Review paper

Tillage systems in winter wheat production as a challenge to mitigate global climate changes

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Abstract

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. 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 (fertilizers, pesticides), good agricultural practice.

Under climate conditions in Serbia, 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 amelioration measures.

Key words: tillage systems, climate changes, soil physical properties, winter wheat

Introduction

The studies on anthropogenic climate change performed in the last decade over Europe show consistent projections of increases in temperature and different patterns of precipitation with widespread increases in northern Europe and decreases over parts of southern and eastern Europe (Olesen and Bindi, 2002).

In many countries and in recent years there is a tendency towards cereal grain yield stagnation and increased yield variability. Some of these trends may have been influenced by the recent climatic changes over Europe. The expected impacts, both positive and negative, are just as large in northern Europe as in the Mediterranean countries, and this is largely linked with the possibilities for effective adaptation to maintain current yields. The most negative effects were found for the continental climate in the Pannonian zone, which includes Hungary, Serbia, Bulgaria and Romania. This region will suffer from increased incidents of heat waves and droughts without possibilities for effectively shifting crop cultivation to other parts of the years. A wide range of adaptation options exists in most European regions to mitigate many of the negative impacts of climate change on crop production in Europe. However, considering all effects of climate change and possibilities for adaptation, impacts are still mostly negative in wide regions across Europe (Olesen et al., 2011).

As a consequence of global climate change, changes in the intensity and frequency of climate extremes - tropical cyclones, droughts, floods, landslides, soil erosion, storm disasters, snow storm and frosts, heavy rains of short duration, waves of extremely high temperatures of air, fires, conditions for the spread of epidemics and pests.

The greatest economic damages in Serbia have been caused by droughts, floods, storms accompanied with hail, landslides, erosion caused by the torrents, and in recent years there has been an increasing number of heat waves and the conditions for the occurrence and spread of forest fires.

Taking a long-term view, the problems arise due to the fact that since the seventies of the twentieth century to the present days average annual temperatures in the country and the region have been constantly rising. However, climate change in this area so far have been reflected in the increased frequency and intensity of extremes, such as this one with the drought in the past two years and with increasingly frequent occurrences of heat waves, etc. If this trend of climate change continues as shown by the various climate change scenarios for this region, it could lead to big problems in weather and climate as well as the water supply.

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, 2012a, 2012c, 2012d). 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 (fertilizers, 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). 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 small 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.

Characteristics of the main climate parameters in Serbia

Climate in Serbia can be described as moderate-continental, with more or less distinct local variations. As the main plant production is carried out under conditions of moderate continental climate in the lowland and undulating regions it is important to specify its main features. The average annual temperature is around 11ºC, the warmest month is July with about 23ºC, and the coldest month is January with about -1ºC of mean monthly temperature. Temperature in spring rises quite rapidly, whereas a temperature drop in the autumn is sharp as well. The length of the period with the mean temperatures above 10ºC, and these are the temperatures for the vegetation of spring crops (maize, sunflower, sugar beet, potatoes, etc.), is equal to about 200 days. The frostless period lasts approximately from 1 April to 15 November, totaling around 230 days. The annual amount of rainfall amounts to 600-750 mm. The rainfall ratio of warm to cold part of the year (warm part of the year lasts from 1 April to 30 September) is 55-60% to 40-45%. In other words, although there are more rainfalls during the vegetative period for spring crops there is often a problem of their lack during July and August. The maximum rainfall is received in June, whereas the minimum is measured in January and February. The annual rainfall rate in different parts of central Serbia is mainly satisfactory, although there are years with the extreme lack of rainfalls (drought periods) that affect a significant decrease in crop yields (*RHSS).

Table 1. Mean temperature and precipitation in different periods of winter wheat growing season Serbia (1991-2011)

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

*RHSS (Republic Hydrometeorological Service of Serbia)

In Serbia 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.

