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# CLIMATE CHANGES: ECOLOGICAL AND AGRONOMIC OPTIONS FOR MITIGATING THE CONSEQUENCES OF DROUGHT IN SERBIA

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## Abstract

Drought represents a certain period of time, which is manifested by a lack of rainfall for a normal growth and development of crops with simultaneously high temperatures and low humidity. Damages caused by drought depend on the time of its duration and its intensity. If this time is longer, therefore damages are greater, and they can sometimes be catastrophic.

Drought occurs over a wide area in the first place as a result of reduced rainfall and due to increased temperatures at the global level. It is believed that 1/2 of the Earth's continental area has the deficit of rainfall. The tendencies of reduction in rainfall were recorded in Serbia as well. In the last three decades, rainfall has decreased in the region of Vojvodina, Šumadija, most of Pomoravlje (the Morava river valley) and southern Serbia. The highest rainfall deficit (20%) was recorded in the last decade. The causes of drought are different. One of the main causes is the lack of a total amount of rainfalls during the year and their distribution during the vegetative period of plants and evaporation intensity of precipitation. Furthermore, these are the properties and soil condition in which there are also water needs of the plants. Within our climate, drought is an occasional occurrence which sometimes manifests itself in a mild and sometimes in a very harsh form.

In the fight against drought, regular and specific cultural practices are used along with an adequate assortment of plants more resistant to drought. Regular practices comprise soil tillage, fertilising, sowing, care treatments, crop rotations, and as regards the particular practices, they include snow retention, mulching, antievaporants. In addition to these practices, it is important to mention irrigation as the most direct practice by which water can be added in desired quantities completely independently of precipitation. However, irrigation essentially changes all of the conditions substantially in a cropping system, so that it represents, for itself, a special practice with far-reaching effects, which should be considered.

The aim of this study was to analyse the data of the two-decade period between 1990-2012 of rainfall and temperature, and to observe the change in Serbia and in the Belgrade area. Based on the evaluation criteria for climate according to Lang for our conditions, we analysed the effects of certain practices on mitigation of drought in which the role of crop rotation was particularly emphasised. On the basis of the data analysis, cultivation practices which can be used for an indirect influence on drought and yields of the two most important crops in Serbia, maize and winter wheat.

**Keywords:** *Climate change, ecological aspect of drought, adaptations, cultivation practices, winter wheat, maize, Serbia*

## 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 possibilties for adaptation, impacts are still mostly negative in wide regions across Europe Olesen, et. al. (2011).

Many definitions exist for each of the main types of drought, including meteorological, agricultural, hydrological and socio-economic Meteorological drought applies to a long-term lack of precipitation that is frequently intensified by anomalously high temperatures that increase evapotranspiration. This often leads to other types of droughts including agricultural - periods during which soil moisture is insufficient to support crops; hydrological - prolonged periods of unusually low surface run-off and shallow groundwater levels and socio-economic droughts an unusual shortage of water that produces an adverse effect on society and the economy (Maybank et al. 1995).

Drought is one of the major hazards affecting Serbia and drought is a normal part of the climate. Most global climate models project increased summer continental interior drying and, as a result, a greater risk of droughts is projected for the twenty-first century. The increased drought risk is described as likely and is a result of a combination of increased temperature and evaporation not being balanced by precipitation. Increasing the efficiency of water use within agricultural systems is an essential priority in many regions and State of the World including the R. Serbia. The primary source of water for agricultural production for most of the world is rainfall. Amount of rainfall, frequency and intensity are three values of which vary from place to place, day to day, month to month and also year to year. For crop growth is important information of the amount, intensity and distribution of days, decades monthly or annual rainfall for the most important places in the world. Crops with high water consumption create greater deficits of moisture in the soil; therefore effective rainfall is directly proportional to the rate of water uptake by the plant. Crop characteristics influencing the rate of water uptake are the degree of ground cover, rooting depth and stage of growth. The crop is an important factor in interpreting the basic data. Hence the seasonal needs of major crops in a given area should be taken into account when the extent of effective rainfall is assessed.

Some recent studies have pointed out more frequent and severe drought in the territory of Serbia and in other parts of the Balkan peninsula (Bosnjak,1997; Dragovic,1997; Spasova Danica et al.,1997; Spasova Danica et al.,1999; Spasov and Spasova Danica, 2001; Spasov, 2003; Marinkovic et.al., 2009; Malesevic et al, 2011).

This review examines the research priorities, the prospects for crop and soil management and plant breeding and biotechnology that are needed to achieve high stable yield under drought. Research must combine the latest latest knowledge including agroecology, crop and soil management practices, genetics and ecophysiological understanding of the interactions between crop plant genotypes and the growing environment to better inform crop improvement.

## Ecological aspects of drought

When speaking about drought in ecology, it most often refers to the lack of active moisture in the environment in which plant organisms are, that is, in lithosphere, pedosphere and atmosphere. Drought occurs, either due to a real lack of water in the environment, or because of difficulty in supplying plants with water in otherwise sufficiently wet environment. Drought occurs over a wide area in the first place as a result of reduced rainfall and due to increased temperatures at the global level. It is believed that 1/2 of the Earth's continental area has the deficit of rainfall. The tendencies of reduction in rainfall were recorded in Serbia as well. In the last three decades, rainfall has decreased in the region of Vojvodina, Šumadija, most of Pomoravlje (the Morava river valley) and southern Serbia. Knowing the problem of drought is of great importance particularly for the planning and rational use of natural potentials in the area of plant production, as well as for taking measures to mitigate and eliminate a harmful effect of drought (Cvetkovic et al., 1996; Cvetkovic and Oljaca, 1999; Oljaca Snezana et al., 2002).

Nature discovered in the course of evolution many different ways for the plants to adapt to drought. It is a big challenge that many of them find their application in grown plants, which are usually not resistant to drying out. Plants can avoid drought in two ways: to avoid it completely by not growing in the dry season, or to actively adapt to those conditions. Plants usually avoid drought by means of accelerated growth and the completion of the life cycle before the onset of a drought period. Tolerance to drought is acquired through various developmental, morphological and physiological adaptations that allow the plant either the balance between water uptake and transpiration, or water-deficit tolerance. Avoiding dehydration is the ability of plants to maintain relatively high leaf water potential, when soil or air droughts occur.

The causes of drought mainly come from the atmosphere. A man can hardly influence the quantity and distribution of rainfall, therefore his actions to combat drought are mainly of indirect character.

Drought represents a certain period of time, which is manifested by a lack of rainfall for a normal growth and development of crops with simultaneously high temperatures and low humidity. Damages caused by drought depend on the time of its duration and its intensity. If this time is longer, therefore damages are greater, and they can sometimes be catastrophic.

Adverse physiological effect of drought reflects in stopping the increase if of lesser intensity, and it can intensify until a complete halt to all vital functions of the plant. Due to drought, transpiration and photosynthesis are reduced, but respiration is carried out continuously and spare organic matters are used. The plant loses its weight, the leaves wither, and their tops dry. When a prolonged dry period occurs, the whole plants dry out. If a dry period in the summer continues in the autumn then it hinders the timely sowing of winter crops.

