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UPPER EXTREMES OF THE RAINLESS PERIODS IN BANAT AND SREM

Gornji ekstremi beskišnih perioda Banata i Srema

VERICA NEŠKOVIĆ-ZDRAVIĆ, EMIR ZELENHASIĆ, MILICA BERIĆ
University of Novi Sad - Faculty of Agriculture
Institut for Water Resources Development and Management
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Abstract: The Zelenhasić-Todorović method of describing and analysing the extremes in hydrology, which is modified for extreme dry weather intervals, is presented. The basic assumption of the method is that the extreme dry weather intervals are independent, identically distributed random variables and that their occurence is subject to the Poisson probability law. According to the theory of supreme of random number of random variables, the explanation and analyses of the largest rainfall deficit and the largest drought is obtained by the Zelenhasić-Todorović method for given location. Application of the method is performed on the records of 13 meteorological stations in Banat and Srem, Yugoslavia, for period 1949-1985. The relations between dry weather intervals and field crops yield, as well as between dry-weather intervals and mean daily air temperature and relative air humidity during these intervals are investigated.

Key words: rainless period, dry weather interval, drought, yield

Sažetak: U radu je pretstavljen metod Zelenhasić-Todorović za opisivanje i analizu ekstrema u hidrologiji koji su modifikovani za ekstremne sušne periode. Osnovna postavka metoda je da su ekstemni sušni periodi nezavisne identično raspoređene slučajne promenljive i da je njihova pojava predmet Poasonovog zakona verovatnoće. Sledeći teoriju supremuma slučajnog broja slučajno promenljivih objašnjenja i analize najvećeg deficita padavina i najveće suše je za datu lokaciju dobijeno primenom metoda Zelenhasić-Todorović. Primena metoda je prikazana na podacima sa 13 meteoroloških stanica u Banatu i Sremu, Jugoslavija, za period 1949-1985. U radu su analizirani odnosi između sušnih perioda i prinosa ratarskih kultura kao i između sušnih perioda i srednje dnevne temperature vazduha i srednje dnevne relativne vlažnosti vazduha tokom ovih intervala.

Ključne reči: beskišni period, sušni period, suša, prinos

1. INTRODUCTION

Zelenhasić - Todorović method (Zelenhasić E., 1970., Todorović P., Zelehasić E. 1970.) modified for dry weather intervals represents the method by which dry weather interval during growing season, on certain meteorological station, is completely described and analysed. All important components of the drought period processes such as their duration, time of occurence, their total number during growing season, the largest dry weather interval duration in growing season and time of its occurence are taken into consideration by this method. In this paper, drought periods are defined as the upper extremes of the rainless periods and they are treated as a random number of random variables. The method on the assumption that dry weather intervals are independent, identically distributed random variables and that their occurence is subject to the Poisson probability law which is confirmed by the analysed examples.

Method is applied on the growing season period and obtained results are of importance for climate and meliorative systems definition as well as for agricultural sowing time planning. One of the basic postulations of this method is to single out the extreme time interval of the rainless periods exceeding adopted reference level in order to analyse dry weather intervals.

By the application of this method general stochastic model of dry weather intervals was tried to be developed, explained and it was based upon the definition by which the occurrence, duration and extent of the dry weather interval are measured from certain adopted reference level. For the adoption of these values sensitiveness of agricultural cultures to the lack of water, which in our conditions lasts 15 days, was considered (Berić M., et al. 1987).