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. The analysis of the past 20 years shows that 1992/93, 1995/96, 2002/03 and 2006/07 were extremely dry years for winter wheat (Kovacevic et al., 2012e). 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 heavy soil with waterlogging and outbreak of diseases, which significantly reduced the yield, aggravated harvest and decreased grain quality (Table 1). 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 sub periods show the increase in the average temperature of 1.4ºC and 1.1ºC 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.

Possibilities for adaptation tillage systems in winter wheat technology to mitigate climate changes

Sustainable agriculture is an important element of the overall effort to make human activities compatible with the demands of the earth's eco-system. Thus, an understanding of the different approaches to ecological agriculture is necessary if we want to utilize the planet's resources wisely.

In conventional systems of tillage, tractors and implements make between 7 and 16 passes over the field for land preparation. In contrast, conservation tillage systems greatly reduce the number of tractor and implement passes required, and leave a protective blanket of leaves, stems and stalks from the previous crop on the soil surface. Less tillage means less soil compaction and lower fuel and labour costs, less wear and tear of the tractor and implements, and more time available for other activities. Moreover, the surface cover of crop residues shields the soil from heat, wind, and rain, keeps the soil cooler, and cuts down moisture losses by evaporation.

Conservation tillage systems reduce efforts spent on intensive weeding. Every time a farmer tills or ploughs to control weeds, he makes the soil more vulnerable to erosion, which is the most significant environmental problem. With conservation tillage a grower relies more on weed control by crop rotation, cover crops and mulch covers. If herbicides are to be used, then conservation tillage systems allow the use of less harmful products than those used in most conventional farming operations. They are generally low in toxicity to wildlife and beneficial insects, and break down so quickly that there is minimal risk to water quality.

Essential change of soil tillage systems, along different levels of tillage reduction until no tillage, has a great impact on soil physical and agrochemical characteristics. Reduction of soil tillage intensity or its total avoidance could affect significantly porosity, especially on heavier soils, increasing shares of micro pores in spite of macro porosity and lowering air capacity and air permeability.

Table 2. Effects of tillage system on dynamic soil physical properties on chernozem luvic type in winter wheat

Tillage systems	Depths cm	Soil physical properties		
		Bulk density ($g\ cm^{-3}$)	Total porosity (%)	Air field capacity (%)
Conventional tillage systems	0-10	1.34	49.81	14.57
	10-20	1.43	47.09	8.70
	20-30	1.45	46.49	7.98
Average		1.41	47.80	10.42
Mulch tillage	0-10	1.37	48.69	8.64
	10-20	1.39	48.83	10.37
	20-30	1.38	49.32	13.37
Average		1.38	48.95	10.79
No- tillage	0-10	1.56	41.45	4.75
	10-20	1.58	41.58	4.60
	20-30	1.51	44.16	7.03
Average		1.55	42.40	5.46
Average	0-10	1.42	46.65	9.32
	10-20	1.47	45.83	7.89
	20-30	1.45	46.66	9.46

The obtained results showed that tillage systems had different effect on the soil physical properties. Generally, differences in soil physical properties between investigated systems were significant at the waxy stage of winter wheat (Table 2). Bulk density is one measure of the soil physical condition. On the plots following no tillage system significantly higher bulk density (1.55 $g\ cm^{-3}$) were found, comparing to values obtained in the CT (1.41 $g\ cm^{-3}$) and MT plots (1.38 $g\ cm^{-3}$). Significant differences were found in soil physical characteristic between investigated depths as analyzed factor. Bulk density was higher in the layer 10-20 cm of depth. The differences between investigated layers were not significant for total porosity and air field capacity.

Reduction and, especially, elimination of agrochemical require major changes in management to assure adequate plant nutrients. The first step in transition from conventional to integrated nutrient management is reduction of chemical fertilizers (Table 3).Reduced amount of N-fertilizer in combination with reduction of tillage increase nutrient content in the soil (Oljača et al., 2002).

