10.7251/AGSY1203270K
UDK 502.3/.7+633(497.11)

# CLIMATE CHANGE IN SERBIA: DEPENDENCE OF WINTER WHEAT YIELD ON TEMPERATURES AND PRECIPITATION

Dusan KOVACEVIC[*1,4], Zeljko DOLIJANOVIC[1], Zivota JOVANOVIC[2], Vesna MILIC[3]

[1]University of Belgrade, Faculty of Agriculture, Zemun, Serbia
[2]Maize Research Institute, Zemun Polje, Beograd, Serbia
[3]University of East Sarajevo, Faculty of Agriculture, Republic of Srpska, Bosnia and Herzegovina
[4]Academy of Engineering of Serbia, Belgrade, Serbia
(Corresponding author: dulekov@agrif.bg.ac.rs)

## Abstract

High and quality yields of winter wheat, as well as other filed crops, largely depend on climatic conditions. Since climate provides good light conditions and sufficient heat energy in a greater part of Serbian territory, the success of the cultivation of this crop mainly depends on precipitation sums and their distribution.

The objective of the present study was to analyse temperature and precipitation regimes during the past two decades (1991-2010) and to determine the dependence of the average winter wheat yields on these climate parameters.

The analysis of temperature and precipitation regimes over full-year periods, growing seasons and three subperiods (autumn, winter and spring) during the 1990-2010 period show extremely dry years such as 1992/93, 1995/96, 2002/03 and 2006/07, but also extremely wet years such as 2003/04, 2008/09 and 2009/10, which also caused damages in crops.

The regression and correlation analysis of the simultaneous effect of observed factors on the winter wheat grain yield show statistical significance in autumn and during the growing season of winter wheat. The greatest dependence of winter wheat grain yield, expressed through the coefficients of correlation, is on autumnal and meteorological conditions during the growing season.

The regression equation shows that the 1-mm precipitation increase of autumnal, winter and total precipitation sums in the growing season resulted in grain yields increase with the exception of lower yields caused by spring rainfalls. Of the two observed meteorological conditions, air temperatures, particularly summer and temperatures during the winter wheat growing season, had greater effects on grain yields.

**Keywords**: *climate changes, temperature, precipitation, winter wheat yield, Serbia*

## Introduction

The effects of a year on winter wheat cannot be avoided. Weather conditions during each production year significantly affect plants directly or indirectly through the soil. In recent decades, abiotic extremes caused by climate factors have had stress effects on filed crops (Kovacevic et al., 2005).

It is necessary to reconsider the following each year: the applied agricultural management systems in all crops, each cropping practice, the period of its application that is meeting deadlines, types of tools, proper selection of cultivars and hybrids for certain regions, level intensities of wheat growing practices (high- and low-inputs), optimum sowing density, amounts of applied agrochemicals (fertilisers, pesticides), good agricultural practice.

The application of cropping practices can provide the undisturbed growth and development of grain crops and can neutralise extreme abiotic climate factors (precipitation, temperature) and their stress effects on crops (Kovacevic et al., 2009, 2010a; Dolijanovic et al., 2006; 2008).

The most powerful cropping practices related to winter wheat cultivation are: tillage systems, proper selection of fertilising methods in accordance with requirements of winter wheat plants, optimum sowing dates, selection of cultivars, optimum vegetation space for each plant as well as crop cultivation during the growing season, protection against pests, weeds and diseases, etc. All stated cultivation elements affect yield either individually, collectively or synergistically, but the optimum sowing date is one of the most important element. Furthermore, very important elements are fertilising and mineral nutrition necessary for cultivars of grain crops (Malesevic et al. 2008). Irrigation is the only efficient measure against drought. However, it is known that wheat is an extensive crop with the lowest inputs, but also with the lowest income, hence irrigation under our conditions is mainly applied to intensive or seed crops that provide greater yields and income.

Under climate conditions of our country, winter wheat primarily develops when there is a sufficient or even surplus amount of precipitation. The precipitation surplus adversely affects winter wheat. If there is a precipitation deficit the following indirect measures, which resulted in reduced water requirements by grain crops are employed: balanced NPK nutrition, optimum nitrogen rates, optimum density in accordance with cultivar properties and climate conditions, well developed crop free of disease and pests. The selection of a proper cultivar for certain agroecological conditions is increasingly important, because not only dry but also extremely wet years last in a longer period of time. These extremely wet years also cause problems that need to be solved with different agromelioration measures (Kovacevic et al., 2010b). All cultivars have a high potential for yield, but resistance to stress conditions, especially to high temperatures or drought, will be a very important criterion, particularly for more arid regions.