On each meteorological station the following can be determined:

- ordinal number of the dry weather intervals during growing season,
- total number of the dry weather intervals during growing season,
- the time of the dry weather interval beginnig,
- the time of the dry weather interval ending,

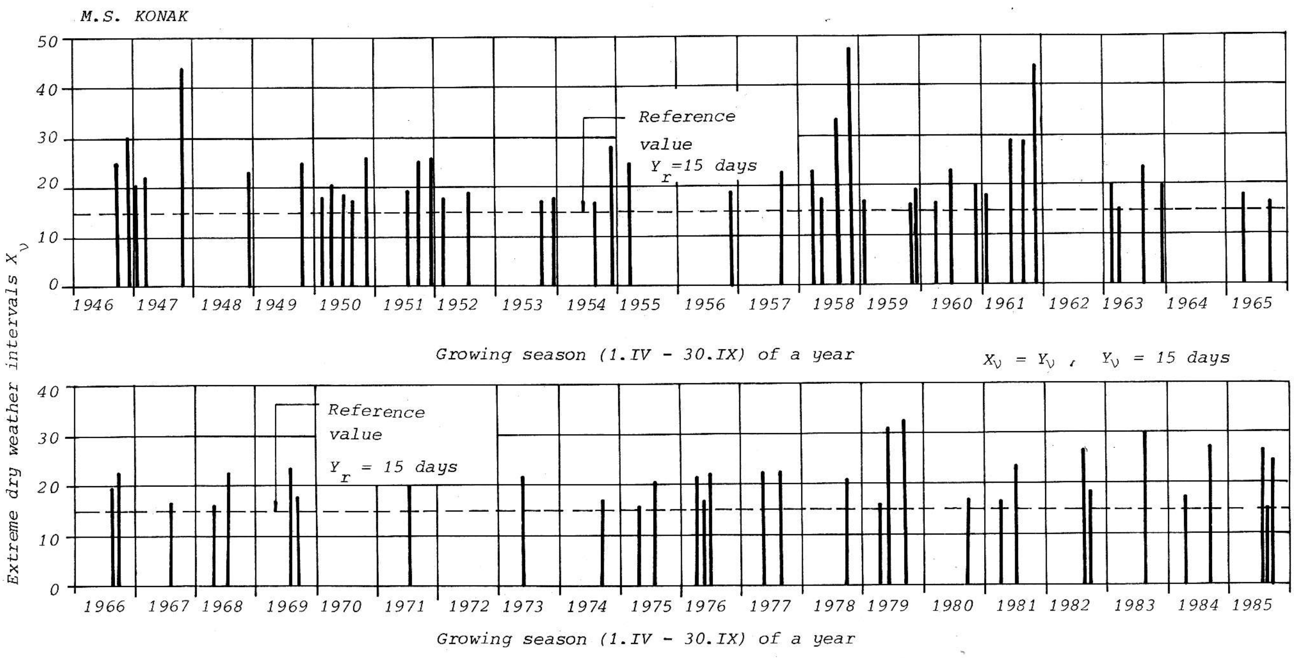


Fig. 1. Observed extreme dry weather intervals at Konak during the growing season.
Sl. 1. Hronološki prikaz sušnih perioda za Konak i okolinu u toku vegetacione sezone.

- the time of the dry weather interval occurrence corresponding to the middle of the interval from the begining to the time of the end of the dry weather interval,
- duration of the dry weather interval during growing season,
- the largest dry weather interval during growing season and
- the time of the largest dry weather interval occurrence during growing season.

For so defined dry weather intervals the Zelenhasić-Todorović method is applied. The method has been applied on thirteen meteorological stations in Banat and Srem, but only the results from meteorological station Konak are shown.

Further explanations concerning theoretical background can be found in the previous works of Zelenhasić and Todorović (Zelenhasić E., 1970, Todorović P. et al., 1970, Zelenhasić E. et al, 1986. Todorović P., et al, 1972)

2. TEST OF RANDOMNESS AND SERIAL CORRELATION

A hypotesis stating that dry weather intervals are independent and identically distributed random variables was verified and accepted applying the run test at the 5% significance level. The test has shown that initial hypotesis can not be discarded. The test of R.L. Anderson confirmed that dry weather intervals are independent. The degree of correlation among certain data is practically negligible.