Disadvantage of these tillage systems is yield decrease of crops. But at the same time the inputs of such production system decrease as well, not mention the benefits in the environment. Some crop cultivars are adapted for less favorable conditions in occurring environment. Low-input cultivars are less sensitive than high-input ones, and they give better yield than high-input cultivars of winter wheat. The choice of crops and their cultivars used in such farming system is very important.

Table 3. Effects of tillage systems and nitrogen level on nitrogen content (ppm) in winter wheat (0-60cm in depth)

Tillage systems	N level	NH_4-N	NO_3-N	Total N
CT (Conventional tillage)	120 kg ha^{-1}	24.50	2.62	27.12
	60 kg ha^{-1}	6.12	1.75	7.87
	control	11.38	3.50	14.88
RT (Reduced tillage)	120 kg ha^{-1}	9.62	4.38	14.00
	60 kg ha^{-1}	9.72	8.75	18.47
	control	5.75	2.62	8.37
NT (No- tillage)	120 kg ha^{-1}	39.38	13.13	52.51
	60 kg ha^{-1}	19.25	7.00	26.25
	control	7.87	4.38	12.25

According to permanent breeding program there was a serious attempt to create concept of low input technology for rational growing practice in winter wheat under Serbian conditions (Kovačević et al., 2009b). Based on it's sustainability this concept must accomplished several issues: conservation tillage methods, adequate mineral nutrition, ad hoc limited herbicide application and of course very strict desirable cropping system (modified Norfolk rotation: corn-winter wheat-spring barley+red clover-red clover. Under these conditions it is important to have best adopted cultivars.

Agricultural producers invested their hopes in the development of sustainable agriculture. a concept that should rely on the breeding of low-input cultivars and cutbacks in production costs. As far as wheat is concerned. we have developed in Serbia several low-input cultivars of winter wheat.

Research carried out by Kovacevic et al. (2010b) has shown that low-input cultivars according to previous experience (Pobeda, Francuska, Lasta, NS Rana 5) positively responded to reduces in tillage systems and different nitrogen amount in side-dressing. Growing practice with certain reduction of tillage, nitrogen fertilizer and weed control was more favorable for low-input cultivars which positively responded by their higher yield 3.24 t ha^{-1} compared with two cultivars created for intensive high-input technology (Pesma, Rana niska) 3.04 t ha^{-1} (Table 4). These results demonstrate potential new technologies comprehend higher flexibility of cultural practices (soil tillage. fertilization. integrated weed management. crop rotation) with proper choice of wheat cultivars adapted to these conditions.

Soils with heavy mechanical texture require processing system that ensures conservation of natural resources of fertility and prevents soil degradation processes, especially in terms of optimization of energy use, action and water.

A large number of researchers who have studied this type of soil, point out that soil heavy texture possess a number of specific characteristics, especially the unfavorable physical and water-air properties. Bearing in mind that in Serbia we have more than 400.000 ha of soil heavy mechanical texture and approximately 1 million hectares of degraded soil in different ways, this kind of researches are important and useful from the standpoint of science, and even more from the point of using this research into practice (Hadas, 1997; Kovacevic et al., 2009a; Ercegovic et al., 2010).

Table 4. Effects of different technology on grain yield different groups winter wheat cultivar (t ha^{-1}).