## Material and methods

The data from Republic Hydrometeorological Service of Serbia (precipitation and air-temperature, initial data series for Belgrade territory in period 1991-2012 are transformed in average in the growing season and three subperiods: autumn, winter and spring) and Statistical Office of the Republic of Serbia (Statistical Yearbooks: winter wheat yields for central part of Serbia) were used for this study.

The obtained data were statistically processed by the multiple regression analysis and the correlation analysis using the software package Statistica V5.5. Based on the equation of the linear regression model ($\hat{y}_i=a+b_1*x_1+b_2*X_2$), the average change (increase or decrease) in wheat grain yield was established in dependence on air temperatures ($b_1$) and total precipitation sums ($b_2$). Testing differences of partial regression coefficients by the t test ($b_1$ and $b_2$: $H_0$:$ß_1$=0 vs. $H_a$:$ß_1$#0 and $H_0$:$ß_2$=0 vs. $H_a$:$ß_2$#0) shows that these differences were statistically significant. The significance of the linear regression model was tested by the F test ($H_0$:$ß_1$=$ß_2$=0 vs. $H_a$:$ß_1$#0 ν $ß_2$#0) and the simultaneous effect of temperatures and precipitations on winter wheat grain yield was established. The correlation dependence between variables was tested by the coefficient of multiple correlation (dependence of yield on the simultaneous effects of temperatures and precipitations) and by the coefficient of partial correlation (dependence of yield on the effect of one factor whereby the effect of the second factor was not considered). Testing of significance of correlation coefficients was done by the F and t tests.

## Results and discussion

In our country, the precipitation distribution in the crop cultivation under rainfed conditions has very often a decisive effect on the occurrence of longer or shorter dry spells. The favourable precipitation distribution during the year is the distribution that provides a proportionally large numbers rainy days and equal intervals between rainy and rainless periods, particularly during the growing season. The occurrence of longer rainless periods in spring and autumn, especially in years with dry summers, when drought continues from summer into autumn, regularly affects grain crops due to uneven and long emergence. Under conditions of our climate, the greatest precipitation sums are recorded in June. If precipitation sums are well distributed over decades and if there are rainfalls during July, maize - our most important crop - rarely suffers from drought. Insufficiency of precipitation in July, and later on, a longer rainless period accompanied with high temperatures and heat waves cause the greatest problems (Spasov and Spasova Danica, 2001).

Table 1. Mean temperature and precipitation in different periods of winter wheat growing season and average grain yield in the region of Central Serbia (1991-2011)