The causes of drought are different. One of the main causes is the lack of a total amount of rainfalls during the year and their distribution during the vegetative period of plants and evaporation intensity of precipitation. Furthermore, these are the properties and soil condition in which there are also water needs of the plants. Within our climate, drought is an occasional occurrence which sometimes manifests itself in a mild and sometimes in a very harsh form. The evaporation intensity depends on the temperature, winds activities and geographical location of a certain area and it increases in our country going from the west to the east or from the north to the south of the country. In particular, these values are high in the southeast. Temperatures unquestionably have a great impact on this phenomenon. The evaporation is a product of the high temperature and it is in the closest relation to the direction of decreasing of the rainfall. This fact should show the reasons why our eastern and southeastern regions often suffer from more or less serious consequences of drought. Soil having favourable properties can absorb and retain moisture, which is available throughout the year. Soils of favourable structure, loose, with plenty of humus better receive and hold moisture than light sandy and heavy clay soil or shallow soils. In addition, if soils are well cultivated, fertilised and generally speaking in a better conditional state, they less suffer from the drought consequences.

Properties of plants and their water needs (xerophytes, hydrophytes) are also different. The size of the transpiration coefficient indicates water needs of the plant. If it is larger, the water needs of the plant concerned are generally greater as well. In these terms, when growing crops it is important to know how great their general water need is and when critical periods for moisture occur.

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 (Easterling, 1996).

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.

## 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 11 ºC, the warmest month is July with about 23 ºC, and the coldest month is January with about -1 ºC 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 10 ºC, and these are the temperatures for the vegetation of spring crops (maize, sunflower, sugar beet, potatoes, etc.), is equal to about 200 days. Mean temperatures above 20 ºC last for three summer months, around 80 days. The frostless period lasts approximately from 1 April to 15 November, totalling 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.

## Influence of meteorological conditions in the area of Belgrade in the period (1990-2012) on maize and winter wheat

Based on many-decade analysis of the data obtained from the Republic Hydrometeorological Service of Serbia in the Belgrade area (Tables 1 and 2 at the end of this paper as a supplement), it can be noticed that droughts have been increasingly frequent in these regions for the last twenty years. Even six years of the last twelve years were dry. It is very important for agriculture when drought occurs. If the drought occurs during the critical periods for moisture in a given crop, or when the fruit is being formed and grain filled, then the damages are the greatest. For example, in the analysed period of 22 years: 1992, 2000, 2007, 2003, 2001 and the current year of 2012 were very dry. In these years, drought was observed in the spring, and it was especially noticeable in the summer period so that the adverse consequences for most of the spring crops were great. In Serbia, 2007 even higher temperatures than those in the current year of 2012 were recorded. The subject under discussion is the highest temperature ever recorded in the area and up to 45 $^{0}$C, when some previous maximums were exceeded. Damages that are registered via reducing yields were severe. Obtained maize yields were lower in comparison with the previous year by 32 per cent, and yields of sunflower as the most resistant to drought were decreased by 23 per cent. The spring drought also occurred in 2009, but it was overcome and it does not belong to severe droughts. During the vegetative period of maize an increasingly frequent heat waves are observed. In the beginning, these were the waves in the month of September, which contributed to more rapid maturation of maize. However, in recent years, tropical heat waves in which the nighttime temperatures do not drop below 20 occur earlier in August, and this year they occurred in the second half of July. These waves contributed to the accelerated maturation and disturbed the grain filling. This is becoming a real problem these days.

A special problem arises when the drought is transferred to the optimal time for sowing of winter crops (regarding our conditions, October to mid-November), which significantly complicates and prolongs their seedling emergence until the winter. As the example the situation from 2011 is given when the drought was pressing during the whole vegetative period, particularly in August and September, when it was the worst. After that, it continued in October and November resulting in the soil without any moisture for a long time, which had an effect on wheat yield the next year.

This 2012 was characterised by the fact that the rainfalls in June, July and August were significantly lower than the average rainfall. In June, the rainfall measured was only 32 per cent of the average, and in July only because of the raining at the end of the month the rainfall received was 86 per cent of the average. In August, only 5 per cent of the average were recorded-there almost was no rainfall at all. Thus, in these three months most of the territory of Serbia received 25-50 per cent of the average rainfall which is actually a severe drought that has an impact not only on agricultural crops, but also on the water levels of rivers and reduction of the amount of groundwater as well.

In contrast to the dry years in the analysed period there were those ones with more abundant rainfalls such as 1999, 2001, 2004, 2005, 2009 and especially 2010. In 2010, the rainfall received was 80 per cent higher than the average, there were even floods. Similar results were obtained for 2005. It is for this reason that humid years with long periods of abundant rains that replaced drought in Serbia have contributed to more favourable situation with the level of groundwaters that are sometimes significant as a source of water for the cultivation, particularly of spring agricultural crops which are more distributed than winter crops in sowing structure in Serbia. Abundant rainfall during the winter period has caused in some years, as was the extreme 2010, severe damages such as floods and lying waters throughout the territory, especially in Vojvodina.

Table 3. Mean temperature and precipitation in different period of maize growing season in Belgrade (1991-2010)

| Period | June | July | August | Average summer | IV-IX | I-XII |
|---|---|---|---|---|---|---|
| | | | Temperature ($^0$C) | | | |
| Average1970/2000 | 20.4 | 22.1 | 22.0 | 21.5 | 18.6 | 12.1 |
| 2001/2012 | 22.1 | 24.3 | 23.9 | 23.4 | 20.3 | *13.4 |
| difference | 1.7 | 2.2 | 1.9 | 1.9 | 1,7 | 1.3 |
| | | | Precipitation in mm | | | |
| Prosek1970/2000 | 95.4 | 68.9 | 57.1 | 73.8 | 404.0 | 688.1 |
| 2001/2012 | 98.1 | 62.6 | 63.0 | 74.6 | 386.3 | *719.2 |
| difference | 2.7 | -6.3 | 5.9 | 0.8 | -18.0 | 31.1 |

*Average 2001/2011: 2012 yet not finished

Using the analysis of the data in the study period for the past eleven years, the average annual temperature has risen by 1.3 $^0$C in relation to the reference period 1971-2000 (Table 3). However, the temperature increase is far more significant in the vegetative period of maize as well as of other spring crops by 1.7 $^0$C compared to the same reference 30-year period at end of the last century. The strongest influence on the crops in some extremely dry years as were in 1992, 2000, 2007 and 2012, was exercised by temperature increase in June by 1.7 $^0$C, in July by 2.2 $^0$C and in August by 1.9 $^0$C, that is, averagely for the three months by 1.9 $^0$C. This is particularly dangerous because the increases are accompanied by several heat waves that increase nighttime temperatures in July and August at the tropical level where the temperatures during the night do not fall to a level below 20 $^0$C.