Tillage systems (A)	Nitrogen level (B)	Cultivars (C)						Average	
		Low-input				High-input			
		Pobeda	Lasta	Evropa	NS rana	Pesma	Rana	AB	A
Conventional tillage	control	2.52	2.46	2.69	2.54	2.56	2.57	2.56	4.03
	60 kg ha^{-1}	3.59	3.82	3.55	3.51	3.61	3.99	3.68	
	120 kg ha^{-1}	6.08	5.80	5.95	6.14	5.70	5.48	5.86	
Average	AC	4.06	4.03	4.06	4.06	3.96	4.01		
Mulch tillage	control	2.09	2.25	2.59	2.24	2.03	1.72	2.15	3.13
	60 kg ha^{-1}	3.03	2.90	2.75	2.71	2.82	2.50	2.78	
	120 kg ha^{-1}	4.30	4.04	4.66	4.46	4.44	4.88	4.46	
Average	AC	3.14	3.06	3.33	3.14	3.10	3.03		
No-tillage	control	1.79	1.48	1.59	1.50	1.49	1.41	1.54	2.37
	60 kg ha^{-1}	2.42	2.66	2.13	2.10	2.13	1.80	2.21	
	120 kg ha^{-1}	3.54	3.74	3.66	3.44	3.04	2.69	3.35	
Average	AC	2.58	2.63	2.46	2.35	2.22	1.97		
Average	BC	2.13	2.06	2.29	2.09	2.03	1.90	2.08	
		3.01	3.13	2.81	2.77	2.85	2.76	2.89	
		4.64	4.53	4.76	4.68	4.39	4.35	4.56	B
	C	3.26	3.24	3.29	3.18	3.09	3.00	3.18	
		3.24				3.04			

In the researched areas, an important and limiting factor for the successful production is over-wetting of the soil. This fact does not allow the respect optimum time for application cultural measures like tillage, seeding, and normal conditions for growth and development of plants or crop-harvesting. Poor infiltration or permeability of soil is the reason of waterlogging, which leads to suppression of crops, lack of normal operation of machinery (jamming and deterioration of the tractor up to the height of the wheels on some depressions).

According to Kovacevic et al., (2012c) ameliorative tillage with new types of machines was obtained a significantly lower bulk density in compared with control (Table 5). In the first period of this research there is a significant difference between the two examined variations and the examined soil depth, except the third (20-30 cm). Greater soil loosening in the experimental area can be seen from the higher porosity. Higher porosity allows better air flow and rapid infiltration of water. This can be seen from the moisture content. Higher moisture content on the control variants is a result of higher density of individual layers. The total amount of water has significantly contributed to this. It can be seen that the control variation at all depths has higher water stored in the soil. In loam soils it does not mean and higher availability of water. This circumstance at higher rainfall could be the limit for fast water flow. Tillage system that was used, was consisted of leveling of the field, of undermining with the drainage plough and of tillage with vibrating subsoiler, has resulted in an increased soil loosening as we can see from significantly lower values of bulk density, higher total porosity and a better connection between the solid, liquid and gaseous phases.

Table 5. Efects of ameliorative tillage on soil properties in full tillering of winter wheat

Variants	Depth in cm	Bulk density g cm^{-3}	Total porosity %	Max. water content % vol.	Moisture % vol.	Amounth of water m^3 ha^{-1}
ATS	0-10	1.31	51.4	40.5	36.7	482.9
	10-20	1.36	48.1	38.7	34.1	984.2
	20-30	1.37	51.2	38.4	32.5	1336.2
Average	0-30	1.35	50.2	39.2	34.4	∑ 2803.3
CTS (control)	0-10	1.32	50.2	39.5	34.9	459.0
	10-20	1.43	48.7	38.2	35.6	1015.6
	20-30	1.42	49.2	37.5	33.6	1439.
Average	0-30	1.39	49.4	38.4	34.7	∑ 2913.9

Abbreviation: ATS- Ameliorative tillage system ; CTS- Conventional tillage system

The soil properties were repaired in the first year and it became more favorable habitat for growing crops, also, it should be noted and the prolonged effect on the other crops (winter wheat in third year of investigations 2010. High precipitation in autumn, winter and early spring in previous year (2010) were a reason to waterlogging on the control variant.

Conclusion

On the basis of the previous theoretical but also practical knowledge some things can be listed which will certainly provoke significant changes in the field of agriculture. First of all global climatic changes will have their reflection on the territory of Serbia as well.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. The precipitation surplus adversely affects winter wheat.