| Year | Temperature ($^oC$) | | | | Precipitation in mm | | | | Average grain yield |
|---|---|---|---|---|---|---|---|---|---|
| | autumn | wint. | spring | grow. season | autumn | wint. | spring | grow. season | |
| | X-XII | I-III | IV-VI | X-VI | X-XII | I-III | IV-VI | X-VI | |
| 1991/92 | 6.0 | 3.7 | 17.2 | 9.0 | 178.6 | 48.0 | 258.2 | 484.8 | 2.8 |
| 1992/93 | 6.5 | 5.9 | 18.1 | 8.9 | 187.0 | 130.8 | 91.9 | 409.7 | 2.8 |
| 1993/94 | 7.4 | 6.0 | 17.4 | 10.3 | 185.5 | 91.1 | 318.2 | 594.8 | 3.8 |
| 1994/95 | 7.4 | 5.2 | 16.6 | 9.7 | 108.2 | 172.0 | 209.3 | 489.5 | 3.1 |
| 1995/96 | 6.6 | 1.8 | 16.3 | 7.8 | 124.4 | 146.0 | 217.4 | 487.8 | 2.2 |
| 1996/97 | 8.1 | 3.6 | 15.6 | 9.1 | 215.6 | 93.6 | 169.0 | 478.2 | 3.4 |
| 1997/98 | 7.8 | 4.9 | 17.1 | 9.9 | 217.0 | 102.8 | 142.6 | 462.4 | 3.4 |
| 1998/99 | 4.9 | 3.8 | 16.8 | 8.5 | 175.4 | 145.3 | 273.2 | 593.9 | 2.9 |
| 1999/00 | 6.4 | 4.1 | 19.6 | 10.0 | 273.6 | 85.9 | 95.5 | 455.0 | 2.5 |
| 2000/01 | 10.6 | 7.1 | 16.4 | 11.4 | 78.5 | 128.1 | 390.9 | 597.5 | 3.0 |
| Average | 7.2 | 4.6 | 17.1 | 9.5 | 174.4 | 114.4 | 216.7 | 505.4 | 2.7 |
| 2001/02 | 5.9 | 7.1 | 18.4 | 10.5 | 114.0 | 43.0 | 156.0 | 313.0 | 2.2 |
| 2002/03 | 9.0 | 2.1 | 19.6 | 10.2 | 167.0 | 88.0 | 95.0 | 350.0 | 3.8 |
| 2003/04 | 8.3 | 3.9 | 16.8 | 9.7 | 195.0 | 145.7 | 238.9 | 579.6 | 3.1 |
| 2004/05 | 9.5 | 2.4 | 17.0 | 9.6 | 210.7 | 172.0 | 195.0 | 577.7 | 2.9 |
| 2005/06 | 8.2 | 3.0 | 17.3 | 9.5 | 133.0 | 206.0 | 274.0 | 613.0 | 2.7 |
| 2006/07 | 10.1 | 8.8 | 19.6 | 12.9 | 94.0 | 189.0 | 191.0 | 474.0 | 4.4 |
| 2007/08 | 6.4 | 6.6 | 18.8 | 10.6 | 269.0 | 131.0 | 141.0 | 541.0 | 3.7 |
| 2008/09 | 10.2 | 4.0 | 19.0 | 11.1 | 147.0 | 201.0 | 193.0 | 541.0 | 3.3 |
| 2009/10 | 9.8 | 4.5 | 17.9 | 10.7 | 285.0 | 246.0 | 306.0 | 837.0 | 3.9 |
| 2010/11 | 8.4 | 3.9 | 18.1 | 10.1 | 155.0 | 119.0 | 114.0 | 388.0 | 3.0 |
| Average | 8.6 | 4.6 | 18.2 | 10.5 | 177.0 | 154.1 | 190.3 | 521.4 | 3.3 |
| Differ. | 1.4 | 0 | 1.1 | 1.0 | 2.6 | 39.7 | -26.4 | 16.0 | 0.6 |

Under conditions of a favourable precipitation distribution during the growing season it is not necessary that the annual precipitation sum is high.

Table 2. Results of statistical analysis in winter wheat

| | | |
|---|---|---|
| Effects of average autumnal air temperatures and total autumnal precipitation sums on grain yields | | |
| Tabular values: $F_{0.05;2;17}$=2.63; $F_{0.01;2;17}$=6.23; $t_{0.05;17}$=2.11; $t_{0.01;17}$=2.898 | | Evaluation of significance |
| Equation of multiple linear regression | $Y_i=1.065 + 0.200X_1 + 0.0029X_2$ | $F=4.4674^{*}$ |
| Regression coefficient | $b_1=0.200$; $b_2=0.0029$ | $t_{b1}=2.840^{*}$; $t_{b2}=1.465^{ns}$ |
| Coefficient of multiple linear correlation and coefficient of determination | $R_{0.12}=0.5869$<br>d= 34.45% | $F=4.455^{*}$ |
| Coefficient of partial determination | $r_{01.2}= 0.567$; $r_{02.1}=0.335$ | $t_{01.2}=2.840^{*}$; $t_{02.1}=1.465^{ns}$ |
| Effects of average winter air temperatures and total winter precipitation sums on grain yields | | |
| Equation of multiple linear regression | $Y_i=2.134 + 0.115X_1 + 0.0036X_2$ | $F=2.5373^{ns}$ |
| Regression coefficient | $b_1=0.115$; $b_2=0.0036$ | $t_{b1}=1.721^{ns}$; $t_{b2}=1.546^{ns}$ |
| Coefficient of multiple linear correlation and coefficient of determination | $R_{0.12}=0.4795$<br>d= 22.99% | $F=2.538^{ns}$ |
| Coefficient of partial determination | $r_{01.2}= 0.385$; $r_{02.1}=0.351$ | $t_{01.2}=1.721^{ns}$<br>$t_{02.1}=1.546^{ns}$ |
| Effects of average spring air temperatures and total spring precipitation sums on grain yields | | |
| Equation of multiple linear regression | $Y_i=-1.261 + 0.224X_1 + 0.0022X_2$ | $F=1.6667^{ns}$ |
| Regression coefficient | $b_1=0.224$; $b_2=0.0022$ | $t_{b1}=1.797^{ns}$ $t_{b2}=1.195^{ns}$ |
| Coefficient of multiple linear correlation and coefficient of determination | $R_{0.12}=0.4049$<br>d= 16.39% | $F=1.667^{ns}$ |
| Coefficient of partial determination | $r_{01.2}= 0.399$; $r_{02.1}= 0.278$ | $t_{01.2}=1.797^{ns}$<br>$t_{02.1}=1.195^{ns}$ |
| Uticaj prosečnih temeperatura vazduha i ukupnih količina padavina u vegetacionom periodu na prinos<br>Effects of average air temperatures and total precipitation sums during the growing season on grain yields | | |
| Equation of multiple linear regression | $Y_i=-0.597 + 0.312X_1 + 0.0012X_2$ | $F=6.8795^{**}$ |
| Regression coefficient | $b_1=0.312$; $b_2=0.0012$ | $t_{b1}=3.348^{**}$; $t_{b2}=1.340^{ns}$ |
| Coefficient of multiple linear correlation and coefficient of determination | $R_{0.12}=0.6688$<br>d= 44.73% | $F=6.879^{**}$ |
| Coefficient of partial determination | $r_{01.2}= 0.630$; $r_{02.1}=0.309$ | $t_{01.2}=3.348^{**}$; $t_{02.1}=1.340^{ns}$ |