3. DISTRIBUTION OF THE NUMBER OF DRY WEATHER INTERVALS

With successful elaboration of his model Zelenhasić secured the importance of Poisson distribution in this method. Test of conformance of the theoretical distributions to the observed distribution at the 5% significance level indicates a good agreement of these two functions.

$$P\left(E_k^t\right)=\left\{\left|\Lambda_1(t)\right|^k\right\}k!^{-1}e^{-\Lambda(t)} \qquad (1)$$

where

E^t_k - the event that exactly k extreme rainless periods occur in [0,t] and where k = 0, 1, 2,

$\Lambda_1(t)$ - the mean number of extreme rainless periods in [0,t] where [0,t] = [April 1 - September 30] = 183 days

4. DISTRIBUTION OF DRY WEATHER INTERVAL DURATION

Observed and corresponding theoretical function of the distribution are shown on Figure 4. from which it could be seen that the exponential distribution gives a good fit to empirical (observed) distribution of dry weather interval duration. The Kolmogorov-Smirnov test confirmed the agreement between the two distribution functions.

$$B(z)=1-e^{\Lambda_2 z} \qquad (2)$$

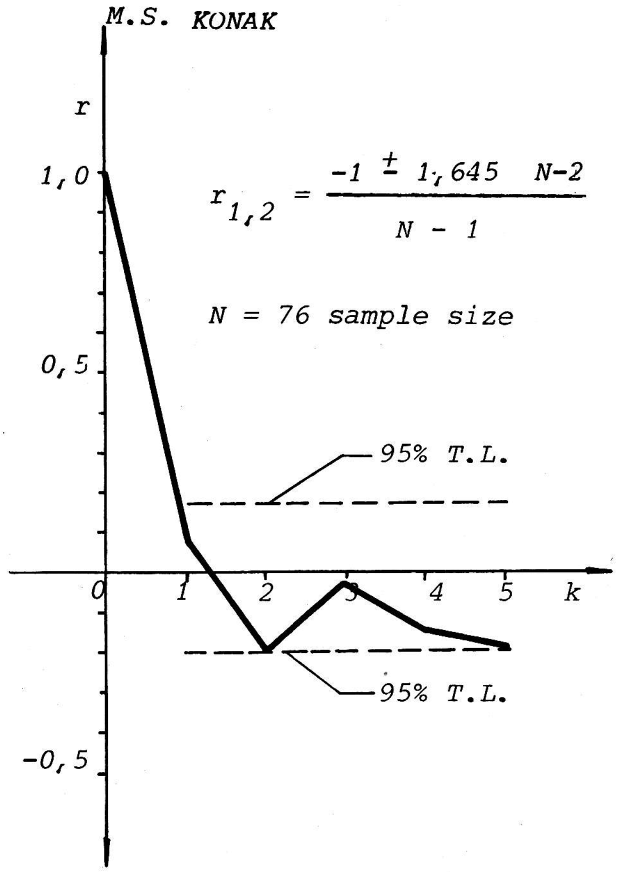


Fig. 2. Correlogram of drought durations in the growing season for Konak and its vicinity.
Sl. 2. Korelogram trajanja sušnih perioda u vegetacionoj sezoni za Konak.

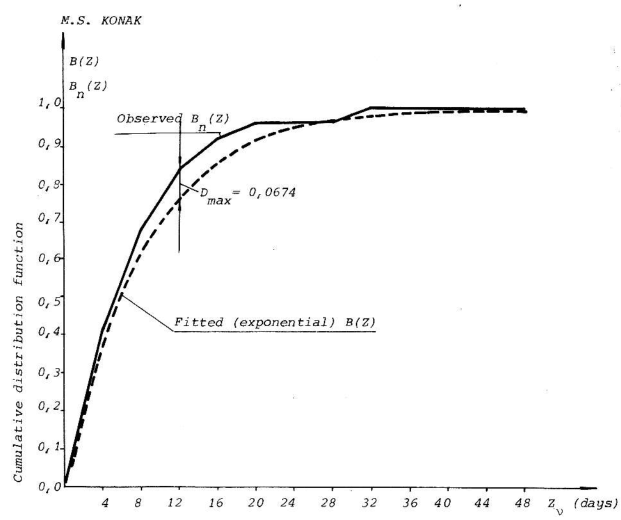


Fig. 4. The theoretical and observed distribution function of the random variable Y for the growing season at Konak.
Sl. 4. Teorijska i osmotrena funkcija raspodele veličine sušnog perioda za Konak.