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. 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.

Some extremely wet years also cause problems that need to be solved with different ameliorative measures. 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.

One of the goals of the sustainable agriculture movement is to create farming systems that mitigate or eliminate environmental harms associated with industrial agriculture. That aim can be realized only in flexible cultural practices in real agroecological conditions (different regional characteristics, cultural practices for different soil types, best adapted cultivars for level of production from conventional to organic organic production. 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.

References

Ercegovic, Dj., Gligorevic, K., Kovacevic, D., Raicevic, D., Vukic, Dj., Oljaca, M., Pajic, M., Radojevic, R. (2010): Research results of long-term use of new line of machines and tools for land surface and depth arrangement. Journal of Agricultural Sciences.Vol. 55. No.2:165-183.

Hadas, A. (1997): Soil tilt-the desired soil structural state obtained through proper soil fragmentation and reorientation processes. Soil and Tillage Research. 43.7: 1-40.

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, M., Oljača, J. (2009a): Uticaj meliorativne obrade na neke fizičke osobine zemljišta, Poljoprivredna tehnika, godina XXXIV, N^{o}2, Beograd:35-42.

Kovačević, D., Dolijanović Ž., Oljača, S. (2009b): 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, J. (2010a): Produžno dejstvo meliorativne obrade na fizičke osobine zemljišta u usevu ozime pšenice. Poljoprivredna tehnika. God. XXXV. No. 2: 45-53.

Kovacevic, D., Oljaca, S., Dolijanovic, Z., Simic, M. (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.

Kovacevic, D., Momirovic, N., Dolijanovic, Z. (2012a): Soil and crop responses to soil tillage systems: a Serbian constraints and perspective toward sustainability. Proceedings. 5 th Internationbal Scientific/Professional Conference Agriculture in Nature and Envoronmental Protection. Vukovar 4-6 June: 34-43.

Kovacevic, D., Lazic Branka (2012b): Modern trends in the development of agriculture and demands on plant breeding and soil management. Genetika. Vol. 44. No.1: 201-216. Belgrade.

Kovacevic, D., Dolijanovic, Z., Jug, D., Jug Irena, Stipesevic, B., Milic Vesna (2012c): The effect of ameliorative tillage on some important soil physical properties and grain yield maize, sunflower and winter wheat, Proceedings. 47th Croatian and 7th International Symposium on Agriculture. 13- 17 February, 2012, Opatija, Croatia:497-501.

Kovacevic, D., Oljaca, S., Dolijanovic, Z., Milic, V. (2012d): Climate changes: Ecological and agronomic options for mitigating the consequences of drought in Serbia. Proceedings. Third International Scientific Symposium "Agrosym 2012", Jahorina, November, 15-17, 2012: 17-35.

Kovacevic, D., Dolijanovic, Z., Jovanovic, Z., Milic Vesna (2012e): Climate change in Serbia: Depedence of winter wheat yield on temperatures and precipitation. Proceedings. Third International Scientific Symposium "Agrosym 2012", Jahorina, November, 15-17, 2012: 270-276.

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.

Olesen, E.J., Bindi, M. (2002): Consequences of climate change for European agricultural productivity, land use and policy. European Journal of Agronomy 16.239–262.

Olesen, E.J., Trnka, M., Kersebaum, K.C., Skjelvåg, A.O., Seguin, B., Peltonen-Sainio, P., Rossi, F., Kozyr, J., Micale, F. (2011): Impacts and adaptation of European crop production systems to climate change. Europ. J. Agronomy 34: 96–112.

Oljaca, S., Kovacevic D., Dolijanovic Z. (2002): Low-external farming system-strategy for environmental protection. Tematski zbornik-monografija, First International Conference on Environmental Recovery of Yugoslavia (ENRY 2001), Beograd: 687-690.

Spasov, P., Spasova, D. (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.