*, ** significantly difference at $p \leq 0.05$ and $p \leq 0.01$. $^{ns}$ not significantly difference

The analysis of the past 20 years shows that 1992/93, 1995/96, 2002/03 and 2006/07 (Table 1) were extremely dry years for winter wheat. However, observations of the whole growing season of winter wheat show that there were extremely wet years, such as 2003/04, 2008/09 and 2009/10, which also caused damages such as complete smothering of crops in haevy soil with waterlogging and outbreak of diseases, which significantly reduced the yield, aggravated harvest and decreased grain quality. The greatest problems related to moisture is insufficient precipitation sums during October and November, as they aggravate emergence, inhibit the growth and accelerate later winter wheat getting around through in the other qualitative stages of organogenesis.

These analyses in which the growing season was divided into three subperiods (Table 1) show the increase in the average temperature of 1.4 $^{o}$C and 1.1 $^{o}$C in the autumnal and spring period in the second decade (2001/02-2010/11) in relation to the first decade (1991/92-2000/01), respectively, while the winter average temperatures were equal. At the same time, the average winter temperatures were equal in both decades. The three-month cumulative precipitations were insignificantly higher in autumn (2.6 mm), significantly higher in winter (39.7 mm) and lower in spring (26.4 mm), which is especially important as early and later spring when is a critical period for moisture for grain filling. The average winter wheat yield regardless of variable conditions was higher by 0.6 t ha$^{-1}$ during the last decade.

Data on the 20-year average grain yields of winter wheat as well as the form and the intensity of the dependence of the yield on autumnal, winter, spring and meteorological conditions during the growing season are presented in Tables 1 and 2. The most significant dependence of the yield was established in the autumnal period and during the whole growing season in which the temperature increase of 1$^{o}$C resulted in the yield increase of 200 and 312 kg ha$^{-1}$, respectively. On the other hand, the precipitation increase of 1 mm resulted in the yield increase that was not significant and amounted to 2.9 and 1.2 kg ha$^{-1}$, respectively, while the changes during winter and spring were also positive (3.6 and 2.2 kg ha$^{-1}$, respectively). The simultaneous effect of both observed factors was statistically significant and very significant, due to, first of all, a great impact of air temperatures (Table 1). The lowest positive change in winter wheat grain yields depending on the temperature, i.e. precipitation sums, was observed in winter ($b_1$=0.115), i.e. during the growing season ($b_2$=0.0012) , respectively.