Table 4. Mean temperature and precipitation in different period of winter wheat growing season in Belgrade (1991-2010)

| Period | autumn | winter | spring | veget.period |
|---|---|---|---|---|
| | X-XII | I-III | IV-VI | X-VI |
| | | Temperature ( $^0$C) | | |
| 1971/2000 | 7.2 | 4.0 | 16.7 | 9.3 |
| 2001/2010 | 8.6 | 4.6 | 18.2 | 10.5 |
| difference | 1.4 | 0.6 | 1.5 | 1.2 |
| | | Precipitation in mm | | |
| 1971/2000 | 166.3 | 127.8 | 223.0 | 517.1 |
| 2001/2010 | 177.0 | 154.1 | 190.3 | 521.4 |
| difference | 10.7 | 26.3 | -32.7 | 4.3 |

As for rainfalls if their rate at the annual level is considered, and even at the level of vegetative period of maize in the first decade of the new century, there was more rainfall. Even in the two months, June, otherwise in this region with the highest rainfall, and in August, the rainfall was averagely higher at a monthly level (Table 4).

Only in July, a small deficit of 6.3 mm was reported. It is certain that the rainfall became more extreme and more shifted in other periods, which is favoured by wheat. Namely, more rainfalls are distributed in the first half of June and the second half of August, which additionally can create drought conditions because that is the critical period for moisture in maize from silking to different stage of maturity.

## Agricultural impacts and adaptations to drought

The causes of drought mainly come from the atmosphere. A man can hardly influence the quantity and distribution of rainfall, therefore his actions to combat drought are mainly of indirect character. In the fight against drought, regular and specific cultural practices are used along with an adequate assortment of plants more resistant to drought. Regular practices comprise soil tillage, fertilising, sowing, cultivation practices, crop rotations, and as regards the particular practices, they include snow retention (to keep snow with residue precrops), mulching etc. All those cultural practices are applied so as to retain moisture and prevent moisture loss while encouraging its more efficient and economical use (Kovacevic et al, 2000; Molnar et al., 2001, Smith and Skinner, 2002; Kovacevic et al., 2005a; Falloon and Betts, 2010). In addition to these practices, it is important to mention irrigation as the most direct practice by which water can be added in desired quantities completely independently of precipitation. However, irrigation essentially changes substantially all of the conditions in a plant production system, so that for itself, it represents a special practice with far-reaching effects and special adjusting of all other cultivation practices that accompany it. The creation of a new assortment of cultivated plants resistant to stressful conditions caused by the drought comprises plant breeding. The proper selection of cultivars (hybrids), that is, genotypes of crops more tolerant to drought is in accordance with the prevailing local conditions.

Fighting against drought is mainly focused on the implementation of certain measures through soil and through the plants.

*Basic tillage with seedbed preparation*. The creation of favourable conditions in the soil through tillage and fertilisation (agromeliorative tillage, creation of tilth, autumn deep tillage) makes a layer of soil that is able to receive and carry or accumulate sufficient reserves of moisture from the period when it is abundant as well as to put them at the disposal of the plants in their critical periods for moisture. Hence the autumn deep tillage is of enormous significance for all, especially for the spring crops. All practices of presowing tillage methods as well as care treatment aimed at capillarity cutting and moisture conservation are also welcome for this purpose (drilling, interrow cultivation and hoe and ridge cultivation). For the purpose of eliminating various unfavourable abiotic influences which are directly manifested in the soil and creating favourable conditions for crops, different care treatments are used, first of all, those of mechanical nature: drilling, rolling and interrow cultivation with hoe and ridge cultivation (Kovacevic et al., 2000; Kovacevic et al., 2009a).

*Sowing*. When speaking about sowing, one should bear in mind the selection of cultivars (hybrids) adaptable to drought for the known area, pre-defined technology (high or low-input), expected meteorological conditions in the given year as far as possible to predict on the basis of certain indicators, plant density and depth of sowing spacing, that is, the quantity of high quality processed seed (high quality cleaning, calibration with full seed treatment which means disinfection, disinfestation and protection).

One of the most common mistakes, but fatal in dry years, is a high crop density, much higher than the predicted optimum that is recommended for a particular hybrid or cultivar. As regards arid conditions or when on the basis of numerous indicators the dry year is expected, the density of the crops sown should be lower than the one predicted for moderate years. In irrigation conditions and humid regions, the density certainly does not have to be a problem provided that there are sufficient quantities of water for all plants.

According Turner (2004) conventional plant breeding so far only increased the yield of crops grown under drought at about half the rate achieved for crops grown in temperate regions Crop response to stress is dependant on numerous traits many of which are constitutive and expressed irrespective of water availability, but such constitutive traits may also be modified by stress. Directed breeding strategies must focus on the key traits important to performance under drought stress [e.g. phenology, rapid establishment, early vigour, root density and depths, low and high temperature tolerance, $^{13}C$ discrimination (a measure of the extent to which photosynthesis is maintained while stomatal conductance decreases), root conductance, osmoregulation, low stomatal conductance, leaf posture, habit, reflectance and duration, sugar accumulation in stems to support later growth of yield components]. The aim is to allow wheat to continue to grow and yield grain under water-limited conditions.

Breeding for drought tolerance is further complicated by the fact that several types of abiotic stress can challenge crop plants simultaneously. High temperatures, high irradiance, scarcity of water, and nutrient deficiencies are commonly encountered under normal growing conditions but may not be amenable to management through traditional farm practices. Certain soil properties such as composition and structure can also affect the balance of these different stresses. However, breeding combined with agronomy in an optimised system may increase efficiency and productivity. Even if breeding for drought tolerance lowers the yield potential of the crop, it may increase yield stability over seasons, which could still benefit many farmers in drought-prone areas (Araus et al., 2003). However, in many cases, newer improved varieties are accepted slowly by farmers.

The improvement is noticed in the field of genetic methods and breeders have been working on the creation of new program to drought tolerance. We will need to develop water use efficency in crop species, tolerance to periodic drought stress both in dryland and irrigated crops, and adaptation of species that are more efficient in use of limited water. In the meantime, until new culitvars more resistant to drought and other stressful conditions are obtained, one should carefully select cultivars, that is, hybrids that have been best adapted so far on the basis of previous experience. The proper selection of cultivars-hybrids, that is, genotypes of crops resistant to drought is in accordance with the prevailing local conditions. (Calderini and Slafer,1998; Brissona Nadine et al., 2010; Fleury et al., 2010; Kovacevic et al., 2011; Kovacevic and Lazic Branka 2012).

Minimising the damage caused by the drought in most areas sown with maize can be achieved by certain cultivation practices, selection of hybrids and sowing at the recommended densities per unit area. The number of plants per unit area has the greatest impact on maize yield in years with favourable weather. However, in years with lower rainfall, or their unfavourable distribution, it is very risky to grow hybrids at large densities because it results in the occurrence of sterile plants (plants without ear). Maize hybrids created in our country are better adapted to drought conditions in these areas. In addition, our hybrids have the ability to produce high yields due to smaller number of plants per unit area in favourable weather conditions, whereas in the dry years they are more tolerant of drought. Similarly, these hybrids at lower density are more tolerant of the drought compared with the hybrids at high density. For the purpose of better using of moisture supplies in the soil and of better preventing of evaporation, there are plans for creating hybrids suitable for very early sowing, even in early April in our climate. The work is being carried out apropos developing hybrids with accelerated growth at the beginning of vegetative period so as to close vegetative area, shade the soil and reduce evaporation, that is, free run-off of water, and besides that, to pass earlier a critical period for moisture, which in our conditions from mid-June to mid-July.