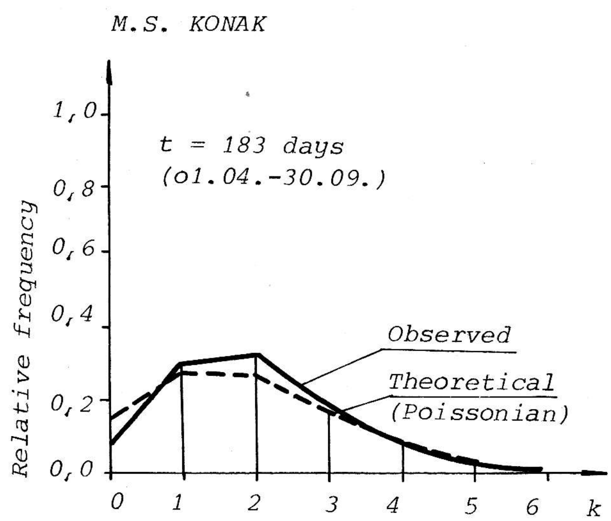


Fig.3. The observed and corresponding theoretical (Poissonian) distributions of the number of extreme dry weather intervals of the growing season at Konak.
Sl. 3. Teorijska (Poasonova) i osmotrena raspodela broja sušnih perioda vegetacione sezone za Konak.

where

Λ_2 - parameter which is estimated as $\Lambda_2 = z^{-1}$
z - extreme rainless period duration

5. DISTRIBUTION OF THE MAXIMUM DRY WEATHER INTERVALS

The distribution function of random variable highest value Z within the time interval (0,t):

$$F(Z/t) = e^{-\Lambda_1(t) e^{-0.19487\, z}} \qquad z \geq 0 \qquad (3)$$

where

$\Lambda_1(t)$ - the mean number of extreme rainless periods during the growing season

Λ_2 - parameter of distribution of extreme rainless periods duration during the growing season

Statistical tests according to Kolmogorov-Smirnov and χ^2 - test justified a good agreement between the two distributions functions.

6. DETERMINATION OF THE DRY WEATHER INTERVALS EXTREME VALUES

A mathematical dry weather interval of 2-, 5-, 10-, 20-, 50-, 100-year return period are shown of Figure 6. Diagrams are very applicable in practice because a return

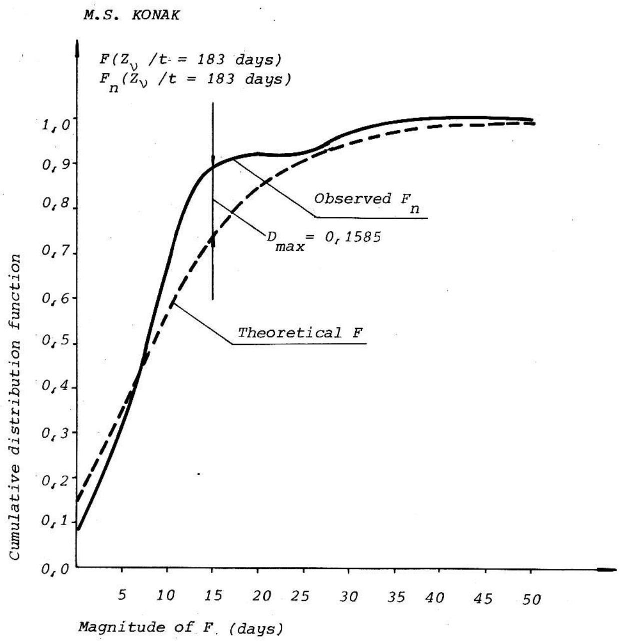


Fig. 5. The theoretical and observed distribution function of the random variable Z for the time interval (0,t) equal to the growing season at Konak.
Sl. 5. Teorijska i osmotrena funkcija raspodele ekscesa maksimalnih sušnih perioda u toku vegetacione sezone za Konak.