According to correlation coefficients and the dependence intensity, the lowest, insignificant dependence of the yield on the precipitation sums and average temperatures was observed during winter. This dependence was statistically significant in autumn and very significant during the whole growing season. Higher correlation coefficients in these periods can be mostly attributed to the greater effects of air temperatures that are presented by the values of coefficients of partial correlation ($r_{01.2}$=0.567 that is 0.630). Based on stated values of changes in wheat grain yields in relation to observed meteorological conditions, significance of air temperatures was significantly higher, particularly in autumnal months and during the growing season. Furthermore, according to data presented in Table 2, the differences between the two 10-year periods are greater in temperatures than in precipitation sums. The average precipitation sum for the growing season of 521.4 mm that is 505.4 mm is mostly sufficient to obtain optimum yields, because wheat can be successfully grown in regions with annual precipitation sums ranging from 650 to 750 mm and with their favourable distribution during the growing season.

The obtained correlation coefficients are significantly lower than coefficients established by Lithourgidis et al., (2006) who determined the very high dependence (r =0.71 and r =0.59) of winter wheat yields in 25-year continuous cropping on spring and total precipitation sums, respectively on sand soils. The corresponding values on clay soils amounted to r =0.89 and r =0.54. The equation of linear regression ($\hat{y}_i$=a + b*$x_i$) showed that the grain yield decrease in the 25-year period varied from 0.0054 to 0.0104 t ha$^{-1}$, depending on the soil type, which was mainly higher decrease than the one obtained in spring in our study (0.0013 t ha$^{-1}$). Moreover, in the present study, the increase of precipitation sums of 1 mm in autumn, winter and the whole growing season resulted in the grain yield higher by 0.0029, 0.0036 and 0.0012 t ha$^{-1}$, respectively, disregarding the effect of the second observed factor - air temperature. Machado et al., 2007, have studied the dependence of winter wheat grain yield on summer precipitation and established a high positive correlation that ranged from 0.32 in the non-fertilised continuous cropping variant with conventional tillage to 0.5932 in the non-fertilised continuous cropping variant with zero tillage. The corresponding values in fertilised variants amounted to 0.76 that is 0.62, respectively. Debreczeni et al., 2006, studied the dependence of winter wheat grain yields on precipitation sums during the growing season and determined a high dependence (r=0.8047) in variants without fertilising, while this dependence in variants with fertilising was significantly lower (r=0.4841). Dolijanovic et. al., 2009, have studied the dependence of winter wheat in continuous cropping on winter, spring and total precipitations sums and determined that the 1-mm increase of winter precipitations resulted in the decrease of grain yields of 2.1 kg. ($\hat{y}_i$=4492 – 2.1* $x_i$). On the other hand, the 1-mm increase of spring and total precipitation sums resulted in the grain yield increase of 0.885 kg ($\hat{y}_i$=3605 + 0.885* $x_i$) and 1.16 kg ($\hat{y}_i$=3013 + 1.16* $x_i$), respectively. The dependence between studied parameters was not statistically significant, which was established by testing coefficients of simple linear regression. Correlation and regression coefficients obtained in the two-crop rotation were higher, while the lowest dependence of yields on precipitations was recorded in spring (r =0.094). In the same period, the regression equation ($\hat{y}_i$=3999 + 0.963*$x_i$) shows that the lowest yield increase (0.963 kg) was established when the precipitation sum increased by 1 mm. The 1-mm increase of winter precipitations in the two-crop rotation resulted in the yield increase of 2.3 kg ($\hat{y}_i$=3500 + 2.3*$x_i$), and the similar form of the dependence was observed when the total sum in the growing period was analysed ($\hat{y}_i$=3018 + 2.2*$x_i$).

## Conclusion

According to the detailed analysis of temperature and precipitation regimes on the territory of Belgrade in the 1991/92-2010/11 period and the analysis of average winter wheat yields in Serbia proper, the following can be concluded:

General global climate changes also affect Serbia. Temperatures and precipitations have been changing faster during the past two decades. The exceedingly dry years for winter wheat were 1992/93, 1995/96, 2002/03 and 2006/07, while extremely wet years were 2003/04, 2008/09 and 2009/10.

The analysis of the last 20-year weather conditions (temperatures and precipitations) related to winter wheat shows the increase of autumnal and spring temperatures at the end of the first decade of the 21st century. There are somewhat higher precipitation sums in autumn, higher in winter and significantly lower in spring, when the critical period for moisture begins. Even the average yield of winter wheat was higher by 0.6 t $ha^{-1}$.