*Interrow cultivation and hoeing.* The soil sown with wide-row crops is unprotected for a long period of time. Applying interrow cultivation, with cultivators intended only for such purposes, the soil is cut and the loosed between the rows. In this way, the following objectives are achieved: the existing crust is destroyed and the emergence of a new one is prevented, capillarity cutting creates a loose layer on the soil surface, which also prevents unnecessary loss of the existing moisture in the soil, as well as the ability of soil to absorb new moisture from rainfall; bulk density is reduced while the porosity and air capacity are increased, which increases aeration and improves the soil thermal regime, weeds from the interrow space, which can be strong competitors to cultivated crops for moisture, are destroyed .

*Mulch Tecniques* reduce evaporation in such a way that the lower surface is exposed to sun and wind. The sun's rays reflect back more from lighter surfaces (mulch is lighter than soil) causing a decrease in temperature. Chopped materials or tinier substances used for mulch better absorb moisture and prevent its run-off or evaporation. The area under the mulch is more porous without soil crust and can absorb more moisture. For these reasons, soil is supplied with moisture.

*Thinning crops.* The need for thinning crops occurs in those cases when due to various reasons we have not succeeded in sowing crop at the desired density. All these redundant plants have to be removed when hoeing for the first time. In this way, the best vegetative area is left to the remaining plants by removing their competitors for water and nutrients.

*Manuring and Fertilizing.* Manuring of the soil under different crops cannot resolve all issues in the field of plant mineral nutrition. Plants have very different needs for some fertilizers (mineral-inorganic fertilizers with macro and microelements in various, only for them typical growth periods, during vegetative period. Fertilizer top dressing significantly improves poor condition in winter worn and damaged winter crops (Malesevic et al, 2011). As regards spring crops with a long vegetative period, it is usually intervened about two times with interrow cultivation and side dressing fertilizers in the way that they significantly help to occupy the space faster and become more competitive regarding adverse conditions including drought.

*Irrigation*. The lack of rainfall and their unfavourable distribution are eliminated in the most effective and most direct way by irrigation. Irrigation is mentioned here as one of the possible care treatments for eliminating the effects of drought. However, irrigation essentially changes all the conditions substantially in a plant production system, so that it represents, for itself, a special practice with far-reaching effects. In irrigation cropping system, there are numerous specific cultivation practices, and the existing ones require some adjustments to the conditions which are significantly different from those in the natural wetting regimes. Irrigation is particularly important in arid areas where crops cannot be successfully grown without it. In other areas, it allows normal water supply and removing the discontinuity in an unfavourable rainfall distribution.

## Our experience with crop rotation in years with different rainfall regime

*Crop Rotation*. Agriculture is increasingly based on market laws of supply and demand, that is, conjuncture and this is where economic interests dominate, which are often not in accordance with the agrobiological reasons, at least when it comes to crop rotation.

Apart from continuous maize cropping that is still evident and is still only possible due to the absolute domination of maize on arable land in sowing structure of Serbia, there is still two-field crop rotation (winter wheat - maize) and an increasing number of three-field crop rotation, which includes soya bean, which is very positive (Dolijanovic et al., 2006; Dolijanović et al., 2007; Dolijanović et al., 2009; Dolijanović et al., 2010).

Crop rotation is the most general and most comprehensive cultural practice, which more or less links all others in a mutually dependent system, designed for the successful achievement of certain objectives. Using modern cropping systems that include multiple cropping, cover crops to create the most favourable conditions reliably ensuring that each of cultivation practices best makes great success (Oljaca et al., 1999; Oljaca et al., 2000; Govaerts et al., 2007; Kovacevic et al., 2005b).

In the crop rotation the crops before in cropping pattern should be taken into account. No sensitive plants should be sown after the crops before in cropping pattern, which had already spent a lot of moisture the previous year. Sunflower, sugar beet, alfalfa are exactly such crops. As for the plants themselves, it should be mentioned that apart from the selection of species, the cultivars (hybrids) of one species should be also taken into account. Some are more resistant to drought and adaptable to such circumstances, and some are still very intense, with very high demands for all factors starting from nutrients to water (Kovacevic et al., Kovacevic et al., 2005b; Kovacevic et al., 2007b, Kovacevic et al., 2008a; Kovacevic et al., 2010).

Water use can be further improved by changing cropping patterns. The choice of crop to be grown is critical and should reflect both the availability of water and socio-economic requirements. Water requirements can be greatly reduced by replacing a crop requiring substantial amounts of water, sugar beet, with crops requiring less water. Similarly, utilisation of the best-adapted cultivars is important in maximising yield under water stress. Even simple adjustments such as cultivars that can be planted earlier to more closely match crop growth to rainfall distribution can increase productivity (Turner, 2004). There may be a compromise between yield and water use as more rapidly maturing varieties may have smaller yield potential.

At "Radmilovac" experimental estate of Faculty of Agriculture in Zemun on chernozem luvic soil type, different cropping systems have been established: continuous cropping (winter wheat, maize and soya bean) and different crop rotations two-field crop rotation (winter wheat - maize); three-field crop rotation (winter wheat - maize - soya bean) and six-field crop rotation (winter wheat, maize - soya bean - spring barley - red clover - sunflower). They are still there.

In order to compare the effects of crop rotation to the abiotic stress in dry years on the yield of our two most important crops of winter wheat and maize, we had to choose, tentatively speaking, dry, moderate and wet years from a series of meteorological data from the last two decades (1991/92-2011/12), which are characterised by very pronounced oscillations in temperature and precipitation. In agrometeorology and agronomy, when we want to gather more information about the type of climate, it is necessary to know the specific climatic indices (Standardized Precipitation Index) - SPI based on the amount of rainfall 30, 60 and 90 days with the step in the calculation of one day; SPI for 1,2,3,4,5,6,9,12 and 24 months - a step in the calculation is the calendar month; Palmer Z-index (Palmer Drought Severity Index - PDSI), which is a measure of the monthly moisture anomaly or detailed climatograms. Considering the dependence of the rate of plant growth on the moisture content in the soil and evaporation it has been shown to be advisable to establish such indices which would indicate that climate characteristic of the region in terms of the intensity of evaporation and soil moisture reserves (Spasov and Danica Spasov 2001; Mihajlovic, 2002; Spasov, 2003, Radicevic Zorica et al., 2011).

