 there were roughly 47 tropical days (Tab. 1), which is an increase by as much as 65% or more. This is consistent with the findings of Klein and Können (2003) that from 1977 to 2000 there was a greater increase in warm extremes in Europe than decrease in cold extremes. In addition, the latest IPCC report (IPCC, 2014) stated that since 1950, high-temperature extremes have become more frequent.

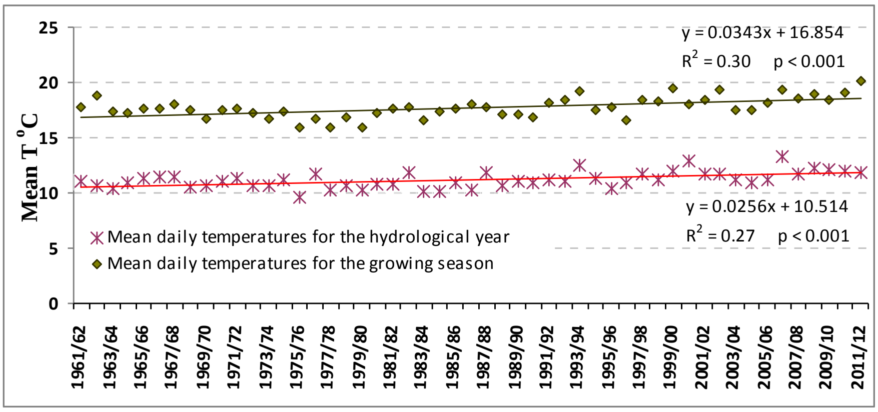

Fig. 2. Time series and linear trends of mean air temperature for hydrologic year and growing season in the Šumadija-Pomoravlje District, 1961/62-2011/12.

While in Vojvodina (Lalić et al., 2011) and the Negotin region of Serbia (Anđelković and Živković 2007; Ducić et al., 2009) annual precipitation totals exhibited a downward trend, an upward trend was noted in south-western Serbia (Ducić et al., 2009; Lukovic et al., 2013). However, no significant precipitation trend was detected in the Šumadija-Pomoravlje region during the study period.

Potential evapotranspiration (April-September) during the past two decades was found to be some 30 mm higher (634 mm) than in the previous three decades (603 mm) (Tab. 1). The increase in air temperatures and potential evapotranspiration, and the relatively unaltered precipitation regime, have resulted in a greater water deficit was detected in the past two decades (268 mm), compared to the previous three (232 mm) (Tab. 1). The Aridity Index shows that the lowlands in the studied district belong to the humid climate category (Ćuprija 0.93, Kragujevac 0.88). The Moisture Availability Index—MAI, adjusted to southern Europe (Hargreaves, 1992), indicates that the climate in the region is semi-humid (MAI 0.8). The average difference between precipitation and potential evapotranspiration over an entire hydrologic year revealed a precipitation deficit of 72 mm (Tab. 1). Judging by these values, the average moisture availability should have been satisfactory. However, there is a general disparity between moisture demand and moisture availability in Serbia in the summer months, and that is why droughts impact spring crops the most (Matović et al., 2013a; Lalić et al., 2011). The average difference between precipitation totals and potential evapotranspiration during the growing season (April-September) was found to be 249 mm (Tab. 1). The average RDI calculated for the 6 month time period (from April to September) was 0.60 (Fig.3). The RDI distribution (Fig. 3) exhibits a greater scatter of data points in the last 20 years. If according to Tsakiris and Vangelis (2005) a 0.7· averageRDI is taken as an extreme drought threshold (Fig. 3), then extreme drought events have been more frequent in the past two decades (5 extremely dry periods in Ćuprija and 7 in Kragujevac), compared to the previous three decades (1 in Ćuprija and 2 extremely dry growing seasons in Kragujevac). Consequently, in the past 20 years farmland in the Pomoravlje region experienced extreme drought events every fourth year, and in the Šumadija region as often as every third year.

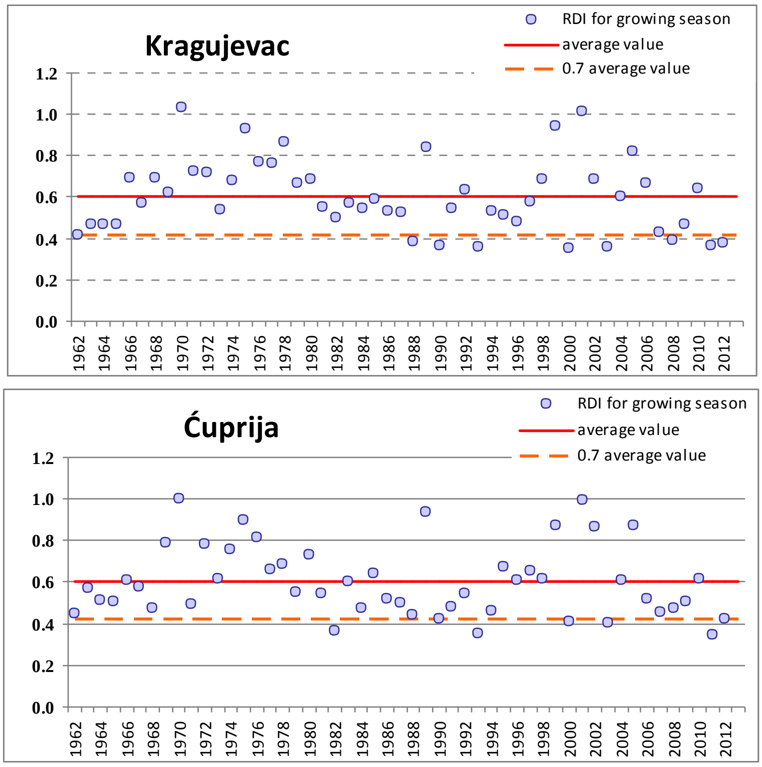

Fig. 3. Reconnaissance Drought Index (RDI) calculated for the 6 month time period (April-September) in Šumadija (upper panel) and Pomoravlje (lower panel), 1962-2012.

