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The intensity and impact of drought on crop production and possibilities of mitigation in Serbia

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SUMMARY – Drought occurrence and intensity under agro-climatic conditions of Serbia cause considerable damage to agricultural production. The climatic conditions of Serbia are characterized by non-uniform rainfall, have changeable and unstable rainfall and dry periods between June and August. In July and August, drought occurrence is about 80% of years. Depending on drought intensity, crop yields could be reduced to 50% in relation to the genetic yield potential. In extremely dry years, yield reductions reach 90% in comparison with years with normal rainfall. Attention of drought mitigation includes various measures such as irrigation, genetics and breeding, agricultural practices, and others. Drought occurs occasionally in a single year or in a series of years, causing severe damage to agricultural production. In some years (e.g. 1951, 1990, 1992, 2000, 2003) drought was harmful not only to some crops but it affected the whole Pannonian Plain, or major parts of it, turning it into an arid region.

Key words: Climatic conditions, rainfall, irrigation, crop production, yields, drought mitigation.

RESUME – *"L'intensité et l'impact de la sécheresse sur la production des cultures et les possibilités d'atténuation en Serbie". La survenue et l'intensité de la sécheresse dans les conditions agroclimatiques de la Serbie causent des dommages considérables à la production agricole. Les conditions climatiques en Serbie sont caractérisées par une précipitation non uniforme, et par des périodes de précipitations instables et de sécheresse entre juin et août. La survenue de la sécheresse en juillet et août est de 80% chaque année. Selon l'intensité de la sécheresse, les rendements des récoltes peuvent être réduits à 50% par rapport au potentiel génétique de rendement. Lors des années extrêmement sèches, la réduction de la récolte peut atteindre 90% en comparaison aux années ayant des précipitations normales. La plus grande attention est portée à une atténuation de la sécheresse qui inclut diverses mesures comme l'irrigation, la génétique et la multiplication, les pratiques agricoles, et d'autres. En quelques années, la sécheresse a été nocive non seulement à quelques récoltes mais elle a transformé la plaine entière de Pannonie, ou ses grandes parties, en région aride.*

Mots-clés : *Conditions climatiques, précipitations, irrigation, production des cultures, rendements, atténuation de la sécheresse.*

Introduction

The climatic conditions of the agricultural parts of Serbia are characterized by non-uniform rainfall both among years and within a single year, especially during the vegetation season. The non-uniform rainfall typically causes a discrepancy between water supply and plant requirements, i.e., there occur droughts of various level of intensity. Bošnjak (1995) according to Moisture Availability Index (MAI) claimed that the regions having the MAI below 0.33 have semiarid to arid climate in the summer period, which does not permit safe agricultural production without irrigation.

Depending on the time of drought occurrence, duration and intensity, agricultural crops suffer yield reductions of various magnitudes. Droughts of variable intensity, i.e., short or long periods with insufficient rainfall occur practically each year. In some years and in some regions of Serbia drought reaches catastrophic proportions for agricultural production. According to Stojšić and Škorić (1997), drought occurs occasionally in a single year or in a series of years, causing severe damage to agricultural production. In some years (e.g. 1928, 1951, 1990, 1992, 2000, 2003) drought was harmful to not only some crops but it turned the whole Pannonian Plain, or major parts of it, into an arid region.

The need for irrigation is evident since droughts occur frequently, cover vast expanses, significantly reduce yields and cause extensive damage in crop production and agriculture in general.

Materials and methods

Methods and techniques of drought mitigation are studied at Institute of Field and Vegetable Crops in Novi Sad and other Institutes in Serbia. Irrigation requirements and irrigation effects on the yields of several fields' crops were analyzed in trials with and without irrigation in the same institutes. The analyzed data cover a long period but our attention will be focused on the dry years.

Results and discussion

Climatic conditions and drought intensity - Precipitation amounts and distribution per hydrological year for the Vojvodina Province where concentrate agricultural production were monitored in Novi Sad in the period from 1923/1924 to 2006/2007 – 84 years (Table 1).

Table 1. Mean hydrological annual, seasonal and monthly sum of precipitation (mm) in northern Serbia (Novi Sad) in the period 1923/1924-2002/2003†

Month	Average	Variation (mm – year)	Month	Average	Variation year; (mm – year)
X	49	0 – 1961/1962 155 – 1932/1933	IV	50	0 – 2007 127 – 1933
XI	54	7 – 1986/1987 156 – 1952/1953	V	62	5 – 1948 185 – 1933
XII	50	3 – 1972/1973 150 – 1969/1970	VI	78	6 – 1938 233 – 2001
I	38	28 – 1928/1929 102 – 1987/1988	VII	60	2 – 1928 193 – 1991
II	37	2 – 1987/1988 113 – 1932/1933	VIII	58	1 – 1992 148 – 1972
III	40	0 – 1929/1930 119 – 1932/1933	IX	44	1 – 1947 162 – 2001
Winter period	268	105 – 1972/1973 438 – 1956/1957	Growing season	352	138 – 2000 683 – 2001

† Mean annual sum: 620 mm, minimum 270 (2000/2001), maximum 931 (2001/2002).

Precipitation distribution during growing season is another important factor determining the occurrence of drought. In summer, precipitation typically occurs in the form of showers, which provide a small percentage of effective water to plants. When drought occurs in three consecutive years, the consequences are devastating. The average precipitation sums for 10 series of three consecutive hydrological years with minimum precipitation sums in the period 1924-2003 were 510, maximum 560, and minimum 465 mm (Dragović *et al.*, 2004).

The evaluations of drought intensity according to mean annual or growing-season precipitation sums are not realistic indicators in contrast to the analysis according to precipitation sums in July and August in which period plant water requirements are highest. This was confirmed by the drought analysis for the Vojvodina Province made by Dragović (1995).