The analysis of the form and intensity of yields on meteorological conditions during the growing season and certain subperiods (autumn, winter and spring) performed by the method of multiple linear regression and correlation shows that the simultaneous effects of observed factors on winter wheat grain yields were statistically significant during the growing season and in autumn. The greatest dependence of winter wheat grain yields on weather conditions, expressed through coefficients of correlation, was established during the growing season and in autumn.

The regression equation shows that the 1-mm increase of precipitation sums in autumn, winter and during the growing season, resulted in the yield increase, with the exception of the yield decrease caused by the increase of spring precipitation sums. Of the two observed meteorological conditions, the greater effect on the grain yield was expressed by the air temperatures, especially during the winter wheat growing season and in autumn.

## Acknowledgements

The work was supported by the Ministry of Science and Environmental Protection of the Republic Serbia (Project TR-31066 ).

## References

Debreczeni, K., Hoffmann S., Berecz, K. (2006): seasonal effects on grain yield of long-term plant nutrition experiments at Keszthely, Hungary, Cereal Research Communications, Vol. 34 No 1 pp 151-154.

Dolijanović, Ž., Kovačević, D., Oljača Snežana, Broćić Z., Simić Milena (2006): Prinos zrna ozime pšenice i kukuruza u monokulturi, dvopoljnom i tropoljnom plodoredu. Arhiv za poljoprivredne nauke, Vol. 67, No. 237, 81-91.

Dolijanović, Ž., Kovačević, D., Oljača Snežana, Momirović, N. (2008): Prinos zrna ozime pšenice u različitim sistemima ratarenja. Poljoprivredna tehnika, Godina XXXIII, Broj 2., 89-94.

Dolijanović Ž., Kovačević, D., Oljača Snežana, Momirović, N. (2009): Gajenje ozime pšenice u monokulturi i dvopoljnom plodoredu, Poljoprivredna tehnika, Godina XXXIV, Broj 2., 143-148.

Kovačević, D., Oljača Snežana, Dolijanović, Ž., Jovanović, Ž., Milić Vesna (2005): Uticaj plodoreda na prinos važnijih ratarskih useva. Traktori i pogonske mašine, Vol. 10, No. 2, 422-429.

Kovačević, D., Dolijanović Ž., Oljača Snežana (2009): Uticaj sistema obrade zemljišta, dopunske ishrane azotom i sorte na prinos ozime pšenice. Poljoprivredna tehnika. Poljoprivredi fakultet. Beograd. God XXXIV.9-13.

Kovačević, D., Dolijanović, Ž., Oljača, M., Oljača Jasmina (2010a): Produžno dejstvo meliorativne obrade na fizičke osobine zemljišta u usevu ozime pšenice. Poljoprivredna tehnika, God. XXXV, No. 2, 45-53.

Kovačević, D., Oljača Snežana, Dolijanović, Ž., Simić Milena (2010b): Sustainable agriculture: importance of cultural practices adaptation in winter wheat technology, 9th Alps-Adria Scientific Workshop Špičák, Czech Republic, 12th – 17th April 2010, DOI: 10.1556/Novenyterm. Vol. 59. 2010. Suppl.4, 501-504.

Lithourgidis, A.S., Damalas, C.A., Gagianas, A.A. (2006): Long-term yield patterns for continuous winter wheat cropping in northern Greece, European Journal of Agronomy: Vol. 25, Issue 3. pp 208-214.

Machado, S., Petrie, S., Rhinhart, K., Qu Annie (2007): Long-term continuous cropping in the Pacific Northwest: Tillage and fertilizer effects on winter wheat, spring wheat, and spring barley production, Soil and Tillage Research, Vol. 94, Issue 2. pp 473-481.

Malešević, M., Jovićević, Z., Štatkić, S., Dolapčev, S., Stojšin V. (2008): Povratak ka višim i stabilnijim prinosima strnih žita. Zbornik naučnih radova, Proceedings of XXIInd Conference of Agronomist, Veterinarians and Technologiest.Vol. 14 br. 1-2 13-30. Beograd.

Spasov, P., Spasova Danica, 2001: Drought occurrences in Serbia and their forecasting possibility (in Serbian). Proceedings of the 35th Seminar of Agronomist, Institute of Field and Vegetable Crops, YU- Novi Sad.393-401.

***Meteorological data and information Republic Hydrometeorological Service of Serbia.

***Statistical Yearbook of Serbia 2011, 2009, 2008, 2006, 2003.