period for each, past and future, dry weather interval can be determined.

7. DISTRIBUTION OF THE TIME OF OCCURENCE OF THE MAXIMUM DRY WEATHER INTERVAL

$$F\{\tau(\max) \le u\} = 0.1246 + 0.4400\,\Delta(u) \qquad (4)$$

for the meteorological station Konak where

$\Lambda_1(t)$ - mean number of extreme rainless periods in the growing season

u - numerical value which is taken by random variable $\tau_{max}(t)$, and where $0 \le u \le t$ and u is given in days

$\Lambda(u)$ - value from Figure $\Lambda(t)$ (1)

$\tau_{max}(t)$- moment in time interval [0,t] when the longest extreme rainless period occured

Such given summary distribution function F, time of occurence of the maximum dry weather interval is compared to the empiric distribution function F_n. The

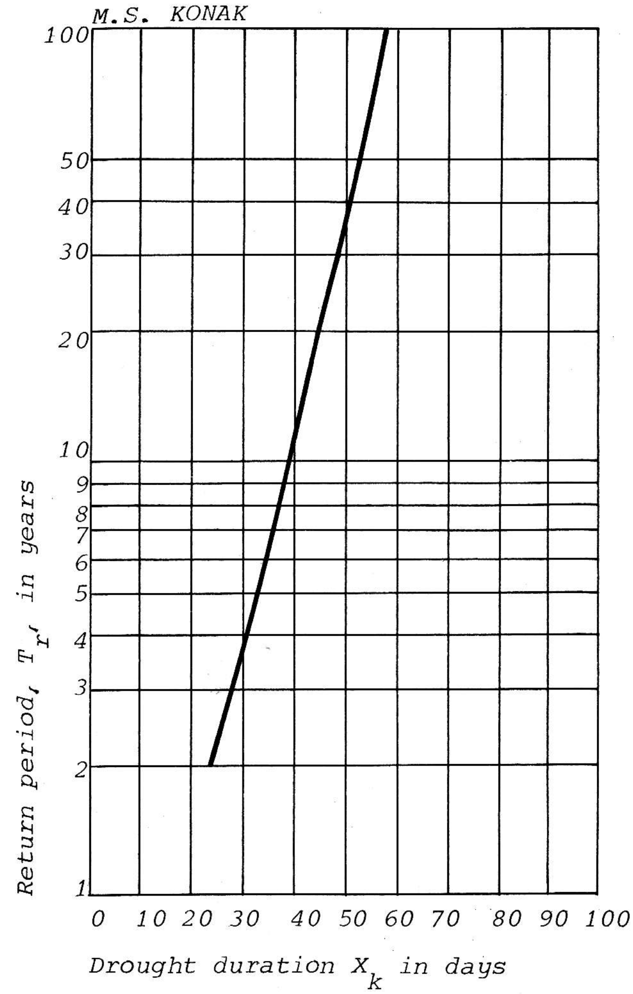


Fig. 6. Return periods of drought durations occuring in the growing season for Konak and its vicinity.
Sl. 6. Vrednosti računskih sušnih perioda različitih povratnih perioda tokom vegetacione sezone za Konak.

Kolmogorov-Smirnov test of the agreement between empiric and theoretical distribution functions gave satisfactory values at the 5% significance level.