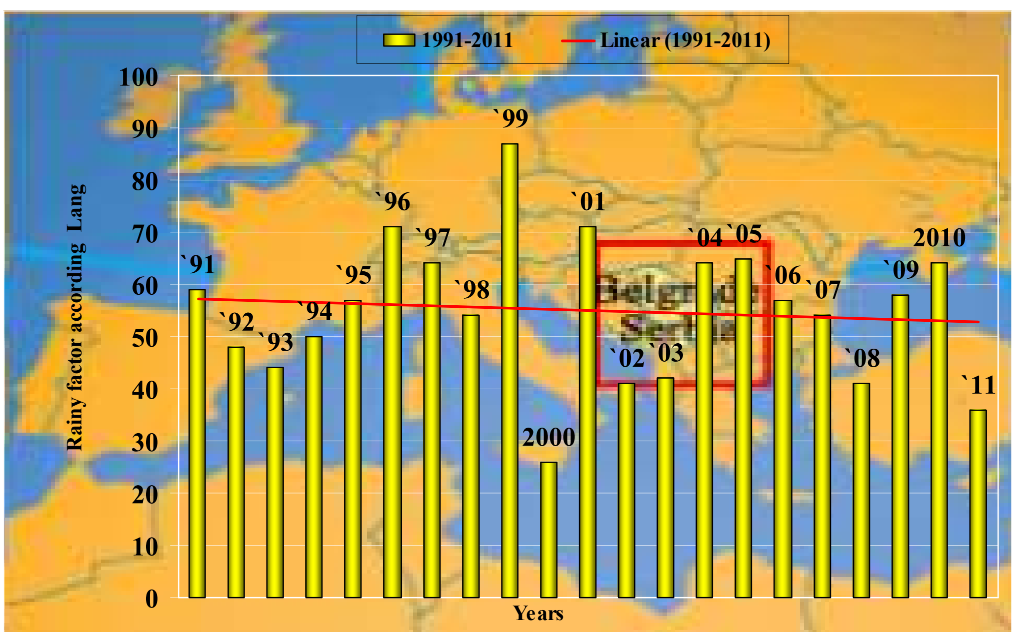


Figure 1. Rainy factor according Lang per year in Belgrade, period 1991-2012

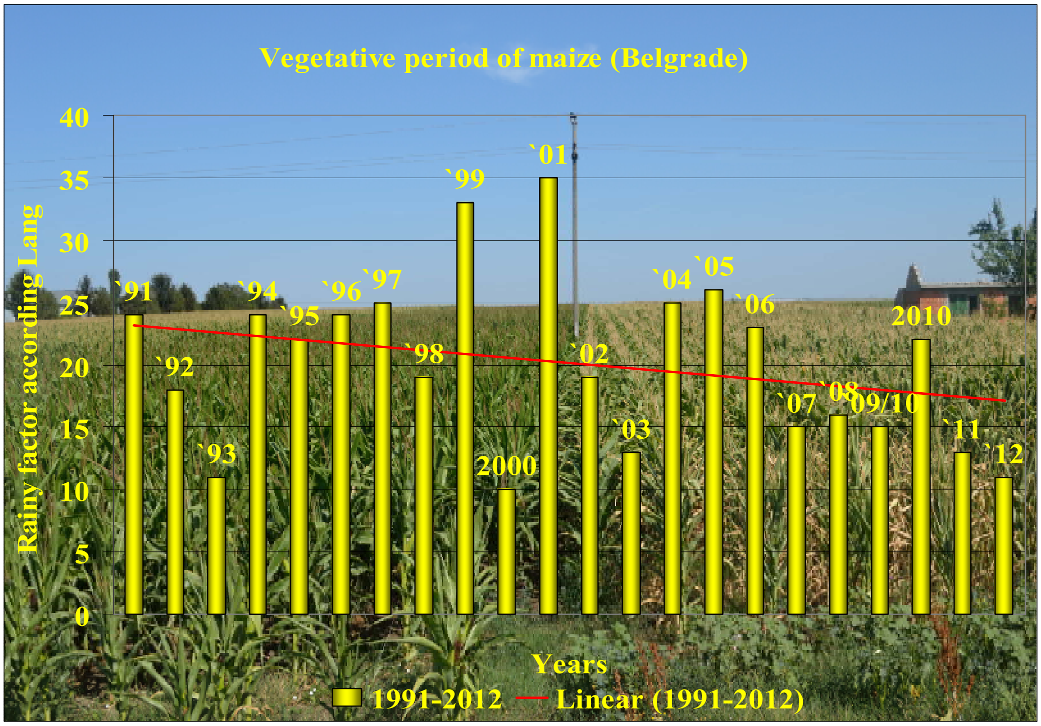


Figure 2. Rainy factor according Lang in vegetative period of maize (Belgrade 1991-2012)

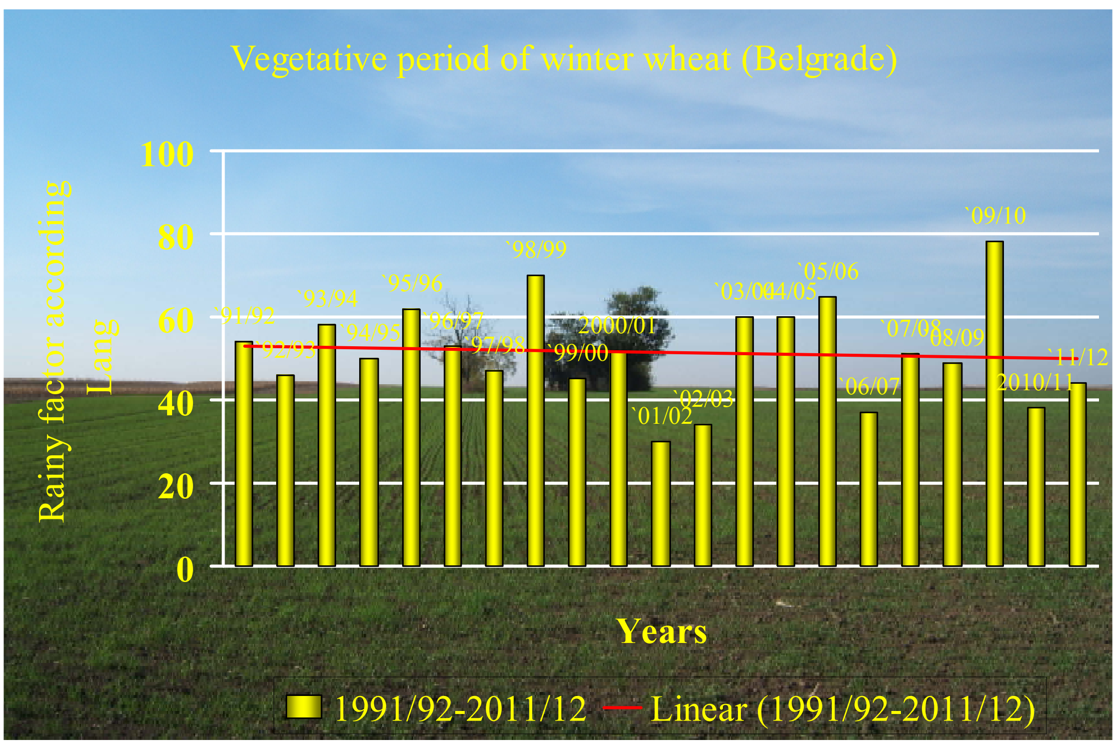


Figure 3. Rainy factor according Lang in vegetative period of winter wheat (Belgrade 1991-2012)