The main reason for the low and unstable yields in Serbia is the variation in the amount of precipitation during growing season, i.e., because of water deficit relative to plant water requirements.

In northern Serbia, severe droughts are typically accompanied by high air temperatures. In 1994, there were 74 tropical days. In August alone, there were 23 tropical days and the temperatures in 15 days exceeded 33°C. During these tropical days, soil temperature at the depth of 5 cm was 4-5°C higher than air temperature, while relative air humidity dropped below 30%.

In exceedingly dry years of 2002 and 2003, the months of July and August had 23 and 37 days, respectively, with maximum temperatures above 30°C, (Dragović *et al.,* 2004). In eastern Serbia where droughts are most frequent and most severe, there were 35 tropical days per year on average in the period 1970-2003 (Maksimović and Dragović, 2002).

Rainfall analysis for July and August for the period of 84 years (1924-2007) in Vojvodina Province, shows that 70 years or 83.35% and 71 years or 84.50% of the years had the monthly precipitation under 100 mm in July and August, respectively. That particular precipitation level was chosen because most annual field crops as well as most perennial crops have their monthly water requirements in July and August over 100 mm (Dragović, 2000). There were 52.40% of extremely dry years with less than 50 mm in July and 48.80% with less than 50 mm in August (Table 2).

Table 2. Percentage of dry years according to rainfall sum in northern Serbia (Province of Vojvodina) for July and August (1924-2007)

Rank	July		August		Category
(mm)	No	%	No	%	
0-25	13	15.50	17	20.25	Extremely dry
26-50	31	36.90	24	28.55	Very dry
51-75	17	20.20	19	22.60	Dry
75-100	9	10.70	11	13.10	Moderately dry
Subtotal	70	83.35	71	84.50	Total dry
101-125	7	8.35	10	11.90	Moderately rainy
>126	7	8.35	3	3.60	Rainy
Total	84	100.00	84	100.00	

Various scientific procedures and disciplines are employed to counteract and mitigate the negative effects of drought. Irrigation is the most reliable tool of drought control, regardless of drought intensity and duration. However, the irrigated land is limited while drought strikes a much wider area. This ratio is not likely to be changed in near future.

In the climatic conditions of the Serbia, irrigation is a supplementary practice that favorable affects the yield performance and stability of cultivated crops, especially in dray years. Effects of irrigation and cultural practices vary from one year to another. Annual yield variations are pronounced with favorable years, yield losses in dry years may range from a few percents to 50%, while in years with extremely severe droughts the losses may be as high as 80-100%. Positive effects of irrigation are evident, to a variable degree, almost every year, while in extremely dry years irrigation doubles or even 3-4 times higher yields of field's crops than those in the non-irrigated conditions.

Drought impact on the yields of several field crops was analyzed in trials with and without irrigation. The trials had been conducted for a long period but our attention will be focused on the very dry years that occurred after 1990 (Table 3).

The most extensive damage caused by drought in the periods 1988-1994 and 2000-2003 in Serbia was registered in 1990 and it amounted to 873 million US dollars i.e., 3.5% of total national income. Drought damage in 1993 was estimated at half a billion US dollars and in 2003 at one billion dollars, (Dragović *et al.*, 2004). Analyzing crop performance in the Vojvodina Province, Bošnjak (1997) concluded that the genetic yield potential of rain fed crops is reduced by 50%.

Among the other scientific disciplines employed in drought control, the most important are genetics and plant breeding. They produce drought resistant or tolerant genotypes, i.e., cultivars capable of maintaining a high yield level in dry conditions. Physiological, biochemical, agro ecological, cultural and other mechanisms are equally important.

Table 3. Yields of field crops in trials with and without irrigation, on loamy soil, in dry years

Crop	Year	Yield in irr. (t/ha)	Yield without irr. (t/ha)	Effect of irrigation (t/ha)	(%)
Corn	1990	17.8	7.1	10.7	150
	1992	14.5	8.5	6.0	70
	1993	14.6	5.6	9.0	160
	1994	13.0	10.0	3.0	30
	2000	14.3	8.3	6.0	73
	2002	14.1	10.6	3.5	33
	2003	12.6	9.2	3.4	37
	Average	14.4	8.5	5.9	79
Sugar beet	1990	81.3	54.0	27.3	50
	1992	79.2	39.9	39.3	98
	1993	101.9	66.0	35.9	54
	1994	123.3	65.8	57.5	87
	2000	76.6	33.2	43.4	131
	2002	77.1	77.6	29.5	62
	2003	94.5	65.3	29.2	45
	Average	90.6	57.4	37.4	75
Soybean	1990	4.2	0.9	3.3	366
	1992	4.7	2.6	2.1	84
	1993	4.5	2.8	1.7	62
	1994	5.3	3.2	2.1	66
	2000	5.1	2.8	2.3	82
	2002	5.0	2.8	2.2	78
	2003	4.8	3.1	1.7	55
	Average	4.8	2.6	2.2	113

Conclusion

Drought regularly occurs over large areas in the agricultural regions of the Serbia. These regions have changeable, unstable rainfall, and very often dry periods during June, July and August. High air temperatures, hot and dry winds, increased plant water requirements, and soil moisture levels below the wilting point also characterize these dry periods. All these phenomena affect plant growth and development and considerably reduce yields of most crops.

Irrigation plays the key role in drought mitigation and increasing crop yields, from a few percents to 100% or more, its expression depending on drought intensity.

Effective drought mitigations achieved by development of hybrids and varieties tolerant or good resistant to drought, by appropriate cultural practices.

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