As final result of the applied method we can consider the maps of the upper extrems of the rainless periods having 2-, 5-, 10-, 20-, 50-, 100-year return period for Banat and Srem.

After such obtained results the connection and relation between dry weather intervals and crops of the agricultural cultures: wheat, corn, sugar beet and soya beans were investigated. The analyses were done for the whole growing season and for the "critical periods" for the plants. The connection between the dry weather intervals and the crops was established for soya beans only.

All the analyses of interrelation between dry weather intervals and crops did not show strong connection from which it might be concluded that the influence of dry weather intervals on crops should not be observed apart from all other factors influencing the crops.

Further analysis was directed to establish relation between dry weather intervals and meteorogical elements: average daily temperature of air during dry weather

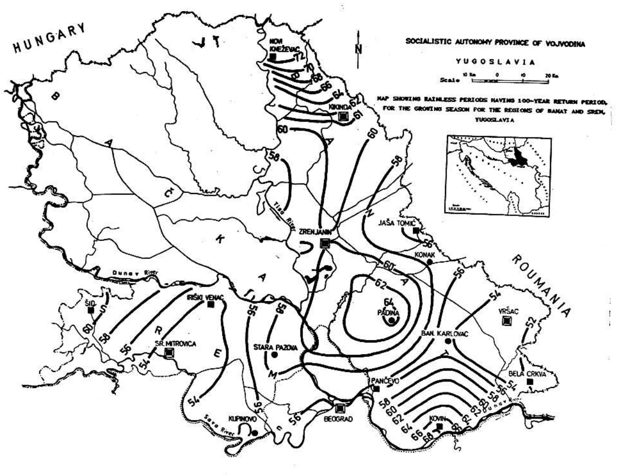


Fig. 8. Map showing rainless periods having 2-year return period, for the growing season for the regions of Banat and Srem.

Sl. 8. Izolinije trajanja sušnih perioda 2-godišnjeg povratnog perioda, tokom vegetacione sezone za Banat i Srem, Jugoslavija

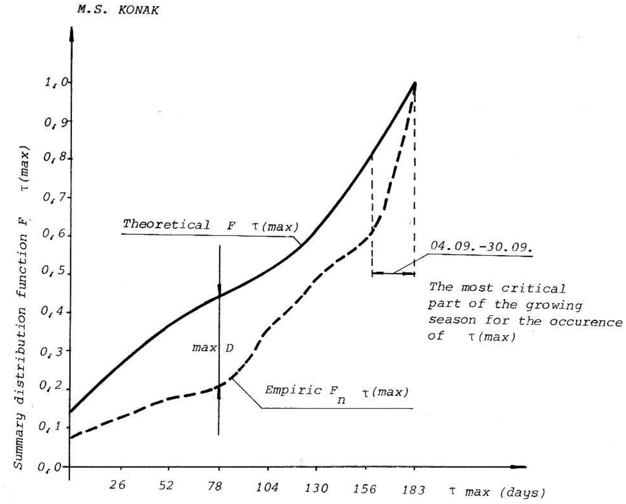
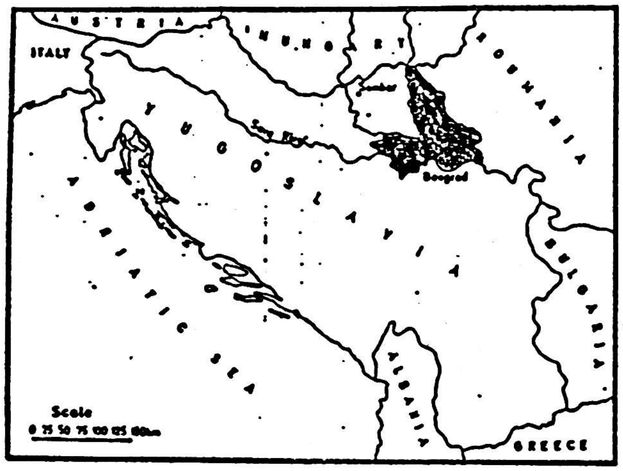


Fig. 7. Summary function of the distribution of the time of occurence of the maximum dry weather interval during growing season for Konak and vicinity.