Table 5. Effects of cropping system in different weather conditions on grain yield of maize (t ha$^{-1}$)

| Weather conditions | RF acc. Lang | Cont. cropp | Crop rotation | | | Average crop rotat. | Decrease in cont. cropp. |
|---|---|---|---|---|---|---|---|
| | | | 2-crop rot. | 3-crop rot. | 6-crop rotat. | | |
| 2000 | 25.9 | 5.75 | 6.50 | 6.50 | 5.55 | 6.18 | |
| 2003 | 42.4 | 6.05 | 5.45 | 5.69 | 5.36 | 5.50 | |
| 2011 | 36.1 | 6.40 | 6.80 | 7.10 | 7.40 | 7.10 | |
| Dry | Average | 6.07 | 6.25 | 6.43 | 6.10 | 6.26 | 0.19 |
| 1994 | 50.2 | 8.52 | 8.87 | 8.91 | 9.34 | 9.04 | |
| 2004 | 64,3 | 7.00 | 9.55 | 10.02 | 9.12 | 9.56 | |
| 2006 | 56.9 | 8.25 | 8.40 | 8.60 | 8.60 | 8.53 | |
| Moderate | Average | 7.92 | 8.94 | 9.18 | 9.02 | 9.05 | 1.13 |
| 1999 | 87.3 | 8.45 | 9.67 | 9.75 | 10.74 | 10.1 | |
| 2001 | 70.1 | 8.00 | 8.50 | 8.75 | 8.54 | 8.60 | |
| 2005 | 64.8 | 7.20 | 9.15 | 10.60 | 8.80 | 9.52 | |
| Wet | Average | 7.88 | 9.11 | 9.70 | 9.36 | 9.39 | 1.51 |
| Decrease grain yield | | 1.85 | 2.86 | 3.27 | 3.26 | 2.80 | |
| | % | 23.4 | 31.4 | 33,7 | 34.8 | 31.1 | |

For this purpose, the most commonly used are Lang's rain factor, De Marton`s drought index, Conrad's index of continentality and Ivanov moisture coefficient (Spasov and Spasov Danica 2001; Lalic Branislava et al., 2002; Spasov, 2003; Radicevic Zorica et al., 2011).

We opted for Lang`s rain factor calculated as the ratio of annual rainfall and mean annual air temperature of an area. (Figure 1, Figure 2 and Figure 3). According to Lang, the characterisation of climate is as follows: 0 - 20 Desert - Arid, 20 - 40 Semi-desert, 40-60 Steppe and Savanna ; 60-100 Weak forests - Humid, 100-160 High forests and over > 160 Steppes and tundras-Perhumid. The graph shows the noticeable trend of decreasing moisture indices according to Lang for the first twelve years of the new millennium compared to the last decade of the old one. This trend is particularly evident in the vegetative period of maize.

On the basis of the rainfall regime and the average annual air temperatures for the whole year in the Belgrade area, we have chosen three extremely dry, three moderate and three very wet years.

In those years, according to data from Table 5, appropriately established crop rotations with greater diversification of crops such as three-field and six-field crop rotations provide better tolerance of extreme humidity conditions as shown in our study compared to the continuous cropping of winter wheat and maize.

Continuous cropping in this sense has proved to be worse solution even for maize that is known to show better tolerance. High maize yields in dry years were obtained in smaller areas with complete cultivation practices and full compliance with all deadlines of implementation of management practices, so it should not be surprising that in widespread practice it is not the case.

Table 6. Effects of cropping system in different weather conditions on grain yield of winter wheat (t ha$^{-1}$)

| Weather conditions | RF acc. Lang | Cont. cropp | Crop rotation | | | Average crop rot. | Decrease in cont. cropp. |
|---|---|---|---|---|---|---|---|
| | | | 2-crop rotat. | 3-crop rotat. | 6-crop rotat. | | |
| 2001/02 | 29.9 | 3.20 | 4.86 | 4.86 | 5.10 | 4.94 | |
| 2002/03 | 34.2 | 2.90 | 3.10 | 3.10 | 3.30 | 3.17 | |
| 2010/11 | 38.3 | 3.01 | 4.02 | 4.16 | 3.89 | 4.02 | |
| Dry | Average | 3.04 | 3.99 | 4.04 | 4.10 | 4.04 | 1.00 |
| 1997/98 | 46.6 | 3.16 | 3.41 | 3.51 | 4.56 | 3.83 | |
| 2000/01 | 52.5 | 3.30 | 4.60 | 4.60 | 4.70 | 4.63 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2008/09 | 48.7 | 3.60 | 3.90 | 4.10 | 3.98 | 3.99 | |
| Moderate | Average | 3.35 | 3.97 | 4.07 | 4.41 | 4.15 | 0.80 |
| 1998/99 | 69.6 | 3.46 | 3.79 | 3.79 | 4.89 | 4.16 | |
| 2005/06 | 64.5 | 3.10 | 3.35 | 3.35 | 3.90 | 3.53 | |
| 2009/10 | 78.1 | 2.96 | 4.10 | 4.24 | 3.90 | 4.08 | |
| Wet | Average | 3.17 | 3.75 | 3.79 | 4.23 | 3.92 | 0.75 |
| Decrease grain yield | | 0.31 | -0.24 | -0.28 | 0.31 | 0.23 | |
| | % | 9.25 | 6.01 | 6.88 | 7.02 | 5.54 | |

All crop rotations produced higher yields, which averagely for three investigated amounts to 0.19 t $ha^{-1}$, and we can say that it is not a big difference. This fact demonstrates that when maize is lacking moisture with much higher temperatures and the above-mentioned heat waves accompanied by the tropical nighttime temperatures, nothing can replace it.

In years with moderate humidity and better distributed rainfall we have significantly increased yield in crop rotation compared to continuous cropping and the highest one in over wet years as for total rainfall (1.13 t $ha^{-1}$; 1.51 t $ha^{-1}$). This shows what a stimulating effect the moisture has on better availability of other vegetation factors, that is, on the synergistic effect of all other applied cultivation practices for maize through well designed crop rotation scheme. As regards winter wheat, it is known that it is not tolerant of continuous cropping, therefore the yields in this system are always expectedly lower (Table 6). Unlike maize, at this point crop rotation effect in dry years compared to continuous cropping was higher 1:00 t $ha^{-1}$. While the moisture content increased, the influence of crop rotation decreased, and in moderately humid that difference was 0.80 t $ha^{-1}$, and in the extremely wet ones it amounted to 0.75 t $ha^{-1}$.