Conclusion

Over the past five decades (1961/62-2011/12) in the Šumadija-Pomoravlje District an increase in air temperatures, the number of tropical days per year, and an increase in potential evapotranspiration have been noted. Bioclimatic conditions for the entire hydrologic year were satisfactory (Aridity Index — humid condition, MAI — semi humid condition), but during the growing season (April-September) there was a water deficit (250 mm on average for reference crop). The RDI calculated for the growing season (April-September) shows more frequent extreme drought events in the past 20 years (every third or fourth year), compared to the previous 30 years. The study results, together with the IPCC report (IPCC, 2014), indicate that agriculture in Southern Europe is highly vulnerable to predicted climate change, and constitutes a serious warning and call for strategic measures to be implemented against increasing drought conditions.

Acknowledgement

This paper is part of research projects 31005 and 37005, funded by the Ministry of Education, Science and Technology Development of the Republic of Serbia.

References

Anđelković, G. and Živković, N. (2007): Precipitation as adverse climatic phenomenon in Negotin. Glasnik Srpskog geografskog drustva, 87(1), 51-62.

Challinor, A.J., Wheeler, T.R., Craufurd P.Q., Slingo J.M. (2005): Simulation of the impact of high temperature stress on annual crop yields. Agricultural and Forest Meteorology 135, 180-189.

Dedijer, A., Mitrović-Josipović, M., Radulović, E., Dimić, B., Marić, L., Krunić-Lazić, M., Špegar, G., Vidojević, D., Jovanović, M., Veljković, N., Jovičić, M., Redžić, N., Popović, S., Pajčin, N., Lekić, D., Popović, T., Mijović, A. (2007): Environment in Serbia: an indicator-based review. Serbian Environmental Protection Agency, Belgrade.

Ducić, V., Luković, J., Milovanović, B. (2009): Promene temperatura i padavina u Srbiji u drugoj polovini XX veka u sklopu globalnih klimatskih promena. Zaštita prirode, 60(1-2), 641-652.

Hargreaves, G.H. (1992): Defining and preparing for Drought in Europe. ICID 16th European Regional Conference “Drought Phenomena”. Budapest ,Proc. Vol. 1 (171-177).

IPCC (2007): Climate Change (2007): Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Parry, ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, editors. Cambridge: Cambridge University Press; UK.

IPCC (2014): Final Draft WGII AR5 Chapter 23. Kovats, S., Valentini, R., Bouwer, L.M., Georgopoulou, E., Jacob, D., Martin, E., Rounsevell, M., Soussana, J.F. http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap23_FGDall.pdf

Jones, P.D. and Moberg, A. (2003): Hemispheric and large scale surface air temperature variations: an extensive revision and an update to 2001. J. Clim. 16, 206-223.

Jovanovic, Z. and Stikic, R. (2012): Strategies for Improving Water Productivity and Quality of Agricultural Crops in an Era of Climate Change. In: Irrigation Systems and Practices in Challenging Environments. Ed. Teang Shui Lee., In Tech. ISBN 978-953-51-0420-9, pp. 77-102.

Kafle, K. H. and Bruins, J. H. (2009): Climatic trends in Israel 1970–2002: warmer and increasing aridity inland. Climatic Change, 96:63-77. DOI 10.1007/s10584-009-9578-2

Klein Tank, A.M.G. and Können, G.P. (2003): Trends in indices of daily temperature and precipitation extremes in Europe. J. Clim., 16, 3665-3680.

Lalić, B., Mihailović, T., Podraščanin, Z. (2011): Future State of Climate in Vojvodina and Expected Effects on Crop Production. Field Veg. Crop Res. 48, 403-418.

Luković, J., Bajat, B., Blagojević, D., Kilibarda, M. (2013): Spatial pattern of recent rainfall trends in Serbia (1961–2009). Regional Environmental Change, 1-11.

Matović, G., Gregorić, E., Glamčlija, Dj. (2013a): Crop production and drought in Serbia in light of climate change (Chapter 12). Agriculture in Serbia and Portugal: Recent Developments and Economic Policy Implications. Faculty of Economics of the University of Coimbra. Portugal, pp. 264-286.

Matović, G., Gregorić, E., Počuča, V., Radovanović, S. (2013b): Drought even in a rainy agricultural region of Serbia. International Conference “Climate Change Impact on Water Resources”, Beograd, pp. 260-268.

Thornthwaite, C.W. (1948): An approach toward a rational classification of climate. Geogr. Rev. 38(1), 55-94.

Tsakiris, G. and Vangelis, H. (2005): Establishing a drought index incorporating evapotranspiration. European Water 9/10, 3-11.

UNEP (1992): World atlas of desertification, 1st edn. Middleton N. (coordinating ed.) Edward Arnold, Nairobi.