Sl. 7. Sumarna funkcija raspodele vremena pojave maksimalnog sušnog perioda u toku vegetacione sezone za Konak.



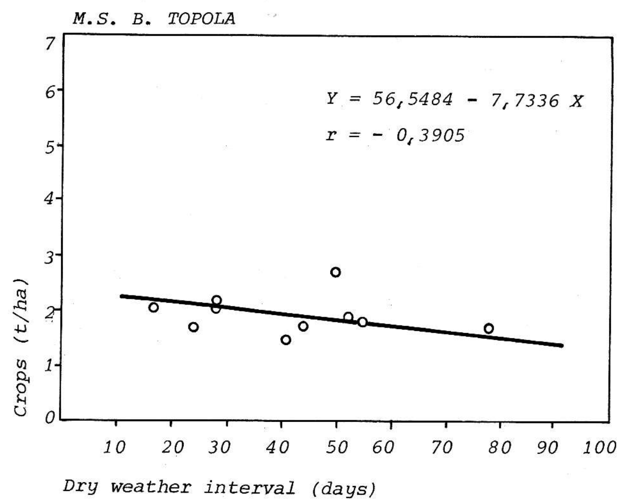


Fig.10. Correlations between dry weather interval duration and soya beans crops.

Sl. 10. Korelaciona zavisnost trajanja sušnih perioda i prinosa ratarske kulture soja.

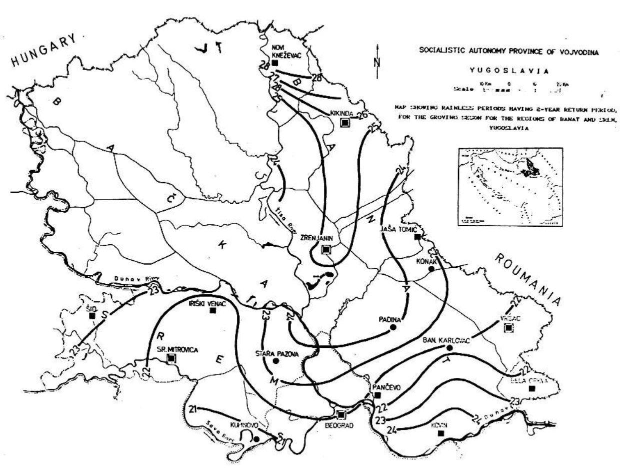


Fig. 9. Map showing rainless periods having 100-year return period, for the growing season for the regions of Banat and Srem.

Sl. 9. Izolinije trajanja sušnih perioda 100-godišnjeg povratnog perioda, tokom vegetacione sezone za Banat i Srem, Jugoslavija.

Table 1. Coefficient of correlation between dry weather intervals, drying "critical periods", and sugar beet, corn and wheat crops.

Tabela 1. Koeficijent korelacije sušnih perioda tokom "kritičnih perioda", iprinosa šećerne repe, kukuruza i pšenice.

Station	Sugar beet	Corn	Wheat crops
NOVI KNEŽEVAC	0,4999	0,6033	0,2990
ZRENJANIN	0,8081	0,3848	0,8295
KIKINDA	0,2913	0,6164	0,2255

Table 2. Coefficient of correlation between dry weather interval and average daily air temperature during dry weather intervals.
Tabela 2. Koeficijent korelacije sušnih perioda i srednje dnevne temperature vazduha u toku sušnih perioda

Meteorological station	Coefficient of correlation
VRŠAC	0,2597
ZRENJANIN	0,5115
KIKINDA	0,5700
SREMSKA MITROVICA	0,1696
BEOGRAD	0,3340

Table 3. Coefficients of correlation between dry weather intervals and air humidity
Tabela 3. Koeficijent korelacije sušnih perioda i relativne vlažnosti vazduha.