This advantage of crop rotation compared to continuous cropping is quite expected. However, if crop rotations are compared with each other in different wetting conditions, then it is noticed that in excessively wet years lower yield was produced than in the dry years in crop rotations with smaller number of crops in rotation, in two-field crop rotation by 0.24 t $ha^{-1}$ (winter wheat-maize) and three-field crop rotation (winter wheat-maize-soya bean) 0.28 t $ha^{-1}$ compared to six-field crop rotation.

## Conclusion

Based on a detailed analysis of climatic factors in the multi-year period for the Belgrade region, which may be representative of the wider area of central Serbia, it can be emphasised that some changes in terms of temperature and precipitation occurred. The causes of drought mainly come from the atmosphere and affect our country and show clearly that the climate is changing in our area. Based on these facts, we must have the right answers in order to mitigate if not to completely eliminate these effects. Agronomic aspect of looking into the problem requires a good knowledge of our crop needs for primary vegetative factors as well as temperature and moisture.

Annual air temperatures in the investigated period increased not only at the annual level, but also in the vegetative period of winter wheat and particularly maize. The temperature increase is particularly dangerous in the vegetative period of maize during the three months of June, July and August by almost 2 $^0$C. Precipitations at a monthly level of the vegetative period or a total per year do not provide such a picture. Besides the lack in July, normally the warmest month, by and large, precipitations are somewhat higher than the reference 30-year period 1971-2000. This fact tells us that precipitations are more frequent in other parts of the year, which is more favourable for winter wheat, at least when regarding warmer years (especially in the wet years as it is known in the case of extremely wet 2010 when it was vice versa).

A man can hardly influence the quantity and distribution of rainfall, therefore his actions to combat drought are mainly of indirect character. This comprises a good knowledge of the problems and prediction. For this, we need a lot of knowledge of agronomy, genetics, ecology, physiology, and relevant technical and economic possibilities. If we start from the assumption that the main goal is to provide sufficient and safe quantities of food for our population, then we need to focus on what we have in our hands and begin with it.

In the fight against drought, regular and specific cultivation practices are used along with an adequate assortment of plants with more tolerance to drought. Out of regular practices, soil tillage, particularly conservation tillage, proper fertilization, elimination of all possible mistakes in sowing should be taken into account as for optimal time and plant density. Care treatments are a useful tool which can eliminate the adverse effects and create favourable conditions for the growth and development of cultivated crops, ranging from the usual ones to some special ones that retain moisture and prevent moisture loss by encouraging its more efficient and economical use.

Appropriately established crop rotations with greater diversification of crops provide better tolerance of extreme moisture, which is particularly the case of wheat. Our research shows inferiority of continuous cropping of both crops compared with crop rotations. However, when comparing crop rotations with each other then it can be noticed that the proper setting, even under extreme conditions, provides better results. As for maize it is evident that all increases of moisture are suitable for it as it is related to the warmer part of the year, either as direct rainfall during the summer or indirectly if the reserve is provided from a period when there are more precipitations during the autumn, winter and spring. Moisture improves the efficiency of all other cultivation practices. In the case of its extended absence followed by high temperatures it is quite the opposite.

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Table 1. Mean monthly temperature ($^{0}C$) in Belgrade, period 1991-2012

| Year | Months | | | | | | | | | | | | Mean | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Octob. | Nov. | Dec. | X-VI | IV-IX | Year |
| 1991 | -0.4 | 4.5 | 9.2 | 13.8 | 16.0 | 17.8 | 21.7 | 16.0 | 11.7 | 11.4 | 7.7 | -1.1 | | 16.1 | 10.7 |
| 1992 | 1.7 | 4.2 | 5.2 | 13.0 | 17.9 | 20.6 | 22.8 | 26.8 | 15.5 | 13.1 | 5.2 | 1.2 | 9.0 | 19.4 | 12.3 |
| 1993 | 1.5 | -0.6 | 5.0 | 12.6 | 20.0 | 21.7 | 22.5 | 23.4 | 18.1 | 14.5 | 3.0 | 4.7 | 8.9 | 19.7 | 12.2 |
| 1994 | 4.3 | 3.5 | 10.4 | 12.8 | 18.5 | 21.0 | 24.3 | 24.1 | 21.7 | 11.2 | 7.5 | 3.4 | 10.3 | 20.4 | 13.6 |
| 1995 | 0.6 | 7.9 | 7.1 | 12.6 | 16.8 | 20.5 | 24.8 | 21.6 | 16.6 | 13.4 | 4.2 | 2.2 | 9.7 | 18.8 | 12.4 |
| 1996 | -0.2 | -0.6 | 2.6 | 12.6 | 14.3 | 21.9 | 22.0 | 22.1 | 14.0 | 12.6 | 10 | 1.7 | 7.8 | 17.8 | 11.1 |
| 1997 | 0.5 | 5.1 | 5.2 | 8.2 | 16.8 | 21.8 | 21.3 | 21.5 | 17.6 | 10.4 | 8.3 | 4.6 | 9.1 | 17.9 | 11.8 |
| 1998 | 3.7 | 6.2 | 4.8 | 13.6 | 16.0 | 21.7 | 22.0 | 21.8 | 15.9 | 12.8 | 4.4 | -2.4 | 9.9 | 18.5 | 11.7 |
| 1999 | 1.4 | 1.9 | 8.2 | 13.2 | 17.3 | 20.0 | 21.1 | 21.1 | 18.4 | 12.2 | 4.8 | 2.2 | 8.5 | 18.5 | 11.8 |
| 2000 | -1.0 | 5.2 | 8.1 | 16.2 | 19.6 | 23.0 | 23.5 | 25.7 | 17.9 | 14.6 | 11.9 | 5.3 | 10.0 | 21.0 | 14.2 |
| 2001 | 4.2 | 5.4 | 11.8 | 12.0 | 18.3 | 19.0 | 23.0 | 24.0 | 16.1 | 14.8 | 4.7 | -1.9 | 11.4 | 18.7 | 12.6 |
| 2002 | 1.4 | 9.1 | 10.7 | 12.7 | 20.2 | 22.4 | 24.6 | 22.8 | 17.9 | 14.0 | 11.5 | 1.6 | 10.5 | 20.1 | 14.1 |
| 2003 | 0.8 | -2.0 | 7.4 | 12.2 | 21.6 | 25.0 | 23.4 | 25.8 | 18.4 | 11.5 | 9.9 | 3.5 | 10.2 | 21.1 | 13.1 |
| 2004 | -0.1 | 3.7 | 8.1 | 13.5 | 16.2 | 20.7 | 23.0 | 22.3 | 17.7 | 15.9 | 8.5 | 4.0 | 9.7 | 18.9 | 12.8 |
| 2005 | 2.1 | -1.0 | 6.0 | 13.1 | 17.7 | 20.2 | 22.9 | 21.4 | 18.9 | 13.8 | 7.1 | 3.6 | 9.6 | 19.0 | 12.2 |
| 2006 | -0.2 | 2.2 | 7.1 | 14.0 | 17.6 | 20.3 | 24.7 | 21.5 | 19.7 | 16.1 | 9.6 | 4.7 | 9.5 | 19.6 | 13.1 |
| 2007 | 7.9 | 7.8 | 10.8 | 14.7 | 19.8 | 24.4 | 26.9 | 25.2 | 15.8 | 12.1 | 5.6 | 1.5 | 12.9 | 21.1 | 14.4 |
| 2008 | 3.4 | 6.6 | 9.8 | 14.2 | 19.3 | 23.0 | 23.6 | 24.2 | 17.5 | 15.9 | 9.9 | 4.9 | 10.6 | 20.3 | 14.4 |
| 2009 | 0.1 | 3.4 | 8.6 | 16.2 | 19.8 | 21.1 | 24.0 | 24.5 | 21.0 | 14.0 | 10.4 | 4.9 | 11.1 | 21.1 | 14.0 |
| 2010 | 1.0 | 3.9 | 8.7 | 13.9 | 18.3 | 21.4 | 24.4 | 24.3 | 18.4 | 10.5 | 12.2 | 2.5 | 10.7 | 20.1 | 13.3 |
| 2011 | 2.0 | 1.4 | 8.2 | 14.6 | 17.3 | 22.4 | 24.1 | 24.7 | 23.2 | 12.9 | 5.0 | 5.8 | 10.1 | 21.1 | 13.5 |
| 2012 | 2.7 | -2.5 | 10.1 | 14.4 | 17.9 | 24.6 | 27.1 | 26.2 | 22.0 | | | | 10.1 | 16.1 | |