Meteorological station	Coefficient of correlation
VRŠAC	0,4744
ZRENJANIN	0,3371
KIKINDA	0,5778
SREMSKA MITROVICA	0,1456
BEOGRAD	0,3830

EXAMPLE
PRIMER
Meteorological station ZRENJANIN
Time of observation (1956-1985)
Meteorološka stanica ZRENJANIN
Period osmatranja (1956 - 1985.)

Year	Dry weather interval	Dry weather interval duration	Average daily air temperature
1962.	17.07. - 08.09.	54	22.5
1981.	27.07. - 21.08.	26	22.5
1961.	18.08. - 30.09.	44	18.6
1973.	30.08. - 19.09.	21	18.5

intervals and average daily relative air humidity during dry weather intervals. From the shown results it could be seen that there is no strong connection between the obtained values for dry weather intervals and given meteorological elements which is the result of insignificant vacillation of the average daily air temperature during dry weather intervals of different duration period (example) and little swaying of the values for the average daily relative air humidity during dry weather intervals. Apart from this, because of the complex circulation of air mass and their different direction, dry weather intervals in Yugoslavia are of different origin. Hence, those originating from the south circulation are of higher temperature than those formed from west or northeast streaming.

8. CONCLUSION

All important components of dry weather intervals such as their total number in a given time interval-growing season, their average number, their duration, the longest period of dry weather intervals and its time of occurrence are obtained by analysis of dry weather intervals for 13 meteorological stations in Banat and Srem, Yugoslavia. These analyses are carried out for each of meteorological stations in detail.

Using results obtained by the Zelenhasić-Todorović method and with applying interpolation technique, regional analysis of extreme dry weather intervals for Banat and Srem resulted in maps of 2-, 5-, 10-, 20-, 50- and 100-year return period. As an illustration two maps are given here: for 2- and 100- year return period (Figure 8 and 9).

All the analyses of interrelation between dry weather intervals and field crops yield, as well as between dry weather intervals and given meteorological elements, did not show strong connection. From these results it could be concluded that exept dry weather intervals field crops yield are influenced by some other factors.

Air temperature and relative air humidity must be combined with quantity of climates elements, and then it could be possible to find connection between dry weather intervals and these elements.

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KRATKI SADRŽAJ

Sve važne komponente sušnih perioda kao što su njihov ukupan broj u datom vremenskom intervalu - vegetaciona sezona, njihov prosečan broj, veličina, najduži sušni period i vreme njegove pojave dobijeni su analizom sušnih perioda za 13 meteoroloških stanica Banata i Srema, Jugoslavija. Analiza je sprovedena detaljno za svaku od meteoroloških stanica.

Kao krajnji rezultat sprovedene analize metodom Zelenhasić-Todorović i primenjujući tehniku interpolacije dobijene su karte 2-, 5-, 20-, 50- i 100- godišnjih sušnih perioda za Banat i Srem. Za ilustraciju ove regionalne analize u ovom radu date su karte 2- i 100- godišnjih sušnih perioda (slike 8 i 9). Sve analize međusobne veze između sušnih perioda i prinosa ratarskih kultura kao i prinosa i datih meteoroloških elemenata (srednje dnevne temperature vazduha i srednje dnevne relativne vlažnosti vazduha tokom sušnih perioda) pokazuju da između njih nema jače veze.

Iz dobijenih rezultata se može zaključiti da osim sušnih perioda, prinos ratarskih kultura zavisi i od nekih drugih faktora, koji nisu analizirani u ovom radu. Temperatura vazduha i relativna vlažnost vazduha moraju biti kombinovane u analizama, ne samo sa sušnim periodima već i sa količinom padavina kao i sa ostalim klimatskim elementima, hidrološkim i zemljišnim i tada se može očekivati da sušni periodi pruže mogućnost procene prinosa.