***Republic Hydrometeorological Service of Serbia

Table 2. Precipitation (mm) in Belgrade, period 1991-2012

| Year | Months | | | | | | | | | | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sept. | Octob. | Nov. | Dec. | X-VI | IV-IX | I-XII |
| 1991 | 20.2 | 11.2 | 83.7 | 51.3 | 94.7 | 86.3 | 43.9 | 32.8 | 25.8 | 84.2 | 62.7 | 31.7 | | 334.8 | 628.5 |
| 1992 | 7.6 | 33.5 | 6.9 | 58.8 | 19.4 | 180.0 | 43.5 | 24.3 | 25.2 | 90.5 | 61.7 | 34.8 | 528.5 | 351.2 | 586.2 |
| 1993 | 21.9 | 31.8 | 77.1 | 28.7 | 12.8 | 50.4 | 56.9 | 24.5 | 51.5 | 18.8 | 77.8 | 88.9 | 484.8 | 224.8 | 541.1 |
| 1994 | 40.4 | 23.0 | 27.7 | 64.6 | 41.4 | 212.2 | 46.1 | 90.5 | 29.5 | 37.9 | 35.9 | 34.4 | 409.7 | 484.3 | 683.6 |
| 1995 | 82.2 | 45.9 | 43.9 | 61.0 | 83.6 | 64.7 | 33.7 | 69.2 | 92.6 | 0.3 | 57.0 | 67.1 | 594.8 | 404.8 | 701.2 |
| 1996 | 42.6 | 62.2 | 41.2 | 52.3 | 108.0 | 57.1 | 35.5 | 66.6 | 107.7 | 37.1 | 77.7 | 100.8 | 489.5 | 427.2 | 788.8 |
| 1997 | 33.0 | 50.4 | 10.2 | 87.0 | 51.0 | 31.0 | 131.0 | 113.0 | 31.0 | 106.0 | 30.0 | 81.0 | 487.8 | 444.0 | 754.6 |
| 1998 | 70.4 | 4.0 | 28.4 | 31.0 | 68.9 | 42.7 | 34.4 | 82.2 | 89.7 | 91.6 | 55.3 | 28.5 | 478.2 | 348.9 | 627.1 |
| 1999 | 60.8 | 68.9 | 15.6 | 68.9 | 68.8 | 135.5 | 275.9 | 7.0 | 55.4 | 54.9 | 69.4 | 149.3 | 462.4 | 611.5 | 1030.4 |
| 2000 | 27.3 | 28.3 | 30.3 | 41.9 | 34.5 | 19.1 | 29.3 | 7.8 | 70.7 | 16.6 | 20.7 | 41.2 | 593.9 | 203.3 | 367.7 |
| 2001 | 35.3 | 27.2 | 65.6 | 157.9 | 47.0 | 186.0 | 19.7 | 56.7 | 183.7 | 16.7 | 63.4 | 33.9 | 455.0 | 651.0 | 893.1 |
| 2002 | 14.0 | 14.0 | 15.0 | 55.0 | 21.0 | 80.0 | 62.0 | 107.0 | 50.0 | 80.0 | 34.0 | 53.0 | 597.5 | 375.0 | 585.0 |
| 2003 | 51.0 | 26.0 | 11.0 | 22.0 | 40.0 | 33.0 | 116.0 | 5.0 | 57.0 | 124.0 | 29.0 | 42.0 | 313.0 | 273.0 | 556.0 |
| 2004 | 99.1 | 28.2 | 18.4 | 69.0 | 62.8 | 107.1 | 93.7 | 88.1 | 45.8 | 30.6 | 128.8 | 51.3 | 350.0 | 466.5 | 822.9 |
| 2005 | 53.0 | 87.0 | 32.0 | 53.0 | 48.0 | 94.0 | 90.0 | 145.0 | 56.0 | 27.0 | 23.0 | 83.0 | 579.6 | 486.0 | 791.0 |
| 2006 | 43.0 | 58.0 | 105.0 | 97.0 | 40.0 | 137.0 | 22.0 | 123.0 | 26.0 | 21.0 | 25.0 | 48.0 | 577.7 | 445.0 | 745.0 |
| 2007 | 36.0 | 53.0 | 100.0 | 4.0 | 79.0 | 108.0 | 18.0 | 72.0 | 35.0 | 104.0 | 131.0 | 34.0 | 613.0 | 316.0 | 774.0 |
| 2008 | 42.0 | 10.0 | 79.0 | 35.0 | 61.0 | 45.0 | 64.0 | 46.0 | 68.0 | 18.0 | 52.0 | 77.0 | 474.0 | 319.0 | 597.0 |
| 2009 | 54.0 | 84.0 | 63.0 | 6.0 | 34.0 | 153.0 | 79.0 | 45.0 | 4.0 | 101.0 | 62.0 | 122.0 | 541.0 | 321.0 | 807.0 |
| 2010 | 89.0 | 111.0 | 46.0 | 41.0 | 85.0 | 180.0 | 41.0 | 54.0 | 51.0 | 49.0 | 45.0 | 61.0 | 541.0 | 452.0 | 853.0 |
| 2011 | 40.0 | 53.0 | 26.0 | 11.0 | 63.0 | 40.0 | 107.0 | 9.0 | 49.0 | 35.0 | 6.0 | 49.0 | 837.0 | 279.0 | 488.0 |
| 2012 | 82.0 | 62.0 | 3.0 | 67.0 | 128.0 | 14.0 | 39.0 | 4.0 | 31.0 | | | | 388.0 | 334.8 | |

***Source: Republic Hydrometeorological Service of Serbia